Question 1 / 85

Which one of the following statements about fuels is correct?

A.

When fuels react, they all produce carbon dioxide.

B.

Heat energy is always released when fuels are burnt.

C.

All fuels are hydrocarbons.

D.

Fuels need pure oxygen to produce energy.

Question 2 / 85

Which one of the following lists contains only fossil fuels?

A.

biogas, bioethanol, biodiesel

B.

coal seam gas, biogas, natural gas

C.

coal, petrol, diesel

D.

peat, wood, charcoal

Question 3 / 85

Propane is often used as a fuel in portable barbecues. The equation for the combustion of propane is:

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

For this reaction, the sign of ΔH is

A.

negative and the total chemical energy of the products is less than that of the reactants.

B.

positive and the total chemical energy of the products is less than that of the reactants.

C.

negative and the total chemical energy of the products is greater than that of the reactants.

D.

positive and the total chemical energy of the products is greater than that of the reactants.

Question 4 / 85

Which one of the following is **not** likely to be a biofuel?

A.

a gas mixture containing ~96% methane and 4% carbon dioxide

B.

ethanol, C_2H_5OH

C.

methyl stearate, $CH_3(CH_2)_{16}COOCH_3$

D.

a gas mixture containing approximately equal amounts of methane and carbon dioxide

Question 5 / 85

Below are four molecules that have been found in fuels.

I cyclohexane, C_6H_{12}

II octane, C_8H_{18}

III methyl palmitate, $CH_3OOC(CH_2)_{14}CH_3$

IV ethanol, C_2H_5OH

Which of these is/are **not** likely to be found in crude oil?

A.

I and II

B.

I, III and IV

C.

III and IV

D.

II only

Question 6 / 85

The following is a list of fuels.

I coal

II biogas

III natural gas

IV biodiesel

V bioethanol

VI petrol

Which of these are renewable fuels?

A. II, IV and VI

B. I, III and VI

C. I, III and V

D. II, IV and V

Question 7 / 85

[VCAA 2018 SA Q3]
Which one of the following statements about fuels is correct?

A. Petroleum gas is a form of renewable energy.

B. Electricity can only be generated by burning coal.

C. Carbon dioxide is not produced when biogas is burnt.

D. Biodiesel can be derived from both plant and animal material.

Question 8 / 85

[VCAA 2015 SA Q5]
Which one of the following statements best defines a renewable energy resource?

A. an energy resource that will not be consumed within our lifetime

B. an energy resource that does not produce greenhouse gases when consumed

C. an energy resource derived from plants that are grown for the production of liquid biofuels

D. an energy resource that can be replaced by natural processes within a relatively short time

Question 9 / 85

[VCAA 2014 SA Q24]
Methane gas may be obtained from a number of different sources. It is a major component of natural gas. Methane trapped in coal is called coal seam gas and can be extracted by a process known as fracking. Methane is also produced by the microbial decomposition of plant and animal materials. In addition, large reserves of methane were trapped in ice as methane hydrate in the ocean depths long ago. Methane is a renewable energy source when it is obtained from

---

A.

natural gas.

B.

coal seam gas.

C.

methane hydrate.

D.

microbial decomposition.

Question 10 / 85

[Adapted VCAA 2017 SA Q5]
Which one of the following is a biofuel?

A.

ethanol produced from crude oil

B.

ethanol produced from plant material

C.

propane produced from natural gas

D.

electricity produced by hydropower

Question 11 / 85

[VCAA 2020 SA Q11]
Which one of the following statements is correct?

A.

Crude oil can be classified as a biofuel because it originally comes from plants.

B.

Methane, CH_4, can be classified as a fossil fuel because it has major environmental impacts.

C.

Ethanol, CH_3CH_2OH, can be classified as a fossil fuel because it can be produced from crude oil.

D.

Hydrogen, H_2, can be classified as a biofuel because, when it combusts, it does not produce carbon dioxide, CO_2.

Question 12 / 85

[VCAA 2018 SA Q14]
An equation for the complete combustion of methanol is

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

ΔH for this equation would be

A.

$+726$ kJ mol^{-1}

B.

-726 kJ mol^{-1}

C.

$+1452$ kJ mol^{-1}

D.

-1452 kJ mol^{-1}

Question 13 / 85

Methane reacts with oxygen according to the following equation:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; $\Delta H = -890$ kJ mol^{-1}

The energy change for this reaction is best described as

A. exothermic, because the net strength of the bonds in the products is greater than the net strength of the bonds in the reactants.

B. endothermic, because the net strength of the bonds in the products is greater than the net strength of the bonds in the reactants.

C. exothermic, because the net strength of the bonds in the products is less than the net strength of the bonds in the reactants.

D. endothermic, because the net strength of the bonds in the products is less than the net strength of the bonds in the reactants.

Question 14 / 85

Which of the following equations best represents the incomplete combustion of ethanol?

A.

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$

B.

$C_2H_5OH(l) \rightarrow C_2H_4(g) + H_2O(g)$

C.

$C_2H_5OH(l) + 2O_2(g) \rightarrow CO_2(g) + C(s) + 3H_2O(g)$

D.

$2C_2H_5OH(l) + O_2(g) \rightarrow 2C_2H_4O(g) + 2H_2O(g)$

Question 15 / 85

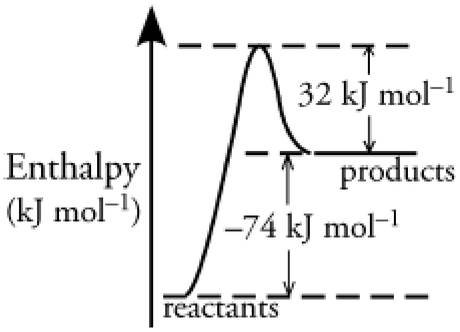
The partial oxidation of methane is one step in the production of methanol.

$2CH_4(g) + O_2(g) \rightarrow 2CO(g) + 4H_2(g)$; $\Delta H = -74$ kJ mol^{-1}

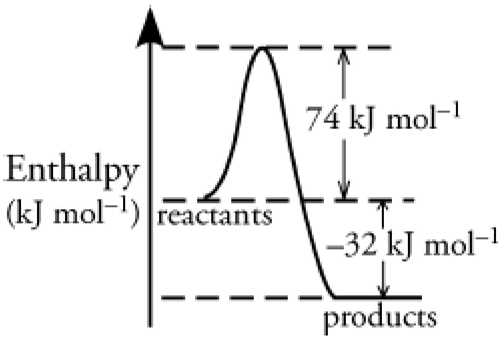
The activation energy for this reaction is 32 kJ mol^{-1}. The energy profile for this reaction is best represented by

---

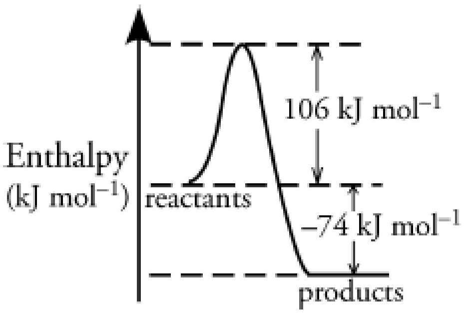
A.



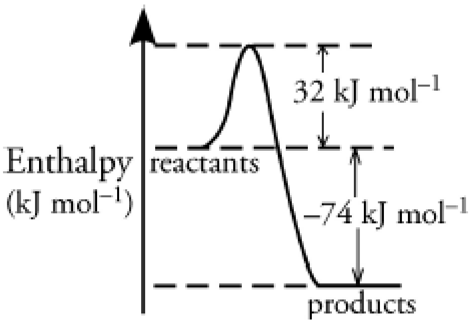
B.



C.



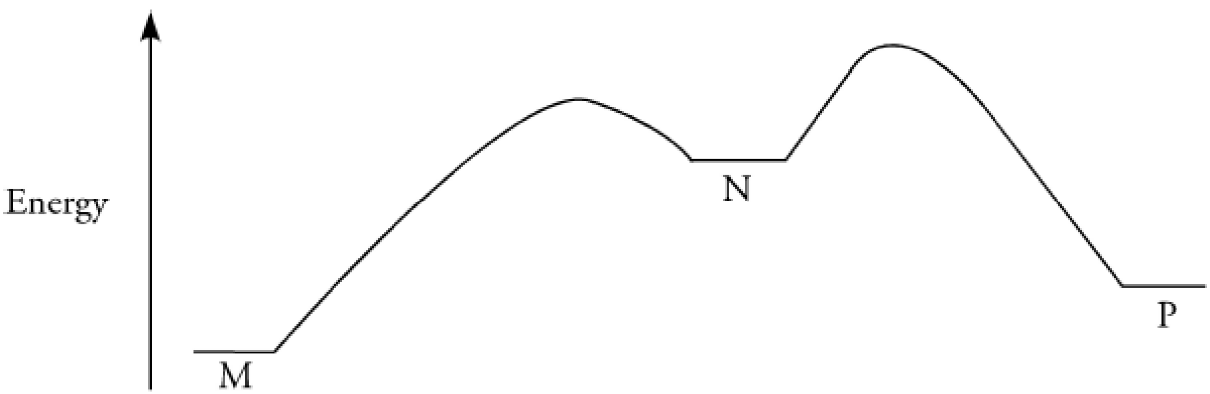
D.



Question 16 / 85

[VCAA 2017 SA Q29]

The following energy profile shows the results obtained during an enzyme-catalysed reaction. Each stage of the reaction is labelled: M represents the initial reactants, N represents a stable intermediate and P represents the final products.



Which one of the following statements is correct?

A.

The energy change from M to N is exothermic and the energy change from N to P is exothermic.

B.

The energy change from M to P is exothermic and the energy change from N to P is endothermic.

C.

The energy change from M to N is endothermic and the energy change from N to P is endothermic.

D.

The energy change from M to N is endothermic and the energy change from M to P is endothermic.

Question 17 / 85

When propane is used as a fuel (for example, as portable camping gas), it reacts with oxygen according to the equation

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

Compared with the energy of the reactants, the chemical energy of the combustion products will be

---

A.

higher and the reaction is endothermic.

B.

lower and the reaction is exothermic.

C.

higher and the reaction is exothermic.

D.

lower and the reaction is endothermic.

Question 18 / 85

[VCAA 2011 E2 SA Q6]
In an endothermic reaction the

A.

reaction system loses energy to the surroundings.

B.

addition of a catalyst increases the activation energy.

C.

activation energy is greater than the enthalpy of reaction.

D.

energy required to break bonds in the reactants is less than the energy released when bonds are formed in the products.

Question 19 / 85

[VCAA 2020 SA Q27]
The heat of combustion of ethanoic acid, $C_2H_4O_2$ is –876 kJ mo1^{-1} and the heat of combustion of methyl methanoate, $C_2H_4O_2$, is –973 kJ mo1^{-1}. The auto-ignition temperature (the temperature at which a substance will combust in air without a source of ignition) of ethanoic acid is 485 °C and the auto-ignition temperature of methyl methanoate is 449 °C.

Which one of the following pairs is correct?

A.

Compound with the lower chemical energy per mole	**Compound with the lower activation energy of combustion per mole**
ethanoic acid	methyl methanoate

B.

ethanoic acid	ethanoic acid

C.

methyl methanoate	methyl methanoate

D.

methyl methanoate	ethanoic acid

Question 20 / 85

[VCAA 2021 SA Q24]
Which one of the following statements describes the effect that adding a catalyst will have on the energy profile diagram for an exothermic reaction?

A.

The energy of the products will remain the same.

B.

The shape of the energy profile diagram will remain the same.

C.

The peak of the energy profile will move to the left as the reaction rate increases.

D.

The activation energy will be lowered by the same proportion in the forward and reverse reactions.

Question 21 / 85

Detonators often contain lead azide, $Pb(N_3)_2$, because when heated or struck, lead azide decomposes very rapidly, according to the equation

$Pb(N_3)_2(s) \rightarrow Pb(s) + 3N_2(g)$; $\Delta H = -440$ kJ mol^{-1}

Compared with the total chemical energy of the products, the chemical energy of the lead azide will be

---

A. higher because the reaction is endothermic.

B. higher because the reaction is exothermic.

C. lower because the reaction is endothermic.

D. lower because the reaction is exothermic.

Question 22 / 85

[VCAA 2017 SA Q9]

The nutrition information panel on a packet of muesli includes the information shown below.

Nutrition information Average serving size = 45 g	
	Average quantity per 100 g
protein	13.2 g
fat, total	16.3 g
– saturated	2.9 g
carbohydrate, total	48.2 g
– sugars	17.4 g
dietary fibre	4.9 g
sodium	10.5 mg

Using the information above, the percentage energy content due to protein in an average serving size of this muesli is

---

A.

31.2%

B.

29.3%

C.

14.0%

D.

13.2%

Question 23 / 85

[VCAA 2022 SA Q3]
The correct equation for the incomplete combustion of ethanol is

---

A.

$C_2H_5OH(l) + 12O_2(g) \rightarrow 2CO(g) + 3H_2(g)$

B.

$C_2H_5OH(l) + 32O_2(g) \rightarrow 2CO_2(g) + 3H_2(g)$

C.

$C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$

D.

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Question 24 / 85

In a laboratory experiment, 100 mL of ethane gas was mixed with 500 mL of oxygen gas at SLC and sparked. The reaction shown by the following equation occurred:

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$

What would be the total volume of gas present when the reaction had cooled back to SLC?

A.

200 mL

B.

350 mL

C.

550 mL

D.

650 mL

Question 25 / 85

[Adapted VCAA 2014 SA Q8]
When hydrochloric acid, HCl, is added to aluminium sulfide, Al_2S_3, the highly toxic gas hydrogen sulfide, H_2S, is evolved. The equation for this reaction is

$Al_2S_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2S(g)$

If excess hydrochloric acid is added to 0.200 mol of aluminium sulfide, then the volume of hydrogen sulfide produced at standard laboratory conditions (SLC) will be

---

A.

1.63 L

B.

4.90 L

C.

7.44 L

D.

14.9 L

Question 26 / 85

Methane, CH_4, ethane, C_2H_6, ethyne, C_2H_2, and propane, C_3H_8, have all been used as fuels. The enthalpy change for the balanced complete combustion reactions of these fuels is given by the following equations:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; $\Delta H = -890$ kJ mol^{-1}

$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$; $\Delta H = -3120$ kJ mol^{-1}

$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$; $\Delta H = -2600$ kJ mol^{-1}

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$; $\Delta H = -2208$ kJ mol^{-1}

When 1.0 g of each fuel is burned, then the fuel releasing the greatest amount of energy would be

---

A.

CH_4

B.

C_2H_6

C.

C_2H_2

D.

C_3H_8

Question 27 / 85

Both ethanol, C_2H_5OH, and methanol, CH_3OH, have been suggested as alternative fuels for transport vehicles. The equations describing the complete combustion of ethanol and methanol are given below.

$C_2H_5OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$; $\Delta H = -1368$ kJ mol^{-1}

$CH_3OH(g) + 32O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; $\Delta H = -726$ kJ mol^{-1}

Separate experiments are conducted in which 1 mol of ethanol and 2 mol of methanol undergo complete combustion. In these experiments

---

A.

the combustion of methanol produces more carbon dioxide.

B.

more heat energy is released from the combustion of ethanol.

C.

more water is formed in the combustion of ethanol.

D.

the two experiments consume the same amount of oxygen.

Question 28 / 85

The heat of combustion for three methyl esters is given in the table below.

Name	**Formula**	***ΔH* (kJ mol^{-1})**
Methyl pentanoate	$C_4H_9COOCH_3$	−3558
Methyl hexanoate	$C_5H_{11}COOCH_3$	−4211
Methyl heptanoate	$C_6H_{13}COOCH_3$	−4863

One of the molecules found in biodiesel is methyl stearate, $C_{17}H_{35}COOCH_3$. The best estimate for the molar enthalpy change (in kJ mol^{-1}) of methyl stearate is

---

A. −7178

B. −12 040

C. −12 632

D. −13 937

Question 29 / 85

[VCAA 2013 SA Q16]

$C(s) + O_2(g) \rightarrow CO_2(g)$; $\Delta H = -393.5$ kJ mol^{-1}

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$; $\Delta H = -571.6$ kJ mol^{-1}

Given the information above, what is the enthalpy change for the following reaction?

$C(s) + 2H_2O(l) \rightarrow CO_2(g) + 2H_2(g)$

A. −965.1 kJ mol^{-1}

B. −107.7 kJ mol^{-1}

C. +178.1 kJ mol^{-1}

D. +679.3 kJ mol^{-1}

Question 30 / 85

[VCAA 2018 SA Q10]
Bioethanol, C_2H_5OH, is produced by the fermentation of glucose, $C_6H_{12}O_6$, according to the following equation.

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

The mass of C_2H_5OH obtained when 5.68 g of carbon dioxide, CO_2, is produced is

---

A.

0.168 g

B.

0.337 g

C.

2.97 g

D.

5.94 g

Question 31 / 85

[VCAA 2014 SA Q23]
Large deposits of methane hydrate have been discovered deep under the sediment on the ocean floor. It has been suggested that methane hydrate deposits could be commercially mined to provide a clean fuel once the trapped methane is extracted. Methane hydrate has a complex structure. The simplified formula for methane hydrate is $CH_4.6H_2O$. The amount of energy released by the complete combustion of methane extracted from a 1.00 kg sample of methane hydrate at SLC is

---

A. 8.89×10^2 kJ

B. 7.17×10^3 kJ

C. 4.30×10^4 kJ

D. 5.56×10^4 kJ

Question 32 / 85

[VCAA 2018 SA Q22]
Four fuels undergo complete combustion in excess oxygen, O_2, and the energy released is used to heat 1000 g of water. Assuming there is no energy lost to the environment, which one of these fuels will increase the temperature of the water from 25.0°C to 85.0°C?

A.

0.889 g of hydrogen, H_2

B.

3.95 g of propane, C_3H_8

C.

0.282 mol of methane, CH_4

D.

0.301 mol of methanol, CH_3OH

Question 33 / 85

[VCAA 2017 SA Q7]
What is the total energy released, in kilojoules, when 100 g of butane and 200 g of octane undergo combustion in the presence of excess oxygen?

A.

9760

B.

14 600

C.

17 300

D.

19 500

Question 34 / 85

Use the following information to answer Questions 35 and 36.

Four identical vehicle models, 1, 2, 3 and 4, were tested for fuel efficiency using LPG, petrol (unleaded, 91 octane), E10 (petrol with 10% ethanol added) and petrodiesel. Carbon dioxide, CO_2, emissions per litre of fuel burnt were also determined. The following table summarises the results.

Vehicle model	**Fuel**	**Fuel consumption (L/100 km)**	**CO_2 produced (g CO_2/L of fuel)**
1	LPG	19.7	1665
2	petrol	14.5	2392
3	E10	14.2	2304
4	petrodiesel	9.2	2640

Question 35 / 85

[VCAA 2017 SA Q13]
Using the information in the table above, which one of the following statements about petrodiesel is correct?

A.

It has the highest energy content.

B.

It has the poorest fuel efficiency.

C.

It is a renewable energy source.

D.

It has the lowest CO_2 emissions when burnt.

Question 36 / 85

[VCAA 2017 SA Q14]
The use of which vehicle has the smallest impact on the environment, in terms of the grams of CO_2 produced per 100 km?

A.

Vehicle model 1

B.

Vehicle model 2

C.

Vehicle model 3

D.

Vehicle model 4

Question 37 / 85

[Adapted VCAA 2018 SA Q25]
The molar enthalpy change for the combustion of pentan-1-ol, $C_5H_{11}OH$, is −3329 kJ mol^{-1}.

$M(C_5H_{11}OH)$ = 88.0 g mol^{-1}

The mass of $C_5H_{11}OH$, in tonnes, required to produce 10 800 MJ of energy is closest to

---

A.

0.0286

B.

0.286

C.

2.86

D.

286

Question 38 / 85

100 mL of a gaseous hydrocarbon is mixed with 500 mL of oxygen at SLC At the end of the reaction, the gaseous mixture is returned to its original temperature and pressure. The final mixture consists of 300 mL of carbon dioxide and 100 mL of oxygen. The molecular formula of the hydrocarbon is

---

A.

C_2H_4

B.

C_3H_4

C.

C_3H_6

D.

C_3H_8

Question 39 / 85

[VCAA 2020 SA Q18]
An experiment was carried out to determine the enthalpy of combustion of propan-1-ol. Combustion of 557 mg of propan-1-ol increased the temperature of 150 g of water from 22.1 °C to 40.6 °C.

The molar enthalpy of combustion is closest to

A.

−2742 kJ mo1^{-1}

B.

−1208 kJ mo1^{-1}

C.

−1250 kJ mo1^{-1}

D.

−1540 kJ mol^{-1}

Question 40 / 85

[VCAA 2020 SA Q22]
The combustion of which fuel provides the most energy per 100 g?

A.

pentane (M = 72 g mol^{-1}), which releases 49 097 MJ tonne^{-1}

B.

nitromethane (M = 61 g mol^{-1}), which releases 11.63 kJ g^{-1}

C.

butanol (M = 74 g mol^{-1}), which releases 2670 kJ mo1^{-1}

D.

ethyne (M = 26 g mol^{-1}), which releases 1300 kJ mo1^{-1}

Question 41 / 85

[VCAA 2021 SA Q12]
Butane, C_4H_{10}, undergoes complete combustion according to the following equation.

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

67.0 g of C_4H_{10} released 3330 kJ of energy during complete combustion at standard laboratory conditions (SLC).

The mass of carbon dioxide, CO_2, produced was

A.

0.105 g

B.

3.18 g

C.

50.9 g

D.

204 g

Question 42 / 85

[VCAA 2021 SA Q22]
1 L of octane has a mass of 703 g at SLC. The efficiency of the reaction when octane undergoes combustion in the petrol engine of a car is 25.0%.

What volume of octane stored in a petrol tank at SLC is required to produce 528 MJ of usable energy in a combustion engine?

A.

3.92 L

B.

11.8 L

C.

15.7 L

D.

62.7 L

Question 43 / 85

For each mole of oxygen consumed, which one of the following fuels produces the largest amount of carbon dioxide?

A.

methane, CH_4

B.

ethyne, C_2H_2

C.

ethene, C_2H_4

D.

propane, C_3H_8

Question 44 / 85

[VCAA 2019 SA Q26]

The calibration factor of a bomb calorimeter was determined by connecting the calorimeter to a power supply. The calibration was done using 100 mL of water, 6.5 V and a current of 3.6 A for 4.0 minutes. The temperature of the water increased by 0.48°C during the calibration. 4.20 g of sucrose underwent complete combustion in the bomb calorimeter. The temperature of the 100 mL of water increased from 19.6°C to 25.8°C.

$M(C_{12}H_{22}O_{11})$ = 342 g mo1^{-1}

The experimental heat of combustion of pure sucrose, in joules per gram, is

---

A.

5.9×10^6

B.

7.3×10^4

C.

1.7×10^4

D.

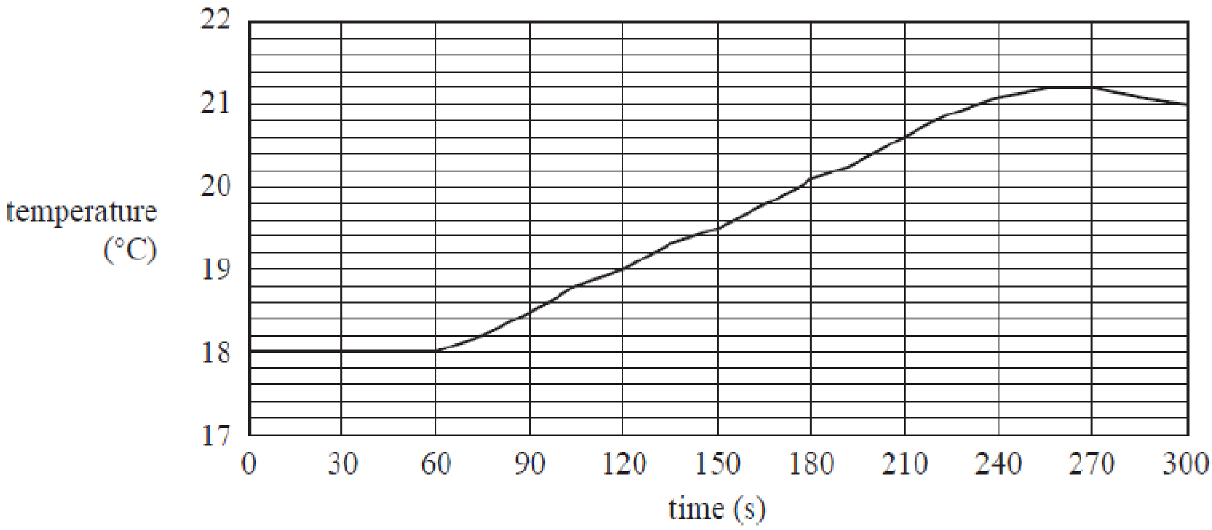
1.2×10^4

Question 45 / 85

Use the following information to answer Questions 46 and 47.

A solution calorimeter containing 350 mL of water was set up. The calorimeter was calibrated electrically and the graph of the results is shown below.

Graph of temperature versus time during electrical calibration of solution calorimeter



The calorimeter was calibrated using a current of 2.7 A, starting at 60 s. The current was applied for 180 s and the applied voltage was 5.4 V.

Question 46 / 85

[VCAA 2020 SA Q9]
What is the calibration factor for this calorimeter?

A.

125 J °C^{-1}

B.

820 J °C^{-1}

C.

847 J °C^{-1}

D.

875 J °C^{-1}

Question 47 / 85

[VCAA 2020 SA Q10]
This type of calorimeter

A.

has no heat loss.

B.

can be used for bomb calorimetry.

C.

requires electrical calibration in order to determine the calibration factor.

D.

measures energy changes that can be measured in a bomb calorimeter.

Question 48 / 85

[VCAA 2021 SA Q19]
A food chemist conducted an experiment in a bomb calorimeter to determine the energy content, in joules per gram, of a muesli bar. A 3.95 g sample of the muesli bar was combusted in the calorimeter and the temperature of the water rose by 16.7 °C. The calibration factor of the calorimeter was previously determined to be 4780 J $°C^{-1}$.

The energy content of the muesli bar is

A.

3.51×10^5 J g^{-1}

B.

2.02×10^4 J g^{-1}

C.

1.13×10^3 J g^{-1}

D.

7.25×10 J g^{-1}

Question 49 / 85

[VCAA 2022 SA Q2]
A fuel undergoes combustion to heat water. Which of the following descriptions of the energy and enthalpy of combustion, *ΔH*, of the reaction is correct?

A.

Energy	***ΔH***
absorbed by water	negative

B.

released by water	negative

C.

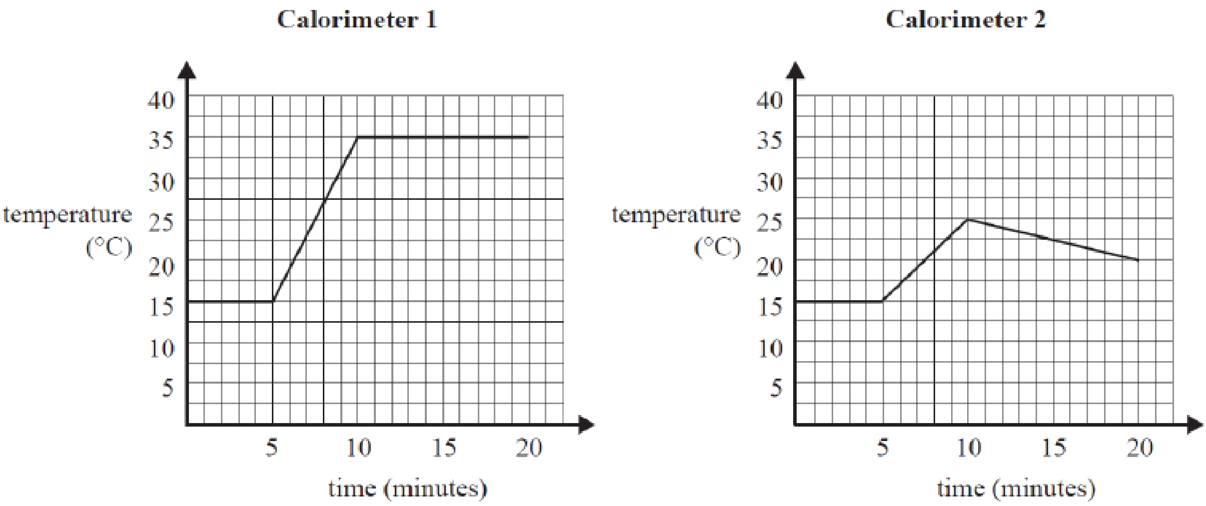
absorbed by water	positive

D.

released by water	positive

Question 50 / 85

[VCAA 2022 SA Q26]
Calorimeter 1 and Calorimeter 2 were each electrically calibrated. The same current, voltage and time were used to calibrate each calorimeter. A reaction was undertaken in Calorimeter 1 and Calorimeter 2. The same amount and type of each reactant was used in both calorimeters. The following temperature versus time graphs were produced for the reaction in each calorimeter.



Which one of the following statements is correct?

A.

Only Calorimeter 1 can be used to calculate m.

B.

Calorimeter 2 has better insulation than Calorimeter 1.

C.

The calibration factor for Calorimeter 2 is higher than the calibration factor for Calorimeter 1.

D.

During the calibration, the temperature increase of Calorimeter 2 was greater than the temperature increase of Calorimeter 1.

Question 51 / 85

For which of the following species is the oxidation number of oxygen the lowest?

A.

Na_2O_2

B.

H_2O_2

C.

O_2

D.

H_2SO_4

Question 52 / 85

In which of the following reactions is nitrous acid, HNO_2, behaving solely as an oxidising agent?

A.

$2H^+(aq) + Zn(s) + 2HNO_2(aq) \rightarrow Zn^{2+}(aq) + 2NO(g) + 2H_2O(l)$

B.

$MnO_2(s) + HNO_2(aq) + H^+(aq) \rightarrow Mn^{2+}(aq) + NO_3^-(aq) + H_2O(l)$

C.

$3HNO_2(aq) \rightarrow HNO_3(aq) + H_2O(l) + 2NO(g)$

D.

$2Fe^{3+}(aq) + HNO_2(aq) + H^+(aq) \rightarrow 2Fe^{2+}(aq) + NO_3^-(aq) + H_2O(l)$

Question 53 / 85

In which one of the following reactions does sulfur have the largest change in oxidation number?

A.

$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

B.

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

C.

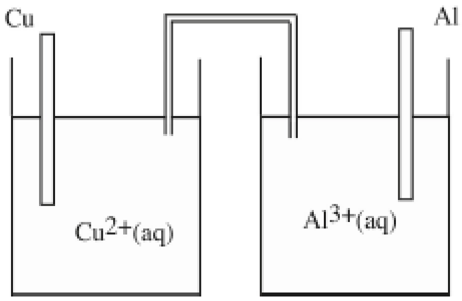
$H_2SO_4(l) + 8HI(g) \rightarrow H_2S(g) + 4H_2O(l) + 4I_2(s)$

D.

$S(l) + O_2(g) \rightarrow SO_2(g)$

Question 54 / 85

A galvanic cell is set up as shown in the diagram below.



In this cell, the aluminium electrode will be the

A. anode and negatively charged.

B. anode and positively charged.

C. cathode and negatively charged.

D. cathode and positively charged.

Question 55 / 85

A Cu/Cu^{2+} half-cell and a Zn/Zn^{2+} half-cell are connected using a salt bridge and the system is used to produce an electric current. The purpose of the salt bridge is to

---

A. allow the reactants to make contact with each other.

B. allow cations and anions to flow in and out of the two half-cells.

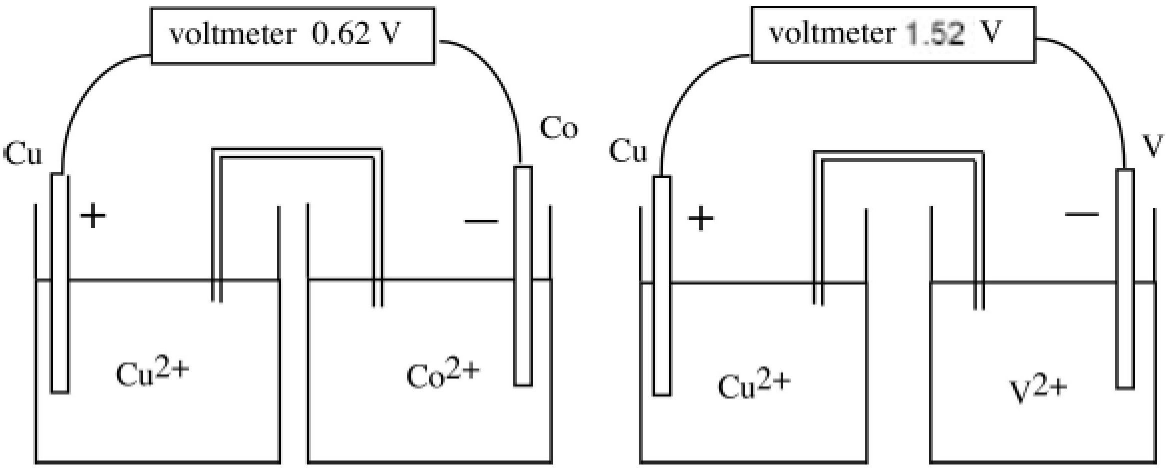
C. provide essential reactants for the overall reaction.

D. provide electrons to complete the circuit in the cell.

Question 56 / 85

The following information refers to Questions 57 and 58.

Two galvanic cells are set up as shown in the diagram below.



Question 57 / 85

The strongest reducing agent present is

A. Co

B. Cu

C. V

D. Cu^{2+}

Question 58 / 85

The voltage of a cell using the Co/Co^{2+} and V/V^{2+} half-cells would be

---

A.

0.90 V with the V electrode negative.

B.

0.90 V with the Co electrode negative.

C.

2.14 V with the V electrode negative.

D.

2.14 V with the Co electrode negative.

Question 59 / 85

A piece of steel plate is placed in each of four separate containers, each containing a different 0.50 M aqueous solution. The four solutions are $Pb(NO_3)_2(aq)$, $Zn(NO_3)_2(aq)$, $AgNO_3(aq)$ and $Cu(NO_3)_2(aq)$. It is expected that the piece of steel will be coated with another metal in the solutions of

---

A.

$Pb(NO_3)_2$, $AgNO_3$ and $Cu(NO_3)_2$.

B.

$Pb(NO_3)_2$ and $AgNO_3$.

C.

$AgNO_3$ and $Cu(NO_3)_2$.

D.

$Zn(NO_3)_2$ only.

Question 60 / 85

Three metals, R, S and T, have the following properties:

• Metal R does not react with 1.0 M H_2SO_4

• Metal S will react with 1.0 M H_2SO_4 to produce H_2, and also reacts with 1.0 M RCl_2 solution to produce R

• Metal T will react with 1.0 M H_2SO_4 to produce H_2 but does not react with 1.0 M SCl_2 solution.

From this information the order of reactivity of the metals and H_2, from the highest to the lowest, is

---

A. R > H_2 > T > S

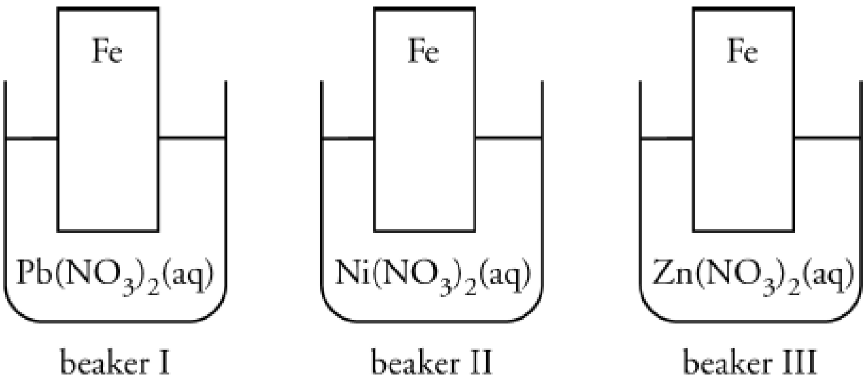
B. H_2 > R > T > S

C. S > H_2 > T > R

D. S > T > H_2 > R

Question 61 / 85

[VCAA 2013 SA Q24]
Three beakers, each containing an iron strip and a 1.0 mol L^{-1} solution of a metal salt, were set up as shown below.



A reaction will occur in beaker(s)

A. I and II only.

B. I and III only.

C. II and III only.

D. III only.

Question 62 / 85

[VCAA 2018 SA Q1]
Which one of the following statements is the **most** accurate?

A. All fuel cells are galvanic cells.

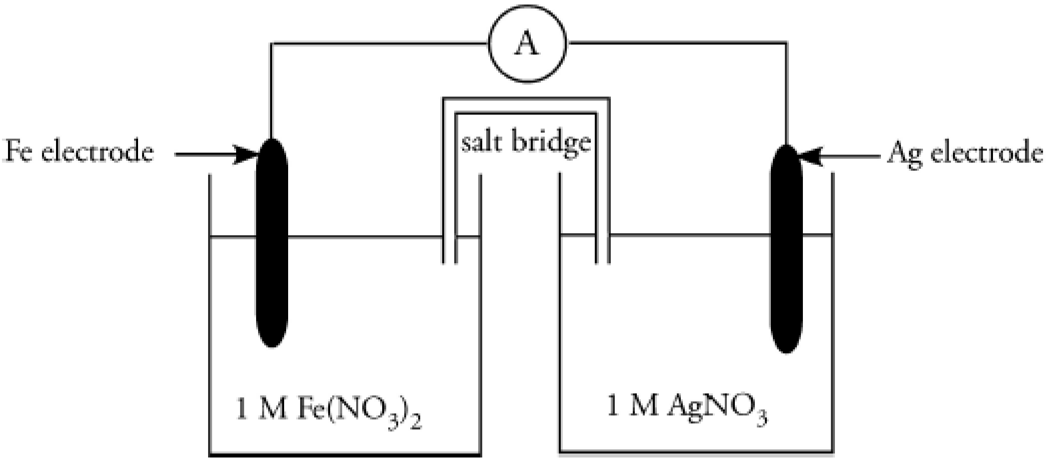
B. All galvanic cells are primary cells.

C. All secondary cells have porous electrodes.

D. All fuel cells are more efficient than all secondary cells.

Question 63 / 85

[VCAA 2018 SA Q11]
A galvanic cell is set up as shown in the diagram below.



When this cell is operating

A.

a gas forms at the Ag electrode.

B.

the mass of the Ag electrode increases.

C.

Ag^+ ions move towards the Fe electrode.

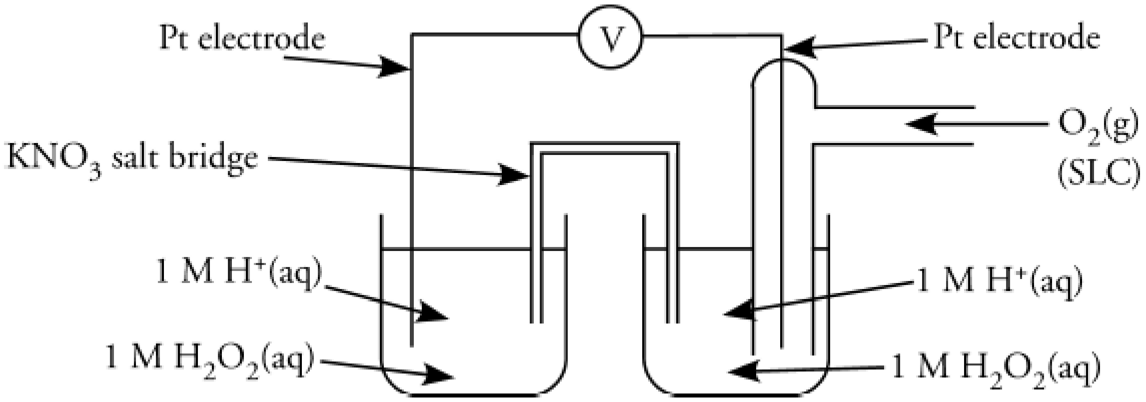
D.

electrons move from the Ag electrode to the Fe electrode.

Question 64 / 85

[VCAA 2013 SA Q25]

A student constructs the following galvanic cell.



The student predicts that the following overall reaction will occur.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

However, no reaction is observed. This is most likely because

---

A.

the difference between the *E*° values is too small for a reaction to occur.

B.

hydrogen peroxide will oxidise water in preference to itself.

C.

the student did not construct standard half-cells.

D.

the rate of the reaction is extremely slow.

Question 65 / 85

[VCAA 2018 SA Q12]
The overall reaction for an acidic fuel cell is shown below.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Porous electrodes are o en used in acidic fuel cells because they

---

A. are highly reactive.

B. are cheap to produce and readily available.

C. are more efficient than solid electrodes at moving charges and reactants.

D. provide a surface for the hydrogen and oxygen to directly react together.

Question 66 / 85

[VCAA 2014 SA Q25]
Consider the information below about the reaction of Ru^{2+} with various reagents.

$Ru^{2+}(aq) + Fe^{2+}(aq) \rightarrow$ no observed reaction

$Ru^{2+}(aq) + Ni(s) \rightarrow Ru(s) + Ni^{2+}(aq)$

$Ru^{2+}(aq) + Ag(s) \rightarrow$ no observed reaction

$Ru^{2+}(aq) + Cu(s) \rightarrow Ru(s) + Cu^{2+}(aq)$

Where would the following reaction be placed in the electrochemical series if the above tests were carried out under standard conditions?

$Ru^{2+}(aq) + 2e^- \rightleftharpoons Ru(s)$

A.

below −0.23 V

B.

between −0.44 V and −0.23 V

C.

between 0.77 V and 0.34 V

D.

above 0.77 V

Question 67 / 85

[VCAA 2014 SA Q26]
Consider the following experiments that are carried out under standard conditions.

Beaker I A strip of nickel metal is placed into a 1.0 M silver nitrate solution.

Beaker II A 1.0 M copper(II) sulfate solution is added to a 1.0 M sodium iodide solution.

Beaker III Chlorine gas is bubbled through a 1.0 M potassium iodide solution.

It would be predicted that a reaction will occur in

A. Beaker I only.

B. Beaker II only.

C. Beakers I and III only.

D. Beakers II and III only.

Question 68 / 85

[VCAA 2015 SA Q24]
The reaction between hydrogen peroxide and ammonium ions is represented by the following equation.

$3H_2O_2(aq) + 2NH_4^+(aq) \rightarrow N_2(g) + 2H^+(aq) + 6H_2O(l)$

Which one of the following is the correct half-equation for the reduction reaction?

A.

$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$

B.

$2NH_4^+(aq) \rightarrow N_2(g) + 8H^+(aq) + 6e^-$

C.

$2NH_4^+(aq) + 2e^- \rightarrow N_2(g) + 4H_2(g)$

D.

$H_2O_2(aq) + 2H_2O(l) \rightarrow 2O_2(g) + 6H^+(aq) + 6e^-$

Question 69 / 85

[VCAA 2015 SA Q25]
Solution I – 1.0 M NaCl

Solution II – 1.0 M $CuCl_2$

Solution III – 1.0 M $MgCl_2$.

Which solution or solutions above will react with Zn powder?

A.

Solution I only

B.

Solution II only

C.

Solutions I and III only

D.

Solutions I, II and III

Question 70 / 85

[VCAA 2017 SA Q6]
The overall equation for a particular methanol fuel cell is shown below.

$2CH_3OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

The equation for the reaction that occurs at the cathode in this fuel cell is

---

A.

$CO_2(g) + 5H_2O(l) + 6e^- \rightarrow CH_3OH(g) + 6OH^-(aq)$

B.

$CH_3OH(g) + 6OH^-(aq) \rightarrow CO_2(g) + 5H_2O(l) + 6e^-$

C.

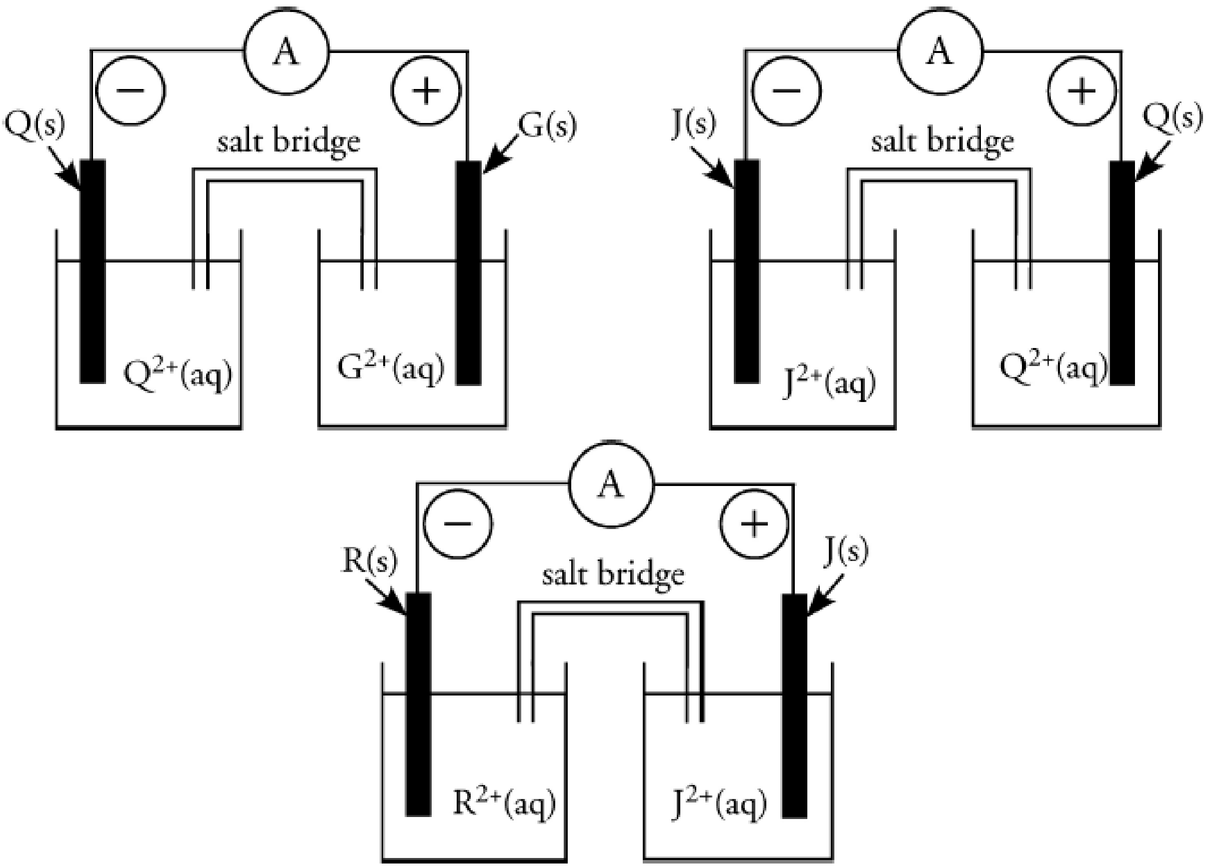
$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

D.

$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

Question 71 / 85

[VCAA 2018 SA Q29]
The diagrams below represent combinations of four galvanic half-cells (G/G^{2+}, J/J^{2+}, Q/Q^{2+} and R/R^{2+}) that were investigated under standard conditions. Each half-cell consisted of a metal electrode placed in a 1.0 M nitrate solution of the respective metal ion. The diagrams show the polarity of the electrodes in each half-cell, as determined using an ammeter. The results were then used to determine the order of the *E*° values of the half-reactions.



Which of the following indicates the order of the half-cell reactions, from the lowest *E*° value to the highest?

A. J/J^{2+}, R/R^{2+}, G/G^{2+}, Q/Q^{2+}

B. Q/Q^{2+}, G/G^{2+}, R/R^{2+}, J/J^{2+}

C. R/R^{2+}, J/J^{2+}, Q/Q^{2+}, G/G^{2+}

D. G/G^{2+}, Q/Q^{2+}, J/J^{2+}, R/R^{2+}

Question 72 / 85

[VCAA 2017 SA Q11]
A galvanic cell consists of two connected half-cells that can produce an electron flow. Which combination of standard half-cell pairs would be expected to result in a cell potential of 1.41 V?

A.

Al electrode with $Al(NO_3)_3$	Ag electrode with $AgNO_3$

B.

Zn electrode with $Zn(NO_3)_2$	Ni electrode with $Ni(NO_3)_2$

C.

Ni electrode with $Ni(NO_3)_2$	Al electrode with $Al(NO_3)_3$

D.

Ag electrode with $AgNO_3$	Zn electrode with $Zn(NO_3)_2$

Question 73 / 85

[VCAA 2019 SA Q8]
Consider the following statements about galvanic and fuel cells.

Statement number	**Statement**
1	The overall reaction is exothermic.
2	Electrons are consumed at the negative electrode.
3	Both the reducing agent and oxidising agent are stored in each half-cell.
4	The electrodes are in contact with the reactants and the electrolyte.

Statement number	Statement
5	The production of electricity requires the electrodes to be replaced regularly.

Which one of the following sets of statements is correct for **both** galvanic cells and fuel cells?

A. statement numbers 2 and 3

B. statement numbers 1 and 4

C. statement numbers 2, 4 and 5

D. statement numbers 1, 3 and 5

Question 74 / 85

[VCAA 2020 SA Q13]
Hydrogen, H_2, fuel cells and H_2-powered combustion engines can both be used to power cars. Three statements about H_2 fuel cells and H_2-powered combustion engines are given below:

I Neither H_2 fuel cells nor H_2-powered combustion engines produce greenhouse gases.

II Less H_2 is required per kilometre travelled when using an H_2-powered combustion engine than when using H_2 fuel cells.

III More heat per kilogram of H_2 is generated in an H_2-powered combustion engine than in H_2 fuel cells.

A. II only

B. I and II only

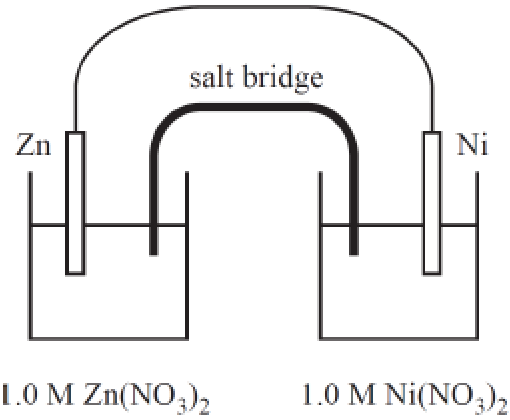
C. only

D. I and III only

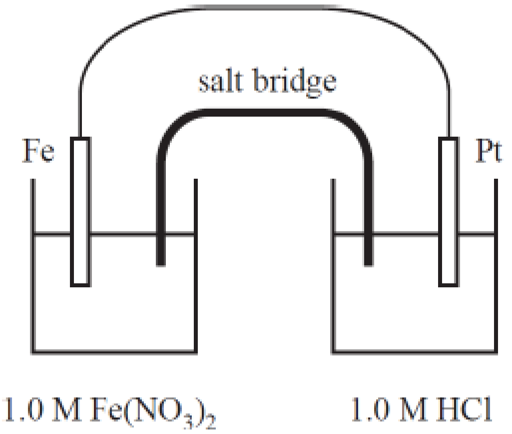
Question 75 / 85

[VCAA 2019 SA Q18]
Which one of the following galvanic cells will produce the largest cell voltage under standard laboratory conditions (SLC)?

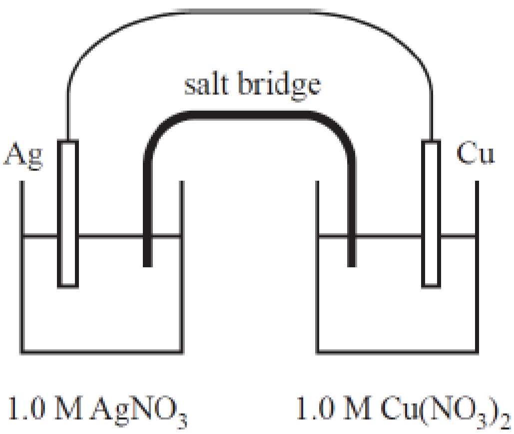
A.



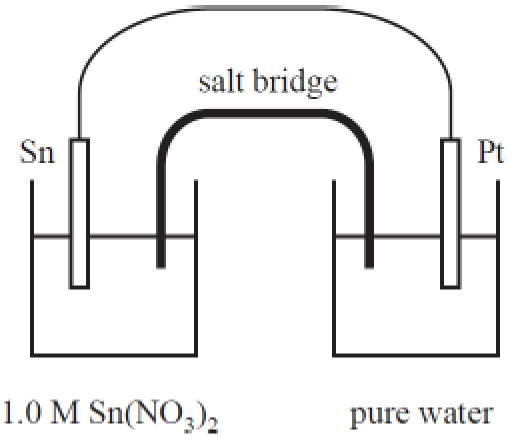
B.



C.

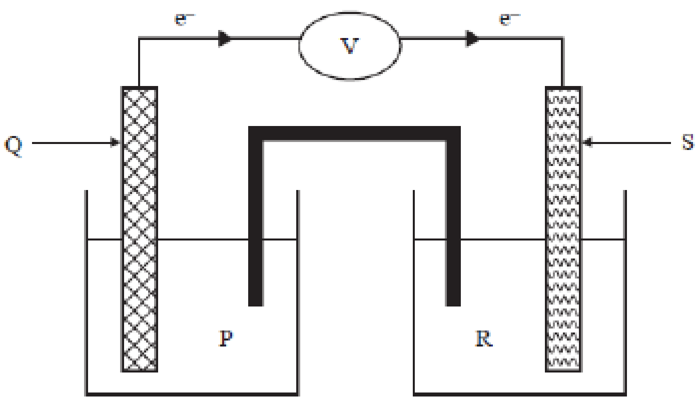


D.



Question 76 / 85

[VCAA 2020 SA Q3]
A diagram of an electrochemical cell is shown below.



Which of the following gives the correct combination of the electrode in the oxidation half-cell and the electrolyte in the reduction half-cell?

A.

Electrode (oxidation half-cell)	Electrolyte (reduction half-cell)
S	P

B.

S	R

C.

Q	R

D.

Q	P

Question 77 / 85

[VCAA 2020 SA Q26]
The following reactions occur in a primary cell battery.

$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

$2MnO_2 + 2e^- + H_2O \rightarrow Mn_2O_3 + 2OH^-$

Which one of the following statements about the battery is correct?

A. The reaction produces heat and Zn reacts directly with MnO_2.

B. The reaction produces heat and Zn does not react directly with MnO_2.

C. The reaction does not produce heat and Zn reacts directly with MnO_2.

D. The reaction does not produce heat and Zn does not react directly with MnO_2.

Question 78 / 85

[VCAA 2020 SA Q30]
Consider the following half-equation.

$ClO_2(g) + e^- \rightleftharpoons ClO_2^-(aq)$

It is also known that:

• $ClO_2(g)$ will oxidise HI(aq), but not HCl(aq)

• $Fe^{3+}(aq)$ will oxidise Hl(aq), but not $NaClO_2(aq)$.

Based on this information, $Fe^{2+}(aq)$ can be oxidised by

A. $Cl_2(g)$ and $I_2(aq)$.

B. $Cl_2(g)$, but not $ClO_2(g)$.

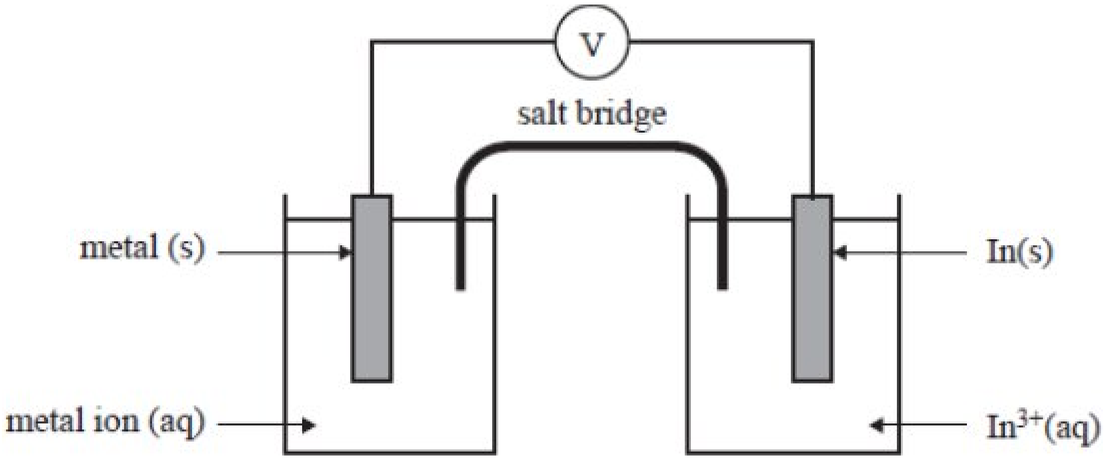
C. $ClO_2(g)$ and $Cl_2(g)$, but not $I_2(aq)$.

D. $Cl_2(g)$, $ClO_2(g)$ and $I_2(aq)$.

Question 79 / 85

[VCAA 2021 SA Q26]

Different metal ion (aq)/metal (s) half-cells are combined with an In^{3+}(aq)/In(s) half-cell to create a galvanic cell at SLC, as shown in the diagram below. The equation for the In^{3+}(aq)/In(s) half-cell is $In^{3+}(aq) + 3e^{-} \rightleftharpoons In(s)$



Which of the following shows the half-cells in decreasing order of voltage produced when combined with the In^{3+}(aq)/In(s) half-cell and In(s) is the negative electrode?

A.

Mn^{2+}(aq)/Mn(s), Al^{3+}(aq)/Al(s), Mg^{2+}(aq)/Mg(s)

B.

Mg^{2+}(aq)/Mg(s), $A1^{3+}$(aq)/Al(s), Mn^{2+}(aq)/Mn(s)

C.

Cu^{2+}(aq)/Cu(s), Pb^{2+}(aq)/Pb(s), Ni^{2+}(aq)/Ni(s)

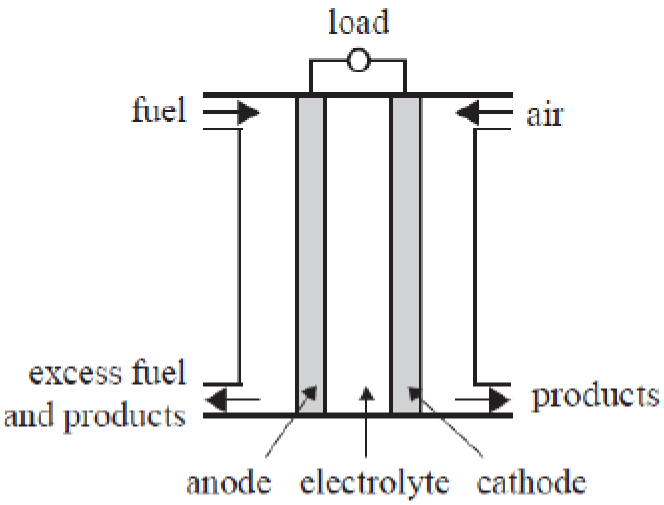
D.

Ni^{2+}(aq)/Ni(s), Pb^{2+}(aq)/Pb(s), Cu^{2+}(aq)/Cu(s)

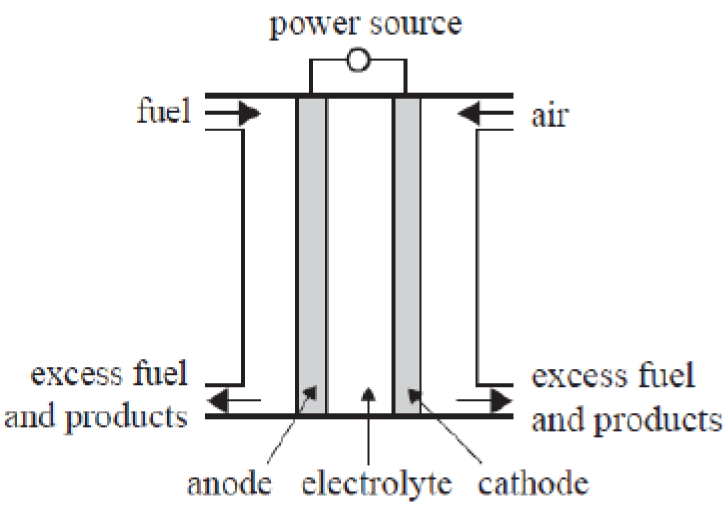
Question 80 / 85

[VCAA 2022 SA Q4]
Which one of the following diagrams shows the common design features of a fuel cell?

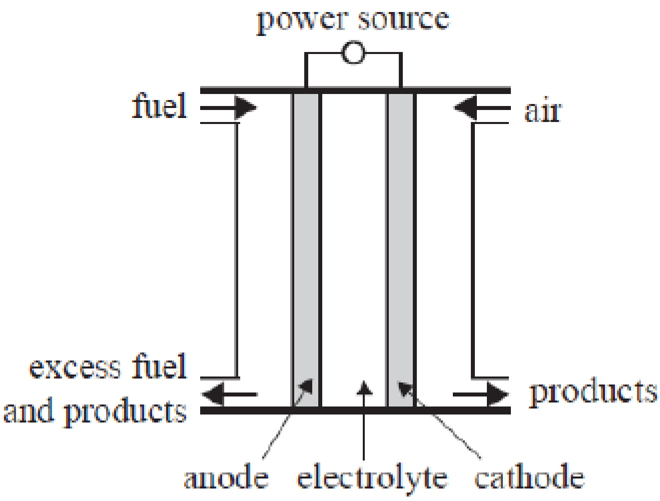
A.



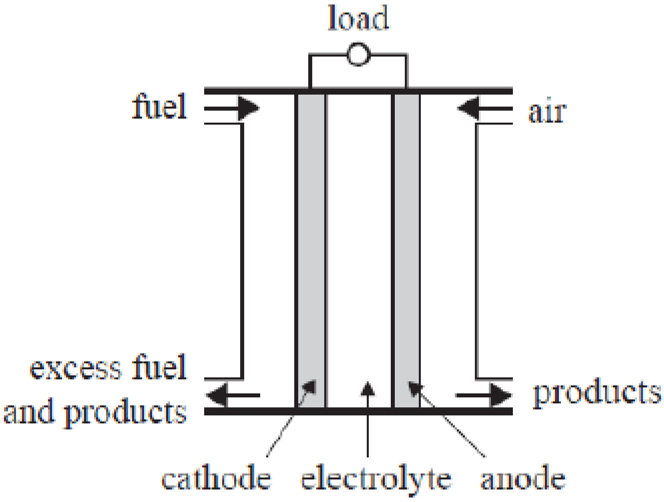
B.



C.



D.



Question 81 / 85

[VCAA 2022 SA Q6
Galvanic cells and fuel cells have

A. the same energy transformations and both are reversible.

B. the same energy transformations and both produce heat.

C. different energy transformations but galvanic cells produce electricity.

D. different energy transformations but fuel cells use porous electrodes.

Question 82 / 85

[VCAA 2022 SA Q8]
Unlike direct combustion of fuel, fuel cells

A.

can be recharged.

B.

do not produce greenhouse gases.

C.

require electrical energy to overcome the activation energy barrier.

D.

do not have direct contact between the oxidising and reducing agents.

Question 83 / 85

[VCAA 2022 SA Q14]
The discharge reaction in a vanadium redox battery is represented by the following equation.

$VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq) \rightarrow V^{3+}(aq) + VO^{2+}(aq) + H_2O(l)$

When the vanadium redox battery is recharging

A.

H^+ is the reducing agent.

B.

H_2O is the oxidising agent.

C.

VO^{2+} is the reducing agent.

D.

VO_2^+ is the oxidising agent.

Question 84 / 85

[VCAA 2022 SA Q18]

A student wants to investigate a galvanic cell consisting of Sn^{4+}/Sn^{2+} and Ag^{+}/Ag half-cells. Which one of the following combinations of electrodes and solutions will produce an operational galvanic cell?

A.

Sn^{4+}/Sn^{2+} half-cell		**Ag^{+}/Ag half-cell**	
Electrode	**Solution(s)**	**Electrode**	**Solution**
Sn	1 M $Sn(NO_3)_2$	graphite	1 M $AgNO_3$

B.

Sn	1 M $Sn(NO_3)_4$, 1 M $Sn(NO_3)_2$	graphite	1 M $AgNO_3$

C.

graphite	1 M $Sn(NO_3)_4$, 1 M $Sn(NO_3)_2$	Ag	1 M $AgNO_3$

D.

graphite	1 M $Sn(NO_3)_4$	Ag	1 M $AgNO_3$

Question 85 / 85

[VCAA 2022 SA Q30]

Consider the following half-equations, which are not in standard electrode potential order.

$HCrO_4^-(aq) + 7H^+(aq) + 3e^- \rightleftharpoons Cr^{3+}(aq) + 4H_2O(l)$

$HBrO(aq) + H^+(aq) + e^- \rightleftharpoons 12Br_2(aq) + H_2O(l)$

$2IO_3^-(aq) + 12H^+(aq) + 10e^- \rightleftharpoons I_2(aq) + 6H_2O(l)$

$BrO_3^-(aq) + 6H^+(aq) + 6e^- \rightleftharpoons Br^-(aq) + 3H_2O(l)$

The following is also known:

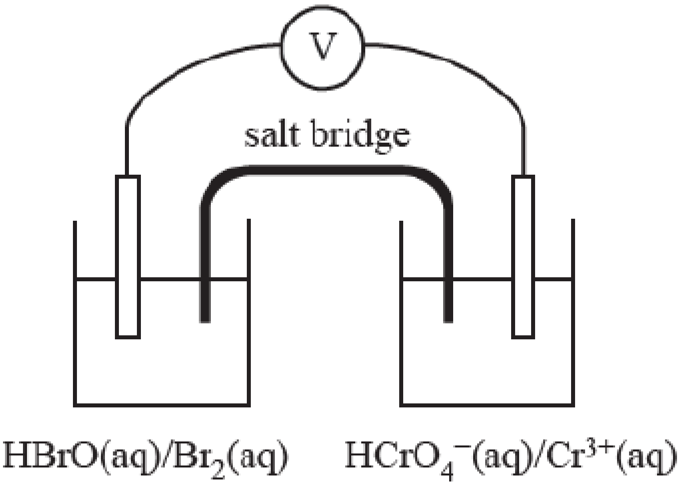
• I_2 reacts with BrO_3^- and HBrO but not with $HCrO_4^-$.

• Br^- reacts with HBrO but not with IO_3^-.

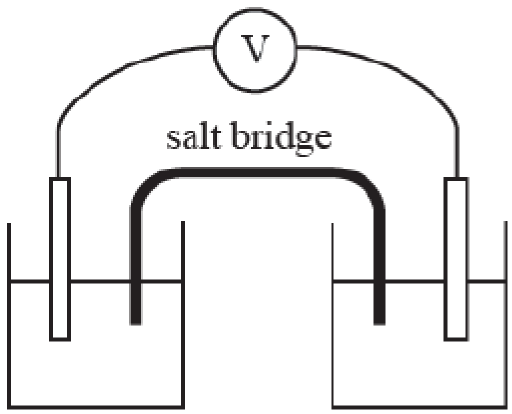
Platinum electrodes were used in each half-cell.

Which one of the following galvanic cells will produce the highest potential difference?

A.

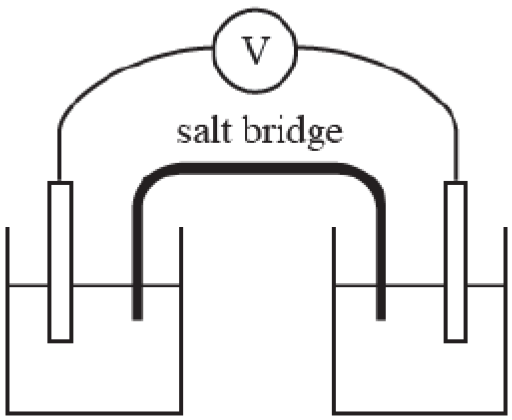


B.



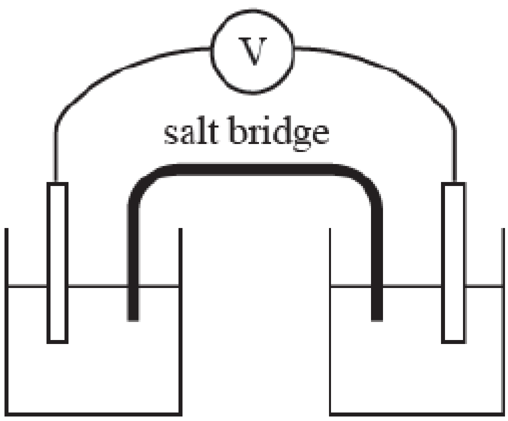
$HCrO_4^-(aq)/Cr^{3+}(aq)$ $BrO_3^-(aq)/Br^-(aq)$

C.



$BrO_3^-(aq)/Br^-(aq)$ $IO_3^-(aq)/I_2(aq)$

D.



$HBrO(aq)/Br_2(aq)$ $IO_3^-(aq)/I_2(aq)$

Question 1 / 29

Methane and methanol will both burn in air. The reactions are described by the equations

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; $\Delta H = -890\ kJ\ mol^{-1}$

$2CH_3OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$; $\Delta H = -1452\ kJ\ mol^{-1}$

(a) If 2 mol of methane and 2 mol of methanol are completely burned in separate experiments, which experiment will release the most energy?

(1 mark)

(b) If each of the above reactions is used to produce 1000 kJ of energy, which one will release the most carbon dioxide?

(2 marks)

(Total = 3 marks)

Question 2 / 29

The reaction between hydrogen and oxygen is described by the equation

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$; $\Delta H = -484$ kJ mol^{-1}

(a) Draw an energy level diagram showing how the energy of the reactants is related to that of the products. Your diagram should also show ΔH and an activation energy.

(3 marks)

(b) Describe how the strength of the bonds in the reactants is related to the strength of the bonds in the products.

(1 mark)

(c) Would you expect the magnitude of the enthalpy change for the reaction

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

to be greater than, less than or the same as the heat change in the first reaction? Explain your answer.

(2 marks)

(Total = 6 marks)

Question 3 / 29

Glucose is a very important energy source and is present in many foods. It is oxidised according to the equation below.

$C_6H_{12}O_6(s) + 6O_2(aq) \rightarrow 6CO_2(g) + 6H_2O(l)$; $\Delta H = -2803$ kJ mol^{-1}

(a) The energy required by a typical VCE chemistry student is about 13 500 kJ per day. If all of the student's energy is derived from the oxidation of glucose, as shown above, calculate the mass of glucose required each day.

(2 marks)

(b) The label on a bottle of fruit juice cordial indicates that 50.00 mL of the cordial yields 350 kJ of energy. If glucose is the only source of energy in the cordial, calculate the concentration of glucose in g L^{-1}.

(3 marks)

(c) (i) According to the label on a packet of breakfast bars, each breakfast bar weighs 36.7 g, of which 66.7% is carbohydrate. If all of the carbohydrate is present as glucose, calculate the amount of energy that could be obtained from the combustion of the glucose in the breakfast bar.

(3 marks)

(ii) If the breakfast bar yields a total of 615 kJ, what percentage of the energy comes from the combustion of the carbohydrate?

(1 mark)

(Total = 9 marks)

Question 4 / 29

One substance used in detonators is lead azide, $Pb(N_3)$, because when given a shock (either thermal or mechanical), it decomposes rapidly according to the equation:

$Pb(N_3)_2(s) \rightarrow Pb(s) + 3N_2(g)$; $\Delta H = -436$ kJ mol^{-1}

(a) Would you expect the bonds in Pb and N_2 to be stronger than those in $Pb(N_3)_2$ or weaker?

Explain your answer.

(2 marks)

(b) Draw an energy level diagram showing how the energy of the reactants is related to that of the products. Your diagram should also show ΔH and an activation energy.

(3 marks)

(c) 10.0 g of lead azide rapidly decomposes in a volume of 5.00 mL.

(i) Calculate the amount of energy released by this decomposition.

(1 mark)

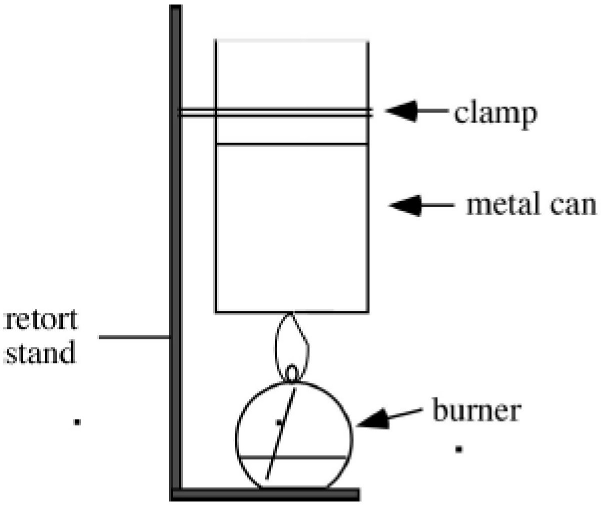
(ii) Calculate the mass of the gas product.

(2 marks)

(Total = 8 marks)

Question 5 / 29

A student is asked to determine the heat of combustion of methanol, CH_3OH, using the apparatus shown below. 300 g of water is placed in a metal can. The can is clamped above the flame from a spirit burner. The temperature of the water is measured before and after heating by the methanol burner. The burner is weighed before and after heating the water.



The student obtains the following results:

- mass of burner and methanol before combustion = 35.674 g
- mass of burner and methanol after combustion = 34.396 g
- temperature of water in can before heating = 16.3°C
- temperature of water in can after heating = 28.1°C

(a) Why was a metal can used rather than a glass container?

(1 mark)

(b) How many mol of methanol was burnt?

(2 marks)

(c) Calculate the heat energy given to the water.

(1 mark)

(d) From parts **(b)** and **(c)**, calculate the heat of combustion of methanol in kJ mol^{-1}.

(1 mark)

(e) The accepted value for the heat of combustion of methanol is −725 kJ mol^{-1}. Suggest two reasons why the value determined in part **(d)** is different from this value.

(2 marks)

(Total = 7 marks)

Question 6 / 29

Natural gas consists largely of methane, CH_4, and is used as a source of energy in domestic gas supplies. In a laboratory using natural gas, a student uses a Bunsen burner to heat 300 g of water. The temperature rises from 16.7°C to 49.6°C.

(a) Calculate the heat supplied to the water if the specific heat of water is 4.18 $J°C^{-1}\ g^{-1}$.

(1 mark)

(b) If only 65% of the energy produced from the combustion of the gas is transmitted to the water, calculate the energy produced by the Bunsen burner.

(1 mark)

(c) Write the equation for the combustion of methane.

(1 mark)

(d) The student also measured the amount of gas used in the above experiment and found that 1.82 L at SLC were required. Calculate *ΔH* for the equation in part **(c)**.

(3 marks)

(Total = 6 marks)

Question 7 / 29

Methylated spirits is mostly ethanol, C_2H_5OH, but also contains small amounts of methanol and water. The energy content of methylated spirits is found to be 28.5 MJ kg^{-1} and it has a density of 0.795 g mL^{-1}. A camper uses methylated spirits as a source of energy to boil his drinking water. He heats 600 g of water from 15°C to boiling point.

(a) Why is it not possible to express the energy content of methylated spirits in kJ mol^{-1}?

(1 mark)

(b) Write a balanced equation for the reaction of ethanol with oxygen.

(1 mark)

(c) Calculate the volume of methylated spirits that must be burnt to heat the water, if only 60% of the energy from burning the methylated spirits reaches the water.

(4 marks)

(Total = 6 marks)

Question 8 / 29

Copper forms two oxides, Cu_2O and CuO. The energy change when each oxide is formed is given by the equations below.

$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$; $\Delta H = -310.4\ \text{kJ mol}^{-1}$

$4Cu(s) + O_2(g) \rightarrow 2Cu_2O(s)$; $\Delta H = -338\ \text{kJ mol}^{-1}$

Use this information to calculate ΔH for the reaction

$Cu_2O(s) \rightarrow Cu(s) + CuO(s)$

(Total = 3 marks)

Question 9 / 29

[Adapted VCAA 2014 SB Q3]
The heat of combustion of ethanol is provided in the VCAA data book. This combustion of ethanol is represented by the following equation.

$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

A spirit burner used 1.80 g of ethanol to raise the temperature of 100.0 g of water in a metal can from 25.0°C to 40.0°C (see diagram below).

(a) Calculate the percentage of heat lost to the environment and to the apparatus.

(5 marks)

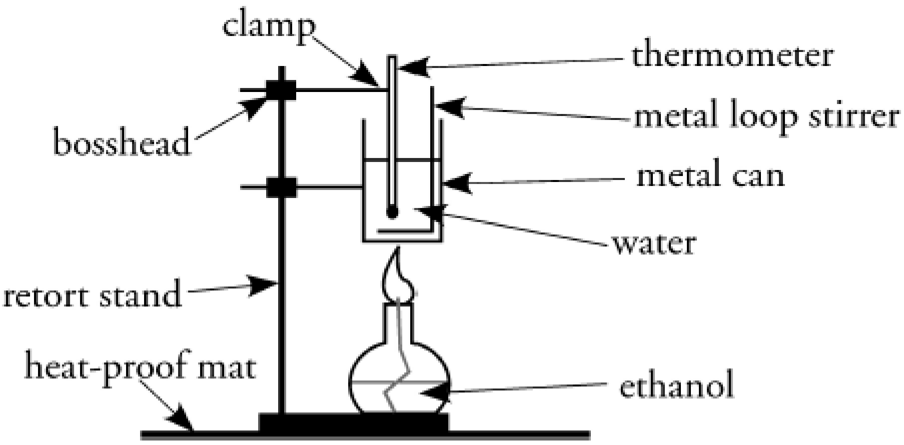
(b)Idntify **one** way to limit heat loss to the environment.

(1 mark)

(c) Biodiesel may be produced by reacting canola oil with methanol in the presence of a strong base. Since canola oil contains a mixture of triglycerides, the reaction produces glycerol and a mixture of biodiesel molecules. A typical biodiesel molecule derived from canola oil has the chemical formula $C_{15}H_{30}O_2$.

The heat content of canola oil can be determined by placing it in the spirit burner in place of ethanol. A typical result is 17 kJ g^{-1}. Suggest why the heat content of fuels such as canola oil and biodiesel are measured in kJ g^{-1} and not kJ mol^{-1}.

(1 mark)



(Total = 7 marks)

Question 10 / 29

[Adapted VCAA 2017 SB Q2]

A vehicle that is powered by a diesel engine is able to use either petrodiesel or biodiesel as a fuel. Petrodiesel and biodiesel are not pure substances but are a mixture of molecules. In general, petrodiesel consists of molecules that are shorter in length, on average, than those found in biodiesel. Biodiesel contains molecules that include functional groups. The table below lists some of the properties of the two fuels.

Fuel	**Major component**	**Energy content (MJ kg^{-1})**	**CO_2 emission (kg CO_2/kg of fuel)**
petrodiesel	$C_{12}H_{26}$	43	3.17
biodiesel	$C_{19}H_{32}O_2$	38	2.52

(a) Assume that combustion occurs in an unlimited supply of oxygen for each of the following calculations. Using the data from the table above:

(i) calculate the number of litres of biodiesel that are required to be burnt to produce the same amount of energy as 2.5 kg of petrodiesel. [density (biodiesel) = 0.89 kg L^{-1}]

(3 marks)

(ii) calculate the mass of carbon dioxide, CO_2, that would be produced from 3.91 kg of biodiesel.

(1 mark)

(b) In some circumstances, there is a limited supply of oxygen. Write the balanced chemical equation for the combustion reaction of the major component of biodiesel, $C_{19}H_{32}O_2$, where carbon monoxide, CO, is the only product containing carbon.

(2 marks)

(Total = 6 marks)

Question 11 / 29

[Adapted VCAA 2020 SB Q6]

Methane gas, CH_4, can be captured from the breakdown of waste in landfills. CH_4 is also a primary component of natural gas. CH_4 can be used to produce energy through combustion.

(a) Write the equation for the incomplete combustion of CH_4 to produce carbon monoxide, CO.

(1 mark)

(b) A Bunsen burner is used to heat a beaker containing 350.0 g of water. Complete combustion of 0.485 g of CH_4 raises the temperature of the water from 20 °C to 32.3 °C. Calculate the percentage of the Bunsen burner's energy that is lost to the environment.

(3 marks)

(c) Compare the environmental impact of CH_4 obtained from landfill to the environmental impact of CH_4 obtained from natural gas.

(2 marks)

(Total = 6 marks)

Question 12 / 29

[VCAA 2021 SB Q1]
Digesters use bacteria to convert organic waste into biogas, which contains mainly methane, CH_4. Biogas can be used as a source of energy.

(a) Both biogas and coal seam gas contain CH_4 as their main component.

Why is biogas considered a renewable energy source but coal seam gas is not?

(1 mark)

(b) A digester processed 1 kg of organic waste to produce 496.0 L of biogas at standard laboratory conditions (SLC). The biogas contained 60.0% CH_4.

(i) Write the thermochemical equation for the complete combustion of CH_4 at SLC.

(2 marks)

(ii) Calculate the amount of energy that could be produced by CH_4 from 1 kg of organic waste.

(3 marks)

(c) Biogas was combusted to release 1.63×10^3 kJ of energy. This energy was used to heat 100 kg of water in a tank. The initial temperature of the water was 25.0 °C.

(i) What is the maximum temperature that the water in the tank could reach?

(2 marks)

(ii) State why this temperature may not be reached.

(1 mark)

(Total = 9 marks)

Question 13 / 29

Carbohydrates, vitamins, fats and proteins are all important components of a balanced diet. Carbohydrates are an immediate source of energy for most living things. Fats and proteins can also be used to provide energy but also have other important functions.

(a) A bomb calorimeter is used to determine the energy content of a vegetable oil. 4.86 g of the vegetable oil was completely combusted in a calorimeter that contained 2.50 L of water. The temperature of the water rose from 19.5°C to 33.8°C. Calculate the energy content of the vegetable oil in kJ g^{-1}.

(3 marks)

(b) Why is the energy content of the vegetable oil calculated in kJ g^{-1} and not kJ mol^{-1}?

(1 mark)

(Total = 4 marks)

Question 14 / 29

A breakfast food company has a new product, Breckyflakes, which it claims is less fattening than the product of its main rival, Iron-bran. To test the accuracy of these claims, the makers of Iron-bran employ a chemist to determine the heat content of each breakfast cereal. A 15.0 g sample of each cereal is placed in a calorimeter where it is burned in an excess of oxygen. The results shown below were obtained.

Breckyflakes sample:

• initial temperature of calorimeter and sample	= 18.417°C
• temperature after complete combustion	= 21.577°C
• temperature of calorimeter and combustion products after electric current is used to add 30.2 kJ	= 22.186°C

Iron-bran sample:

(a) Determine the calibration factor of the calorimeter in kJ $°C^{-1}$.

(1 mark)

(b) For each of the breakfast cereals, calculate the energy content in kJ g^{-1}.

(4 marks)

(c) From these results can you decide which cereal is most fattening? If you cannot make a decision, what extra evidence might you need?

(2 marks)

(Total = 7 marks)

• initial temperature of calorimeter and sample	= 18.961°C
• temperature after combustion of sample	= 22.384°C

Question 15 / 29

Calorimeters are often calibrated by measuring the temperature change when a compound with a known heat of combustion is reacted. In a typical experiment 0.1049 g of benzoic acid, C_6H_5COOH, is completely burned in a calorimeter. The temperature of the calorimeter changes from 18.674°C to 21.905°C. The equation for the reaction is

$2C_6H_5COOH(s) + 15O_2(g) \rightarrow 14CO_2(g) + 6H_2O(l)$; $\Delta H = -6526$ kJ mol^{-1}

(a) How many moles of benzoic acid reacted?

(1 mark)

(b) How much heat energy was released during the reaction?

(2 marks)

(c) Calculate a value for the calorimeter constant in J°C^{-1}.

(2 marks)

Ethanol, C_2H_5OH, has been suggested as an alternative fuel to petrol. 0.545 mL of ethanol is burned in the same calorimeter and a temperature rise of 14.618°C is recorded.

(d) How much energy was released by the burning ethanol?

(1 mark)

(e) Calculate the heat of combustion of ethanol in kJ mL^{-1}.

(1 mark)

(Total = 7 marks)

Question 16 / 29

A middle-distance runner runs for 4 minutes 30 seconds and takes 70 breaths per minute. He has a lung capacity of 7.2 L and exchanges all of the air in his lungs with each breath. Air contains 20% oxygen, 25% of which is used in his cells for the reaction

$C_6H_{12}O_6(aq) + 6O_2(aq) \rightarrow 6CO_2(g) + 6H_2O(l)$; $\Delta H = -2800$ kJ mol^{-1}

(a) What volume of oxygen is inhaled in 4.5 minutes?

(1 mark)

(b) What volume of oxygen reacts at the cells?

(1 mark)

(c) Assuming the oxygen was at SLC, calculate the minimum mass of glucose that the runner uses while running.

(2 marks)

(d) Calculate the energy the runner has obtained from the reaction of the glucose.

(1 mark)

(Total = 5 marks)

Question 17 / 29

[Adapted VCAA 2019 SB Q6]
There are many varieties of bread available to consumers in Australia. The nutritional values for one type of wholemeal bread are given in the table below.

	Per 100 g
Energy	1000 kJ
Protein	9.1 g
Fats and oils	2.5 g
Carbohydrates	41.5 g
Sugars	3.0 g
Fibre	6.4 g

(a) Calculate the energy, in kilojoules, provided by the protein and fats and oils in 100 g of this wholemeal bread.

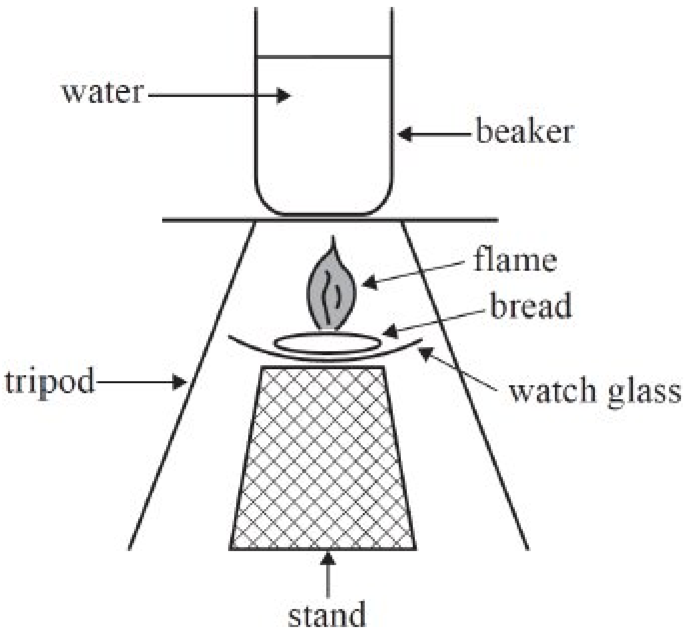
(1 mark)

(b) The wholemeal bread undergoes complete combustion in a bomb calorimeter containing 200 g of water. Assume that all of the energy in the combustion is transferred to the water.

(i) Calculate the mass of bread needed to raise the temperature of the water by 6°C.

(2 marks)

(ii) The combustion of the bread was investigated using a different method. The bread was ignited under a beaker containing 200 g of water, which was set on a tripod. The equipment used is shown below.



If 1.2 g of bread was needed to raise the temperature of the water by 6°C using this different method, calculate the efficiency of the energy transfer in this combustion.

(1 mark)

(Total = 4 marks)

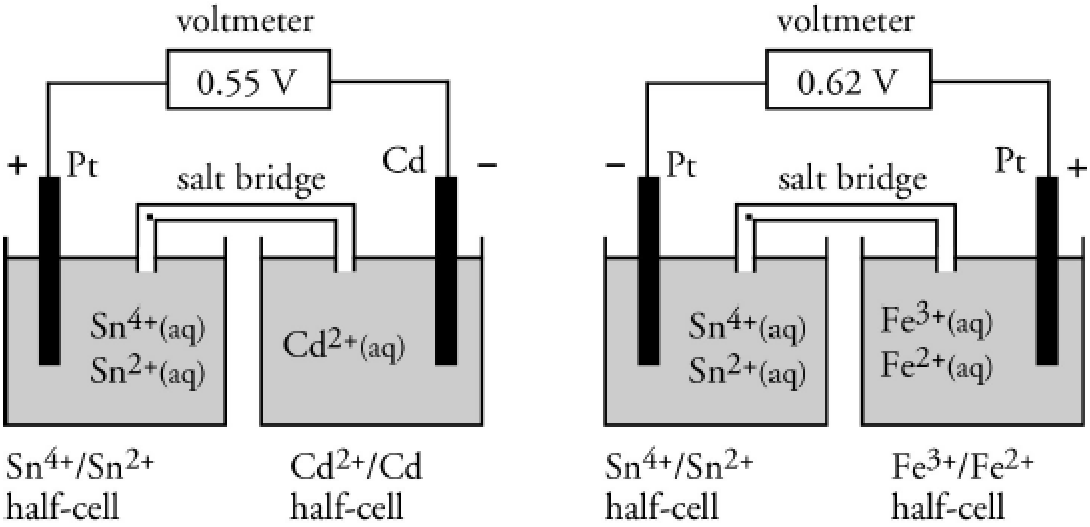
Question 18 / 29

A chemist places tin rods in each of four 1.0 M aqueous solutions. The solutes are respectively $AgNO_3$, $CuSO_4$, $FeSO_4$ and $ZnCl_2$. Describe what you would expect to happen in each of these experiments. Give reasons for your answers. Give equations for any reactions that occur.

(Total = 4 marks)

Question 19 / 29

The potential differences and electrode polarities of two standard electrochemical cells are shown below. (Note that not all of these half-cells are listed in the electrochemical series provided in the VCAA data book.)



(a) From the information given above, deduce which species in the two cells is the strongest oxidising agent. Explain your reasoning.

(2 marks)

(b) Give the equation for the reaction occurring at the anode in each cell.

(2 marks)

(c) If a cell was constructed from the Fe^{3+}/Fe^{2+} and the Cd^{2+}/Cd half-cells, what would be the value for the potential difference of the cell?

(1 mark)

(Total = 5 marks)

Question 20 / 29

A home chemistry kit contains solutions of Sn^{2+}, Cu^{2+}, Fe^{3+}, a dilute acid and pieces of metallic copper, iron, lead and zinc.

(a) Describe an experiment in which $Sn^{2+}(aq)$ would be oxidised to $Sn^{4+}(aq)$. Give a balanced equation for the reaction.

(2 marks)

(b) If a mixture of $Cu^{2+}(aq)$ and $Fe^{3+}(aq)$ was prepared, how could the $Fe^{3+}(aq)$ be reduced without the $Cu^{2+}(aq)$ reacting? Give a balanced equation for the reaction.

(2 marks)

(c) Give a balanced equation for a reaction that could be used to prepare a sample of hydrogen gas.

(1 mark)

(Total = 5 marks)

Question 21 / 29

A chemist carried out reactions with three metals, X, Y and Z, and solutions of their nitrate salts. The observations below were made when clean metal surfaces were used.

I Metal Z dissolved in a 1.0 M YNO_3 solution, forming a deposit of metal Y.

II Metal X did not react with a 1.0 M $Z(NO_3)_3$ solution.

III Metal Y did not react with a 1.0 M $X(NO_3)_2$ solution.

(a) Use this information to place the three metals in order of increasing strength as reducing agents (put the least reactive first). Give reasons for your answer.

(3 marks)

(b) Some methods for mining metals from metal ores utilise a reaction between the metal and a substance pumped into the ore, such as an acid. This means that more reactive metals are more easily extracted in this type of process as they more readily react and dissolve, as metal ions, into the solution. The liquid is then extracted from the ore with the dissolved ions.

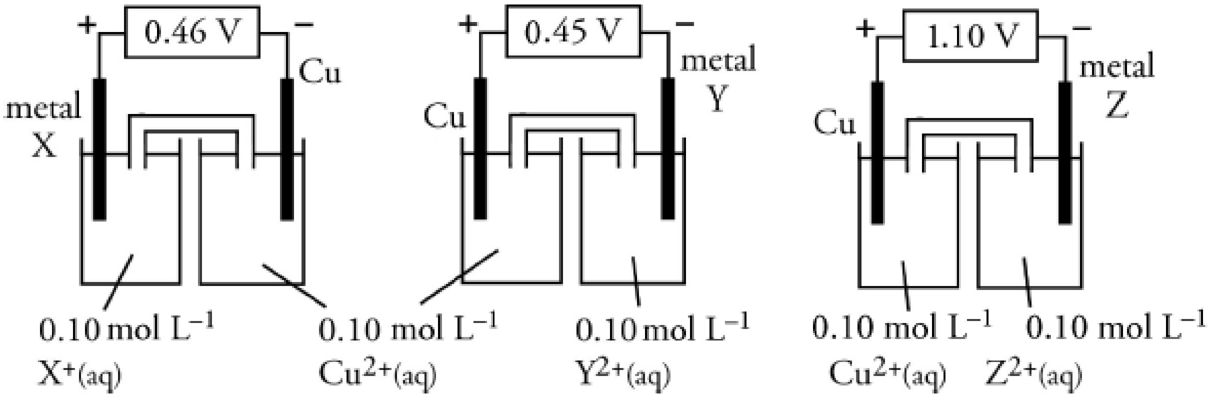
The naturally occurring ores of these metals are XS, Y_2S and Z_2O_3. Which metal is likely to be the easiest to extract from its ore and which metal is likely to be the most difficult to extract? Give reasons for your answers.

(2 marks)

(Total = 5 marks)

Question 22 / 29

Three electrochemical cells are set up as shown below. The potential difference is shown on each voltmeter.



(a) From this information, deduce the order of the four half-cells Cu^{2+}/Cu, X^{+}/X, Y^{2+}/Y and Z^{2+}/Z in the electrochemical series. (List the one with the strongest oxidant first.)

(3 marks)

(b) If a cell was constructed from the Y^{2+}/Y and Z^{2+}/Z half-cells, deduce the polarity of the electrodes and the potential difference of the cell.

(2 marks)

(Total = 5 marks)

Question 23 / 29

Six experiments were carried out in which pairs of reagents were mixed. The pairs are indicated in the left-hand column of the table below. For those cases where the electrochemical series would predict that a reaction should occur, write a balanced chemical equation for the predicted reaction. Where you do not expect a reaction, write ‘no reaction’.

Reactants	**Predicted reaction Yes/No**	**Equation**
Fe^{2+}(aq)/Cl_2(g)		
$AgNO_3$(aq)/Sn(s)		
$SnCl_2$(aq)/Cu(s)		
Cd^{2+}(aq)/Ag(s)		
Ni^{2+}(aq)/Cd(s)		
Cl^{-}(aq)/I_2(aq)		

(Total = 9 marks)

Question 24 / 29

Copper plates were once attached to the hulls of wooden ships. In water, the copper corroded and produced $Cu^{2+}(aq)$ ions. These ions are poisonous to many marine organisms and so the formation of barnacles and other organisms on the ships' hulls was prevented. In seawater, the copper corroded very rapidly. To slow down the removal of the copper, pieces of a reactive metal were attached to the copper plates. Zinc was often used as the reactive metal.

The copper plates then lasted for a longer time, but the barnacles and other organisms quickly attached themselves to the hulls of the ships.

Use the electrochemical series to answer the questions below.

(a) Why do the copper plates corrode? Write a balanced equation for the reaction.

(2 marks)

(b) The corrosion is faster in seawater. Suggest a reason for this.

(1 mark)

(c) Why do pieces of a reactive metal prevent the copper from corroding? What happens to the reactive metal, such as zinc? Write the equation for any reaction that occurs.

(3 marks)

(d) When a piece of zinc is joined to the copper plates, barnacles rapidly become attached to the hull. Suggest a reason for this.

(1 mark)

(Total = 7 marks)

Question 25 / 29

Consider the following electrochemical series.

$Cu^{+}(aq) + e^{-} \rightleftharpoons Cu(s)$ $E° = 0.52$ V

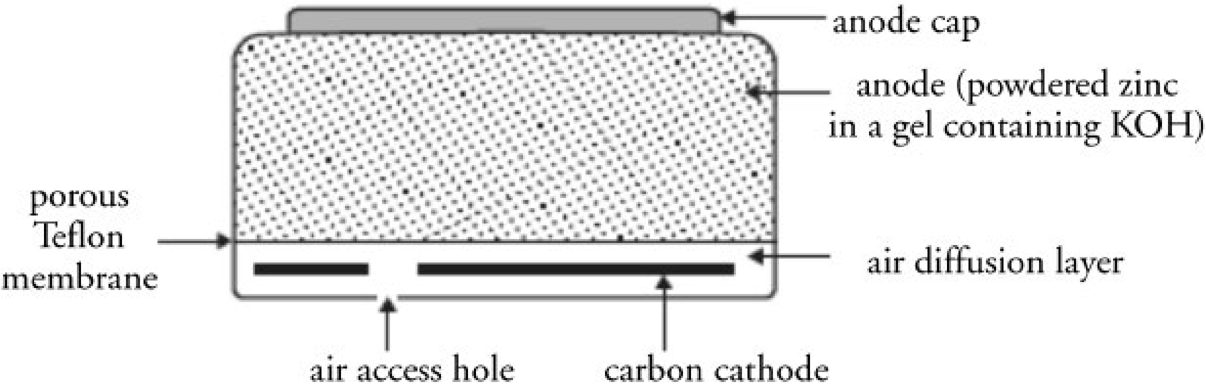
$Cu^{2+}(aq) + e^{-} \rightleftharpoons Cu^{+}(aq)$ $E° = 0.16$ V

Many solid compounds of copper(I) are known (such as solid copper(I) oxide, Cu_2O; solid copper(I) chloride, CuCl) and are quite stable. However, attempts to prepare solutions containing $Cu^{+}(aq)$ are always unsuccessful. Use the information provided above to explain why solutions of $Cu^{+}(aq)$ are unstable.

(Total = 3 marks)

Question 26 / 29

[VCAA 2014 SB Q10]
The diagram below shows a cross-section of a small zinc-air button cell, a button cell that is used in hearing aids. The zinc acts as the anode. It is in the form of a powder dispersed in a gel (a jelly-like substance) that also contains potassium hydroxide. The cathode consists of a carbon disc. Oxygen enters the cell via a porous Teflon membrane. This membrane also prevents any chemicals from leaking out.



The following reaction takes place as the cell discharges.

$2Zn(s) + O_2(g) + 2H_2O(l) \rightarrow 2Zn(OH)_2(s)$

(a) Write a balanced half-equation for the reaction occurring at the anode.

(1 mark)

(b) Suggest **one** role of potassium hydroxide in this cell.

(1 mark)

(c) A zinc-air button cell is run for 10 hours at a steady current of 2.36 mA.

What mass of zinc metal reacts to form zinc oxide during that time?

(3 marks)

(d) A hydrogen-oxygen fuel cell can operate with an alkaline electrolyte such as potassium hydroxide. In this cell, the reaction at the cathode is the same as that in the zinc-air cell. A porous carbon cathode is used. Write the half-equation for the reaction that occurs at the anode in a hydrogen-oxygen cell with an alkaline electrolyte.

(1 mark)

(Total = 6 marks)

Question 27 / 29

[VCAA 2018 SB Q6]
Redox reactions occur in the human body as well as in electrochemical cells.

(a) Nicotinamide adenine dinucleotide (NAD) is a vital coenzyme for energy production in the human body. It exists in two forms: an oxidised form, NAD^+, and a reduced form, NADH. NAD is involved in the conversion of ethanol, CH_3CH_2OH, to ethanal, CH_3CHO, in the human body. The overall equation for this redox reaction is

$CH_3CH_2OH + NAD^+ \rightarrow CH_3CHO + NADH + H^+$

(i) Write the two half-equations for this redox reaction. States are not required.

Oxidation half-equation:

Reduction half-equation:

(2 marks)

(ii) Identify the reducing agent in this redox reaction.

(1 mark)

(b) The Daniell cell, a type of galvanic cell, was first constructed in the mid-1800s and this type of cell is still in use today. A diagram of the Daniell cell is shown below.

(i) Label the polarity of the electrodes by placing a positive (+) or negative (−) sign in each of the circles next to the electrodes on the diagram.

(1 mark)

(ii) Use the electrochemical series to determine the theoretical voltage of this cell.

(1 mark)

(iii) In the diagram below, the electrolyte in the salt bridge is a potassium nitrate solution, $KNO_3(aq)$. In the box above the salt bridge, use an arrow to indicate the direction of flow of $K^+(aq)$ ions.

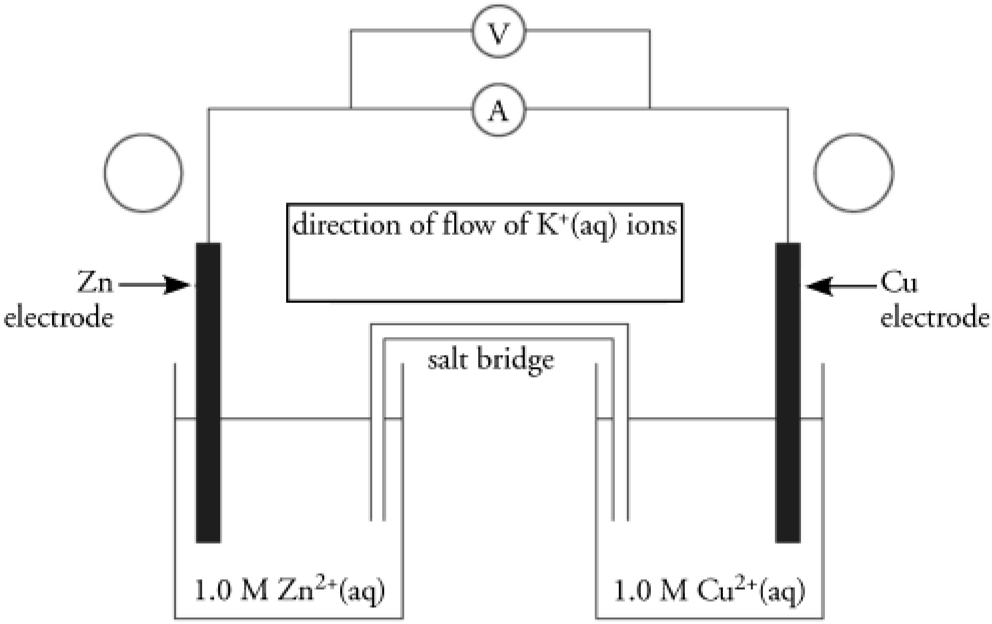
(1 mark)

(iv) List **two** visible changes that are likely to be observed when the Daniell cell has been operating for some time.

(2 marks)

(c) What design features of the Daniell cell structure would allow it to produce electrical energy?

(2 marks)


V
A
direction of flow of K+(aq) ions
Zn electrode
Cu electrode
salt bridge
1.0 M Zn2+(aq)
1.0 M Cu2+(aq)

Question 28 / 29

[VCAA 2019 SB Q4]
Internal combustion engines are used in large numbers of motor vehicles. Historically, internal combustion engines have used fuels obtained from crude oil as a source of power. As concerns for the environment have grown, efforts have been made to obtain fuel for combustion engines from other sources.

(a) One way of reducing the environmental effects of fossil fuels is to blend them with biofuels. A common method is to blend petrol with ethanol in varying ratios. A fuel can be obtained by blending 1 mole of octane, C_8H_{18}, and 1 mole of ethanol, C_2H_5OH.

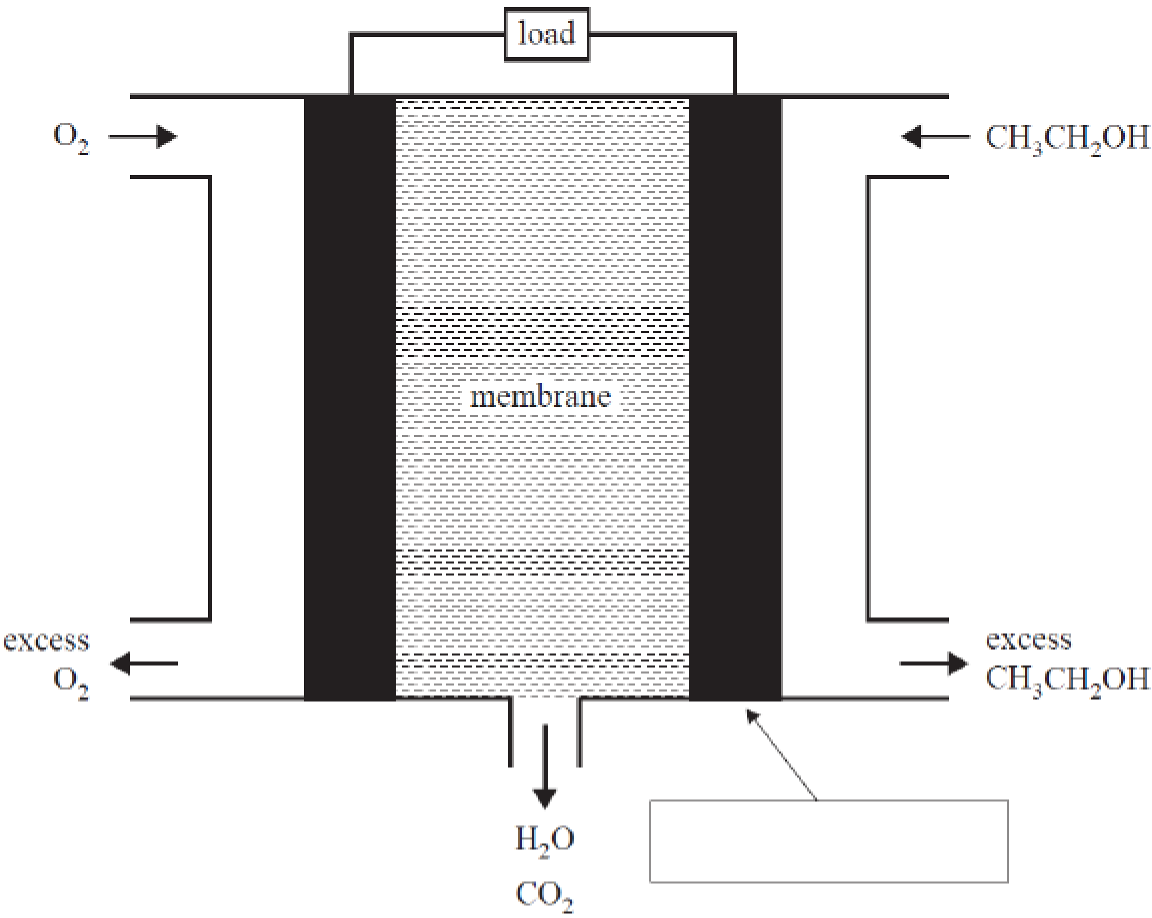
The chemical equation for the complete combustion of this fuel mixture is

$C_8H_{18}(l) + C_2H_5OH(l) + 15\frac{1}{2}O_2(g) \rightarrow 10CO_2(g) + H_2O(g)$

Calculate the energy released, in kilojoules, when 80 g of this fuel mixture undergoes complete combustion. Show your working.

(3 marks)

(b) Some car manufacturers are exploring the use of an acidic ethanol fuel cell to power vehicles. In this fuel cell, the ethanol at one electrode reacts with water that has been produced at the other electrode. A membrane is used to transport ions between the electrodes. A diagram of an acidic ethanol fuel cell is shown below.



(i) Identify the electrode as either the cathode or the anode in the box provided in the diagram above.

(1 mark)

(ii) Write the half-equation for the reaction occurring at the anode.

(1 mark)

(iii) The combustion of ethanol and the combustion of octane release about the same amount of energy per moeof carbo d oxide produced. Identify **two** advantages of powering a vehicle using an ethanol fuel cell instead of an internal combustion engine powered by octane.

(2 marks)

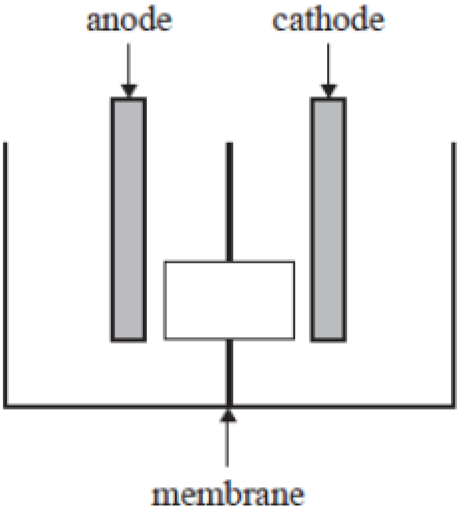
(Total = 7 marks)

Question 29 / 29

[VCAA 2021 SB Q4]
(a) What is a fuel cell?

(2 marks)

(b) The diagram below shows part of an ethanol fuel cell, which produces carbon dioxide and uses an acidic electrolyte.



(i) Name the species that crosses the membrane to enable fuel cell operation.

(1 mark)

(ii) In the box provided on the diagram above, indicate the direction of flow of the species named in **part b.i.**

(1 mark)

(c) Write the equation for the reaction that occurs at the anode of an ethanol fuel cell, which produces carbon dioxide and uses an acidic electrolyte.

(1 mark)

(d) If an ethanol fuel cell was operating at 25 °C and at 100% efficiency, how much electrical energy could be produced from 1.0 g of ethanol?

(1 mark)

(e)Idntify **two** aspects of electrode design that can improve the efficiency of a fuel cell.

(2 marks)

(f) State how the environmental impact of using an ethanol fuel cell operating at 100% efficiency can be minimised.

(1 mark)

(Total = 9 marks)

Question 1 / 15

In the species <u>Cl</u>O_3^- and H_3<u>P</u>O_3, the oxidation states of the underlined atoms are respectively

---

A.

+5 and +3

B.

+5 and 0

C.

+6 and +3

D.

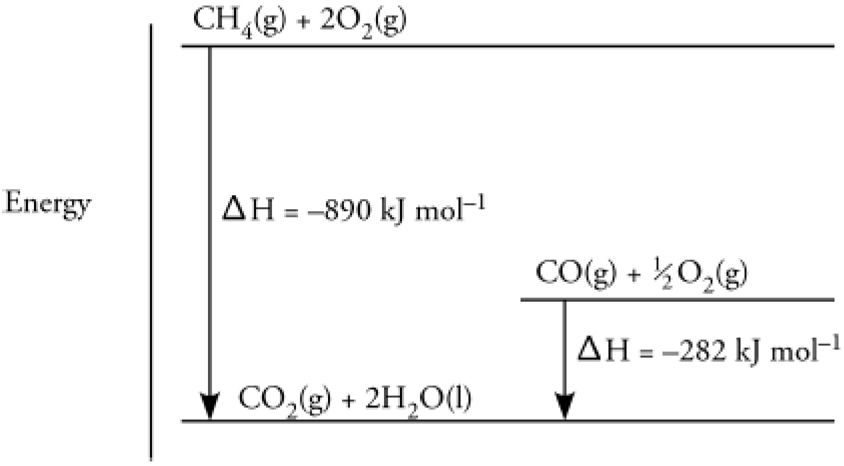
−5 and −3

Question 2 / 15

The energy diagram shown below contains the information from the following two combustion reactions.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$;   *ΔH* = −890 kJ mol^{-1}

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$;   *ΔH* = −282 kJ mol^{-1}



From the information above, *ΔH* for the reaction

$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l)$

is most likely to be

A.

$-608\ \text{kJ mol}^{-1}$

B.

$-1172\ \text{kJ mol}^{-1}$

C.

$-1216\ \text{kJ mol}^{-1}$

D.

$-2344\ \text{kJ mol}^{-1}$

Question 3 / 15

One of the reactions involved in the production of methanol, CH_3OH, is

$CO_2(g) + 3H_2(g) \rightarrow CH_3OH(g) + H_2O(g);$ $\Delta H = -48\ \text{kJ mol}^{-1}$

From this information it can be concluded that

A.

formation of 1 mol of water releases 24 kJ.

B.

when 3.0 g of hydrogen reacts 48 kJ of energy are released.

C.

reaction of 1 mol of carbon dioxide absorbs 48 kJ of energy.

D.

production of 2 mol of methanol would release 96 kJ of energy.

Question 4 / 15

A recently developed fuel cell uses methanol and oxygen as the two reactants. In this cell, complete combustion of methanol takes place. The reaction occurring at the anode of this cell is

---

A.

$2CH_3OH(aq) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$

B.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

C.

$CH_3OH(aq) \rightarrow CO(g) + 4H^+(aq) + 4e^-$

D.

$CH_3OH(aq) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$

Question 5 / 15

Using a data table, a student finds that the heat of combustion of propan-1-ol is 2021 kJ mol^{-1}. What value would the student calculate for the heat of combustion of propan-1-ol in kJ g^{-1}?

A.

23.0

B.

27.3

C.

33.6

D.

43.9

Question 6 / 15

Silver oxide and zinc are used in some galvanic cells. When these cells produce an electric current, the following reaction occurs.

$Ag_2O(s) + Zn(s) + H_2O(l) \rightarrow 2Ag(s) + Zn(OH)_2(s)$

The reaction occurring at the positive electrode when cells of this type produce a current is

---

A.

$Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$

B.

$Ag^2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$

C.

$Zn(OH)_2(s) + 2e^- \rightarrow Zn(s) + 2OH^-(aq)$

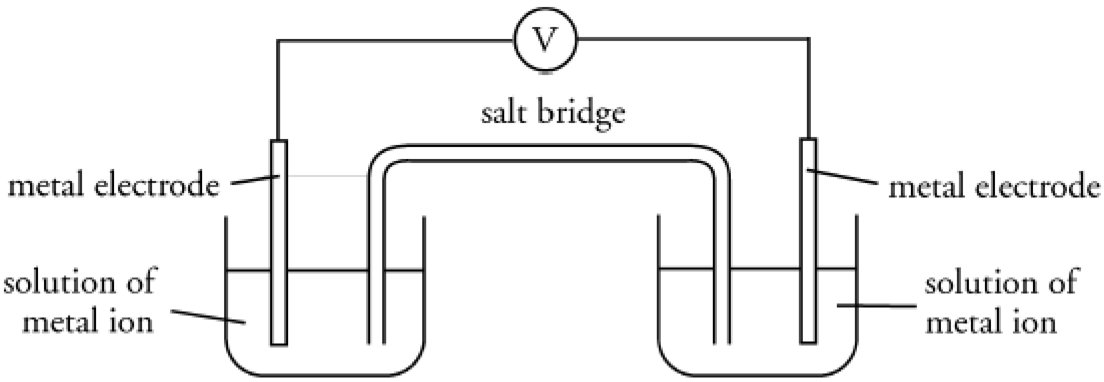
D.

$2Ag(s) + 2OH^-(aq) \rightarrow Ag_2O(s) + H_2O(l) + 2e^-$

Question 7 / 15

The following information refers to Questions 8 and 9.

Four metals, Cu, *p*, *q* and *r*, were each placed in a solution of their metal ions. The electrodes and solutions were then connected in pairs as shown in the diagram below and the voltage of each cell was recorded.



The table below shows the results obtained.

Negative terminal	Positive terminal	Voltage (V)
Cu	*p*	0.45
Cu	*q*	1.29
r	Cu	0.75

Question 8 / 15

From this information, place the metals in order showing the increasing ease of oxidation (easiest to oxidise last).

A.

$p < q < r <$ Cu

B.

Cu $< r < q < p$

C.

$q < p <$ Cu $< r$

D.

$r <$ Cu $< p < q$

Question 9 / 15

If the metals *p* and *q* were connected, then the results expected would be

---

A.

Negative terminal	**Voltage (V)**
p	0.84

B.

p	1.74

C.

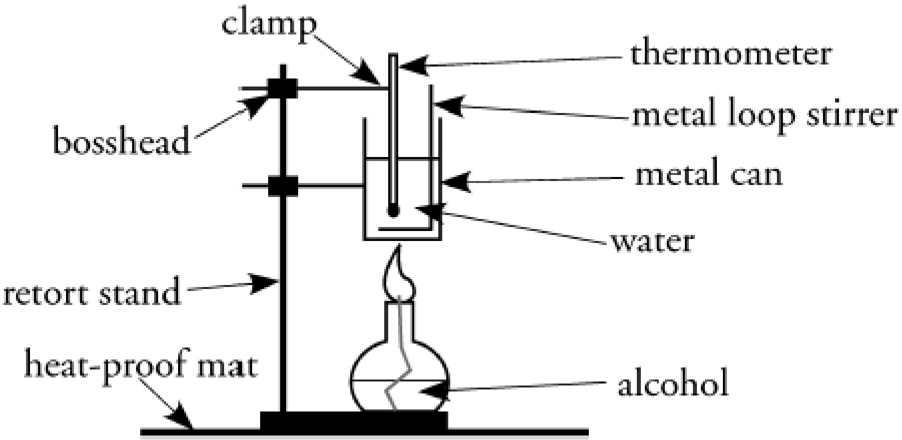
q	0.84

D.

q	1.74

Question 10 / 15

Students in a VCE Chemistry class were asked to determine the heat of combustion of an alcohol. Each pair of students used a different alcohol. The alcohols studied were methanol, ethanol, propan-1-ol, butan-1-ol and pentan-1-ol. All students used the equipment shown in the diagram below.



The results obtained by the students using propan-1-ol are shown below.

Mass of water in can = 250 g

Mass of propan-1-ol burned = 0.496 g

Temperature rise of water = 7.2°C

(a) (i) What value, in kJ mol^{-1}, should the students calculate for the heat of combustion of propan-1-ol using their results?

(2 marks)

(ii) Write the thermochemical equation for the heat of combustion of propan-1-ol.

(2 marks)

The heats of combustion determined by some of the other groups of students are given in the table below.

Alcohol	**Heat of combustion (kJ mol^{-1})**
Methanol	380
Butan-1-ol	1140
Pentan-1-ol	1330

(b) (i) Use the results in the table and the value calculated in part **(a)** to plot a graph of heat of combustion against the number of carbon atoms in the alcohol.

(2 marks)

(ii) From your graph, determine the heat of combustion obtained by the students who used ethanol.

(1 mark)

(c) The students using butan-1-ol noticed that the alcohol burned with a yellow flame and concluded that some of the alcohol was undergoing incomplete combustion and producing carbon rather than carbon dioxide. Write the equation for the incomplete combustion of butan-1-ol.

(2 marks)

(Total = 9 marks)

Question 11 / 15

Methanol can be produced by the partial oxidation of methane in a two-step process.

$2CH_4(g) + O_2(g) \rightarrow 2CO(g) + 4H_2(g)$; $\Delta H = -74$ kJ mol^{-1}

followed by

$2CO(g) + 4H_2(g) \rightarrow 2CH_3OH(g)$; $\Delta H = -180$ kJ mol^{-1}

(a) The methanol produced in this way can be described as a renewable fuel or as a non-renewable fuel. Explain why this is possible.

(3 marks)

(b) Calculate the amount of energy released (in MJ) when 1.00 kg of methane is converted into methanol.

(3 marks)

(Total = 6 marks)

Question 12 / 15

In recent years, solid oxide fuel cells have been developed that use methane as the fuel. The other reactant is oxygen from the air. The electrodes are often made from metals such as platinum or nickel. The fuel cell operates at high temperatures and the electrolyte is a solid ceramic oxide. At high temperatures, O^{2-} ions are able to move through the electrolyte.

(a) The half-equation for the reaction occurring at one of the electrodes is

$O_2(g) + 4e^- \rightarrow 2O^{2-}(s)$

Give the name of this electrode and state its polarity.

(2 marks)

(b) Give two properties of the electrode essential for the successful operation of the fuel cell.

(2 marks)

(c) At the other electrode, methane is consumed, and carbon dioxide and water are produced.

Write the half-equation for the reaction occurring at this electrode.

(2 marks)

(d) Give the overall cell reaction.

(1 mark)

(Total = 7 marks)

Question 13 / 15

(a) Sucrose is a sugar found in many foods. It has the formula $C_{12}H_{22}O_{11}$ and can be oxidised to form carbon dioxide and water. Write an equation for the oxidation of sucrose.

(1 mark)

(b) A bomb calorimeter can be used to determine the energy released when sucrose is oxidised.

Draw and label a bomb calorimeter suitable for measuring the energy released when sucrose is oxidised in oxygen.

(3 marks)

(c) 0.281 g of sucrose is burned in excess oxygen in a bomb calorimeter. The temperature is observed to rise from 294.156 K to 294.781 K. This bomb calorimeter has a calibration factor of 7380 J K^{-1}.

(i) How much heat is evolved by the combustion of 0.281 g of sucrose?

(1 mark)

(ii) Calculate the heat that would be evolved by burning 1 mol of sucrose.

(1 mark)

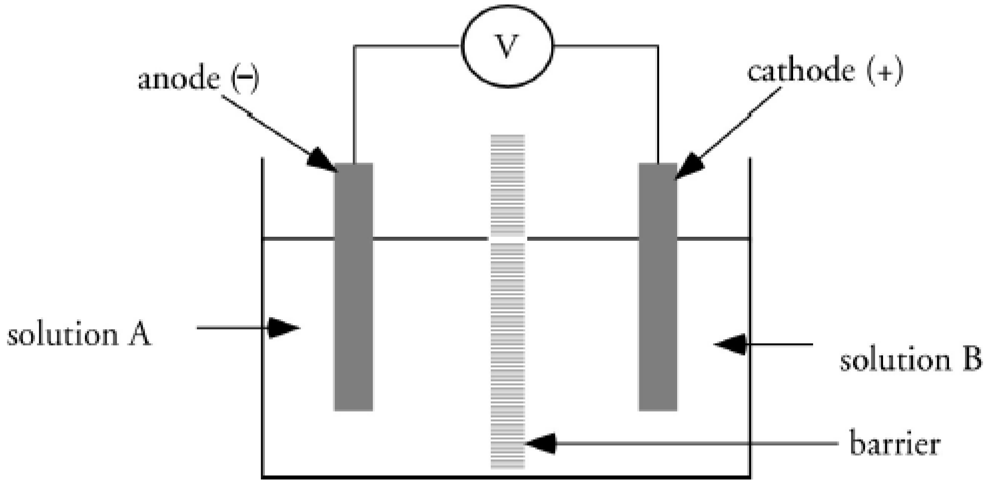
(Total = 6 marks)

Question 14 / 15

In acidic solution and in the presence of a suitable catalyst, the following reaction proceeds rapidly:

$2H_2O_2(aq) + N_2H_4(aq) \rightleftharpoons N_2(g) + 4H_2O(l)$

A chemist wishes to use this reaction as the cell reaction in the galvanic cell shown below.



(a) What changes in oxidation number occur in the above equation?

(2 marks)

(b) The barrier prevents solutions A and B from directly reacting. It is made of a chemically inert material. Give another important property that the barrier must possess.

(1 mark)

(c) Identify the solutions, A and B.

(2 marks)

(d) Suggest two necessary properties of the electrode materials.

(2 marks)

(e) Assuming that solutions A and B are acidic, write the half-cell reactions when the cell is operating for

(i) the reaction at the positive electrode (cathode).

(ii) the reaction at the negative electrode (anode).

(1 + 1 = 2 marks)

(Total = 9 marks)

Question 15 / 15

(a) Why is glucose, $C_6H_{12}O_6$, important to life? Give an equation to show how the body uses glucose.

(2 marks)

(b) Plants are able to synthesise glucose. Give an equation for the reaction in which glucose is synthesised and mention any conditions that are essential for the process to occur.

(2 marks)

(c) Name the major food group to which glucose belongs.

(1 mark)

(Total = 5 marks)

Total marks for test = 50 marks

Question 1 / 65

Acetone, CH_3COCH_3, and iodine, I_2, react according to the equation given below. A small amount of sulfuric acid is needed to catalyse the reaction.

$CH_3COCH_3(l) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$

A student determines which factors will change the rate of this reaction. Four experiments are carried out with different initial concentrations of acetone, iodine and sulfuric acid. The time taken to form a small amount of product is measured. This amount of product is the same for each experiment.

The results are listed in the table.

$[CH_3COCH_3]$	**$[I_2]$**	**$[H^+]$**	**Time taken**
0.100 M	0.100 M	0.010 M	60 s
0.100 M	0.100 M	0.020 M	30 s
0.200 M	0.100 M	0.010 M	30 s
0.100 M	0.200 M	0.010 M	60 s

The student deduces that the rate of the reaction

A.

depends only on the concentration of acetone.

B.

is not affected by the concentration of sulfuric acid.

C.

depends on the concentrations of acetone, iodine and acid.

D.

is only affected by the concentrations of acetone and acid.

Question 2 / 65

[VCAA 2019 SA Q11]
5 mL of ethanol, CH_3CH_2OH, undergoes combustion in a test tube with a diameter of 1 cm. This experiment is performed in a fume cupboard. The temperature in the fume cupboard is 20 °C. Which one of the following actions will reduce the rate of reaction?

A.

Mix 2 mL of a dilute solution of sodium hydroxide, NaOH, with the ethanol.

B.

Perform the experiment in a test tube with a diameter of 2 cm.

C.

Increase the temperature in the fume cupboard to 25 °C.

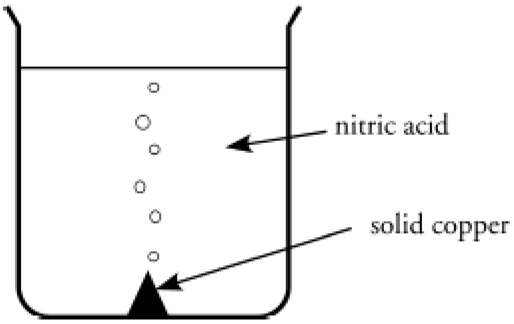
D.

Increase the volume of the ethanol to 7 mL.

Question 3 / 65

Use the following information to answer Questions 4 and 5.

$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$



Question 4 / 65

[VCAA 2013 SA Q14]
Which one of the following will **not** increase the rate of the above reaction?

A.

decreasing the size of the solid copper particles

B.

increasing the temperature of HNO_3 by 20°C

C.

increasing the concentration of HNO_3

D.

allowing NO_2 gas to escape

Question 5 / 65

[VCAA 2013 SA Q15]
In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions. The **major** reason for this is that

---

A.

the nitric acid is ionised in solution.

B.

some reactant particles have too much kinetic energy.

C.

the kinetic energy of the particles is reduced when they collide with the container's walls.

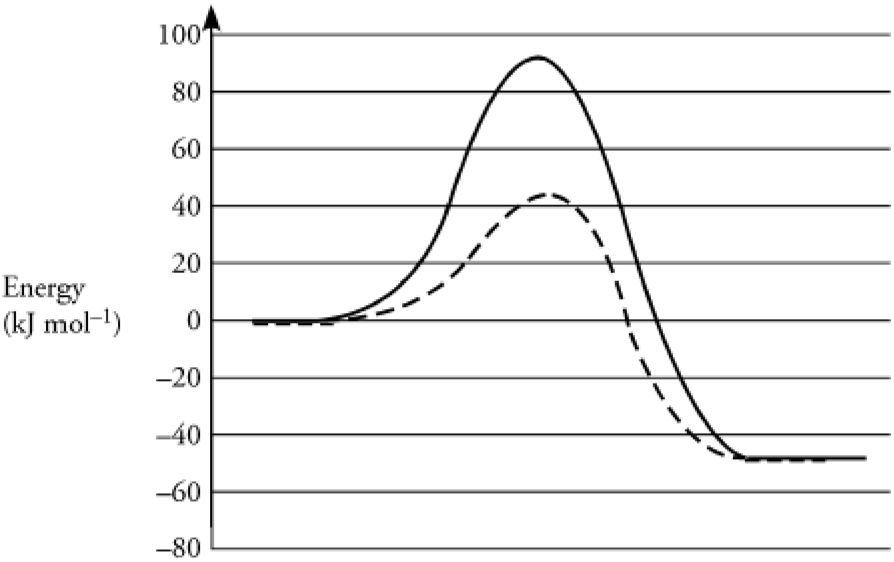
D.

not all reactant particles have the minimum kinetic energy required to initiate the reaction.

Question 6 / 65

[VCAA 2018 SA Q13]

The energy profile diagram below represents a particular reaction. One graph represents the uncatalysed reaction and the other graph represents the catalysed reaction.



Which of the following best matches the energy profile diagram?

A.

E_a **uncatalysed reaction (k mol** $^{-1}$**)**	ΔH **catalysed reaction (k mol** $^{-1}$**)**
40	−140

B.

90	−140

C.

40	−50

D.

90	−50

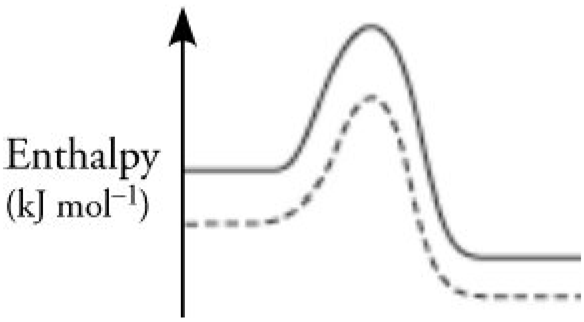
Question 7 / 65

[Adapted VCAA 2015 SA Q17]
The oxidation of sulfur dioxide is an exothermic reaction. The reaction is catalysed by vanadium(V) oxide.

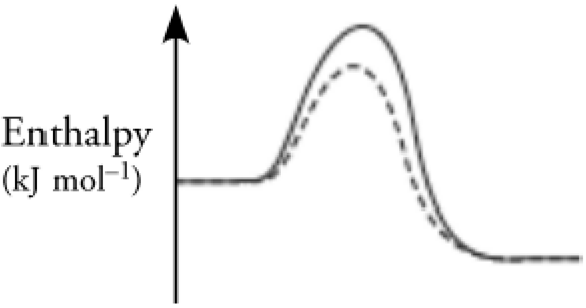
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

Which one of the following energy profile diagrams correctly represents both the catalysed and the uncatalysed reaction?

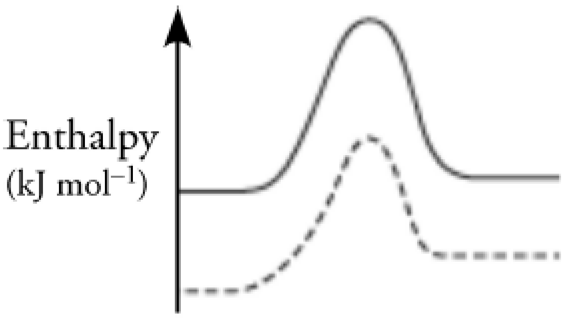
A.



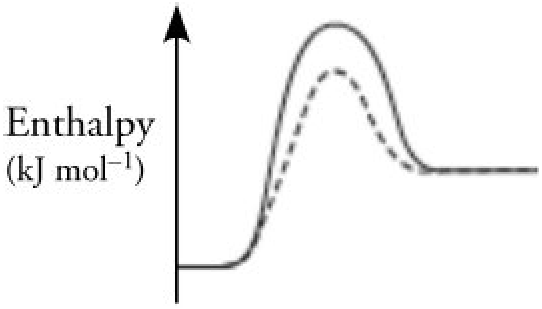
B.



C.



D.



Question 8 / 65

An important industrial process is the conversion of carbon monoxide into carbon dioxide using steam.

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; $\Delta H = -40$ kJ mol^{-1}

Which of the following would increase the percentage conversion of CO into CO_2?

A.

increasing the pressure

B.

increasing the temperature

C.

increasing the concentration of water

D.

increasing the volume of the container

Question 9 / 65

An important reaction in the production of ammonia, NH_3, is given below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -90$ kJ mol^{-1}

If the reaction takes place in a sealed container, which of the following procedures would **not** cause the rate of the forward reaction to increase?

A.

adding an inert gas

B.

increasing the pressure

C.

adding a suitable catalyst

D.

increasing the temperature

Question 10 / 65

In the commercial production of methanol, CH_3OH, carbon monoxide and hydrogen are heated and passed over a catalyst. The following equilibrium is set up.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$; $\Delta H = -95$ kJ mol^{-1}

The reaction does not go to completion and the conditions have to be carefully adjusted to produce a maximum yield. Which of the following would be expected to increase the yield of methanol?

A. Condense the methanol and recycle the remaining gases.

B. Lower the pressure in the reaction vessel.

C. Use a more effective catalyst.

D. Increase the temperature in the reaction vessel.

Question 11 / 65

When hydrogen (H_2) and iodine (I_2) react, hydrogen iodide (HI) is formed.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

In one experiment in a 2.0 L vessel at a certain temperature, the equilibrium mixture contained 0.5 mol of HI, 0.25 mol of H_2 and 0.1 mol of I_2. The value for the equilibrium constant at this temperature is

---

A.

0.05

B.

0.1

C.

10

D.

20

Question 12 / 65

In the production of nitric acid, an important step is the conversion of nitric oxide (NO) into nitrogen dioxide (NO_2).

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$; $\Delta H = -114$ kJ mol^{-1}

Which of the following sets of conditions would be expected to give the best equilibrium yield of nitrogen dioxide?

A. 500°C and 4 atm pressure

B. 30°C and 4 atm pressure

C. 500°C and 1 atm pressure

D. 30°C and 1 atm pressure

Question 13 / 65

Aqueous solutions containing dichromate ions ($Cr_2O_7^{2-}$) are orange, while those containing chromate ions (CrO_4^{2-}) are yellow. These two ions can be interconverted by the reaction below.

$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$

A yellow solution of CrO_4^{2-} will be converted into one containing orange $Cr_2O_7^{2-}$ when

---

A.

HCl(aq) is added.

B.

NaOH(aq) is added.

C.

water is added.

D.

$K_2Cr_2O_7$ is added.

Question 14 / 65

The following information is referred to in Questions 15 and 16.

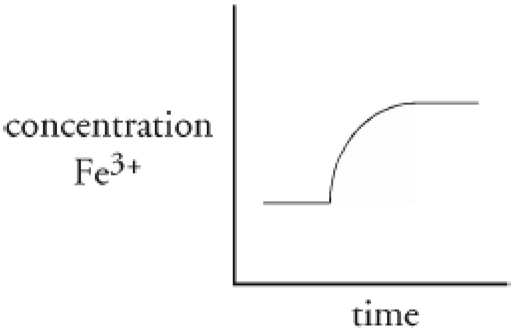
The equilibrium below is established when solutions containing Fe^{3+} and SCN^- are mixed.

Fe3+(aq)+   SCN−(aq)⇌Fe(SCN)2+(aq)(colourless)(colourless) (deep red)

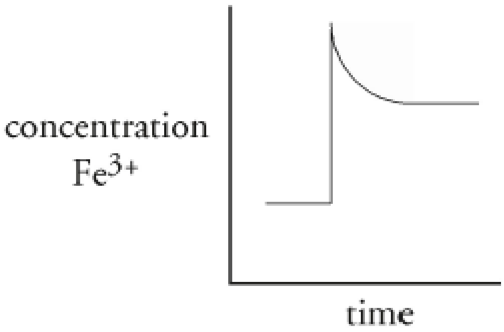
Question 15 / 65

When a small volume of a concentrated solution containing $Fe(NO_3)_3$ is added to this system, the colour changes, showing that more $Fe(SCN)^{2+}$ has been formed. Which of the graphs shown below correctly shows the changes in Fe^{3+} concentration before and after the addition of $Fe(NO_3)_3$?

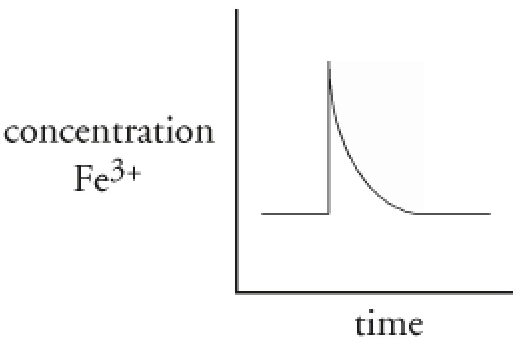
A.



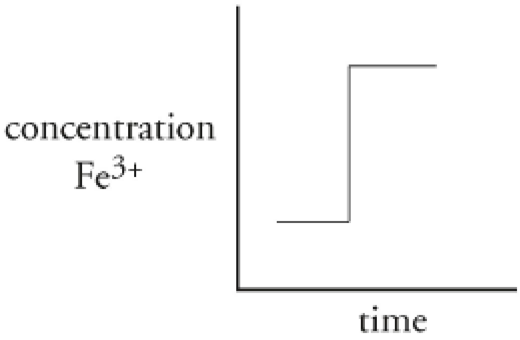
B.



C.



D.



Question 16 / 65

The solution from Question 13 is diluted with an equal volume of water. The colour becomes a paler red. The addition of water has caused the concentration

---

A.

and the number of moles of $Fe(SCN)^{2+}$ to decrease.

B.

and the number of moles of $Fe(SCN)^{2+}$ to remain unchanged.

C.

of $Fe(SCN)^{2+}$ to decrease but the number of moles of $Fe(SCN)^{2+}$ to remain unchanged.

D.

of $Fe(SCN)^{2+}$ to decrease but the number of moles of $Fe(SCN)^{2+}$ to increase.

Question 17 / 65

[VCAA 2018 SA Q24]

The four equations below represent different equilibrium systems.

Equation 1	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$	$\Delta H = -180$ kJ mol^{-1}
Equation 2	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	$\Delta H = -46$ kJ mol^{-1}
Equation 3	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$	$\Delta H = +93$ kJ mol^{-1}
Equation 4	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	$\Delta H = +205$ kJ mol^{-1}

After equilibrium was established in each system, the temperature was decreased and the pressure was increased. In which equilibrium system would both changes result in an increase in yield?

A.

Equation 1

B.

Equation 2

C.

Equation 3

D.

Equation 4

Question 18 / 65

The reaction below is allowed to reach equilibrium at 500°C.

$2H_2O(g) + C_2H_6(g) \rightleftharpoons 2CO(g) + 5H_2(g)$; ΔH = +347 kJ mol^{-1}

The temperature is then **lowered** and the amount of H_2O changes by 0.20 mol. The changes occurring would be

---

A.

H_2O	C_2H_6	CO	H_2
increase by 0.20 mol	increase by 0.40 mol	decrease by 0.20 mol	decrease by 0.040 mol

B.

increase by 0.20 mol	increase by 0.10 mol	decrease by 0.20 mol	decrease by 0.50 mol

C.

decrease by 0.20 mol	decrease by 0.40 mol	increase by 0.20 mol	increase by 0.040 mol

D.

decrease by 0.20 mol	decrease by 0.10 mol	increase by 0.20 mol	increase by 0.50 mol

Question 19 / 65

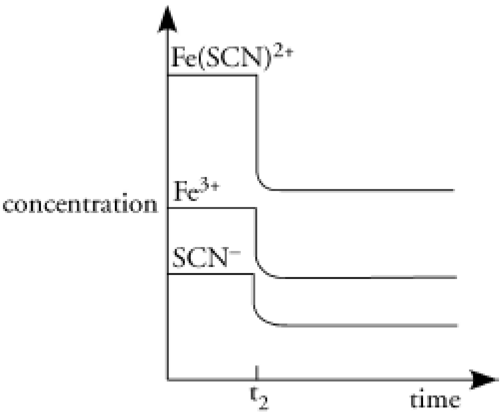
[Adapted VCAA 2012 E2 SA Q8]

The following equilibrium is established.

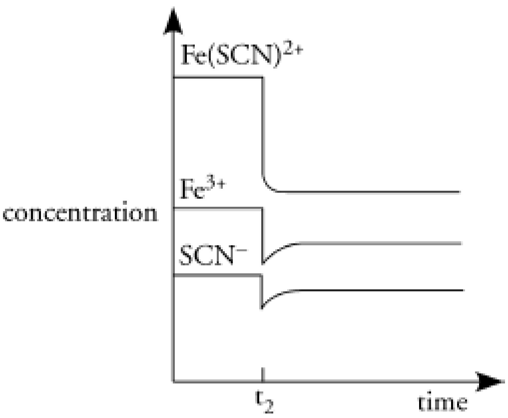
$Fe^{3+}(aq)+SCN^{-}(aq)\rightleftharpoons Fe(SCN)^{2+}(aq)$yellowdeepred

Which one of the graphs below best represents the changes in concentration when the equilibrium mixture is diluted at time t_2?

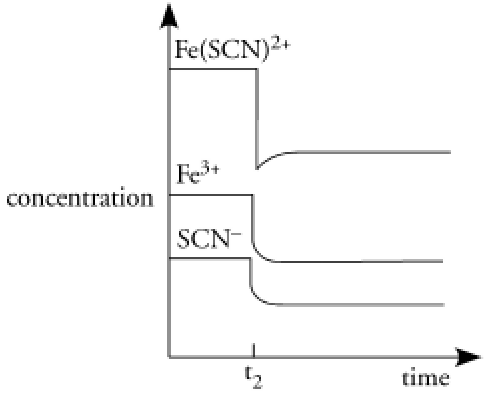
A.



B.

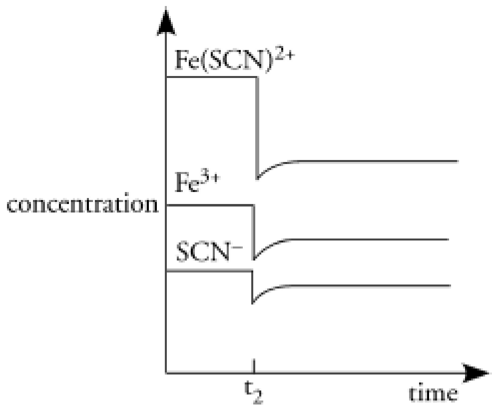


C.



Fe(SCN)2+
Fe3+
concentration
SCN−
t2
time

D.



Fe(SCN)2+
Fe3+
concentration
SCN−
t2
time

Question 20 / 65

[VCAA 2011 E2 SA Q1]
Consider the following equilibrium expression.

$K=[\frac{[L][M^4}{[J\}^6[K]}$

The equation of the forward reaction for this equilibrium expression is

---

A.

$6J + K \rightleftharpoons L + 4M$

B.

$L + M_4 \rightleftharpoons J_6 + K$

C.

$J_6 + K \rightleftharpoons L + M_4$

D.

$L + 4M \rightleftharpoons 6J + K$

Question 21 / 65

[VCAA 2018 SA Q27]
$Br_2(g) + I_2(g) \rightleftharpoons 2IBr(g)$ $K = 1.2 \times 10^2$ at 150°C

Given the information above, what is K for the reaction $4IBr(g) \rightleftharpoons 2Br_2(g) + 2I_2(g)$ at 150°C?

A.

1.6×10^{-2}

B.

4.1×10^{-3}

C.

6.9×10^{-5}

D.

8.03×10^{-5}

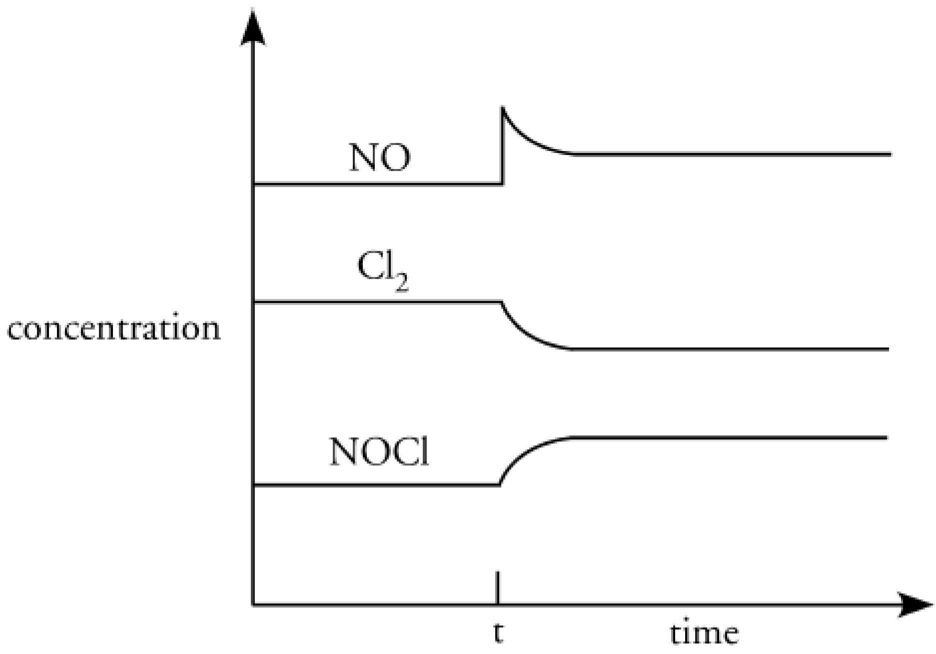
Question 22 / 65

[Adapted VCAA 2013 SA Q18]

Use the following information to answer the question.

$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$; ΔH is positive.

A concentration–time graph for this system is shown below.



What event occurred at time *t* to cause the change in equilibrium concentrations?

A.

The pressure was decreased at a constant temperature.

B.

The temperature was increased at a constant volume.

C.

A catalyst was added at a constant temperature and volume.

D.

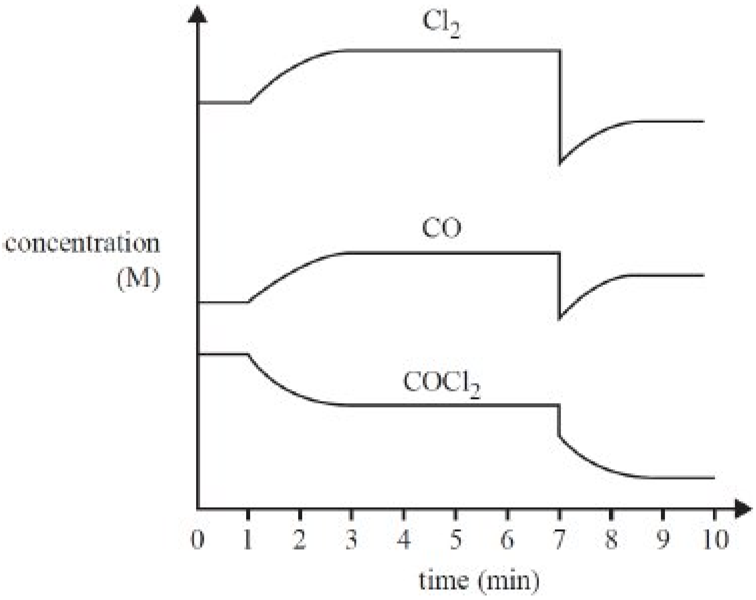
Additional NO gas was added at a constant volume and temperature.

Question 23 / 65

[VCAA 2020 SA Q17]
The following equation represents the reaction between chlorine gas, Cl_2, and carbon monoxide gas, CO.

$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g)$ $\Delta H = -108$ kJ mol^{-1}

The concentration–time graph below represents changes to the system.



Which of the following identifies the changes to the system that took place at 1 minute and at 7 minutes?

A.

1 minute	7 minutes
increase in temperature	increase in volume

B.

decrease in temperature	decrease in volume

C.

decrease in temperature	increase in volume

D.

increase in temperature	decrease in volume

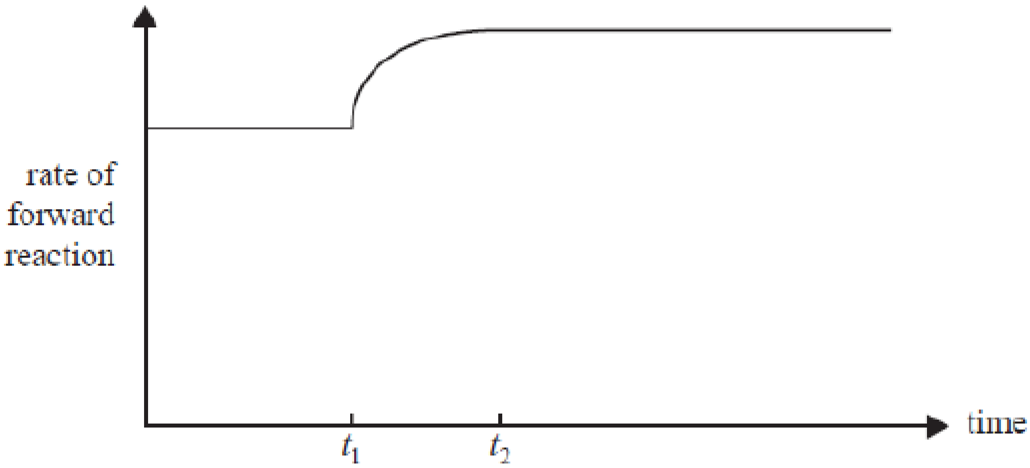
Question 24 / 65

[VCAA 2020 SA Q19]
Nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, form an equilibrium mixture represented by the following equation.

$2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -57.2$ kJ mol^{-1}

brown colourless

A change was made at time t_1 to an equilibrium mixture of NO_2 and N_2O_4, which achieved a new equilibrium at time t_2. A graph showing the rate of the forward reaction is shown below.



Which one of the following describes the change that was made to the initial equilibrium system and the colour change that occurred between t_1 and t_2?

A.

The temperature was increased and the colour lightened.

B.

The temperature was increased and the colour darkened.

C.

The temperature was decreased and the colour lightened.

D.

The temperature was decreased and the colour darkened.

Question 25 / 65

[VCAA 2019 SA Q28]

The concentration of all of the gases in the equilibrium reactions below is 1.0 M.

Reaction 1 $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$

Reaction 2 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Reaction 3 $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

Reaction 4 $2NO_2(g) \rightleftharpoons N_2O_4(g)$

In which reaction does K = 1.0 M^{-2}?

A.

Reaction 1

B.

Reaction 2

C.

Reaction 3

D.

Reaction 4

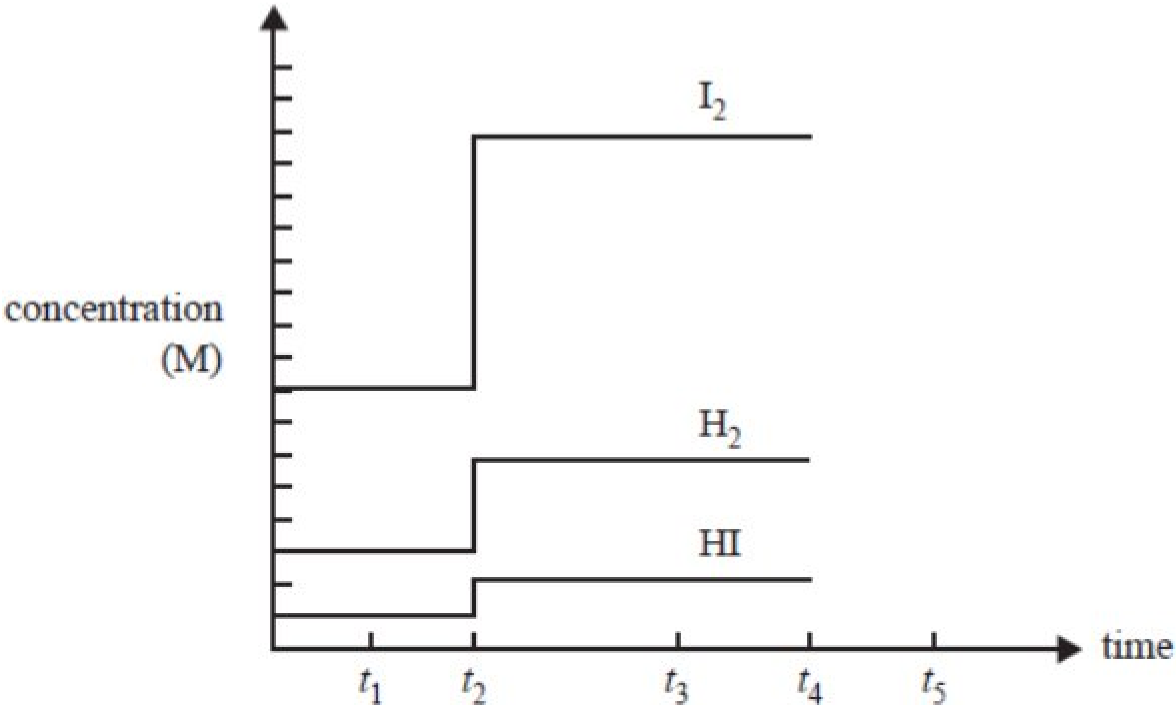
Question 26 / 65

The following information is referred to in Questions 27 and 28.

Hydrogen, H_2, and iodine, I_2, react to form hydrogen iodide, HI.

$12\ H_2(g) + 12\ I_2(g) \rightleftharpoons HI(g)$ $\quad$ $\Delta H = +25.9$ kJ mo1^{-1}

The graph below shows the concentrations of H_2, I_2 and HI in a sealed container. One change was made to the equilibrium system at time t_2.



Question 27 / 65

[VCAA 2021 SA Q27]
Which one of the following statements is correct?

A.

A catalyst was added at time t_2.

B.

The amount of HI is greater at time t_3 compared with time t_1.

C.

The rate of reaction producing HI is the same at time t_1 and time t_3.

D.

The rate of production of HI at time t_3 is double the rate of production of H_2 at time t_3.

Question 28 / 65

[VCAA 2021 SA Q28]
One change was made to the equilibrium system at time t_4, which altered the equilibrium constant. Equilibrium was re-established at time t_5. The rate of the reverse reaction at time t_5 was higher than at time t_3. Which of the following options correctly shows the change in the equilibrium system from time t_3 to time t_5?

A.

Changes from t_3 to time t_5	
Euilibrium constant	**Total chemical energy**
increase	increase

B.

increase	decrease

C.

decrease	increase

D.

decrease	decrease

Question 29 / 65

Which one of the statements below regarding galvanic and electrolytic cells is correct?

A.

Reduction occurs at the cathode in galvanic cells but at the anode in electrolytic cells.

B.

Oxidation occurs at the cathode in both cells.

C.

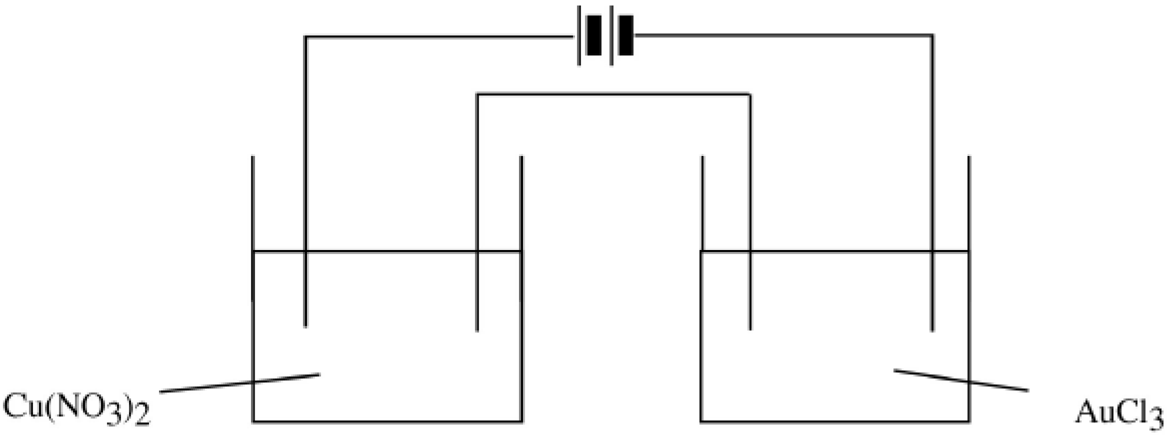
Reduction occurs at the cathode and oxidation occurs at the anode in both cells.

D.

Oxidation occurs at the anode in galvanic cells but at the cathode in electrolytic cells.

Question 30 / 65

A student sets up the circuit shown below to electrolyse solutions of copper nitrate and gold(III) chloride using inert electrodes.



The mass of gold to the mass of copper deposited at the two cathodes will be in the ratio

---

A. 1.00 : 1.00

B. 2.07 : 1.00

C. 3.10 : 1.00

D. 4.65 : 1.00

Question 31 / 65

An aqueous solution of zinc nitrate is electrolysed for 75.0 minutes by a current of 4.50 A. The mass of zinc deposited, in grams, is closest to

---

A.

0.23

B.

6.85

C.

13.70

D.

27.40

Question 32 / 65

In the electrolytic production of aluminium, the current, in amps, needed to deposit 5.0 kg of aluminium in 60.0 minutes is closest to

---

A.

15

B.

5.0×10^3

C.

1.5×10^4

D.

8.9×10^5

Question 33 / 65

In the electrolysis of thallium nitrate solution, 0.168 g of thallium is deposited at the cathode in 144 seconds by a current of 1.65 A. The charge on the thallium ion in the solution of thallium nitrate is

---

A.

−3

B.

−1

C.

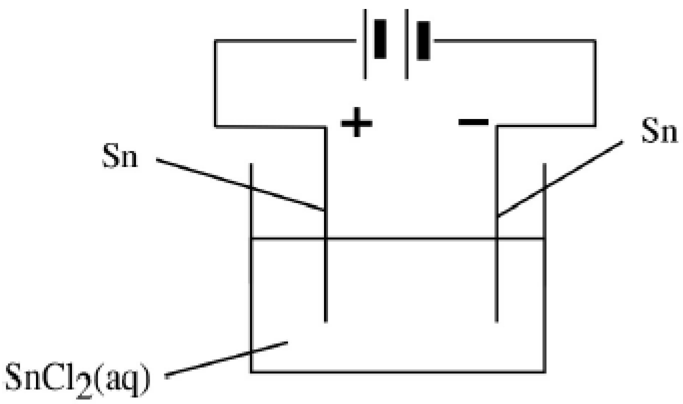
+1

D.

+3

Question 34 / 65

A solution of tin(II) chloride was electrolysed using the circuit shown below.



The reaction that is most likely to occur at the positive electrode is

---

A. $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$

B. $2Cl^-(aq) \rightarrow Cl\ (g) + 2e^-$

C. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

D. $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$

Question 35 / 65

9650 C of electrical charge is used to electrolyse 1.00 L of a 0.50 M lead nitrate solution. If the volume of the solution remains unchanged, then the Pb^{2+}(aq) concentration after electrolysis will be

---

A.

0 M

B.

0.30 M

C.

0.40 M

D.

0.45 M

Question 36 / 65

[VCAA 2018 SA Q9]
When molten sodium chloride, NaCl, is electrolysed, the product formed at the cathode is

---

A.

sodium liquid, Na.

B.

hydrogen gas, H_2.

C.

chlorine gas, Cl_2.

D.

oxygen gas, O_2.

Question 37 / 65

[VCAA 2011 E2 SA Q17]
If we compare a galvanic cell with an electrolytic cell, it is true to state that

---

A.

in a galvanic cell reduction occurs at the negative electrode.

B.

in both cells the anode is positive and the cathode is negative.

C.

in an electrolytic cell oxidation occurs at the cathode.

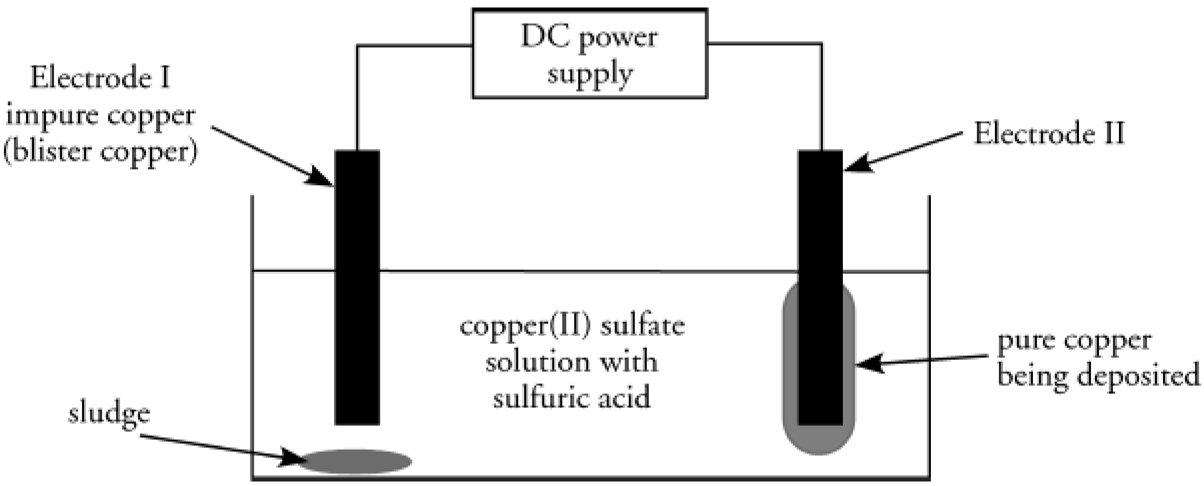
D.

in both cells reduction occurs at the cathode.

Question 38 / 65

Use the following information to answer Questions 39 and 40.

An electrolytic cell is set up to obtain pure copper from an impure piece of copper called ‘blister copper’. The electrolyte solution contains both copper(II) sulfate and sulfuric acid. The blister copper, Electrode I, contains impurities such as zinc, cobalt, silver, gold, nickel and iron. The cell voltage is adjusted so that only copper is deposited on Electrode II. Sludge, which contains some of the solid metal impurities present in the blister copper, forms beneath Electrode I. The other impurities remain in solution as ions. The diagram below represents the cell.



Question 39 / 65

[VCAA 2015 SA Q28]
The solid metal impurities that are found in the sludge are

A.

gold, nickel and cobalt.

B.

cobalt, nickel and iron.

C.

nickel and iron.

D.

silver and gold.

Question 40 / 65

[VCAA 2015 SA Q29]
Which of the following correctly shows both the equation for the reaction occurring at the cathode and the polarity of Electrode I?

A.

Cathode reaction	**Polarity of Electrode I**
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	positive

B.

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	negative

C.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	negative

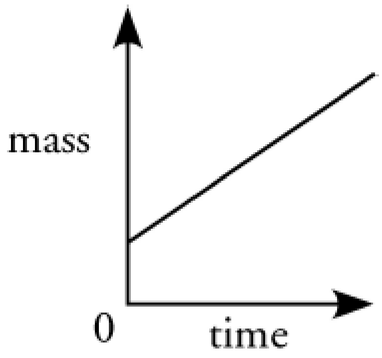
D.

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	positive

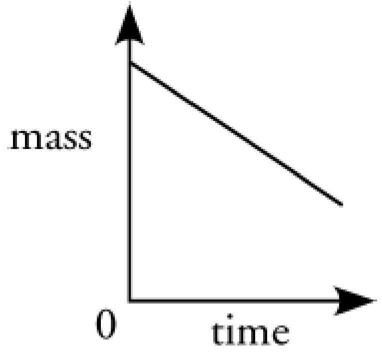
Question 41 / 65

[VCAA 2015 SA Q30]
Which one of the following graphs best shows the change in mass of Electrode I over a period of time, starting from the moment the power supply is connected?

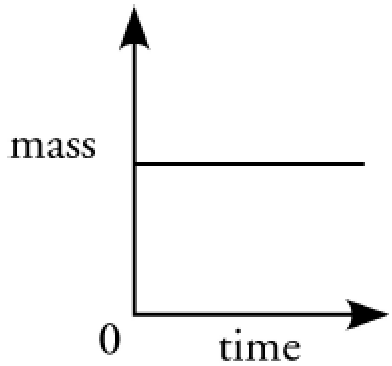
A.



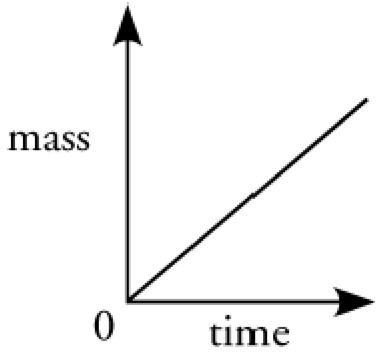
B.



C.



D.



Question 42 / 65

[VCAA 2019 SA Q7]
A molten mixture of equal parts aluminium fluoride, AlF_3, and sodium chloride, NaCl, undergoes electrolysis. Which one of the following statements about this reaction is correct?

A.

Sodium metal will be produced at the cathode and fluorine gas will be produced at the anode.

B.

Sodium metal will be produced at the anode and chlorine gas will be produced at the cathode.

C.

Aluminium metal will be produced at the cathode and chlorine gas will be produced at the anode.

D.

Aluminium metal will be produced at the anode and fluorine gas will be produced at the cathode.

Question 43 / 65

[VCAA 2021 SA Q9]
An electrolysis cell consumed a charge of 4.00 C in 5.00 minutes.

This represents a consumption of

A.

4.15×10^{-5} mol of electrons.

B.

2.07×10^{-4} mol of electrons.

C.

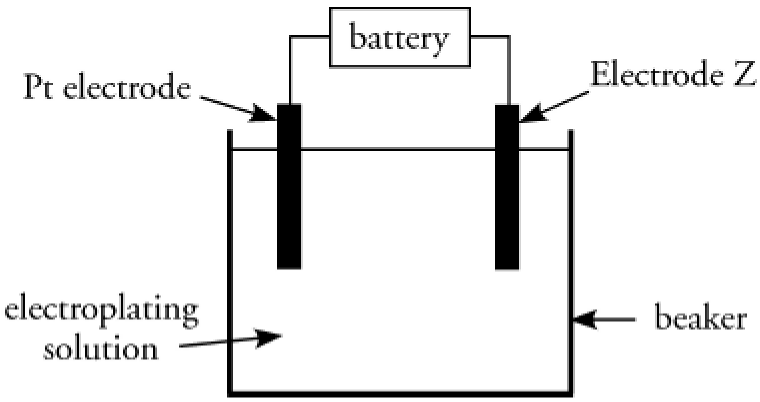
1.93×10^{4} mol of electrons.

D.

2.41×10^{4} mol of electrons.

Question 44 / 65

[VCAA 2017 SA Q30]
The diagram below shows the basic set-up of an electroplating cell.



Initially the cell is set up with a lead, Pb, electrode as Electrode Z and 1.0 mol L^{-1} lead nitrate, $Pb(NO_3)_2$, as the electroplating solution. The cell runs for a set time and current, with 1.0 g of Pb deposited onto Electrode Z. Four subsequent electroplating cells are set up, each containing a platinum, Pt, electrode, a different Electrode Z and an appropriate 1.0 mol L^{-1} electroplating solution. These four electroplating cells are operated for the same time and at the same current as the original Pb electroplating cell. Which combination of Electrode Z and electroplating solution would be expected to deposit **more** metal by mass onto Electrode Z than the original Pb electroplating cell?

A.

Electrode Z	Electroplating solution
chromium, Cr	1.0 mol L^{-1} $Cr(NO_3)_3$

B.

silver, Ag	1.0 mol L^{-1} $AgNO_3$

C.

gold, Au	1.0 mol L^{-1} $AuCl_3$

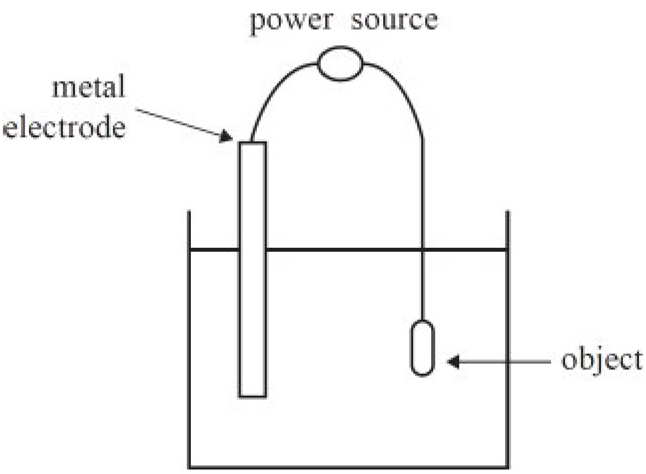
D.

tin, Sn	1.0 mol L^{-1} $SnSO_4$

Question 45 / 65

[VCAA 2019 SA Q24]

The diagram below shows an electroplating cell.



The cell contains 1 L of an electroplating solution. The electroplating cell is run for one hour at 3 A. Which one of the following electroplating solutions will deposit the largest mass of metal onto the object?

A.

1 M $AgNO_3$

B.

1 M $Cd(NO_3)_2$

C.

1 M $Pb(NO_3)_2$

D.

1 M $Al(NO_3)_3$

Question 46 / 65

[VCAA 2021 SA Q7]
Consider the following characteristics of electrolytic and galvanic cells.

Characteristic number	**Electrolytic cells**	**Galvanic cells**
1	cathode is negative	cathode is positive
2	have non-spontaneous reactions	have spontaneous reactions
3	reduction occurs at the anode	reduction occurs at the cathode
4	produce ectricity	consume ectricity

Which of the following combinations of characteristics of electrolytic cells and galvanic cells are correct?

A.

only 1 and 2

B.

only 2 and 3

C.

only 3 and 4

D.

only 1, 2 and 4

Question 47 / 65

Use the following information to answer Questions 48 and 49.

The lead-acid battery is made up of a series of secondary cells in which the following half-reactions are utilised.

$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ $\quad E° = -0.36$ V

$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$ $\quad E° = 1.69$ V

Question 48 / 65

[VCAA 2011 E2 SA Q13]
When the battery is discharging the

A.

H^+ concentration decreases resulting in a higher pH.

B.

H^+ concentration increases resulting in a higher pH.

C.

H^+ concentration decreases resulting in a lower pH.

D.

H^+ concentration increases resulting in a lower pH.

Question 49 / 65

[VCAA 2011 E2 SA Q15]
The reaction which occurs at the anode when the battery is recharging is

---

A. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

B. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

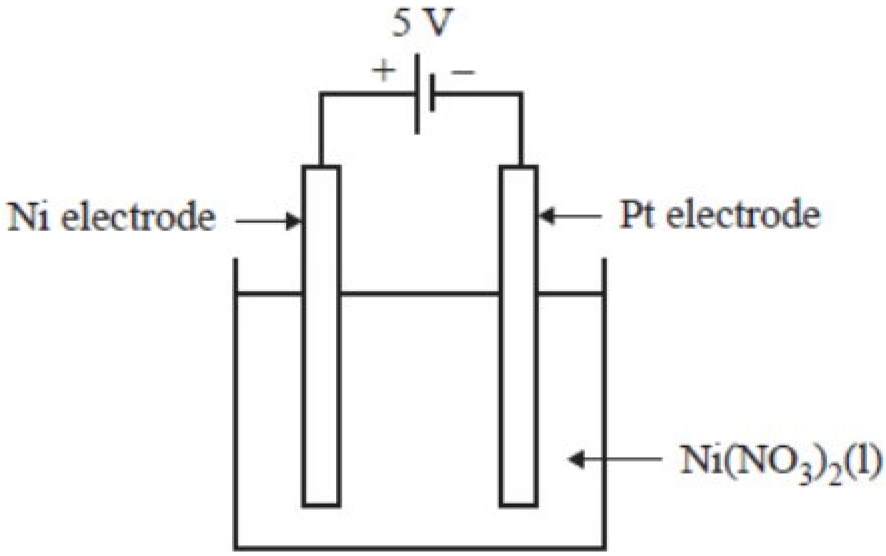
C. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

D. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Question 50 / 65

The following information is referred to in Questions 51 and 52.

An electrolysis cell with a 5 V power supply is shown below.



Question 51 / 65

[VCAA 2021 SA Q20]
l F is equivalent to the charge on 1 mol of electrons.

The mass of nickel, Ni, that can be electroplated onto the platinum, Pt, electrode with 320 F of charge is

---

A.

9.73×10^{-2} g

B.

1.95×10^{-l} g

C.

9.39×10^{3} g

D.

1.88×10^{4} g

Question 52 / 65

[VCAA 2021 SA Q21]
Using the electrochemical series, which one of the following changes to the electrolysis cell may reduce the amount of Ni electroplated onto the Pt electrode?

A.

replacing the Ni electrode with a Cu electrode

B.

replacing $Ni(NO_3)_2(l)$ with 1 M $Ni(NO_3)_2(aq)$

C.

replacing the Pt electrode with Pb(s)

D.

replacing $Ni(NO_3)_2(l)$ with $NiCl_2(l)$

Question 53 / 65

[VCAA 2017 SA Q20]
The reaction below represents the discharge cycle of a standard lead–acid rechargeable car battery.

$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

During the recharge cycle, the pH

A.

increases and solid Pb is a reactant.

B.

increases and solid PbO_2 is produced.

C.

decreases and chemical energy is converted to electrical energy.

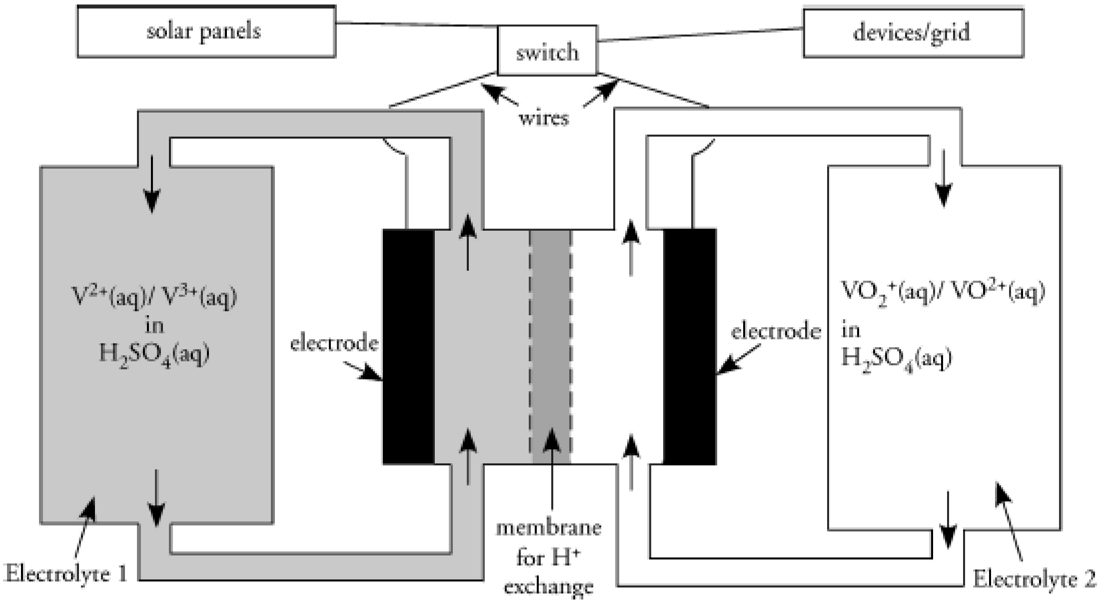
D.

decreases and electrical energy is converted to chemical energy.

Question 54 / 65

Use the following information to answer Questions 55 and 56.

An increasingly popular battery for storing energy from solar panels is the vanadium redox battery. The battery takes advantage of the four oxidation states of vanadium that are stable in aqueous acidic solutions in the absence of oxygen. A schematic diagram of a vanadium redox battery is shown below.



The two relevant half-equations for the battery are as follows.

$VO_2^{+}(aq) + 2H^{+}(aq) + e^{-} \rightarrow VO^{2+}(aq) + H_2O(l)$ $E° = +1.00$ V

$V^{3+}(aq) + e^{-} \rightarrow V^{2+}(aq)$ $E° = -0.26$ V

Question 55 / 65

[VCAA 2017 SA Q27]
The overall reaction that occurs when the battery is discharging is

---

A. $VO_2^{+}(aq) + 2H^{+}(aq) + V^{2+}(aq) \rightarrow VO^{2+}(aq) + V^{3+}(aq) + H_2O(l)$

B. $VO^{2+}(aq) + H_2O(l) + V^{3+}(aq) \rightarrow VO_2^{+}(aq) + V^{2+}(aq) + 2H^{+}(aq)$

C. $VO^{2+}(aq) + V^{2+}(aq) + 2H^{+}(aq) \rightarrow 2V^{3+}(aq) + H_2O(l)$

D. $VO_2^{+}(aq) + V^{3+}(aq) \rightarrow 2VO^{2+}(aq)$

Question 56 / 65

[VCAA 2017 SA Q28]
If air is present, the following half-equations are also relevant.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ $E° = +1.23$ V

$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$ $E° = +0.34$ V

If air is present, the

A.

$VO^{2+}(aq)$ ion is oxidised to the $V^{2+}(aq)$ ion.

B.

$VO^{2+}(aq)$ ion is reduced to the $V^{3+}(aq)$ ion.

C.

$V^{2+}(aq)$ ion is oxidised to the $VO^{2+}(aq)$ ion.

D.

$VO_2^+(aq)$ ion is reduced to the $VO^{2+}(aq)$ ion.

Question 57 / 65

[VCAA 2018 SA Q16]
The silver oxide-zinc battery is rechargeable and utilises sodium hydroxide, NaOH, solution as the electrolyte. The battery is used as a backup in spacecraft, if the primary energy supply fails. The overall reaction during discharge is

$Zn + Ag_2O \rightarrow ZnO + 2Ag$

When the silver oxide-zinc battery is being **recharged**, the reaction at the anode is

---

A. $2Ag + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$

B. $Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$

C. $ZnO + H_2O + 2e^- \rightarrow Zn + 2OH^-$

D. $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

Question 58 / 65

[VCAA 2021 SA Q13]
Rechargeable batteries

A.

use reversible reactions.

B.

operate as galvanic cells during recharge.

C.

require a continuous flow of reactants to operate.

D.

have fewer side reactions as temperature increases.

Question 59 / 65

Use the following information to answer Questions 60 and 61.

The overall discharge reaction for a lead-acid battery is

$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

Question 60 / 65

During recharge, the reaction at the cathode is

A.

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

B.

$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

C.

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(1)$

D.

$PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$

Question 61 / 65

[VCAA 2021 SA Q14]
When the lead-acid battery is discharging, the oxidising agent is

---

A.

Pb

B.

PbO_2

C.

$PbSO_4$

D.

H_2SO_4

Question 62 / 65

[VCAA 2022 SA Q13]
An electrolysis cell is set up with inert platinum, Pt, electrodes. Which one of the following will produce a gas at the cathode when undergoing electrolysis in the cell?

A.

potassium iodide, KI(aq)

B.

sodium chloride, NaCl(l)

C.

lead bromide, $PbBr_2$(l)

D.

copper sulfate, $CuSO_4$(aq)

Question 63 / 65

Use the following information to answer Questions 64 and 65.

Lithium-ion batteries are used in a range of electronic devices, including mobile phones. The discharge reaction for this type of battery is

$LiC_6(s) + CoO_2(s) \rightarrow C_6(s) + LiCoO_2(s)$

Question 64 / 65

[VCAA 2022 SA Q22]
Which of the following is correct about lithium-ion batteries?

A.

During discharge, reduction occurs at the	During recharge, reduction occurs at the
anode	cathode

B.

cathode	anode

C.

anode	anode

D.

cathode	cathode

Question 65 / 65

[VCAA 2022 SA Q23]
Which one of the following statements about lithium-ion batteries is correct?

A. During recharge, $LiCoO_2$ is formed at the negative electrode.

B. During discharge, Li^+ ions move towards the positive electrode.

C. Raising the battery temperature increases the rate of reaction, thereby increasing the battery life.

D. The battery operates as an electrolytic cell during discharge and as a galvanic cell during recharge.

Question 1 / 29

Under certain conditions of temperature and pressure, incomplete combustion of ethane can occur according to the equation

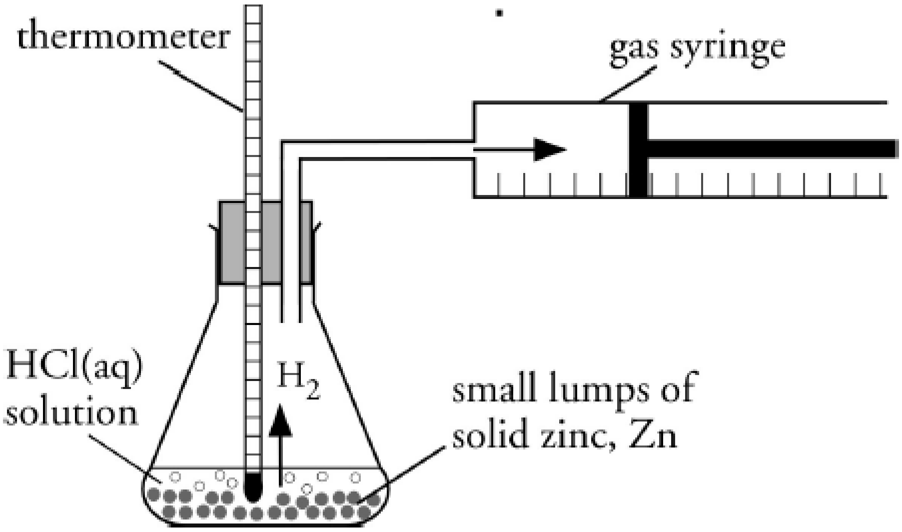
$C_2H_6(g) + O_2(g) \rightarrow 2CO(g) + 3H_2(g)$

In one experiment 0.10 mol of ethane and 0.10 mol of oxygen are brought to equilibrium in a 1.0 L flask. 0.16 mol of carbon monoxide is formed. Calculate a value for the equilibrium constant for this reaction.

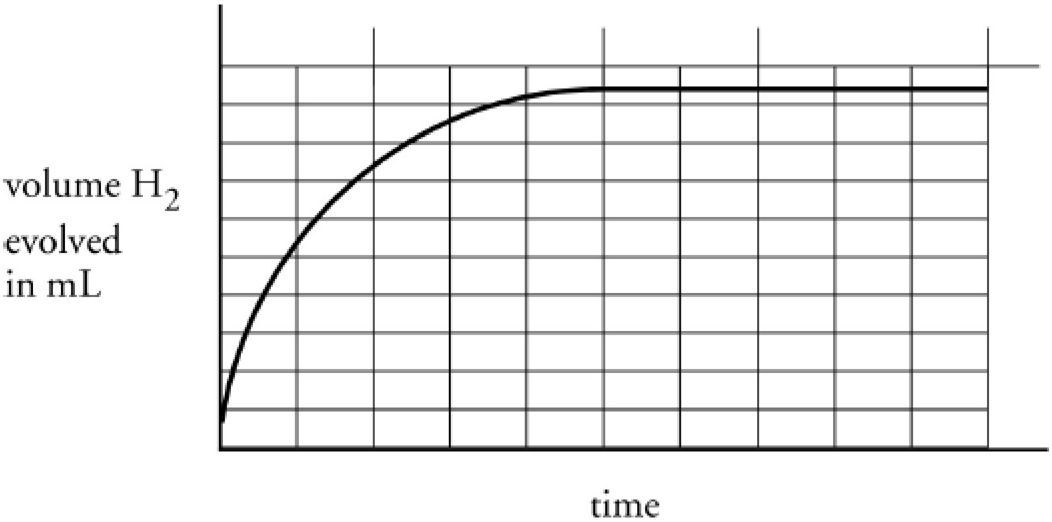
(Total = 4 marks)

Question 2 / 29

A student added 0.260 g of zinc to 100 mL of 1.00 M hydrochloric acid in the equipment shown below. The temperature recorded was 25°C and the pressure was 100 kPa.



The student noted the volume of gas in the syringe at regular intervals and plotted the graph shown below.



(a) Write an equation for the reaction between hydrochloric acid and zinc.

(1 mark)

(b) Calculate the mass of hydrogen produced in the reaction.

(2 marks)

(c) What is the maximum volume of hydrogen that could be collected from this experiment?

(1 mark)

(d) How did the rate of evolution (production) of hydrogen change over the time taken for the reaction?

(1 mark)

(e) Give an explanation for your answer to part **(d)**.

(2 marks)

(f) Suggest two changes to the experiment that would decrease the rate of evolution of hydrogen.

(2 marks)

(Total = 9 marks)

Question 3 / 29

[VCAA 2013 SB Q4]
The industrial production of hydrogen involves the following two reactions.

reaction I: $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$; $\Delta H = +206$ kJ mol^{-1}

reaction II: $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; $\Delta H = -41$ kJ mol^{-1}

(a) (i) Write 'increase', 'decrease' or 'no change' in the table below to identify the expected effect of each change to reaction I and reaction II on the equilibrium yield of hydrogen.

(3 marks)

Change to reaction I and reaction II	**Effect of the change on the hydrogen yield in reaction I**	**Effect of the change on the hydrogen yield in reaction II**
addition of steam at a constant volume and temperature		
increase in temperature at a constant volume		
addition of a suitable catalyst at a constant volume and temperature		

(ii) Explain the effect of decreasing the volume, at constant temperature, on the hydrogen equilibrium yield in each reaction.

(4 marks)

(iii) What is the effect of an increase in temperature at constant volume on the rate of hydrogen production in each reaction?

(2 marks)

The reaction between hydrogen and oxygen is the basis of energy production in a number of fuel cells.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$; $\Delta H = -571.6$ kJ mol^{-1}

(b) An **alkaline** electrolyte is used in a particular hydrogen/oxygen fuel cell. Write a balanced half-equation for the reaction occurring at the

(i) cathode (ii) anode.

(2 marks)

(c) What is the maximum voltage predicted for one alkaline hydrogen/oxygen fuel cell under standard conditions?

(1 mark)

Much of the hydrogen used in fuel cells is produced from methane.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

(d) Explain why methane generated by biomass is a renewable fuel while methane derived from fossil fuels is not.

(2 marks)

(Total = 14 marks)

Question 4 / 29

[VCAA 2018 SB Q2]
Hydrogen peroxide, H_2O_2, in aqueous solution at room temperature decomposes slowly and irreversibly to form water, H_2O, and oxygen, O_2, according to the following equation.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$; $\Delta H < 0$

(a) What effect will increasing the temperature have on the rate of O_2 production? Use collision theory to explain your answer.

(3 marks)

(b) When a small lump of manganese(IV) dioxide, MnO_2, is added to the H_2O_2 solution, the rate of O_2 production increases, but when powdered MnO_2 is added instead, the rate of O_2 production is **greatly** increased. The MnO_2 is recovered at the end of the reaction. State the function of MnO_2 in this reaction.

(1 mark)

(c) A solution of H_2O_2 is labelled '10 volume' because 1.00 L of this solution produces 10.0 L of O_2 measured at standard laboratory conditions (SLC) when the H_2O_2 in the solution is fully decomposed. Calculate the concentration of H_2O_2 in the '10 volume' solution, in grams per litre, when this solution is first prepared.

(2 marks)

(d) Propose a method to determine how quickly a solution of H_2O_2 decomposes when stored at a particular temperature.

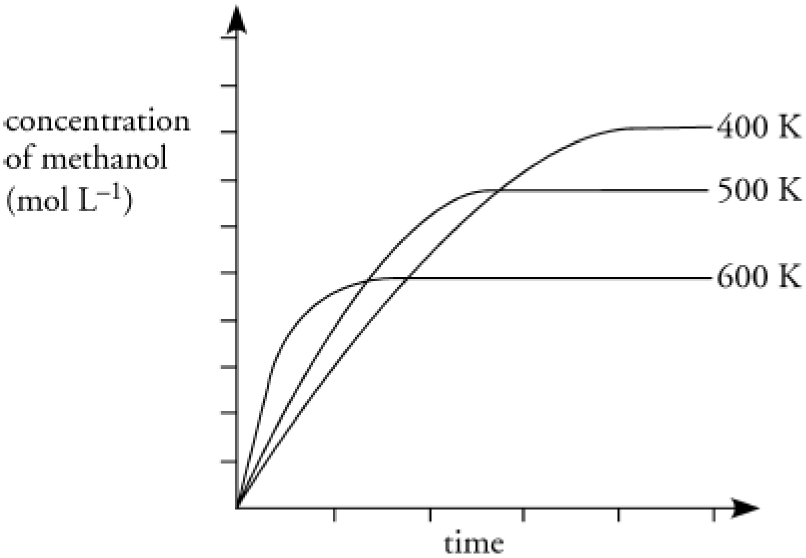
(3 marks)

(Total = 9 marks)

Question 5 / 29

[VCAA 2011 E2 SB Q7]
Methanol is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen and carbon monoxide gases at a temperature of 520 K and a pressure of 50 to 100 atmospheres. The reaction that occurs in the methanol converter is

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$



(a) Carbon monoxide gas and hydrogen gas are mixed in a reaction vessel and equilibrium is established. The graph above shows how the concentration of methanol in this vessel changes with time at three different temperatures. The pressure is the same at each temperature.

(i) Is the reaction exothermic or endothermic? Explain your answer.

(2 marks)

(ii) Explain why a moderately high temperature of 520 K is used although the equilibrium concentration of methanol is greater at a lower temperature.

(1 mark)

(iii) Explain why, at a given temperature, the use of high pressures results in a greater equilibrium concentration of methanol.

(2 marks)

(b) A catalyst consisting of a mixture of copper, zinc and aluminium is used to increase the rate of this reaction. Explain how a catalyst can increase reaction rate.

(1 mark)

(Total = 6 marks)

Question 6 / 29

[VCAA 2015 SB Q7]
Consider the reaction shown in the following equation.

$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$; $\Delta H = -16.1$ kJ mol^{-1}, $K = 1.3 \times 10^{-2}$ M^{-1} at 1000 K

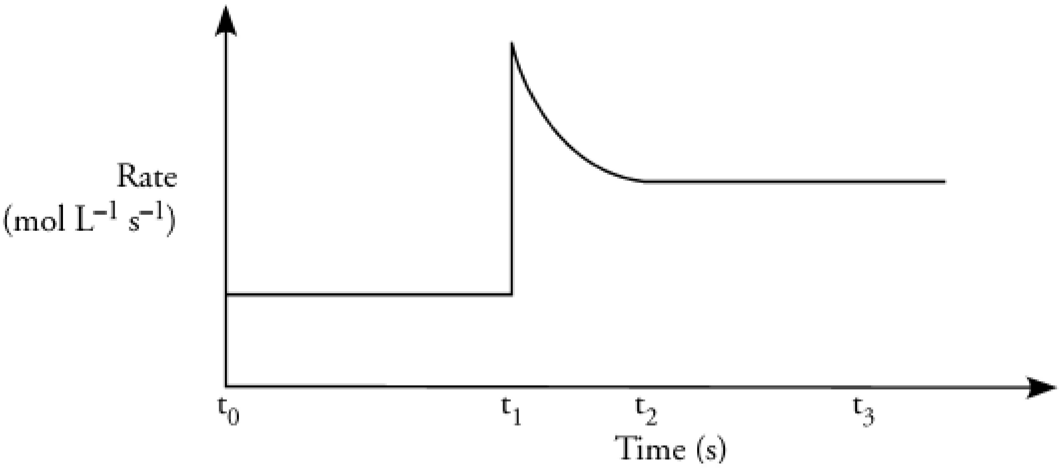
(a) Write an expression for the equilibrium constant for this reaction.

(1 mark)

(b) 10.0 mol of NOBr, 10.0 mol of NO and 5.0 mol of Br_2 are placed in a 1.0 L container at 1000 K. Predict in which direction the reaction will proceed. Justify your answer.

(3 marks)

(c) A mixture of NO, NOBr and Br_2 is initially at equilibrium. The graph below shows how the **rate** of formation of NOBr in the mixture changes when the volume of the reaction vessel is decreased at time t_1.



Use collision theory and factors that affect the rate of a reaction to explain the shape of the graph at the time intervals indicated in the table below.

(3 marks)

Time	**Explanation**
between t_0 and t_1	
at t_1	
between t_1 and t_2	

(Total = 7 marks)

Question 7 / 29

[VCAA 2017 SB Q4]
Sulfur trioxide, SO_3, is made by the reaction of sulfur dioxide, SO_2, and oxygen, O_2, in the presence of a catalyst, according to the equation below.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$; $\Delta H < 0$

In a closed system in the presence of the catalyst, the reaction quickly achieves equilibrium at 1000 K.

(a) A mixture of 2.00 mol of $SO_2(g)$ and 2.00 mol of $O_2(g)$ was placed in a 4.00 L evacuated, sealed vessel and kept at 1000 K until equilibrium was reached. At equilibrium, the vessel was found to contain 1.66 mol of $SO_3(g)$. Calculate the equilibrium constant, *K*, at 1000 K.

(4 marks)

(b) A manufacturer of SO_3 investigates changes to the reaction conditions used in part **(a)** in order to increase the percentage yield of the product in a closed system, where the volume may be changed, if required. What changes would the manufacturer make to the temperature and volume of the system in order to increase the percentage yield of SO_3? Justify your answer.

(4 marks)

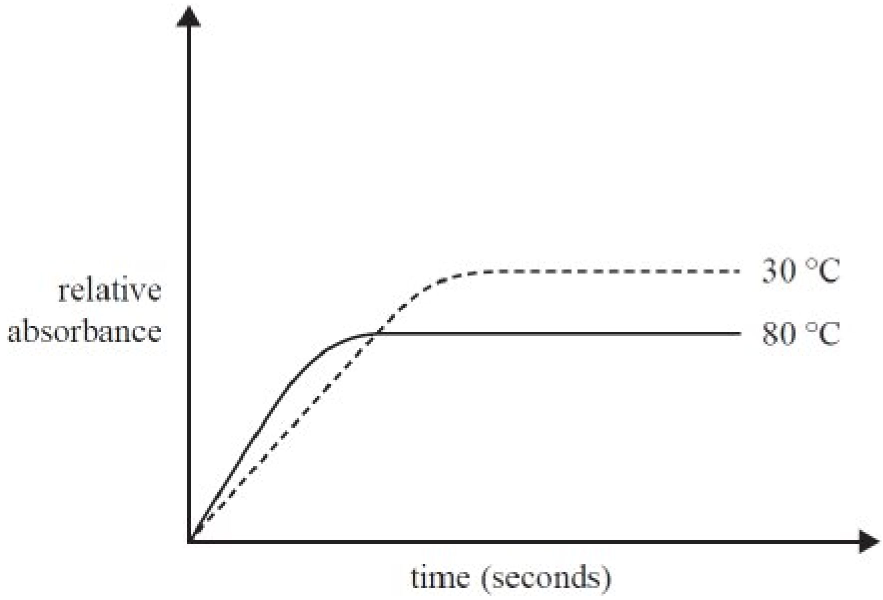
(Total = 8 marks)

Question 8 / 29

[VCAA 2019 SB Q3]
The cobalt(II) tetrachloride ion, $CoCl_4^{-}$, dissociates into the cobalt(II) ion, Co^{2+}, and chloride ions, Cl^{-}, according to the following chemical equation.

$CoCl_4^{2-}(aq) \rightleftharpoons Co^{2+}(aq) + 4Cl^{-}(aq)$

20 mL samples of the equilibrium mixture were heated to two temperatures, 30°C and 80°C. The intensity of the pink colour of the Co^{2+} product was recorded every 30 seconds by measuring the absorbance of the solution. The higher the intensity of the pink colour, the higher the absorbance. The results of this experiment are shown in the graph below.



(a) State whether the forward reaction is exothermic or endothermic. Justify your answer by referring to the graph.

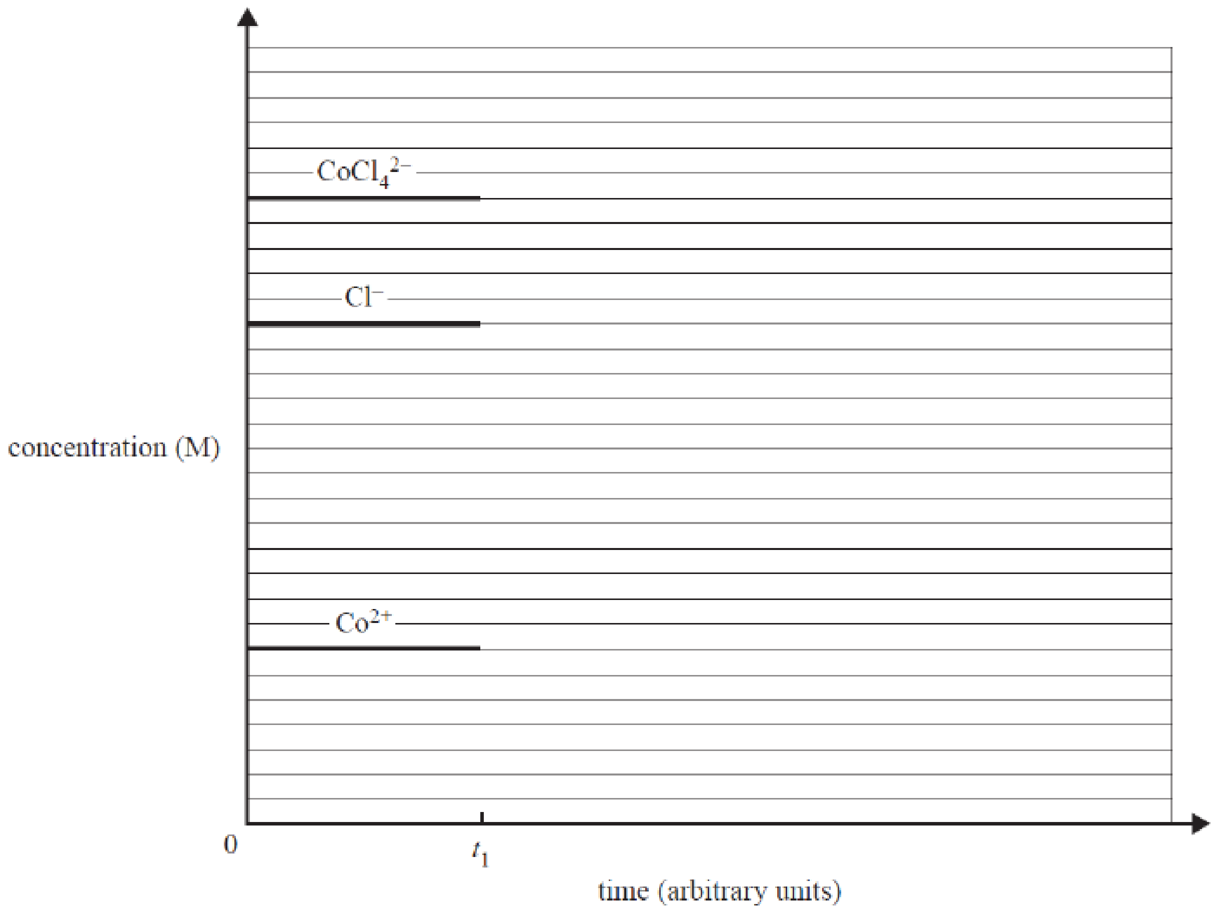
(2 marks)

(b) When 5 mL of water was added to the equilibrium mixture, the colour of the solution immediately became lighter pink. Describe the final colour of the solution once equilibrium is re-established. Explain your answer.

(2 marks)

(c) Five drops of silver nitrate, $AgNO_3$, solution are added to the equilibrium mixture at time t_1.

A concentration–time graph for this reaction is shown below for times between zero and t_1.



Continue the graph to show the changes that occur to the system from t_1 until equilibrium is re-established.

(3 marks)

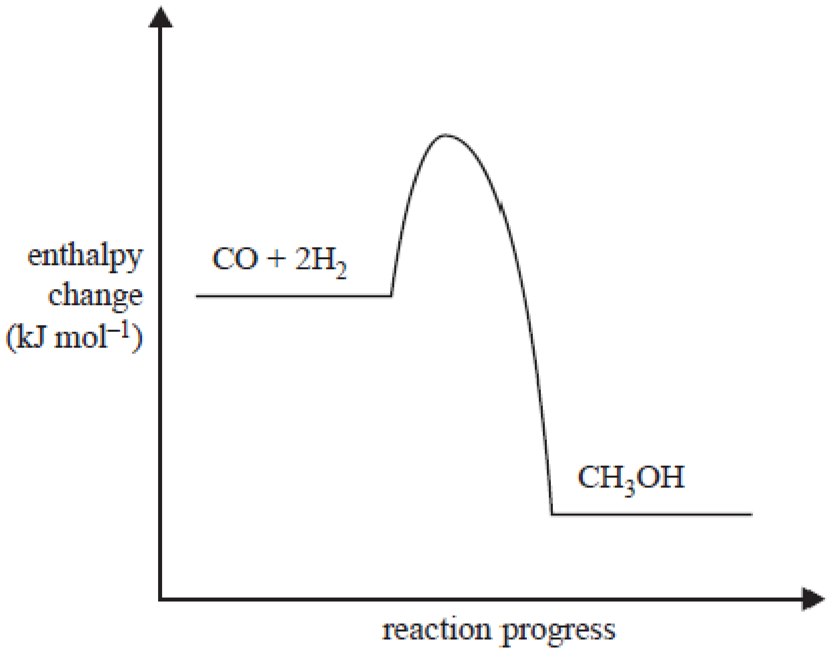
(Total = 7 marks)

Question 9 / 29

[VCAA 2020 SB Q1]
Methanol is a very useful fuel. It can be manufactured from biogas. The main reaction in methanol production from biogas is represented by the following equation.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H < 0$

This reaction requires the use of a catalyst to maximise the yield of methanol produced in optimum conditions. The energy profile diagram below represents the uncatalysed reaction.



(a) On the energy profile diagram, sketch how the catalyst would alter the reaction pathway.

(1 mark)

(b) (i) How does the reaction temperature affect the yield of methanol from biogas?

In your answer, refer to Le Chatelier's principle.

(2 marks)

(ii) How does the reaction pressure affect the yield of methanol from biogas?

In your answer, refer to Le Chatelier's principle.

(2 marks)

(c) Write the expression for the equilibrium constant, *K*, for this reaction.

(1 mark)

(d) 0.760 mol of carbon monoxide, CO, and 0.525 mol of hydrogen, H_2, were allowed to reach equilibrium in a 500 mL container. At equilibrium the mixture contained 0.122 mol of methanol. Calculate the equilibrium constant, *K*.

(3 marks)

(Total = 9 marks)

Question 10 / 29

[VCAA 2021 SB Q8]
The reaction for the oxidation of sulfur dioxide, SO_2, is shown below.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$

(a) 1.00 mol of SO_2 and 1.00 mol of oxygen, O_2, are placed into an evacuated, sealed 3.00 L container at 100 °C. After the reaction reaches equilibrium, the container contains 20.0 g of sulfur trioxide, SO_3.

Calculate the equilibrium constant, *K*, for this reaction at 100 °C.

(4 marks)

(b) The volume of the closed container is doubled.

Describe the effect that this has on the concentration of SO_2 from the time just before the volume was changed until after the system re-established its equilibrium.

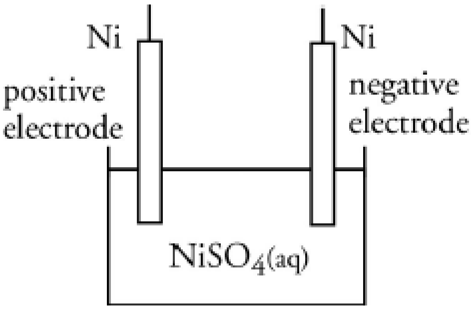
(3 marks)

(Total = 7 marks)

Question 11 / 29

An electrolysis cell is constructed from two pure nickel electrodes and an aqueous solution of $NiSO_4$. The cell is used to measure the amount of electricity flowing in a circuit. The reaction at the negative electrode (cathode) is

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$.



What current, in amps, is required to deposit 20 mg of nickel in 30 minutes?(Total = 4 marks)

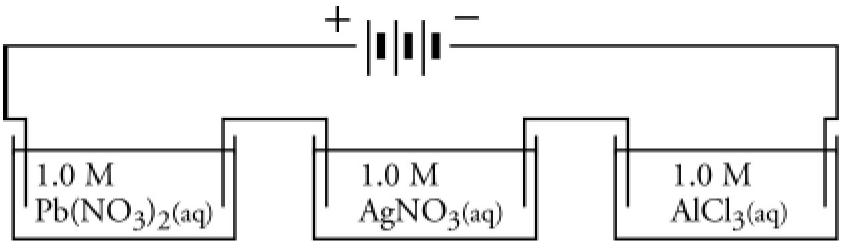
Question 12 / 29

A piece of copper can be polished by making it the anode in an electrolysis cell. If it is assumed that the only reaction occurring at the anode is the conversion of copper metal into Cu^{2+} ions, calculate the mass of copper removed from the piece of copper by a current of 9.5 A passing for 4 minutes.

(Total = 4 marks)

Question 13 / 29

Three cells are connected as shown in the diagram below, and a steady current is passed for a fixed time. The aqueous solutions contain Pb^{2+}, Ag^{+} and Al^{3+} respectively, and Pt electrodes are used.



(a) Write the equations for the reactions occurring at the cathode in each of the three cells.

(3 marks)

(b) If 0.03 mol of silver is deposited at the cathode in the centre cell, how much material (in moles) would you expect to be produced in each of the other cells? Explain your answer.

(2 marks)

(Total = 5 marks)

Question 14 / 29

Two platinum electrodes were placed in 1.00 L of a 0.210 M $AgNO_3$ solution. An electric current of 0.57 A was passed through the solution for some time, and silver metal formed on one of the electrodes. The volume of the solution was unchanged, and the final concentration of silver ion in the solution was 0.110 M.

(a) At which electrode (anode or cathode) was the silver deposited?

(1 mark)

(b) What is the polarity of this electrode?

(1 mark)

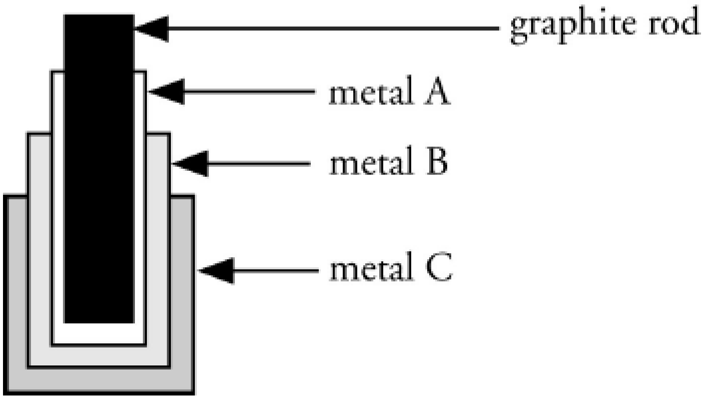
(c) Calculate the time taken to deposit the silver.

(4 marks)

(Total = 6 marks)

Question 15 / 29

0.75 L of an aqueous solution is prepared and contains 0.025 mol each of $SnCl_2$, $ZnCl_2$ and $CuCl_2$. Two graphite rods are placed in the solution and an electric current is passed through. When the electrolysis is finished, all of the metal ions (Sn^{2+}, Zn^{2+} and Cu^{2+}) have been deposited onto one of the graphite rods. The metals form three successive coatings: A, B and C (see diagram below).



(a) Identify the three metals A, B and C. Explain your answer.

(2 marks)

(b) Calculate the amount of electricity, in coulombs, needed to deposit the zinc layer alone.

(3 marks)

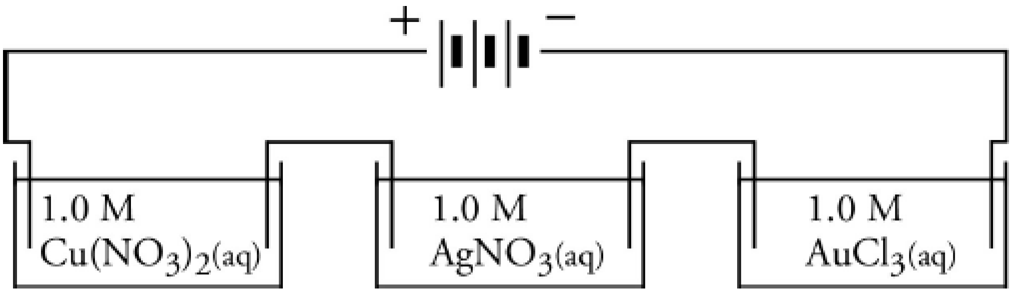
(c) How many coulombs would be needed to deposit the other two metals? Explain your answer.

(2 marks)

(Total = 7 marks)

Question 16 / 29

A student sets up a circuit for electroplating copper, silver and gold in three separate cells as shown in the diagram below. The cells are connected in series. A current flows through the circuit for 1.0 hour and 1.30 g of copper is deposited.



(a) At which electrode was the copper deposited?

(1 mark)

(b) The student measures the masses of the three metals deposited in this experiment, and then calculates the moles of each metal produced. What result would you expect the student to find for the ratio '*n*(Cu) : *n*(Ag) : *n*(Au)'? Explain your answer.

(2 marks)

(c) Calculate the current, in amps, that flowed through the circuit.

(3 marks)

(d) What were the masses of silver and gold deposited in the other two cells?

(4 marks)

(Total = 10 marks)

Question 17 / 29

Electrolysis of aqueous solutions containing nickel ions, $Ni^{2+}(aq)$, leads to the formation of nickel metal on the cathode (or negative electrode). However, calcium metal cannot be produced in this way from the electrolysis of aqueous solution containing calcium ions, $Ca^{2+}(aq)$.

(a) What would you expect to occur at the cathode when an aqueous solution of calcium chloride is electrolysed? Use an equation to illustrate your answer.

(2 marks)

(b) How can calcium metal be obtained from calcium chloride by electrolysis?

(1 mark)

(Total = 3 marks)

Question 18 / 29

A student connects two cells in series and passes an electric current through both. The first cell contains 2.0 M hydrochloric acid and platinum electrodes. In the second cell, the student uses silver electrodes and silver nitrate solution. The student passes a current of 2.85 A through both cells. A gas is produced at the cathode in the first cell and 2.00 g of silver is deposited on the cathode of the second cell.

(a) Draw a labelled diagram to show how the experiment described above would be set up. For each cell, indicate the polarity of the electrodes and label the cathode.

(3 marks)

(b) Calculate the time for which the current was passed.

(2 marks)

(c) Identify the gas formed at the cathode in the first cell and give the equation for the reaction that produces this gas.

(2 marks)

(d) What volume of the gas in part **(c)** would be formed at SLC?

(2 marks)

(Total = 9 marks)

Question 19 / 29

A metal ornament of total surface area 48 cm^2 is to be completely covered with a nickel coating of 2.50×10^{-3} cm thickness. The nickel is deposited by electrolysis. The ornament is suspended in an aqueous solution containing nickel ions, $Ni^{2+}(aq)$, and is made one of the electrodes of an electrolysis cell.

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

(a) To which electrode (cathode or anode) should the ornament be connected?

(1 mark)

(b) What volume of nickel is needed to plate the ornament?

(volume (mL) ≈ surface area (cm^2) × thickness (cm))

(1 mark)

(c) What mass of nickel will be used? (Density of nickel = 8.90 g mL^{-1})

(1 mark)

(d) Calculate the time needed to deposit the nickel coating if a steady current of 0.750 A is passed through the cell.

(4 marks)

(Total = 7 marks)

Question 20 / 29

A student is asked to determine a value for the Faraday constant by electrolysis of a copper sulfate solution using copper electrodes. Copper is deposited at the cathode, which is washed and dried at the end of the experiment. 0.175 g of copper was deposited by a current of 0.863 A in 10.00 minutes.

(a) Calculate a value for the Faraday constant from these results in C mol^{-1}.

(3 marks)

(b) The data table gives the value of the Faraday constant as 96 500 C mol^{-1}. Suggest a reason why the value determined from the student's results differs from the value in the data table.

(1 mark)

(c) The student repeats the experiment using a different solution of copper sulfate and this time obtains a value for the Faraday constant of 98 900 C mol^{-1}. The student then discovers that the copper sulfate solution used contained small amounts of nickel sulfate and zinc sulfate. What effect would these impurities have (if any) on the result?

(1 marks)

(Total = 5 marks)

Question 21 / 29

When current is drawn from a lead-acid accumulator, the electrode reactions are

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

$PbO_2(s) + 3H^+(aq) + HSO_4^-(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

(a) As the accumulator discharges, describe what happens to the

(i) sulfuric acid concentration

(ii) number of ions in solution

(iii) pH

(1 + 1 + 1 = 3 marks)

(b) In the overall cell reaction, what are the changes in oxidation number?

(2 marks)

(c) Give the equation of the reaction that occurs at the positive electrode during discharge.

(1 mark)

(d) Give the equation of the reaction that occurs at the negative electrode when the accumulator is being recharged.

(1 mark)

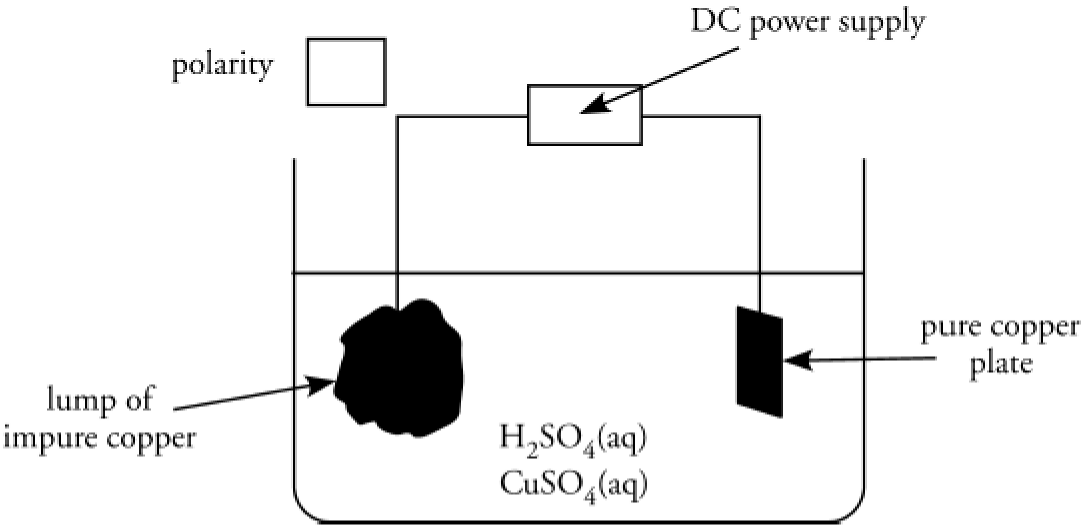
(Total = 7 marks)

Question 22 / 29

[Adapted VCAA 2013 SB Q7]
An electrolytic process known as electrorefining is the final stage in producing highly purified copper. In a small-scale trial, a lump of impure copper is used as one electrode and a small plate of pure copper is used as the other electrode. The electrolyte is a mixture of aqueous sulfuric acid and copper sulfate.

(a) Indicate in the box labelled 'polarity' on the diagram below, the polarity of the impure copper electrode.

(1 mark)



In a trial experiment, the electrodes were weighed before and after electrolysis. The results are provided in the following table.

	Mass of lump of impure copper	**Mass of pure copper**
before electrolysis	10.30 kg	1.55 kg
after electrolysis	0.855 kg	9.80 kg

(b) On the basis of these results

• calculate a percentage purity of the lump of impure copper

• indicate **one** factor that may affect the accuracy of these results.

(4 marks)

(c) Conditions in the electrolytic cell shown in the diagram above are carefully controlled to ensure a high degree of copper purity and electrical efficiency. Use the mass of pure copper deposited that is given in the table in part **(a)** to determine the time, in days, taken for this electrolysis reaction to be completed. Assume the current was a constant 24 A.

(5 marks)

Lumps of impure copper typically contain impurities such as silver, gold, cobalt, nickel and zinc. Cobalt, nickel and zinc are oxidised from the copper lump and exist as ions in the electrolyte. Silver and gold are not oxidised and form part of an insoluble sludge at the base of the cell.

(d) Why is it important that silver and gold are not present as cations in the electrolyte?

(1 mark)

(Total = 11 marks)

Question 23 / 29

[Adapted VCAA 2011 E2 SB Q8]
A chemical engineer designs a pilot plant to determine the conditions that will give the best results for copper plating different objects. A range of experiments indicates that an electroplating cell with an aqueous electrolyte containing copper(I) cyanide, CuCN, potassium cyanide, KCN, and potassium hydroxide, KOH, will produce a uniform copper coating.

(a) Write a balanced half-equation for the cathode reaction in this electrolytic cell.

(1 mark)

The quality of the copper coating depends on maintaining a low, constant concentration of copper(I) ions in the electrolyte. This is achieved by making use of the following reaction, which takes place in the electrolyte bath. In this reaction, copper(I) ions, Cu^+, react with the cyanide ions, CN^-, according to the equation

$Cu^+(aq) + 4CN^-(aq) \rightleftharpoons Cu(CN)_4^{3-}$ $\quad$ $K = 1 \times 10^{28}$

(b) Refer to this information to explain how the presence of excess potassium cyanide in the electrolyte maintains a low concentration of $Cu^+(aq)$ ions in solution.

(1 mark)

The cyanide ion, CN^-, is the conjugate base of the acid hydrogen cyanide, HCN.

$CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq);$ $\quad$ $K = 10^{-4.8}$

Hydrogen cyanide is highly toxic and can bubble out of solution.

(c) Explain how the presence of potassium hydroxide in the electrolyte is essential to the safe operation of this cell.

(1 mark)

Any gas produced at the cathode is found to damage the quality of the copper plate. This is avoided by maintaining a low current.

(d) Write a balanced equation for the gas most likely to be produced at the cathode if the current is too high.

(1 mark)

(e) In one trial, a medal is copper plated in the cell. The experimental data is given below.

Mass of medal before copper plating = 25.2 g

Mass of medal after copper plating = 36.4 g

Current = 0.900 A

Calculate the time, in minutes, taken to copper plate the medal.

(4 marks)

(Total = 8 marks)

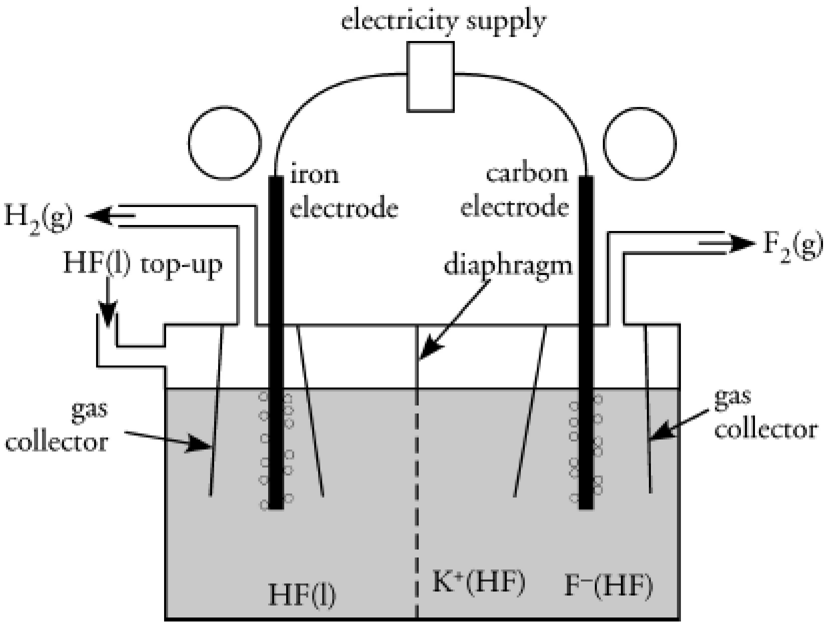
Question 24 / 29

[VCAA 2017 SB Q8]
Fluorine, F_2, gas is the most reactive of all non-metals. Anhydrous liquid hydrogen fluoride, HF, can be electrolysed to produce F_2 and hydrogen, H_2, gases. Potassium fluoride, KF, is added to the liquid HF to increase electrical conductivity.

The equation for the reaction is

$2HF(l) \rightarrow F_2(g) + H_2(g)$

F_2 is used to make a range of chemicals, including sulfur hexafluoride, SF_6, an excellent electrical insulator, and xenon difluoride, XeF_2, a strong fluorinating agent. The diagram below shows an electrolytic cell used to prepare F_2 gas.



Liquid HF, like water, is an excellent solvent for ionic compounds. In the same way that water molecules in an aqueous solution form the ions $K^+(aq)$ and $F^-(aq)$, when KF is dissolved in HF, the K^+ and F^- ions form ions that are written as $K^+_{(HF)}$ and $F^-_{(HF)}$.

(a) Label the polarities of each electrode in the circles provided on the diagram above.

(1 mark)

(b) Write the equation for the half-reaction occurring at the anode.

(1 mark)

(c) Suggest why the diaphragm, shown in the diagram above, is important for the safe operation of the electrolytic cell.

(1 mark)

(d) Explain why the carbon electrode cannot be replaced with an iron electrode.

(3 marks)

(e) Calculate the volume of F_2 gas, measured at standard laboratory conditions (SLC), that would be produced when a current of 1.50 A is passed through the cell for 2.00 hours.

(3 marks)

(Total = 9 marks)

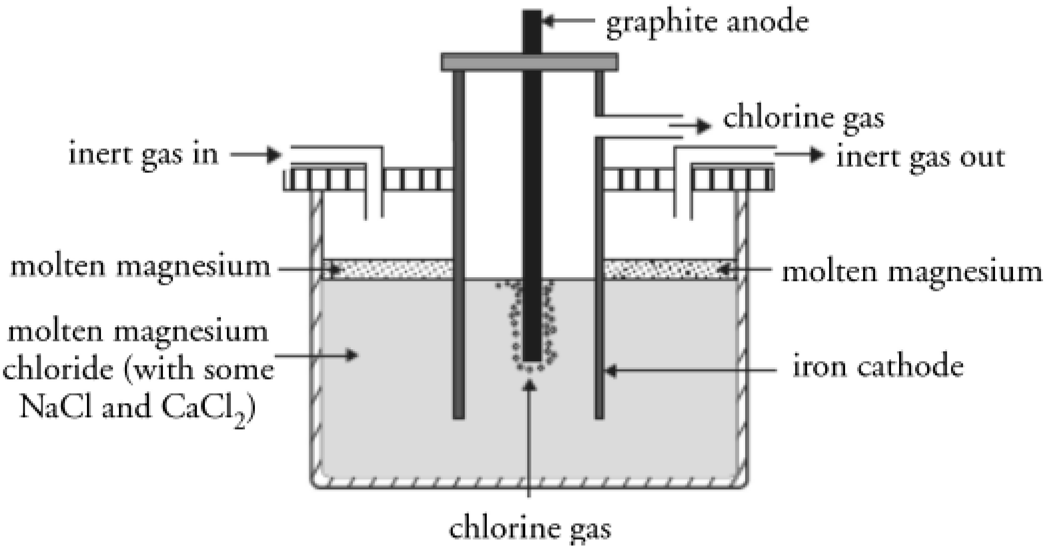
Question 25 / 29

[VCAA 2014 SB Q9]
Magnesium is one of the most abundant elements on Earth. It is used extensively in the production of magnesium-aluminium alloys. It is produced by the electrolysis of molten magnesium chloride. A schematic diagram of the electrolytic cell is shown below.

The design of this cell takes into account the following properties of both magnesium metal and magnesium chloride: Molten magnesium reacts vigorously with oxygen. At the temperature of molten magnesium chloride, magnesium is a liquid. Molten magnesium has a lower density than molten magnesium chloride and forms a separate layer on the surface.

(a) Write a balanced half-equation for the reaction occurring at each of the cathode and the anode.

(2 marks)



(b) Explain why an inert gas is constantly blown through the cathode compartment.

(1 mark)

(c) The melting point of a compound can often be lowered by the addition of small amounts of other compounds. In an industrial process, this will save energy. In this cell, NaCl and $CaCl_2$ are used to lower the melting point of $MgCl_2$. Why can NaCl and $CaCl_2$ be used to lower the melting point of $MgCl_2$ but $ZnCl_2$ cannot be used?

(2 marks)

(d) What difference would it make to the half-cell reactions if the graphite anode were replaced with an iron anode? Write the half-equation for any different half-cell reaction. Justify your answer.

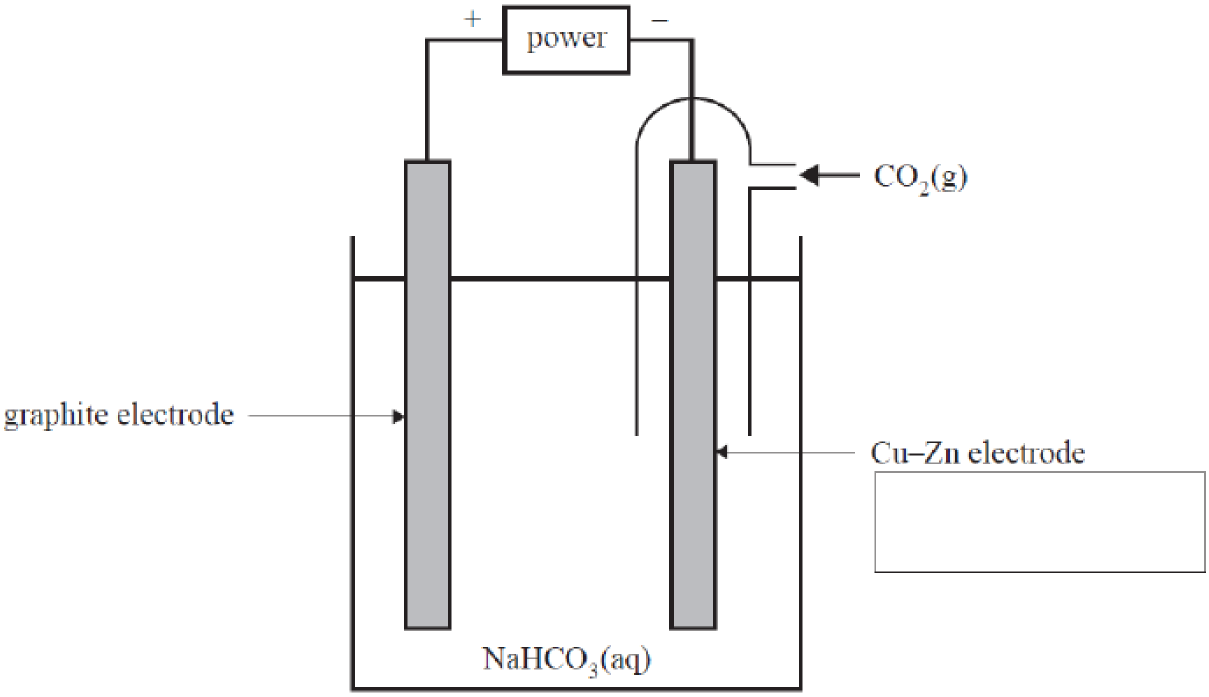
(3 marks)

(Total = 8 marks)

Question 26 / 29

[VCAA 2020 SB Q2]

The electrolysis of carbon dioxide gas, CO_2, in water is one way of making ethanol, C_2H_5OH. The diagram below shows a CO_2-H_2O electrolysis cell. The electrolyte used in the electrolysis cell is sodium bicarbonate solution, $NaHCO_3(aq)$.



The following half-cell reactions occur in the CO_2–H_2O electrolysis cell.

$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$ $E° = +0.40$ V

$2CO_2(g) + 9H_2O(l) + 12e^- \rightleftharpoons C_2H_5OH(l) + 12OH^-(aq)$ $E° = -0.33$ V

(a) Identify the Cu-Zn electrode as either the anode or the cathode in the box provided in the diagram above.

(1 mark)

(b) Determine the applied voltage required for the electrolysis cell to operate.

(1 mark)

(c) Write the balanced equation for the overall electrolysis reaction.

(1 mark)

(d) Identify the oxidising agent in the electrolysis reaction.

Give your reasoning using oxidation numbers.

(2 marks)

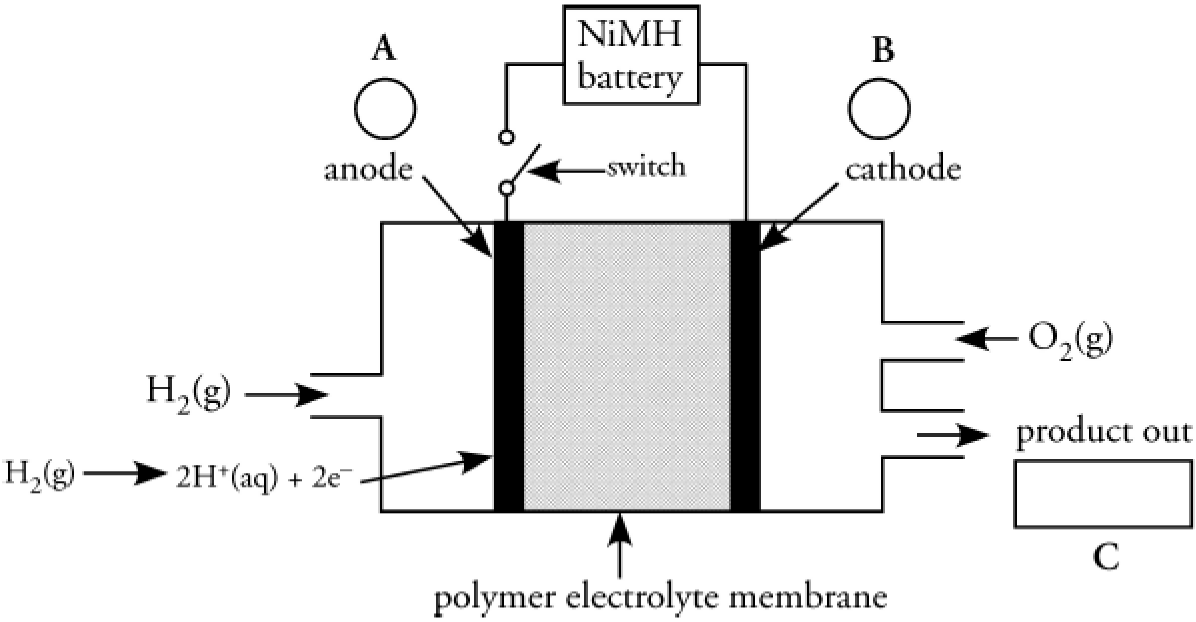
(e) A current of 2.70 A is passed through the CO_2–H_2O electrolysis cell. The cell has an efficiency of 58%. Calculate the time taken, in minutes, for this cell to consume 6.05×10^{-3} mol of $CO_2(g)$.

(3 marks)

(Total = 8 marks)

Question 27 / 29

[Adapted VCAA 2015 SB Q10]
A car manufacturer is planning to sell hybrid cars powered by a type of hydrogen fuel cell connected to a nickel metal hydride, NiMH, battery. A representation of the hydrogen fuel cell is given below.



The overall cell reaction is

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

(a) (i) On the diagram above, indicate the polarity of the anode and the cathode in circles A and B, and identify the product of the reaction in box C.

(2 marks)

(ii) Write an equation for the reaction that occurs at the cathode when the switch is closed.

(1 mark)

(iii) Identify one advantage and one disadvantage of using this fuel cell instead of a petrol engine to power the car.

(2 marks)

(b) The storage battery to be used in the hybrid cars is comprised of a series of nickel metal hydride, NiMH, cells. MH represents a metal hydride alloy that is used as one electrode. The other electrode contains nickel oxide hydroxide, NiOOH. The electrolyte is aqueous KOH.

The simplified equation for the reaction at the anode while **recharging** is

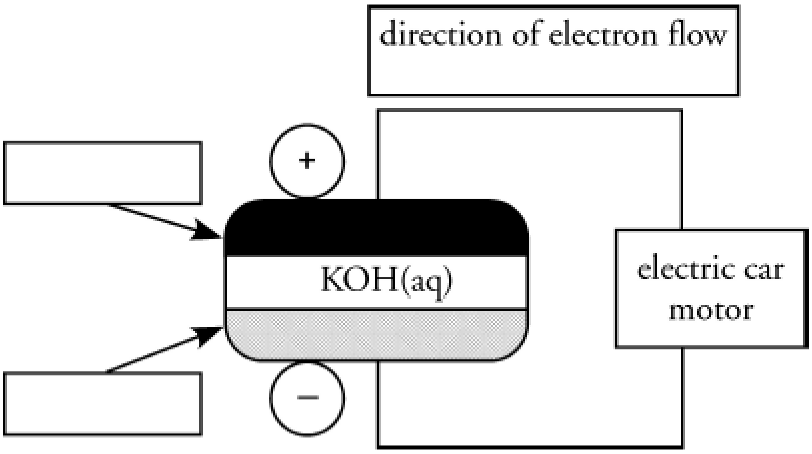
$Ni(OH)_2(s) + OH^-(aq) \rightarrow NiOOH(s) + H_2O(l) + e^-$

The simplified equation for the reaction at the cathode while **recharging** is

$M(s) + H_2O(l) + e^- \rightarrow MH(s) + OH^-(aq)$

(i) What is the overall equation for the **discharging** reaction?

(1 mark)



(ii) In the boxes on the diagram above, indicate which is the MH electrode and which is the NiOOH electrode.

(1 mark)

(iii) In the box provided in the cell diagram, use an arrow, → or ←, to indicate the direction of the electron flow as the cell is discharging.

(1 mark)

(iv) The battery discharged for 60 minutes, producing a current of 1.15 A. What mass, in grams, of NiOOH would be used during this period?

(3 marks)

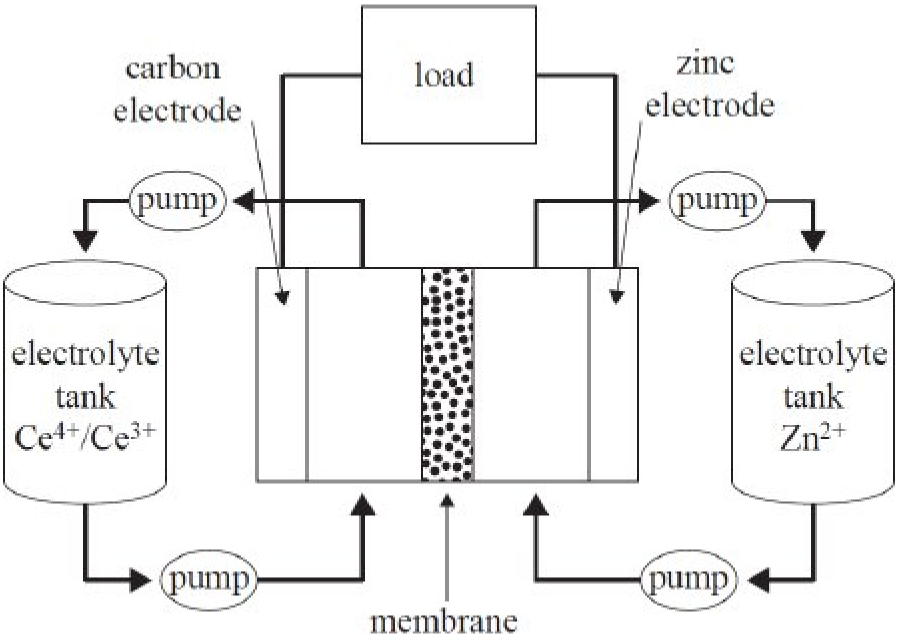
(Total = 11 marks)

Question 28 / 29

[VCAA 2019 SB Q7]
The zinc-cerium battery is a commercial rechargeable battery that comprises a series of cells.

During recharging, the cells use energy from wind farms or solar cell panels. During discharging, energy is supplied to electric grids to power local factories and homes. The electrolytes are stored in separate storage tanks and are pumped into and out of each cell when in use. A membrane separates the two electrodes that are immersed in 1 M methanesulfonic acid, CH_3SO_3H.

A diagram representing a zinc-cerium cell is shown below.



The following half-cell reactions occur in the zinc-cerium cell.

$Zn(CH_3SO_3)_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons Zn(s) + 2CH_3SO_3H(aq)$ $\quad E° = -0.76$ V

$Ce(CH_3SO_3)_4(aq) + H^+(aq) + e^- \rightleftharpoons Ce(CH_3SO_3)_3(aq) + CH_3SO_3H(aq)$ $\quad E° = 1.64$ V

(a) Write the equation for the overall discharge reaction.

(1 mark)

(b) Identify the oxidising agent during discharging and justify your answer using oxidation numbers.

(2 marks)

(c) Determine the theoretical voltage produced by a single cell as it discharges.

(1 mark)

(d) Write the ionic equation for the reaction occurring at the positive electrode during recharging.

(1 mark)

(e) Other than transporting ions between the electrodes, describe one function of the membrane in the zinc-cerium cell.

(1 mark)

(f) Specify one factor that would limit the life of the zinc-cerium cell.

(1 mark)

(g) Experts have regarded the zinc-cerium cell as a hybrid of a fuel cell and a secondary cell. Why would this be the case?

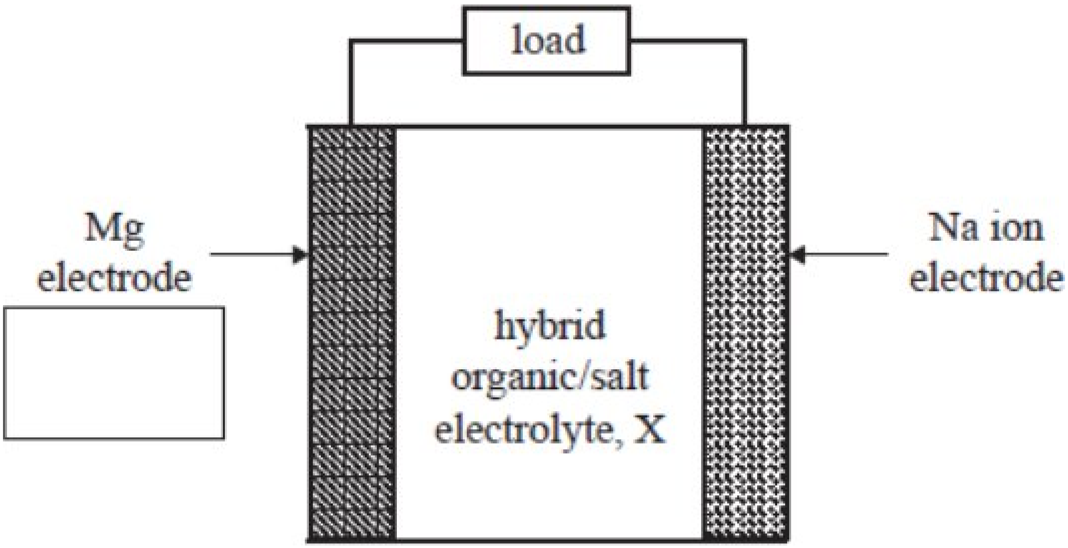
(1 mark)

(Total = 8 marks)

Question 29 / 29

[VCAA 2021 SB Q2]
Research scientists are developing a rechargeable magnesium-sodium, Mg-Na, hybrid cell for use in portable devices. The Mg-Na hybrid cell uses magnesium metal and sodium ion electrodes and a hybrid organic/salt electrolyte, X.

A simplified diagram of the rechargeable Mg-Na hybrid cell is shown below.



(a) The equation for the overall reaction during **recharge** is

$2NaX + Mg^{2+} \rightarrow Mg + 2Na^{2+} + 2X$

(i) Identify the polarity of the Mg electrode when the cell is discharging by placing a positive (+) or a negative (-) sign in the box provided in the diagram above.

(1 mark)

(ii) Write the half-cell equation of the reaction that occurs at the Mg electrode when the cell is **discharging.**

(1 mark)

(b) A pacemaker is a small electronic device that is implanted in the body to regulate a person's heart rate. If the Mg-Na hybrid cell were to be used to power pacemakers, what would be **two** potential safety hazards of having this cell in the body?

(2 marks)

(c) One source of Mg is magnesium chloride, $MgCl_2$, which can be obtained from seawater.

Explain how Mg can be produced from $MgCl_2$ in an electrolytic cell.

(3 marks)

(Total = 7 marks)

Question 1 / 23

The following information is referred to in Questions 2 to 4.

The important reaction in the Haber process for the production of ammonia, NH_3, is

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -91$ kJ mol^{-1}

Question 2 / 23

The highest yield of ammonia would be obtained using

A.

high temperatures and high pressures.

B.

low temperatures and high pressures.

C.

high temperatures and low pressures.

D.

low temperatures and low pressures.

Question 3 / 23

In the industrial process a catalyst is used. The catalyst

A.

increases the rates of the forward and back reactions but does not change the equilibrium constant.

B.

increases the rates of the forward and back reactions and increases the equilibrium constant.

C.

increases the rate of the forward reaction only but does not change the equilibrium constant.

D.

increases the rate of the forward reaction only and increases the equilibrium constant.

Question 4 / 23

In a certain equilibrium mixture $[N_2]$ = 0.100 M, $[H_2]$ = 0.200 M and $[NH_3]$ = 0.800 M. The value of the equilibrium constant is

---

A.

1.00 × 10

B.

40.0

C.

800

D.

2.67

Question 5 / 23

An alloy of iridium and rhodium is used to catalyse the following reaction.

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$; $\Delta H = -900$ kJ mol^{-1}

The purpose of the catalyst is to

A.

increase the equilibrium constant, *K*, of the reaction.

B.

increase the activation energy of the reaction.

C.

decrease the equilibrium constant, *K*, of the reaction.

D.

decrease the activation energy of the reaction.

Question 6 / 23

Butane can be 'cracked' into two smaller molecules.

$C_4H_{10}(g) \rightleftharpoons C_2H_6(g) + C_2H_4(g)$; ΔH = +93 kJ mol^{-1}

Which of the following sets of conditions would lead to the greatest amount of cracking?

A.

280°C and 2 atmospheres pressure

B.

280°C and 10 atmospheres pressure

C.

350°C and 2 atmospheres pressure

D.

350°C and 10 atmospheres pressure

Question 7 / 23

When limestone, $CaCO_3$, reacts with hydrochloric acid, the following reaction occurs.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

Which of the following would **not** increase the rate of the reaction?

A.

Increasing the volume of the container

B.

Using finely powdered limestone

C.

Changing the temperature from 15°C to 25°C

D.

Using 2.0 M acid instead of 1.0 M acid

Question 8 / 23

In the conversion of carbon monoxide to carbon dioxide, the following reaction is used.

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; $\Delta H = -40\ kJ\ mol^{-1}$

Which of the following would **not** increase the percentage conversion of CO into CO_2?

A. Decreasing the temperature

B. Decreasing the pressure

C. Adding more steam

D. Removing CO_2

Question 9 / 23

[VCAA 2020 SA Q6]
Which one of the following pairs of statements is correct for both electrolysis cells and galvanic cells?

A.

Electrolysis cell	**Galvanic cell**
Both electrodes are always inert.	Both electrodes are always made of metal.

B.

Electrical energy is converted to chemical energy.	The voltage of the cell is independent of the electrolyte concentration.

C.

Chemical energy is converted to electrical energy.	The products are dependent on the half-cell components.

D.

The products are dependent on the half-cell components.	Chemical energy is converted to electrical energy.

Question 10 / 23

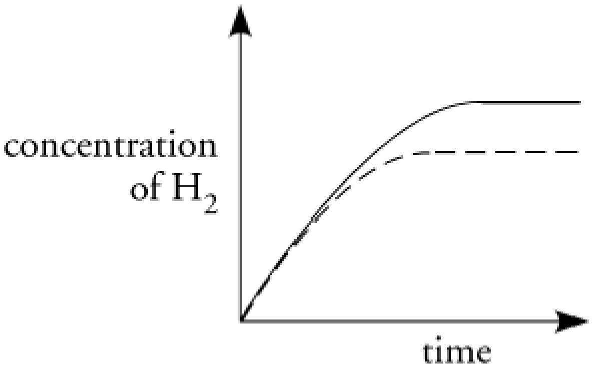
[Adapted VCAA 2012 E2 SA Q11]
The following reaction is used in some industries to produce hydrogen.

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; $\Delta H = -41$ kJ mol^{-1}

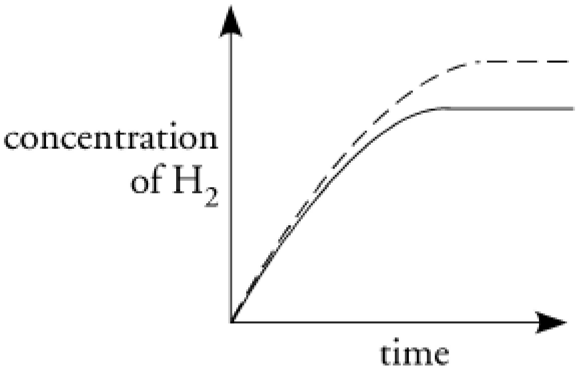
In trials, the reaction is carried out with and without a catalyst in the sealed container. All other conditions are unchanged. The change in hydrogen concentration with time between an uncatalysed and a catalysed reaction is represented by a graph. Which graph below is correct?

——— uncatalysed reaction   - - - - - catalysed reaction

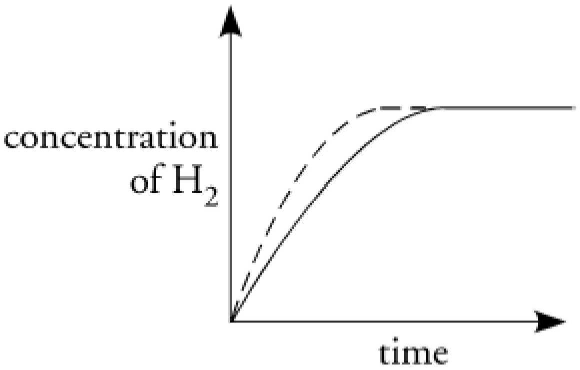
A.



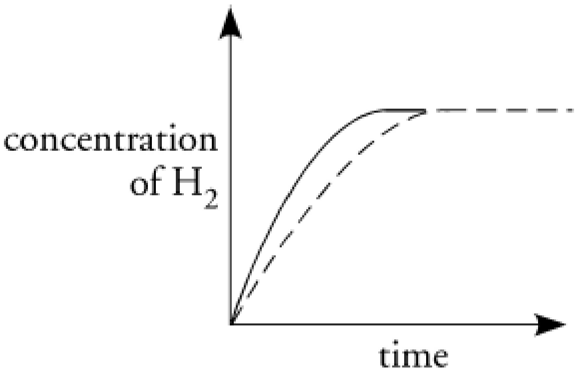
B.



C.



D.



Question 11 / 23

The following information is referred to in Questions 12 and 13.

The following reaction is allowed to come to equilibrium at 350°C.

$C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$; ΔH = +137 kJ mol^{-1}

Question 12 / 23

Which of the following will increase the yield of ethene, C_2H_4?

A.

Adding more hydrogen at constant pressure

B.

Increasing the overall pressure

C.

Lowering the temperature

D.

Removing hydrogen

Question 13 / 23

When the volume of the container is reduced

A.

there will be no change in the position of equilibrium.

B.

the equilibrium constant will decrease.

C.

more ethene, C_2H_4, and hydrogen will be produced.

D.

more ethane, C_2H_6, will be formed.

Question 14 / 23

When galvanic and electrolytic cells are compared

A.

the cathode is positive in galvanic cells but negative in electrolytic cells.

B.

the anode is positive in galvanic cells but negative in electrolytic cells.

C.

the cathode is negative in galvanic cells but positive in electrolytic cells.

D.

the anode is negative in both galvanic and electrolytic cells.

Question 15 / 23

The following information is referred to in Questions 16 and 17.

A student wishes to plate a steel rod with copper. The steel rod is one electrode, a copper rod is the second electrode and the electrolyte is a solution of copper(II) sulfate. A battery is used to provide the electrical energy.

Question 16 / 23

Which one of the following is correct?

A.

Steel rod is connected to battery at	**Reaction occurring at the steel rod is**
positive terminal	an oxidation

B.

positive terminal	a reduction

C.

negative terminal	an oxidation

D.

negative terminal	a reduction

Question 17 / 23

The mass of copper deposited on the steel rod is 0.247 g. If the current used in the experiment was 1.50 A, then the time, in seconds, needed for the experiment is closest to

---

A.

250

B.

500

C.

750

D.

1000

Question 18 / 23

A student passed 750 C of electricity through an aqueous solution of an ionic salt, MCl_n 0.81 g of metal, M, is deposited at the cathode. The metal and the value of *n* are most likely to be

---

A.

Metal, M	***n***
lead	2

B.

chromium	2

C.

palladium	2

D.

silver	1

Question 19 / 23

An important reaction in the production of nitric acid is the conversion of nitric oxide into nitrogen dioxide.

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$; $\Delta H = -114\ kJ\ mol^{-1}$

For each of the actions (a) and (b), indicate what effect it would have on (i) the equilibrium constant, *K*, and (ii) the yield of nitrogen dioxide.

Action	**(i) Effect on *K***	**(ii) Effect on yield of NO_2**
(a) Changing the temperature from 400°C to 450°C		
(b) Adding more oxygen at constant temperature and pressure		

(Total = 4 marks)

Question 20 / 23

Hydrogen iodide will decompose when heated according to the following reaction:

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

0.100 mol of hydrogen iodide was placed in a 1.00 L flask and heated to 350 K. When equilibrium had been established, 0.033 mol of HI remained.

(a) How many moles of HI have been reacted at equilibrium?

(1 mark)

(b) How many moles of H_2 have been formed at equilibrium?

(2 marks)

(c) Calculate the numerical value for the equilibrium constant for this reaction at 350 K.

(2 marks)

(Total = 5 marks)

Question 21 / 23

When steam and carbon monoxide are heated, the following reaction occurs

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$; $\Delta H = -40$ kJ mol^{-1}

For each of the actions mentioned in the table below, state how it would affect the

(a) yield of hydrogen.

(2 marks)

(b) equilibrium constant, *K*, for the reaction.

(2 marks)

(c) rate of reaction.

(2 marks)

Action	**(a) Yield of hydrogen**	**(b) *K***	**(c) Rate of reaction**
Increasing the pressure			
Increasing the temperature			

(Total = 6 marks)

Question 22 / 23

When methane is heated with steam at 650°C, the following reaction occurs

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$; $\Delta H = +220\ \text{kJ mol}^{-1}$

In one equilibrium mixture, the following concentrations were measured.

$[CH_4] = 0.15$ M, $[H_2O] = 3.25$ M, $[CO] = 1.05$ M, $[H_2] = 1.05$ M

(a) Write an expression for the equilibrium constant for this reaction.

(1 mark)

(b) Calculate a value for the equilibrium constant at 650°C.

(3 marks)

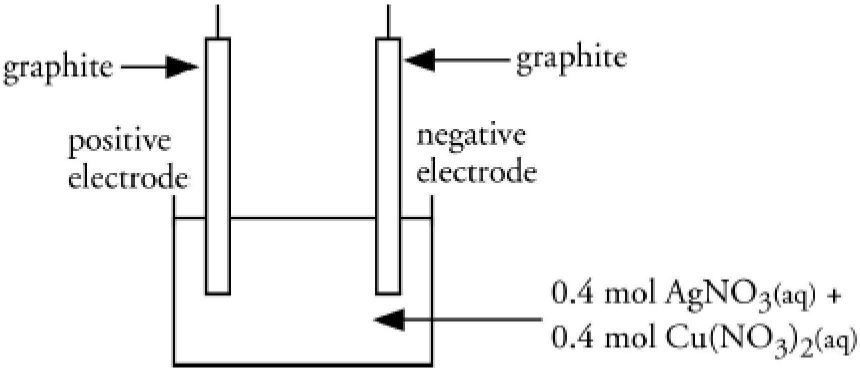
(c) How would you expect the value of the equilibrium constant at 400°C to differ from the value at 650°C? Give a reason for your answer.

(2 marks)

(Total = 6 marks)

Question 23 / 23

A student sets up the electrolysis cell shown below. Two graphite rods are placed in an aqueous solution that contains 0.40 mol of $AgNO_3$ and 0.40 mol of $Cu(NO_3)_2$.



(a) If a current of 9.65 A is passed through the cell for 8000 seconds, describe what will happen at the negative electrode.

(3 marks)

(b) For how much longer must the electrolysis be continued to completely deposit all of the two metals?

(2 marks)

(Total = 5 marks)

Total marks for test = 41 marks

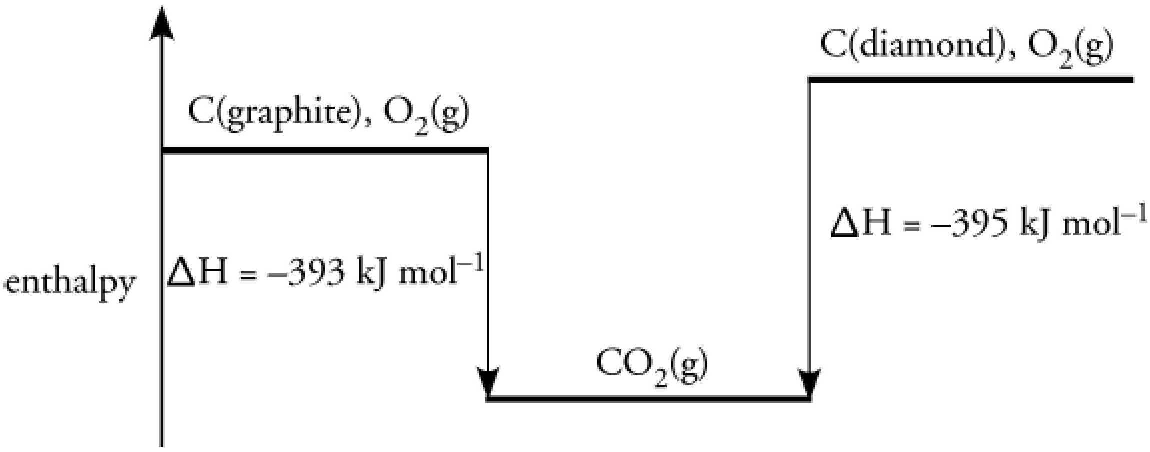
Question 1 / 23

[VCAA 2011 E2 SA Q7]
Consider the following combustion reactions for graphite and diamond.

C(graphite) + O_2(g) → CO_2(g); *ΔH* = −393 kJ mol^{-1}

C(diamond) + O_2(g) → CO_2(g); *ΔH* = −395 kJ mol^{-1}

The following diagram summarises this information.



From the data provided it can be determined that the enthalpy change, *ΔH*, for the conversion of graphite to diamond

C(graphite) → C(diamond) is

A.

−2 kJ mol^{-1}

B.

+2 kJ mol^{-1}

C.

−788 kJ mol^{-1}

D.

+788 kJ mol^{-1}

Question 2 / 23

VCAA 2011 E2 SA Q8]
What mass of butane (M = 58.0 g mol^{-1}) must undergo complete combustion to raise the temperature of 100.0 g of water by 1.00°C? Assume that there is no heat loss.

A.

8.44 g

B.

6.88 g

C.

0.399 g

D.

8.44×10^{-3} g

Question 3 / 23

[Adapted VCAA 2012 E2 SA Q2]
Which one of the following fuels is the most sustainable?

A.

biodiesel

B.

petrol

C.

coal

D.

natural gas

Question 4 / 23

Consider the enthalpy changes for the decomposition of two oxides of nitrogen.

$2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$ $\Delta H = -66$ kJ mol^{-1} (reaction 1)

$2NO(g) \rightarrow N_2(g) + O_2(g)$ $\Delta H = -180$ kJ mol^{-1} (reaction 2)

From this information, the enthalpy change for the reaction represented by the equation

$NO(g) + \frac{1}{2}O_2(g) \rightarrow NO_2(g)$ is

A.

−57 kJ mol^{-1}

B.

−114 kJ mol^{-1}

C.

−123 kJ mol^{-1}

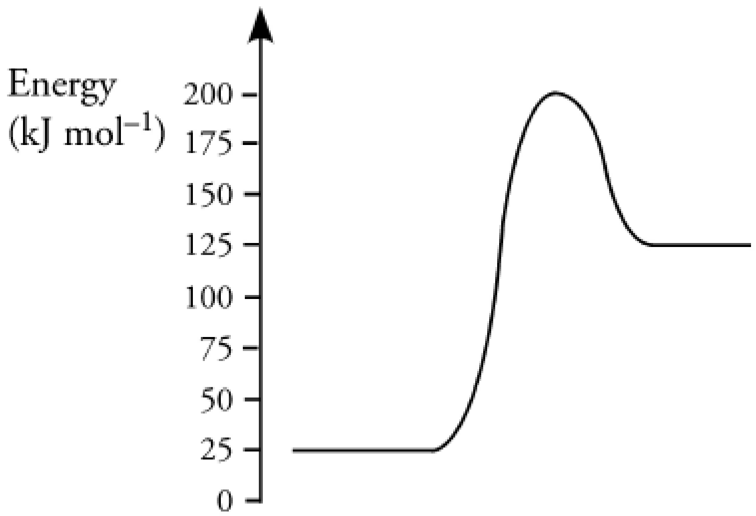
D.

−246 kJ mol^{-1}

Question 5 / 23

[Adapted VCAA 2012 E2 SA Q12]
Consider the following energy profile diagram for a reaction represented by the equation

X + Y → Z.



Which one of the following provides the correct values of the activation energy and enthalpy change for the reaction X + Y → Z?

A.

Activation energy (kJ mol^{-1})	**Enthalpy change (kJ mol^{-1})**
+75	+100

B.

+100	+175

C.

+175	+100

D.

+200	−125

Question 6 / 23

One methanol oxygen fuel cell uses 2.00×10^{-7} mol of methanol per second. The current (in mA) produced by this cell is

---

A.

3.22

B.

19.3

C.

77.2

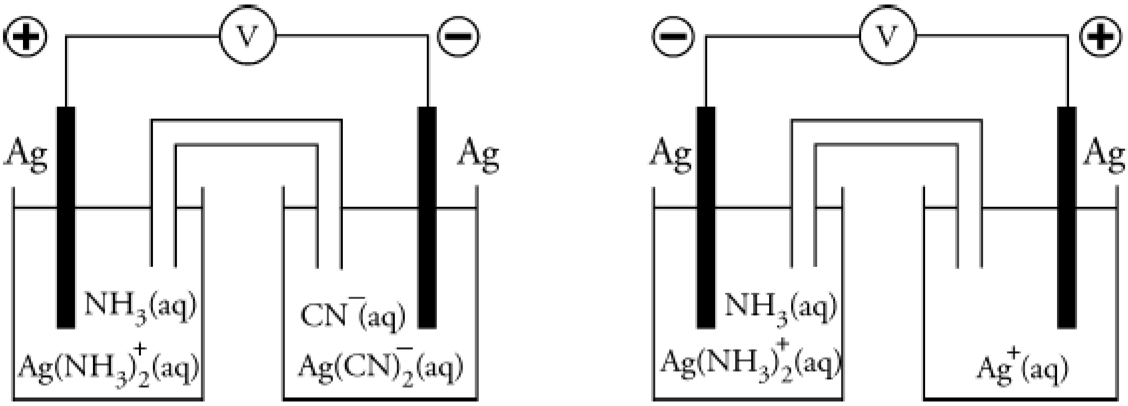
D.

116

Question 7 / 23

[VCAA 2011 E2 SA Q10]

Two galvanic cells were constructed under standard conditions in an experiment to determine the relative positions in the electrochemical series of the standard electrode potential, *E*°, for the following reactions. Both cells generate a potential difference.



$Ag(NH_3)_2^+(aq) + e^- \rightleftharpoons Ag(s) + 2NH_3(aq)$ $E°_1$

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $E°_2$

$Ag(CN)_2^-(aq) + e^- \rightleftharpoons Ag(s) + 2CN^-(aq)$ $E°_3$

The values of the electrode potentials in order from highest to lowest would be

---

A.

$E°_1$, $E°_2$, $E°_3$

B.

$E°_1$, $E°_3$, $E°_2$

C.

$E°_2$, $E°_1$, $E°_3$

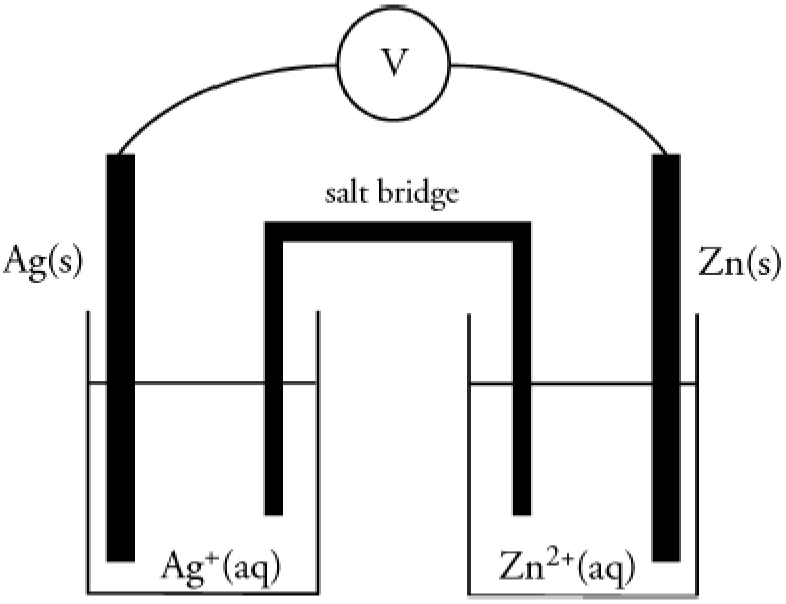
D.

$E°_3$, $E°_2$, $E°_1$

Question 8 / 23

Use the following information to answer Questions 9 to 11.

A galvanic cell set up under standard conditions is shown below.



Question 9 / 23

[Adapted VCAA 2012 E2 SA Q16]
Which one of the following is correct as the cell discharges?

A.

Electrons would flow from the	n the salt bridge
zinc electrode to the silver electrode.	anions migrate to the Ag^+/Ag half-cell.

B.

silver electrode to the zinc electrode.	cations migrate to the Zn^{2+}/Zn half-cell.

C.

silver electrode to the zinc electrode.	cations migrate to the Ag^+/Ag half-cell.

D.

zinc electrode to the silver electrode.	anions migrate to the Zn^{2+}/Zn half-cell.

Question 10 / 23

[VCAA 2012 E2 SA Q17]
In this cell

A.

$Ag^{+}(aq)$ is reduced and the Zn(s) is oxidised.

B.

Ag(s) is oxidised and the $Zn^{2+}(aq)$ is reduced.

C.

Ag(s) is reduced and the $Zn^{2+}(aq)$ is oxidised.

D.

$Ag^{+}(aq)$ is oxidised and the Zn(s) is reduced.

Question 11 / 23

[VCAA 2012 E2 SA Q18]
The cathode in this cell and the maximum voltage produced by this cell, under standard conditions, are respectively

---

A.

Ag and 0.16 V

B.

Ag and 1.56 V

C.

Zn and 0.16 V

D.

Zn and 1.56 V

Question 12 / 23

[VCAA 2017 SA Q18]
Ammonia, NH_3, can be produced by the reaction of hydrogen, H_2, and nitrogen, N_2. When this reaction takes place in a sealed container of fixed volume, an equilibrium system is established. The equation for the reaction is shown below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H = -92$ kJ mol^{-1}

If the pressure and volume remain constant when the temperature is increased, the forward reaction rate will

---

A.

increase and the $[NH_3]$ will increase.

B.

increase and the $[NH_3]$ will decrease.

C.

decrease and the $[NH_3]$ will decrease.

D.

decrease and the $[NH_3]$ will remain the same.

Question 13 / 23

[VCAA 2019 SA Q1]
An understanding of Le Chatelier's principle is useful in the chemical industry.

The prediction that can be made using this principle is the effect of

---

A. catalysts on the rate of reaction.

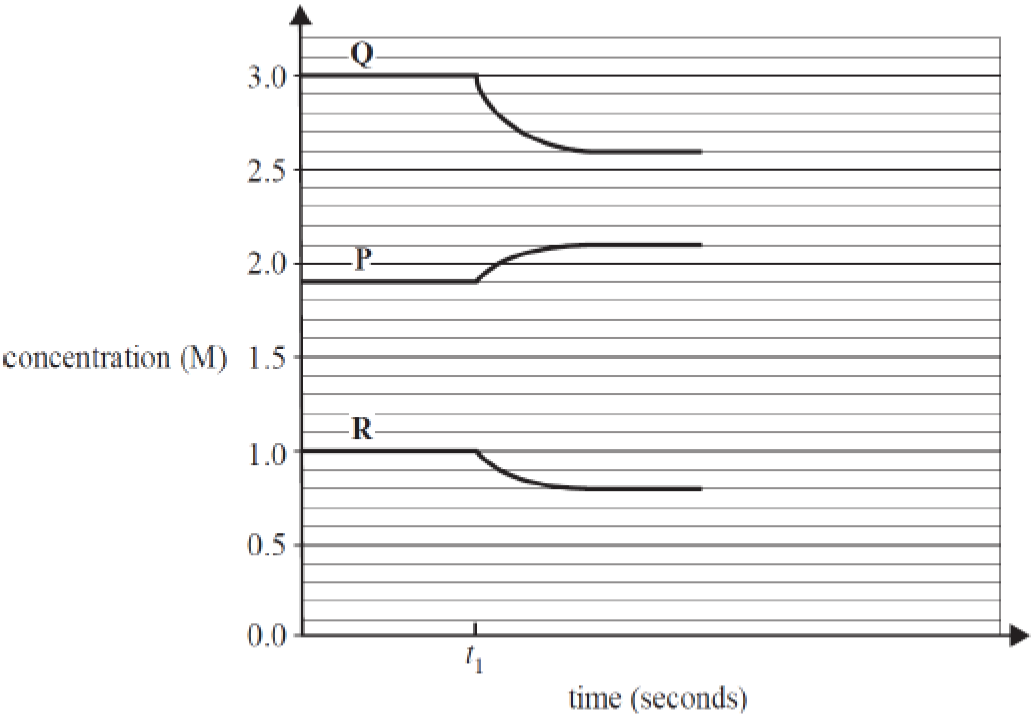
B. catalysts on the position of the equilibrium.

C. changes in temperature on the rate of reaction.

D. changes in the concentration of reactants on the position of the equilibrium.

Question 14 / 23

[VCAA 2019 SA Q25]
The following concentration–time graph refers to a mixture of three gases, P, Q and R, in an enclosed 5.0 L container. At time t_1 the mixture is heated.



The equilibrium system that represents the graph is

A.

P(g) $\rightleftharpoons$ 2Q(g) + R(g) and the forward reaction is exothermic.

B.

2Q(g) $\rightleftharpoons$ P(g) + R(g) and the forward reaction is endothermic.

C.

2Q(g) + R(g) $\rightleftharpoons$ P(g) and the forward reaction is exothermic.

D.

P(g) + 2Q(g) $\rightleftharpoons$ R(g) and the forward reaction is endothermic.

Question 15 / 23

Use the following information to answer Questions 16 and 17.

The magnitude of the equilibrium constant, *K*, at 25 °C for the following reaction is 640.

$N_2(g) + 3H_2(g) \rightleftharpoons NH_3(g)$ $\Delta H = -92.3$ kJ mol^{-1}

Question 16 / 23

[VCAA 2020 SA Q14]
For the reaction 13 $N_2(g) + H_2(g) \rightleftharpoons$ 23 $NH_3(g)$, the magnitude of *K* at 25 °C is

---

A.

9 and $\Delta H = -30.8$ kJ mol^{-1}

B.

213 and $\Delta H = -30.8$ kJ mol^{-1}

C.

640 and $\Delta H = -30.8$ kJ mol^{-1}

D.

640 and $\Delta H = -92.3$ kJ mol^{-1}

Question 17 / 23

[VCAA 2020 SA Q15]
For the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

A. a catalyst increases the number of collisions between the reactants.

B. the rate of the forward reaction increases when the temperature increases.

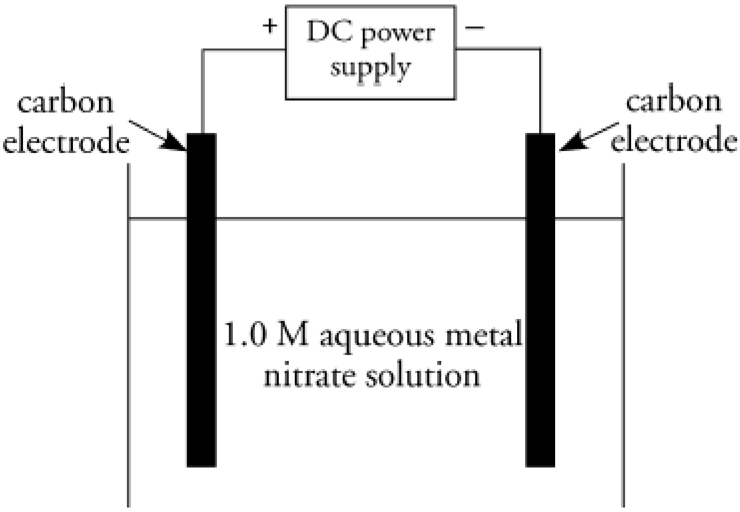
C. a catalyst reduces the activation energy of the forward and backward reactions by the same proportion.

D. the activation energy of the forward reaction is greater than the activation energy of the reverse reaction.

Question 18 / 23

[VCAA 2011 E2 SA Q18]

A series of electrolysis experiments is conducted using the apparatus shown below.



An electric charge of 0.030 faraday was passed through separate solutions of 1.0 M $Cr(NO_3)_3$, 1.0 M $Cu(NO_3)_2$ and 1.0 M $AgNO_3$. In each case the corresponding metal was deposited on the negative electrode. The amount, in mol, of each metal deposited is

---

A.

Amount, in mol, of chromium deposited	**Amount, in mol, of copper deposited**	**Amount, in mol, of silver deposited**
0.030	0.030	0.030

B.

0.010	0.015	0.030

C.

0.090	0.060	0.030

D.

0.030	0.020	0.010

Question 19 / 23

[VCAA 2011 E2 SA Q19]
An ornament was coated with a metal, M, by electrolysis of a solution of the metal ion, M^{x+}. During the electrolysis, a current of 1.50 amperes was applied for 180 seconds. The ornament was coated in 0.0014 mol of metal. The value of *x* in M^{x+} is

---

A.

1

B.

2

C.

3

D.

4

Question 20 / 23

Use the following information to answer Questions 21 to 23.

A solution contains an equilibrium mixture of two different cobalt(II) ions.

$Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons$	$CoCl_4^{2-}(aq) + 6H_2O(l)$
pnk	blue

The solution contains pink $Co(H_2O)_6^{2-}$ ions and blue $CoCl_4^{2-}$ ions, and the solution has a purple colour. 10 mL of the purple solution was poured into each of three test tubes labelled X, Y and Z.

Question 21 / 23

[VCAA 2015 SA Q19]
The test tubes were placed in separate water baths, each having a different temperature. The resulting colour changes in the equilibrium mixtures were observed. The results are shown in the following table.

Test tube	**Water bath temperature**	**Observation**
X	20°C	solution remained purple
Y	80°C	solution turned blue
Z	0°C	solution urned pink

Which one of the following conclusions can be drawn from these observations?

A. Cooling significantly reduced the volume of the solution and this favoured the forward reaction.

B. Heating caused some water to evaporate and this favoured the reverse reaction.

C. Heating increased the value of the equilibrium constant for the reaction.

D. The forward reaction must be exothermic.

Question 22 / 23

[VCAA 2015 SA Q20]
Which one of the following changes would cause 10 mL of the purple cobalt(II) ion solution to turn blue?

A. the addition of a few drops of 10 M hydrochloric acid at a constant temperature

B. the addition of a few drops of 0.1 M silver nitrate at a constant temperature

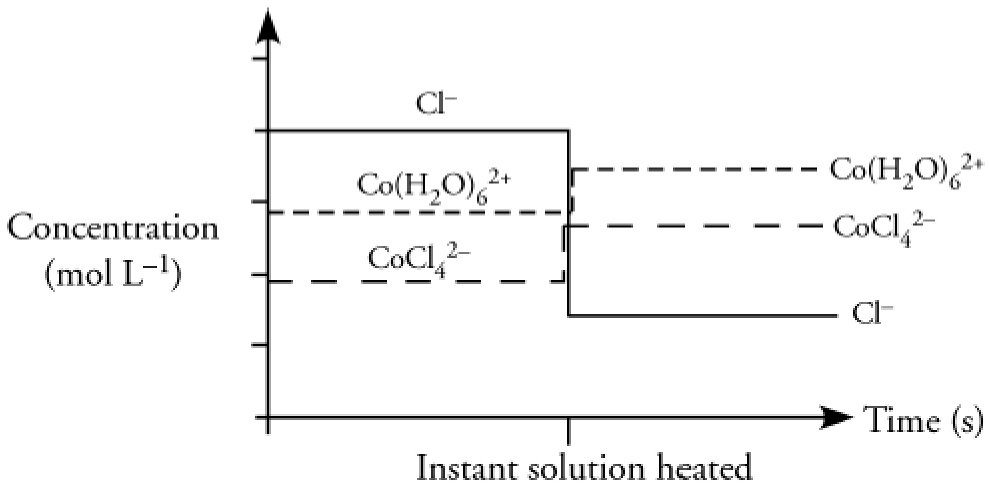
C. the addition of a few drops of a catalyst at a constant temperature

D. the addition of a few drops of water at a constant temperature

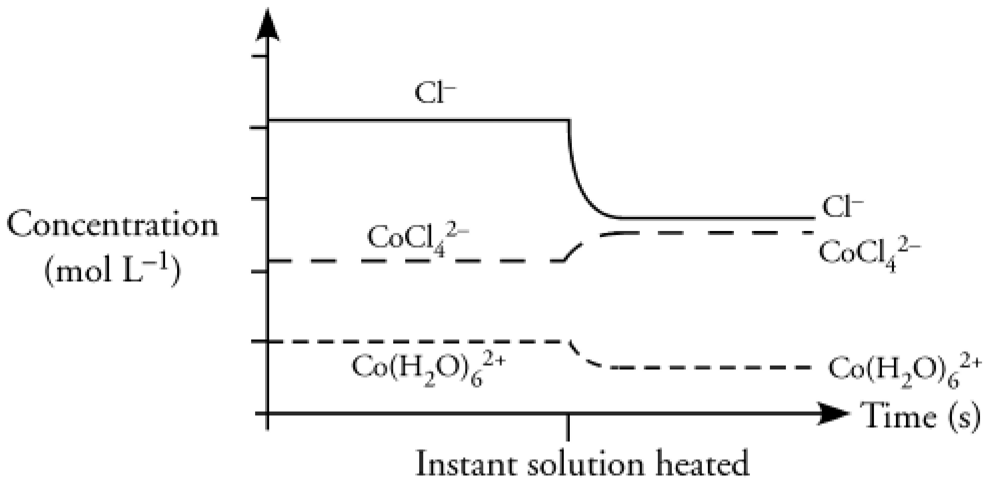
Question 23 / 23

[VCAA 2015 SA Q21]
When the equilibrium system was heated, the colour changed from purple to blue.
Which one of the concentration–time graphs below best represents this change?

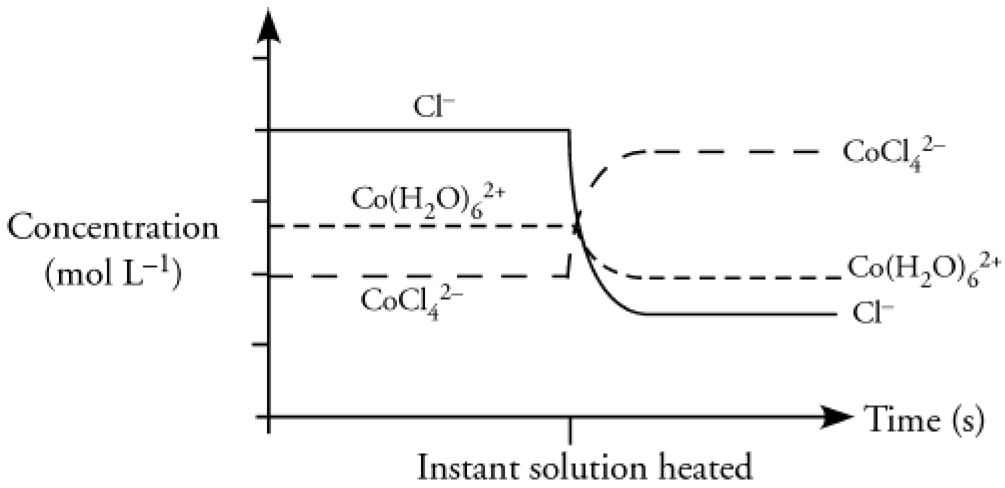
A.



B.

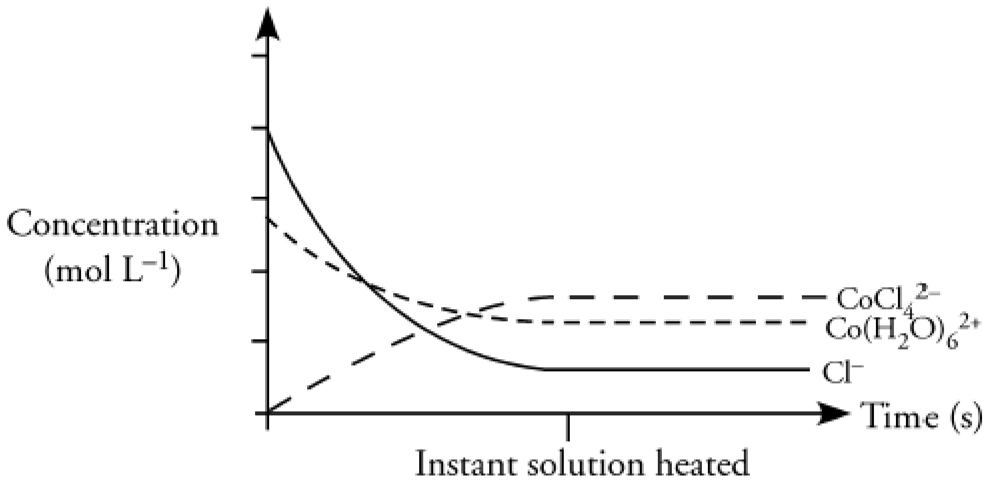


C.



Cl⁻
$CoCl_4^{2-}$
$Co(H_2O)_6^{2+}$
Concentration (mol L⁻¹)
$Co(H_2O)_6^{2+}$
$CoCl_4^{2-}$
Cl⁻
Time (s)
Instant solution heated

D.



Concentration (mol L⁻¹)
$CoCl_4^{2-}$
$Co(H_2O)_6^{2+}$
Cl⁻
Time (s)
Instant solution heated

Question 1 / 10

[VCAA 2012 E2 SB Q8]
Decisions about clean energy with reduced carbon dioxide emissions will have an impact on electricity generation from brown coal. However, there will be a much smaller impact on the use of black coal for electricity generation. The table below compares the energy and carbon content of three different coal samples.

	Percentage carbon* by mass	**Energy content (kJ g^{-1})**
Black coal	93	36.0
Brown coal (dried)	66	28.0
Brown coal (wet – as mined)	40	5.0

Coal is not a pure substance   and the composition of samples will vary even within one mine.

From the data in this table, it can be deduced that the complete combustion of 1 tonne of black coal will generate 3.6×10^7 kJ of energy.

(a)   (i) Calculate the mass, in tonne, of wet brown coal that is required to generate 3.6×10^7 kJ of energy.

(1 mark)

(ii) Calculate the mass, in tonne, of carbon dioxide that is produced from the complete combustion of this mass of wet brown coal.

(2 marks)

(b) What are the most likely reasons for the energy content of wet brown coal being so much lower than the energy content of dried brown coal? Justify your answer.

(2 marks)

(Total = 5 marks)

Question 2 / 10

A piece of jewellery was coated with gold by electrolysis in a cell containing an aqueous solution of gold ions. The electrolysis was carried out using a current of 5.25 A for 18.00 minutes. The volume of gold deposited was 0.200 mL.

(a) To which electrode of the electrolytic cell should the piece of jewellery be attached?

(1 mark)

(b) Given that the density of gold is 19.3 g mL^{-1}, what amount of gold, in mole, was deposited on the jewellery?

(2 marks)

(c) What number of electrons, in mole, was passed through the electrolytic cell?

(2 marks)

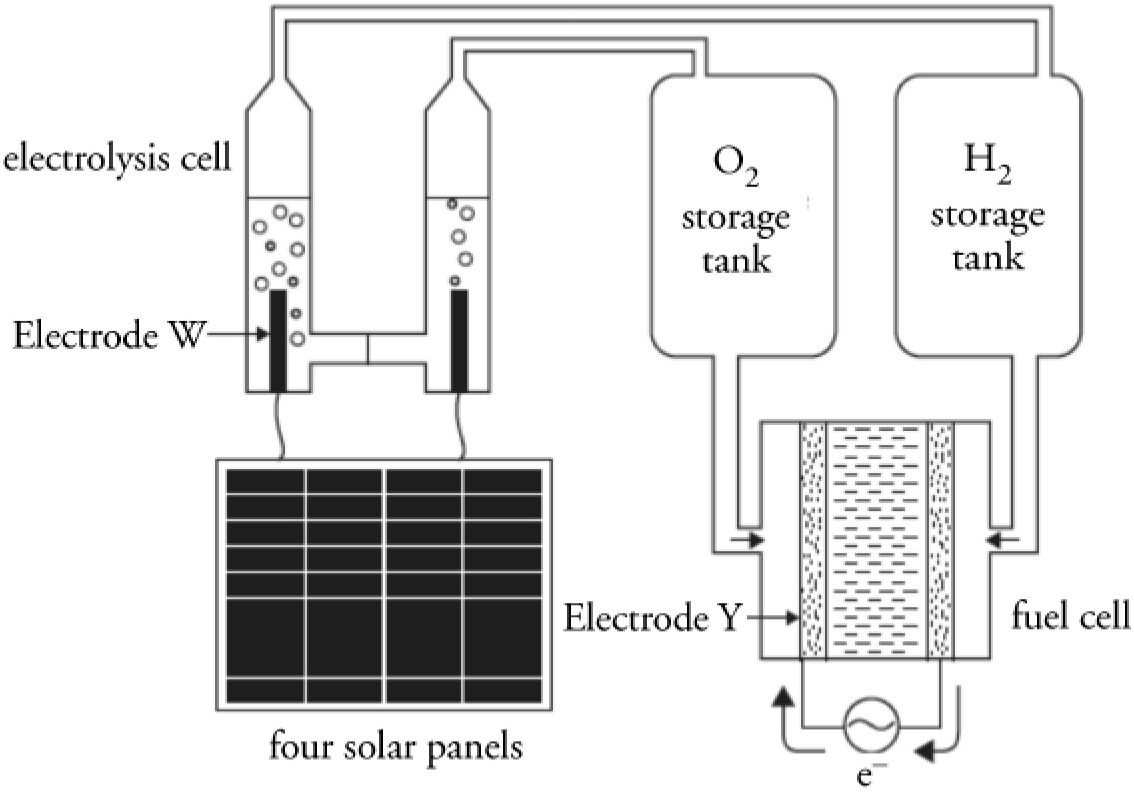
(d) Determine the charge on the gold ions in the solution used for the electrolysis.

(2 marks)

(Total = 7 marks)

Question 3 / 10

[Adapted VCAA 2018 SB Q8]
An energy company investigates the feasibility of supplying energy while reducing greenhouse gas emissions. Solar panels collect energy from the sun during daylight hours and this energy is used to electrolyse water, H_2O, to produce oxygen gas, O_2, and hydrogen gas, H_2. These gases are stored separately and then used in a fuel cell to produce energy when required. The diagram below shows a simplified representation of the set-up used.



(a) (i) State the polarity of Electrode W in the electrolysis cell.

(1 mark)

(ii) The fuel cell operates in an alkaline environment. Write the half-equation for the reaction that takes place at Electrode Y.

(1 mark)

(b) Each of the four solar panels produces an average current of 5.20 A and operates over an eight-hour period. The electrical energy generated is used by the electrolysis cell to produce O_2 and H_2. Calculate the amount, in moles, of H_2 produced by the electrolysis cell.

(3 marks)

(c) The fuel cell produces 3553 kJ when 20 mol of H_2 is consumed. Another possible energy source is a generator using petrodiesel as a fuel. The generator operates with an efficiency of 35%. A particular petrodiesel containing a range of hydrocarbons has been found to have a heat content of 45 kJ g^{-1}. The formula for this petrodiesel can be represented by $C_{12}H_{24}$ (M = 168 g mol^{-1}).

(i) Calculate the mass of petrodiesel required to produce 3553 kJ.

(2 marks)

(ii) Calculate the mass of CO_2(g) released when 3553 kJ of energy is produced from petrodiesel.

(2 marks)

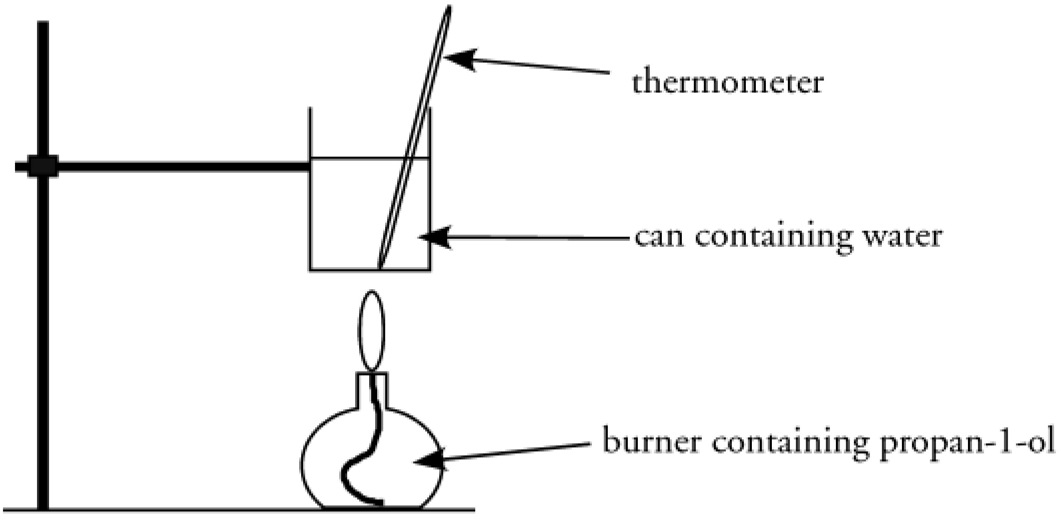
(iii) How would the mass of CO_2 produced from the combustion of this petrodiesel compare with the mass of CO_2 produced by the fuel cell?

(1 mark)

(Total = 10 marks)

Question 4 / 10

Propan-1-ol was used to heat water in a can as shown in the diagram below.



The results obtained from the experiment were:

Initial temperature of water in the can = 20.2°C

Mass of water in the can = 500 g

Mass of propan-1-ol burnt = 3.15 g

Final temperature of water = 53.1°C

(a) Write the equation for the complete combustion of propan-1-ol.

(1 mark)

(b) (i) From the results above, calculate the heat of combustion of propan-1-ol.

(3 marks)

(ii) What is ΔH for the equation given in part **(a)**?

(1 mark)

(c) The accepted value for the heat of combustion of propan-1-ol is 2021 kJ mol^{-1}. Calculate the percentage heat lost in the above experiment.

(1 mark)

(d) Calculate the expected temperature if no heat had been lost during the experiment.

(2 marks)

(e) Some of the expected heat energy is lost through incomplete combustion. Write an equation for the incomplete combustion of propan-1-ol.

(1 mark)

(Total = 9 marks)

Question 5 / 10

[VCAA 2012 E2 SB Q4]
In an experiment, 1.0 mol of pure phosgene, $COCl_2$, is placed in a 3.0 L flask where the following reaction takes place.

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $\quad K = 2.1 \times 10^{-8}$ M

(a) It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol. On the basis of the data provided, explain why this assumption is justified.

(2 marks)

(b) (i) Calculate the equilibrium concentration, in mol L^{-1}, of carbon monoxide, CO. Assume that the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol.

(3 marks)

(ii) What is the equilibrium concentration of chlorine gas?

(1 mark)

(Total = 6 marks)

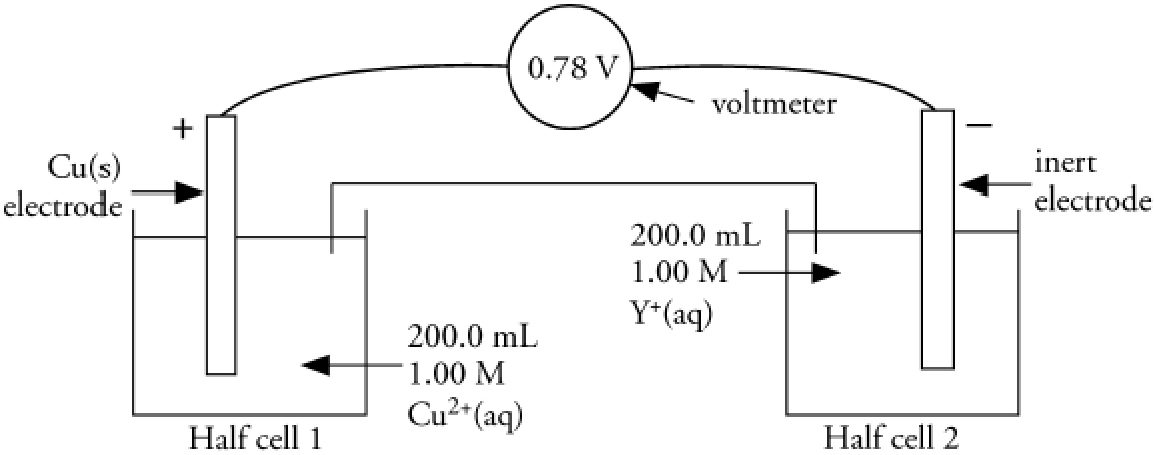
Question 6 / 10

A galvanic cell was constructed using the following two half-cells.

Half-cell 1: A copper electrode in 200 mL of 1.00 mol L^{-1} $Cu^{2+}(aq)$.

Half-cell 2: An inert electrode in 200 mL of 1.00 mol L^{-1} $Y^{+}(aq)$.

The cell is shown in the diagram below.



The cell is used to provide power to a device. After delivering 5790 C of electricity, the concentration of $Y^{+}(aq)$ in half-cell 2 was 0.850 mol L^{-1}. The initial voltmeter reading is shown. The volume of the liquids in the two half-cells was unchanged.

(a) Calculate the amount, in mol, of $Y^{+}(aq)$ that has reacted in half-cell 2.

(1 mark)

(b) Calculate the ratio of $n(e^{-})$ delivered to $n(Y^{+})$ reacted in this cell.

(2 marks)

(c) Determine the oxidation state of the product of the half-reaction in half-cell 2.

(1 mark)

(d) Write an equation for the half-reaction that occurred in half-cell 2.

(1 mark)

(e) Calculate the standard reduction potential for the species in half-cell 2.

(1 mark)

(Total = 6 marks)

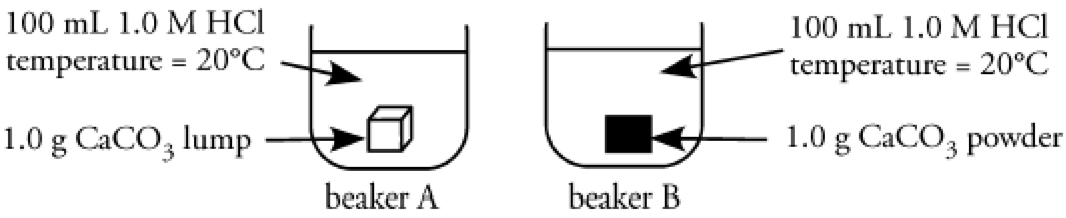
Question 7 / 10

[VCAA 2012 E2 SB Q1]
Two experiments were conducted to investigate various factors that affect the rate of reaction between calcium carbonate and dilute hydrochloric acid.

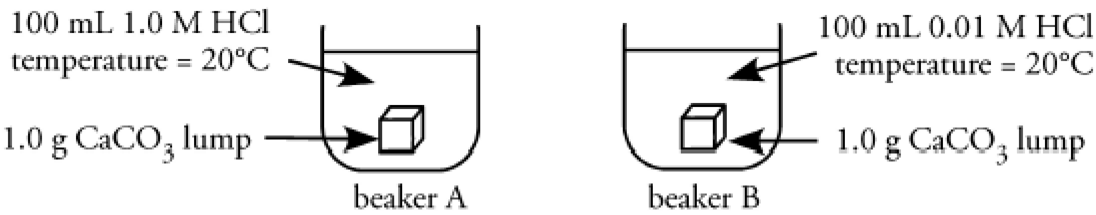
$CaCO_3(s) + 2HCl(aq) \rightleftharpoons CO_2(g) + CaCl_2(aq) + H_2O(l)$

The two experiments are summarised in the diagrams below.

Experiment 1



Experiment 2



(a) How could the rate of this reaction be measured in these experiments?

(1 mark)

(b) (i) Identify the rate determining factor that is investigated in experiment 1.

(1 mark)

(ii) In experiment 2, will the rate of reaction be faster in beaker A or beaker B? Explain your selection in terms of collision theory.

(2 marks)

(c) Why is the following statement incorrect?

'Collision theory states that all collisions between reactant particles will result in a chemical reaction.'

(2 marks)

(Total = 6 marks)

Question 8 / 10

[VCAA 2012 E2 SB Q2]

The reaction between 2-bromo-2-methylpropane and hydroxide ions occurs in two steps.

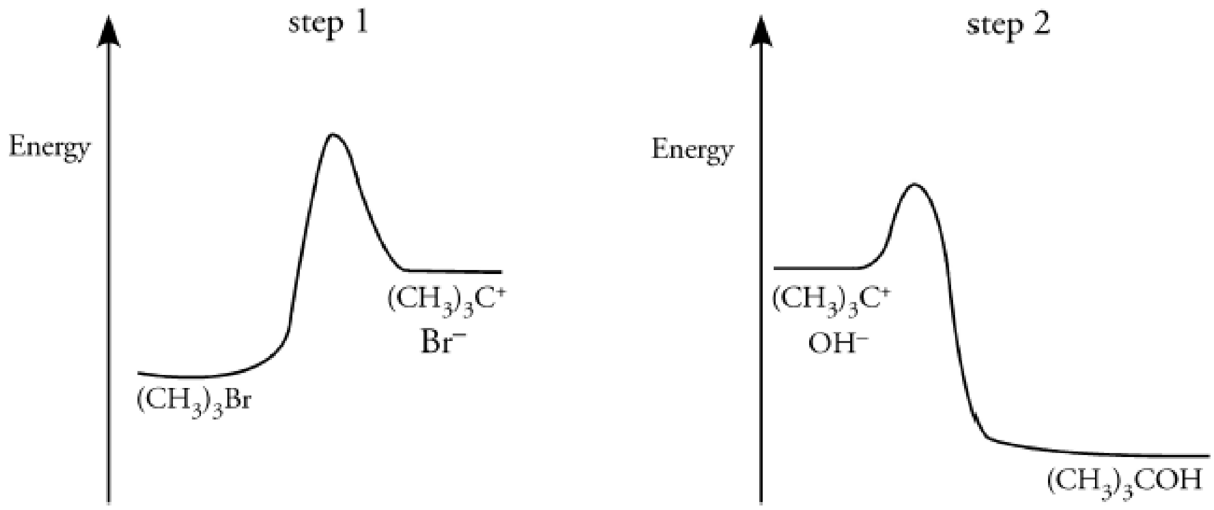
step 1: $(CH_3)_3CBr(aq) \rightarrow (CH_3)_3C^+(aq) + Br^-(aq)$

step 2: $(CH_3)_3C^+(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq)$

(a) Write an equation that represents the overall reaction between hydroxide ions and 2-bromo-2-methylpropane.

(1 mark)

The energy profile diagrams for step 1 and step 2 are shown below. Both are drawn to the same scale.



(b) (i) Which step involves an endothermic reaction? Provide a reason for your answer.

(1 mark)

The reaction at step 1 occurs at a different rate to the reaction at step 2.

(ii) Which step is slower? Justify your answer.

(2 marks)

(Total = 4 marks)

Question 9 / 10

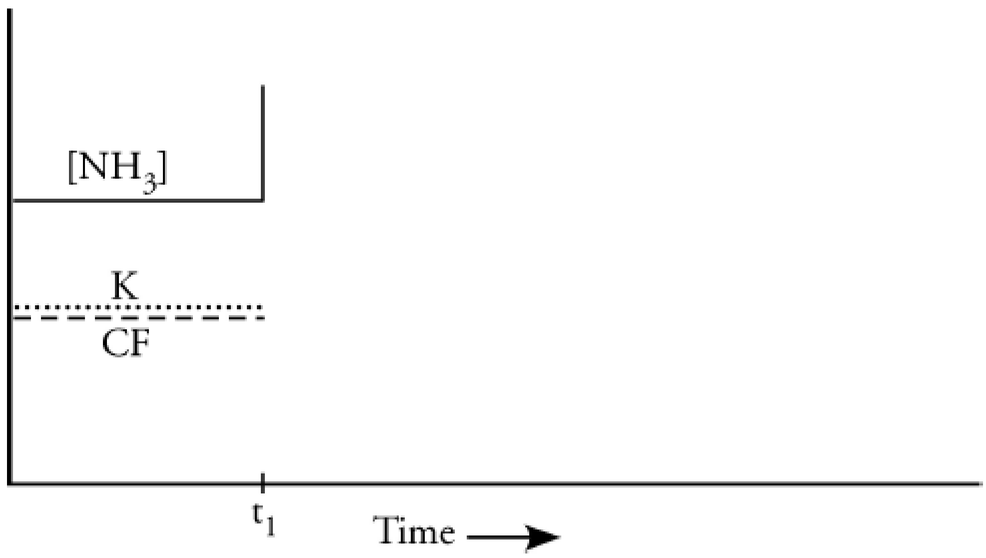
In the presence of a suitable catalyst, ammonia, NH_3, will decompose into nitrogen, N_2, and hydrogen, H_2, to reach equilibrium at a fixed temperature.

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

The graph below shows how the concentration of ammonia, the equilibrium constant, *K*, and the concentration fraction, CF, vary with time. At time t_1, the concentration of ammonia is suddenly increased, but the temperature remains constant.

(a) Complete the graph to show how these three factors will change to re-establish equilibrium.

(3 marks)



(b) Give explanations for your answers.

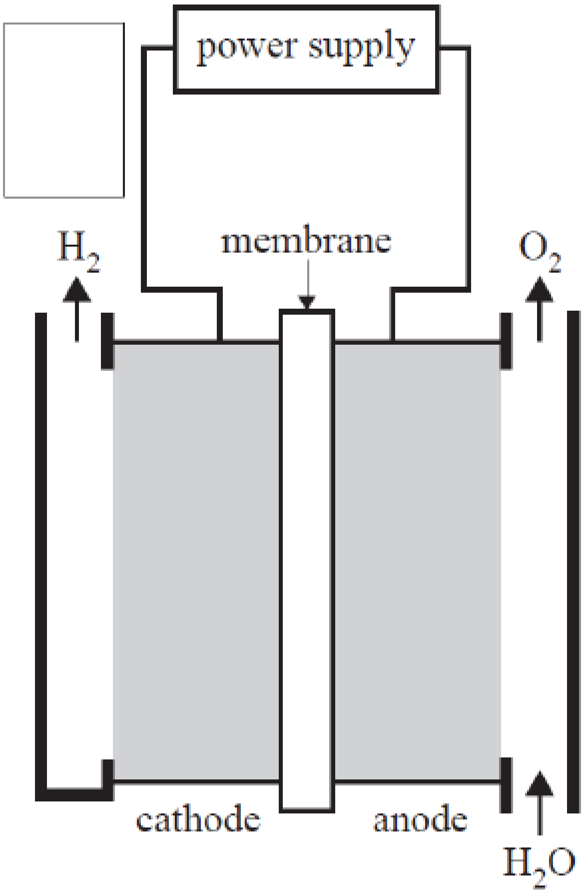
(2 marks)

(Total = 5 marks)

Question 10 / 10

[VCAA 2022 SB Q2]
A coal-fired power station is used to generate electricity. Carbon dioxide, CO_2, gas is produced as part of the process.

(a) Hydrogen, H_2, can be produced using electricity generated by renewable sources. A simplified diagram of an acidic electrolyser used to produce hydrogen is shown below.



(i) Draw an arrow in the box provided on the diagram above to show the direction of flow of electrons through the wire. Justify your answer.

(2 marks)

(ii) State two functions of the membrane.

(2 marks)

(b) (i) Write the overall equation for the reaction that takes place in the acidic electrolyser shown in the diagram above when it is operating at 80 °C.

(1 mark)

(ii) How many moles of H_2 could be produced by the acidic electrolyser using 1625.0 A in 1.25 hours, assuming 100% efficiency?

(3 marks)

(Total = 8 marks)

Question 1 / 35

Which of the following pairs of compounds are **not** isomers?

A.

$CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_3$

B.

CH_3OCH_3 and CH_3CH_2OH

C.

CH_3CHCl_2 and CH_2ClCH_2Cl

D.

$CH_3CH_2CH_3$ and $CH_3CH_2CH_2CH_3$

Question 2 / 35

A compound has the molecular formula C_3H_9X. The atom X is most likely to be

---

A.

chlorine.

B.

hydrogen.

C.

nitrogen.

D.

oxygen.

Question 3 / 35

A substance is in the same homologous series as chloroethane, CH_3CH_2Cl, is

---

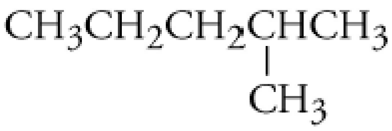
A. CH_3CHCl_2

B. CH_2Cl_2

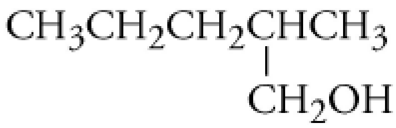
C. CH_3CH_2OH

D. $CH_3CH_2CH_2Cl$

Question 4 / 35



compound 1



compound 2

The two compounds shown above are correctly named as

A.

Compound 1	***Compound 2***
2-methylpentane	2-methylpentan-1-ol

B.

2-methylpentane	1-hydroxy-2-methylpentane

C.

hexane	2-hexanol

D.

2-methylhexane	1-hexanol

Question 5 / 35

A hydrocarbon has the molecular formula C_6H_{10}. If its structure does **not** contain any rings, how many carbon-to-carbon double bonds must be present?

A.

0

B.

1

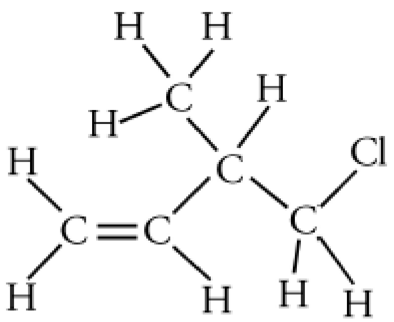
C.

2

D.

3

Question 6 / 35



The correct name for this compound is

A.

4-chloro-3-methylbut-1-ene.

B.

1-chloro-2-methylbut-3-ene.

C.

4-chloropent-1-ene.

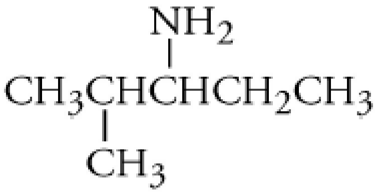
D.

1-chloro-2-methylbutene.

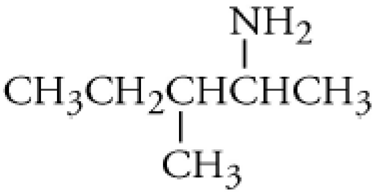
Question 7 / 35

The compound 3-methylpentan-2-amine has the structure

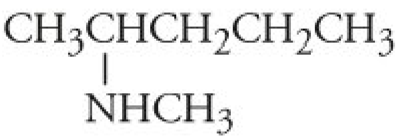
A.



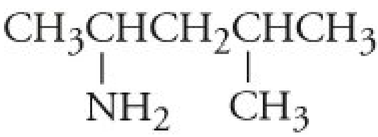
B.



C.



D.



Question 8 / 35

The number of chloroalkene isomers with the molecular formula C_3H_5Cl is

---

A. 1

B. 2

C. 3

D. 4

Question 9 / 35

A compound has the empirical formula CH_2Cl. What is a possible name for this compound?

A.

chloroethene

B.

1,2-dichloroethene

C.

1,2-dichloroethane

D.

chloroethane

Question 10 / 35

The ketone, butan-2-one, has the semi-structural formula $CH_3COCH_2CH_3$. An isomer of this compound is most likely to be

---

A.

another ketone.

B.

an aldehyde.

C.

a carboxylic acid.

D.

an ester.

Question 11 / 35

[VCAA 2011 E1 SB Q4]
The compound that is **not** an isomer of 2,2,4-trimethylpentane is

---

A.

octane.

B.

3-ethylhexane.

C.

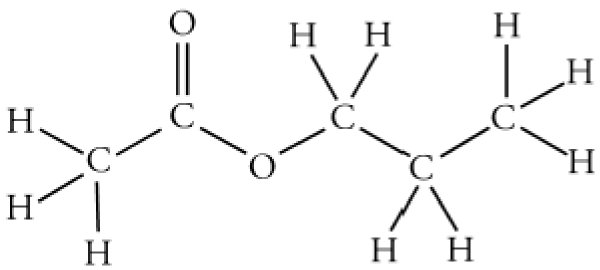
2,4-dimethylpentane.

D.

2,4-dimethylhexane.

Question 12 / 35

[VCAA 2013 SB Q9]



The systematic IUPAC name for the molecule shown above is

A.

ethyl ethanoate.

B.

ethyl propanoate.

C.

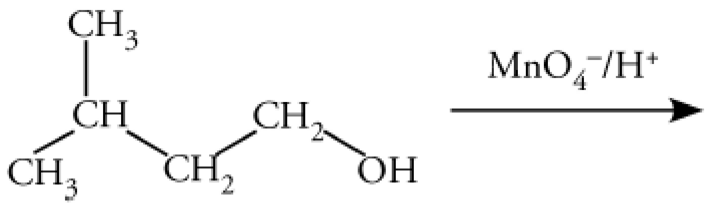
propyl ethanoate.

D.

methyl propanoate.

Question 13 / 35

[VCAA 2014 SA Q19]



What is the systematic name for the product of the reaction above?

A.

2-methylpentanoic acid

B.

4-methylpentanoic acid

C.

2-methylbutanoic acid

D.

3-methylbutanoic acid

Question 14 / 35

[VCAA 2015 SA Q13]
What is the name of the product formed when chlorine, Cl_2, reacts with but-1-ene?

A.

1,2-dichlorobutane

B.

1,4-dichlorobutane

C.

2,2-dichlorobutane

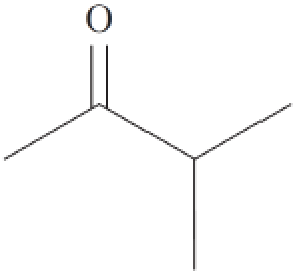
D.

2,3-dichlorobutane

Question 15 / 35

[VCAA 2019 SA Q3]

A compound has the following skeletal formula.



The molar mass of the compound is

A. 71 g mol^{-1}

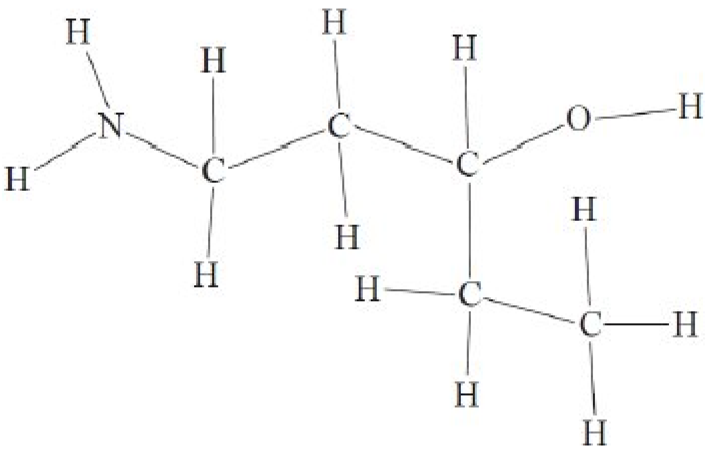
B. 74 g mol^{-1}

C. 85 g mol^{-1}

D. 86 g mol^{-1}

Question 16 / 35

[VCAA 2020 SA Q4]



What is the IUPAC name of the molecule shown above?

A. 3-hydroxy-3-ethyl-propan-1-amine

B. 3-amino-l-methylpropan-1-ol

C. 3-hydroxypentan-1-amine

D. l-aminopentan-3-ol

Question 17 / 35

[VCAA 2020 SA Q7]
How many structural isomers have the molecular formula C_3H_6BrCl?

A. 4

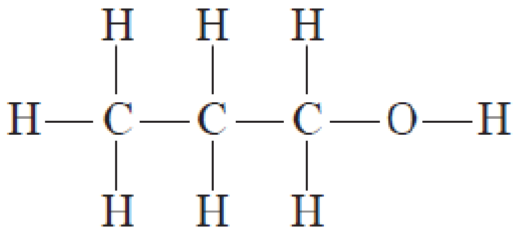
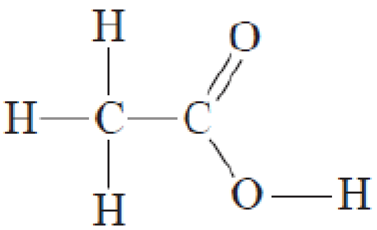
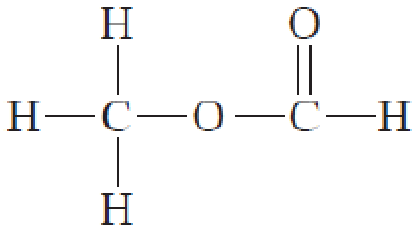
B. 5

C. 6

D. 7

Question 18 / 35

[VCAA 2020 SA Q16]
The following table provides information about three organic compounds, X, Y and Z.

Compound	**Structural formula**	**Molar mass (g mol^{-1})**	**Boiling point (°C)**
X		60	97
Y		60	118
Z		60	?

Which one of the following is the best estimate for the boiling point of Compound Z?

A. 31 °C

B. 101 °C

C. 114 °C

D. 156 °C

Question 19 / 35

[VCAA 2022 SA Q16]
The correct IUPAC name for $CH_3CH_2CHClCHOHCH_3$ is

A. 3-chloropentan-4-ol

B. 3-chloropentan-2-ol

C. 2,3-chloro-pentanol

D. 3,2-chloro-pentanol

Question 20 / 35

1 mol of propane, C_3H_8, is mixed with 8 mol of oxygen. The mixture is ignited so that complete combustion occurs. The number of mole of oxygen remaining will be

---

A.

1.0

B.

3.0

C.

5.0

D.

7.0

Question 21 / 35

Propene, C_3H_6, undergoes an addition reaction with bromine, Br_2. The molecular formula of the product is $C_3H_6Br_2$. The semi-structural formula of this product is

---

A.

$CH_3CHBrCH_2Br$

B.

$CH_3CH_2CHBr_2$

C.

$CH_3CBr_2CH_3$

D.

$BrCH_2CH_2CH_2Br$

Question 22 / 35

Polyenes are organic molecules that contain more than one carbon-to-carbon double bond. A particular polyene undergoes an addition reaction with bromine. The empirical formula of the product is $C_3H_5Br_2$. The molecular formula of the polyene is most likely to be

---

A.

C_3H_4

B.

C_3H_5

C.

C_6H_8

D.

C_6H_{10}

Question 23 / 35

1-butene and 2-butene are isomers and have the molecular formula C_4H_8. If both compounds are hydrogenated, in an addition reaction with hydrogen, in separate reactions, the products will

---

A.

have the same formula and be isomers.

B.

be the same compound.

C.

differ in formula by CH_2 but be in the same homologous series.

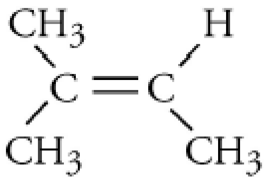
D.

be alcohols.

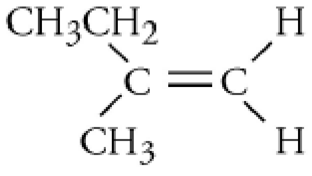
Question 24 / 35

An alkene has the molecular formula C_5H_{10}. When it is reacted with hydrogen in the presence of a catalyst, 2-methylbutane is formed. Which one of the structures below could **NOT** be that of the alkene?

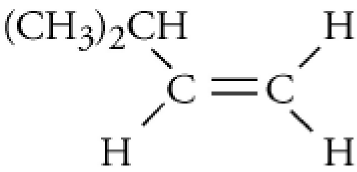
A.



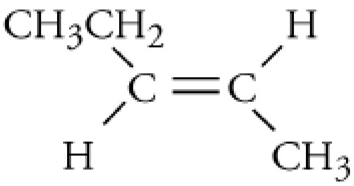
B.



C.



D.



Question 25 / 35

Consider the following reactions

$CH_3CH_2CH_2CH_3 \rightarrow CH_4 + X$;   followed by

$X + H_2O \rightarrow Y$;   X and Y would be represented by

A.

X	**Y**
$CH_3CH_2CH{=}CH_2$	$CH_3CH_2CH_2CH_2OH$

B.

$CH_3CH_2CH_3$	$CH_3CH(OH)CH_3$

C.

$CH_3CH{=}CH_2$	CH_3CH_2COOH

D.

$CH_3CH{=}CH_2$	$CH_3CH(OH)CH_3$

Question 26 / 35

The flow chart below refers to the preparation of ethyl ethanoate and is referred to in Questions 27 and 28.

$$\boxed{\text{ethane}} \xrightarrow{\text{step 1}} \boxed{\text{chloroethane}} \xrightarrow{\text{step 2}} \boxed{\text{ethanol}} \xrightarrow{\text{step 3}} \boxed{\text{ethanoic acid}} \xrightarrow{\text{step 4}} \boxed{\text{ethyl ethanoate}}$$

Question 27 / 35

Step 4 is best described as

A.

oxidation.

B.

hydrogenation.

C.

condensation.

D.

addition.

Question 28 / 35

A substitution reaction occurs in

A.

step 1 only.

B.

steps 1 and 2.

C.

step 2 only.

D.

step 3 only.

Question 29 / 35

If the desired product in each case is the organic compound, which one of the reactions below has the lowest atom economy?

A.

$CH_3I + NaOH \rightarrow CH_3OH + NaI$

B.

$C_2H_5I + NaOH \rightarrow C_2H_5OH + NaI$

C.

$CH_3Br + NaOH \rightarrow CH_3OH + NaBr$

D.

$C_2H_5Br + NaOH \rightarrow C_2H_5OH + NaBr$

Question 30 / 35

When 1.50 g of propan-1-ol is heated with an excess of acidified potassium dichromate oxidation of the alcohol occurs. After removal of the other oxidation products, 0.78 g of pure propanoic acid is obtained. The percentage yield of propanoic acid is closest to

---

A.

42%

B.

44%

C.

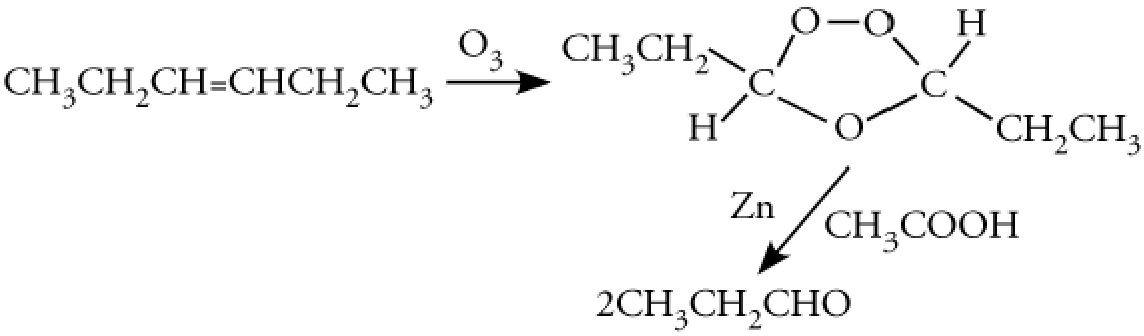
52%

D.

64%

Question 31 / 35

Hex-3-ene can be converted into CH_3CH_2CHO in a two-step process as shown below.



If the percentage yield for the overall process is 80.0%, what mass of propanal, CH_3CH_2CHO, will be obtained from 2.00 g of hex-3-ene?

A.

1.10 g

B.

1.60 g

C.

2.21 g

D.

2.76 g

Question 32 / 35

A student performs two tests on an organic compound. In the first test, 3 mol of the compound was completely reacted with oxygen and 6 mol of carbon dioxide were produced. In the second test, a few drops of bromine were added to the compound. The compound did **not** react rapidly with bromine. The formula of the compound is likely to be

---

A. C_2H_4

B. C_2H_6

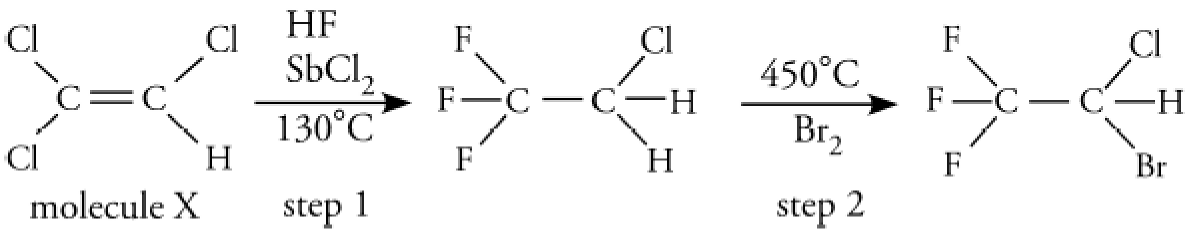
C. C_3H_8

D. C_6H_{14}

Question 33 / 35

[VCAA 2011 E1 SA Q7]

Halothane is a general anaesthetic. The following diagram represents the reaction pathway that produces halothane.



Which one of the following answers correctly identifies the type of reaction occurring in step 2 and correctly states the systematic name of molecule X?

A.

Type of reaction in step 2	**Systematic name of molecule X**
substitution	1,2,2-trichloroethane

B.

addition	1,1,2-trichloroethane

C.

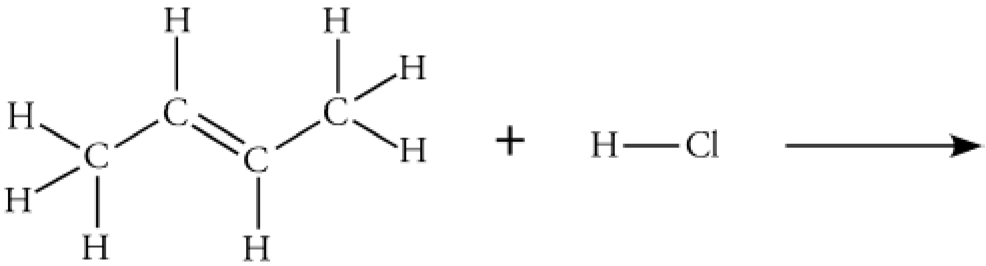
substitution	1,1,2-trichloroethene

D.

addition	1,2,2-trichloroethene

Question 34 / 35

[VCAA 2013 SA Q10]



The systematic IUPAC name for the product of the above chemical reaction is

---

A.

1-chlorobutane.

B.

2-chlorobutane.

C.

3-chlorobutane.

D.

4-chlorobutane.

Question 35 / 35

[VCAA 2022 SA Q27]
Which one of the following reactions has the highest atom economy in the production of an organic molecule?

A. complete combustion of propyne, C_3H_4

B. reaction of iodine, I_2, with propane, C_3H_8

C. reaction of bromine, Br_2, and propene, C_3H_6

D. formation of a dipeptide from alanine, $C_3H_7NO_2$

Question 1 / 11

Draw structural formulas for the following compounds.

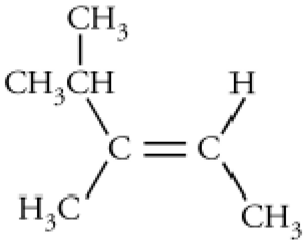
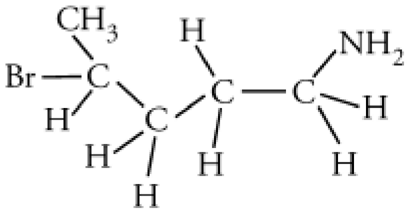
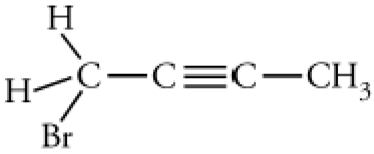
(a) 2,3-dimethylbutan-1-amine

(b) 2,2-dimethylhex-3-yne

(2 marks)

Question 2 / 11

Give the name for each of the structures shown below.

<table>
<tr><td>(a)</td><td></td><td>(b)</td><td></td></tr>
<tr><td>(c)</td><td></td><td></td><td></td></tr>
</table>

(3 marks)

Question 3 / 11

There are a number of alcohols with the formula $C_4H_{10}O$.

(a) Draw semi-structural formulae of four of these alcohols and give their names.

(4 marks)

(b) Can any of these alcohols exist as optical isomers? Explain your answer.

(1 mark)

(c) (i) Draw the semi-structural formula of one compound that is isomeric with these alcohols but contains a different functional group.

(1 mark)

(ii) The boiling temperatures of the four alcohols are in the range 80° to 120°C and their flash points range from +11°C to +30°C. How would you expect the boiling temperature and flash point of the isomer you drew in part **(i)** to compare with these values for the alcohols? Give a reason for your answer.

(2 marks)

(d) Four of the five alcohols are readily oxidised by acidified potassium permanganate solution.

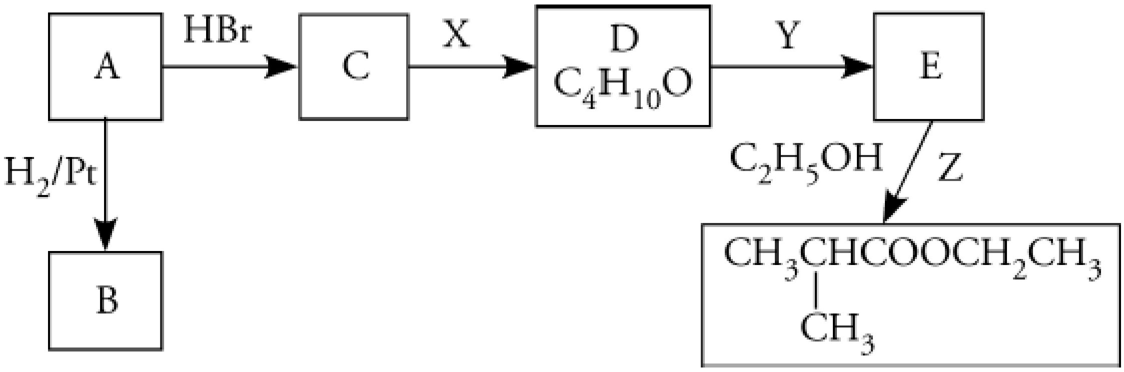
For each of these reactions, draw the semi-structural formula of the product.

(3 marks)

(Total = 11 marks)

Question 4 / 11

The flow chart below shows a sequence of reactions used to convert an alkene, A, into the ester, $CH_3CH(CH_3)COOCH_2CH_3$.



(a) Deduce the structures of the compounds A to E.

(5 marks)

(b) Give the formulae for the reagents labelled 'X', 'Y' and 'Z'.

(3 marks)

(c) Draw the structure of an isomer of A.

(1 mark)

(d) Name the type of reaction used to convert

(i) A to C (ii) C to D.

(2 marks)

(Total = 11 marks)

Question 5 / 11

A compound of carbon, hydrogen and oxygen is found by analysis to contain 40.91% carbon and 4.55% hydrogen.

(a) Deduce the empirical formula of the compound.

(3 marks)

The compound is a carboxylic acid but the molar ratio for reaction with sodium hydroxide is not known. 0.262 g of the compound reacts with 17.86 mL of 0.250 M sodium hydroxide.

(b) How many moles of sodium hydroxide was used?

(1 mark)

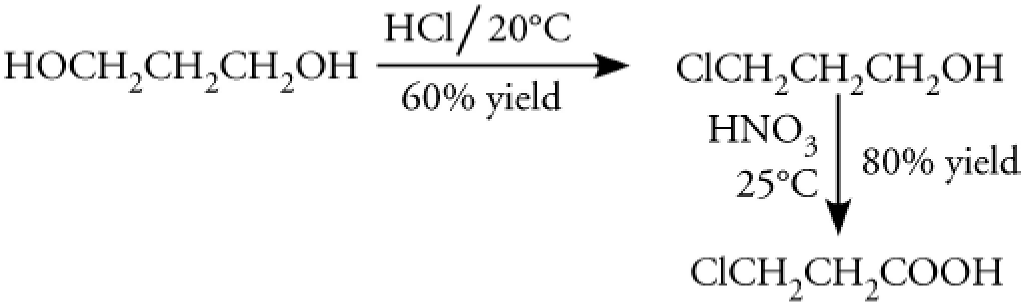
(c) Deduce a possible molecular formula for the compound and give a possible structure.

(4 marks)

(Total = 8 marks)

Question 6 / 11

1,3-dihydroxypropane can be converted into 3-chloropropanoic acid in a two-step process as shown below.



(a) 2.50 g of 1,3-propanediol is reacted in the sequence shown above. Calculate the mass of 3-chloropropanoic acid produced.

(2 marks)

The balanced equation for the second step is

$ClC_2H_4CH_2OH + 4HNO_3 \rightarrow ClC_2H_4CO_2H + 4NO_2 + 3H_2O$

(b) Calculate the atom economy for this reaction.

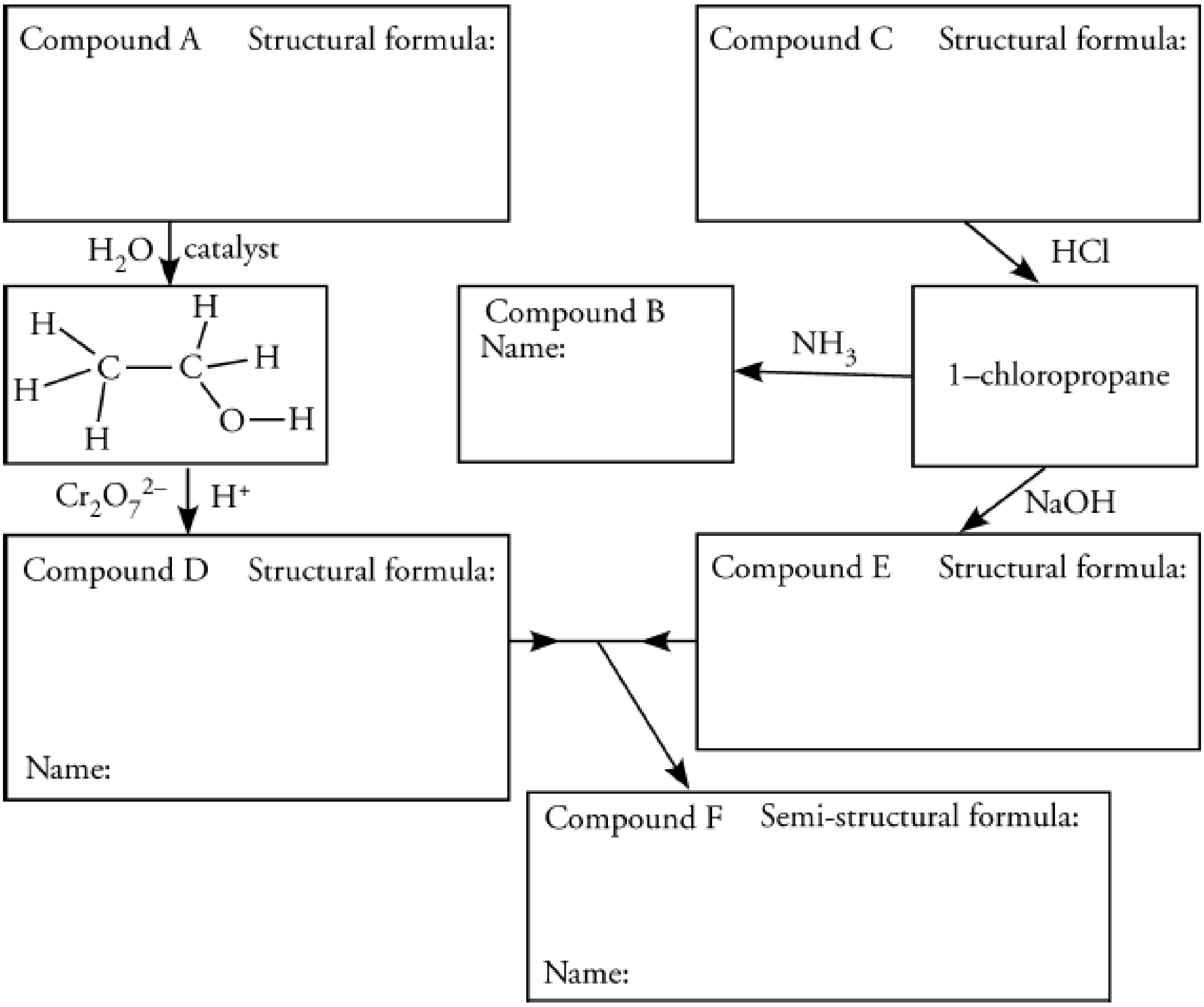
(2 marks)

(Total = 4 marks)

Question 7 / 11

[VCAA 2014 SB Q2]

Compounds B and F may be synthesised as follows.



(a) Draw the structural formulas of Compounds A, C, D and E in the boxes provided.

(4 marks)

(b) Write the systematic **names** of Compounds B and D in the appropriate boxes.

(2 marks)

(c) Insert the semi-structural formula and systematic name of Compound F in the box provided.

(2 marks)

(Total = 8 marks)

Question 8 / 11

[Adapted VCAA 2018 SB Q1]
Organic compounds are numerous and diverse due to the nature of the carbon atom. There are international conventions for the naming and representation of organic compounds.

(a) (i) Draw the structural formula of 2-methylpropan-2-ol.

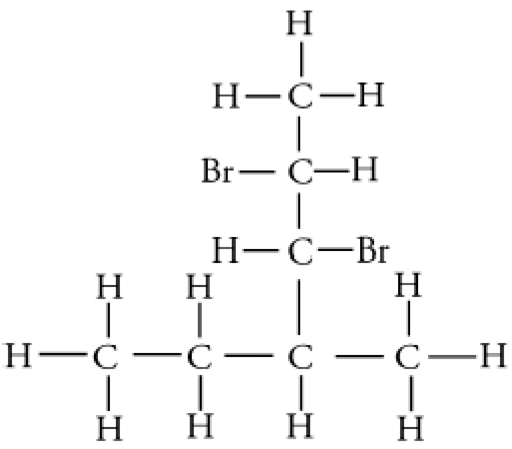
(1 mark)

(ii) Give the molecular formula of but-2-yne.

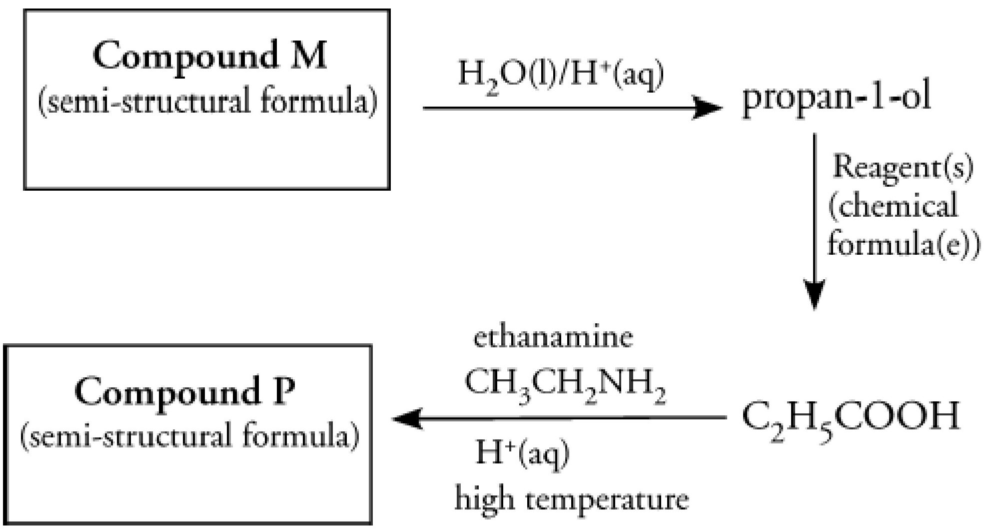
(1 mark)

(iii) Give the IUPAC name of the compound that has the structural formula shown below.

(1 mark)



(b) The following diagram represents a reaction pathway for the synthesis of Compound P.



(i) Identify the starting substance, Compound M, by writing its semi-structural formula.

(1 mark)

(ii) Identify the reagent(s) needed to convert propan-1-ol to propanoic acid, C_2H_5COOH, by writing the chemical formula(e) of the reagent(s).

(1 mark)

(iii) When C_2H_5COOH is mixed with ethanamine, $CH_3CH_2NH_2$, in an acidified high-temperature environment, Compound P is formed.

Write the semi-structural formula of Compound P.

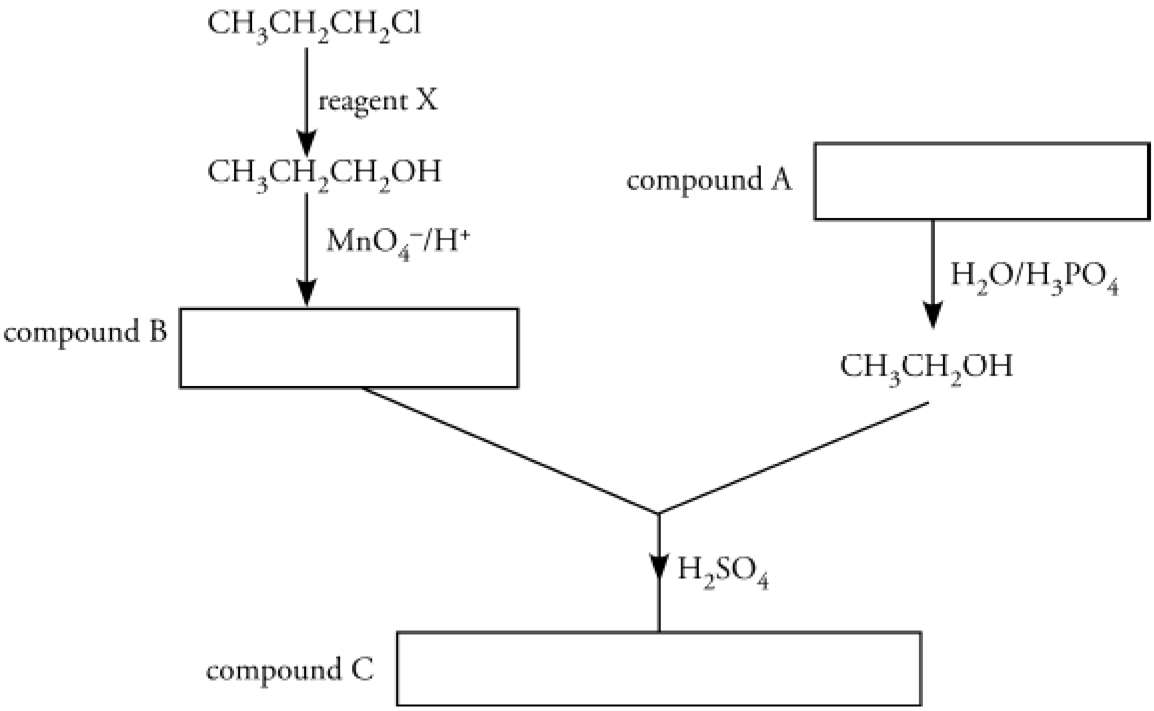
(1 mark)

(Total = 6 marks)

Question 9 / 11

[VCAA 2013 SB Q6]

The reaction pathway shown below represents the synthesis of compound C.



(a) Identify reagent X.

(1 mark)

(b) In the appropriate boxes above, write the semi-structural formulae for compounds A, B and C.

(3 marks)

(c) Give the systematic IUPAC names for compounds A and B.

(2 marks)

(d) Sketch the energy profile for the complete combustion of compound C, labelling the energy of the reactants, the products and the activation energy.

(1 mark)

(Total = 7 marks)

Question 10 / 11

[VCAA 2017 SB Q1]

Industrially, ethanol, C_2H_5OH, is made by either of two methods. One method uses ethene, C_2H_4, which is derived from crude oil. The other method uses a sugar, such as sucrose, $C_{12}H_{22}O_{11}$, and yeast, in aqueous solution. The production of C_2H_5OH from $C_{12}H_{22}O_{11}$ and yeast proceeds according to the equation

$C_{12}H_{22}O_{11}(aq) + H_2O(l) \rightarrow 4C_2H_5OH(aq) + 4CO_2(g)$

(a) Determine the mass, in grams, of pure C_2H_5OH that would be produced from 1.250 kg of $C_{12}H_{22}O_{11}$ dissolved in water. $M(C_{12}H_{22}O_{11})$ = 342 g mol^{-1}

(2 marks)

(b) (i) Complete the reaction by writing the formula for the reactant in the box provided below.

(1 mark)

$$C_2H_4(g) + \boxed{} \xrightarrow{\text{catalyst}} C_2H_5OH(g)$$

(ii) Classify this type of reaction.

(1 mark)

(c) C_2H_5OH can be converted into ethanoic acid, CH_3COOH, in the presence of Reagent X. Write the formula for Reagent X in the box provided below.

(1 mark)

$$C_2H_5OH \xrightarrow{\boxed{\text{Reagent X}}} CH_3COOH$$

(d) CH_3COOH can be used in the production of esters.

(i) Write a balanced chemical equation for the reaction of CH_3COOH with propan-1-ol using semi-structural formulas for all organic compounds.

(2 marks)

(ii) Write the IUPAC name for the ester product of the equation written in **part (d)(i)**.

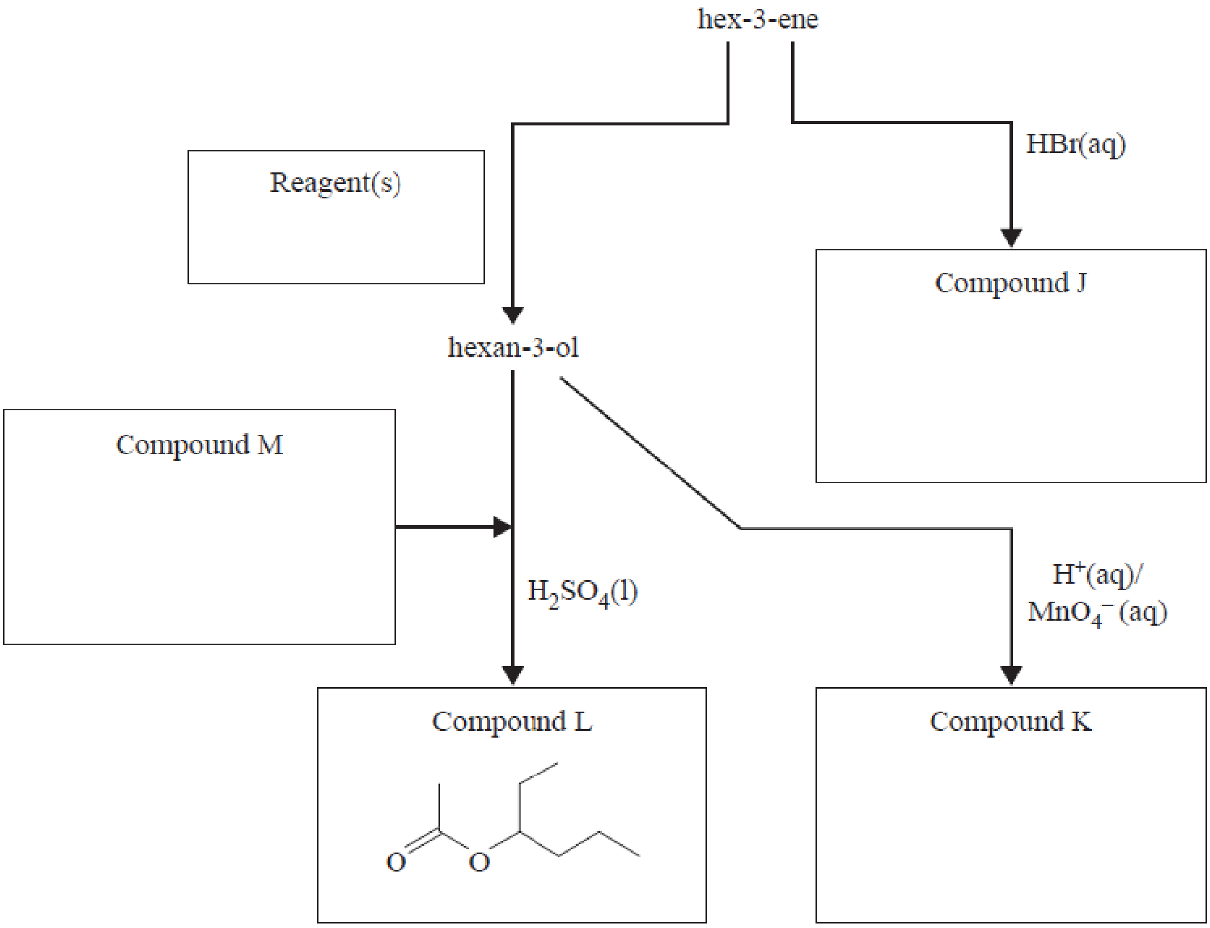
(1 mark)

(Total = 8 marks)

Question 11 / 11

[VCAA 2020 SB Q3]

Below is a reaction pathway beginning with hex-3-ene.



(a) Write the IUPAC name of Compound J in the box provided.

(1 mark)

(b) State the reagent(s) required to convert hex-3-ene to hexan-3-ol in the box provided.

(1 mark)

(c) Draw the structural formula for a tertiary alcohol that is an isomer of hexan-3-ol.

(1 mark)

(d) Hexan-3-ol is reacted with Compound M under acidic conditions to produce Compound L.

Draw the semi-structural formula for Compound M in the box provided.

(1 mark)

(e) (i) Draw the semi-structural formula for Compound K in the box provided.

(1 mark)

(ii) Name the class of organic compound (homologous series) to which Compound K belongs.

(1 mark)

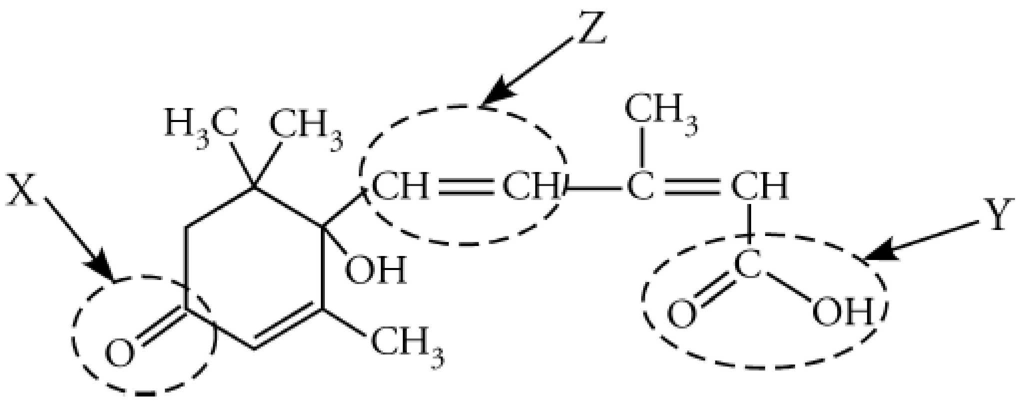
(f) What type of reaction produces Compound K from hexan-3-ol?

(1 mark)

(Total = 7 marks)

Question 1 / 15

Abscisic acid is a substance that regulates the growth of plants and has the structure shown below.



The correct names for the functional groups labelled X, Y and Z are

---

A.

X	Y	Z
ester	carboxylic acid	alkene

B.

aldehyde	ester	alkyne

C.

ketone	carboxylic acid	alkene

D.

hydroxy	amide	alkane

Question 2 / 15

Molecules of vitamin A have the formula $C_{20}H_{30}O$ and their structure contains one ring and one hydroxy group. The number of carbon-to-carbon double bonds present is

---

A.

3

B.

4

C.

5

D.

6

Question 3 / 15

The correct names for the compounds $CH_3CH_2CH_2CH_2CH{=}CH_2$ and $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ are, respectively,

---

A.

1–hexene and heptane.

B.

1–heptene and hexane.

C.

hexane and 1–heptene.

D.

1–heptene and octane.

Question 4 / 15

The sequence of reactions required to convert ethene, C_2H_4, into ethyl ethanoate, $CH_3COOCH_2CH_3$, would be

---

A.

addition, oxidation, esterification.

B.

addition, substitution, oxidation.

C.

oxidation, esterification, substitution.

D.

esterification, oxidation, addition.

Question 5 / 15

Which of the lists below contains compounds that are isomers of each other?

A.

$CH_3CH(OH)CH_3$, $CH_3CH_2CH_2OH$, $CH_3CH_2OCH_3$

B.

CH_3OH, CH_3CH_2OH, $CH_3CH_2CH_2OH$

C.

$CH_3CH_2CH_2OH$, $CH_3CH(OH)CH_2OH$, $CH_2(OH)CH(OH)CH_2OH$

D.

$CH_3CH_2CH_3$, $CH_3CH_2CH_2OH$, $CH_3CH(OH)CH_3$

Question 6 / 15

When ethanol, CH_3CH_2OH, is oxidised by acidified potassium permanganate, the most likely product is

---

A.

$CH_2=CH_2$

B.

$CH_2(OH)CH_2OH$

C.

$HCOOH$

D.

CH_3COOH

Question 7 / 15

The reaction between methanol, CH_3OH, and propanoic acid, CH_3CH_2COOH, is an example of

---

A.

alcoholysis.

B.

substitution.

C.

esterification.

D.

addition.

Question 8 / 15

Which of the substances below is in the same homologous series as CH_3CH_2COOH?

A.

butane

B.

ethanol

C.

butanoic acid

D.

propene

Question 9 / 15

Which of the following pairs of compounds will both undergo substitution reactions?

A.

$CH_3CH_2CH_3$ and CH_3CH_2Cl

B.

$CH_2{=}CH_2$ and $CH_3CH{=}CH_2$

C.

$CH_3CH_2CH_3$ and CH_3CH_2COOH

D.

CH_3CH_2Cl and $CH_2{=}CH_2$

Question 10 / 15

To carry out the following sequence of reactions

$$CH_2{=}CH_2 \xrightarrow{X} CH_3CH_2OH \xrightarrow{Y} CH_3COOH$$

the reagents X and Y are, respectively,

A.

ethanol and ethanoic acid.

B.

acidified $KMnO_4$ and water/catalyst.

C.

HCl(aq) and acidified $KMnO_4$.

D.

water/catalyst and acidified $KMnO_4$.

Question 11 / 15

The pair of compounds CH_3CH_2OH and CH_3OCH_3 are best described as

---

A.

alcohols.

B.

isomers.

C.

alkanes.

D.

isotopes.

Question 12 / 15

Alkanes and alkenes are two important classes of organic compounds.

(a) Describe the difference in structure between alkanes and alkenes.

(2 marks)

(b) There are five isomers with the molecular formula C_5H_{10} that are alkenes.

Give the semi-structural formula and correct name for any three of these isomers.

(3 marks)

(Total = 5 marks)

Question 13 / 15

[Adapted VCAA 2020 SB Q10]

Analytical chemistry deals with methods for determining the chemical composition of samples of matter. A qualitative method yields information about the identity of atomic or molecular species or the functional groups in the sample ...

Analytical methods are often classified as being either *classical* or *instrumental*.

Source: DA Skoog, FJ Holler and SR Crouch, *Principles of Instrumental Analysis*, 6th edition, Thomson Brooks/Cole , Belmont (CA), 2007, p. 1

Classical methods include qualitative analysis, such as treating a compound with reagents to observe any reaction, and quantitative methods, such as volumetric analysis, where the amount of a compound is determined by its reaction with a standard reagent. Instrumental methods include a variety of spectroscopy, such as IR spectroscopy and NMR spectroscopy.

(a) Explain how the classical methods of analytical chemistry can be used to determine information about alcohols. In your answer, refer to:

- qualitative analysis and how it can be used to determine whether a compound is an alcohol and, if it is, the type of alcohol
- quantitative analysis.

(3 marks)

(b) C_3H_6O can exist as a ketone or as a primary alcohol.

Explain how IR spectroscopy and ^1H NMR spectroscopy can be used to differentiate between the ketone and primary alcohol isomers of C_3H_6O.

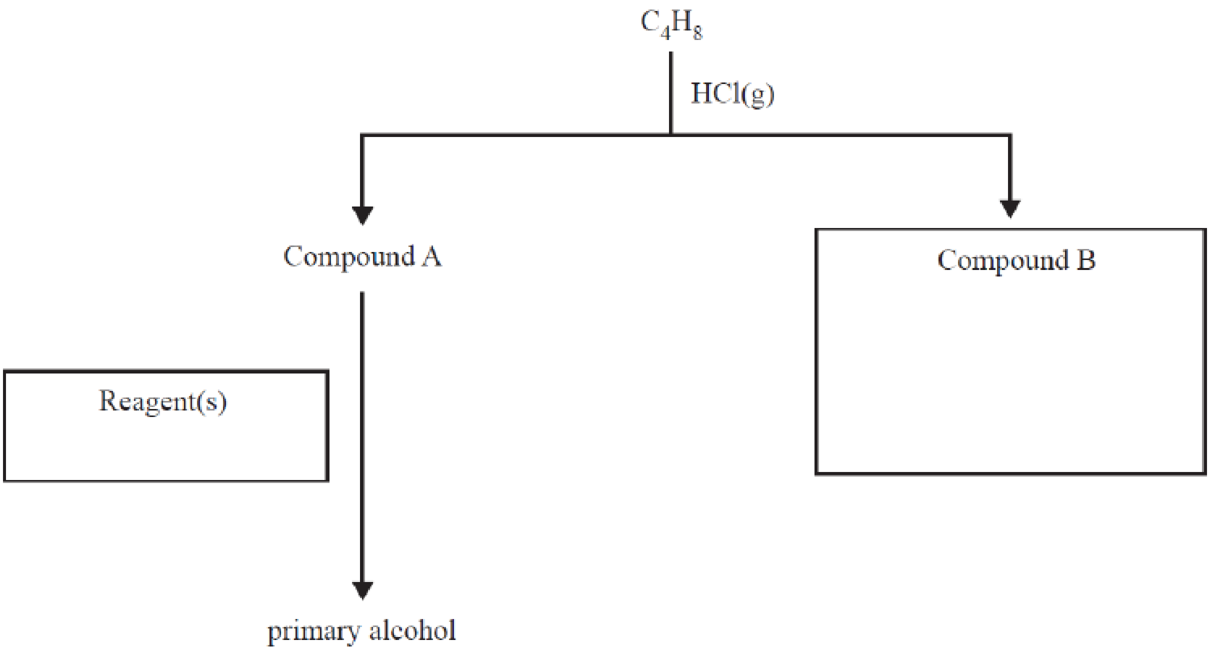
(2 marks)

(Total = 5 marks)

Question 14 / 15

[VCAA 2022 SB Q1]

A reaction pathway to produce a primary alcohol is shown below.



C_4H_8 reacts with HCl(g) to form two unbranched isomers – Compound A and Compound B. Only Compound A can react to produce a primary alcohol.

(a) Identify the type of reaction that converts C_4H_8 into Compound A.

(1 mark)

(b) Write the semi-structural formula for Compound B in the box provided.

(1 mark)

(c) State the reagent(s) required to convert Compound A into a primary alcohol in the box provided.

(1 mark)

(d) Propan-1-ol can react with methanoic acid to produce an organic molecule.

(i) Identify the catalyst for this reaction.

(1 mark)

(ii) Write a balanced chemical equation for the reaction.

(2 marks)

(iii)Write the systematic IUPAC name for the organic molecule produced.

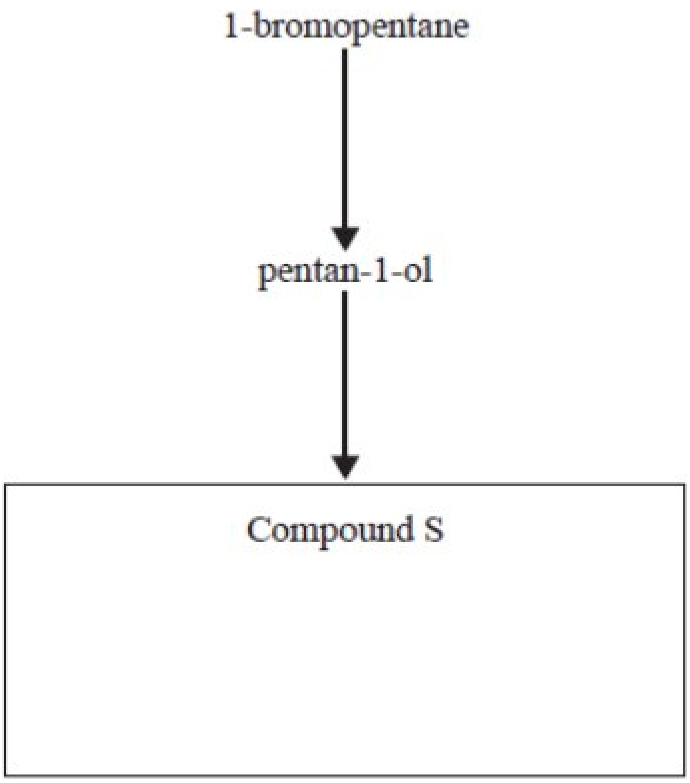
(1 mark)

(Total = 7 marks)

Question 15 / 15

[Adapted VCAA 2021 SB Q6]

A reaction pathway beginning with 1-bromopentane is shown below.



(a) (i) Write a balanced equation for the reaction that will produce pentan-1-ol from 1-bromopentane and a sodium salt.

(2 marks)

(ii) Calculate the atom economy in the production of pentan-1-ol from 1-bromopentane and a sodium salt.

(3 marks)

(b) Pentan-1-ol is fully oxidised to Compound S.

Write the IUPAC name of Compound S in the box provided.

(1 mark)

(c) In an alternative reaction pathway, pentanamide can be formed from 1-bromopentane.

Draw the skeletal formula for pentanamide.

(1 mark)

(Total = 7 marks

Question 1 / 74

A 0.0491 M solution of sodium carbonate was used to standardise a solution of ethanoic acid. A 20.00 mL aliquot of the sodium carbonate solution was placed in a conical flask and titrated with the ethanoic acid solution from a burette. The correct indicator for this reaction would be one that changes colour when the number of mole of hydrogen ions added

---

A.

results in the pH of the solution in the flask being 7.

B.

just exceeds the number of mole of CO_3^{2-} ions present originally.

C.

just exceeds double the number of mole of CO_3^{2-} ions present originally.

D.

equals the number of mole of CO_3^{2-} ions present originally.

Question 2 / 74

200 mL of 0.10 mol L^{-1} hydrochloric acid, 200 mL of 0.20 mol L^{-1} hydrochloric acid and 100 mL of 0.40 mol L^{-1} hydrochloric acid are mixed together. The concentration of hydrochloric acid in the resulting solution, in mol L^{-1}, is

---

A.

0.10

B.

0.20

C.

0.70

D.

5.0

Question 3 / 74

Anhydrous sodium carbonate, Na_2CO_3, is a good primary standard. What mass of sodium carbonate, when dissolved in water in a 250 mL volumetric flask, is needed to make a 0.0650 mol L^{-1} solution?

A.

0.01625 g

B.

1.722 g

C.

6.890 g

D.

27.56 g

Question 4 / 74

The label on a 5.00 L container of 'Pool Acid' states that it contains 33% w/w of hydrochloric acid. Calculate the mass of acid present in the container, in kilograms, if the density of the acid is 1.17 g mL^{-1}.

A.

17.7

B.

1.93

C.

1.65

D.

1.41

Question 5 / 74

Lithium hydroxide can be used to remove carbon dioxide from gas mixtures. The equation for the reaction is

$2LiOH(s) + CO_2(g) \rightarrow Li_2CO_3(s) + H_2O(l)$

The volume of carbon dioxide, measured at SLC, that could be absorbed by 1.00 kg of LiOH is

---

A.

0.511 L

B.

1023 L

C.

511 L

D.

468 L

Question 6 / 74

0.1851 g of a pure dicarboxylic acid, $Z(COOH)_2$, was added to approximately 20.00 mL of water and titrated with 0.136 M NaOH solution. To reach the endpoint, a titre of 20.62 mL was required. The identity of the dicarboxylic acid is most likely to be

---

A.

$CH_2(COOH)_2$

B.

$C_2H_4(COOH)_2$

C.

$C_3H_6(COOH)_2$

D.

$C_4H_8(COOH)_2$

Question 7 / 74

[VCAA 2021 SA Q4]
A titration was performed to determine the concentration of an ethanoic acid, $C_2H_4O_2$, solution using the following procedure:

1. 25.00 mL of the $C_2H_4O_2$ solution was pipetted into a conical flask.

2. A few drops of indicator were added to the flask.

3. A burette was filled with standard sodium hydroxide, NaOH, solution.

4. The $C_2H_4O_2$ solution was then titrated with the NaOH solution.

5. Steps 1–4 were repeated until three concordant titres were obtained.

A systematic error could result if the

A.

burette tap leaked during one of the titrations.

B.

burette readings were recorded to the nearest 0.1 mL.

C.

number of drops of indicator was not consistent for each titration.

D.

actual concentration of the standard NaOH solution was lower than the stated concentration.

Question 8 / 74

The following information refers to Questions 9 and 10.

Four students titrate 20.00 mL of 0.100 mol L^{-1} sodium hydroxide solution with a solution of ethanoic acid. The students used the same solutions of sodium hydroxide and ethanoic acid and delivered the ethanoic acid from different 50 mL burettes. Their results are given in the table below.

	Student I	**Student II**	**Student III**	**Student IV**
Titre 1 (mL)	21.47	22.63	22.57	22.86
Titre 2 (mL)	21.49	22.65	22.69	22.73
Titre 3 (mL)	21.39	22.58	22.46	22.62
Titre 4 (mL)	21.42	22.60	22.76	22.63
Average (mL)	21.44	22.62	22.62	22.71

Question 9 / 74

Which student is most likely to have made a systematic error?

A.

Student I

B.

Student II

C.

Student III

D.

Student IV

Question 10 / 74

Which student may have rinsed their burette incorrectly?

A.

Student I

B.

Student II

C.

Student III

D.

Student IV

Question 11 / 74

0.153 g of an organic base is dissolved in ~20 mL of water and titrated with 0.1051 mol L^{-1} hydrochloric acid. 24.56 mL of the acid is required to reach the end point. The formula of the organic base is most likely to be

---

A.

$CH_3CH_2NH_2$

B.

$CH_3CH_2CH_2NH_2$

C.

$H_2NCH_2CH_2NH_2$

D.

$CH_3CH_2CH_2CH_2NH_2$

Question 12 / 74

[VCAA 2013 SA Q3]
In a titration, a 25.00 mL titre of 1.00 M hydrochloric acid neutralised a 20.00 mL aliquot of sodium hydroxide solution. If, in repeating the titration, a student failed to rinse one of the pieces of glassware with the appropriate solution, the titre would be

---

A.

equal to 25.00 mL if water was left in the titration flask after final rinsing.

B.

less than 25.00 mL if the final rinsing of the burette is with water rather than the acid.

C.

greater than 25.00 mL if the final rinsing of the 20.00 mL pipette is with water rather than the base.

D.

greater than 25.00 mL if the titration flask had been rinsed with the acid prior to the addition of the aliquot.

Question 13 / 74

Use the following information to answer Questions 14 and 15.

A clear, colourless liquid extract of the rhubarb plant was analysed for the concentration of oxalic acid, $H_2C_2O_4$, by direct titration with a recently standardised and acidified potassium permanganate solution, $KMnO_4(aq)$. The balanced equation for this titration is shown below.

2MnO4−(aq)+5C2O42−(aq)+16H+(aq)→2Mn2+(aq)+10CO2(g)+8H2O(l)purplecolourless colourless

The steps in the titration were as follows:

Step 1 – A 20.00 mL aliquot of the rhubarb extract was placed in a 200 mL conical flask.

Step 2 – The burette was filled with acidified 0.0200 M $KMnO_4$ solution.

Step 3 – The acidified 0.0200 M $KMnO_4$ solution was titrated into the rhubarb extract in the conical flask. The titration was considered to have reached the end point when the solution in the conical flask showed a permanent change in colour to pink. The volume of the titre was recorded.

Step 4 – The titration was repeated until three concordant results were obtained. The average of the concordant titres was 21.7 mL.

Question 14 / 74

[VCAA 2018 SA Q17]
The concentration of $H_2C_2O_4$ in the rhubarb extract is closest to

---

A.

5.43×10^{-2} M

B.

5.00×10^{-2} M

C.

2.17×10^{-2} M

D.

7.40×10^{-4} M

Question 15 / 74

[VCAA 2018 SA Q18]
Which of the following rinses is **least** likely to affect the accuracy of the results?

A.

Item	**Rinse solution**
burette	distilled water

B.

burette	rhubarb extract

C.

pipette	$KMnO_4(aq)$

D.

conical flask	distilled water

Question 16 / 74

To find the ethanol content of a low alcohol beer, a student reacts 20.00 mL of the beer with an acidified solution of potassium dichromate. 23.75 mL of 0.105 mol L^{-1} $K_2Cr_2O_7$ is required for complete reaction. The equation for the reaction is

$2Cr_2O_7^{2-}(aq) + 16H^+(aq) + 3C_2H_5OH(aq) \rightarrow 4Cr^{3+}(aq) + 11H_2O(l) + 3CH_3CO_2H(aq)$

The concentration of ethanol in the beer in g mL^{-1} is

A.

0.172

B.

0.115

C.

8.62×10^{-3}

D.

5.75×10^{-3}

Question 17 / 74

Use the following information to answer Questions 18 and 19.

The concentration of vitamin C in a filtered sample of grapefruit juice was determined by titrating the juice with 9.367×10^{-4} M iodine, I_2, solution using starch solution as an indicator. The molar mass of vitamin C is 176.0 g mo1^{-1}. The reaction can be represented by the following equation.

$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$

The following method was used:

1. Weigh a clean 250 mL conical flask.

2. Use a 10 mL measuring cylinder to measure 5 mL of grapefruit juice into the conical flask and reweigh it.

3. Add 20 mL of deionised water to the conical flask.

4. Add a drop of starch solution to the conical flask.

5. Titrate the diluted grapefruit juice against the I_2 solution.

Question 18 / 74

[VCAA 2019 SA Q29]
Which one of the following errors would result in an underestimation of the concentration of vitamin C in grapefruit juice?

A.

19 mL of deionised water was added to the conical flask.

B.

The concentration of the I_2 solution was actually 9.178×10^{-4} M.

C.

The initial volume of the I_2 solution in the burette was 1.50 mL, but it was read as 2.50 mL.

D.

The balance was faulty and the measured mass of grapefruit juice was lower than the actual mass.

Question 19 / 74

[VCAA 2019 SA Q30]
If the measured mass of grapefruit juice was 4.90 g and the titre was 21.50 mL, what was the measured percentage mass/mass (% m/m) concentration of vitamin C in the grapefruit juice?

A.

0.00987

B.

0.0723

C.

0.354

D.

3.36

Question 20 / 74

[VCAA 2015 SA Q3]
In an experiment, 0.051 mol of sodium hydroxide, NaOH, reacted completely with 0.017 mol of citric acid, $C_6H_8O_7$. Which one of the following equations correctly represents the reaction between citric acid and the sodium hydroxide solution?

A.

$NaOH(aq) + C_6H_8O_7(aq) \rightarrow NaC_6H_7O_7(aq) + H_2O(l)$

B.

$2NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_2C_6H_6O_7(aq) + 2H_2O(l)$

C.

$3NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$

D.

$4NaOH(aq) + C_6H_8O_7(aq) \rightarrow Na_4C_6H_4O_7(aq) + 4H_2O(l)$

Question 21 / 74

Use the following information to answer Questions 22 and 23.

A solution of citric acid, $C_3H_5O(COOH)_3$, was analysed by titration.

25.0 mL aliquots of the $C_3H_5O(COOH)_3$ solution were titrated against a standardised solution of 0.0250 M sodium hydroxide, NaOH. Phenolphthalein indicator was used and the average titre was found to be 24.0 mL.

Question 22 / 74

[VCAA 2020 SA Q23]
Based on the titration, the concentration of $C_3H_5O(COOH)_3$ in the solution was

---

A. 8.0×10^{-3} M

B. 8.7×10^{-3} M

C. 2.6×10^{-2} M

D. 7.2×10^{-2} M

Question 23 / 74

[VCAA 2020 SA Q24]
Which one of the following would have resulted in a concentration that is higher than the actual concentration?

A. The pipette was rinsed with NaOH solution.

B. The pipette was rinsed with $C_3H_5O(COOH)_3$ solution.

C. The conical flask was rinsed with NaOH solution.

D. The conical flask was rinsed with $C_3H_5O(COOH)_3$ solution.

Question 24 / 74

[VCAA 2021 SA Q23]
A student titrated 25 mL aliquots of three different concentrations of an organic acid against a standardised potassium hydroxide, KOH, solution. The student's results are shown in the table below.

	KOH titre for Sample 1 (mL)	**KOH titre for Sample 2 (mL)**	**KOH titre for Sample 3 (mL)**
Titration 1	20.35	19.85	21.55
Titration 2	20.45	19.65	21.45
Titration 3	20.30	20.45	21.65
Average Titre	20.37	19.98	21.55

Which one of the following statements is consistent with the results shown in the table?

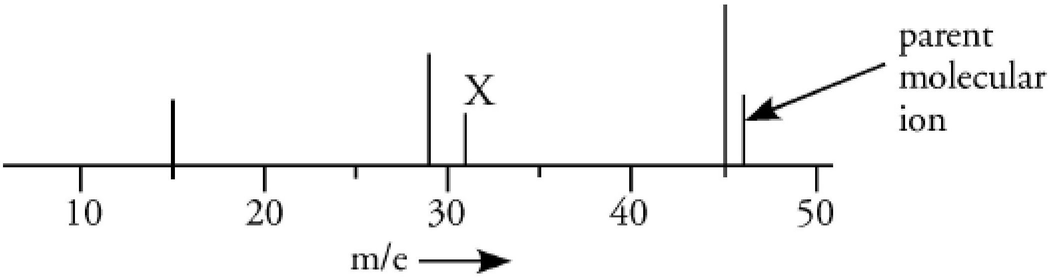
A. Sample 2 is the most concentrated acid.

B. Sample 3 is the most concentrated acid.

C. There is not enough information to draw a valid conclusion.

D. The averages in the table are correct as the results are concordant.

Question 25 / 74



The mass spectrum of dimethyl ether is shown above. The parent molecular ion (m/e = 46.0) has the formula $CH_3OCH_3^+$. When this ion breaks up, other particles are produced. Which species is most likely to have been **lost** from the parent ion to form the particle with m/e = X in the above spectrum?

A.

CH_3

B.

CH_3^+

C.

CH_3O

D.

CH_3O^+

Question 26 / 74

Which one of the compounds below will **not** have an absorption band between 1700 cm^{-1} and 1800 cm^{-1} in its infrared spectrum?

A. $CH_3CH_2COCH_3$

B. $CH_3CH_2OCOCH_3$

C. $CH_3CH_2OCH_2CH_3$

D. $CH_3CH_2NHCOCH_3$

Question 27 / 74

A hydrocarbon has the formula C_6H_{14}. Its ^{13}C NMR spectrum consists of two lines at 33.89 ppm and 19.49 ppm. Which one of the structures below is consistent with this information?

A.

$CH_3CH_2CH_2CH_2CH_2CH_3$

B.

$CH_3CH_2CH_2CH(CH_3)_2$

C.

$CH_3CH_2CH(CH_3)CH_2CH_3$

D.

$(CH_3)_2CHCH(CH_3)_2$

Question 28 / 74

There are two isomers with the molecular formula $C_2H_4Cl_2$. The ^{13}C NMR is measured for one of the isomers and consists of two singlets. If the ^1H NMR spectrum of this isomer were measured it would consist of

---

A.

a singlet.

B.

two singlets.

C.

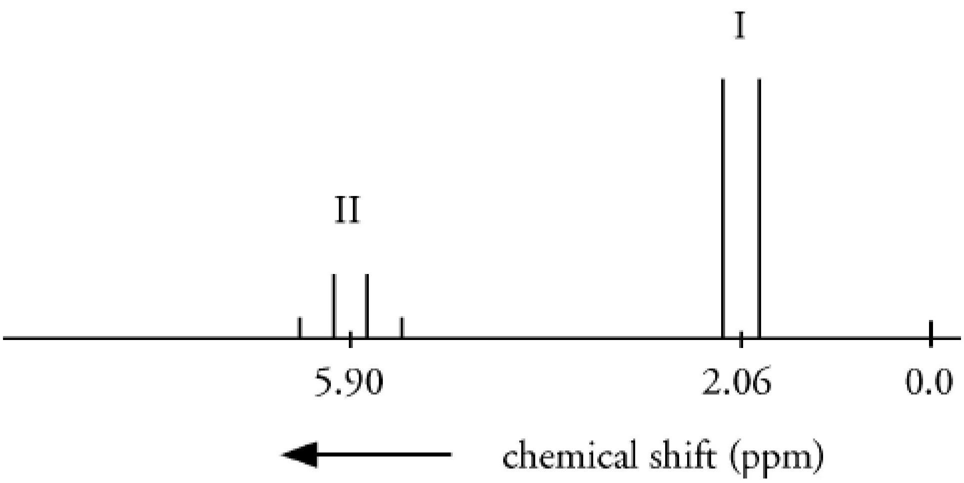
two triplets.

D.

a doublet and a quartet.

Question 29 / 74

The ^{1}H NMR spectrum of a compound is represented in the sketch below. It consists of two signals, I and II.



The relative areas of the two signals I and II is 3:1. Which one of the following compounds is consistent with this spectrum?

A. CH_3CHCl_2

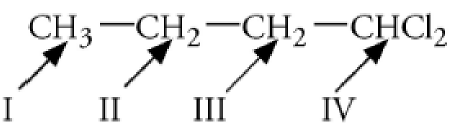
B. $ClCH_2CH_2Cl$

C. $(CH_3)_3COCH_3$

D. $CH_3CH_2OCH_2CH_3$

Question 30 / 74

There are four different groups of protons in 1,1-dichlorobutane as shown in the diagram below.



In the ^{1}H NMR spectrum the group of protons expected to have the largest chemical shift would be

---

A. I

B. II

C. III

D. IV

Question 31 / 74

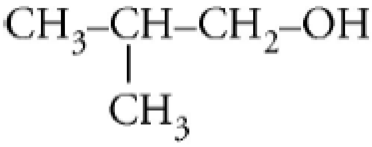
There are four alcohols with the molecular formula C_4H_9OH. The one that has the **least** number of signals in its ^{13}C NMR spectrum is

---

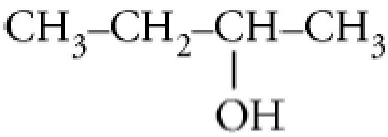
A.

$CH_3–CH_2–CH_2–CH_2–OH$

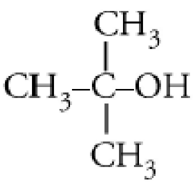
B.



C.



D.



Question 32 / 74

The instruments shown below are used in different techniques.

I mass spectrometer

II NMR spectrometer

III HPLC

IV IR spectrometer

Which instruments make use of a magnetic field in their operation?

A. I and II

B. II and III

C. III and IV

D. and IV

Question 33 / 74

[VCAA 2015 SA Q9]
Which two isomers of $C_3H_6Br_2$ have two peaks (other than the TMS peak) in their ^{13}C NMR spectrum?

A.

$CH_3CBr_2CH_3$ and $CHBr_2CH_2CH_3$

B.

$CHBr_2CH_2CH_3$ and $CH_2BrCHBrCH_3$

C.

$CH_2BrCHBrCH_3$ and $CH_2BrCH_2CH_2Br$

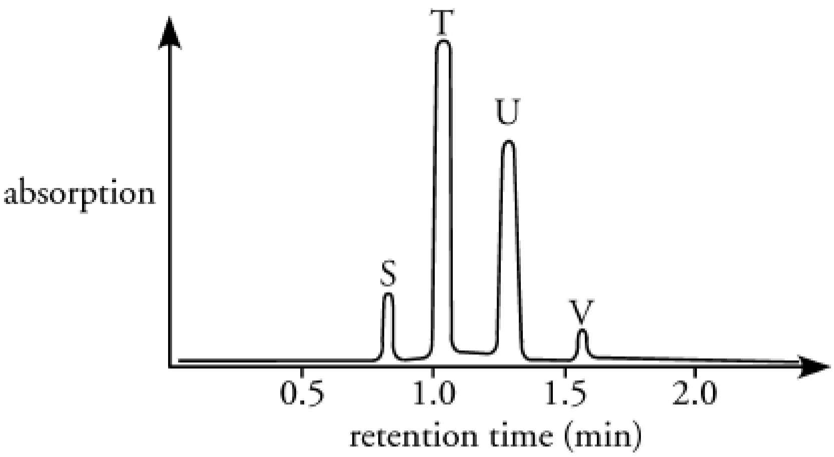
D.

$CH_2BrCH_2CH_2Br$ and $CH_3CBr_2CH_3$

Question 34 / 74

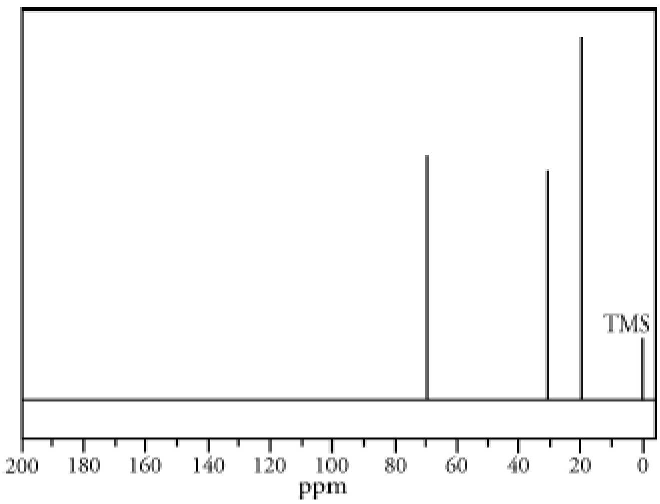
Use the following information to answer Questions 35 and 36.

Four straight chain alcohols, S, T, U, V, with a general formula ROH, were analysed using a gas chromatograph combined with a mass spectrometer. The following chromatogram was produced.



Question 35 / 74

[VCAA 2014 SA Q15]
The ^{13}C NMR spectrum below corresponds to which one of the following compounds?



A.

propane

B.

2-methylbutane

C.

2-methylpropan-1-ol

D.

2-methylpropan-2-ol

Question 36 / 74

[VCAA 2015 SA Q10]
The high-resolution proton NMR spectrum of chloroethane has two sets of peaks. Both peaks are split. Which of the following correctly describes the splitting pattern?

A. a singlet and a doublet

B. a doublet and a doublet

C. a doublet and a triplet

D. a triplet and a quartet

Question 37 / 74

[VCAA 2019 SA Q12]
A compound has the molecular formula C_4H_9Cl. Which type of chemical analysis would be **most** useful in determining whether this compound has a stereoisomer?

A.

mass spectrometry

B.

infra-red spectroscopy

C.

high-performance liquid chromatography

D.

nuclear magnetic resonance spectroscopy

Question 38 / 74

[VCAA 2019 SA Q27]
An organic compound has a molar mass of 88 g mo1^{-1}. The ^{13}C NMR spectrum of the organic compound shows four distinct peaks. The organic compound is **most** lkely

---

A.

butan-1-ol.

B.

2-methyl-butan-1-ol.

C.

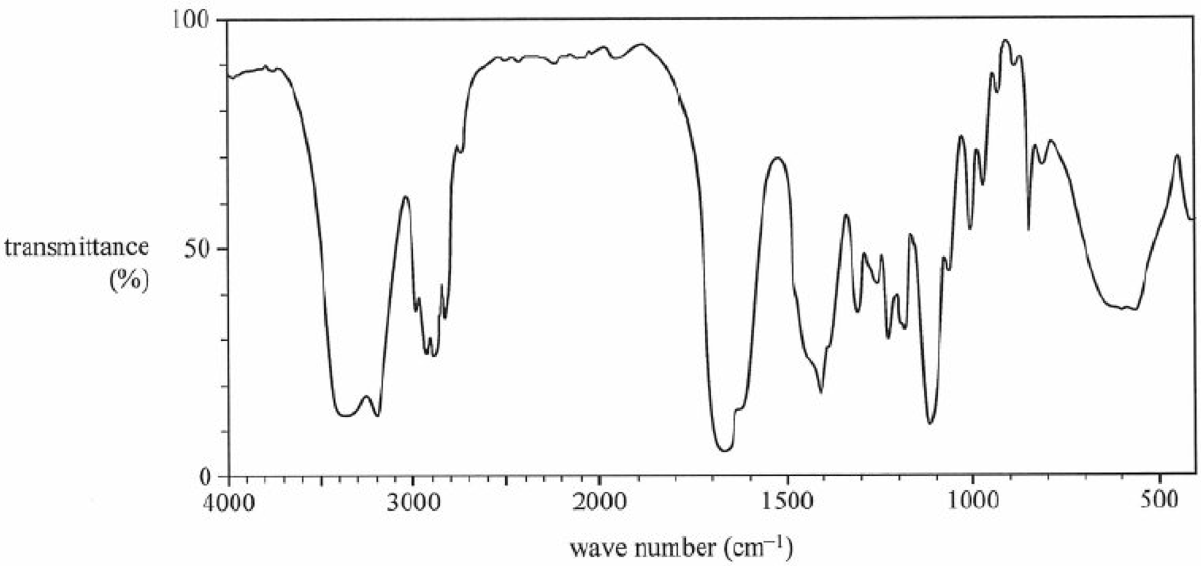
2-methyl-butan-2-ol.

D.

2,2-dimethyl-propan-1-ol.

Question 39 / 74

[VCAA 2020 SA Q21]
The infra-red (IR) spectrum of an organic compound is shown below.



Data: SDBS Web www.d.db.aist.go.jp, National Institute of Advanced Industrial Sience and Technology

Referring to the IR spectrum above, the compound could be

A.

$CH_3CH_2COOCH_3$

B.

$CH_3CH_2CH_2CHO$

C.

$NH_2CH_2CH_2CONH_2$

D.

$NH_2CH_2CH_2CHOHCH_3$

Question 40 / 74

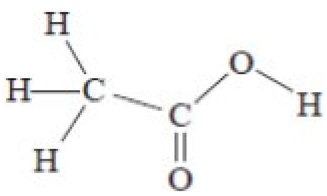
[VCAA 2021 SA Q11]

The spectroscopy information for an organic molecule is given below.

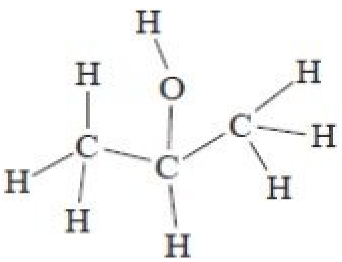
number of peaks in ^{13}C NMR	2
number of sets of peaks in ^{1}H NMR	3
m/z of the last peak in the mass spectrum	60
infra-red (IR) spectrum	an absorption peak appears at 3350 cm^{-1}

The organic molecule is

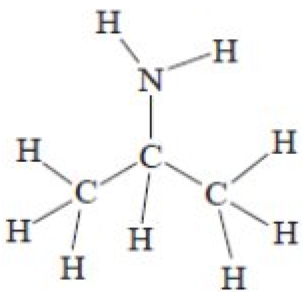
A.



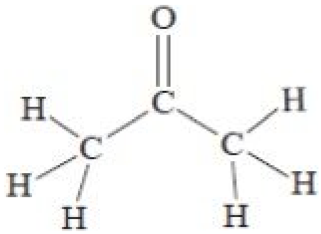
B.



C.



D.



Question 41 / 74

[VCAA 2021 SA Q16]
Which one of the following statements about IR spectroscopy is correct?

A.

IR radiation changes the spin state of electrons.

B.

Bond wavenumber is influenced only by bond strength.

C.

An IR spectrum can be used to determine the purity of a sample.

D.

In an IR spectrum, high transmittance corresponds to high absorption.

Question 42 / 74

[Adapted VCAA 2021 SA Q30]
The ^{1}H NMR spectrum of an organic compound has three unique sets of peaks: a single peak, seven peaks (septet) and two peaks (doublet).

The compound is

A. 3-methylbutanoic acid.

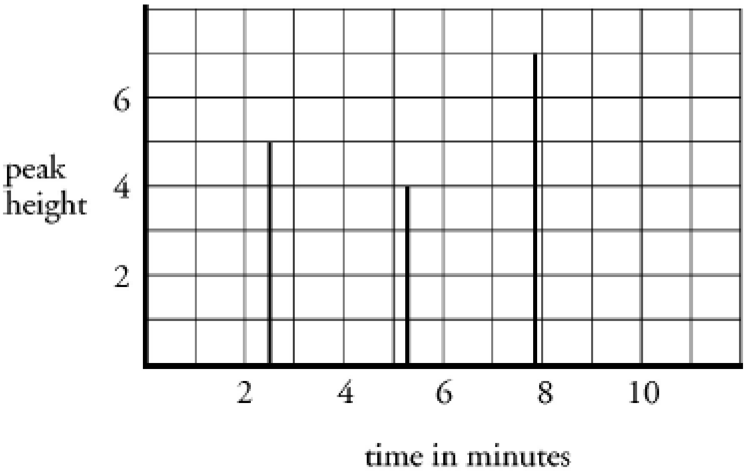
B. 2-methylpropanoic acid.

C. 2-chloro-2-methylpropane.

D. 1,2-dichloro-2-methylpropane.

Question 43 / 74

A mixture of ethanol (C_2H_5OH), methanol (CH_3OH) and 1-propanol (C_3H_7OH) was analysed by high performance liquid chromatography. The output from the chart recorder is shown below.



If the sensitivity of the detector is the same per mole for all three alcohols, the mole percentage of ethanol in the sample is closest to

---

A.

25

B.

31

C.

44

D.

50

Question 44 / 74

[VCAA 2020 SA Q20]
Consider the following changes that could be applied to the operating parameters for a chromatogram set up to carry out high-performance liquid chromatography (HPLC) with a polar stationary phase and a non-polar mobile phase:

I decreasing the viscosity of the mobile phase

II using a more tightly packed stationary phase

III using a mobile phase that is more polar than the stationary phase

---

A.

I only

B.

I and III only

C.

III only

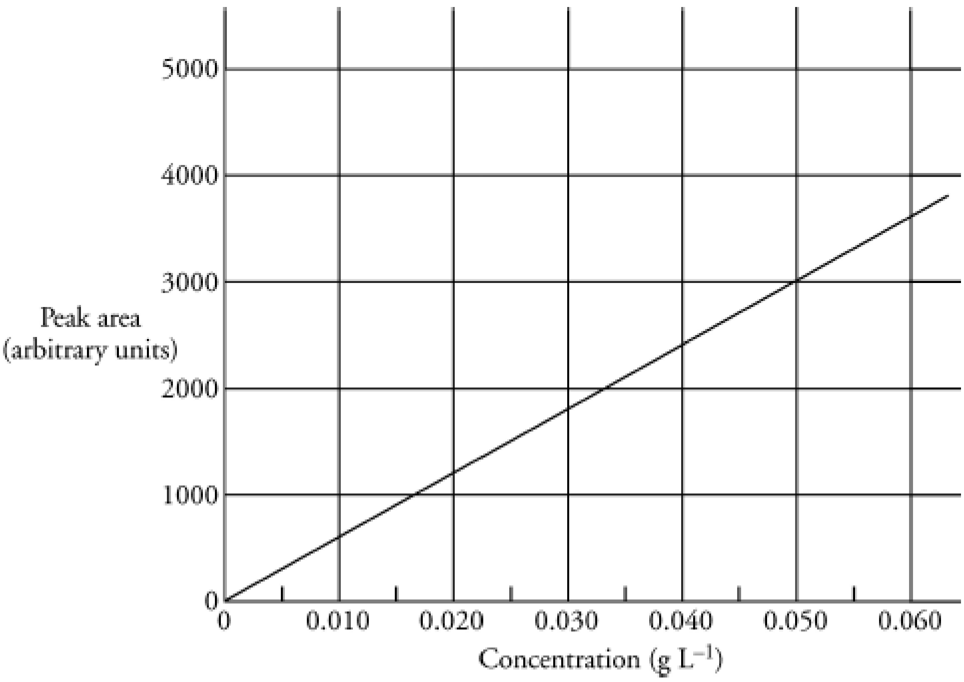
D.

an III only

Question 45 / 74

Use the following information to answer Questions 46 and 47.

The mass of caffeine in a particular coffee drink was determined by high-performance liquid chromatography (HPLC). The calibration curve produced from running standard solutions of caffeine through an HPLC column is shown below.



A 5.0 mL aliquot of the coffee drink was diluted to 50.0 mL with de-ionised water. A sample of the diluted coffee drink was run through the HPLC column under identical conditions to those used to obtain the calibration curve. The peak area obtained for this diluted sample was 2400 arbitrary units.

Question 46 / 74

[VCAA 2017 SA Q21]
The HPLC column used has a non-polar stationary phase. The most suitable solvent for determining the concentration of caffeine in the sample is

---

A.

carbon tetrachloride, CCl_4

B.

methanol, CH_3OH

C.

octanol, $C_8H_{17}OH$

D.

hexane, C_6H_{14}

Question 47 / 74

[VCAA 2017 SA Q22]
The mass of caffeine, in grams, in 350 mL of the undiluted coffee drink is closest to

---

A.

0.014

B.

0.070

C.

0.14

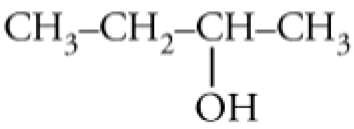
D.

0.40

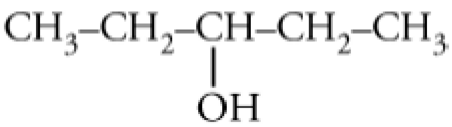
Question 48 / 74

Which one of the following molecules contains a chiral carbon atom?

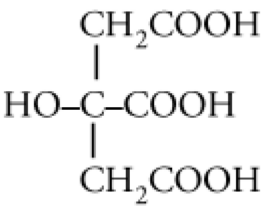
A.



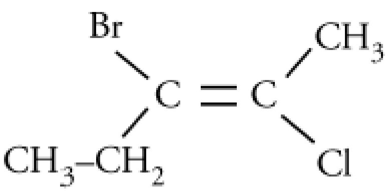
B.



C.



D.



Question 49 / 74

[VCAA 2018 SA Q19]
Which one of the following molecules contains a chiral carbon?

A. $CH_2CHCH_2CH_3$

B. $CH_2FCH_2CH_2Cl$

C. $CH_3CHOHCH_2CH_3$

D. $CH_3CH_2CFClCH_2CH_3$

Question 50 / 74

[VCAA 2017 SA Q4]

Which of the following contains a chiral carbon?

A.

Name	**Semi-structural formula**
2-methylbut-1-ene	$CH_2C(CH_3)CH_2CH_3$

B.

2-chlorobutane	$CH_3CHClCH_2CH_3$

C.

Propanoic acid	CH_3CH_2COOH

D.

1,2-dichloroethene	ClCHCHCl

Question 51 / 74

Which two functional groups react to form the peptide link found in proteins?

A.

$-NH_2$ and $-OH$

B.

$-NH_2$ and $-NH_2$

C.

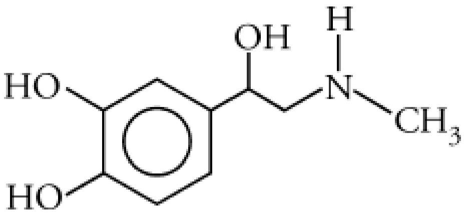
$-OH$ and $-COOH$

D.

$-COOH$ and $-NH_2$

Question 52 / 74

One of the hormones produced in the adrenal gland is epinephrine, which has the structure shown below.



It is most likely that the amino acids used to make this hormone are

---

A.

phenylalanine or tyrosine.

B.

tyrosine or tryptophan.

C.

proline or phenylalanine.

D.

proline or tryptophan.

Question 53 / 74

Maltose is a naturally occurring disaccharide formed when two molecules of glucose, $C_6H_{12}O_6$, react together. The most likely formula of maltose is

---

A.

$C_{12}H_{22}O_{11}$

B.

$C_{12}H_{24}O_{12}$

C.

$C_{10}H_{22}O_{11}$

D.

$C_{12}H_{20}O_{10}$

Question 54 / 74

Part of the secondary structure of many proteins is a spiral shape, often called an α-helix. This shape is mostly maintained by

---

A.

hydrogen bonding between C=O and N–H groups on different parts of the protein chain.

B.

hydrogen bonding between C=O and N–H groups within each peptide linkage.

C.

covalent S–S bonds formed from S–H groups within the protein chain.

D.

ionic bonds formed when –COOH and $-NH_2$ groups react to make the protein chain.

Question 55 / 74

In living things, polypeptides and proteins can be converted into amino acids such as glycine and alanine. These reactions of polypeptides to produce amino acids are classified as

---

A.

denitrification.

B.

condensation.

C.

hydrogenation.

D.

hydrolysis.

Question 56 / 74

The numbe of iffrent dipeptides tht can be formed containing any **two** of the amino acids, alanine, glycine and serine, is

---

A.

2

B.

3

C.

4

D.

6

Question 57 / 74

Most living things need a number of enzymes in order to function correctly. Which one of the following statements is correct concerning enzymes?

A.

Enzymes function well over a wide range of pH and temperature conditions.

B.

All enzymes catalyse a wide variety of chemical reactions.

C.

Enzymes are more effective than other catalysts at increasing the rate of reaction.

D.

Many enzymes are consumed by the chemical reaction they help to catalyse.

Question 58 / 74

Which one of the substances below is most likely to be involved in the production of a protein?

A.

$CH_3(CH_2)_{14}COOH$

B.

$H_2NCH_2CH_2COOH$

C.

$HOCH_2CH(OH)CH_2OH$

D.

$H_2NCH(CH_3)COOH$

Question 59 / 74

Spiders spin their webs using a silky protein. This material contains ~42% glycine (M = 75.0 g mol^{-1}) and ~25% alanine (M = 89.0 g mol^{-1}). A strand of this protein is found to have a molar mass of ~200 000 g mol^{-1}. The number of glycine residues present in this protein is closest to

---

A.

1120

B.

1475

C.

2670

D.

3510

Question 60 / 74

A pentapeptide used in the manufacture of anti-wrinkle creams has the amino acid sequence

Lys–Thr–Thr–Lys–Ser.

The number of hydroxy, amide (peptide) and amine functional groups present in this pentapeptide is

---

A.

–OH	**–CONH–**	**$-NH_2$**
3	5	3

B.

2	4	2

C.

2	5	2

D.

3	4	3

Question 61 / 74

After digestion of proteins in the diet any unwanted amino acids are broken down in the liver and the nitrogen is converted into urea, CH_4N_2O (M = 60.0 g mol^{-1}). The maximum mass of urea that could be obtained from 2.0 g of arginine (M = 174.0 g mol^{-1}) is

---

A. 0.345 g

B. 0.690 g

C. 1.38 g

D. 5.80 g

Question 62 / 74

The hydrolysis of proteins in food produces amino acids. Which one of the following is most likely to be an amino acid obtained in this way?

A.

$NH_2CH_2CH_2COOH$

B.

$NH_2CH(SH)COOH$

C.

$(CH_3)_2CHCH_2CH(NH_2)COOH$

D.

$C_6H_5CH(NH_2)COOH$

Question 63 / 74

The amino acids glycine, threonine and valine are reacted to produce a tripeptide.

The number of different tripeptides that could be produced from these amino acids is

---

A.

1

B.

3

C.

5

D.

6

Question 64 / 74

[VCAA 2018 SA Q4]
At the molecular level, Protein P is shaped like a coil. When a solution of Protein P is mixed with citric acid, solid lumps form. The change in the structure of Protein P is due to

---

A.

hydrolysis.

B.

denaturation.

C.

polymerisation.

D.

the formation of peptide bonds.

Question 65 / 74

[VCAA 2013 SA Q11]
Australian jellyfish venom is a mixture of proteins for which there is no antivenom. Jellyfish stings are painful, can leave scars and, in some circumstances, can cause death. Some commercially available remedies disrupt ionic interactions between the side chains on amino acid residues. These products most likely disrupt the protein's

---

A.

primary structure only.

B.

secondary structure only.

C.

tertiary structure only.

D.

primary, secondary and tertiary structures.

Question 66 / 74

[VCAA 2015 SA Q14]
Which one of the following is **not** true of protein denaturation?

A.

It could result from a temperature change.

B.

It may be caused by a pH change.

C.

It alters the primary structure.

D.

It results in a change in the shape of the protein.

Question 67 / 74

[VCAA 2015 SA Q14]
An enzyme

A.

can distinguish between optical isomers.

B.

catalyses forward and reverse reactions.

C.

always needs a coenzyme to function.

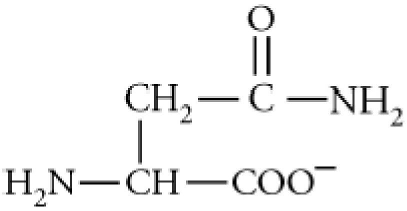
D.

is not able to change shape.

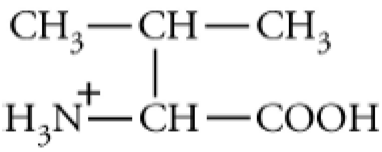
Question 68 / 74

[VCAA 2017 SA Q10]
Which one of the following structures represents a zwitterion of a 2-amino acid?

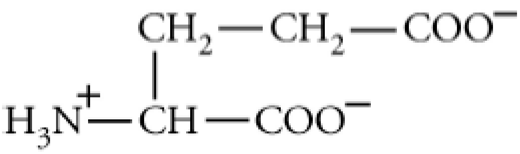
A.



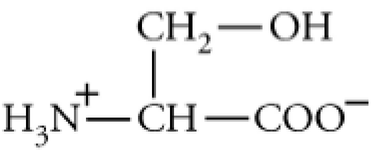
B.



C.



D.



Question 69 / 74

[VCAA 2017 SA Q15]
Which one of the following is a correct statement about the denaturation of a protein?

A.

Denaturation is characterised by the release of peptides.

B.

Alcohol denatures proteins by disrupting the hydrogen bonding.

C.

Denaturation involves disruption of all bonds in the tertiary structure.

D.

The primary and secondary structures are disrupted when denaturation occurs.

Question 70 / 74

[VCAA 2018 SA Q15]
The following table contains the percentage composition by mass of the nutritional value of some common foods.

Food	**% Carbohydrates**	**% Fats and oils**	**% Protein**
fish	0	8	29
bread	50	4	8
cheese	1	34	25
milk	5	4	3

Which one of the following servings has the highest energy content?

A. 100 g of fish

B. 80 g of bread

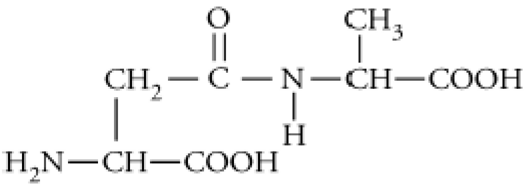
C. 40 g of cheese

D. 258 g (250 mL) of milk

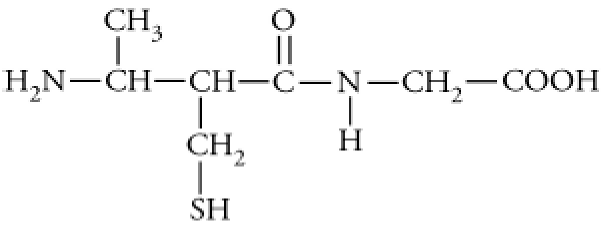
Question 71 / 74

[VCAA 2018 SA Q28]
Which one of the following is a dipeptide made from α-amino acids?

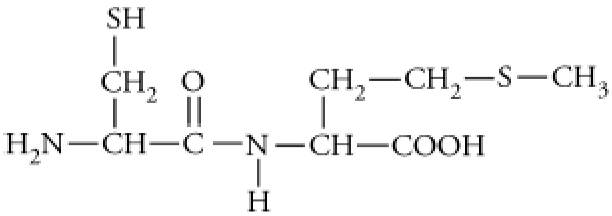
A.



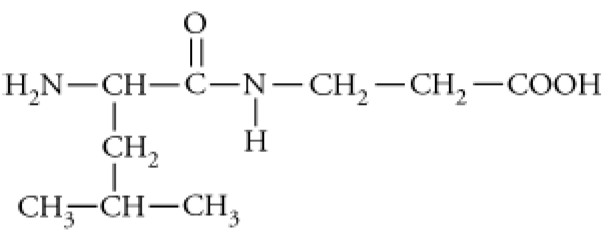
B.



C.



D.



Question 72 / 74

[Adapted VCAA 2018 SA Q30]
In the human body, not all energy available from the metabolism of food is dissipated as heat energy. A student carried out further research on this and found that some of the energy is used in the production of adenine triphosphate, ATP^{3-}, from adenine diphosphate, ADP^{2-}, and inorganic phosphate, PO_4^{3-}, according to the following equation.

$ADP^{2-} + PO_4^{3-} + 2H^+ \rightarrow ATP^{3-} + H_2O$

The student also learnt that the overall equation for aerobic respiration can be represented as shown below.

$C_6H_{12}O_6 + 6O_2 + 32ADP^{2-} + 32PO_4^{3-} + 64H^+ \rightarrow 6CO_2 + 32ATP^{3-} + 38H_2O$

It is reasonable to deduce that in aerobic respiration

A. the formation of ATP^{3-} is a hydrolysis reaction.

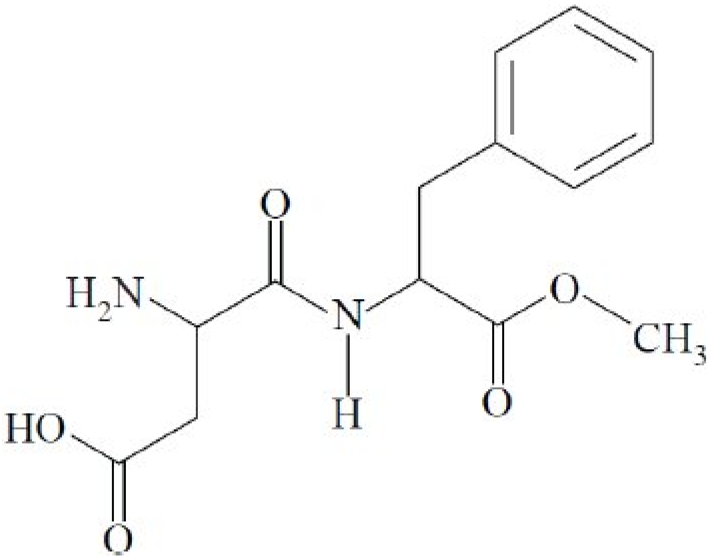
B. for 3.3 g of CO_2 to be produced, 0.40 mol of ADP^{2-} is needed [$M(CO_2)$ = 44.0 g mol^{-1}].

C. the production of ATP^{3-} from ADP^{2-} and PO^{3-} is an exothermic reaction.

D. 9.5 g of $C_2H_{12}O_6$ will produce 2.0 mol of ATP^{3-} [$M(C_6H_{12}O_6)$ = 180.0 g mol^{-1}].

Question 73 / 74

[Adapted VCAA 2019 SA Q15]
Aspartame is an artificial sweetener sometimes added to make foods taste sweeter while not adding much additional energy consumed.



Aspartame has only

A. one chiral centre.

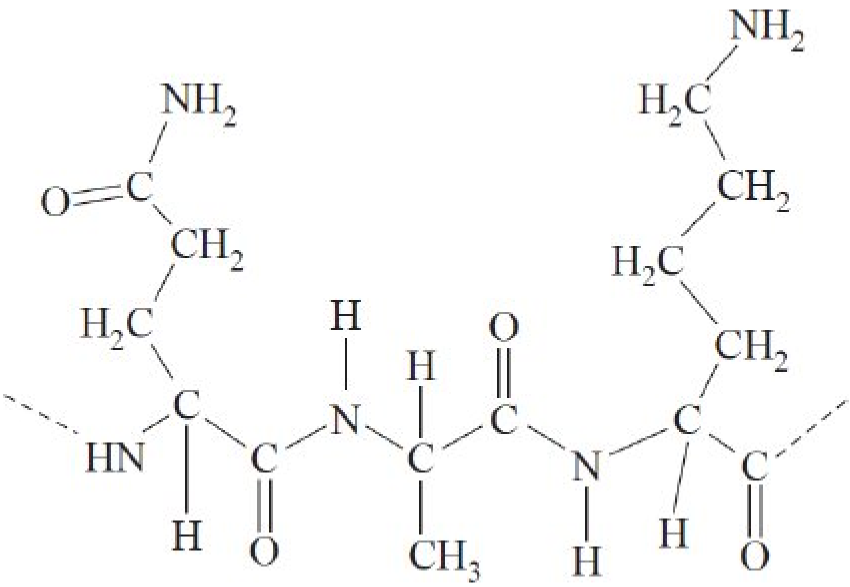
B. two stereoisomers.

C. four optical isomers.

D. three structural isomers.

Question 74 / 74

[VCAA 2020 SA Q12]
The diagram below represents a section of an enzyme.



The diagram can be described as a

A.

secondary structure consisting of glutamine, glycine and lysine.

B.

primary structure consisting of asparagine, glycine and lysine.

C.

secondary structure consisting of asparagine, alanine and lysine.

D.

primary structure consisting of glutamine, alanine and lysine.

Question 1 / 35

A student determined the concentration of ethanoic acid in vinegar by the following method. Using a pipette, 25.00 mL of the vinegar were added to a 250 mL volumetric flask. Water was added until the solution reached the calibration mark. A 20.00 mL aliquot of 0.1152 mol L^{-1} hydroxide solution was added to a conical and the solution was titrated with the diluted vinegar solution from a burette. This part of the experiment was repeated three times. The following results were obtained.

Titration	Titre (mL)
1	24.16
2	22.68
3	22.71
4	22.64

(a) (i) Calculate the amount of sodium hydroxide used in each titration.

(1 mark)

(ii) Write the equation for the reaction between sodium hydroxide and ethanoic acid.

(1 mark)

(iii) Calculate the molarity of the diluted vinegar solution.

(2 marks)

(iv) Calculate the concentration of the original vinegar solution in g L^{-1}.

(2 marks)

(v) Why was the vinegar diluted before being used in the titrations?

(1 mark)

(b) The pieces of glassware used in the experiment were all rinsed before use. In the table below, indicate which liquid should be used to rinse each piece of glassware. The choices are:

- original vinegar solution
- water
- diluted vinegar solution

• sodium hydroxide solution.

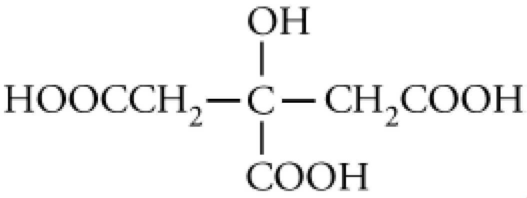
Glassware	**Solution used for rinsing**
25.00 mL pipette	
voluetric flask	
20.00 mL pipette	
conical flask	
burette	

(5 marks)

(Total = 12 marks)

Question 2 / 35

Citric acid is found in many fruits and some vegetables and has the semi-structural formula shown below.



, i.e. $C_3H_5O(COOH)_3$

A student determines the concentration of citric acid in lemon juice by the following method. 25.00 mL of the lemon juice is accurately diluted to 250 mL in a volumetric flask. The diluted lemon juice solution was then used to titrate 20.00 mL aliquots of 0.0946 mol L^{-1} sodium hydroxide solution. The average of three concordant titres was 25.16 mL.

(a) Write a balanced equation for the reaction between sodium hydroxide and citric acid.

(1 mark)

(b) (i) Calculate the amount of sodium hydroxide used in each titration.

(1 mark)

(ii) Calculate the concentration, in mol L^{-1}, of citric acid in the volumetric flask.

(2 marks)

(iii) Calculate the concentration, in g L^{-1}, of the citric acid in lemon juice.

(2 marks)

(Total = 6 marks)

Question 3 / 35

Glucose tablets are used by people with diabetes and help to treat low levels of sugar in the blood. A student determines the percentage of glucose in a glucose tablet by the following procedure. Two glucose tablets are weighed, crushed and added to water to dissolve the glucose. The resulting solution is filtered into a 250 mL volumetric flask and the volume made up to the mark. A 20.00 mL aliquot of an alkaline copper sulfate solution (concentration 0.1362 mol L^{-1}) is pipetted into a conical flask, heated to approximately 75°C and titrated with the glucose solution from a burette. When most of the blue Cu^{2+} ions have reacted, a few drops of methylene blue indicator are added and more glucose solution is added until the intense blue colour of the indicator vanishes. The process is repeated until three concordant results are obtained. The equation for the reaction is

$C_6H_{12}O_6(aq) + 2Cu^{2+}(aq) + 5OH^-(aq) \rightarrow C_6H_{11}O_7^-(aq) + Cu_2O(s) + 3H_2O(l)$

Results: Mass of two tablets = 2.986 g

Average of concordant titres = 21.62 mL

(a) Explain why the reaction above is classified as a redox reaction.

(1 mark)

(b) Calculate the amount of $Cu^{2+}(aq)$, in mol, used in each titration.

(1 mark)

(c) Calculate the amount of glucose, in mol, in the volumetric flask.

(2 marks)

(d) Calculate the percentage of glucose in the tablets.

(2 marks)

(e) Suggest a reason why the copper sulfate solution is heated.

(1 mark)

(f) Suggest a reason why an indicator is needed for this reaction.

(1 mark)

(g) Comment on any safety aspects of this procedure.

(1 mark)

(Total = 9 marks)

Question 4 / 35

The stalks of the rhubarb plant are edible. They are cooked with sugar and used in desserts such as pies and crumbles. However, the leaves of the rhubarb plant are poisonous since they contain small amounts of oxalic acid, HOOCCOOH or $H_2C_2O_4$. A student determined the amount of oxalic acid in rhubarb leaves by the following method. 95.0 g of rhubarb leaves were cut and crushed into small pieces and treated to extract the oxalic acid as an aqueous solution. The extract was concentrated and added to a 100 mL volumetric flask. The level was made up to the calibration mark with water and the mixture thoroughly shaken. 20.00 mL aliquots of the solution were heated to approximately 60°C and titrated with 0.01961 mol L^{-1} potassium permanganate solution until a pale pink colour just remained. The average of three concordant titres was 21.62 mL. The equation for the reaction is

$$2MnO_4^-(aq) + 5H_2C_2O_4(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

(a) (i) Calculate the amount of potassium permanganate used in the titration.

(1 mark)

(ii) Calculate the amount of oxalic acid that reacted with the MnO_4^-.

(1 mark)

(iii) Calculate the mass of oxalic acid in the rhubarb leaves.

(2 marks)

(iv) Express the concentration of oxalic acid as a %(m/m).

(1 mark)

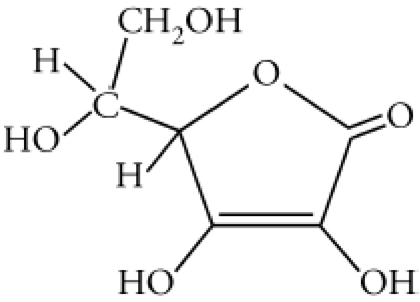
(b) Describe two possible sources of error in this procedure and explain how these errors would affect the final result.

(2 marks)

(Total = 7 marks)

Question 5 / 35

Vitamin C (ascorbic acid) is an essential nutrient in the human diet and is present in most fruits and vegetables. The formula of vitamin C is $C_6H_8O_6$ and has the structure shown below.



(a) Circle any chiral carbon atoms in this structure.

(1 mark)

Vitamin C reacts readily with iodine.

$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$

(b) Is vitamin C an oxidising agent or a reducing agent? Explain your answer.

(1 mark)

Iodine can be produced by reacting iodate ions, IO_3^-, in acidic solution with an excess of iodide ions, I^-.

$IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

Potassium iodate, KIO_3, is a primary standard. 0.1085 g of potassium iodate is added to a 250 mL volumetric flask. Water is added to dissolve the solid and then the volume is made up to the mark.

(c) Calculate the molarity of the potassium iodate solution.

(1 mark)

The concentration of vitamin C was determined by the following procedure. 50.00 mL of grapefruit juice was pipetted into a conical flask. 5 mL of 1.0 mol L^{-1} potassium iodide solution and 5 mL of 1.0 mol L^{-1} hydrochloric acid were added to the flask, followed by 2 mL of starch solution. The mixture in the flask was titrated with the potassium iodate solution from a burette. As the iodate solution was added, it reacted with the iodide and acid to produce I_2, which then reacted with the vitamin C. When all of the vitamin C had reacted, a slight excess of I_2 reacted with the starch to produce a blue-black colour. The average of three concordant titres was 17.31 mL.

(d) (i) Calculate the amount, in mol, of iodate used in each titre.

(1 mark)

(ii) Calculate the amount, in mol, of vitamin C in the aliquot.

(1 mark)

(iii) Calculate the concentration of vitamin C in the grapefruit juice in mg L^{-1}.

(3 marks)

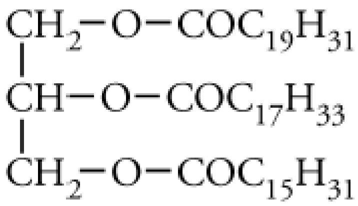
(e) Apart from the equipment used, suggest a source of a systematic error in this experiment.

(1 mark)

(Total = 9 marks)

Question 6 / 35

The following compound has been found in some naturally occurring oils.

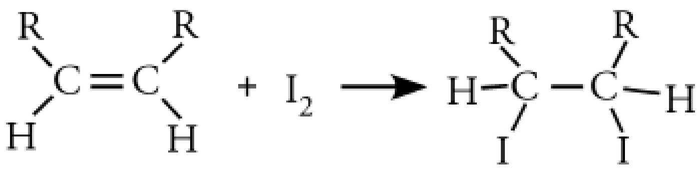


The compound has the molecular formula $C_{57}H_{100}O_6$ (M = 880 g mol^{-1}).

(a) How many carbon-to-carbon double bonds are present in this compound? Explain your answer.

(2 marks)

The iodine number is often used to indicate the amount of unsaturation present in a fat or oil. The iodine number is defined as the number of grams of iodine (I_2) that will react with 100 g of the fat or oil. Iodine will react with carbon-to-carbon double bonds as shown in the equation below.



(b) Calculate the iodine number for the oil shown above.

(2 marks)

(c) Give the semi-structural formulae of the products formed when this substance undergoes hydrolysis. Identify any mono-unsaturated and/or any polyunsaturated products.

(4 marks)

(Total = 8 marks)

Question 7 / 35

There are a number of isomers with the molecular formula $C_2H_4O_2$. One is a carboxylic acid and another is an ester.

(a) Draw the structural formula **and** give the name of:

(i) the carboxylic acid with this formula

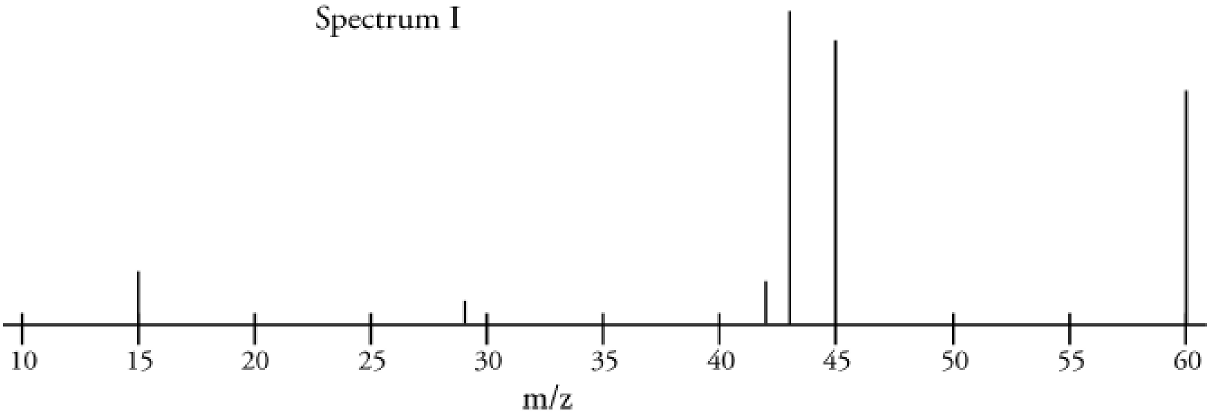
(1 mark)

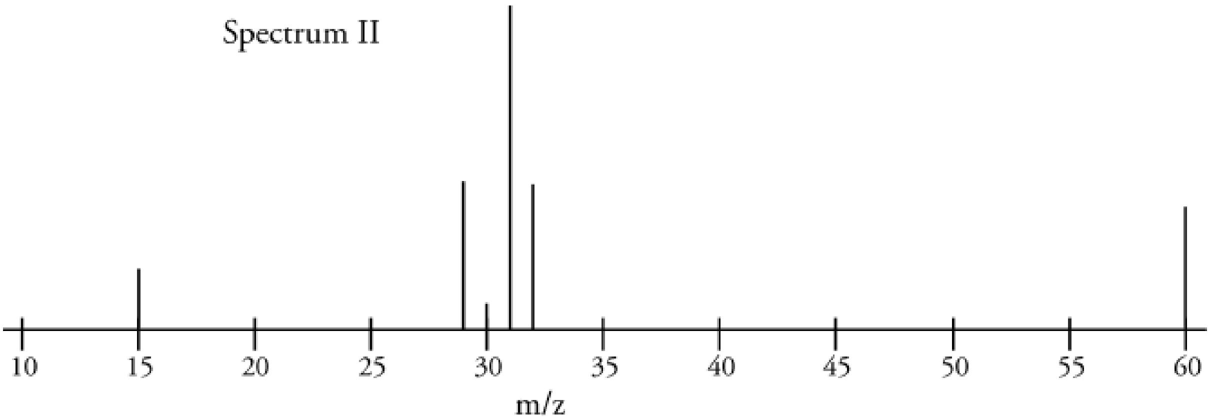
(ii) the ester with this formula.

(1 mark)

(b) The mass spectra of the compounds in part **(a)** are shown below.

(spectrum I and spectrum II). Assign a spectrum to each of the isomers you have drawn in part **(a)** and in each case give a reason for your choice.



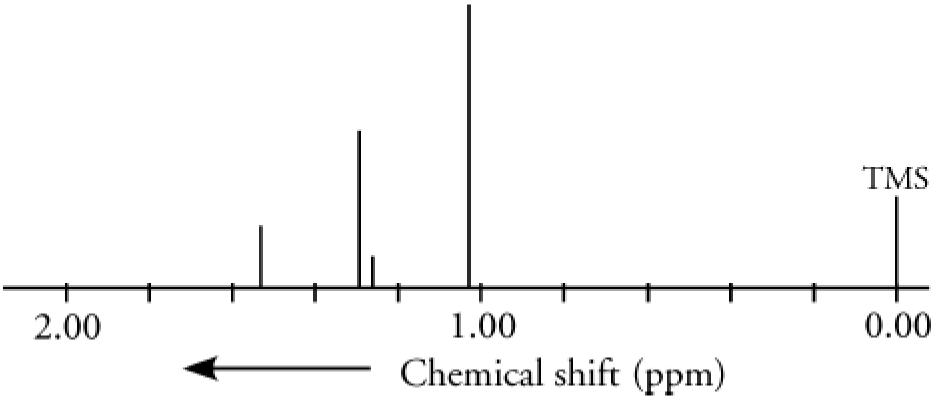


(4 marks)

(Total = 6 marks)

Question 8 / 35

The ^{1}H NMR spectrum of 2,4,4-trimethylpentan-2-ol consists of four singlets, as shown below.



The chemical shifts and peak areas are shown in the table below.

Chemical shift (ppm)	Relative peak area
1.03	125 units
1.26	14 units
1.29	85 units
1.53	29 units

(a) Draw the semi-structural formula of 2,4,4-trimethylpentan-2-ol.

(1 mark)

(b) Use the information in the table to assign the peaks in the spectrum to the hydrogen atoms in the compound.

(3 marks)

(c) How many lines will be present in the ^{13}C NMR spectrum of this compound?

(1 mark)

(Total = 5 marks)

Question 9 / 35

Five of the peaks observed in the mass spectrum of 1-bromo-2-chloroethane, $BrCH_2CH_2Cl$ (M = 143.5 g mol^{-1}), are listed below, along with their relative areas.

mass/charge	relative area
146	2.0
144	8.1
142	6.8
65	33
63	100

Both chlorine and bromine have two naturally occurring isotopes with significant relative abundances. This information is given below.

Isotope	Relative isotopic mass	Relative abundance (%)
^{35}Cl	34.97	75.5
^{37}Cl	36.97	24.5
^{79}Br	78.92	50.5
^{81}Br	80.92	49.5

(a) Use the information given on the previous page to explain the observation of three peaks at 146, 144 and 142 but no peak at 143.5 in the mass spectrum of this compound. (Assume that carbon is 100% ^{12}C and hydrogen is 100% ^{1}H.)

(3 marks)

(b) The peak at 144 is more intense than the peaks at 146 and 142. Suggest a reason for this.

(1 mark)

(c) Give possible isotopic compositions for the peaks at 65 and 63 m/z and explain why their relative areas are approximately 1:3.

(3 marks)

(Total = 7 marks)

Question 10 / 35

A scientist prepares a compound with the following composition:

24.44% carbon, 3.42% hydrogen and 72.14% chlorine.

(a) Deduce the empirical formula of the compound.

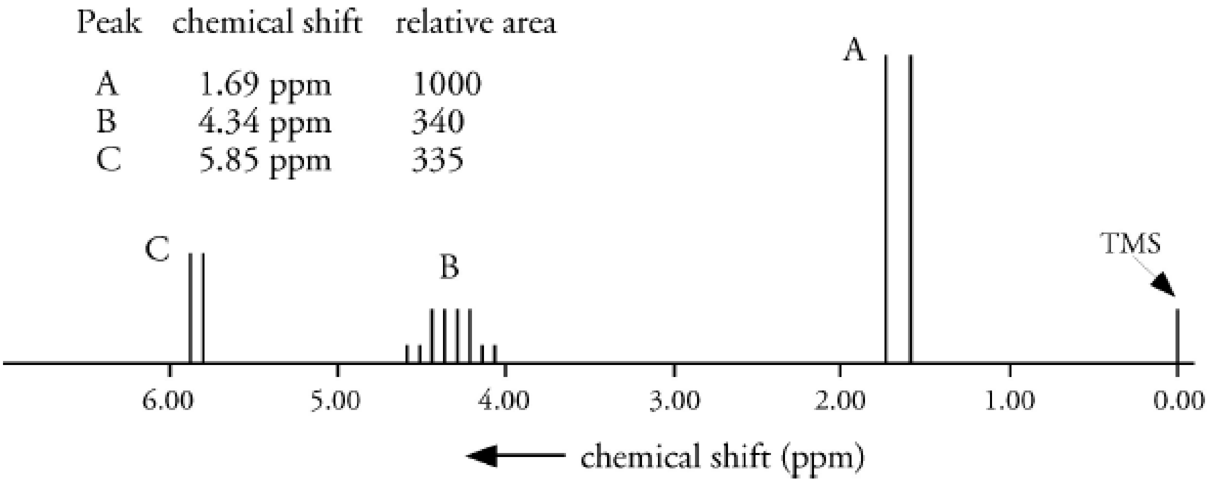
(2 marks)

In another experiment, the scientist finds that 0.025 mol of the compound has a mass of 3.69 g.

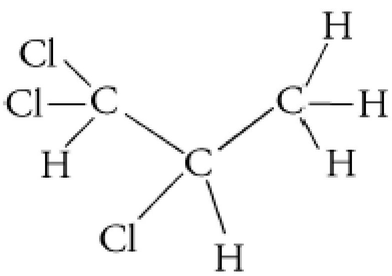
(b) Determine the molecular formula of the compound.

(2 marks)

(c) The scientist obtains the ^1H NMR spectrum of the compound, which is shown below.



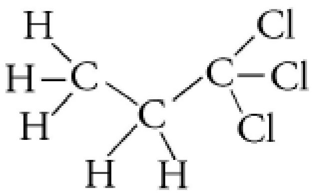
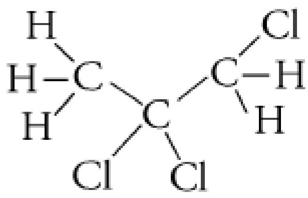
From this spectrum, the scientist suggests that the structure of the compound must be as shown below.



Assuming that the structure above is the correct one, explain how the scientist assigned the peaks in the spectrum to the H atoms in the structure.

(4 marks)

(d) Two other isomers with this formula have the structures shown below. For each of these structures sketch the ^1H NMR spectrum you would expect to observe.

(i)  and (ii) 

(4 marks)

(Total = 12 marks)

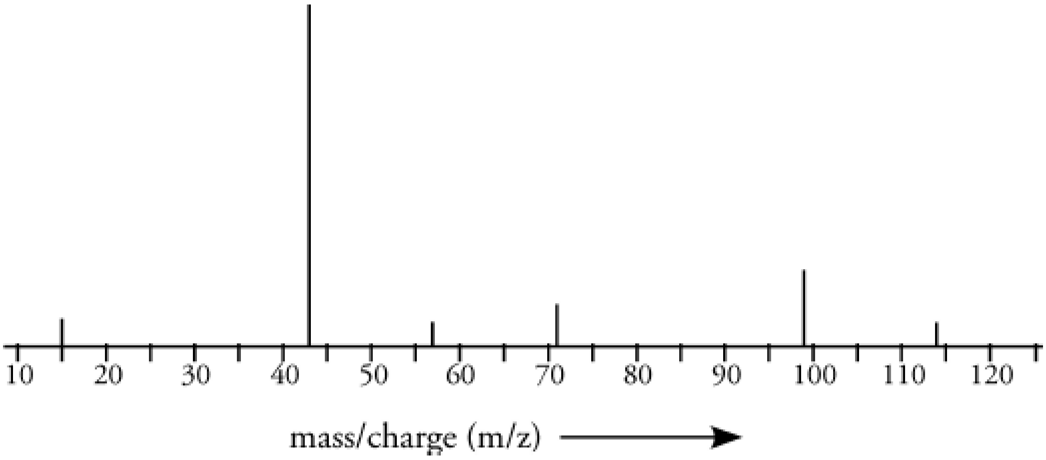
Question 11 / 35

A compound of carbon, hydrogen and oxygen contains 63.16% carbon and 8.77% hydrogen.

(a) Determine the empirical formula of the compound.

(3 marks)

The mass spectrum of the compound is shown below.



(b) Use the information in the mass spectrum to determine the molecular formula of the compound.

(1 mark)

The compound is only slightly soluble in water, is not easily oxidised by acidified potassium dichromate and does not react with sodium hydrogen carbonate.

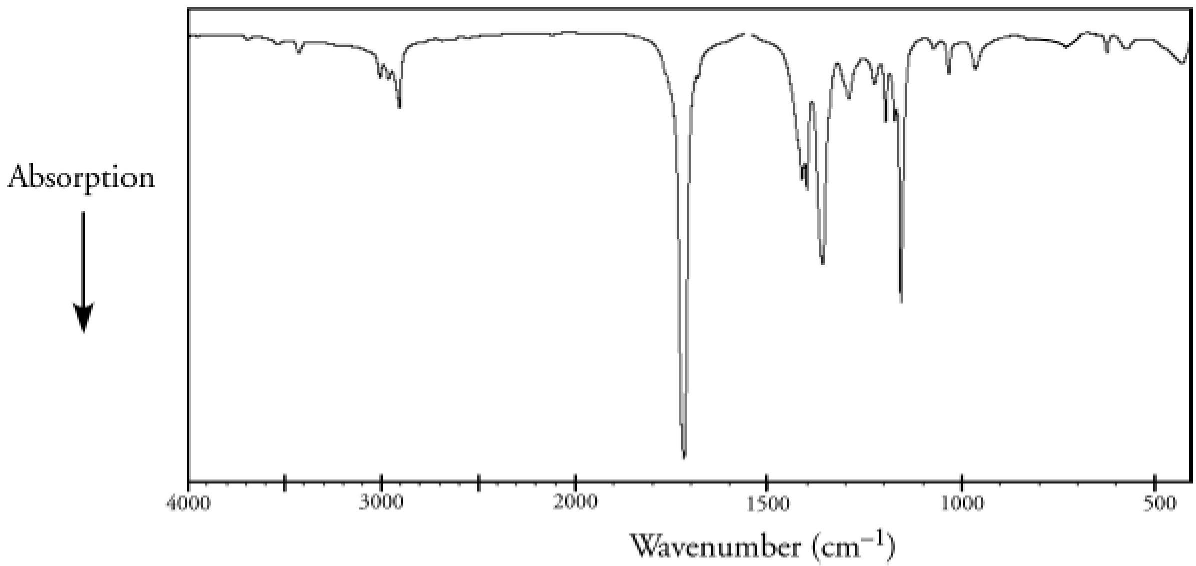
(c) From this information and the molecular formula, name two functional groups that are unlikely to be present in the compound.

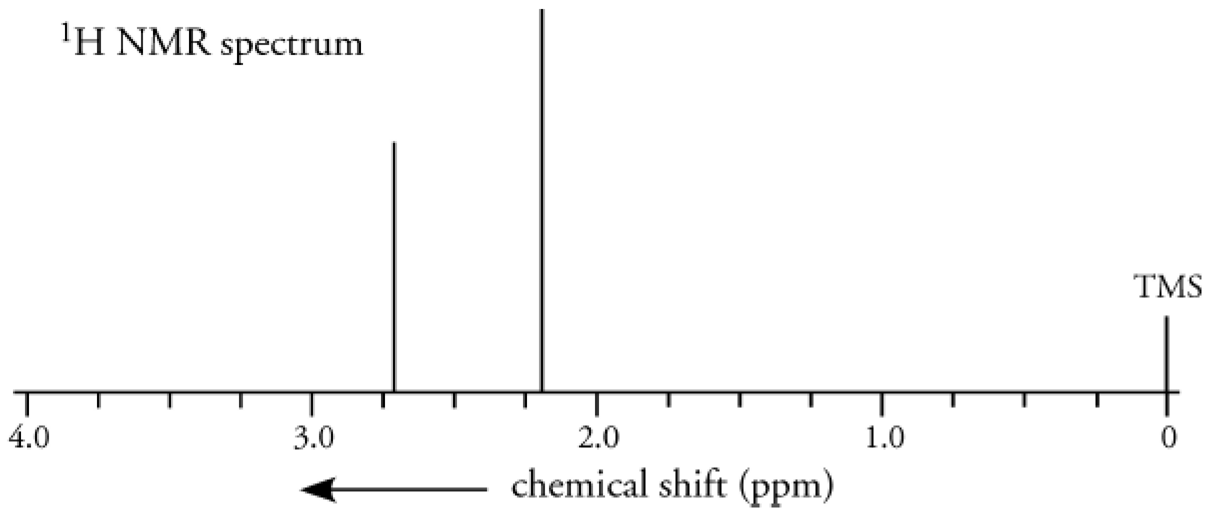
(2 marks)

The infrared spectrum and the ^{1}H and ^{13}C NMR spectra of the compound are shown below and on the following page.

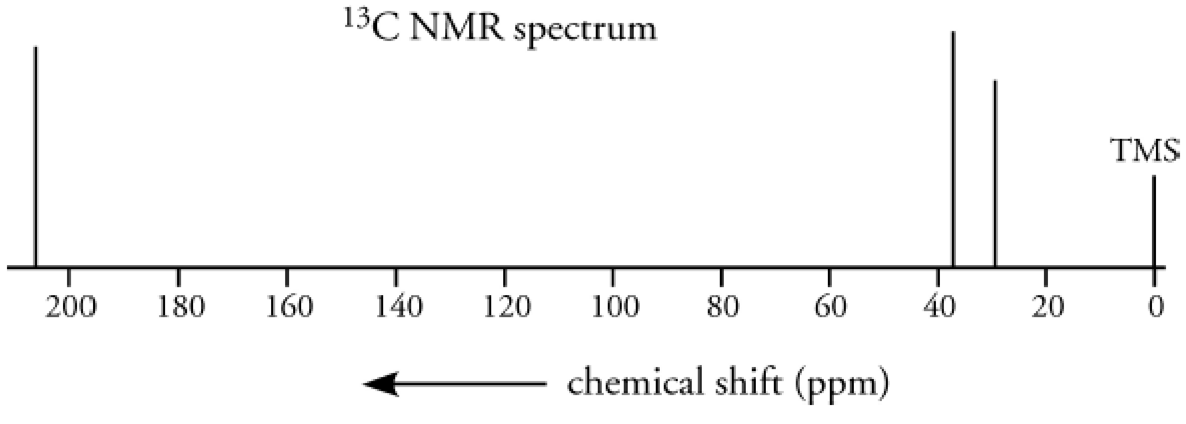
(d) Use the IR and NMR spectra to deduce the most likely structure of the compound.

(3 marks)





The areas of the two peaks in the ^{1}H NMR spectrum at 2.71 and 2.19 are in the ratio 2:3, respectively.



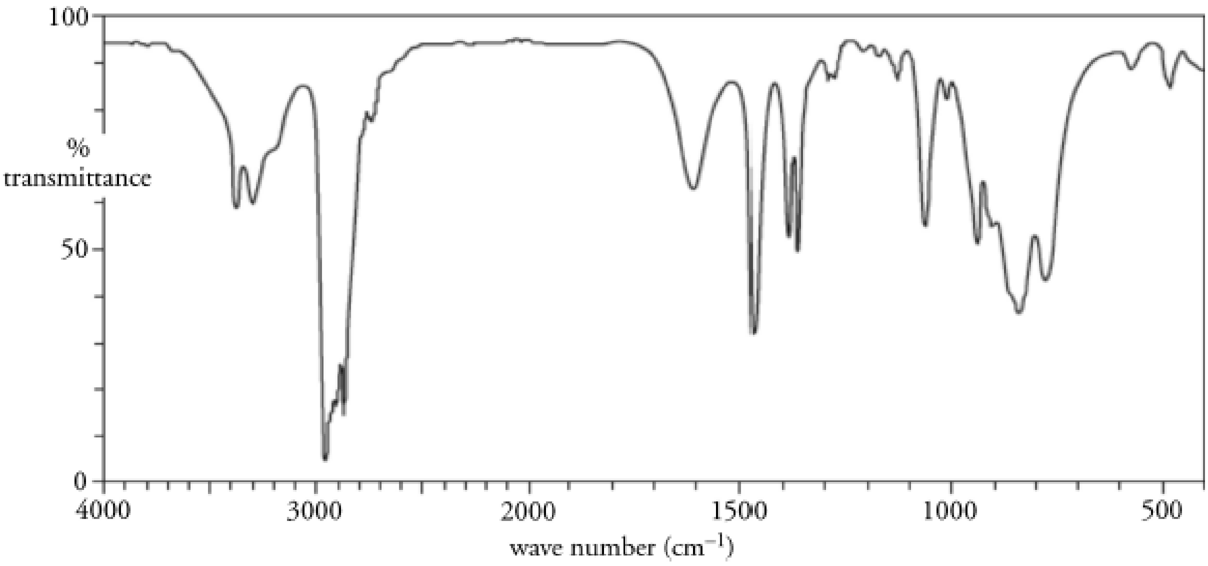
(Total = 9 marks)

Question 12 / 35

[VCAA 2018 SB Q3]

A chemical that contains carbon, C, nitrogen, N, and hydrogen, H, in the ratio 4:1:11 is analysed using spectroscopy.

(a) The infra-red (IR) spectrum of the chemical is shown below.



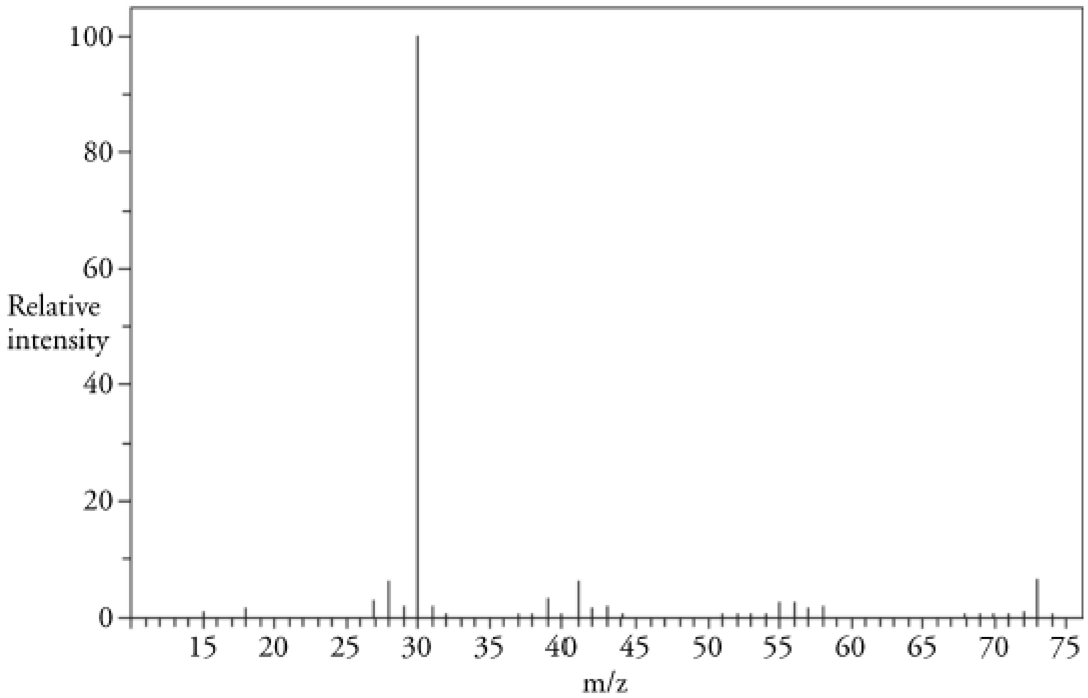
Data: SDBS Web, www.dssaist.go.ip, National Institute of Advanced Industrial Sience and Technology

In the table below, write the bond responsible for the wave numbers given.

(1 mark)

Wavenumber (cm^{-1})	Bond
2956	
3376	

(b) The mass spectrum of the chemical is shown below.



Data: SDBS Web, www.dssaist.go.ip, National Institute of Advanced Industrial Sience and Technology

(i) What is the molecular formula for the parent molecule?

Justify your answer using information from the mass spectrum.

(2 marks)

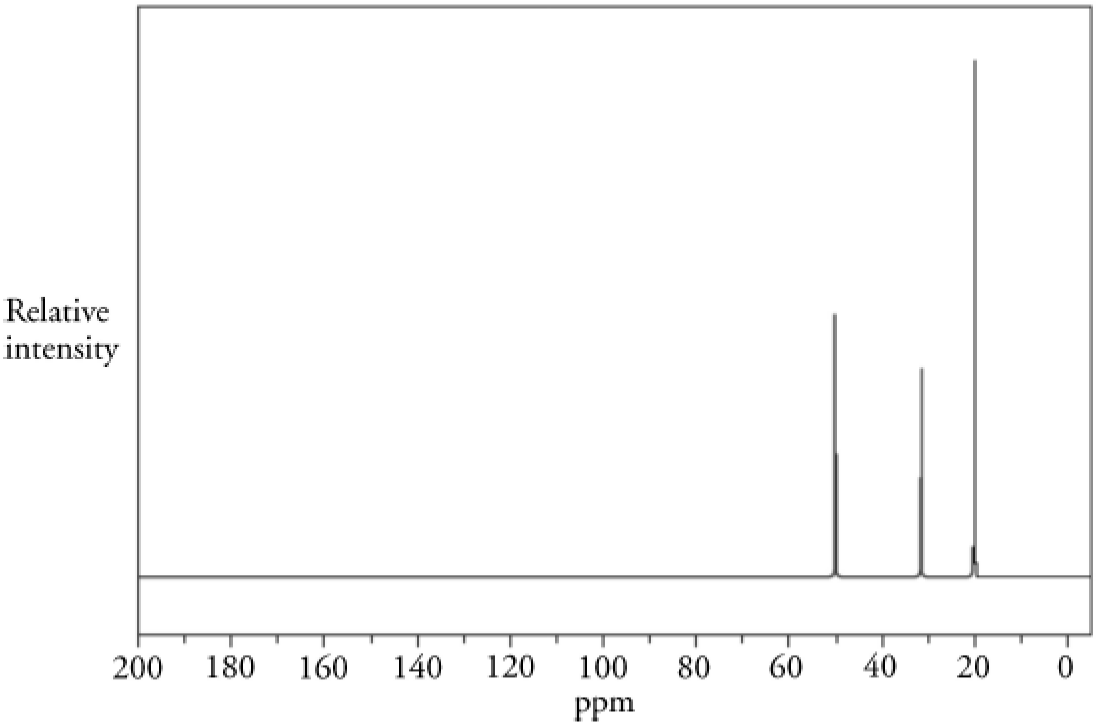
(ii) Identify the fragment that produces the base peak.

(1 mark)

(iii) Draw the structural formulas for **two** possible structural isomers of the chemical, which are consistent with the mass spectrum and the IR spectrum.

(2 marks)

(c) The ^{13}C NMR spectrum of the chemical is shown below.



Data: SDBS Web, www.dssaist.go.ip, National Institute of Advanced Industrial Sience and Technology

(i) Complete the following table using the ^{13}C NMR spectrum.

(2 marks)

Chemical shift	**Type of carbon**
20.0	
50.2	

(ii) Draw the skeletal formula for the chemical, which is consistent with the IR spectrum, mass spectrum and ^{13}C NMR spectrum.

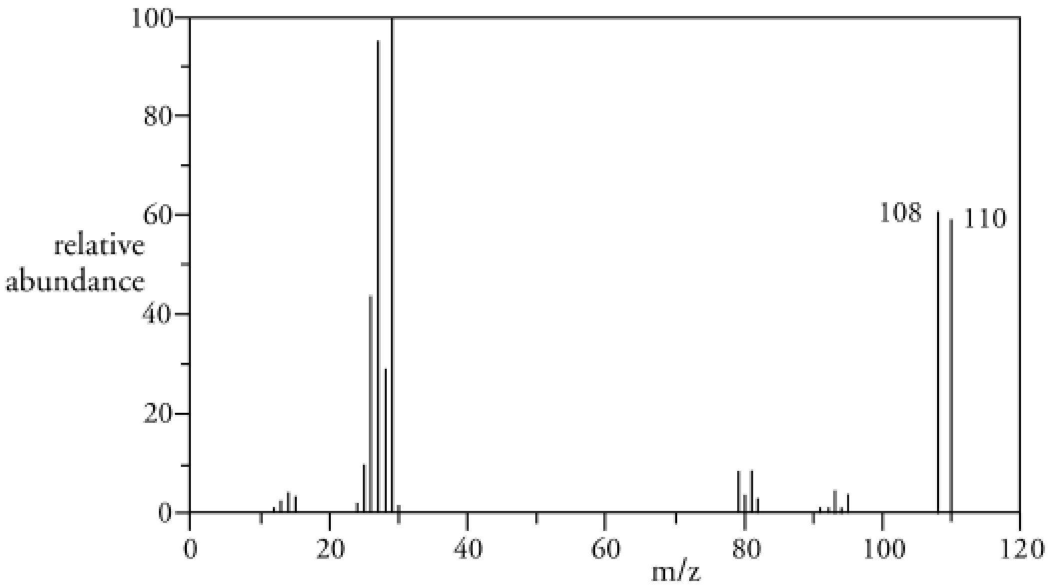
(2 marks)

(Total = 10 marks)

Question 13 / 35

[Adapted VCAA 2011 E1 SB Q2]

(a) Bromine exists as two isotopes, ^{79}Br and ^{81}Br. The mass spectrum of bromoethane, C_2H_5Br, with two molecular ion peaks at m/z 108 and 110, is shown below.

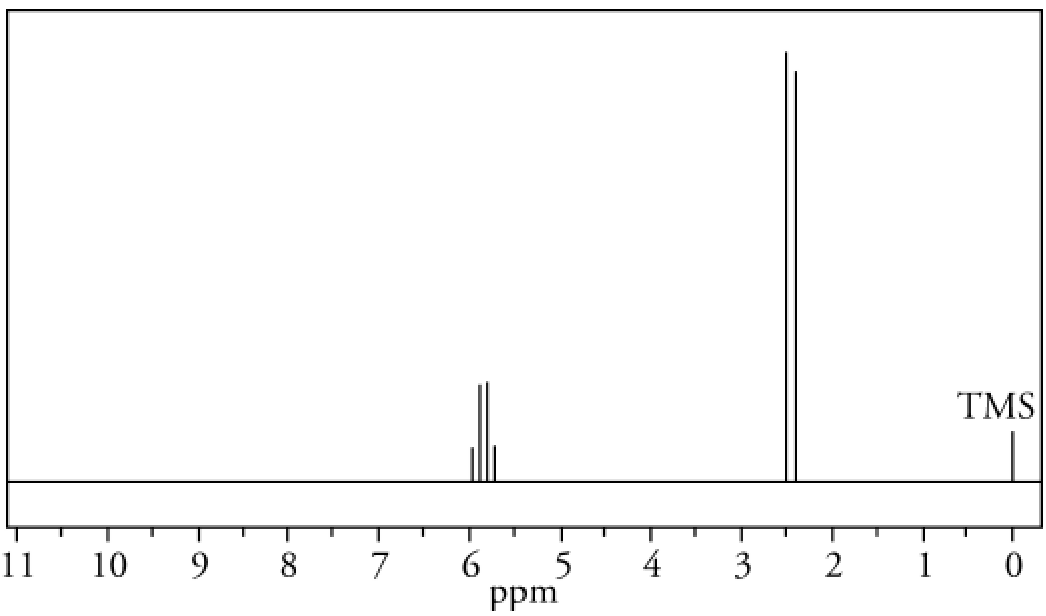


(i) Identify the species that produces the peak at m/z = 29.

(ii) What do the two molecular ion peaks indicate about the relative abundance of ^{79}Br and ^{81}Br? Give a reason for your answer.

(1 + 2 = 3 marks)

(b) There are two compounds that have the molecular formula $C_2H_4Br_2$. The ^1H NMR spectrum of **one** of these compounds is provided below.



(i) Draw the structural formula of each of the two compounds that have the molecular formula $C_2H_4Br_2$.

(ii) Which structure in part **(i)** corresponds to the ^1H NMR spectrum provided? Justify your selection by referring to both the ^1H NMR spectrum and to the structure of the compound.

(2 + 3 = 5 marks)

(Total = 8 marks)

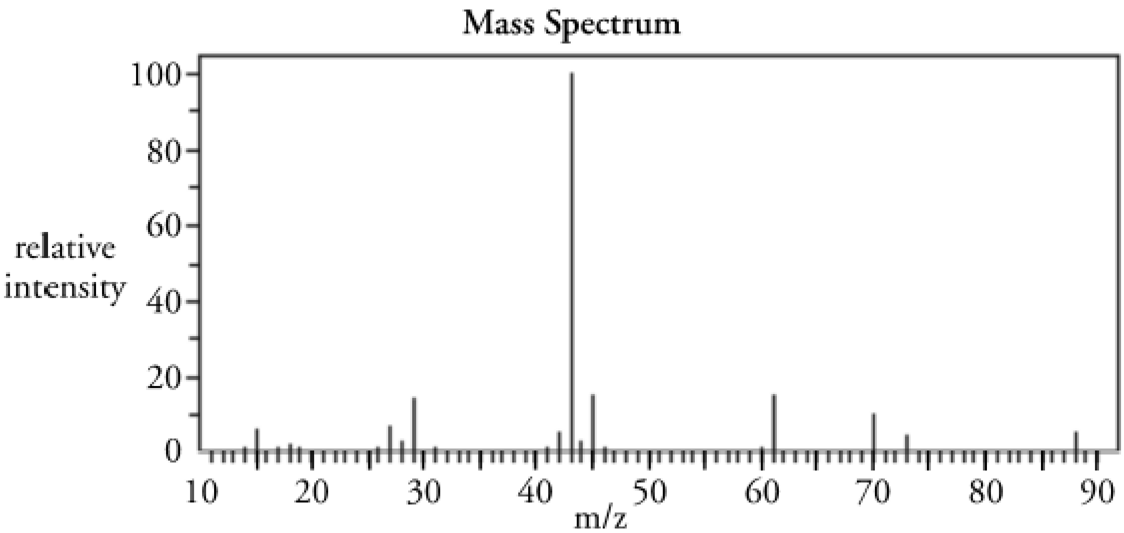
Question 14 / 35

[VCAA 2013 SB Q9]
An unknown organic compound, molecular formula $C_4H_8O_2$, was presented to a spectroscopy laboratory for identification. A mass spectrum, infrared spectrum, and both ^{1}H NMR (proton NMR) and ^{13}C NMR spectra were produced. These are shown below and following. The analytical chemist identified the compound as ethyl ethanoate. A report was submitted to justify the interpretation of the spectra. The chemist's report indicating information about the structure provided by the ^{13}C NMR spectrum has been completed for you.

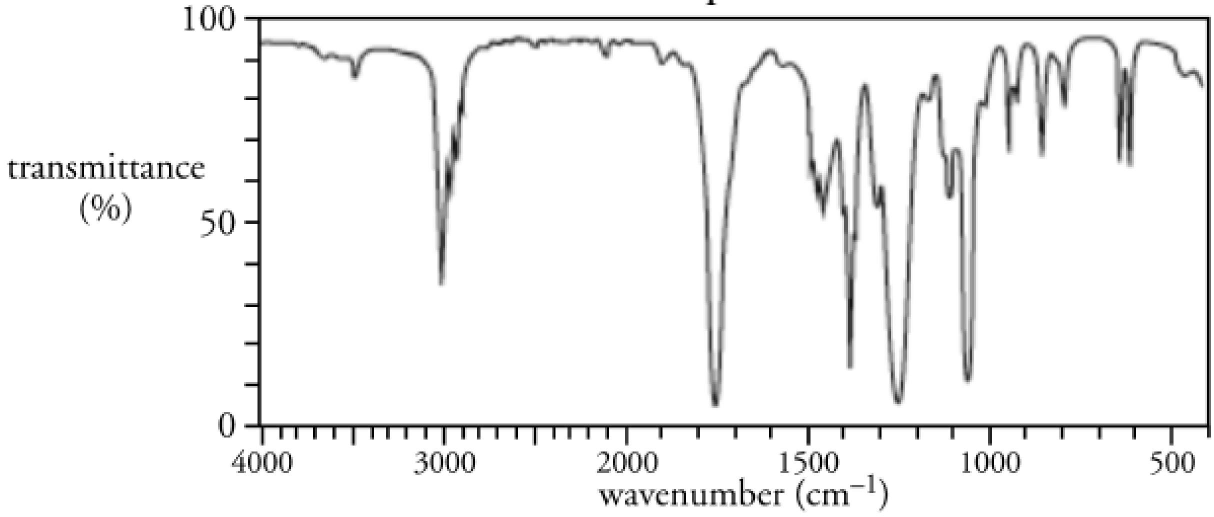
(a) Complete the rest of the report by identifying **one** piece of information from each spectrum that can be used to identify the compound. Indicate how the interpretation of this information justifies the chemist's analysis.

Spectroscopic technique	**Information provided**
^{13}C NMR spectrum	The four signals in the ^{13}C NMR spectrum indicate four different carbon environments, $CH_3COOCH_2CH_3$ has four different carbon environments.
Mass spectrum	
Infrared spectrum	
^{1}H NMR spectrum	

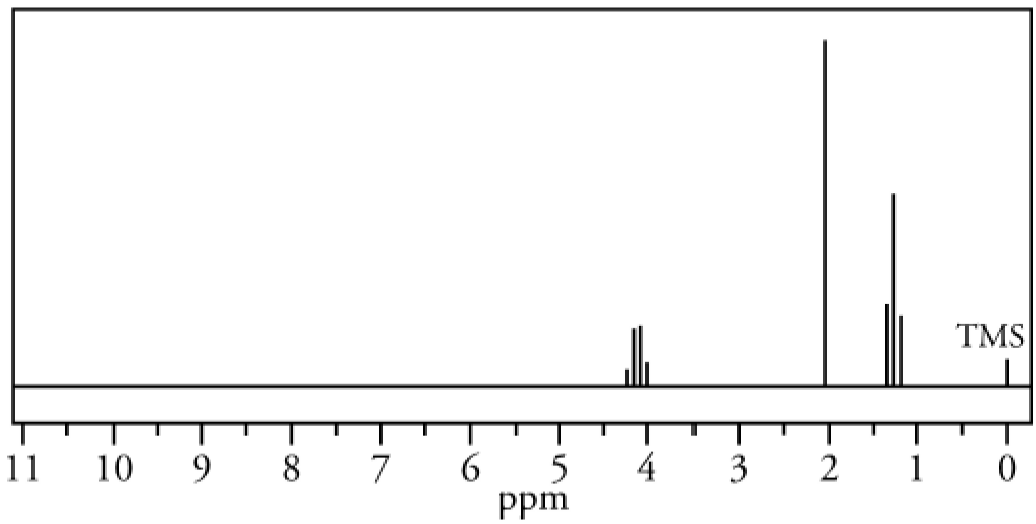
(6 marks)



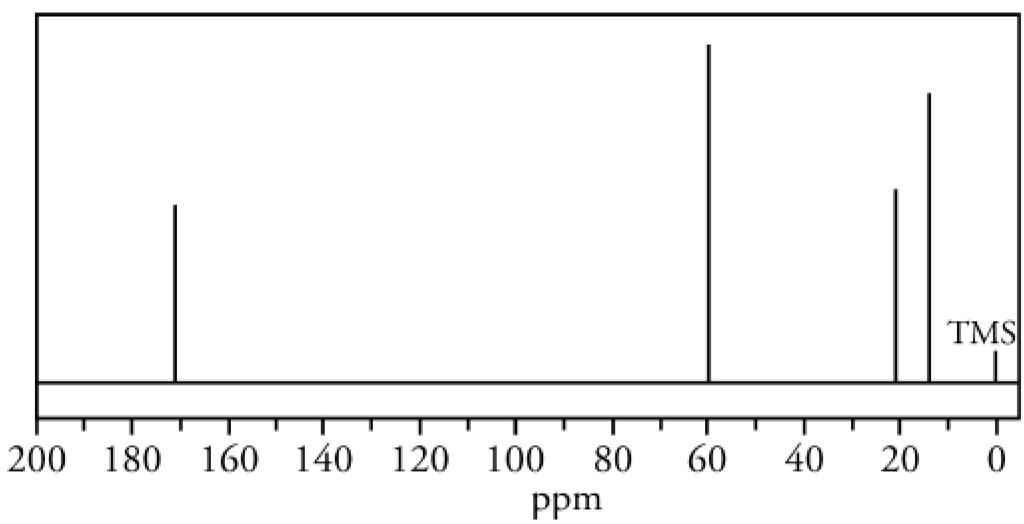
Infrared spectrum



Proton NMR spectrum



^{13}C NMR spectrum



(b) Another compound has the same molecular formula as ethyl ethanoate. However, the carbon ^{13}C NMR spectrum of this compound shows only three signals. Draw a possible structure of this compound.

(1 mark)

(Total = 7 marks)

Question 15 / 35

[VCAA 2013 SB Q9]
A small organic molecule has the molecular formula of the form $C_xH_yO_2Cl$. A pH probe was inserted into a dilute aqueous solution of this compound and the pH was 4.5. The infrared spectrum, mass spectrum, ^1H NMR spectrum and ^{13}C NMR spectrum of this compound are provided below and following.

(a) On the infrared spectrum, label the peaks that correspond to the presence of two functional groups in this compound. Note: The peak due to the C-Cl stretch has been labelled.

(2 marks)

(b) Use the data provided to determine the values of *x* and *y* in $C_xH_yO_2Cl$.

(2 marks)

(c) (i) What specific information about the structure of the compound is provided by the splitting pattern in the ^1H NMR spectrum?

(1 mark)

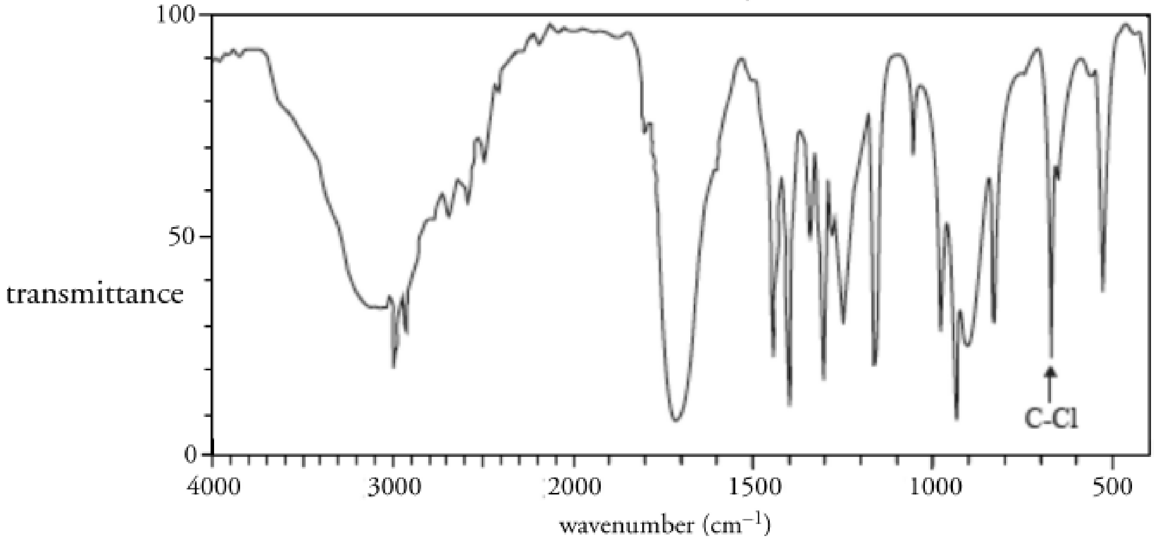
(ii) Draw the complete molecular structure for this molecule.

(1 mark)

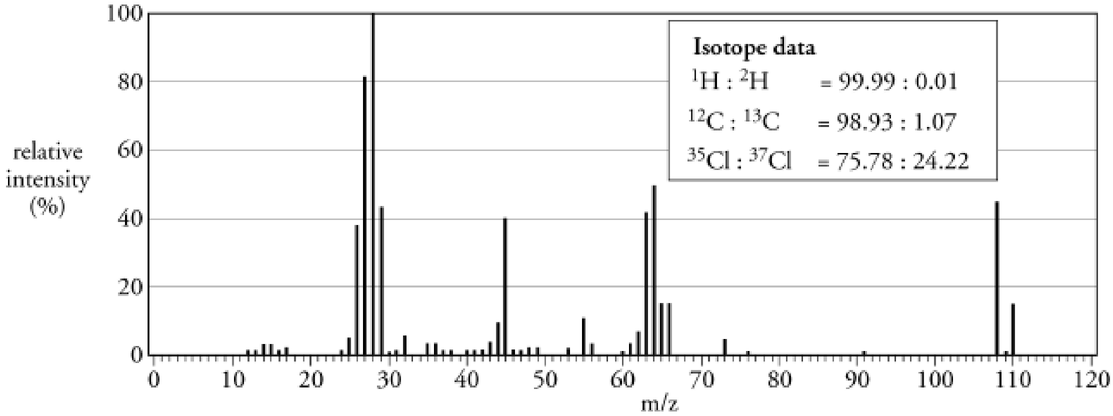
(d) Give a reason why the mass spectrum shows two molecular ion peaks at m/z = 108 and 110, rather than just one.

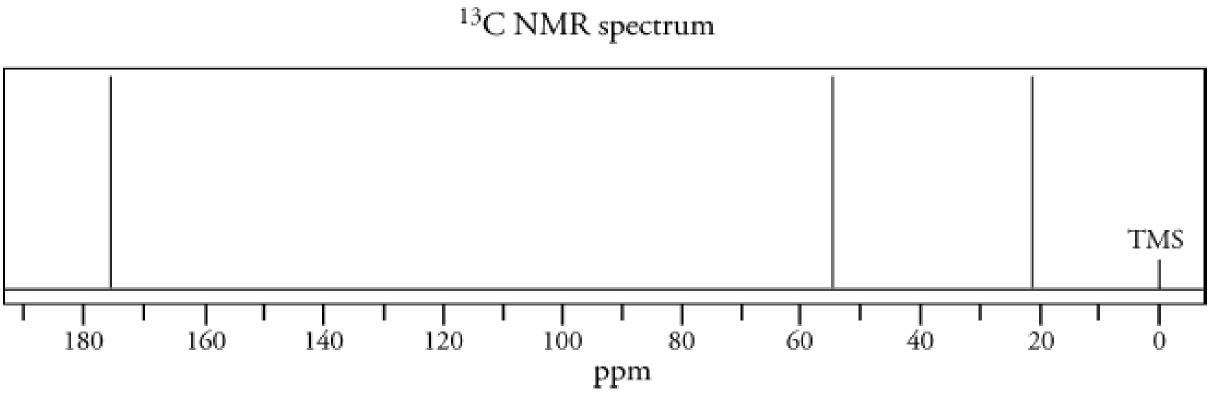
(1 mark)

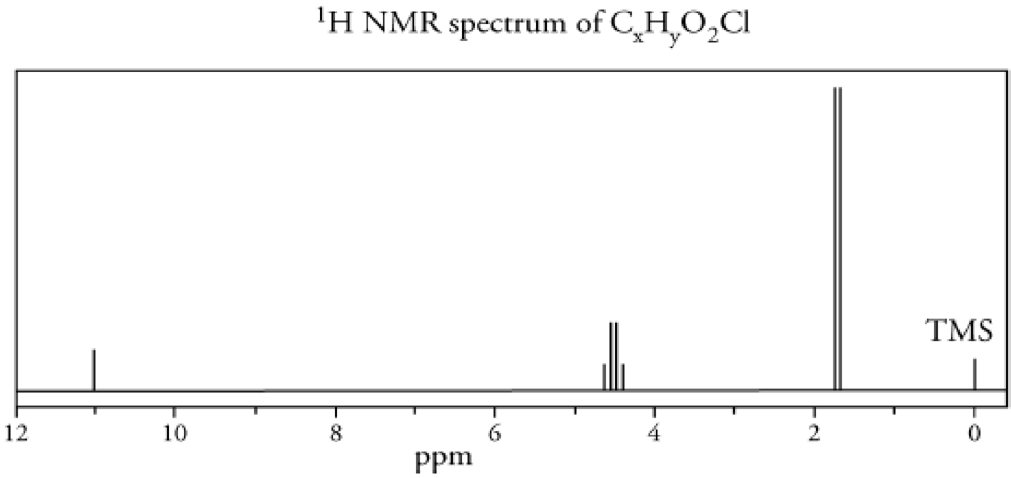
IR Spectrum of $C_xH_yO_2Cl$



$C_xH_yO_2Cl$ mass spectrum







^{1}H NMR data

Chemical shift (ppm)	**Peak splitting**	**Relative peak area**
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

(Total = 7 marks)

Question 16 / 35

[VCAA 2017 SA Q5]

There are a number of structural isomers for the molecular formula C_3H_6O. Three of these are propanal, propanone and prop-2-en-1-ol. The skeletal structure for the aldehyde propanal is as follows.

(a) (i) Write the semi-structural formula for the ketone isomer propanone.

(1 mark)

(ii) Draw the structural formula for the isomer prop-2-en-1-ol.

(1 mark)

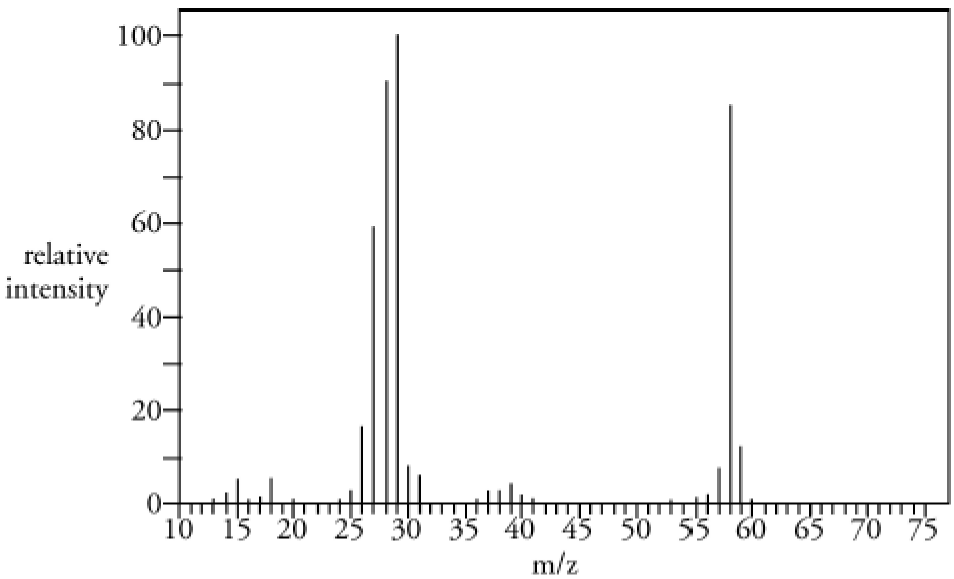
(b) The mass spectrum on the following page was produced by one of the three named isomers of C_3H_6O.

(i) Identify the fragment at 29 m/z.

(1 mark)

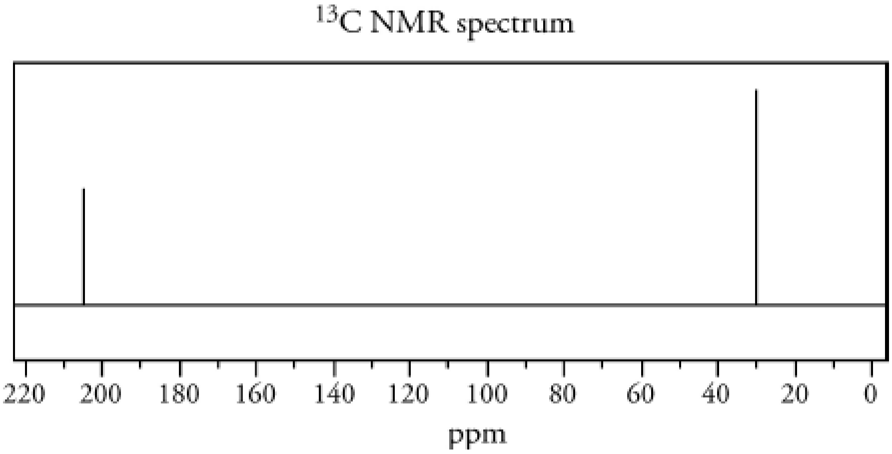
(ii) Name the isomer of C_3H_6O that produced this spectrum and justify your answer.

(3 marks)

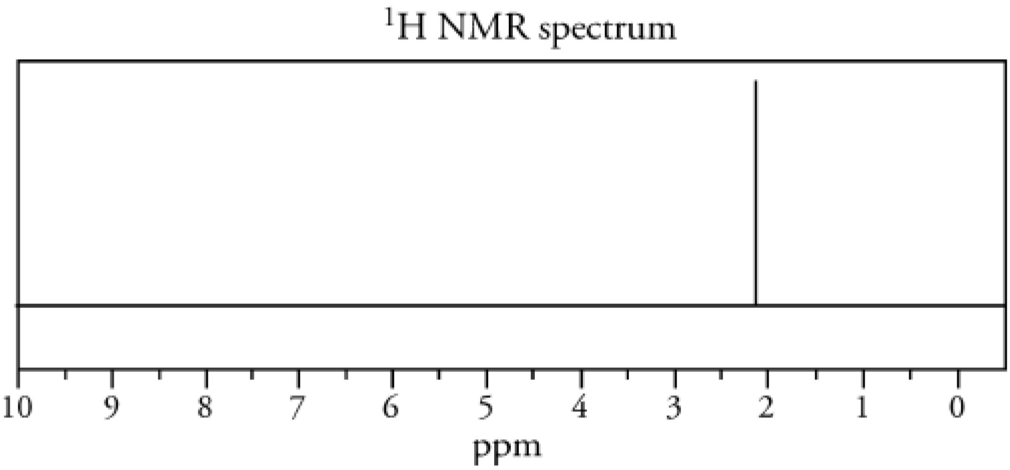


Data: SDBS Web, www.d.db.aist.go.jp, National Institute of Advanced Industrial Sience and Technology

(c) Consider the ^{13}C NMR and ^{1}H NMR spectra below.



Data: SDBS Web, www.d.db.aist.go.jp , National Institute of Advanced Industrial Sience and Technology



Data: SDBS National Institute of Advanced Industrial Science and Technology

Identify which one of the three named isomers of C_3H_6O produced these NMR spectra. Justify your answer by referencing both spectra.

(3 marks)

(Total = 9 marks)

Question 17 / 35

[VCAA 2019 SB Q8]
An unknown organic compound contains carbon, hydrogen and oxygen. It is known that:

• the compound does not contain carbon-to-carbon double bonds (C=C)

• the molecular ion peak is found at a mass-to-charge ratio (m/z) of 74

• the ^{13}C NMR has three distinct peaks.

(a) A small peak in the mass spectrum can be identified at m/z = 75.

Explain the presence of this peak.

(1 mark)

(b) (i) Use the information provided to give **two** possible molecular formulas for this compound.

(2 marks)

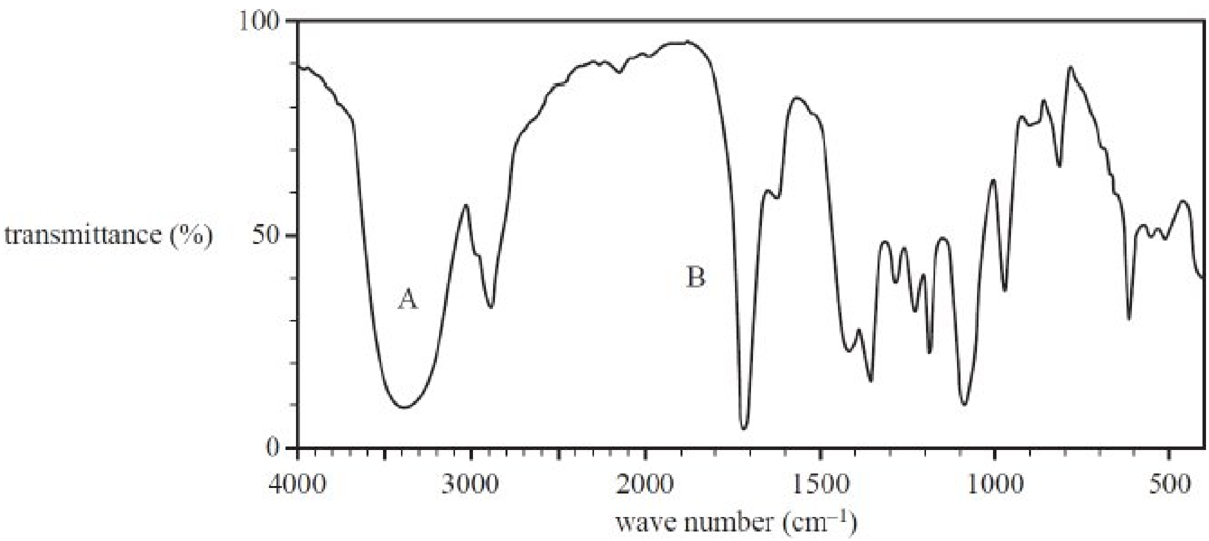
(ii) The ^{1}H NMR spectrum of the compound shows three sets of peaks with a peak area ratio of 3:2:1. What does this information tell you about the structure of the compound and its molecular formula? Justify your answer by referring to the information given about the peaks in the ^{1}H NMR spectrum.

(2 marks)

(c) There are many structural isomers of this compound. Draw the structural formulas of two possible isomers.

(2 marks)

(d) The infra-red (IR) spectrum of the compound is shown below.



Data: SDBS Web, www.d.db.aist.go.jp, National Institute of Advanced Industrial Sience and Technology

(i) Identify the functional groups responsible for the absorption peaks labelled A and B in the IR spectrum.

(1 mark)

A _______ B _______

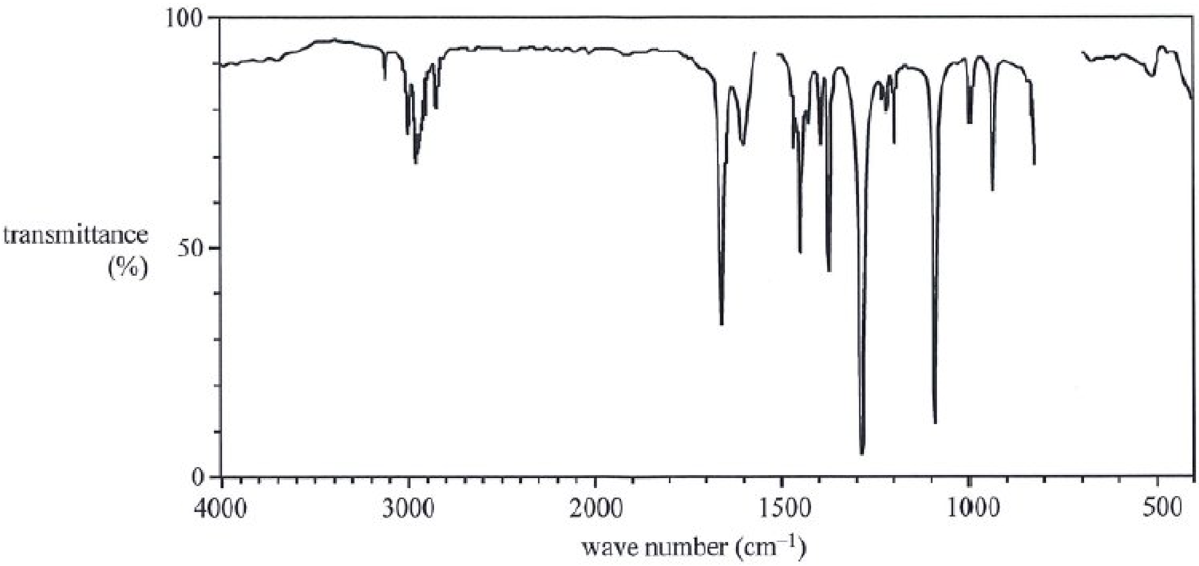
(ii) Using the ^{1}H NMR information given in **part (b)(ii)** and the IR spectrum provided above, draw the structural formula of the compound.

(1 mark)

(Total = 9 marks)

Question 18 / 35

[VCAA 2020 SB Q8]
An unknown organic compound has a molecular formula of C_4H_8O. The compound is **non-cyclic** and contains a **double bond**. The infra-red (IR) spectrum of the molecule is shown below.



Data: SDBS Web, www.d.db.aist.go.jp, National Institute of Advanced Industrial Sience and Technology

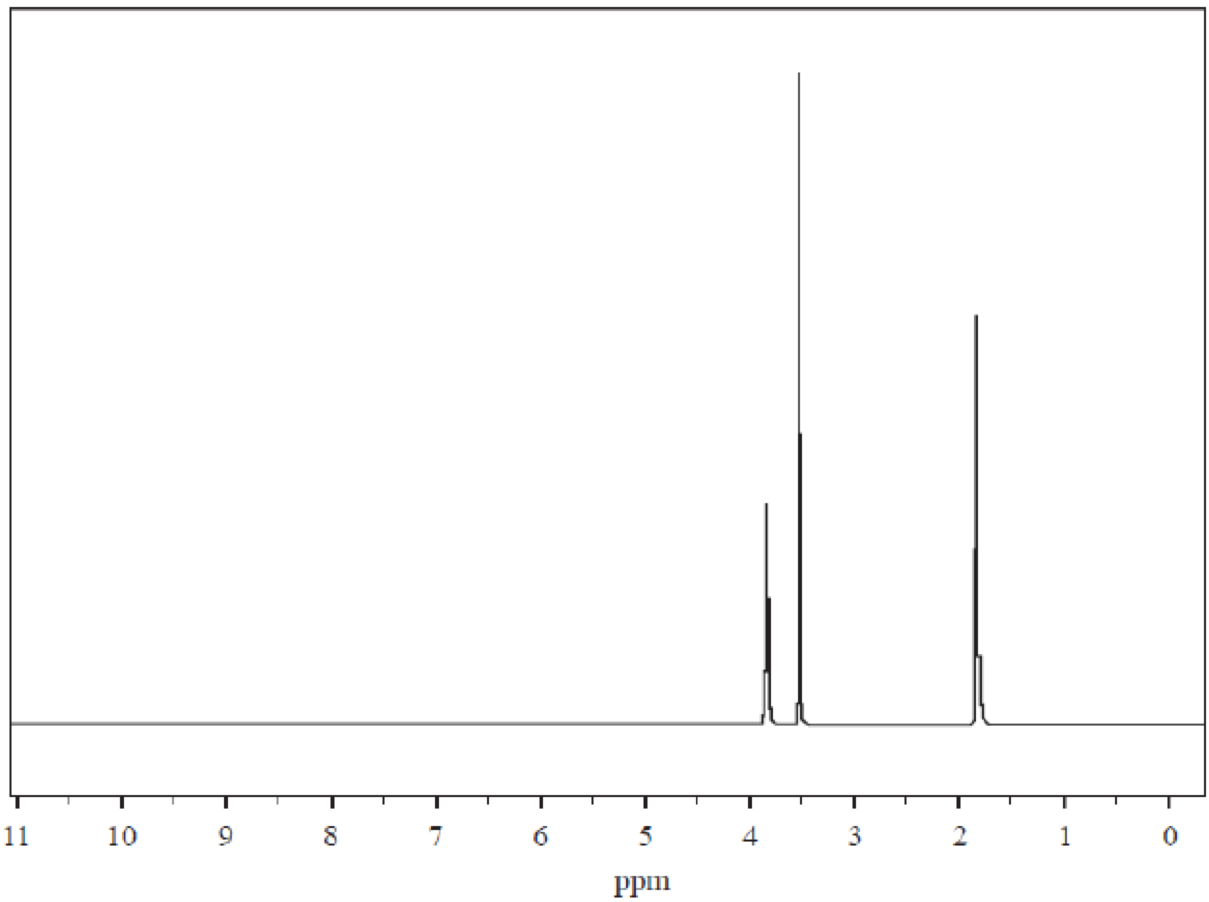
(a) What does the region 3100–4000 cm^{-1} indicate about the bonds in C_4H_8O? Give your reasoning.

(2 marks)

(b) The ^{13}C NMR spectrum of the unknown compound has four distinct peaks.
Draw **two** possible structural formulas of the unknown compound using the information provided.

(2 marks)

(c) The high-resolution ^1H NMR spectrum of the unknown compound has three single peaks, as shown below.



Data: SDBS Web, www.d.db.aist.go.jp, National Institute of Advanced Industrial Sience and Technology

Chemical Shift (ppm)	Relative peak area
1.82	3
3.53	3
3.85	2

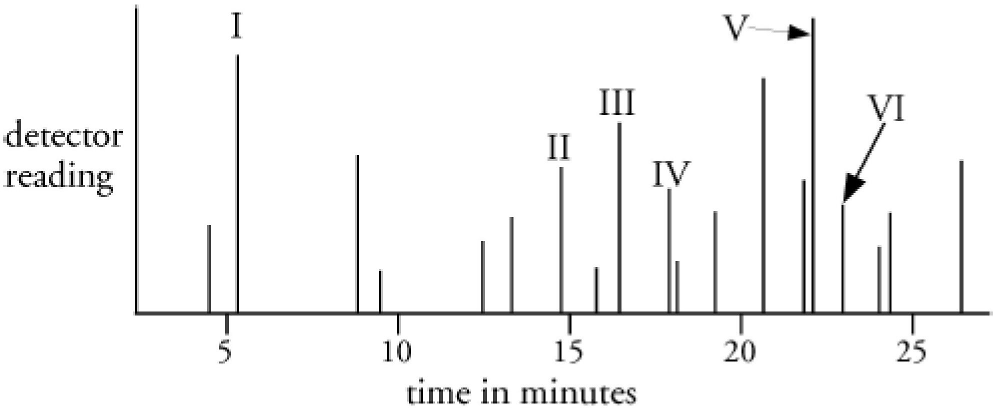
Refer to the ^{1}H NMR spectrum and the table of spectrum information provided. Identify three pieces of information about the unknown compound and indicate how each would assist in determining its structure.

(3 marks)

(Total = 7 marks)

Question 19 / 35

A simplified high-performance liquid chromatogram (HPLC) of a sample of standard grade petrol is shown below.



Some of the components labelled 'I' to 'VI' have been identified, as shown in the table below.

Component	Name	Formula
I	Butane	C_4H_{10}
II	Hexane	C_6H_{14}
III	Benzene	C_6H_6
V	Trimethylpentane	C_8H_{18}
VI	Methylheptane	C_8H_{18}

(a) Two of the identified compounds are isomers. Name the two compounds and explain your choice.

(2 marks)

(b) One of the above compounds is **not** an alkane. Identify this compound and give a reason for your choice.

(2 marks)

(c) Suggest a likely formula for the component labelled 'IV'.

(1 mark)

(d) When these compounds burn in an engine, the products are carbon dioxide and water. Write a balanced equation for the combustion of methylheptane.

(2 marks)

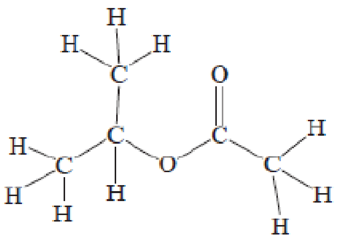
(Total = 7 marks)

Question 20 / 35

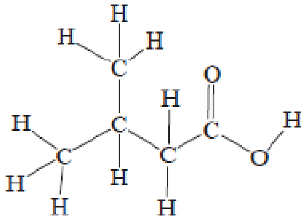
[VCAA 2021 SB Q7]

Two students are given a homework assignment that involves analysing a set of spectra and identifying an unknown compound. The unknown compound is one of the molecules shown below.

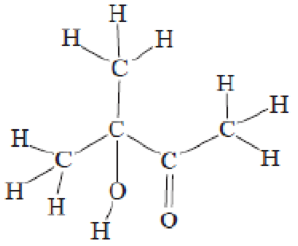
P



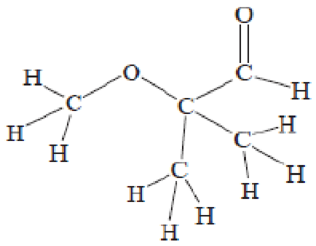
Q



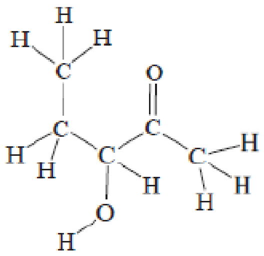
R



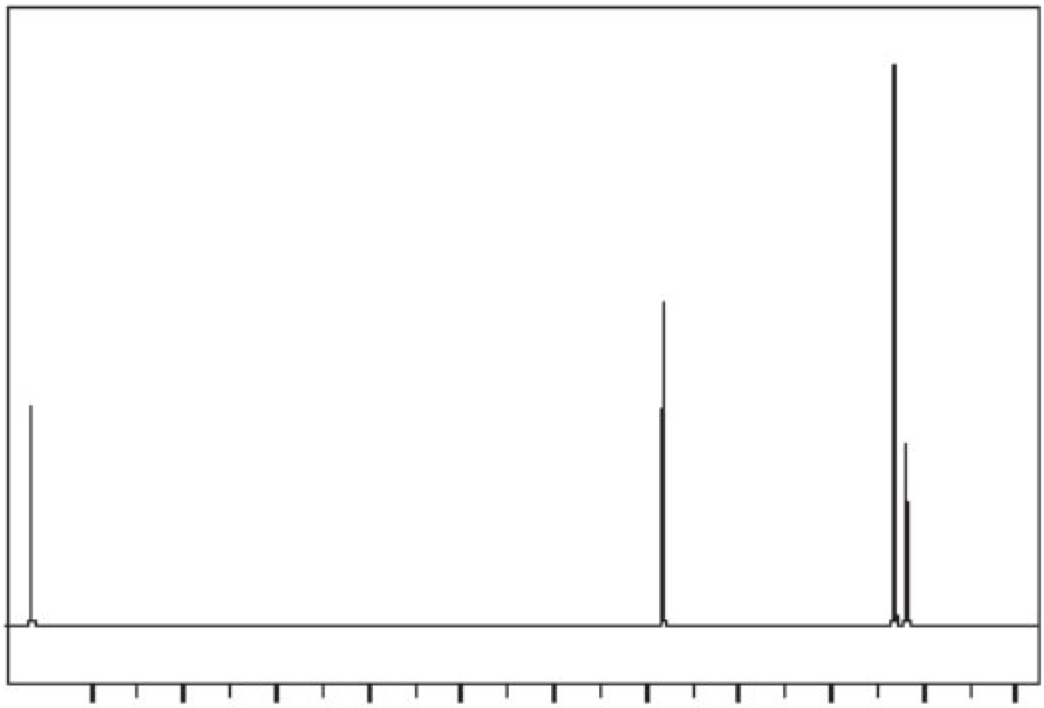
S



T



The ^{13}C NMR spectrum of the unknown compound is shown below.

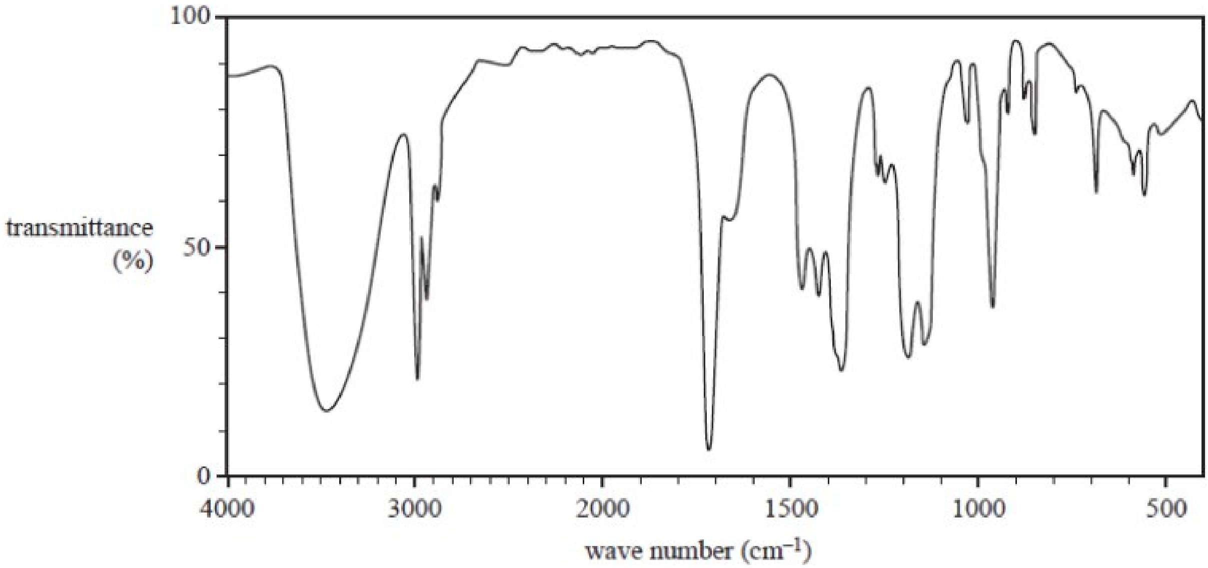


Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

(a) Based on the number of peaks in the ^{13}C NMR spectrum above, which compound- P, Q, R, S or T - could be eliminated as the unknown compound?

(1 mark)

(b) The infra-red (IR) spectrum of the unknown compound is shown below.

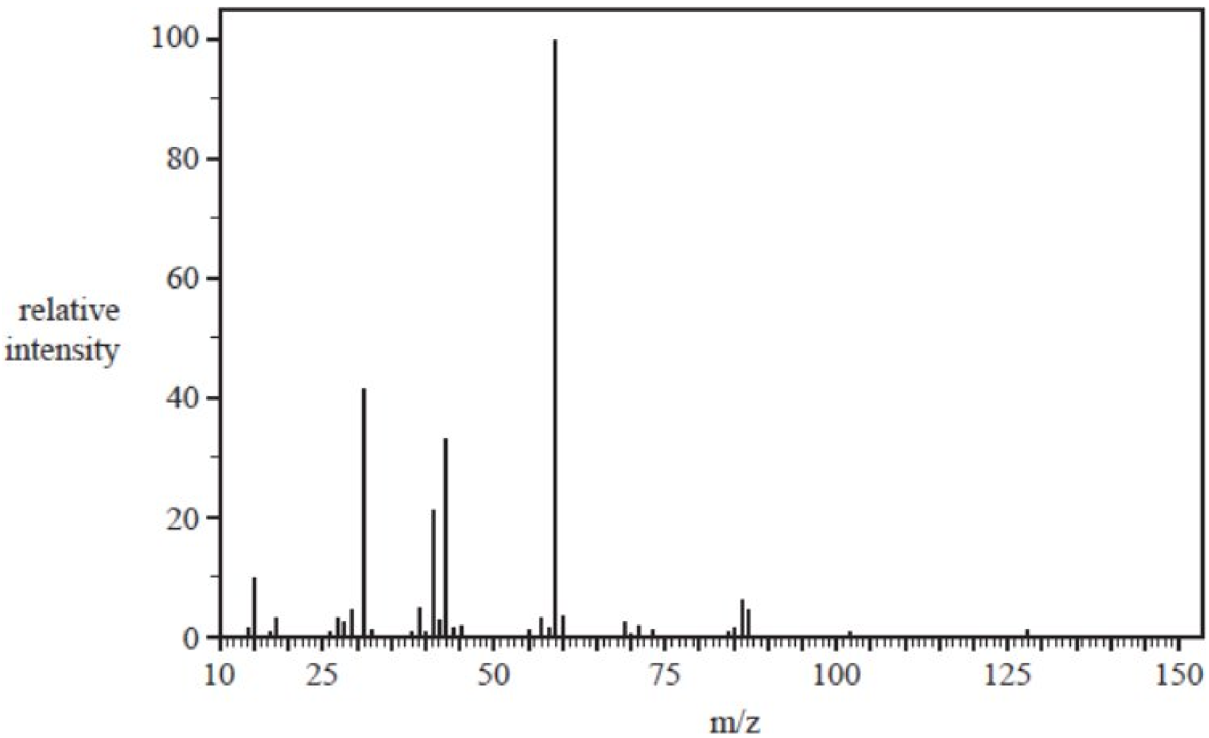


Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

Identify which of the five compounds can be eliminated on the basis of the IR spectrum. Justify your answer using data from the IR spectrum.

(3 marks)

(c) The mass spectrum of the unknown compound is shown below.



Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

(i) Write the chemical formula of the species that produces a peak at m/z = 43.

(1 mark)

(ii) Define m/z as used in mass spectroscopy.

(1 mark)

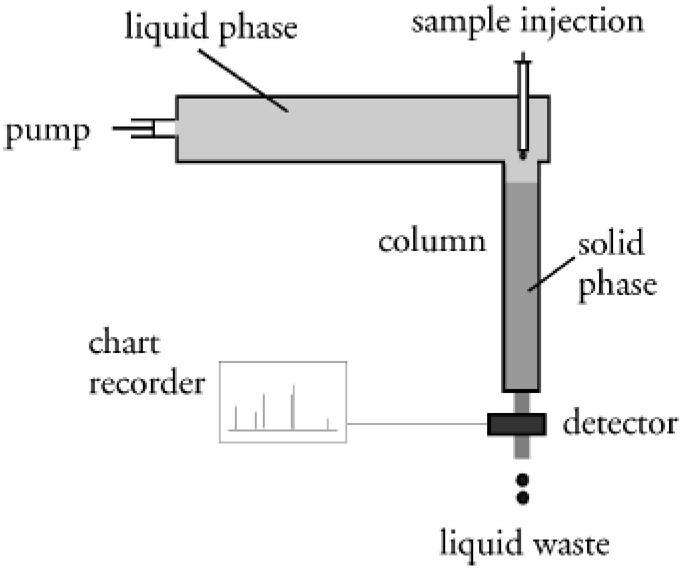
(iii) Explain why one molecule can produce multiple peaks on a mass spectrum.

(2 marks)

(Total = 8 marks)

Question 21 / 35

The diagram below represents the equipment used in high-performance liquid chromatography.



(a) What function does the liquid phase perform?

(1 mark)

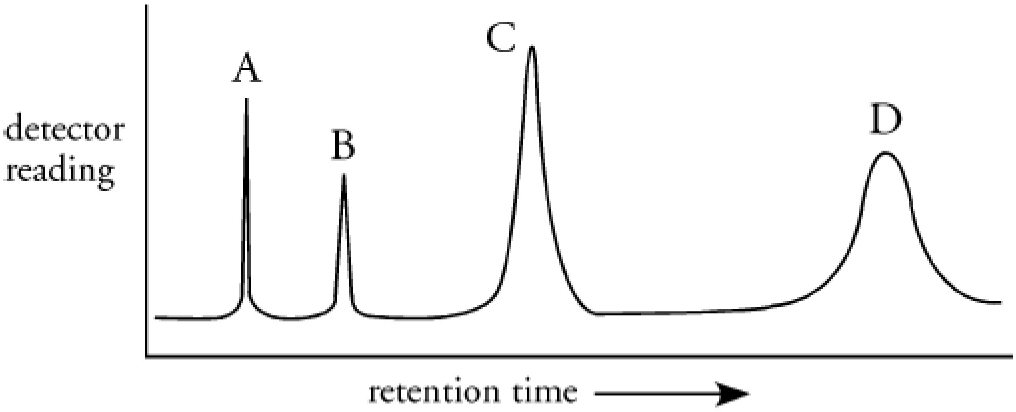
(b) How would a sample consisting of a mixture of solids be introduced into the equipment?

(1 mark)

(c) The size of the particles of the solid in the column is normally very small. Give one advantage and one disadvantage of using very small particles.

(2 marks)

(d) A mixture of liquid hydrocarbons was introduced into the equipment and part of the chromatogram is shown below.



Four of the hydrocarbons present in the mixture are heptane C_7H_{16}, hexane C_6H_{14}, nonane C_9H_{20} and pentane C_5H_{12}. If the strength of the interaction between the solid in the column and the hydrocarbon increases with increasing molar mass of the hydrocarbon, then give the name of the hydrocarbon that is most likely to give the peaks A, B, C and D.

A ___________

B ___________

C ___________

D ___________

(2 marks)

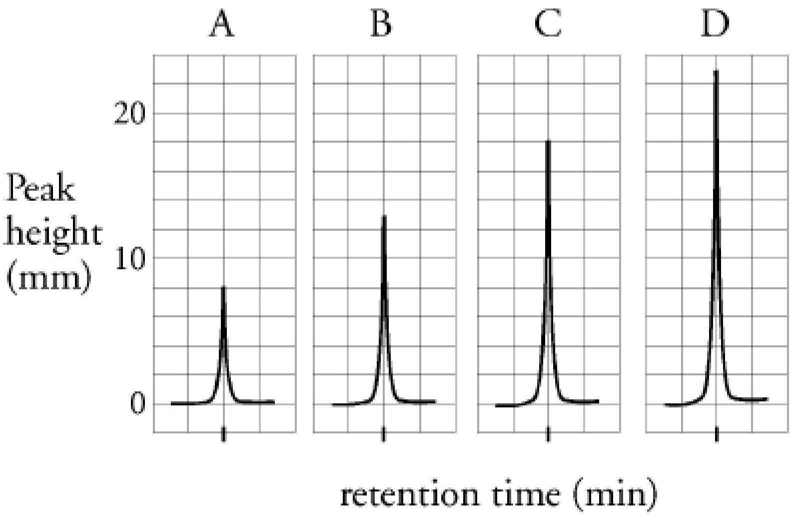
(e) If octane, C_8H_{18}, had been present in the mixture, how would you expect the chromatogram to differ from the one shown?

(2 marks)

(Total = 8 marks)

Question 22 / 35

High-performance liquid chromatography has been used to measure the amount of nicotine in biological fluids. In one experiment, a sample of a biological fluid was divided into four equal parts (A, B, C and D). Pure nicotine was added to parts B, C and D to increase their nicotine concentrations by 100 ng/mL, 200 ng/mL and 300 ng/mL, respectively. Part A was not modified. The high-performance liquid chromatogram of each part was measured using the same conditions each time. The results for each part are shown below.



(a) How does the experimenter know that the peak being observed is due to nicotine?

(1 mark)

(b) Use the information above to deduce the concentration of nicotine in the biological fluid.

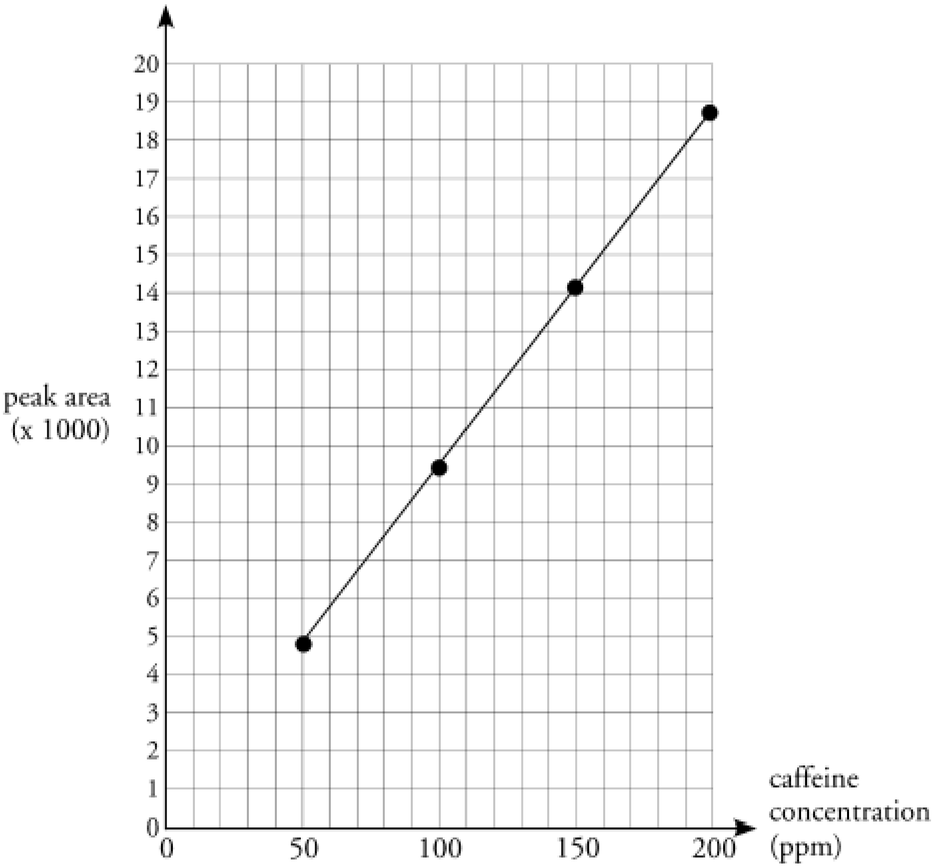
(2 marks)

(Total = 3 marks)

Question 23 / 35

[VCAA 2011 E1 SB Q3]

Caffeine is a stimulant drug that is found in coffee, tea, energy drinks and some soft drinks. The concentration of caffeine in drinks can be determined using HPLC. Four caffeine standard solutions containing 50 ppm, 100 ppm, 150 ppm and 200 ppm were prepared. 25μL of each sample was injected into the HPLC column. The peak areas for the standard solutions were measured and used to construct the calibration graph shown below. The chromatograms of the standard solutions each produced a single peak at a retention time of 96 seconds.



25μL samples of various drinks thought to contain caffeine were then separately passed through the HPLC column. The results are summarised below.

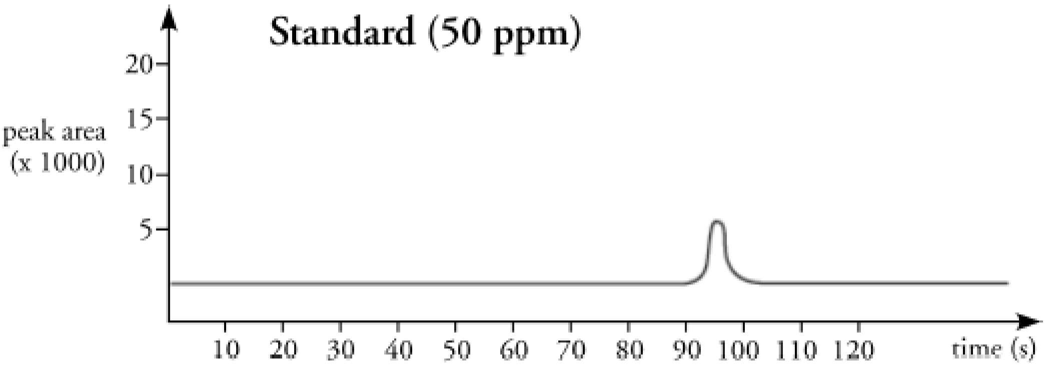
Sample	**Retention time of major peak (seconds)**	**Peak area of largest peak**
Soft drink A	96	12 000
Soft drink B	32	8 500

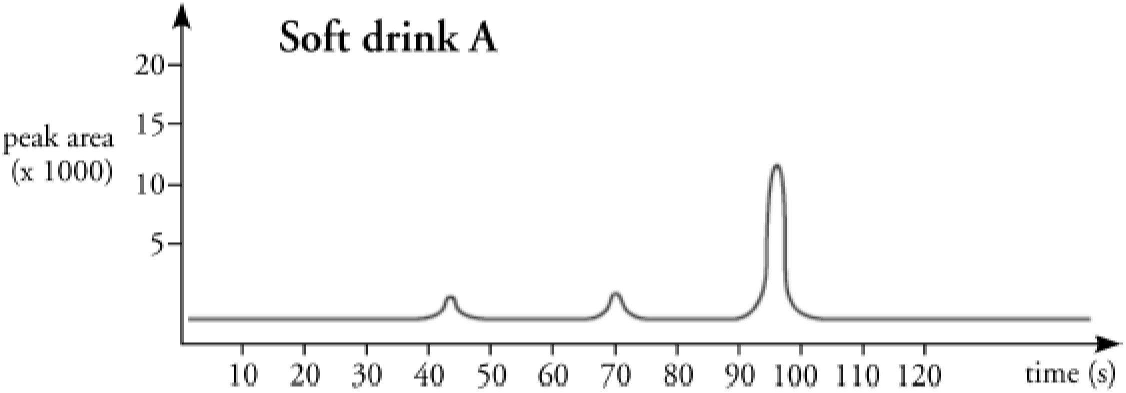
Sample	Retention time of major peak (seconds)	Peak area of largest peak
Espresso coffee	96	211 000

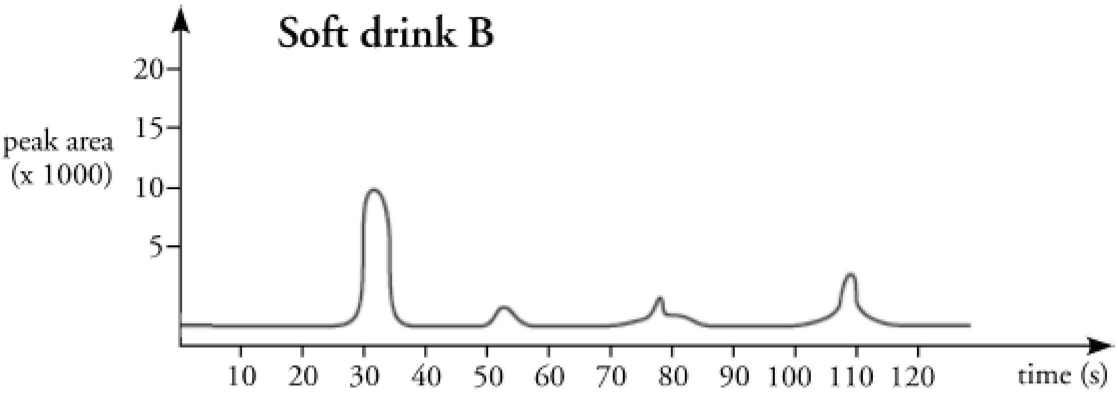
(a) Determine the caffeine content, in ppm, of soft drink A.

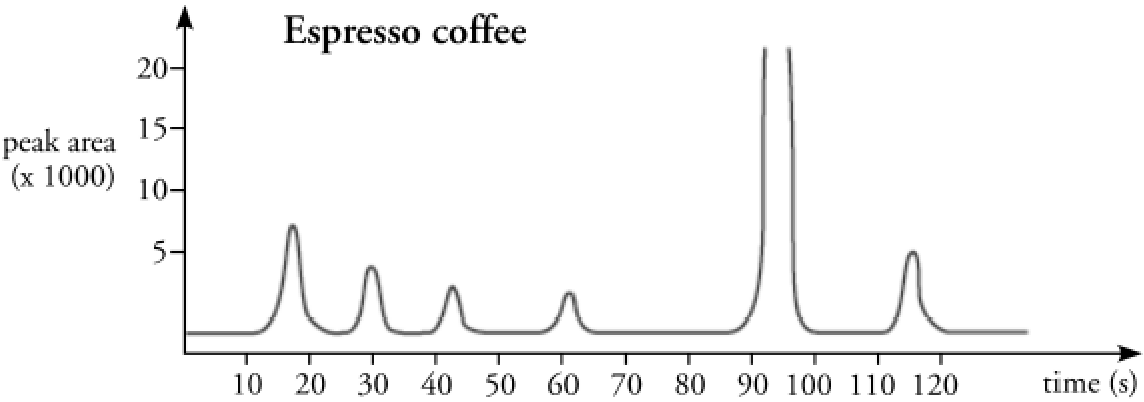
(1 mark)

The chromatograms of the 50 ppm standard caffeine solution, soft drink A, soft drink B and espresso coffee are shown below.









(b) What evidence is presented in the chromatogram that supports the conclusion that soft drink B does not contain any caffeine?

(1 mark)

(c) (i) Explain why the caffeine content of the espresso coffee sample cannot be reliably determined using the information provided.

(1 mark)

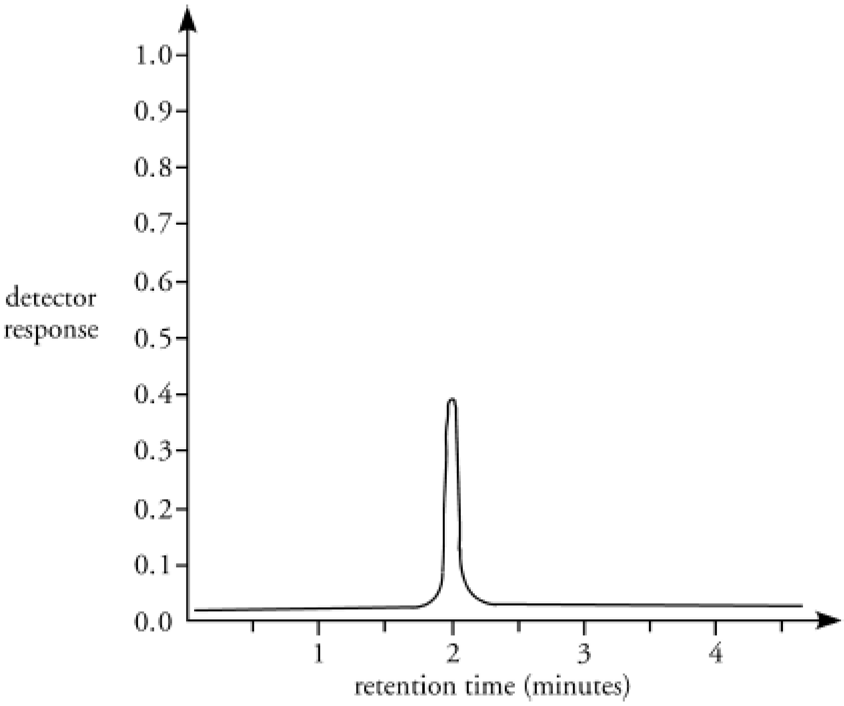
(ii) Describe what could be done to the espresso coffee sample so that its caffeine content can be reliably determined using the information provided.

(1 mark)

(Total = 4 marks)

Question 24 / 35

[VCAA 2013 SB Q1]
High-performance liquid chromatography is used to determine the amount of caffeine in a sample of a soft drink. The chromatogram below shows the detector response when a standard solution of caffeine with a concentration of 200 mg L^{-1} is measured using the instrument.



(a) What is the retention time of caffeine in this experiment?

(1 mark)

(b) On the chromatogram above, sketch the detector response when a commercial soft drink with a caffeine content of 350 mg L^{-1} is measured using the same instrument.

(1 mark)

(Total = 2 marks)

Question 25 / 35

[VCAA 2021 SB Q9]
Aspartame is an ingredient in some soft drinks. Aspartame is unstable in some conditions and reacts to form four main products. One of the products of aspartame breakdown is 5-benzyl-3,6-dioxo-2-piperazineacetic acid (DKP). It is thought that DKP may be harmful to humans.

A student, Kim, investigates the effect of storage temperature on the rate of production of DKP from aspartame in lemonade. Experimental data is obtained using high-performance liquid chromatography (HPLC) to analyse the aspartame and DKP content in lemonade samples.

HPLC calibration

Kim first calibrated the HPLC using the following method:

1. Prepare and refrigerate a standard solution of pure aspartame with a concentration of 1000 mg L^{-1}.

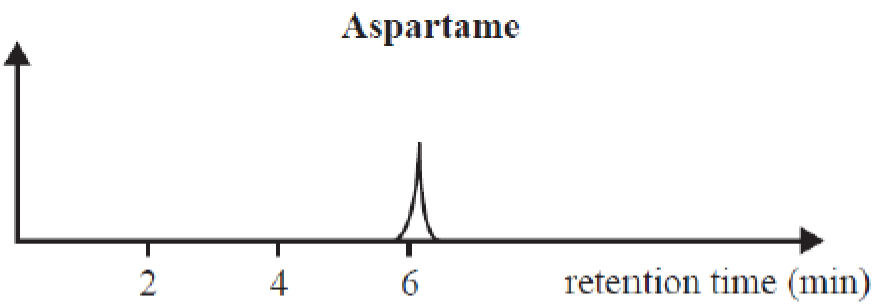
2. Transfer a 10.00 mL aliquot of the pure aspartame solution into a 1.000 L volumetric flask.

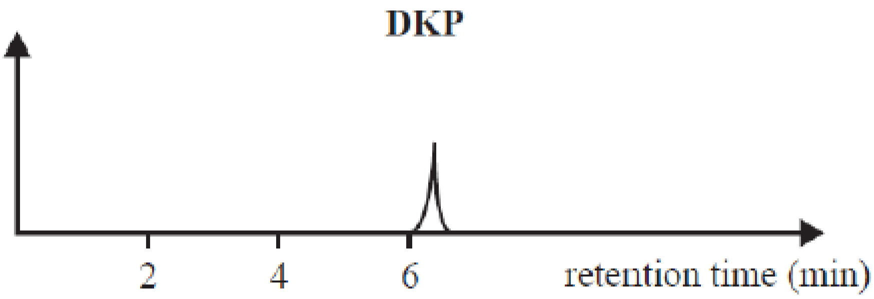
3. Fill the volumetric flask up to the 1.000 L mark with deionised water and shake the flask.

4. Inject a sample of the diluted aspartame solution into the HPLC to obtain a chromatogram.

5. Repeat steps 1–4 with DKP.

The following two calibration chromatograms were obtained.





Analysis of lemonade samples

Kim then followed the method given in steps 6–14 to investigate the rate of production of DKP from aspartame in lemonade at different storage temperatures.

6. Open a can of lemonade.

7. Transfer a 10.00 mL aliquot of lemonade from the can into a 1.000 L volumetric flask.

8. Fill the volumetric flask up to the 1.000 L mark with de-ionised water and shake the flask.

9. Inject a sample of the diluted lemonade into the HPLC using the same operating conditions used during calibration.

10. Set up three water baths at temperatures of 15 °C, 25 °C and 35 °C.

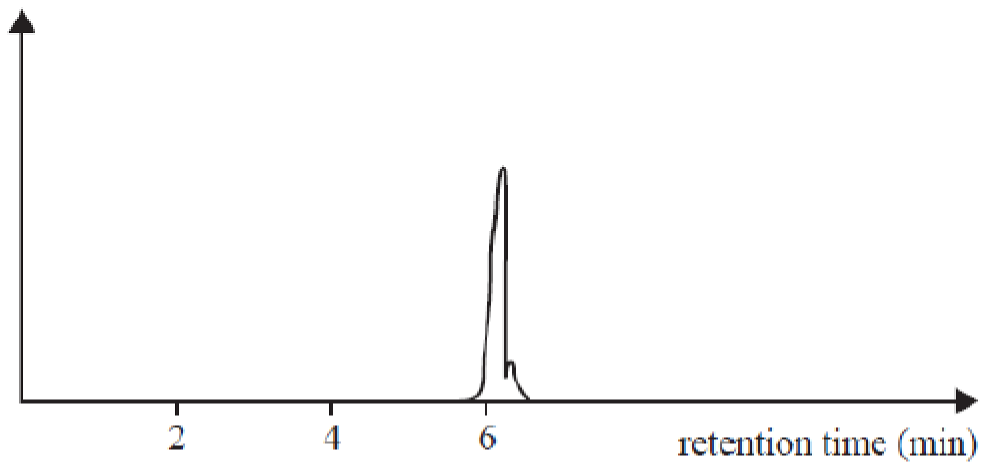
11. Put three unopened cans of lemonade into each of the three water baths.

12. After one day, take one can from each water bath and follow steps 6–9.

13. After two days, take one can from each water bath and follow steps 6–9.

14. After three days, take one can from each water bath and follow steps 6–9.

One of the chromatograms from the diluted lemonade is given below.



(a) Using your knowledge of food chemistry, explain why aspartame is sometimes added to lemonade.

(2 marks)

(b) (i) What is the dependent variable?

(1 mark)

(ii) What steps, in addition to steps 1–14, need to be taken to use the HPLC data to measure the dependent variable?

(3 marks)

(c) (i) State a change to the operating conditions of the HPLC that could be made to reduce the errors in measuring the concentrations of aspartame and DKP.

(1 mark)

(ii) State how this change would reduce the measurement errors.

(1 mark)

Kim found that the can of lemonade tested at the beginning of the experiment contained:

• 0.00178 M aspartame

• 0.00045 M DKP.

Kim quantified the remaining data from the HPLC and prepared the following table.

Storage temperature	**Concentration after one day (M)**		**Concentration after two days (M)**		**Concentration after three days (M)**	
	Aspartame	**DKP**	**Aspartame**	**DKP**	**Aspartame**	**DKP**
15 °C	0.00179	0.000430	0.00175	0.00042	0.00176	0.00041
25 °C	0.00175	0.00044	0.00172	0.00046	0.00171	0.00063
35 °C	0.00160	0.00051	0.00155	0.00049	0.00154	0.00058

(d) Write a conclusion based on the results given in the table above.

(1 mark)

(e) (i) Identify a variable that has not been controlled.

(1 mark)

(ii) Explain how the variable identified in **part e.i.** affects the validity of the experiment.

(1 mark)

(Total marks = 11 marks)

Question 26 / 35

There are many alcohol isomers with the formula $C_5H_{12}O$.

(a) Draw semi-structural formulae for two of the isomers that contain a chiral carbon atom. Identify the carbon atom with a ‘*’.

(4 marks)

(b) For one of the isomers given in part **(a)**, draw the structural formulae to show how the two optical isomers are related to each other.

(2 marks)

(Total = 6 marks)

Question 27 / 35

Two closely related nonapeptides are oxytocin and vasopressin. They have many amino acid residues in common but have very different functions. The sequence of amino acid residues in the two peptides are given below.

Cys — Tyr — Ile — Gln — Asn — Cys — Pro — Leu — Gly

oxytocin

and

Cys — Tyr — Phe — Gln — Asn — Cys — Pro — Arg — Gly

vasopressin

Oxytocin regulates two female reproductive functions, childbirth and breast feeding. Vasopressin helps prevent loss of water by reducing urine output and helps the kidneys re-absorb water.

(a) List the differences in amino residues between the two nonapeptides.

(2 marks)

(b) In each nonapeptide, how are the two cysteine residues bonded together?

(1 mark)

(c) How many amide functional groups are in each oxytocin molecule?

(1 mark)

(d) What changes have followed from the variation in amino acid sequence that have led to the different properties of the two nonapeptides?

(2 marks)

(Total = 6 marks)

Question 28 / 35

Glycine, lysine and glutamic acid are three amino acids found in proteins.

(a) 0.05 M aqueous solutions of each of these amino acids are prepared. Place the three solutions in order of increasing pH. Give an explanation for your answer.

(3 marks)

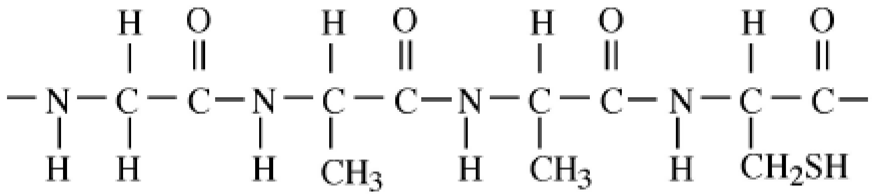
(b) When glycine reacts with lysine, apart from water, there are three possible products. Give the structures of these three products.

(3 marks)

(Total = 6 marks)

Question 29 / 35

The structure of part of a protein is shown below.



(a) Circle any peptide links in this structure.

(1 mark)

(b) Draw the structural formulae of the three amino acids from which this part of the protein has been made.

(3 marks)

(c) What type of reaction is needed to convert the protein into its constituent amino acids?

(1 mark)

(d) Large protein molecules are usually twisted and folded into a unique shape that determines the function of the protein. Describe two ways in which the protein structure is maintained.

(2 marks)

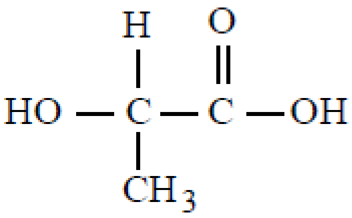
(e) An amino acid found in many proteins has the molecular formula $C_3H_7O_3N$. Draw the structural formula of this amino acid and name it.

(2 marks)

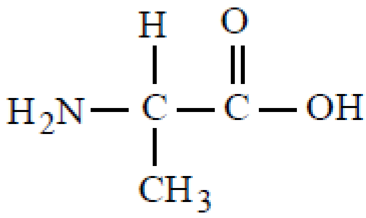
(Total = 9 marks)

Question 30 / 35

Alanine and lactic acid are two molecules that are found in many living systems. The structural formulae of these molecules are shown below.



lactic acid



alanine

(a) Name the functional group present in both compounds.

(1 mark)

(b) When alanine reacts with lactic acid two different organic products are formed.

(i) What type of reaction is most likely to occur between alanine and lactic acid?

(1 mark)

(ii) Draw the semi-structural formulae of these two products.

(2 marks)

(iii) For one of the substances given in part **(ii)**, name the new functional group formed.

(1 mark)

(Total = 5 marks)

Question 31 / 35

[VCAA 2011 E1 SB Q8]
Bradykinin is a peptide that lowers blood pressure. Diagram I shows the amino acid sequence of bradykinin.

Arg—Pro—Pro—Gly—Phe—Ser—Pro—Phe—Arg

Diagram 1

Diagram II below shows the structure of a section of the bradykinin molecule.

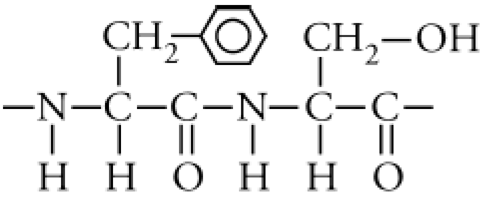


Diagram II

(a) On **diagram I**, circle the section of bradykinin that is represented in diagram II.

(1 mark)

(b) Peptides can be completely hydrolysed to their component amino acids by treatment with 6 M HCl. Identify the two functional groups that are formed as a result of the hydrolysis of the peptide link.

(2 marks)

(c) Draw the chemical structure, showing all bonds, of the amino acid glycine as it would exist in solution at pH = 1.

(1 mark)

(Total = 4 marks)

Question 32 / 35

[VCAA 2014 SB Q7]
Amino acids can be classified according to the nature of their side chains (Z groups). These may be polar, non-polar, acidic or basic.

(a) Referring to the data book, name one amino acid that has a non-polar side chain and one amino acid that has an acidic side chain.

(2 marks)

The table below provides examples of different categories of side chains at a pH of 7.

Name of amino acid	**Structure of side chain of pH 7**
alanine (Ala)	$–CH_3$
asparagine (Asn)	$–CH_2–CO–NH_2$
aspartic acid (Asp)	$–CH_2COO^-$
cysteine (Cys)	$–CH_2–SH$
lysine (Lys)	$–CH_2–CH_2–CH_2–CH_2–NH_3^+$
serine (Ser)	$–CH_2OH$

(b) The tertiary structure of proteins is a result of the bonding interactions between side chains of amino acid residues. Use the information provided in the table to

(i) identify the amino acid that is involved in the formation of disulfide bonds (sulfur bridges).

(1 mark)

(ii) give an example of **two** amino acid side chains that may form hydrogen bonds between each other.

(1 mark)

(iii) give an example of amino acid side chains that may form ionic bonds (salt bridges) between each other.

(1 mark)

(iv) identify the type of bonding that exists between the side chains of two alanine residues.

(1 mark)

(c) The enzyme trypsin catalyses the breaking of peptide bonds in proteins. Trypsin is active in the upper part of the small intestine, where the pH is between 7.5 and 8.5. Trypsin is not effective in the stomach, where the pH is 4. Suggest a reason why.

(1 mark)

(Total = 7 marks)

Question 33 / 35

[VCAA 2013 SB Q3]
Spider webs are very strong and elastic. Spider web silk is a protein that mainly consists of glycine and alanine residues.

(a) Assuming that these amino acid residues alternate in a spider web, draw a section of the spider web protein that contains at least **three** amino acid residues.

(2 marks)

(b) What is the name of the bond between each amino acid residue?

(1 mark)

(c) What type of polymerisation reaction occurs in the formation of spider web silk?

(1 mark)

Glycine forms an ion at a pH of 6 that has both a positive and negative charge.

(d) Draw the structure of a glycine ion at a pH of less than 4.

(1 mark)

(e) Describe the bonds that contribute to the spiral secondary structure of this protein.

(2 marks)

(Total = 7 marks)

Question 34 / 35

[Adapted VCAA 2015 SB Q6]
After a murder had been committed, a forensic chemist obtained crime scene blood samples and immediately placed them in two sterile containers labelled Sample I and Sample II.

The chemist discovered that Sample I contained a particular protein, which was analysed to reveal the following sequence of amino acid residues.

-ser-gly-tyr

(a) Referring to the data book, draw the structure of this sequence of amino acid residues and circle one amide link/peptide bond in your drawing.

(3 marks)

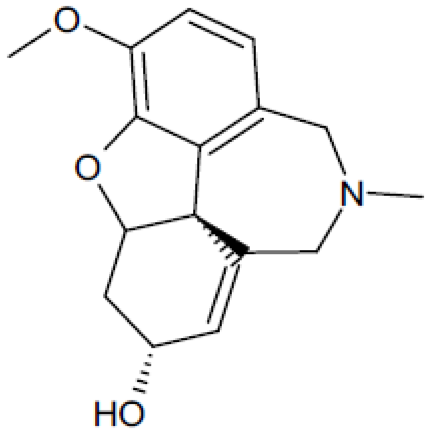
(b) The protein was hydrolysed in the presence of a suitable enzyme and the amino acid glycine was isolated. The glycine sample was then dissolved in a 0.1 M solution of sodium hydroxide. Draw the structure of glycine in this solution.

(1 mark)

(Total = 4 marks)

Question 35 / 35

Amaryllidaceae is a family of plants that grow from bulbs and are generally found in tropical regions. Many plants from the Amaryllidaceae family contain an organic compound called galanthamine, the structure of which is shown below.



(a) Circle and name **one** functional group found in galanthamine.

(1 mark)

(b) Acetylcholinesterase is an enzyme found within human neural tissue. This enzyme helps produce choline, a neural transmitter, in the simplified reaction shown:

acetylcholine + H_2O → choline + acetate

Galanthamine can be used as a treatment for Alzheimer's disease, a degenerate neurological disease that slowly impacts memory in humans. Galanthamine works by slowing the rate of the above reaction through interacting with acetylcholinesterase. Provide an explanation for how galanthamine might slow the rate of the reaction.

(2 marks)

(c) Galanthamine is extracted from the bulbs and flowers using ethanol.

This leaves a 0.10 % mixture of galanthamine in ethanol. The galanthamine must be isolated from the ethanol.

(i) Explain how mixing the galanthamine mixture with a significant volume of water can be used to separate the galanthamine from the ethanol.

(ii) Explain how distillation can be used to separate the galanthamine from the ethanol.

(2 + 2 = 4 marks)

(Total = 7 marks)

Question 1 / 14

The most commonly found amino acids have the general formula $H_2N–CHZ–COOH$. For an amino acid with the molecular formula $C_4H_7O_4N$, the formula of the group Z will be

---

A.

$–CH(OH)CH_3$

B.

$–CH_2OCH_3$

C.

$–CH_2COOH$

D.

$–CH_2CH_2COOH$

Question 2 / 14

Three amino acids are glycine (relative molecular mass = 75), alanine (relative molecular mass = 89) and serine (relative molecular mass = 105). The molar mass of the tripeptide formed when one molecule of each react together is

---

A.

269

B.

251

C.

233

D.

215

Question 3 / 14

The following statements concern the amino acids isoleucine and leucine.

I They can both react with acids and bases.

II They are soluble in water and are present as zwitterions.

III They are isomers.

IV They react with each other to form one dipeptide.

Which of these statements are correct?

A.

I, III and IV

B.

II, III and IV

C.

I, II and IV

D.

I, II, and III

Question 4 / 14

Three functional groups that are found in many naturally occurring compounds are

I hydroxy, –OH

II carboxylic acid, –COOH

III amino, $–NH_2$

These functional groups can react either with themselves or with each other. Which combination of groups will **not** react?

A. I and I

B. I and II

C. II and III

D. III and III

Question 5 / 14

Consider the following statements about enzymes.

I An enzyme will usually increase the rate of one reaction or a few closely related reactions.

II The shape of the active site of an enzyme determines which molecule or molecules will undergo reaction.

III Enzymes can function effectively over a wide range of temperatures.

IV All proteins are enzymes but only some enzymes are proteins.

V Enzymes are more effective than other catalysts at increasing the rate of a reaction.

Which of the above statements are correct?

A.

I, II and V

B.

II, III and IV

C.

I, III and IV

D.

I, IV and V

Question 6 / 14

Fats, carbohydrates and proteins are important molecules for many living organisms. Moderate amounts of sulfur occur in

---

A. fats.

B. carbohydrates.

C. proteins.

D. none of these substances.

Question 7 / 14

2.00 g of each of four carboxylic acids is added to four separate containers. Enough water is added to dissolve the four acids. The names, semi-structural formulas and molar masses of the four acids are given in the table below.

Name	**Semi-structural formula**	**Molar mass (g mol^{-1})**
Ethanoic acid	CH_3COOH	60.1
Butanoic acid	$CH_3CH_2CH_2COOH$	88.1
Oxalic acid	HOOC–COOH	90.0
Citric acid	$HO–C(COOH)(CH_2COOH)_2$	192.0

The acid that requires the largest volume of 0.15 mol L^{-1} sodium hydroxide solution for complete reaction is

---

A. ethanoic acid.

B. butanoic acid.

C. oxalic acid.

D. citric acid.

Question 8 / 14

[VCAA 2022 SA Q7]
In a protein, hydrogen bonding takes place during the formation of the

---

A. secondary, tertiary and quaternary structures only.

B. primary, secondary and tertiary structures only.

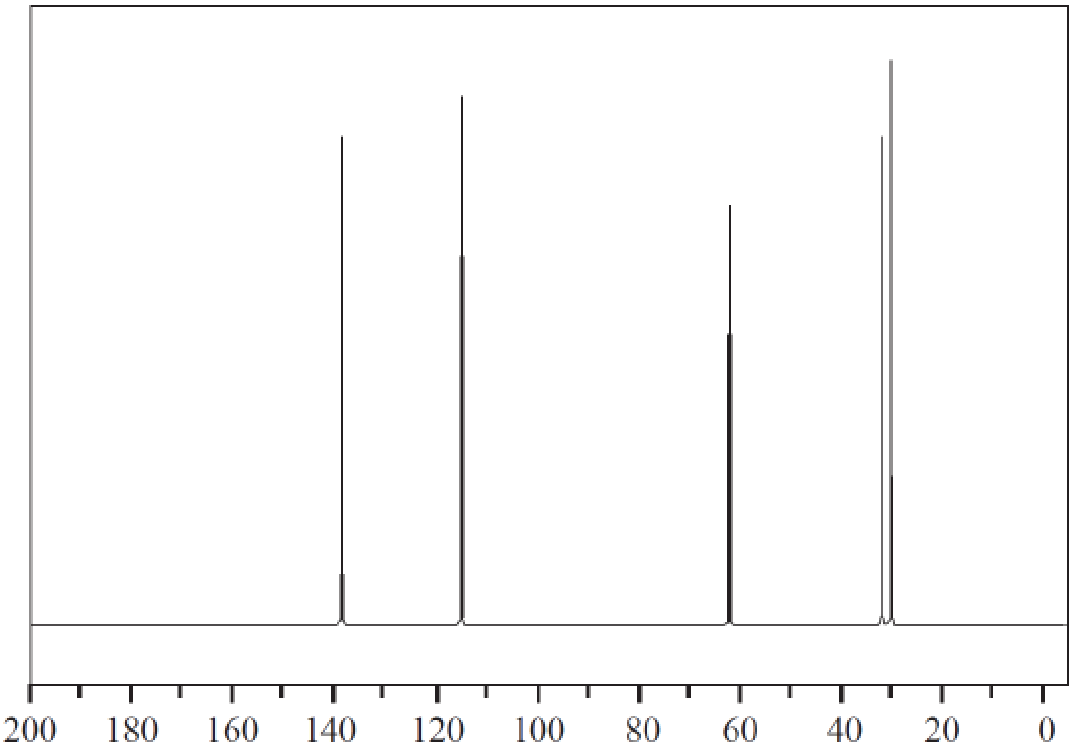
C. tertiary and quaternary structures only.

D. primary and tertiary structures only.

Question 9 / 14

[VCAA 2022 SB Q28]

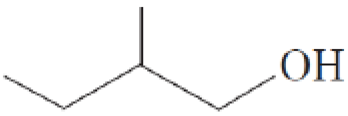
The ^{13}C NMR spectrum of an organic compound is shown below.



Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

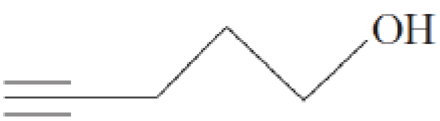
The organic compound could be

A.

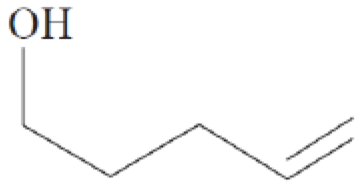


B.

C.



D.

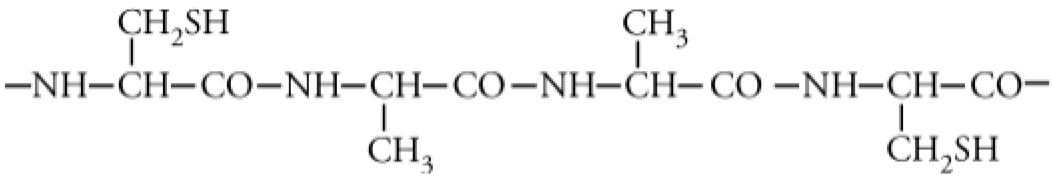


Question 10 / 14

(a) Name the five elements that are often found in proteins.

(2 marks)

(b) Part of a polypeptide chain is represented below.



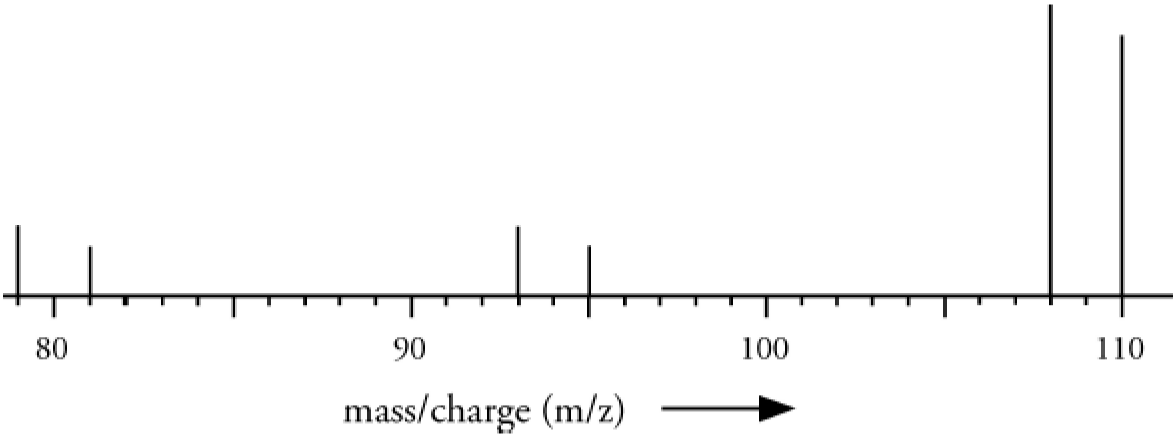
Draw the structures of the amino acids that were used to make this part of the polypeptide.

(2 marks)

(Total = 4 marks)

Question 11 / 14

Part of the mass spectrum of bromoethane, CH_3CH_2Br, is shown in the sketch below.



There are two naturally occurring isotopes of bromine whose details are shown below.

Isotope	Relative isotopic mass	Relative abundance (%)
^{79}Br	78.92	50.5
^{81}Br	80.92	49.5

(a) The relative molecular mass of bromoethane is 109 but there is no peak with this mass to charge ratio in the mass spectrum. Give an explanation for this observation. (Assume that carbon is 100% ^{12}C and hydrogen is 100% ^{1}H.)

(2 marks)

(b) Suggest possible formulas for the peaks observed at 93 and 95 m/z in the mass spectrum. How might these particles have been formed?

(3 marks)

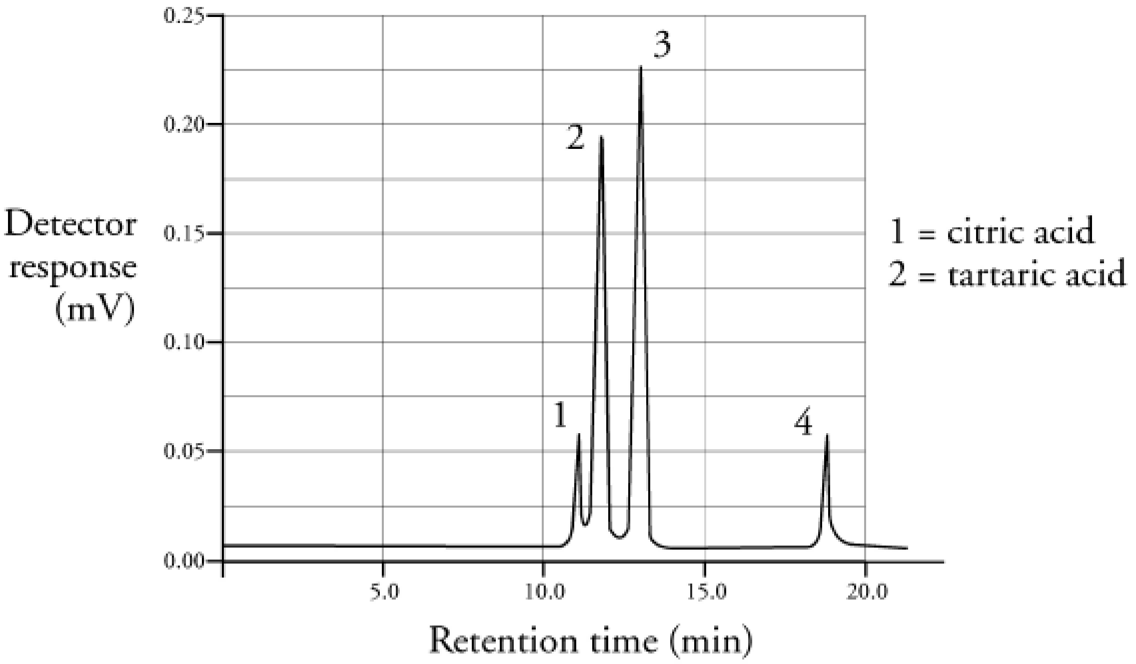
(c) The mass spectrum of bromoethane also shows a strong peak at 29 m/z. Suggest a formula for the species responsible for this peak.

(1 mark)

(Total = 6 marks)

Question 12 / 14

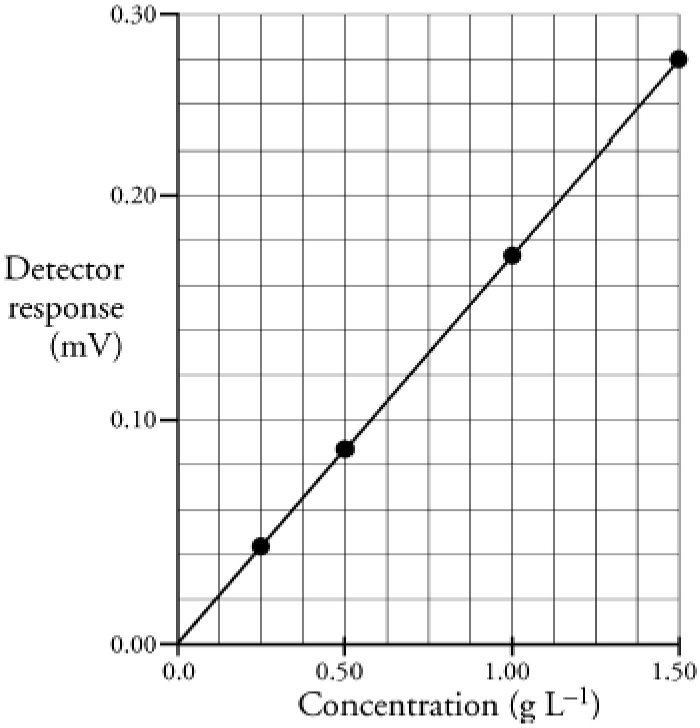
White wines contain a number of different organic acids. Four of these acids are citric acid, $C_3H_5O(COOH)_3$, tartaric acid, $(CH(OH)COOH)_2$, lactic acid, $CH_3CH(OH)COOH$ and malic acid, $HOOCCH_2CH(OH)COOH$. 25.00 mL of a particular wine is diluted to 50.00 mL in a volumetric flask. HPLC is used to examine the acids present in this solution of wine. The result is shown in the diagram below. Only two of the peaks have been labelled.



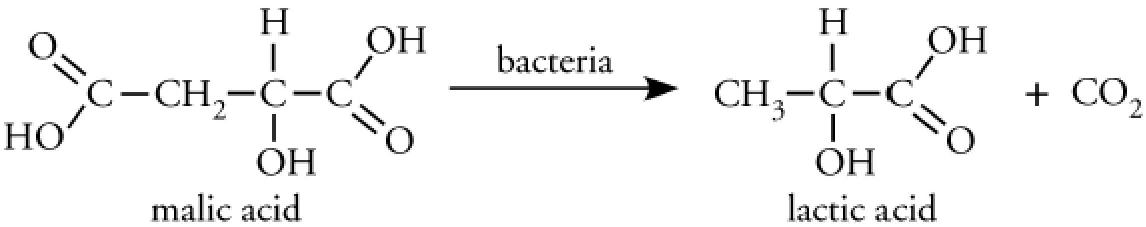
For tartaric acid, a calibration curve is obtained by recording the detector response for varying concentrations of tartaric acid. The calibration curve is shown below.

(a) Use the graph to determine the concentration of tartaric acid in the wine sample.

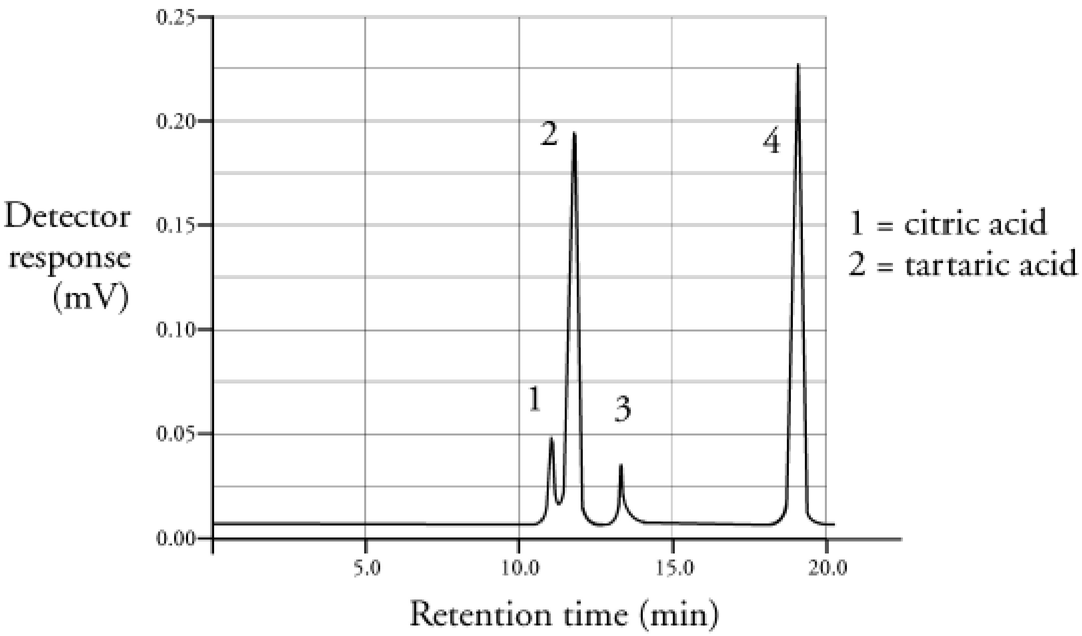
(2 marks)



After the primary fermentation, in which glucose is converted into ethanol, winemakers often use a secondary fermentation to convert most of the tart tasting malic acid into the softer tasting lactic acid. The reaction is shown below.



At the completion of this reaction, the winemaker takes another sample of the wine, treats it the same way as the first sample and examines it by HPLC. The result is shown below.



(b) Use the two HPLC results to identify peaks 3 and 4.

(1 mark)

(c) Calculate the percentage of malic acid that has been converted into lactic acid.

(1 mark)

(d) What effect will the malolactic fermentation have on the pH of the wine?

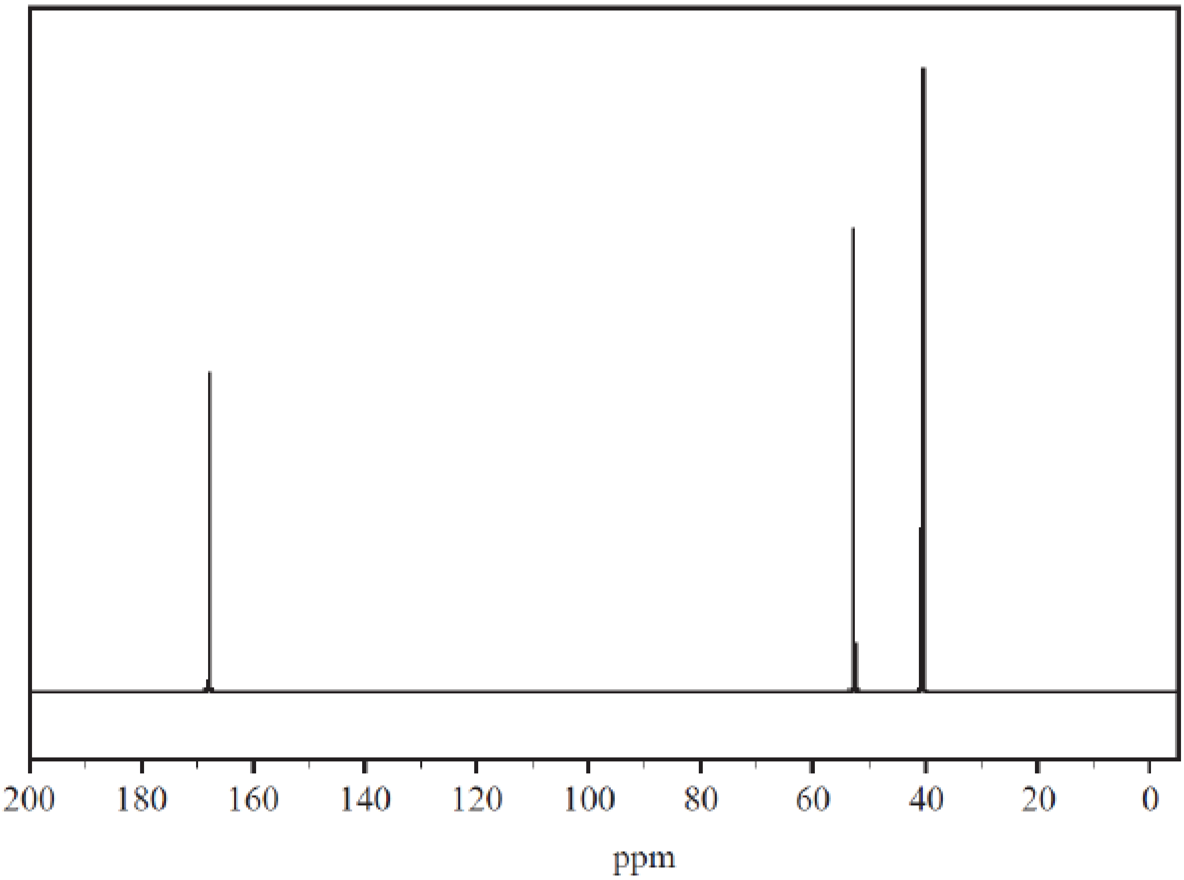
Explain your answer.

(2 marks)

(Total = 6 marks)

Question 13 / 14

[VCAA 2022 SB Q5]
A chemist uses spectroscopy to identify an unknown organic molecule, Molecule J, that contains chlorine. The ^{13}C NMR spectrum of Molecule J is shown below.

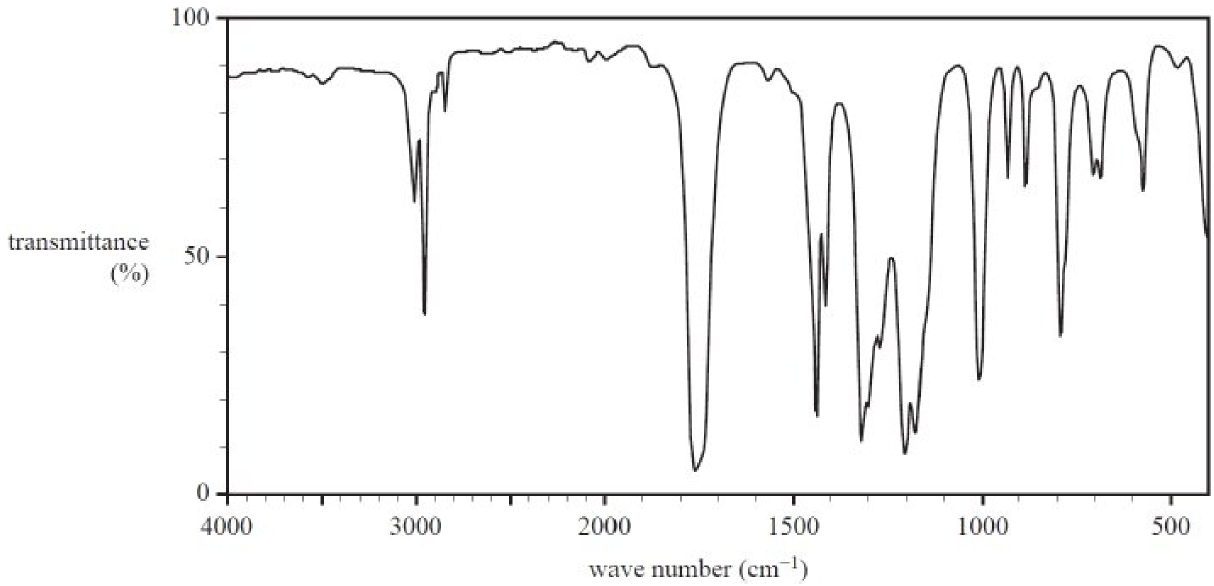


Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

(a) There are two possible carbon environments that can produce the peak at 168 ppm. Identify one of the two possible carbon environments that can produce the peak at 168 ppm.

(1 mark)

The infra-red (IR) spectrum of Molecule J is shown below.

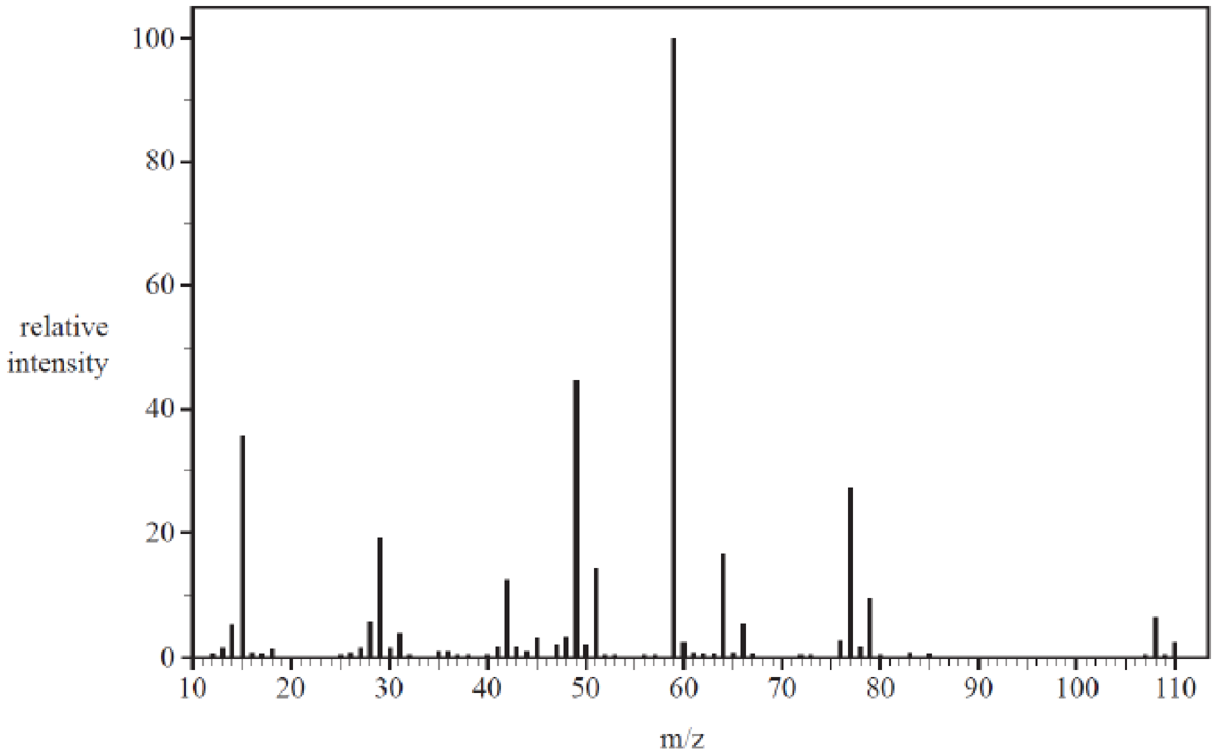


Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Science and Technology

(b) Name the functional group that produces the peak at 168 ppm in the ^{13}C NMR spectrum above, which is consistent with the IR spectrum shown above. Justify your answer with reference to the IR spectrum.

(2 marks)

The mass spectrum of Molecule J is shown below.



Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Sience and Technology

(c) The molecular mass of Molecule J is 108.5

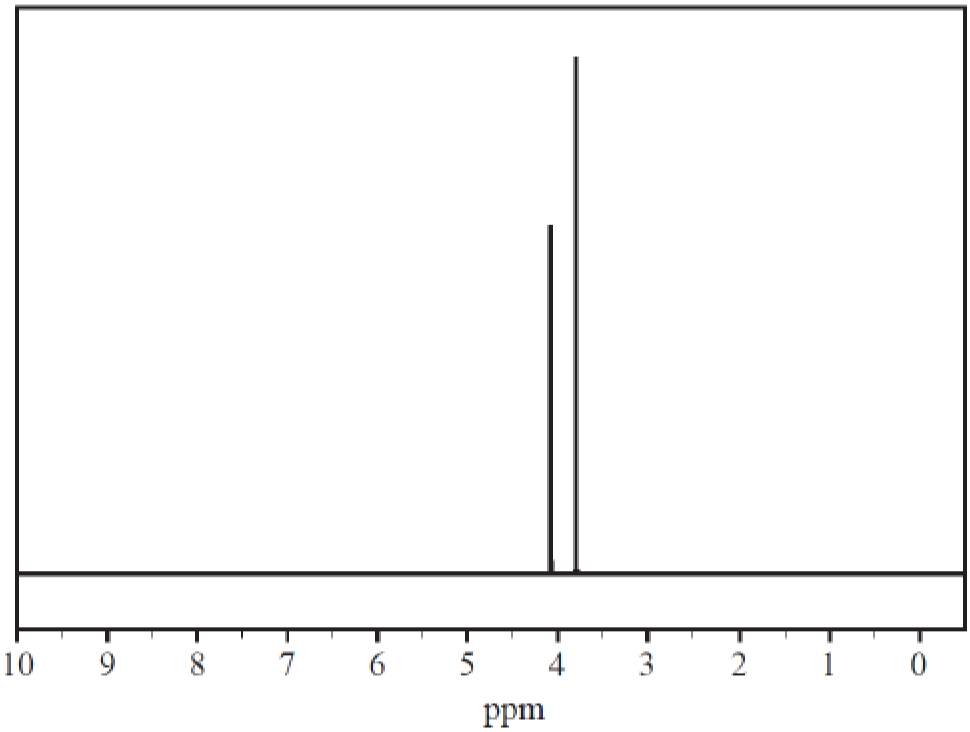
(i) Explain the presence of the peak at 110 rn/z.

(1 mark)

(ii) Explain how the peaks in the mass spectrum relate to the molecular mass of Molecule J.

(2 marks)

The [1]H NMR spectrum of Molecule J is shown below.



Data: SDBS Web, <https://sbsd.aist.go.jp>, National Institute of Advanced Industrial Science and Technology

(d) The [1]H NMR spectrum consists of two singlet peaks.

What information does this give about the molecule?

(2 marks)

(e) Draw a structural formula for Molecule J that is consistent with the information provided in **parts (a)–(d).**

(2 marks)

(Total = 10 marks)

Question 14 / 14

[Adapted VCAA 2017 SB Q3]
Glucagon is a peptide hormone that works with insulin to help regulate blood glucose levels. Glucagon acts to increase blood glucose levels through targeted action on the polysaccharide stored in the liver. Glucagon consists of a chain of 29 amino acids, the sequence of which is given below, and folds to form a short alpha-helix.

H_2N-His-Ser-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Arg-Arg-Ala-Gln-Asp-Phe-Val-Gln-Trp-Leu-$\boxed{\text{Met-Asn-Thr-COOH}}$

(a) Draw a diagram of the structure of the section of the glucagon peptide shown in the box in the amino acid sequence above.

(3 marks)

(b) Describe the bonding that is found in the primary and secondary structures of the glucagon molecule.

(3 marks)

(Total = 6 marks)

Total marks for test = 41 marks

Question 1 / 10

[VCAA 2019 SA Q22]
Which one of the following statements about conducting an experiment is the most correct?

A.

Precise results may be biased.

B.

Accuracy is assured if sensitive instruments are used.

C.

A method is valid if it identifies all controlled variables.

D.

Repeating a procedure will remove the uncertainty of the results.

Question 2 / 10

[VCAA 2020 SA Q2]
Using large sample sizes in an experiment increases

A.

reliability.

B.

precision.

C.

validity.

D.

uncertainty.

Question 3 / 10

[VCAA 2018 SA Q6]
Ethoxyethane, $C_2H_5OC_2H_5$, is commonly used as a solvent in the purification of compounds. The boiling point of $C_2H_5OC_2H_5$ is 36°C. The safety data sheet for $C_2H_5OC_2H_5$ states: ‘Extremely flammable. Keep away from sources of ignition.’ During the purification process, a compound is dissolved in $C_2H_5OC_2H_5$ by heating it for an extended period of time. This is done using glassware that is open to the atmosphere. This step in the purification process should be carried out using a

---

A.

water bath in a fume cupboard.

B.

water bath on a laboratory bench.

C.

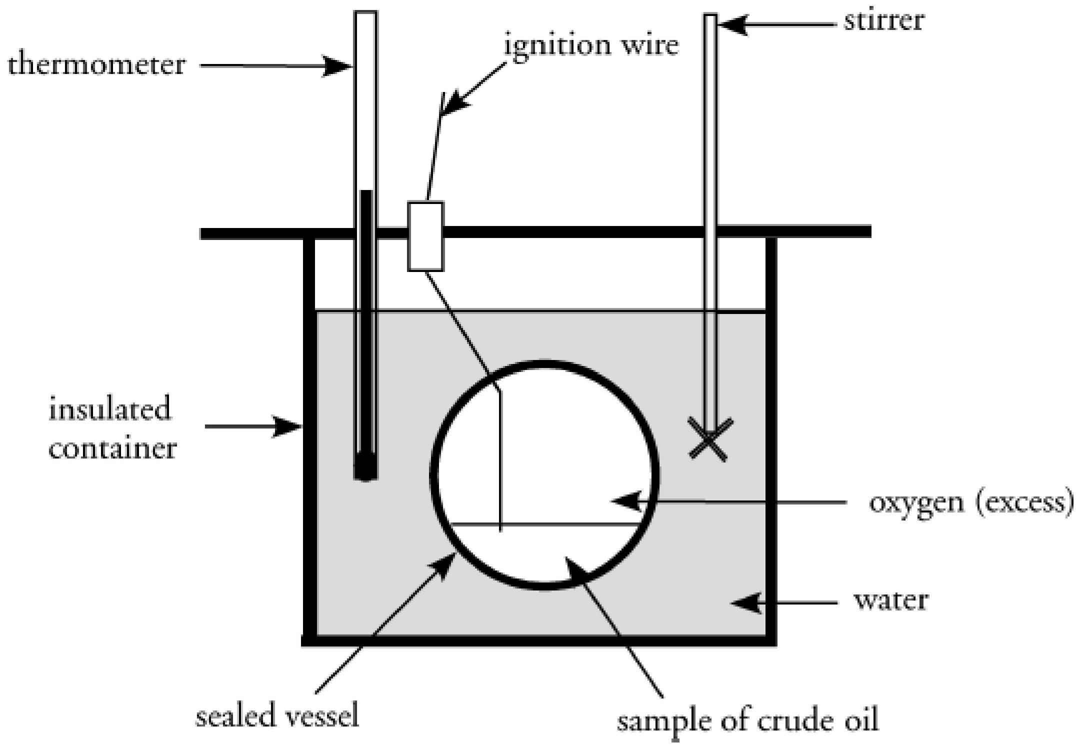
Bunsen burner in a fume cupboard.

D.

Bunsen burner on a laboratory bench.

Question 4 / 10

[VCAA 2017 SA Q23]
The heat of combustion of a sample of crude oil is to be determined using a bomb calorimeter. All of the students in a class are given the same method to follow. The apparatus used by the students is shown below.



For this experiment, the students could maximise

A.

precision by using a digital thermometer ±0.2°C.

B.

validity by calculating the heat of combustion per mole.

C.

accuracy by taking samples from three different sources.

D.

uncertainty by having all students closely follow the same experimental procedure.

Question 5 / 10

[VCAA 2012 E2 SA Q1]
A solvent has the following risk statement printed on its label.

‘Inhalation of fumes may cause dizziness.’

To minimise the risk associated with the effects of exposure when using this solvent, a student should

---

A.

use gloves.

B.

wear a laboratory coat.

C.

keep the solvent away from flames.

D.

use the solvent in a well-ventilated area.

Question 6 / 10

[VCAA 2013 SA Q1]
Consider the following.

‘Calculate the pressure exerted by 6.9 g of argon in a 0.07500 L container at 11.5 °C.’

The number of significant figures that should be expressed in the answer is

---

A.

2

B.

3

C.

4

D.

5

Question 7 / 10

[VCAA 2017 SA Q19]
A Year 12 Chemistry assignment requires students to quantitatively and qualitatively compare fossil fuels and biofuels. Which one of the following investigations would be most appropriate for this comparison?

A. Use a bomb calorimeter to determine the heat of combustion for both fossil fuels and biofuels.

B. Interview car owners to determine what petrol price would make them consider using biofuels.

C. Produce biodiesel from vegetable oil and compare the viscosity of the biodiesel produced with that of a range of fossil fuels.

D. Find reliable information about the environmental impacts of producing fossil fuels and biofuels, and the amount of carbon dioxide produced per litre from the combustion of these fuels.

Question 8 / 10

[VCAA 2021 SA Q10]
A student hypothesised that polishing the zinc, Zn, electrode in an Fe-Zn galvanic cell would increase the current produced by the cell.

What would be the most valid method of testing this hypothesis?

A.

researching the scientific literature to determine how polishing changes the structure of Zn

B.

measuring the conductivity of a Zn electrode after polishing it

C.

measuring the change in mass per unit time of the Fe electrode in the same Fe-Zn galvanic cell before and after the Zn electrode was polished

D.

measuring the current produced by two different Fe-Zn galvanic cells, one using a polished Zn electrode and the other using an unpolished Zn electrode

Question 9 / 10

[VCAA 2022 SA Q1]
Scientific posters communicate the findings of scientific investigations. Which section of a scientific poster should explain the reason for undertaking an investigation?

A.

discussion

B.

conclusion

C.

introduction

D.

methodology

Question 10 / 10

[VCAA 2022 SA Q5]
Scientists often repeat trials of an experiment using the same experimental method and the same equipment. Which one attribute of experimental data will be improved when there is an increase in the number of times that a trial is repeated?

A.

bias

B.

validity

C.

accuracy

D.

reliability

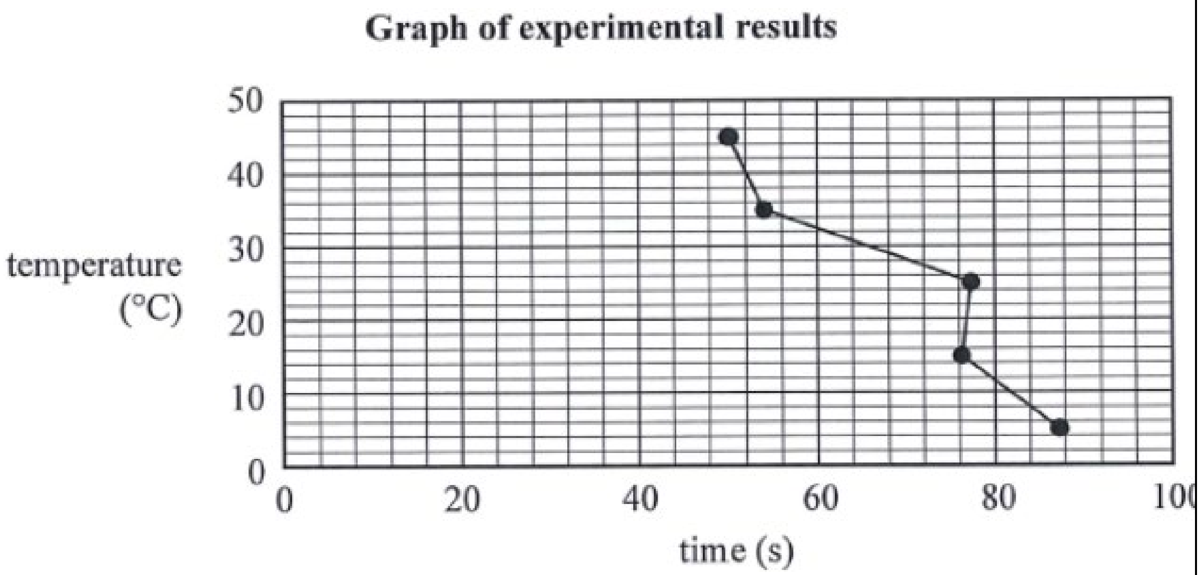
[VCAA 2020 SB Q9]

A student decided to investigate the effect of temperature on the rate of the following reaction.

$2HCl(aq) + CaCO_3(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

Part of the student's experimental report is provided below.

Effect of temperature on the rate of production of carbon dioxide gas
Aim
To find out how temperature affects the rate of production of carbon dioxide gas, CO_2, when a solution of hydrochloric acid, HCl, is added to chips of calcium carbonate, $CaCO_3$
Method
1. Put 0.6 g of $CaCO_3$ chips into a conical flask.
2. Put a reagent bottle containing 2 M HCl into a water bath at 5 °C.
3. When the temperature of the HCl solution has stabilised at 5 °C, use a pipette to put 10.0 mL of the HCl solution into the conical flask containing the $CaCO_3$ chips.
4. Put a balloon over the conical flask and begin timing.
5. When the top of the balloon has inflated so that it is 10 cm over the conical flask, stop timing and record the time.
6. Repeat steps 1–5 using temperatures of 15 °C, 25 °C, 35 °C and 45 °C.
Results



(a) What does the student need to do to ensure that they comply with all applicable safety guidelines during the investigation?

(2 marks)

(b) What is the independent variable?

(1 mark)

(c) What is the dependent variable and how is it measured?

(2 marks)

(d) (i) Predict the relationship between the independent variable and the dependent variable. Explain your prediction.

(3 marks)

(ii) Is the graph of the student's results consistent with your prediction?

Give your reasoning.

(1 mark)

(e)Idntify **two** ways in which the graph could have been presented differently to better illustrate the relationship between the independent variable and the dependent variable.

(2 marks)

(f)Idntify **two** changes that could be made to the experimental method to improve the precision of the results if the experiment was repeated. For each change, explain how it would improve precision.

(2 marks)

(Total = 13 marks)

Question 2 / 7

[VCAA 2019 SB Q9]
A student designed an experiment to investigate current efficiency during the electrolysis of a sodium chloride, NaCl, solution. Current efficiency is the amount of product produced, expressed as a percentage of the theoretical amount of product, calculated using Faraday's law.

When the products of an electrolysis are gases, current efficiency can be calculated using the following.

current efficiency=volume of gas producedvolume of gas expected based on Faradaysla w ×100

All experimental work was carried out under standard laboratory conditions (SLC). The experiment involved the use of a Hoffman electrolysis apparatus.

The following is the first section of the student's report.

What is the effect on current efficiency during electrolysis when the concentration of a sodium chloride, NaCl, solution is changed?

Aim

To investigate the effect on current efficiency during electrolysis when the concentration of a sodium chloride, NaCl, solution is changed

Procedure

Step 1: Rinse the Hoffman electrolysis apparatus with distilled water.

Step 2: Fill the Hoffman electrolysis apparatus with distilled water so that the bottom of the meniscus in both tubes is level with the 170 mL mark.

Step 3: Connect the power supply and ammeter to the electrodes of the Hoffman electrolysis apparatus.

Step 4: Turn on the power supply and start timing. Record the current displayed on the ammeter.

Step 5: After five minutes turn off the power supply and record the volume level on each of the tubes.

Step 6: Repeat steps 2–5 four times.

Step 7: Average the readings of the initial and final volumes at each electrode and current readings.

Step 8: Repeat steps 1–7 using 1.5 M NaCl solution instead of distilled water.

Step 9: Repeat steps 1–7 using 4 M NaCl solution instead of distilled water.

(a) Identify the dependent variable.

(1 mark)

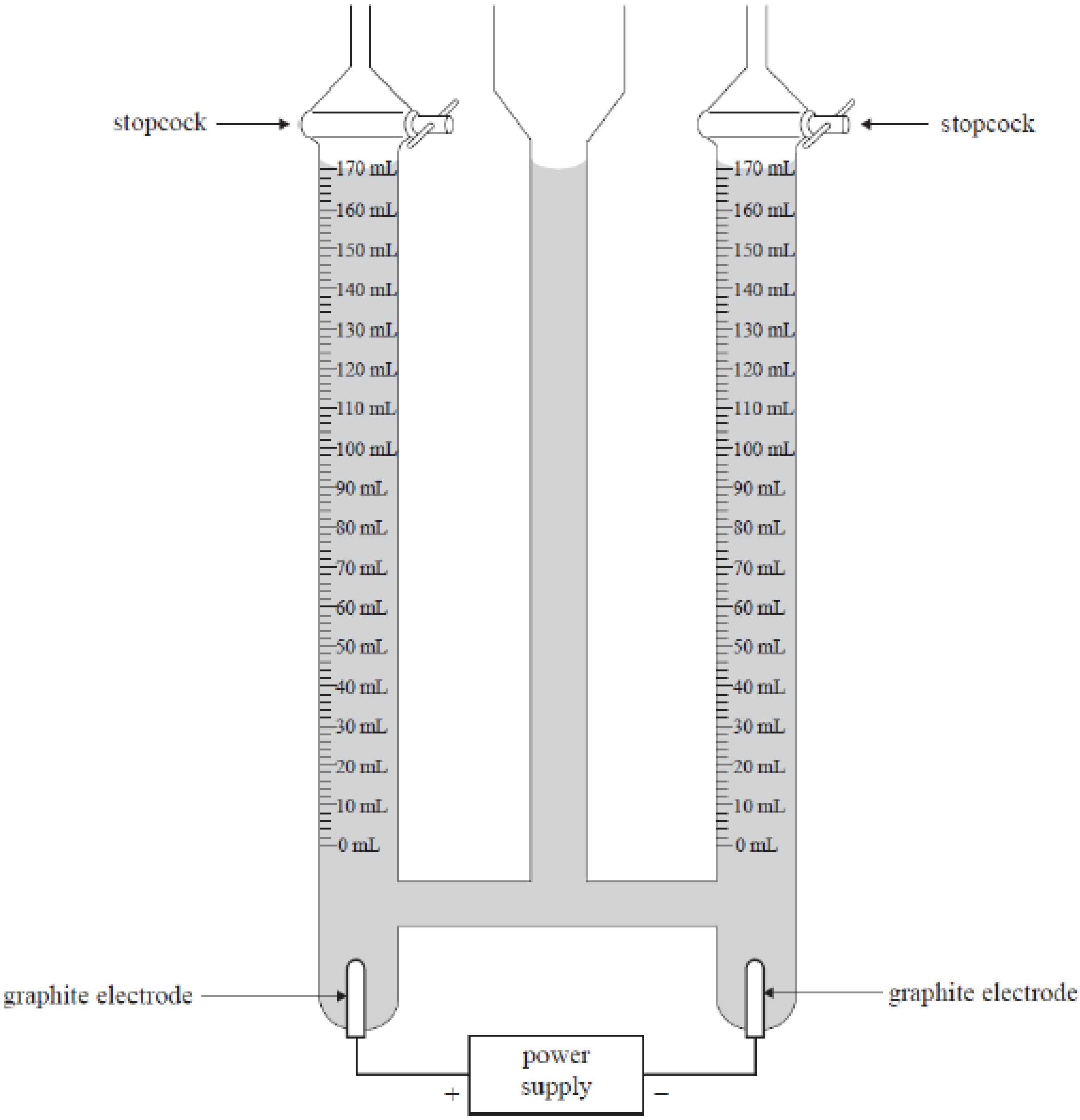
(b) (i) Identify a safety risk associated with the chemicals produced during the experiment.

(1 mark)

(ii) What are the safety measures required to reduce the safety risk identified in **part b.i.**?

(1 mark)

A diagram of the Hoffman electrolysis apparatus, correctly filled as required in Step 2, is shown below.



The results for steps 1–7 of the procedure are given in Part 1 below.

Part 1 – Distilled water

Trial	Initial volume (mL)		Final volume (mL)		Current (A)
	Negative electrode	Positive electrode	Negative electrode	Positive electrode	
1	170.0	170.0	100.2	135.3	2.0
2	170.0	170.0	100.3	135.3	2.0
3	170.0	170.0	99.9	135.0	2.0

Trial	**Initial volume (mL)**		**Final volume (mL)**		**Current (A)**
	Negative electrode	**Positive electrode**	**Negative electrode**	**Positive electrode**	
4	170.0	170.0	99.8	134.8	2.0
5	170.0	170.0	100.1	135.1	2.0
Average	**170.0**	**170.0**	**100.1**	**135.1**	**2.0**

(c) Are the results in Part 1 precise? Justify your answer.

(1 mark)

(d) Write the half-equation for the reaction that would be expected to be observed at the negative electrode.

(1 mark)

(e) (i) Calculate the volume of gas expected at the negative electrode for Part 1 of the experiment using Faraday's law.

(3 marks)

(ii) Calculate the current efficiency for Part 1 of the experiment.

(1 mark)

The results for steps 8 and 9 of the procedure are given in Part 2 and Part 3.

Part 2 – 1.5 M NaCl (Step 8 of the procedure)

Trial	**Initial volume (mL)**		**Final volume (mL)**		**Current (A)**
	Negative electrode	**Positive electrode**	**Negative electrode**	**Positive electrode**	
Average	170.0	170.0	98.0	133.2	2.0

Part 3 – 4 M NaCl (Step 9 of the procedure)

Trial	Initial volume (mL)		Final volume (mL)		Current (A)
	Negative electrode	Positive electrode	Negative electrode	Positive electrode	
Average	170.0	170.0	95.2	100.0	2.0

(f) What conclusion can be drawn from the results for parts 1, 2 and 3?

Give your reasoning.

(2 marks)

(g) State the change the student should make to their experimental design to ensure they achieve their aim. Justify your answer.

(2 marks)

(h) Scientists may use scientific posters to convey their research results to other scientists. State two different aspects of the electrolysis experiment that the student should include in the discussion section of their scientific poster.

(2 marks)

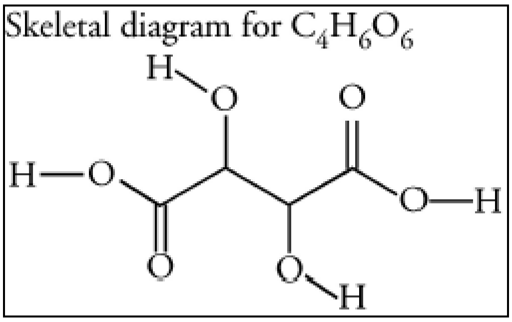
(Total = 15 marks)

Question 3 / 7

[VCAA 2019 SB Q9]
A group of students designed and carried out an experiment to investigate if tartaric acid, $C_4H_6O_6$, that was bought commercially is 99% pure, as claimed by the manufacturer. The experiment involved titrating $C_4H_6O_6$ with sodium hydroxide, NaOH, solution, calculating the percentage purity of $C_4H_6O_6$ and comparing the experimental value to the manufacturer's stated value. Part of the report submitted by one of the students is shown below.

Research

Tartaric acid is a diprotic acid that occurs naturally in grapes and other fruit.



Equation for reaction $C_4H_6O_6(aq) + 2NaOH(aq) \rightarrow Na_2C_4H_4O_6(aq) + 2H_2O(l)$

Aim

To determine the percentage purity of the commercial sample of tartaric acid by titration to verify the stated value of 99.0%

Calculations of predicted titre, in mL

$[C_4H_6O_6]$ solution = 30150×10.50 = 0.40 mol L^{-1}

$n(C_4H_6O_6)$ in 10.00 mL = 0.40×101000 = 0.0040 mol

$n(NaOH) = 2 \times n(C_4H_6O_6)$ = 0.0080 mol

$V(NaOH)$ titre = 0.00800.5 = 0.016 L = 16.00 mL

Method

Part A – Preparation of tartaric acid solution

1. Purchase tartaric acid, $C_4H_6O_6$, powder.

2. Prepare a solution of $C_4H_6O_6$ by accurately measuring 30.0 g of the powder, placing it in a 500.00 mL volumetric flask and then making it up to 500.00 mL with de-ionised water.

Part B – Titration

1. Collect stock solution of 0.5 M sodium hydroxide, NaOH, and use this to fill a burette.

2. Deliver a 10.00 mL aliquot of $C_4H_6O_6$ solution into a conical flask. Add four drops of phenolphthalein indicator.

3. Carefully titrate 0.5 M NaOH into the $C_4H_6O_6$ solution until a permanent pink colour remains.

4. Record the volume of the titre.

5. Repeat the titration until concordant titres are obtained.

Results

Trial number	Volume of aliquot of $C_4H_6O_6$ (mL)	Volume of titre of NaOH (mL)
1	10.00	14.96
2	10.00	14.81
3	10.00	14.70
4	10.00	14.76
5	10.00	14.79

Calculations

Average titre = 14.81+14.76+14.793 = 14.79 mL

n(NaOH) = 0.5 × 0.01479 mol = 0.00749

n($C_4H_6O_6$) = 12× *n*(NaOH) = 0.007492

= 0.00370 mol in 10.00 mL of $C_4H_6O_6$ solution

Percentage purity

% purity of $C_4H_6O_6$ = actualnpredictedn×100=0.00370.0040×100 = 92.5%

Conclusion

Through direct titration of tartaric acid with sodium hydroxide solution, the percentage purity of the commercial supply of tartaric acid was found to be 92.5%. This is less than the stated value of 99% purity. Consequently, the manufacturer's claim is wrong.

(a) Name the independent variable in this experiment.

(1 mark)

(b) Identify a controlled variable in this experiment and state why it is important for this variable to be controlled.

(2 marks)

(c) Is the value the student used for the average titre in the ‘Calculations’ section above appropriate? Explain your reasoning.

(2 marks)

(d) Consider the method undertaken by the student in this experiment to determine the percentage purity of $C_4H_6O_6$ powder. Identify how specific steps in the method affect the accuracy and reliability of the data.

(4 marks)

(e) Identify a limitation of the student's conclusion. How could this limitation be addressed?

(2 marks)

(f) The material safety data sheet (MSDS) for $C_4H_6O_6$ powder includes the statement below:

‘Warning! This product causes eye, skin and respiratory tract irritation.’

Apart from a laboratory coat, what personal protective equipment (PPE) should be used by the students in each of the following situations?

(i) Preparing the $C_4H_6O_6$ solution

(ii) Conducting the titration

(2 marks)

(Total = 13 marks)

Question 4 / 7

[VCAA 2014 SB Q12]
A student investigated the effect of different catalysts on the molar enthalpy of the decomposition reaction of hydrogen peroxide. The student's report is provided below.

Report – Effect of different catalysts on the enthalpy of a reaction

Background

Different catalysts, such as manganese dioxide, MnO_2, and iron(III) nitrate solution, $Fe(NO_3)_3$, will increase the rate of decomposition of hydrogen peroxide.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

Purpose

This experiment investigated the effect of using different catalysts on the molar enthalpy of the decomposition of hydrogen peroxide.

Procedure

The temperature change was measured when MnO_2 catalyst was added to a volume of hydrogen peroxide in a beaker. The procedure was repeated using $Fe(NO_3)_3$ solution as a catalyst.

Results

	Trial 1	**Trial 2**
Volume H_2O_2	100 mL	200 mL
Concentration H_2O_2	2.0 M	4.0 M
Catalyst	0.5 g MnO_2	50 mL 0.1 M $Fe(NO_3)_3$
Temperature change °C	3.0	10.1

Conclusion

The change in temperature using the $Fe(NO_3)_3$ catalyst was greater than the change in temperature using the MnO_2 catalyst. This demonstrates that the molar enthalpy for the decomposition reaction depends on the catalyst used.

The student's conclusion is not valid because the experimental design is flawed. Critically review the student's experimental design. In your response, you should:

• identify and explain **three** improvements or modifications that you would make to the experimental design

• discuss the experimental outcomes you would expect regarding the effect of different catalysts on molar heats of reaction. Justify your expectations in terms of chemical ideas you have studied this year.

(Total = 5 marks)

Question 5 / 7

[VCAA 2016 SB Q11]

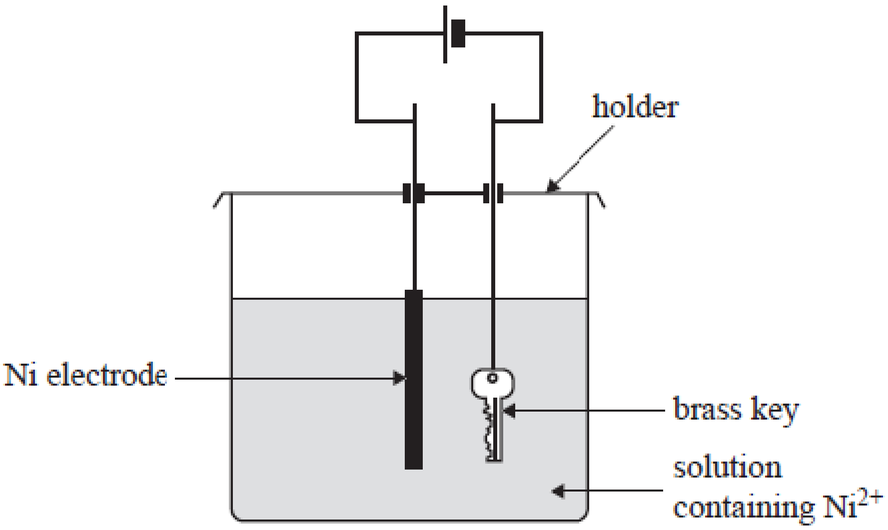
A student investigated the electroplating of a metal with nickel. The following is her report.

Aim

To investigate whether Faraday's laws apply to the electroplating of a brass key with nickel

Procedure

Step 1 – The apparatus was set up as in the diagram below. The electrolyte solution was supplied. The brass key was sanded, weighed and placed in the solution, as shown below.



Step 2 – The current was turned on for exactly 20 minutes. The current and voltage were measured when the power was turned on.

Step 3 – The key was removed from the solution, patted dry with a paper towel and weighed. Steps 1–3 were repeated for two more keys.

Results

Three trials of the experiment were conducted, X, Y and Z.

Trial	Initial mass of brass key (g)	Final mass of brass key (g)	Mass of nickel deposit (g)	Current (A)	Voltage (V)
X	2.774	2.907	0.133	0.52	2.4

Y	3.068	3.269	0.201	0.54	2.2
Z	3.122	3.310	0.188	0.50	1.9

Predicted mass for Trial X using Faraday's laws

$m(Ni)=0.52\times20\times6096500\times58.72=0.19$ g

Conclusion

Faraday's laws apply to the electroplating of a brass key with nickel.

Evaluate the student's experimental design and report. In your response:

• identify and explain **one** strength of the experimental design

• suggest **two** improvements or modifications that you would make to the experimental design and justify your suggestions

• comment on the validity of the conclusion based on the results obtained.

(Total = 7 marks)

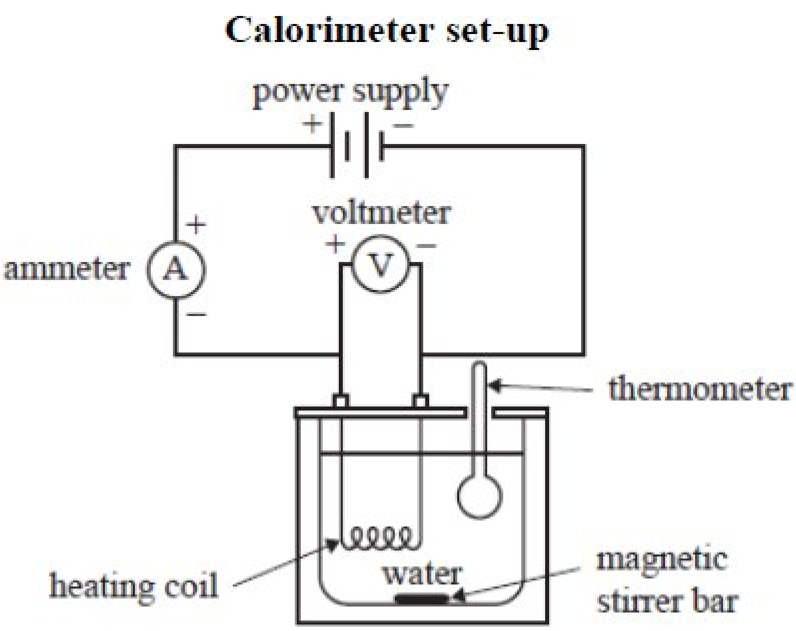
Question 6 / 7

[VCAA 2018 SB Q9]
A Chemistry class conducted a practical investigation to determine the calibration factor of a calorimeter using two different methods: electrical and chemical. Each student compared the results from the two different methods and presented the investigation as a scientific poster.

The materials, set-up and methods used by the students are shown below.

Materials

calorimeter	ammeter
DC power supply	voltmeter
5 × wire leads	3 g potassium nitrate (KNO_3)
thermometer	electronic balance
stopwatch	measuring cylinder



Methods

Electrical method for collecting calibration data

1. Add 100 mL of water to the calorimeter. Stir the water and record its temperature every 30 seconds for several minutes.

2. Apply a voltage of 6 V for three minutes. Stir throughout and record the temperature every 30 seconds.

3. Record the voltage and the current while the water is heating.

4. Once the power is turned off, continue to stir the water and record the temperature every 30 seconds for a further three minutes.

Chemical method for collecting calibration data

1. Measure 3.0 g of KNO_3 accurately.

2. After completing the electrical calibration, add the KNO_3 to the calorimeter.

3. Stir and record the temperature every 30 seconds.

Student A wrote the following aim.

Student A **Aim** To compare the calibration factors obtained from two different methods The calibration factors were found by recording the temperature change of a solution resulting from the addition of a measured electrical input and from potassium nitrate dissolving in water.

(a) The dependent variable in this investigation is the calibration factor. Identify the independent variable from Student A's aim.

(1 mark)

(b) Identify one systematic error that applies only to the electrical method of calibration.

(1 mark)

(c) Identify one limitation of the chemical method of calibration, given on the previous page. Explain how it could affect the reliability of the results.

(2 marks)

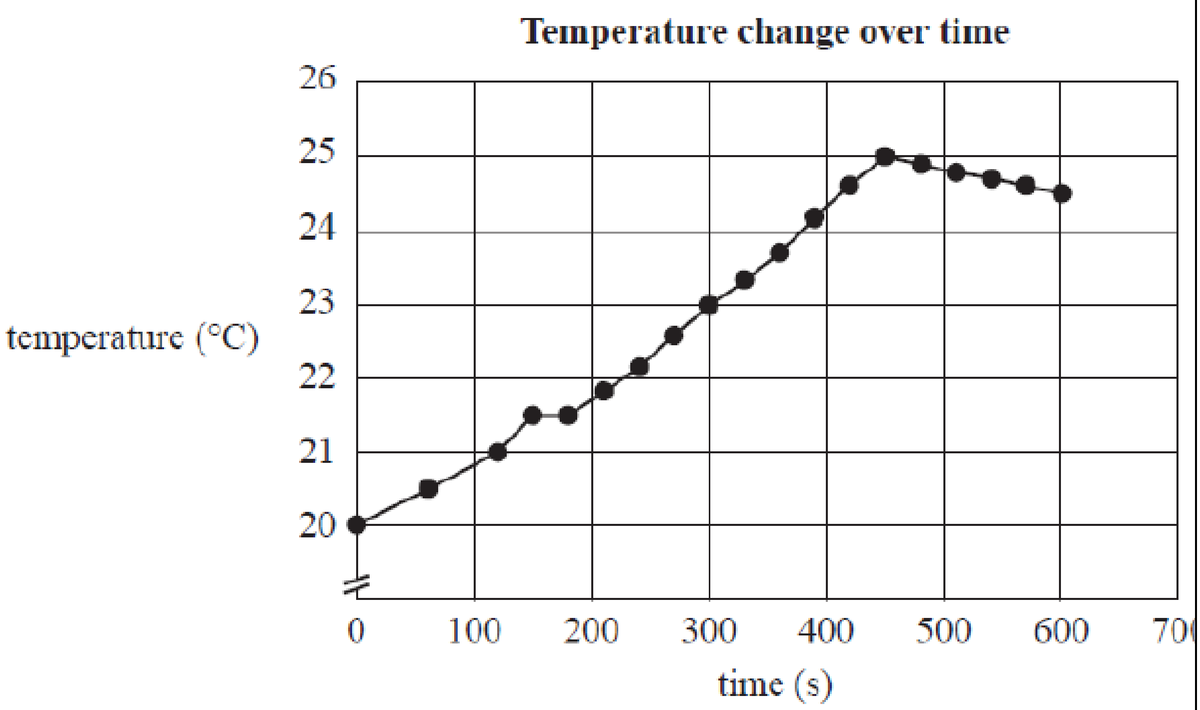
(d) Examine the graphs below prepared by Student A and Student B for the temperature change during electrical calibration.

Student A

Results – Electrical method of calibration

voltage = 5.8 V

current = 1.6 A

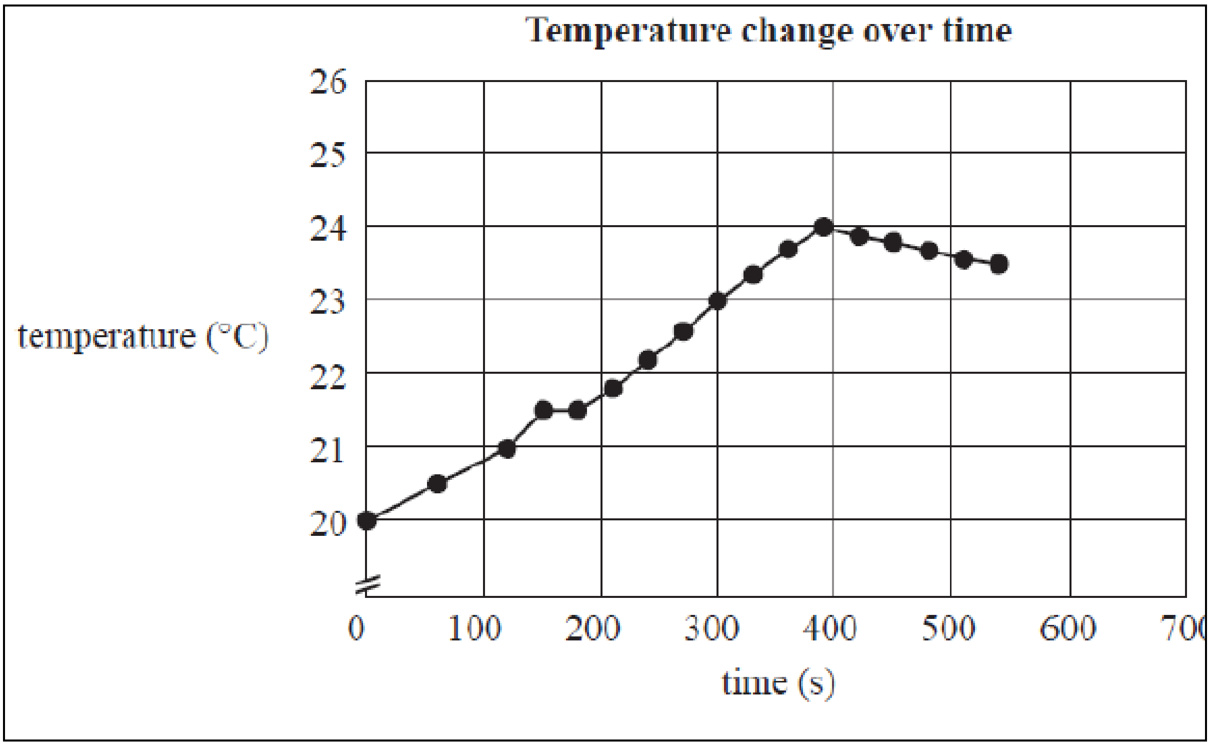


Student B

Results – Electrical method of calibration

voltage = 5.8 V

current = 1.6 A



Identify one difference in the results between the students' graphs and suggest what variation in the students' experiments might account for this difference.

(2 marks)

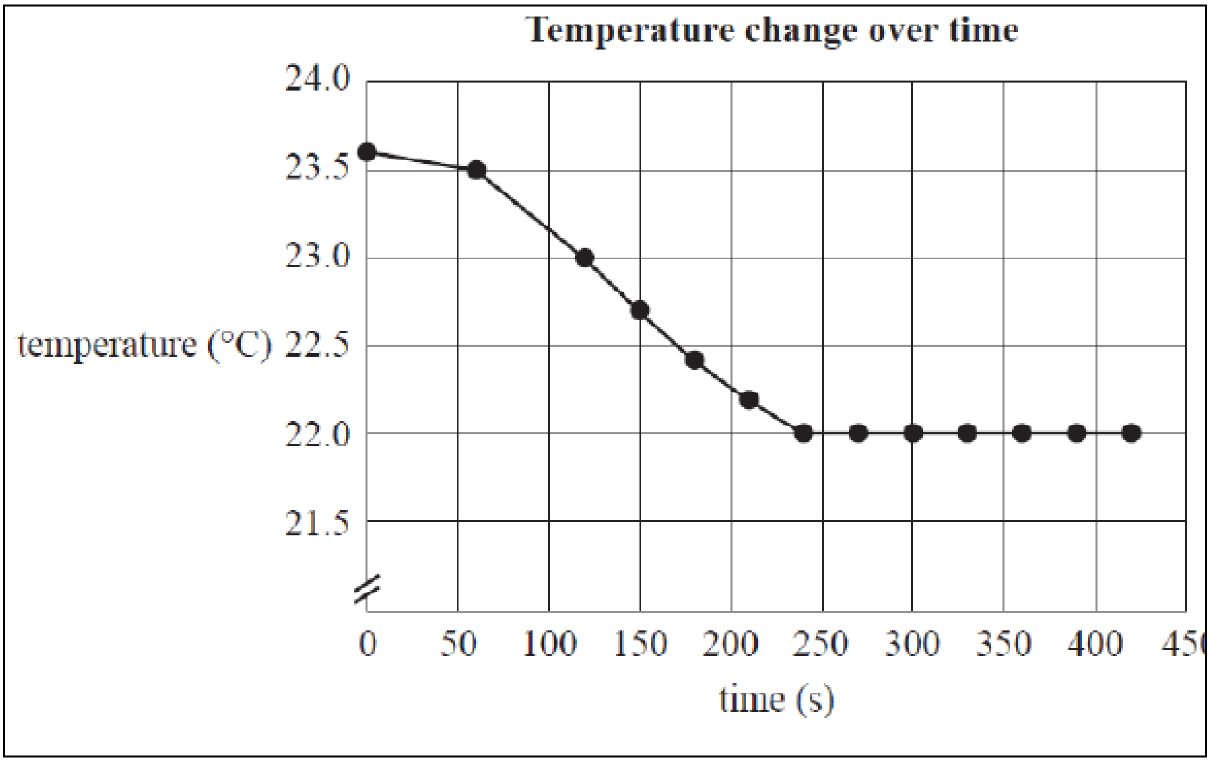
Student B's data for the chemical method of calibration is shown in the graph below.

Student B

Results – Chemical method of calibration

Below is the chemical equation and enthalpy used to calculate the calibration factor for the chemical method.

$$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq) \qquad \Delta H = 35 \text{ kJ mol}^{-1}$$



Use this data to calculate the calibration factor, in J °C^{-1}, for the chemical method of calibration.

(3 marks)

(Total = 9 marks)

Question 7 / 7

[VCAA 2022 SB Q8]
A student wrote the following partial experimental report.

Experimental report

Introduction

Wine is made from grapes containing sugars that are fermented by bacteria to produce ethanol. If a bottle of wine is left open, the ethanol will oxidise.

Aim

To investigate how the oxidation rate of ethanol in white wine from a freshly opened bottle is affected by the concentration of ethanol in the wine

Method

Open a bottle of white wine and prepare samples in four beakers according to Part I below. Then, determine the acidity of the samples in each beaker after two weeks using the method described in Part II.

Part I – Beaker preparation

Prepare four different beakers.

1. Put a clean and dry 250 mL beaker on a balance.

2. Zero the balance and add 250.00 g of wine to the beaker.

3. Remove the first beaker from the balance and put a second 250 mL beaker on the balance.

4. Zero the balance and add 245.00 g of wine to the beaker.

5. Zero the balance and add 5.00 g of pure ethanol to the beaker.

6. Repeat steps 4 and 5 with different amounts of wine and ethanol for Beaker 3 and Beaker 4, as shown in Table 1.

Table 1

	Mass of wine added to beaker (g)	**Mass of pure ethanol added to beaker (g)**	**Total mass of contents (g)**
Beaker 1	250.00	0.00	250.00

Beaker 2	245.00	5.00	250.00
Beaker 3	240.00	10.00	250.00
Beaker 4	235.00	15.00	250.00

7. Cover each of the four beakers with a watch glass and leave the covered beakers on a bench in an unused corner of the laboratory for two weeks.

Part II – Acid–base titrations

1. Rinse a clean and dry burette with a freshly standardised solution of 0.0100 M sodium hydroxide, NaOH.

2. Fill the burette with more of the freshly standardised solution of NaOH.

3. Flush about 5 mL of the NaOH through the burette and into a waste beaker to remove any air bubbles.

4. Rinse a clean conical flask with distilled water.

5. Rinse a 25.00 mL pipette using a small amount of the contents of Beaker 1.

6. Use the rinsed pipette to transfer 25.00 mL of the contents of Beaker 1 to the rinsed conical flask.

7. Add two drops of phenolphthalein indicator to the conical flask.

8. Note the initial volume reading on the burette.

9. Slowly add the NaOH from the burette to the conical flask, swirling to mix. As soon as the colour permanently changes, stop adding NaOH and note the final volume reading on the burette.

10. Calculate the titre.

11. Repeat steps 4 to 10 to obtain three concordant titres for Beaker 1. Refill the burette as necessary.

12. Repeat steps 2 to 11 for Beaker 2, Beaker 3 and Beaker 4.

(a) State how the precision of the experimental data will be affected by the acid–base titration method specified in Part II.

(1 mark)

Immediately after the bottle was opened, an experienced and qualified laboratory technician analysed a sample of the wine and found that:

• the wine contained 8.12% m/m ethanol

• the concentration of acid in the sample was 9.45×10^{-4} M (assuming a monoprotic acid).

(b) Use the laboratory technician's results and the information given in Table 1 above to calculate the initial ethanol concentration of the ethanol–wine mixture in Beaker 2 in % m/m.

(3 marks)

(c) What is the independent variable in the student's investigation?

(1 mark)

(d) At Step 5 of Part II above, the student mistakenly rinsed the pipette with distilled water instead of a small amount of the contents of the beaker. Explain how this change would affect the student's calculated value for the concentration of a monoprotic acid in the sample.

(2 marks)

(e) State why analysing the acidity of the wine in beakers 1, 2, 3 and 4 can be related to the oxidation of ethanol in the wine in each beaker.

(1 mark)

The student obtained the following results.

Table 2

	Titre 1 (mL)	**Titre 2 (mL)**	**Titre 3 (mL)**	**Titre 4 (mL)**	**Titre 5 (mL)**	**Titre 6 (mL)**
Beaker 1	23.65	24.54	24.64	24.59		
Beaker 2	21.32	24.55	22.25	21.25	21.30	

	Titre 1 (mL)	**Titre 2 (mL)**	**Titre 3 (mL)**	**Titre 4 (mL)**	**Titre 5 (mL)**	**Titre 6 (mL)**
Beaker 3	3.55	2.60	4.45	2.65	2.58	
Beaker 4	1.80	2.45	2.75	2.65	2.85	2.72

(f) (i) Write a conclusion relating to the oxidation rate of ethanol, which is consistent with the student's results in Table 2.

(1 mark)

(ii) Discuss your conclusion in relation to the white wine tested in this experiment. In your answer, make **two** points relating to **one or both** of the following:

- the limitations of your conclusion
- an explanation for the student's findings.

(2 marks)

(Total = 11 marks)