VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2017

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER									Letter

CHEMISTRY

Written examination

Tuesday 14 November 2017

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	10	10	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 37 pages
- Data book
- Answer sheet for multiple-choice questions

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

A catalyst

A. slows the rate of reaction.

B. ensures that a reaction is exothermic.

C. moves the chemical equilibrium of a reaction in the forward direction.

D. provides an alternative pathway for the reaction with a lower activation energy.

Question 2

Lithium-ion rechargeable batteries are used in mobile phones. Environmental conditions can affect the number of charge cycles for a lithium-ion battery until the end of its useful life.

Which of the following environmental conditions would be expected to result in the **largest** number of charge cycles for a lithium-ion battery?

	Minimum temperature (°C)	Maximum temperature (°C)
A.	–8	11
B.	9	21
C.	18	37
D.	28	40

Question 3

A hydrolytic reaction occurs when

A. a dipeptide is formed.

B. a triglyceride is formed.

C. water is a reaction product.

D. glucose is formed from maltose.

Question 4

Which of the following contains a chiral carbon?

	Name	Semi-structural formula
A.	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 5

Which one of the following is a biofuel?

A. ethanol produced from crude oil
B. ethanol produced from cellulose
C. propane produced from natural gas
D. electricity produced by hydropower

Question 6

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 7

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 8

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.

DO NOT WRITE IN THIS AREA

Question 9

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

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

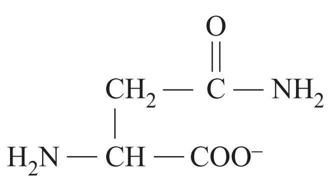
Using the information above, the percentage energy content due to protein in an average serving size of this muesli is

A. 31.2%
B. 29.3%
C. 14.0%
D. 13.2%

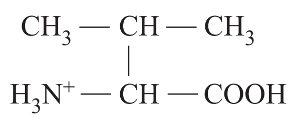
Question 10

Which one of the following structures represents a zwitterion of a 2-amino acid?

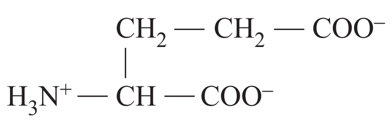
A.



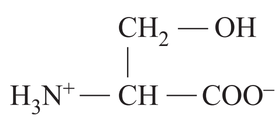
B.



C.



D.



DO NOT WRITE IN THIS AREA

Question 11

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 12

When stored under identical conditions, which one of the following fatty acids is likely to undergo oxidative rancidity in the shortest time?

A. linolenic acid

B. linoleic acid

C. stearic acid

D. oleic acid

Use the following information to answer Questions 13 and 14.

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 13

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 14

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 15

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.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 16

A patient's blood tests indicate clinically low levels of vitamins C and D.

Which one of the following recommendations would **most** effectively and safely increase the patient's levels of both vitamins C and D?

A. Take a supplement of oil containing vitamin D regularly and eat citrus fruit daily.

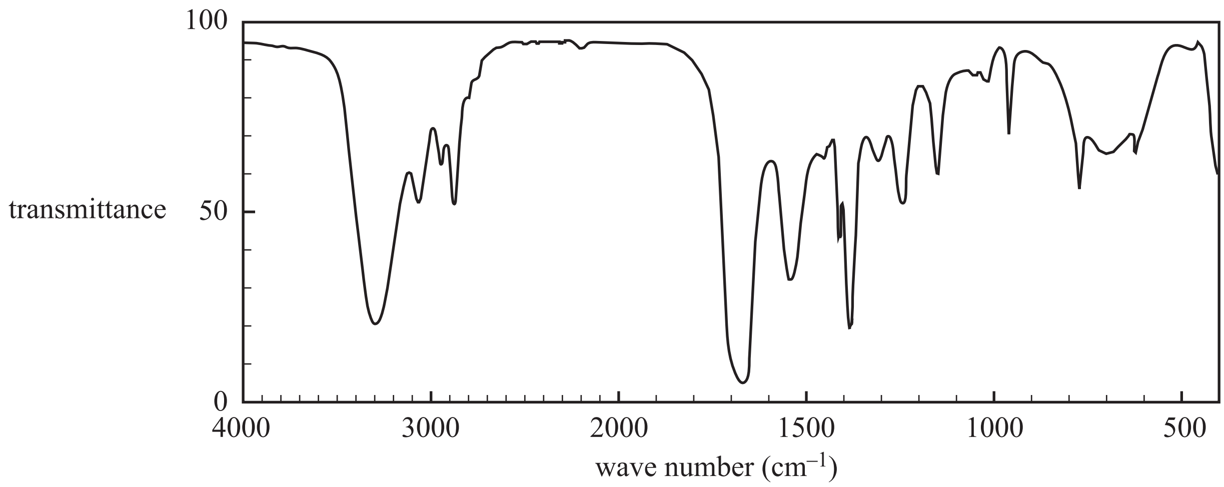
B. Eat more dairy products and spend one hour per day in the sun wearing sun protection.

C. Dissolve a vitamin C tablet and a vitamin D tablet in a glass of water each morning and drink it.

D. Eat more green leafy vegetables and spend one hour per day in the sun without wearing sun protection.

Question 17

Shown below is the infra-red spectrum of an organic compound.



Data: SDBS Web, <http://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

The organic compound that produces this spectrum is an

A. aldehyde.

B. alcohol.

C. amide.

D. ester.

Question 18

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.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

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 19

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 20

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.

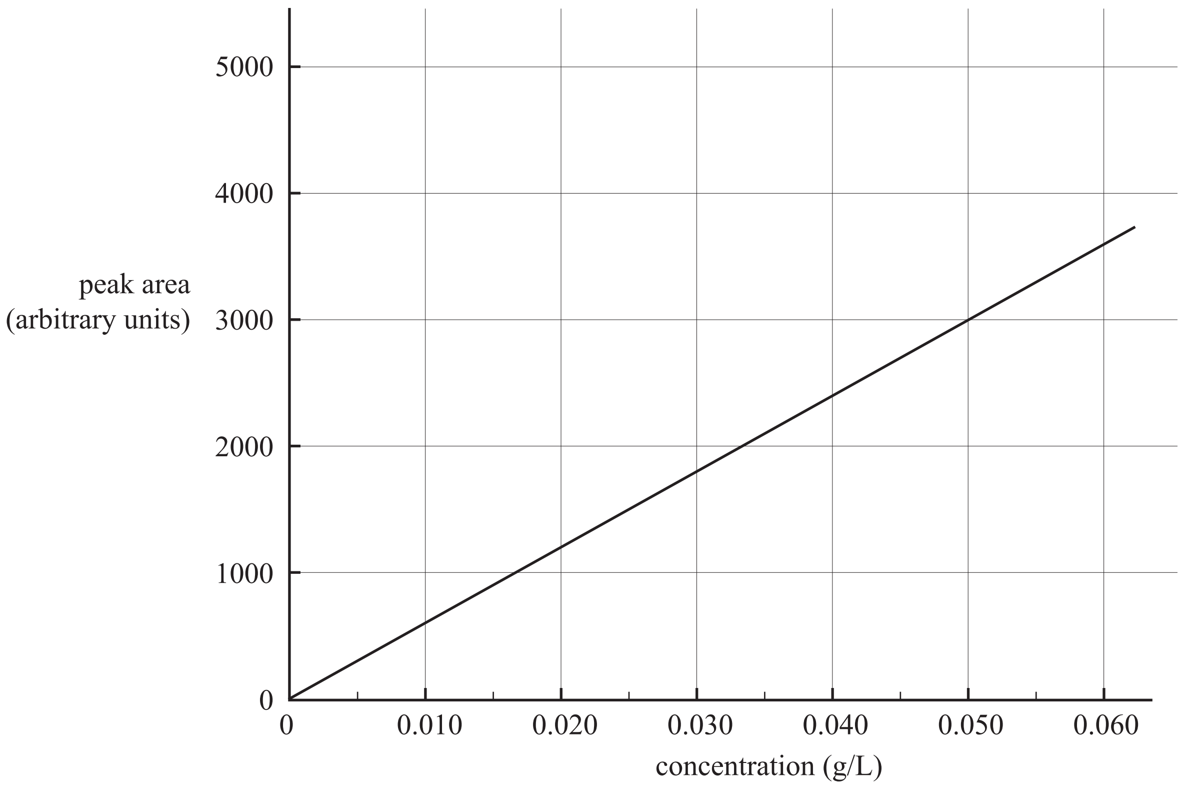
D. decreases and electrical energy is converted to chemical energy.

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 21 and 22.

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 21

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 22

The mass of caffeine, in grams, in 350 mL of the undiluted coffee drink is closest to

A. 0.014

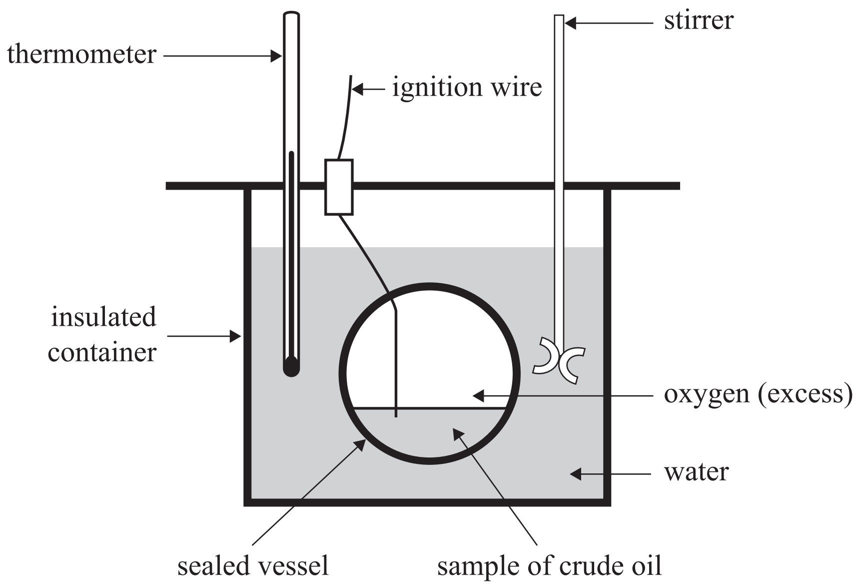
B. 0.070

C. 0.14

D. 0.40

Question 23

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.

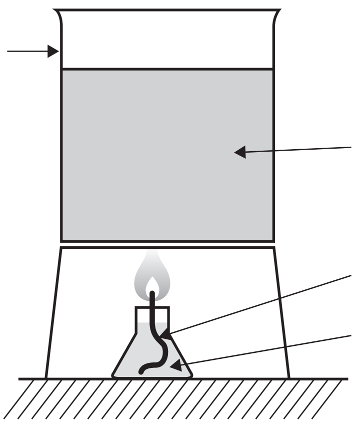
C. accuracy by taking samples from three different sources.

D. uncertainty by having all students closely follow the same experimental procedure.

Question 24

A sample of olive oil with a wick in a jar is ignited and used to heat a beaker containing 500.0 g of water, H_2O.

The relevant data for the experiment is included in the table below.



Data

initial temperature (H_2O)	21.0 °C
ΔH (olive oil)	41.0 kJ g^{-1}
total energy lost to the environment	28.0 kJ

After complete combustion of 2.97 g of olive oil, the **final** temperature of the water, in degrees Celsius, would be

A. 44.9

B. 58.0

C. 65.9

D. 79.3

Question 25

The glycaemic index (GI) indicates how quickly carbohydrates in food are broken down and raise a person's blood glucose level. The table below shows the percentage of amylose and amylopectin in the carbohydrate content of four foods, P, Q, R and S.

Based on this information, which one of the foods listed would be expected to have the lowest GI value?

	Food	Amylose (%)	Amylopectin (%)
A.	P	30	70
B.	Q	24	76
C.	R	14	86
D.	S	20	80

Question 26

10 g of carbon dioxide, CO_2, gas is injected into a sealed, evacuated 12 L vessel at 30 °C.

After a further 1 g of CO_2 gas is injected into the vessel, what is the temperature change, in degrees Celsius, required to maintain the original pressure?

A. –28

B. –3.7

C. +3.7

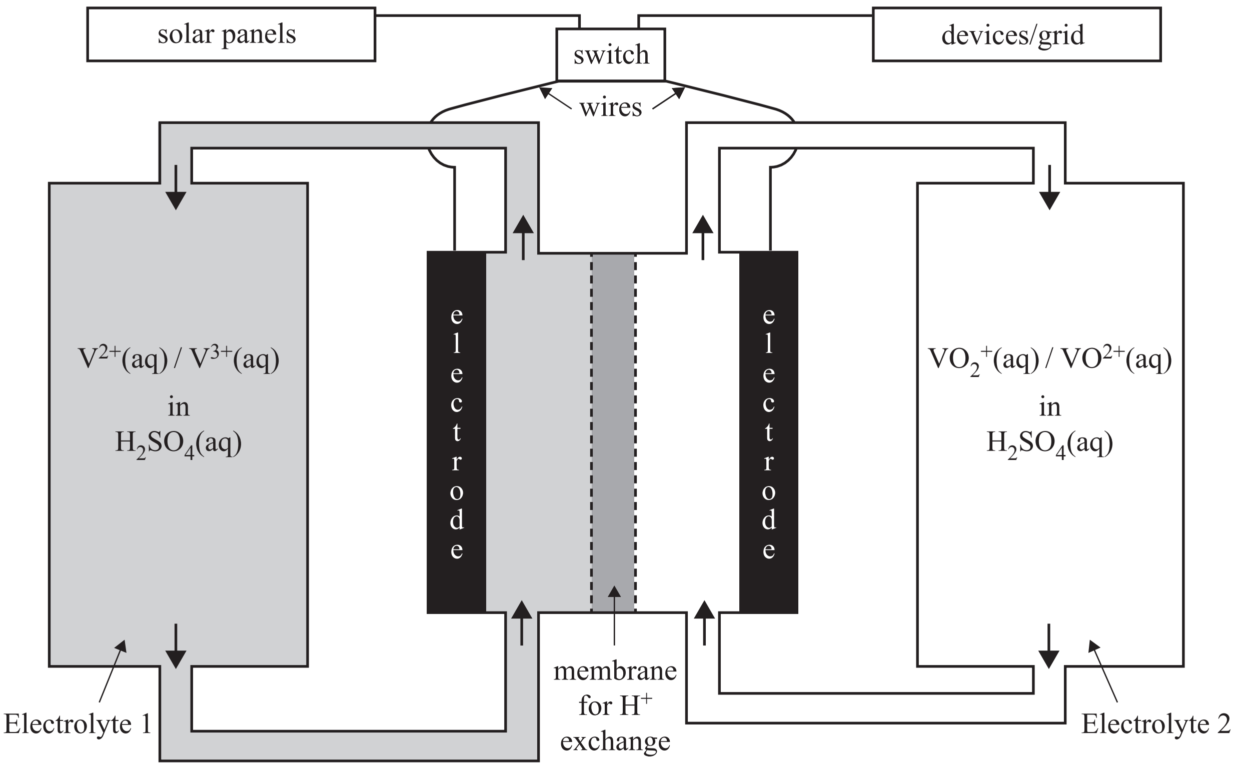
D. +28

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 27 and 28.

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.

$$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l) \qquad E^0 = +1.00\ V$$
$$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq) \qquad E^0 = -0.26\ V$$

Question 27

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

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 28

If air is present, the following half-equations are also relevant.

$$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l) \qquad E^0 = +1.23\ V$$
$$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l) \qquad E^0 = +0.34\ V$$

If air is present, the

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

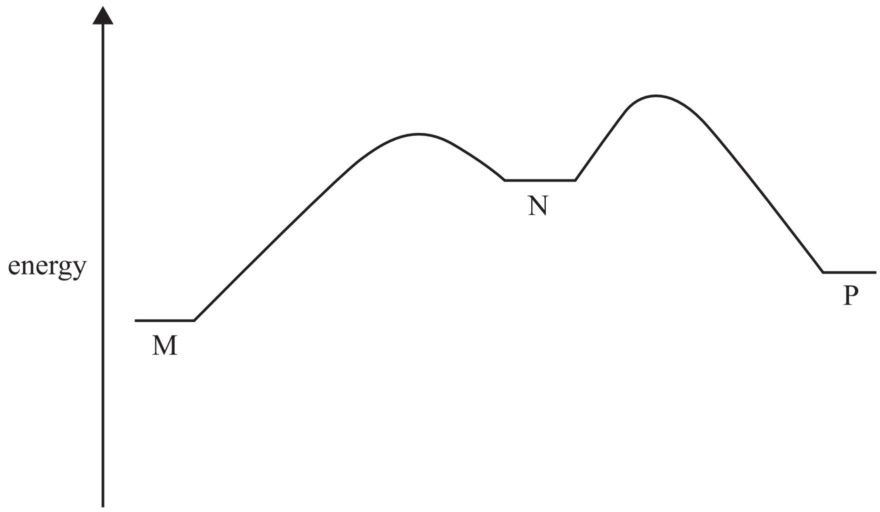
B. $VO^{2+}(aq)$ ion is reduced to the $V^{3+}(aq)$ ion.

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 29

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.

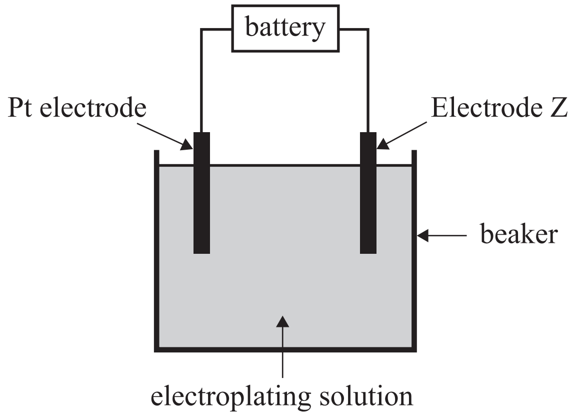
B. The energy change from M to P is exothermic and the energy change from N to P is endothermic.

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 30

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 M 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 M 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?

	Electrode Z	Electroplating solution
A.	chromium, Cr	1.0 M $Cr(NO_3)_3$
B.	silver, Ag	1.0 M $AgNO_3$
C.	gold, Au	1.0 M $AuCl_3$
D.	tin, Sn	1.0 M $SnSO_4$

DO NOT WRITE IN THIS AREA

END OF SECTION A

DO NOT WRITE IN THIS AREA

CONTINUES OVER PAGE

TURN OVER

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, $NaCl(s)$.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (8 marks)

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.

$M(C_{12}H_{22}O_{11}) = 342 \text{ g mol}^{-1}$ — 2 marks

b. **i.** Complete the reaction by writing the formula for the reactant in the box provided below. — 1 mark

$$C_2H_4(g) \quad + \quad \boxed{} \quad \xrightarrow{\text{catalyst}} \quad C_2H_5OH(g)$$

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

Reagent X

$$C_2H_5OH \longrightarrow CH_3COOH$$

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

Question 2 (9 marks)

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)	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. Describe and explain the difference in viscosity, under the same conditions, of the two fuels and how this would affect the flow of each fuel. 3 marks

DO NOT WRITE IN THIS AREA

b. Assume that combustion occurs in an unlimited supply of oxygen for each of the following calculations.

Using the data from the table on page 18

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

c. 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

DO NOT WRITE IN THIS AREA

Question 3 (10 marks)

Liver cells can store excess glucose.

a. **i.** Name the polysaccharide that is used to store excess glucose in the liver. 1 mark

____

ii. Name the bond connecting two glucose units in the polysaccharide named in **part a.i.** 1 mark

____

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-[Met-Asn-Thr-COOH]

b. **i.** 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

ii. Describe the bonding that is found in the primary and secondary structures of the glucagon molecule. 3 marks

____

____

____

____

____

c. Explain why the amino acids serine and glutamine are **not** needed in the human diet, whereas histidine and threonine are needed. 2 marks

____

____

____

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 4 (8 marks)

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.

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

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_c, at 1000 K. 4 marks

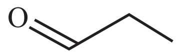
b. A manufacturer of SO_3 investigates changes to the reaction conditions used in **part a.** in order to increase the percentage yield of the product in a closed system, where the volume may be changed, if required.

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

Question 5 (9 marks)

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.



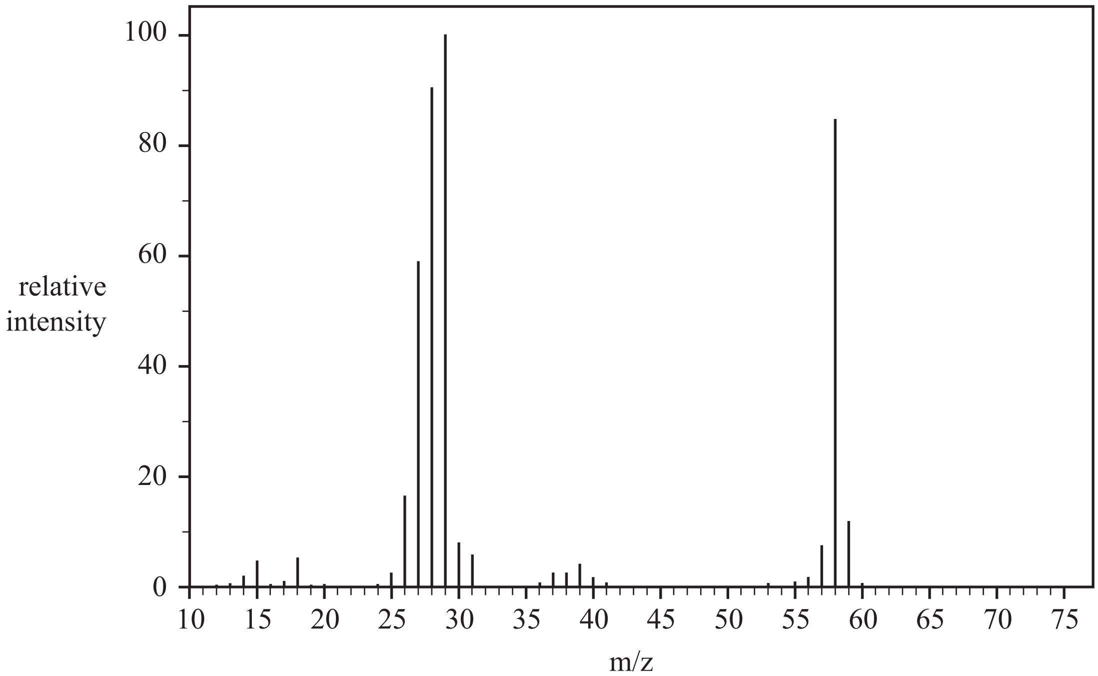
a. **i.** Write the semi-structural formula for the ketone isomer propanone. 1 mark

____

ii. Draw the structural formula for the isomer prop-2-en-1-ol in the space provided below. 1 mark

DO NOT WRITE IN THIS AREA

b. The mass spectrum below was produced by one of the three named isomers of C_3H_6O.



Data: SDBS Web, <http://sdbs.db.aist.go.jp>, National Institute of Advanced Industrial Science and Technology

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

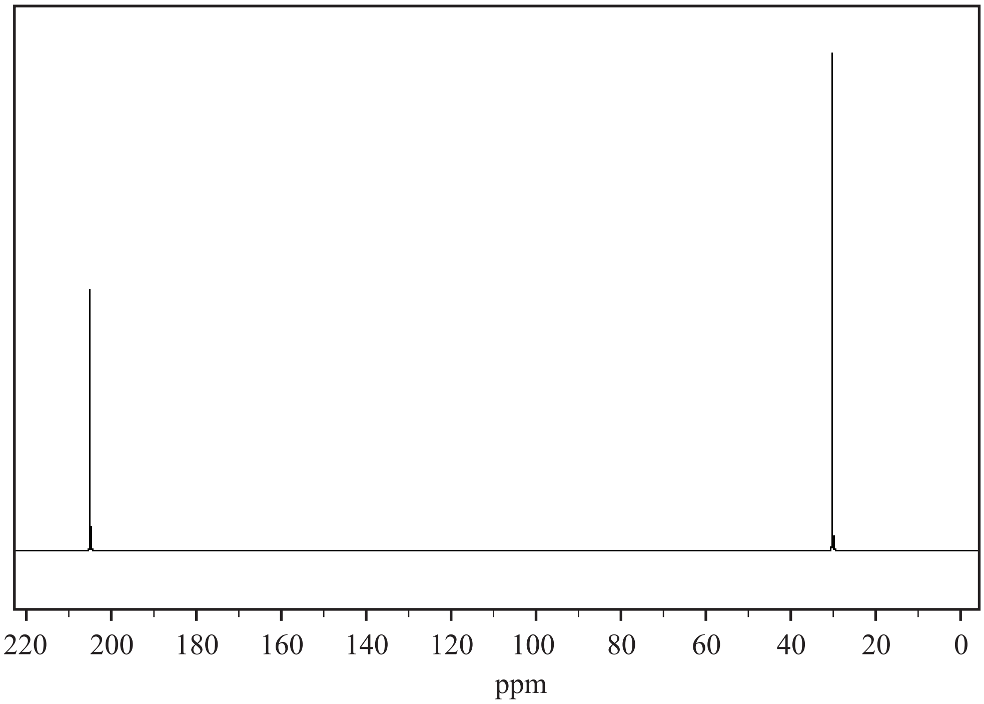
____

____

____

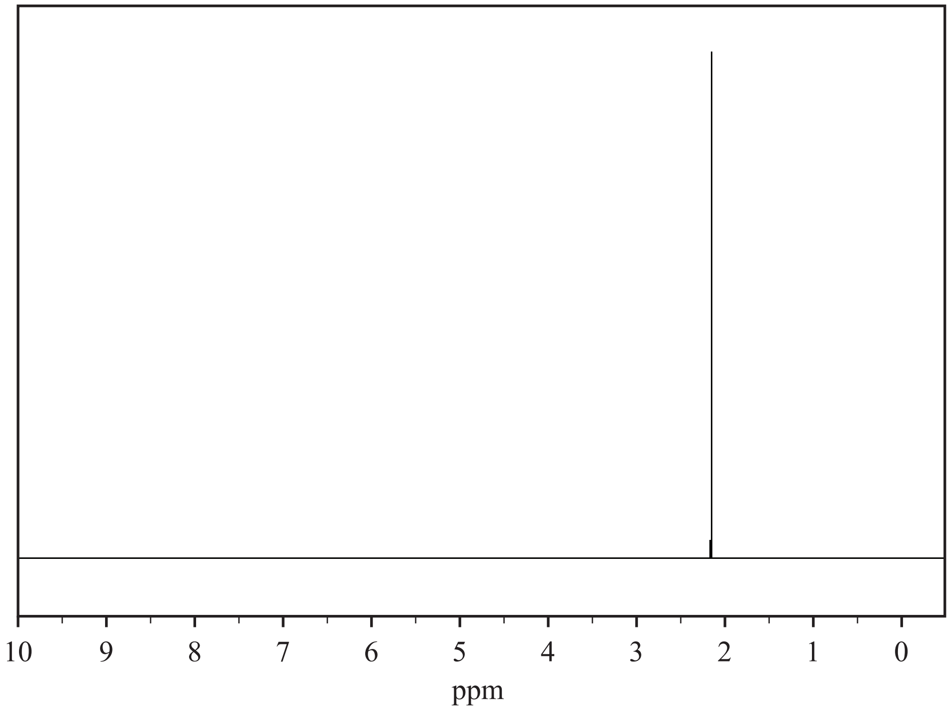
c. Consider the ^{13}C NMR and ^{1}H NMR spectra below.

^{13}C NMR spectrum



Data: SDBS Web, <http://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

^{1}H NMR spectrum



Data: SDBS Web, <http://sdbs.db.aist.go.jp>,
National Institute of Advanced Industrial Science and Technology

DO NOT WRITE IN THIS AREA

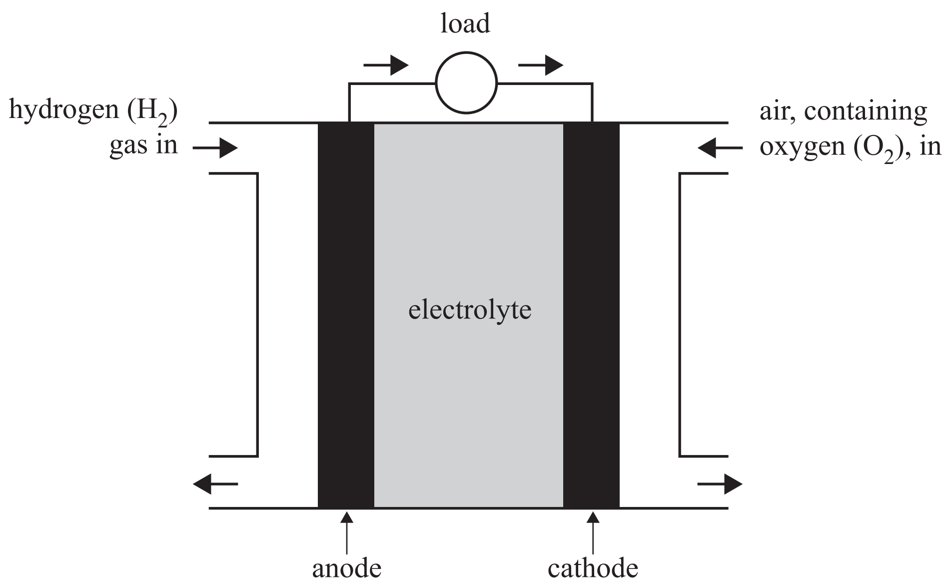
DO NOT WRITE IN THIS AREA

Identify which one of the three named isomers of C_3H_6O produced the NMR spectra on page 24. Justify your answer by referencing both spectra. 3 marks

Question 6 (8 marks)

Submarines operate both on the surface and underwater. When operating underwater, the submarine acts as a closed system, where there is no interaction with the atmosphere. Most types of submarines use both batteries and diesel engines to provide their energy requirements. A new type of submarine uses proton exchange membrane (PEM) fuel cells and diesel engines.

Below is a diagram of a PEM fuel cell.



a. **i.** State the function of the electrolyte in a fuel cell. 1 mark

ii. Write the balanced overall redox reaction that occurs in this PEM fuel cell. 1 mark

iii. Give **two** safety considerations for the safe storage of hydrogen, H_2, gas on a submarine. 2 marks

DO NOT WRITE IN THIS AREA

b. **i.** State **two** advantages of using a PEM fuel cell compared to a diesel engine when a submarine is underwater. 2 marks

ii. Most submarines generate more H_2 gas for their fuel cells when travelling on the surface.

Explain how the H_2 gas could be generated. 2 marks

Question 7 (10 marks)

A table of fatty acids and melting points is shown below.

Fatty acid	Melting point (°C)
palmitic	63
stearic	70
oleic	16
linoleic	–5

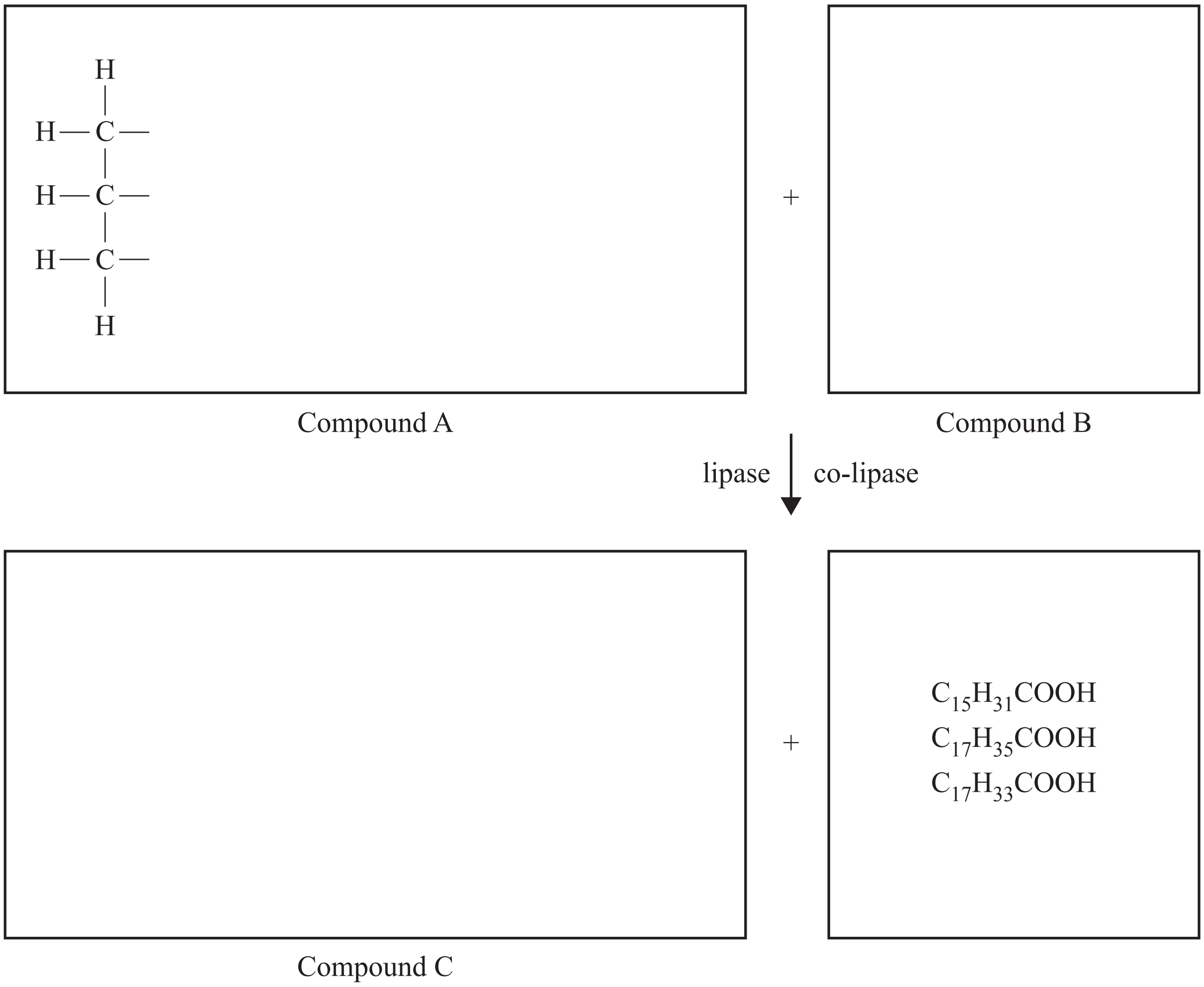
a. With reference to their structure and bonding, explain the difference in melting points between 4 marks

- palmitic and stearic acids

- stearic and linoleic acids.

DO NOT WRITE IN THIS AREA

b. A particular triglyceride found in beef, Compound A, contains three different fatty acid chains: palmitic, stearic and oleic. Compound A undergoes hydrolysis in the human body before its nutrients can be absorbed. The reaction pathway below represents this reaction.



i. Complete the structure of Compound A in the box provided. 2 marks

ii. Write the formula of Compound B and its correct stoichiometric ratio in the box provided. 1 mark

iii. Draw the structural formula of the product molecule, Compound C, in the box provided. 1 mark

c. Lipase and co-lipase work together to catalyse the reaction in **part b.**

Describe how enzymes and coenzymes interact to catalyse a reaction. 2 marks

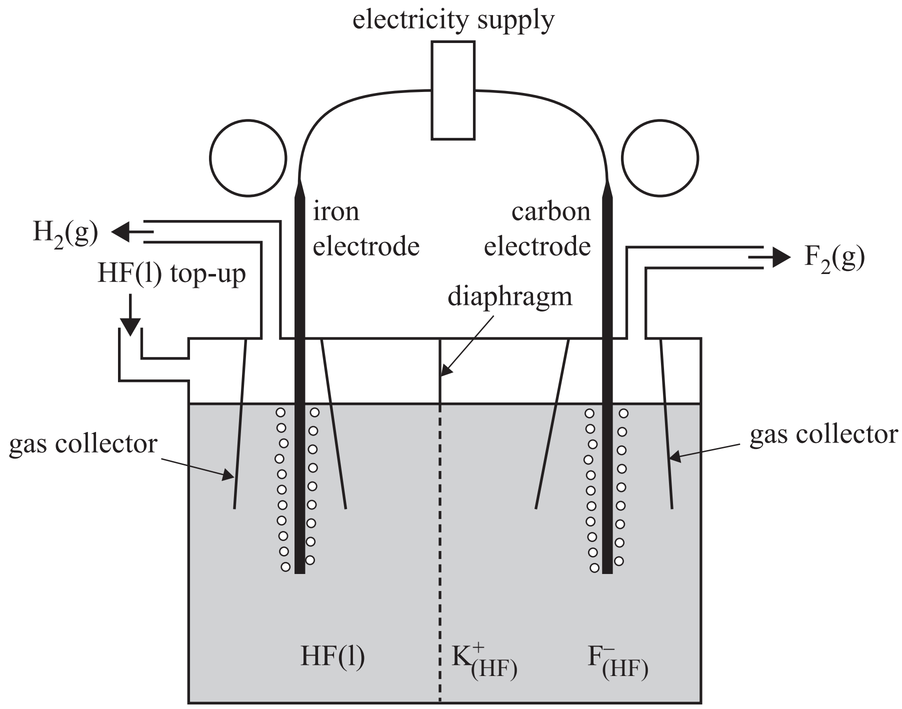
Question 8 (9 marks)

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

DO NOT WRITE IN THIS AREA

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

Question 9 (13 marks)

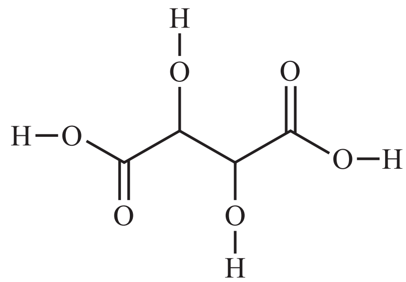
A group of students designed and carried out an experiment to investigate if tartaric acid, $C_4H_6O_6$, that was bought commercially is 99% pure, as claimed by the manufacturer. The experiment involved titrating $C_4H_6O_6$ with sodium hydroxide, NaOH, solution, calculating the percentage purity of $C_4H_6O_6$ 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.

Skeletal diagram for $C_4H_6O_6$



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 = 30/150 × 1/0.50 = 0.40 mol L^{-1}

$n(C_4H_6O_6)$ in 10.00 mL = 0.40 × 10/1000 = 0.0040 mol

$n(NaOH) = 2 \times n(C_4H_6O_6)$ = 0.0080 mol

$V(NaOH)$ titre = 0.0080/0.5 = 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.

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

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 + 14.79)/3 = 14.79 mL

n(NaOH) = 0.5 × 0.01479 mol = 0.00749

$n(C_2H_6O_6)$ = 1/2 × n(NaOH) = 0.00749/2 = 0.00370 mol in 10.00 mL of $C_4H_6O_6$ solution

Percentage purity

% purity of $C_4H_6O_6$ = actual n/predicted n × 100 = 0.0037/0.0040 × 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 on page 33 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

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

f. The material safety data sheet (MSDS) for $C_4H_6O_6$ powder includes the following statement:
'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? 2 marks

- Preparing the $C_4H_6O_6$ solution ______________________________

____

- Conducting the titration ______________________________

____

Question 10 (6 marks)

The planet Mars has a similar day and night cycle to Earth and a day on Mars lasts about 24 hrs 40 min. The atmospheric pressure on Mars is less than 1% of Earth's atmospheric pressure and over 95% of the Mars atmosphere is carbon dioxide. Water, as ice, is found in abundance just below the surface in several locations. The average temperature is –55 °C. The surface temperature may reach 20 °C at the equator and as low as –153 °C at the poles.

A company is preparing a proposal to set up a colony on Mars for a government space agency. A major component of the planning stage is ensuring that the energy needed to sustain the colony is available. The colony on Mars is expected to become self-sufficient in energy after six months.

The company has identified the need to generate usable energy in the short term and over a longer time period. One suggestion is using biofuels to generate usable energy. Biological organisms would be transported from Earth, along with the equipment needed to generate biogas, bioethanol and biodiesel.

a. Using the chemistry you studied this year and the information above, evaluate the feasibility of this suggestion for meeting the energy needs of a colony on Mars. 4 marks

DO NOT WRITE IN THIS AREA

b. An alternative suggestion is to use batteries that have the advantage of being recharged using solar energy.

State **one** other advantage of this suggestion. Give a reason for your answer. 2 marks

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2017

CHEMISTRY
Written examination

DATA BOOK

Instructions

This data book is provided for your reference.
A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

Table of contents

1. Periodic table of the elements

atomic number	79	symbol of element
relative atomic mass	Au 197.0	
	gold	name of element

1 **H** 1.0 hydrogen																	**2** **He** 4.0 helium
3 **Li** 6.9 lithium	**4** **Be** 9.0 beryllium											**5** **B** 10.8 boron	**6** **C** 12.0 carbon	**7** **N** 14.0 nitrogen	**8** **O** 16.0 oxygen	**9** **F** 19.0 fluorine	**10** **Ne** 20.2 neon
11 **Na** 23.0 sodium	**12** **Mg** 24.3 magnesium											**13** **Al** 27.0 aluminium	**14** **Si** 28.1 silicon	**15** **P** 31.0 phosphorus	**16** **S** 32.1 sulfur	**17** **Cl** 35.5 chlorine	**18** **Ar** 39.9 argon
19 **K** 39.1 potassium	**20** **Ca** 40.1 calcium	**21** **Sc** 45.0 scandium	**22** **Ti** 47.9 titanium	**23** **V** 50.9 vanadium	**24** **Cr** 52.0 chromium	**25** **Mn** 54.9 manganese	**26** **Fe** 55.8 iron	**27** **Co** 58.9 cobalt	**28** **Ni** 58.7 nickel	**29** **Cu** 63.5 copper	**30** **Zn** 65.4 zinc	**31** **Ga** 69.7 gallium	**32** **Ge** 72.6 germanium	**33** **As** 74.9 arsenic	**34** **Se** 79.0 selenium	**35** **Br** 79.9 bromine	**36** **Kr** 83.8 krypton
37 **Rb** 85.5 rubidium	**38** **Sr** 87.6 strontium	**39** **Y** 88.9 yttrium	**40** **Zr** 91.2 zirconium	**41** **Nb** 92.9 niobium	**42** **Mo** 96.0 molybdenum	**43** **Tc** (98) technetium	**44** **Ru** 101.1 ruthenium	**45** **Rh** 102.9 rhodium	**46** **Pd** 106.4 palladium	**47** **Ag** 107.9 silver	**48** **Cd** 112.4 cadmium	**49** **In** 114.8 indium	**50** **Sn** 118.7 tin	**51** **Sb** 121.8 antimony	**52** **Te** 127.6 tellurium	**53** **I** 126.9 iodine	**54** **Xe** 131.3 xenon
55 **Cs** 132.9 caesium	**56** **Ba** 137.3 barium	**57–71** lanthanoids	**72** **Hf** 178.5 hafnium	**73** **Ta** 180.9 tantalum	**74** **W** 183.8 tungsten	**75** **Re** 186.2 rhenium	**76** **Os** 190.2 osmium	**77** **Ir** 192.2 iridium	**78** **Pt** 195.1 platinum	**79** **Au** 197.0 gold	**80** **Hg** 200.6 mercury	**81** **Tl** 204.4 thallium	**82** **Pb** 207.2 lead	**83** **Bi** 209.0 bismuth	**84** **Po** (210) polonium	**85** **At** (210) astatine	**86** **Rn** (222) radon
87 **Fr** (223) francium	**88** **Ra** (226) radium	**89–103** actinoids	**104** **Rf** (261) rutherfordium	**105** **Db** (262) dubnium	**106** **Sg** (266) seaborgium	**107** **Bh** (264) bohrium	**108** **Hs** (267) hassium	**109** **Mt** (268) meitnerium	**110** **Ds** (271) darmstadtium	**111** **Rg** (272) roentgenium	**112** **Cn** (285) copernicium	**113** **Nh** (280) nihonium	**114** **Fl** (289) flerovium	**115** **Mc** (289) moscovium	**116** **Lv** (292) livermorium	**117** **Ts** (294) tennessine	**118** **Og** (294) oganesson

57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium

89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

2. Electrochemical series

Reaction	Standard electrode potential (E^0) in volts at 25 °C
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(1)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.25
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	–0.40
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.18
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.66
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.37
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.04

3. Chemical relationships

Name	Formula
number of moles of a substance	$n = \frac{m}{M}$; $n = cV$; $n = \frac{V}{V_m}$
universal gas equation	$pV = nRT$
calibration factor (CF) for bomb calorimetry	$\text{CF} = \frac{VIt}{\Delta T}$
heat energy released in the combustion of a fuel	$q = mc\Delta T$
enthalpy of combustion	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
number of moles of electrons	$n(e^-) = \frac{Q}{F}$
% atom economy	$\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times \frac{100}{1}$
% yield	$\frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
charge on one electron (elementary charge)	e	-1.60×10^{-19} C
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25 °C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25 °C	d	997 kg m^{-3} or 0.997 g mL^{-1}

5. Unit conversions

Measured value	Conversion
0 °C	273 K
100 kPa	750 mm Hg or 0.987 atm
1 litre (L)	1 dm^3 or 1×10^{-3} m^3 or 1×10^{3} cm^3 or 1×10^{3} mL

6. Metric (including SI) prefixes

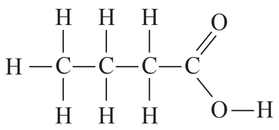
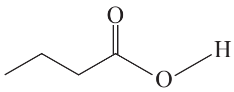
Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^{9}	1 000 000 000
mega (M)	10^{6}	1 000 000
kilo (k)	10^{3}	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

7. Acid-base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2–2.8	red → yellow
methyl orange	3.1–4.4	red → yellow
bromophenol blue	3.0–4.6	yellow → blue
methyl red	4.4–6.2	red → yellow
bromothymol blue	6.0–7.6	yellow → blue
phenol red	6.8–8.4	yellow → red
thymol blue (2nd change)	8.0–9.6	yellow → blue
phenolphthalein	8.3–10.0	colourless → pink

8. Representations of organic molecules

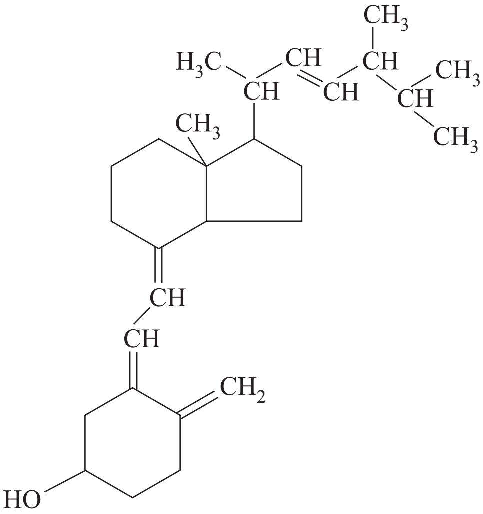
The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

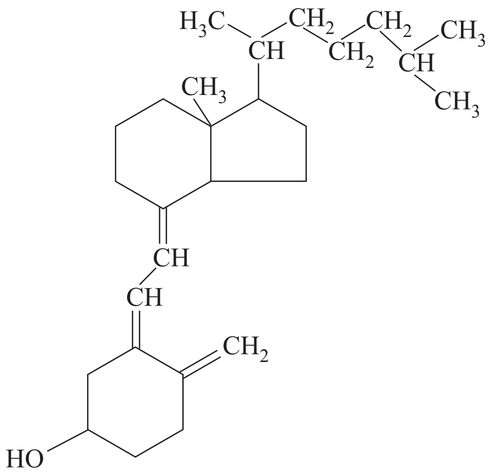
9. Formulas of some fatty acids

Name	Formula	Semi-structural formula
lauric	$C_{11}H_{23}COOH$	$CH_3(CH_2)_{10}COOH$
myristic	$C_{13}H_{27}COOH$	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{15}H_{31}COOH$	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{15}H_{29}COOH$	$CH_3(CH_2)_4CH_2CH{=}CHCH_2\ (CH_2)_5CH_2COOH$
stearic	$C_{17}H_{35}COOH$	$CH_3(CH_2)_{16}COOH$
oleic	$C_{17}H_{33}COOH$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$
linoleic	$C_{17}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$
linolenic	$C_{17}H_{29}COOH$	$CH_3CH_2(CH{=}CHCH_2)_3(CH_2)_6COOH$
arachidic	$C_{19}H_{39}COOH$	$CH_3(CH_2)_{17}CH_2COOH$
arachidonic	$C_{19}H_{31}COOH$	$CH_3(CH_2)_4(CH{=}CHCH_2)_3CH{=}CH(CH_2)_3COOH$

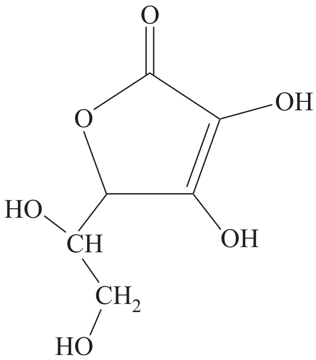
10. Formulas of some biomolecules



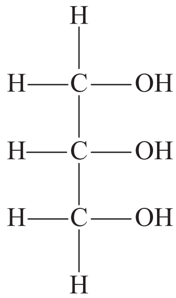
vitamin D_2 (ergocalciferol)



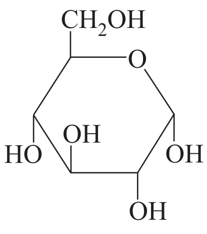
vitamin D_3 (cholecalciferol)



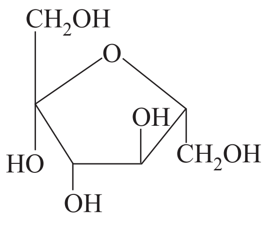
vitamin C (ascorbic acid)



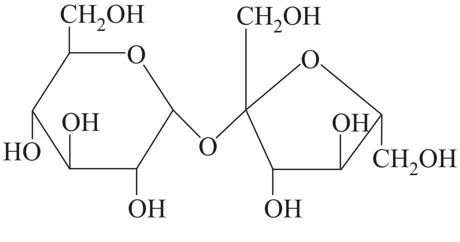
glycerol



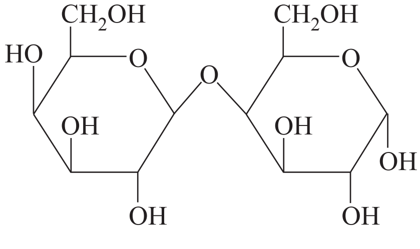
α-glucose



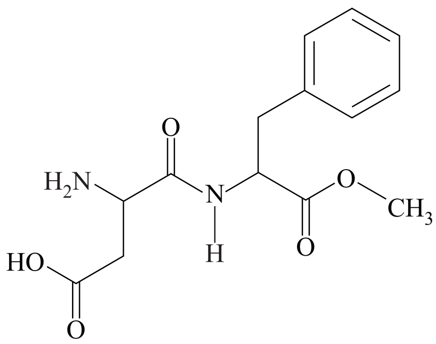
β-fructose



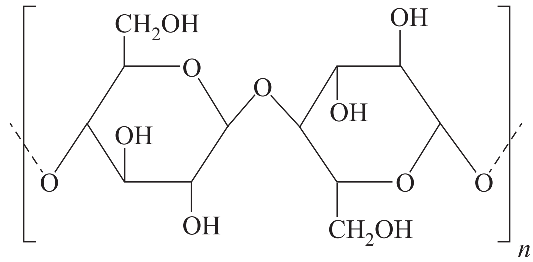
sucrose



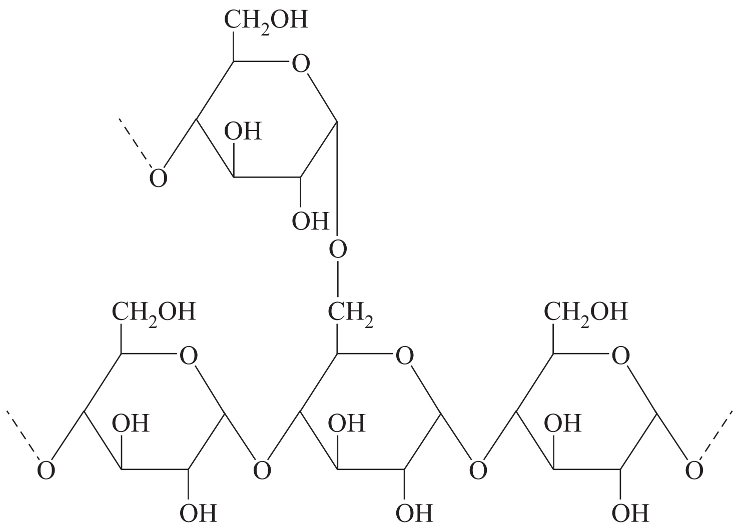
lactose



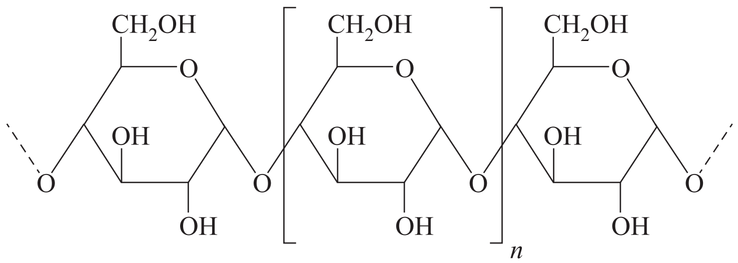
aspartame



cellulose



amylopectin (starch)



amylose (starch)

11. Heats of combustion of common fuels

The heats of combustion in the following table are calculated at SLC (25 °C and 100 kPa) with combustion products being CO_2 and H_2O. Heat of combustion may be defined as the heat energy released when a specified amount of a substance burns completely in oxygen and is, therefore, reported as a positive value, indicating a magnitude. Enthalpy of combustion, ΔH, for the substances in this table would be reported as negative values, indicating the exothermic nature of the combustion reaction.

Fuel	Formula	State	Heat of combustion (kJ g^{-1})	Molar heat of combustion (kJ mol^{-1})
hydrogen	H_2	gas	141	282
methane	CH_4	gas	55.6	890
ethane	C_2H_6	gas	51.9	1560
propane	C_3H_8	gas	50.5	2220
butane	C_4H_{10}	gas	49.7	2880
octane	C_8H_{18}	liquid	47.9	5460
ethyne (acetylene)	C_2H_2	gas	49.9	1300
methanol	CH_3OH	liquid	22.7	726
ethanol	C_2H_5OH	liquid	29.6	1360

12. Heats of combustion of common blended fuels

Blended fuels are mixtures of compounds with different mixture ratios and, hence, determination of a generic molar enthalpy of combustion is not realistic. The values provided in the following table are typical values for heats of combustion at SLC (25 °C and 100 kPa) with combustion products being CO_2 and H_2O. Values for heats of combustion will vary depending on the source and composition of the fuel.

Fuel	State	Heat of combustion (kJ g^{-1})
kerosene	liquid	46.2
diesel	liquid	45.0
natural gas	gas	54.0

13. Energy content of food groups

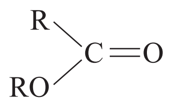
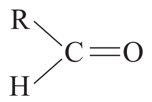
Food	Heat of combustion (kJ g^{-1})
fats and oils	37
protein	17
carbohydrate	16

14. Characteristic ranges for infra-red absorption

Bond	Wave number (cm^{-1})	Bond	Wave number (cm^{-1})
C–Cl (chloroalkanes)	600–800	C=O (ketones)	1680–1850
C–O (alcohols, esters, ethers)	1050–1410	C=O (esters)	1720–1840
C=C (alkenes)	1620–1680	C–H (alkanes, alkenes, arenes)	2850–3090
C=O (amides)	1630–1680	O–H (acids)	2500–3500
C=O (aldehydes)	1660–1745	O–H (alcohols)	3200–3600
C=O (acids)	1680–1740	N–H (amines and amides)	3300–3500

15. ^{13}C NMR data

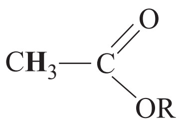
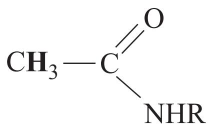
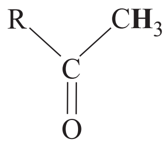
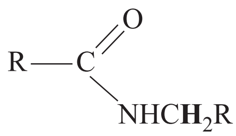
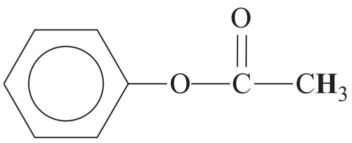
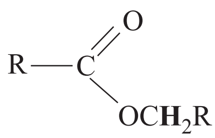
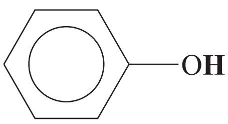
Typical ^{13}C shift values relative to TMS = 0
These can differ slightly in different solvents.

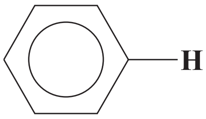
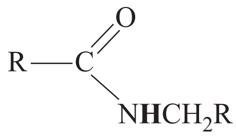
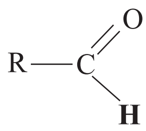
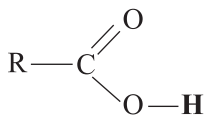
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$, $R_3C–NR$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185
	165–175
	190–200
$R_2C=O$	205–220

16. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

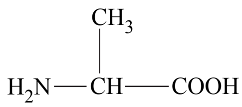
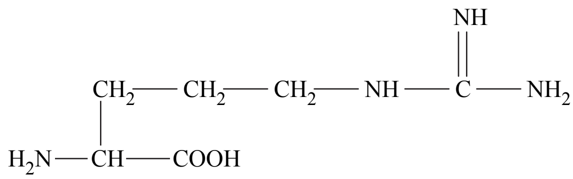
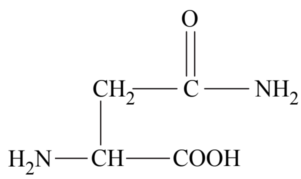
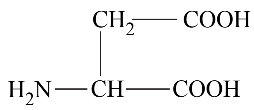
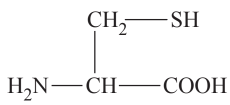
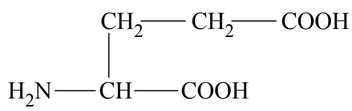
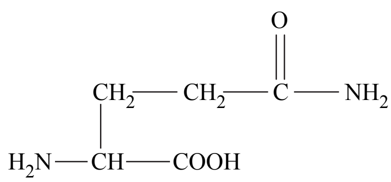
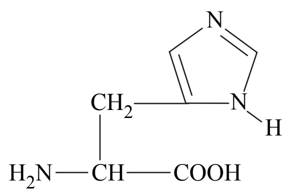
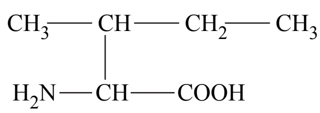
These can differ slightly in different solvents. The shift refers to the proton environment that is indicated in bold letters in the formula.

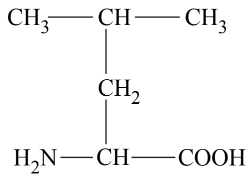
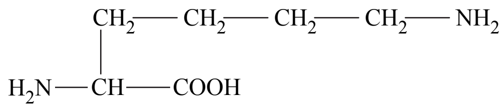
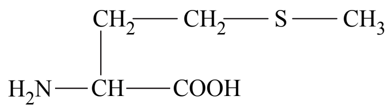
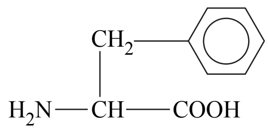
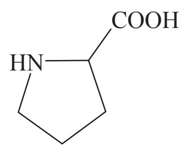
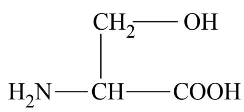
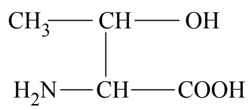
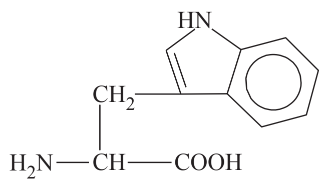
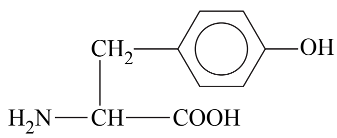
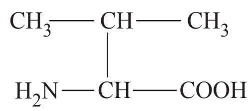
Type of proton	Chemical shift (ppm)
$R{-}C\mathbf{H}_3$	0.9–1.0
$R{-}C\mathbf{H}_2{-}R$	1.3–1.4
$RCH{=}CH{-}C\mathbf{H}_3$	1.6–1.9
$R_3{-}C\mathbf{H}$	1.5
 or 	2.0
	2.1–2.7
$R{-}C\mathbf{H}_2{-}X$ (X = F, Cl, Br or I)	3.0–4.5
$R{-}C\mathbf{H}_2{-}OH$, $R_2{-}C\mathbf{H}{-}OH$	3.3–4.5
	3.2
$R{-}O{-}C\mathbf{H}_3$ or $R{-}O{-}C\mathbf{H}_2R$	3.3–3.7
	2.3
	3.7–4.8
$R{-}O{-}\mathbf{H}$	1–6 (varies considerably under different conditions)
$R{-}N\mathbf{H}_2$	1–5
$RHC{=}C\mathbf{H}R$	4.5–7.0
	4.0–12.0

Type of proton	Chemical shift (ppm)
	6.9–9.0
	8.1
	9.4–10.0
	9.0–13.0

17. 2-amino acids (α-amino acids)

The table below provides simplified structures to enable the drawing of zwitterions, the identification of products of protein hydrolysis and the drawing of structures involving condensation polymerisation of amino acid monomers.

Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamic acid	Glu	
glutamine	Gln	
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

END OF DATA BOOK