VCE CHEMISTRY 2015

YEAR 12 **TRIAL** EXAM

Units 3/4
Reading time: 15 minutes
Writing time: 2 hours 30 minutes

Section	Number of questions	Number of questions to be answered	Number of marks
A	30	30	30
B	7	59	103
			Total 133

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• **Biology** • **Physics** • **Chemistry** • **Psychology**

Student Name...…………………...

VCE Chemistry 2015 Year 12 Trial Exam Units 3/4

Student Answer Sheet

Instructions for completing test. Use only a 2B pencil. If you make a mistake, erase it and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer Section in the space provided directly below the question. There are **30 Multiple Choice** questions to be answered by circling the correct letter in the table below.

Question 1	A	B	C	D		*Question 2*	A	B	C	D
Question 3	A	B	C	D		*Question 4*	A	B	C	D
Question 5	A	B	C	D		*Question 6*	A	B	C	D
Question 7	A	B	C	D		*Question 8*	A	B	C	D
Question 9	A	B	C	D		*Question 10*	A	B	C	D
Question 11	A	B	C	D		*Question 12*	A	B	C	D
Question 13	A	B	C	D		*Question 14*	A	B	C	D
Question 15	A	B	C	D		*Question 16*	A	B	C	D
Question 17	A	B	C	D		*Question 18*	A	B	C	D
Question 19	A	B	C	D		*Question 20*	A	B	C	D
Question 21	A	B	C	D		*Question 22*	A	B	C	D
Question 23	A	B	C	D		*Question 24*	A	B	C	D
Question 25	A	B	C	D		*Question 26*	A	B	C	D
Question 27	A	B	C	D		*Question 28*	A	B	C	D
Question 29	A	B	C	D		*Question 30*	A	B	C	D

VCE Chemistry 2015 Year 12 Trial Exam Units 3/4

SECTION A – Multiple Choice Questions

> *Section A consists of 30 multiple-choice questions.*
> *Section A is worth approximately 22 per cent of the marks available.*
> *Choose the response that is **correct** or **best answers** the question.*
> *A correct answer scores 1, an incorrect answer scores 0.*
> *No mark is awarded if more than one answer is supplied for a question.*
> *Indicate your choice on the answer sheet provided.*

Question 1
Lactic acid and benzoic acids are both weak monoprotic acids.
Which of the following statements relating to aqueous solutions of these acids at 25°C is correct?
A. Diluting aqueous solutions of the acids increases both the number of H_3O^+ ions present and the pH.
B. At equal concentrations, benzoic acid has the higher concentration of H_3O^+.
C. If equal volumes of 0.10 M solutions of both acids are neutralised with 0.10M NaOH(aq), less is needed for benzoic acid.
D. At equal concentrations, lactic acid has the higher pH.

Question 2
Which of the following techniques would be a key analytical tool used in an analysis to identify an unknown organic compound?
A. Atomic absorption spectroscopy.
B. Gas chromatography.
C. Mass spectroscopy.
D. Thin-layer chromatography.

The following information applies to Questions 3, 4 and 5.
Oxygen, $O_2(g)$, and Ozone, $O_3(g)$ can coexist in the atmosphere as part of the equilibrium
$2O_3(g) \rightleftharpoons 3O_2(g)$, $\Delta H = -285.4$ kJ mol^{-1}.
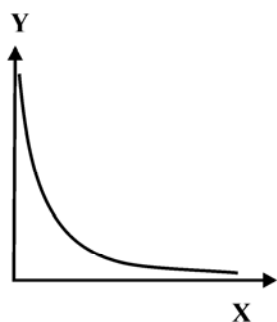At 298 K, $K_c = 1.62 \times 10^{57}$ M

Question 3
The ratio of O_3 to O_2 present in the atmosphere would be expected to increase as a result of
A.   a decrease in atmospheric pressure.
B.   lightning.
C.   a sudden decrease in temperature.
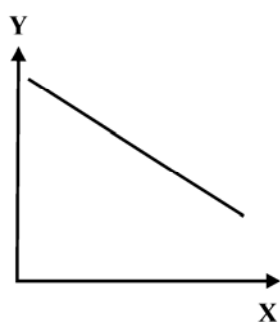D.   extensive flooding.

Question 4
Which of the graphs below best represents the change in value of the equilibrium constant
with temperature for the reaction $2O_3(g) \rightleftharpoons 3O_2(g)$?
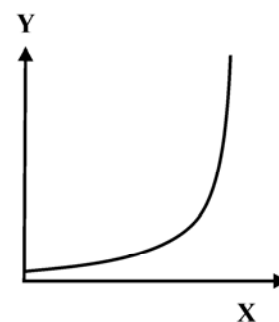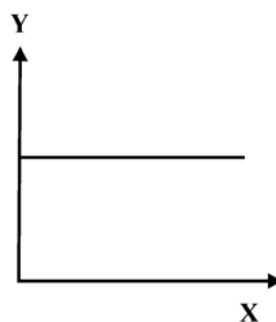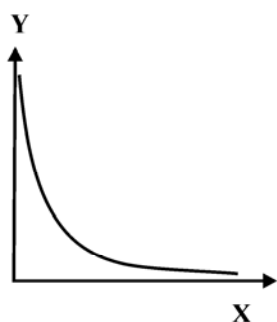A.   B.   C.   D.

Question 5
Which of the graphs below best represents how the change in value of the equilibrium
constant with pressure at constant temperature for the reaction $2O_3(g) \rightleftharpoons 3O_2(g)$?
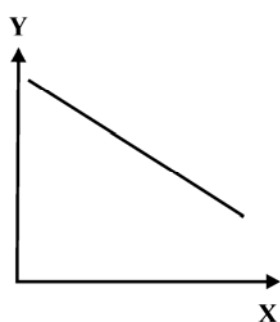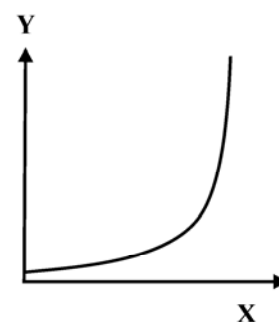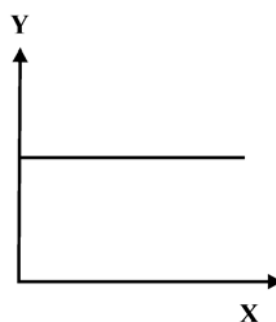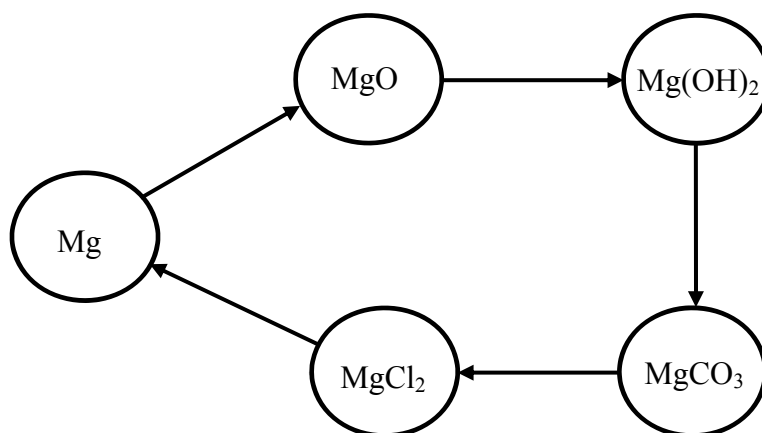A.   B.   C.   D.

Question 6

The diagram below represents a sequence of reactions involving magnesium or its compounds.

The smallest number of other elements or compounds required to complete the reaction sequence is

A.   3
B.   4
C.   5
D.   6

Question 7

A 100 g sample of a metal was heated to 100°C and then quickly immersed in 200 g of water in an insulated container. The water was initially at 22.6°C and when the water and the metal reached thermal equilibrium, the temperature had increased to 29.0°C.

What was the specific heat capacity, in $J\ g^{-1}\ °C^{-1}$, of the metal?

A.   0.376
**B.**   0.754
C.   3.26
D.   4.18

Question 8

Nitrogen molecules absorb ultraviolet light but not visible light, whereas iodine molecules absorb both visible and ultraviolet light. Which of the following alternatives best explains these observations?

A.   Visible light does not contain the wavelengths necessary to make nitrogen molecules change their vibrational energy levels.
B.   Nitrogen molecules are held together by triple covalent bonds and visible light is unable to change their nucleus spin energy levels.
C.   Visible light does not produce transitions between electronic energy levels in nitrogen molecules.
D.   More energy is required to break intramolecular bonds in nitrogen.

Question 9

The concentration-time graphs for a change imposed on an equilibrium system are shown below.
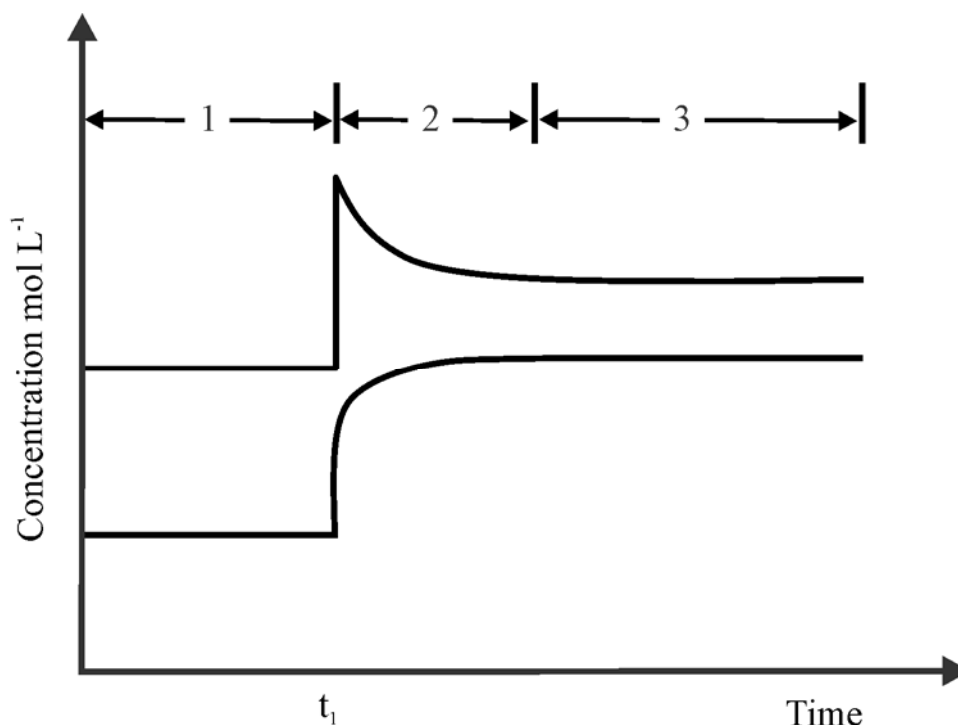
The change imposed at t_1 could have been

A.   the addition of reactant to the equilibrium $3O_2(g) \rightleftharpoons 2O_3(g)$.

B.   a decrease in the volume of the equilibrium $2O_3(g) \rightleftharpoons 3O_2(g)$.

C.   a decrease in the temperature of the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(g)$.

D.   an increase in the temperature of the equilibrium $N_2O_4(g) \rightleftharpoons 2NO_2(g)$.

Question 10

When a small piece of potassium metal was added to water in a beaker the following observations were recorded:

- the potassium spins vigorously and skims across the surface of the water.
- a lilac tinted flame is produced.

Which of the following statements best explains these observations?

A.   The product of the reaction producing the flame was water.

B.   The lilac flame was caused by electrons in potassium atoms moving to higher energy levels.

C.   The pH of the solution formed during the reaction is less than 7.

D.   Potassium is a stronger reductant than water.

Question 11

The relative peak areas for a mixture of four steroids separated by HPLC is given in the following table.

Compound	Relative peak area
Testosterone	32.4
Deoxycorticosterone	47.1
Norgestrel	40.6
Progesterone	27.3

What percentage of the total steroid mixture was made up by Norgestrel?
A.   27.3
B.   27.5
C.   40.6
D.   47.4

Question 12

A mixture of the amino acids, arginine, lysine and phenylalanine are to be separated by reverse phase HPLC. In reverse phase chromatography, the stationary phase is hydrophobic and the mobile phase is hydrophilic. The expected order of elution from the column would be, in order of increasing retention time,
A.   lysine, arginine, phenylalanine.
B.   phenylalanine, arginine, lysine.
C.   lysine, phenylalanine, arginine.
D.   arginine, lysine, phenylalanine.

Metals such as zinc and manganese are essential trace elements for animals and plants. However, heavy metals such as lead or cadmium are toxic, even at low concentrations. When cyanidin is added to an aqueous solution containing traces of heavy metals, it combines with them to produce species that absorb UV-Visible radiation. The species formed when cyanidin combines with lead absorbs at 390 nm.

A set of standards with known concentrations of Pb^{2+}(aq) were made up and the absorbances measured at 390 nm. The calibration curve below was produced. (1 ppb (m/V) = 1 µg L^{-1}).
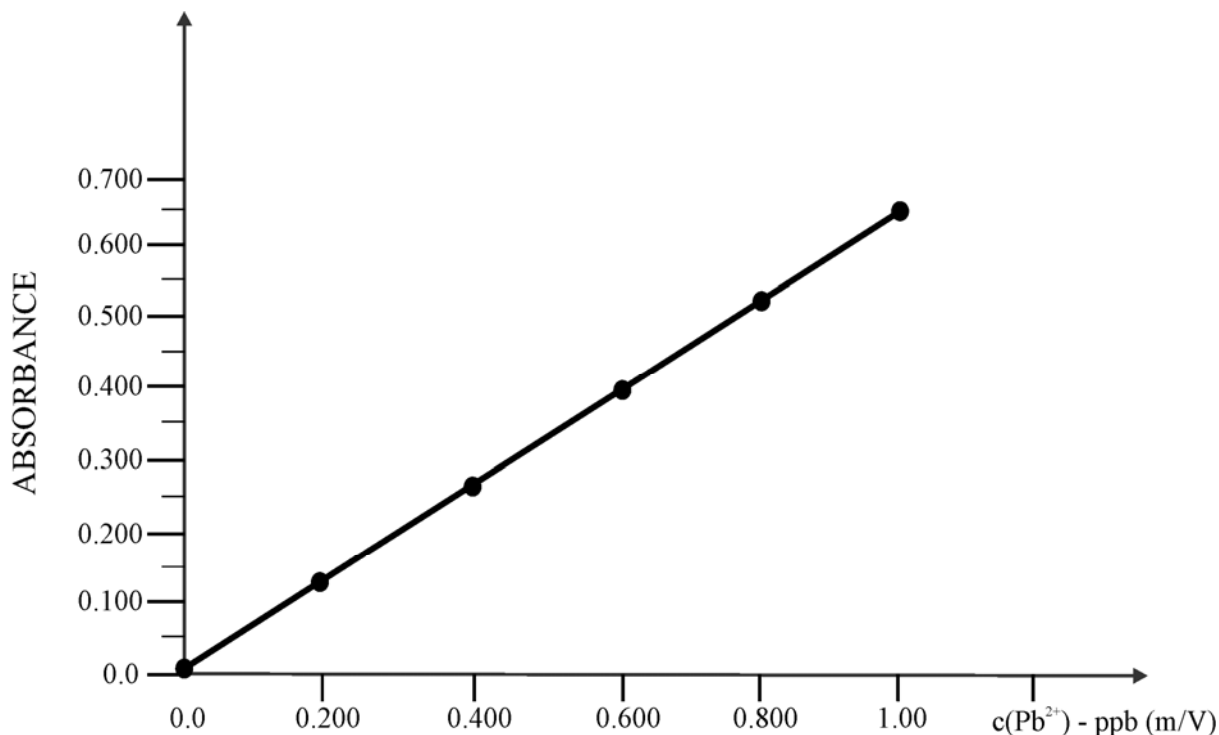

A 2.5 g sample of milk powder was added to water, along with cyanidin to make up 50.0 mL of solution. This solution was further diluted to 200 mL and the absorbance of the diluted solution at 390 nm, measured and recorded as 0.260.

The lead content of the milk in ng g^{-1} is closest to

A.   0.375
B.   7.5
C.   30
D.   150

Question 14

Magnesium carbonate reacts with dilute nitric acid according to the equation

$$MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2 (aq) + H_2O(l) + CO_2(g)$$
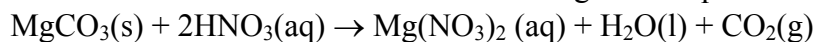
In an experiment to investigate the effect of different conditions on the rate of reaction between excess solid magnesium carbonate and 200 mL of nitric acid, the gas produced in the reaction is collected in a gas syringe and volume collected plotted against time for four different sets of reaction conditions.

The resulting graphs are shown below.
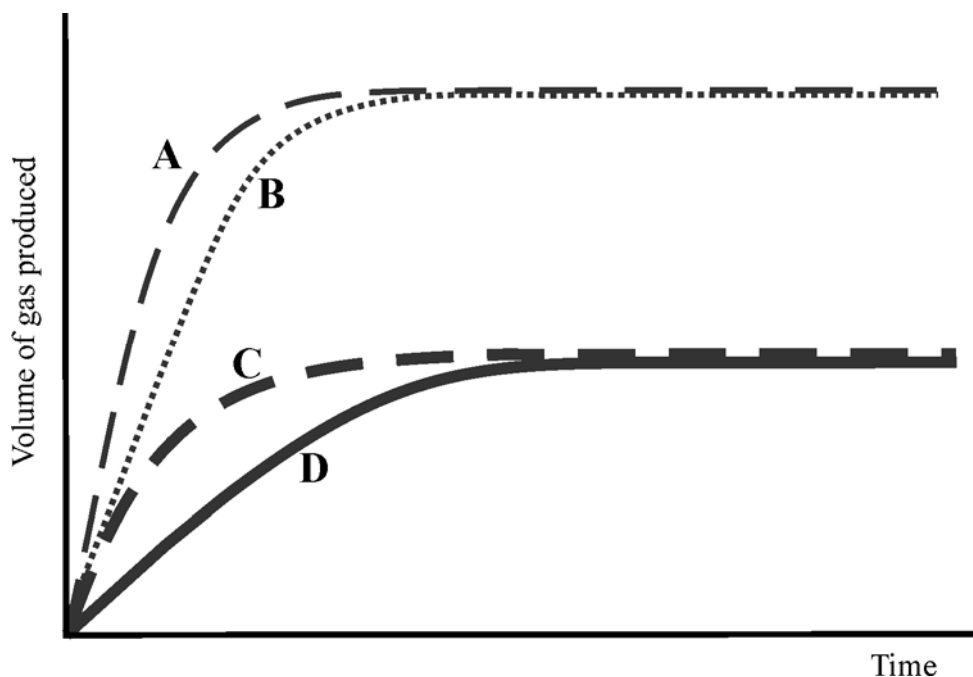
Which of the following statements is **not** consistent with the recorded data?

A. The size of $MgCO_3$ particles was not the same in all four investigations.

B. The concentration of HNO_3 was the same in all four investigations.

C. A catalyst may have been used in one or more of the investigations.

D. The initial temperature may not have been consistent across all four investigations.
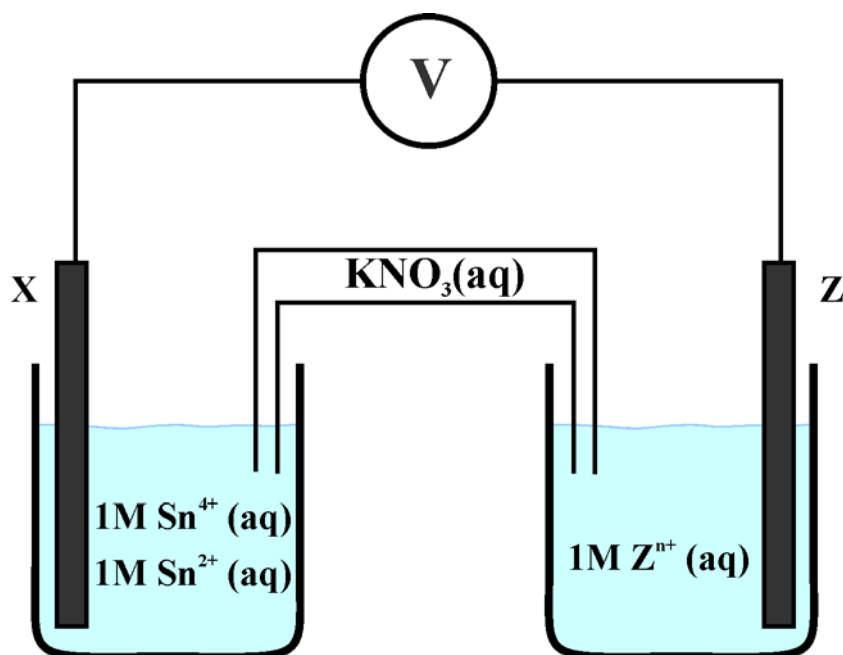
Question 15

20 mL of 0.10 M propanoic acid is diluted to 100 mL with deionised water.

Which of the following is **not** an expected outcome of that change?

A. The $[H_3O^+]$ increases.

B. The number of $H_3O^+(aq)$ ions increases.

C. The pH increases.

D. The percentage ionisation increases.

The information below applies to Questions 16 and 17.
The diagram below represents a simple galvanic cell assembled in a laboratory.

Question 16
Which of the following elements would be **least** suitable for electrode X?
A.   Carbon (graphite).
B.   Silver.
C.   Platinum.
D.   Tin.

Question 17
If the galvanic cell has a potential difference of 1.53 V at 25°C,
A.   the half-equation for the reaction at electrode Z is $Z(s) \rightarrow Z^{n+}_{(aq)} + ne^-$.
B. $K^+(aq)$ ions are moving towards electrode Z.
C.   the cathode is electrode X.
D.   the number of tin(IV) ions in the cell is decreasing.

Question 18
A food cannery is investigating using methane produced by bacterial decomposition of food waste to reduce the use of heating oil which has an average energy value of 38.5 MJ L^{-1}. What is the maximum volume of heating oil that would be saved if 2.45×10^5 L of methane, stored at SLC, is produced from food waste?
A.   43.3 L.
B.   231 L.
C.   636 L.
D. 2.56×10^3 L.

Question 19

A very well insulated bomb calorimeter contains 600 mL of water surrounding the reaction bomb. The calorimeter is calibrated electrically. The heat capacity of the calorimeter hardware, i.e. bomb and other solid components, is 785 J K^{-1}. The calorimeter constant would be closest to

A.   3.29 kJ °C^{-1}
B.   4.18 kJ °C^{-1}
C.   4.97 kJ °C^{-1}
D.   789 kJ °C^{-1}

Question 20

An unknown metal M forms a soluble compound, $M(NO_3)_2$.
When a constant current of 2.50 amperes is applied for 35.0 minutes to an aqueous solution of $M(NO_3)_2$, 3.06 grams of the metal M is deposited.
The metal M was

A.   zinc.
B.   strontium.
C.   cadmium.
D.   copper.

Question 21

A vegetable oil contains only the triglyceride (molar mass 882 g mol^{-1}) shown below
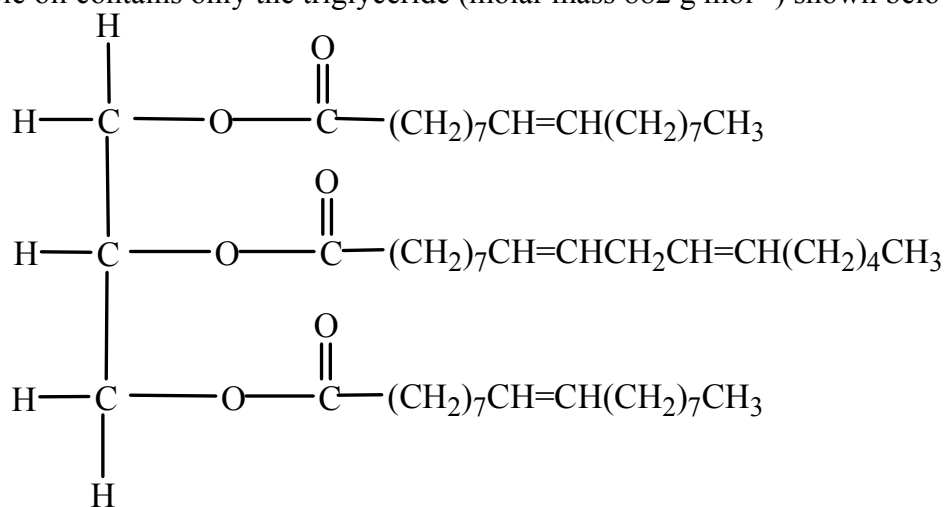
Which of the molecular compounds was **not** used in the production of the triglyceride?
A.   Glycerol.
B.   Stearic acid.
C.   Oleic acid.
D.   Linoleic acid.

Question 22

In aqueous solutions, amino acids often exist in the form of zwitterions. On **zwitterions**

A.   the basic end is the $-NH_2$ and the acidic end is $-COOH$.

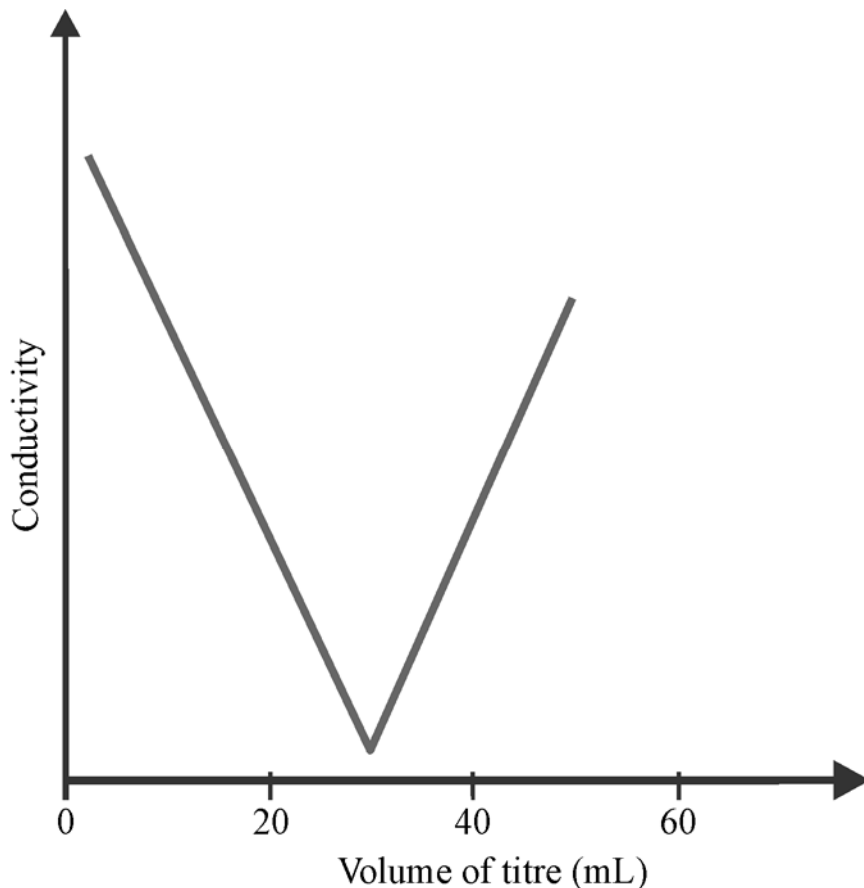B.   the basic end is $-NH_3^+$ and the acidic end is $-COO^-$.

C.   the basic end is $-COO^-$ and the acidic end is $-NH_3^+$.

D.   there is no basic or acid end since proton transfer occurs during the formation of a zwitterion.

Question 23

Shown below is a conductivity curve for the titration of 25.0 ml of $Ba(OH)_2(aq)$ with 0.10 M $H_2SO_4(aq)$.

The $Ba(OH)_2(aq)$

A.   was in excess when 40 mL of titre had been added.

B.   was originally 0.12 M.

C.   was initially at pH 13.1.

D.   released $Ba^{2+}(aq)$ ions which remained in solution throughout the titration.

Question 24

When an aqueous solution of ethanoic acid is titrated with an aqueous solution of sodium hydroxide, the pH at the equivalence point is 8.8.

The species that causes this pH value is

A.   ethanoate ions.

B.   hydroxide ions.

C.   sodium ions.

D.   ethanoic acid molecules.

Question 25
Some heart pacemakers are powered by lithium-iodide batteries. One of the electrodes is lithium metal and the other a solid complex of molecular iodine. The electrolyte is solid lithium iodide in a nickel mesh.
The overall equation for the energy releasing reaction is $2Li(s) + I_2(s) \rightarrow 2LiI(s)$.
What is the maximum amount of electrical energy that could be released by one of these batteries operating at 2.75 V and average current 85.6 µA over 10.0 years of operation?
A.   1.23 kJ
B.   856 J
C.   27.0 MJ
D.   74.2 kJ

Question 26
The titration curve below occurred during a particular acid-base reaction.

Volume of titre (mL)
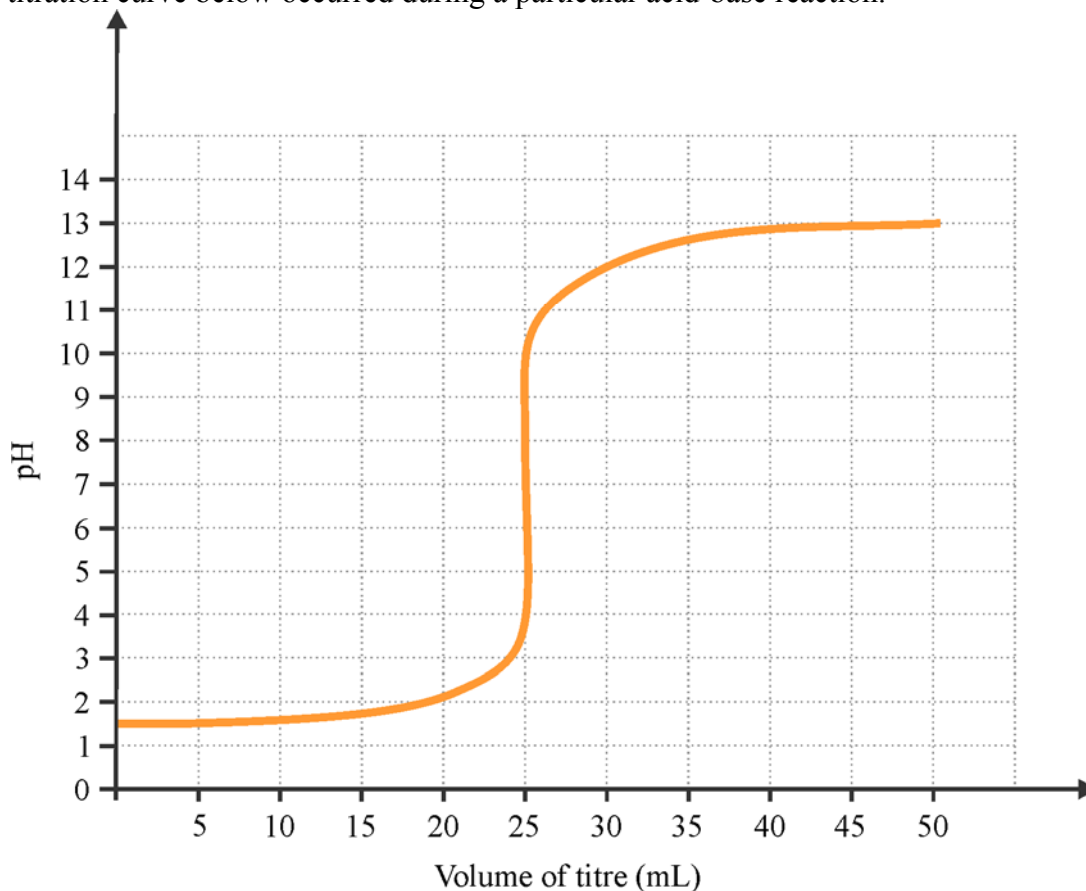
The solution in the titration flask prior to addition of any titre was most likely
A.   0.050 M sulfuric acid.
B.   0.010 M hydrochloric acid.
C.   0.030 M nitric acid.
D.   1.0 M ethanoic acid.

Question 27
A sample of anhydrous sodium carbonate, Na_2CO_3, is dissolved in enough water to make exactly three litres of solution. The concentration of thi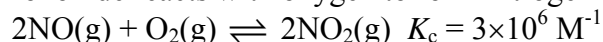s solution with respect to sodium ions, Na^+, was 0.0430 mol L^{-1}. The mass of Na_2CO_3 used to make this solution was
A.   3.42 g.
B.   5.35 g.
C.   6.84 g.
D.   13.7 g.

Question 28
At $200^{\circ}C$, nitrogen monoxide reacts with oxygen to form nitrogen dioxide as follows:
$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \quad K_c = 3\times10^6 \ M^{-1}$$
If the concentrations in a particular mixture of these three gases, at 200°C, are
0.10 M NO, 0.10 M NO_2 and 0.010 M O_2,
A.   the reaction is at equilibrium.
B.   the reaction is not at equilibrium and must proceed from left to right to reach equilibrium.
C.   the reaction is not at equilibrium and must proceed from right to left to reach equilibrium.
D.   the reverse reaction is faster than the forward reaction.

Question 29
Shown below is some of the energy profile information for the reaction described by the equation:
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$
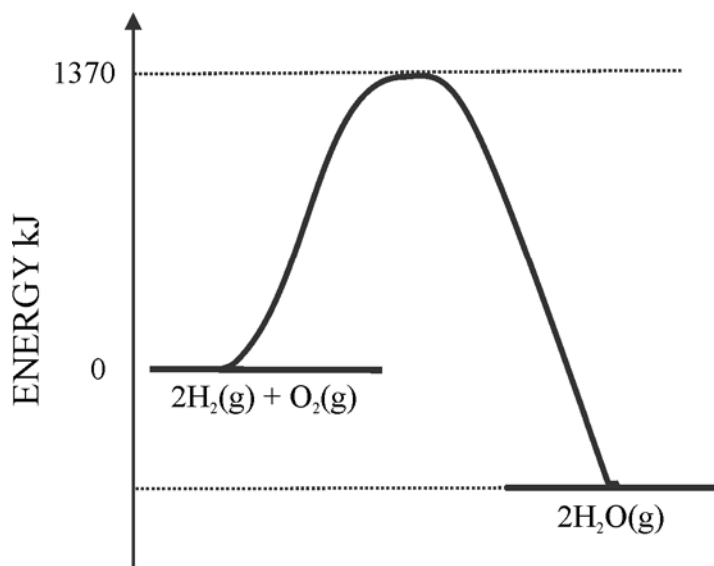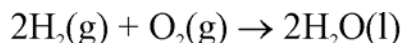
When the bonds between oxygen and hydrogen atoms form in 2 mol H_2O molecules,
A.   1370 kJ of energy is absorbed.
B.   286 kJ of energy is released.
C.   572 kJ of energy is absorbed.
D.   1942 kJ of energy is released.

Question 30

There are a number of landfill gas extraction facilities in Australia. Landfill gas contains approximately forty to sixty percent methane, with the remainder being mostly carbon dioxide.

Methane obtained from a landfill for use as a fuel is considered to be

A. a biofuel.

B. a non-renewable resource.

C. a fossil fuel.

D. a by-product of the chemical process occurring in the landfill.

End of Section A

VCE Chemistry 2015 Year 12 Trial Exam Units 3/4

SECTION B – Short Answer Questions

Section B consists of 7 short answer questions.
You should answer all of these questions in the spaces provided.
This section is worth approximately 78 per cent of the total marks available.
The marks allotted are shown at the end of each part of each question.

Question 1 (17 marks)

Consider the organic reaction pathways shown below.

$\underline{A} \rightarrow \underline{B}$
$\underline{C} \rightarrow \underline{D} \rightarrow \underline{E} \rightarrow \underline{F}$
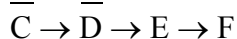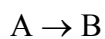
Compounds $\underline{A}$ and $\underline{C}$ both contain the same number of carbon atoms but different numbers of hydrogen atoms. Compounds $\underline{\textbf{B}}$ and $\underline{E}$ are structural isomers with the same functional group. Spectra for some of the compounds are provided below.

1.   Compound $\underline{F}$ – mass spectrum
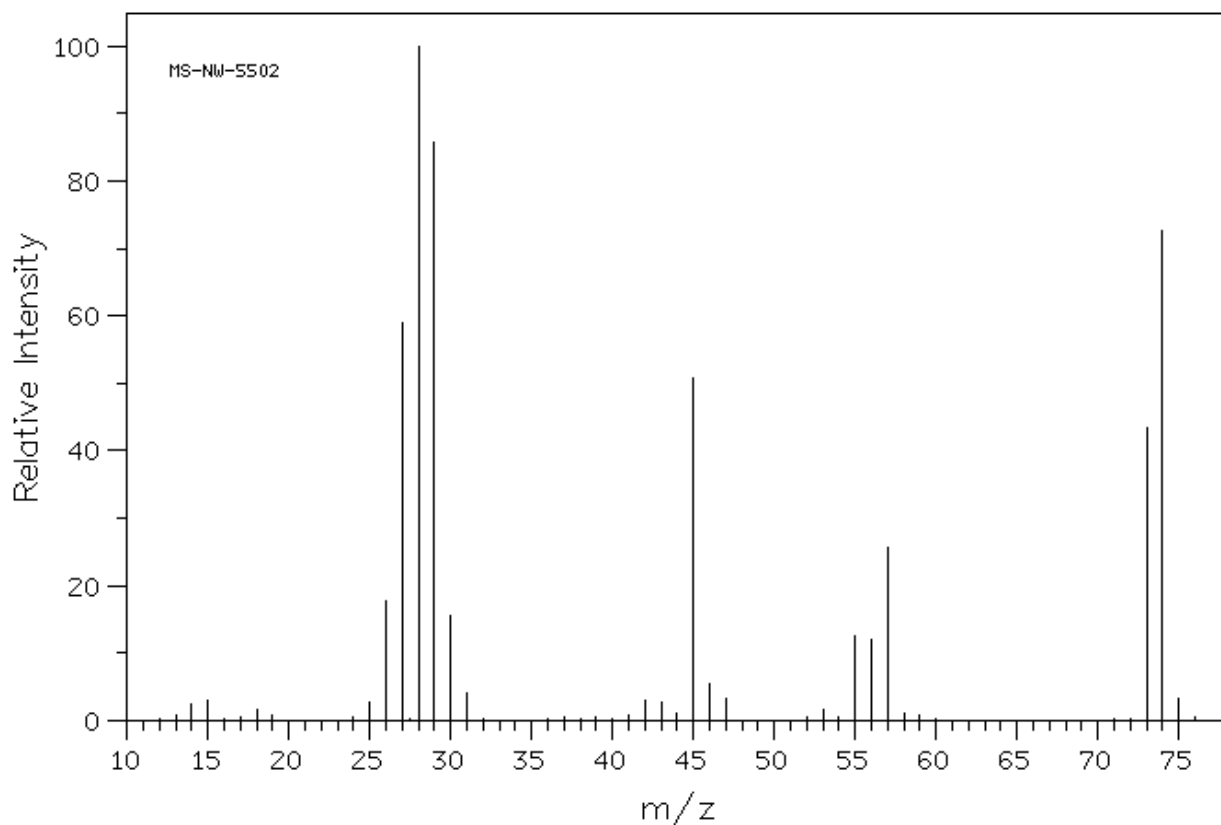
2.   Compound <u>B</u> – ¹H NMR spectrum

HSP-03-214
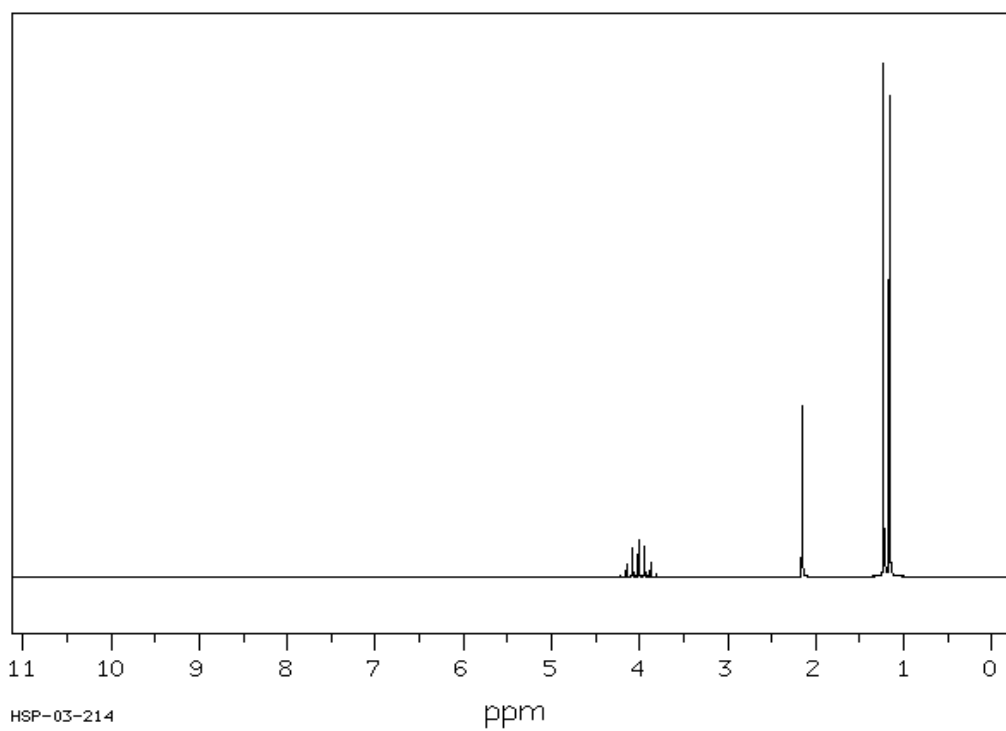
3.   Compound <u>E</u> – IR spectrum
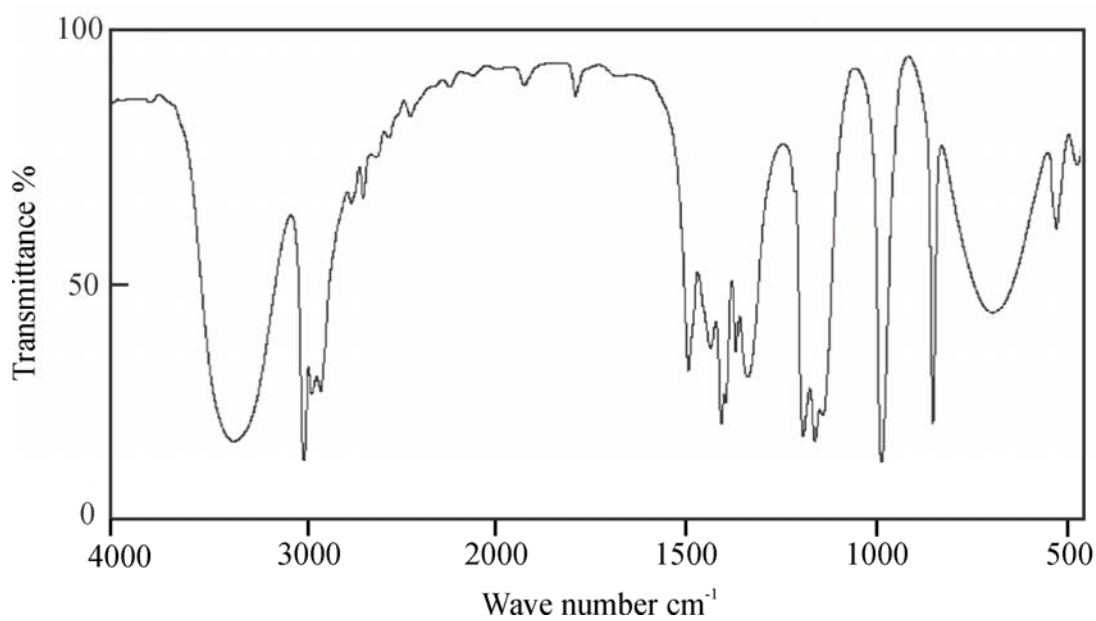
4.   Compound <u>D</u> – ^{13}C spectrum.
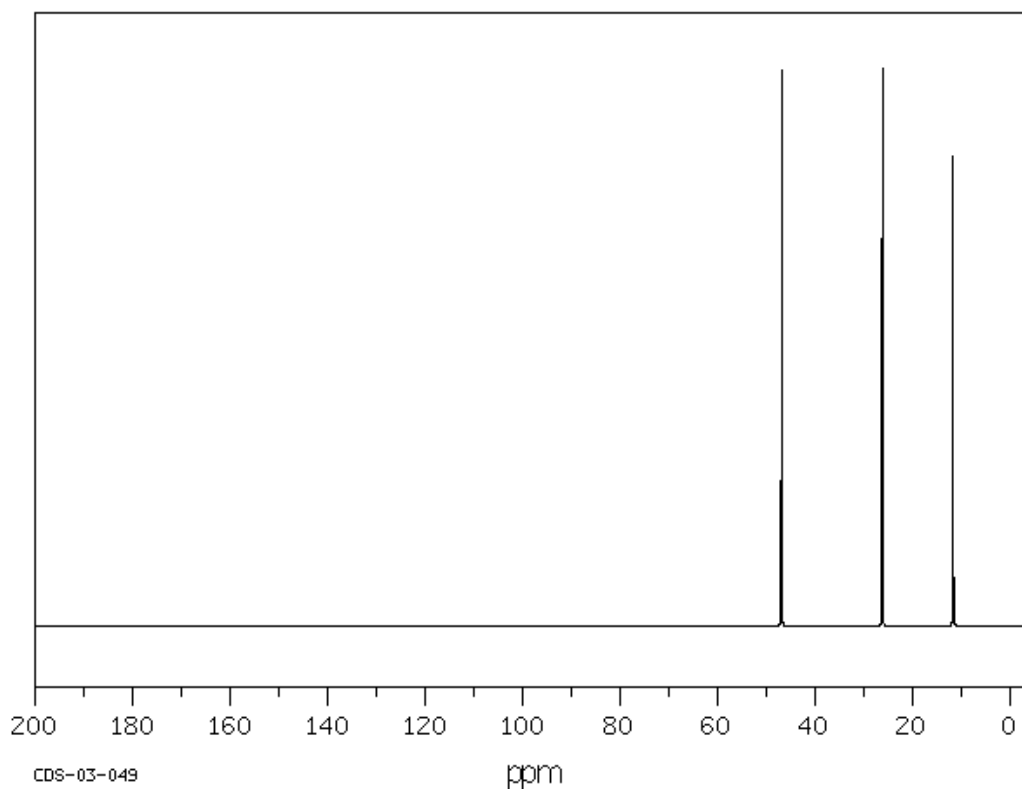
SDBSWeb: http://sdbs.db.aist.go.jp(National Institute of Advanced Industrial Science and Technology, 24/03/2015)

a.   What is the most significant piece of information that can be deduced from the mass
       spectrum of compound F?   **1 mark**

b.   Explain how the ^1H NMR spectrum of compound B suggests that it contains three
       different hydrogen environments and that one of the carbon atoms in each molecule is
       bonded to a single hydrogen atom.   **2 marks**

c.   Explain how the IR spectrum of compound E enables the identification of the
       functional group present.   **1 mark**

d. When solid sodium carbonate is added to compound F, gas bubbles are produced. Draw the full structural formula, showing all bonds of compound F. **1 mark**

e. **i.** Write the semi-structural formula of compound E. **1 mark**

ii. Give the full structural formula, showing all bonds, of compound B. **1 mark**

iii. Using half-equations justify the claim that the conversion of compound E to compound F is a redox reaction. **2 marks**

iv. Explain why compound B cannot be converted to compound F. **1 mark**

f. Compound C is converted to compound D by reaction with bromine.

    i. Give the full structural formula, showing all bonds, for compound D and explain why this is consistent with its ^{13}C NMR spectrum.   **2 marks**

    ii. Write a balanced equation for the conversion of compound C to compound D.   **1 mark**

g. Name compound A and write a balanced equation for its conversion to compound B.   **2 marks**

h. When compound F is reacted with an alcohol in the presence of concentrated sulfuric acid, a compound, G, which has the same molar mass as pentanoic acid is produced.

    i. Give the name of compound G.   **1 mark**

    ii. Write a balanced equation, using semi-structural formulae, for the production of compound G from compound F and the alcohol.   **1 mark**

Question 2 (9 marks)
The thermochemical equation for the conversion of carbon to carbon monoxide is
$$2C(s) + O_2(g) \rightarrow 2CO(g) \qquad \Delta H = \text{-221 kJ mol}^{-1}$$
a.   Write a balanced thermochemical equation for the complete combustion of carbon to
carbon dioxide.   **1 mark**
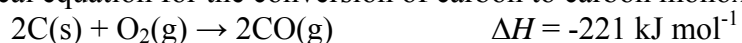
b.   Write a balanced thermochemical equation for the complete combustion of octane.   **1 mark**

c.   Use all three thermochemical equations to determine ΔH for the incomplete
combustion of octane according to the equation
$$2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l) \qquad \textbf{3 marks}$$

d.   Part of a 200 mL sample of octane undergoes incomplete combustion and produces
100 L of CO, collected at 35°C and 102.3 kPa pressure. What percentage of the octane
reacted? Density of octane is 0.703 g mL^{-1}.   **4 marks**

Question 3 (18 marks)
On April 30 2015, Elon Musk the CEO and product architect of Tesla Motors unveiled the Powerwall - a compact, wall mounted, rechargeable, lithium ion battery designed for homes and small businesses. The Powerwall will enable load-shifting where energy usage is spread for maximum benefit. The Powerwall can be charged using solar energy or less expensive off-peak electricity for maximum benefit.
Lithium-ion cells have solid electrodes which allow for the intercalation of lithium ions, i.e. lithium ions can become part of the electrodes without significantly affecting the structure. During operation, some lithium ion batteries have lithium intercalated graphite as one electrode material and a lithium intercalated transition metal oxide such as MnO_2 as the other. The overall discharge equation for these lithium-ion cells may be represented as $Li_xC_6(s) + Li_{1-x}MnO_2(s) \rightarrow C_6(s) + LiMnO_2(s)$.
'$\times$' represents the amount of lithium ions transferred between the electrodes.
a.   Part of one cell of the battery during discharging is represented in the diagram below.
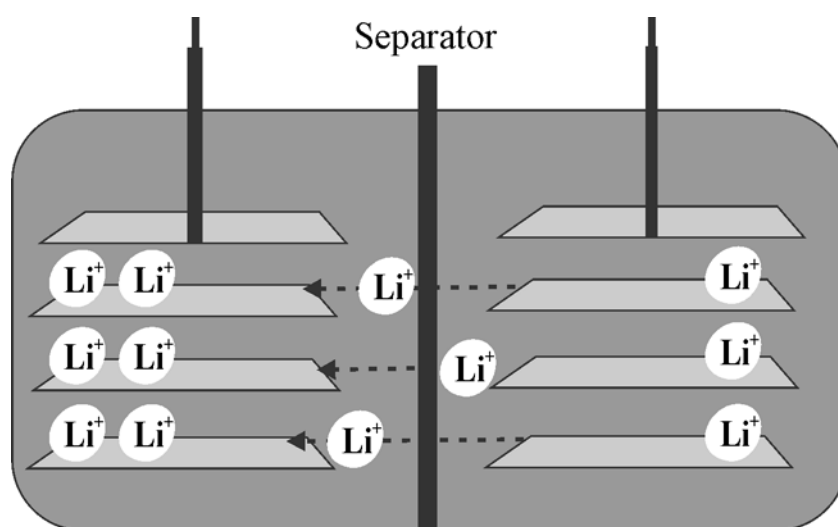
    i.   Show, on the diagram, the signs of the two electrodes.   **1 mark**

    ii.   Write balanced equations for the reactions occurring at the two electrodes.   **2 marks**

         ANODE:

         CATHODE:

    iii.   Write a balanced half-equation for the reaction occurring at the cathode when the cell is recharged.   **1 mark**

b. One of the Powerwall batteries that will be available is rated at 7.0 kWh (kilowatt hour). One kilowatt per hour is equivalent to 3.6 MJ of energy.

    i. Assuming coal to be carbon, what mass of coal, in kg, must be used to produce 7.0 kWh of electricity in a coal-fired power station if the conversion from chemical to electrical energy is 35 per cent efficient? **4 marks**

    ii. What would be two main advantages of improved efficiency in coal power stations? **2 marks**

c. Identify a significant advantage that would be associated in integrating a Powerwall with a domestic solar energy system. **1 mark**

d. Energy from a Powerwall supply could be used to produce hydrogen by electrolytic decomposition of water. This hydrogen can then be used in hydrogen-oxygen fuel cells.

    i. Write a balanced equation for the electrolytic decomposition of water. **1 mark**

    ii. Write a balanced half-equation for the reaction occurring at the positive electrode in a hydrogen-oxygen fuel cell which has an alkaline electrolyte. **1 mark**

e. Intercalation is one of the methods by which DNA replication in cancerous cells can be inhibited. DNA intercalators fit in between nitrogen base pairs. Proflavine is an intercalator which may inhibit the replication of some bacterial DNA.
The structure of proflavine is shown below.
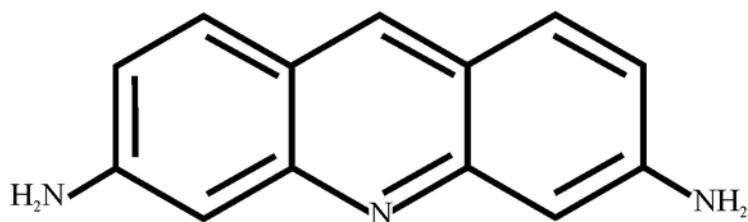
    i.   What is the molecular formula of proflavine?   **1 mark**

    ii.   Discuss the links between nitrogen bases and the primary and secondary structures of DNA.   **3 marks**

    iii.   Describe how proflavine might be expected to be attracted to nitrogen base pairs.   **1 mark**

Question 4 (24 marks)

Iodine deficiency is the world's leading cause of preventable intellectual disability or mental retardation in children. If the diet is lacking in iodine, the thyroid, a gland that regulates many metabolic process such as growth and energy use, does not function efficiently.

In 2009 the mandatory fortification of baked bread with iodised salt was introduced in Australia in response to the re-emergence of mild levels of iodine deficiency in the population. The iodine in iodised salt may be present in the form of potassium iodide, KI, or potassium iodate, KIO_3

a.   The recommended daily intake of iodine by an adult is 150 µg.

A particular brand of iodised salt contains 0.0055 per cent, by mass, of iodine in the form of potassium iodate.

What mass, in milligrams, of potassium iodate is present in a 500 g container of the iodised salt?   **3 marks**

b.   Potassium iodide tablets may be prescribed in cases of exposure to radiation that may damage the thyroid gland. Because potassium iodide is very bitter, such tablets also contain a soluble sugar as a filler. The iodide content of such tablets was determined by gravimetric analysis. One tablet was dissolved in 50.0 mL of distilled water and an excess of 0.20 M $Pb(NO_3)_2$(aq) was added. A yellow precipitate formed and this was collected, washed and dried. The following data were recorded.

Mass of potassium iodide tablet	0.425 g
Mass of filter paper	1.462 g
Mass of filter paper and precipitate after first drying	1.775 g
Mass of filter paper and precipitate after second drying	1.699 g
Mass of filter paper and precipitate after third drying	1.698 g

i.   Write a balanced ionic equation for the precipitation reaction.   **1 mark**

ii.   Explain why the precipitate was dried three times and how stopping at the first drying would affect the determination of the iodine content of the tablet.   **1 mark**

iii. Determine the percentage, by mass, of iodine in the tablet. **3 marks**

c. Lugol's solution is a solution of iodine, I_2, and potassium iodide, in water and is used as an antiseptic and disinfectant. Iodine is normally sparingly soluble in water but in the presence of potassium iodide in Lugol's solution, its solubility is enhanced by the formation of the triiodide ion, I_3^- and the solution is in effect an equilibrium mixture described by the equation $I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$.

Lugol's solution can be used to distinguish between some carbohydrates.
In the presence of starch, Lugol's solution changes to a blue-black colour.
In the presence of glycogen, Lugol's solution changes to a brown-blue colour.
In the presence of simple carbohydrates, Lugol's solution retains its characteristic yellow-brown colour.

i. What do these observations suggest as a significant factor in the behaviour of Lugol's solution in the presence of carbohydrates? **1 mark**

ii. Referring to appropriate chemical reactions, describe the relationship between starch and glycogen in humans. **2 marks**

iii. Using chemical equations where appropriate, describe how glycogen is linked via one of the 'other carbohydrates' to respiration. **2 marks**

d. Triiodide ions are also produced by reaction between iodide ions and iodate ions in aqueous solution, according to the skeleton redox equation: __I^- + __IO_3^- → __I_3^-(aq)

i. Use half-equations to establish a balanced overall equation for this production of triiodide ions. **3 marks**

ii. The concentration of I_3^-(aq) in solution can be determined by titration with an aqueous solution of sodium thiosulfate, $Na_2S_2O_3$(aq). In this reaction $S_2O_3^{2-}$(aq) is converted to $S_4O_6^{2-}$(aq) and triiodide ions to iodide ions. The equation for this reaction is

$$2S_2O_3^{2-}(aq) + I_3^-(aq) \rightarrow S_4O_6^{2-}(aq) + 3I^-(aq)$$
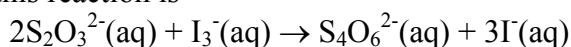
If a 25.00 mL sample of 0.0120 M KIO_3 was added to excess of KI and the product, triiodide, required 35.40 mL of $Na_2S_2O_3$ to reach the equivalence point, what is the molarity of the sodium thiosulfate solution? **3 marks**

e. Folic acid is also added to bread to reduce the likelihood of birth defects that may result from folate deficiency in pregnant women.
The structure of folic acid is represented below.
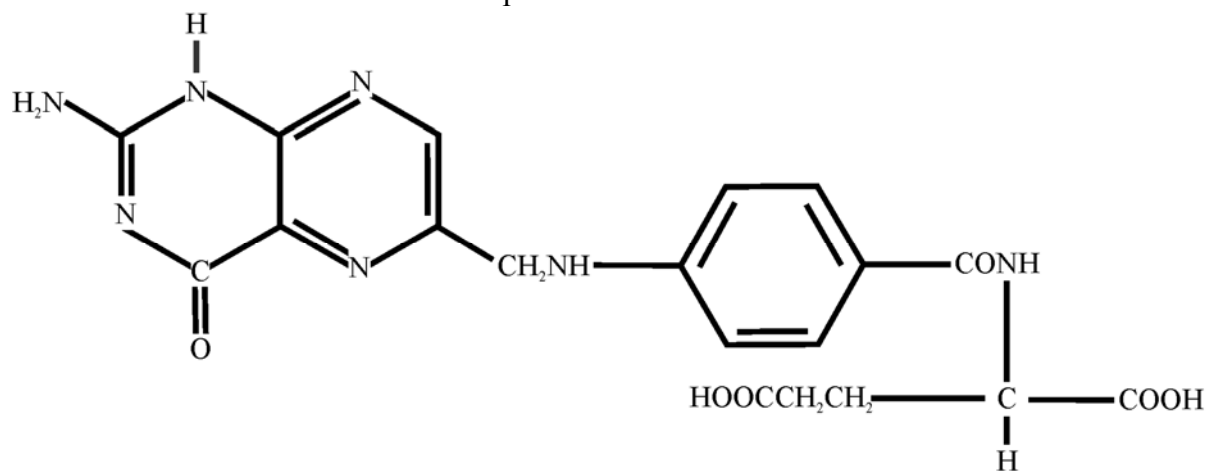
i. Circle and name three different functional groups on the molecule. **3 marks**

ii. Folic acid is much less soluble in water (1.6 mg mL^{-1}) at room temperature than it is in 1 M NaOH(aq) (50 mg mL^{-1}). Referring to the structure of folic acid molecules, discuss this difference in solubility. **2 marks**
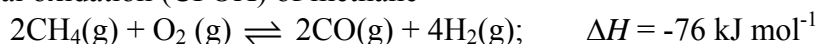
Question 5 (18 marks)
Underground coal gasification (UCG) and gas to liquid conversion (GTL) are significant components of the industrial energy mix. One of the products of coal gasification is 'syngas', the major components of which are hydrogen and carbon monoxide which are major building blocks in the production of some liquid fuels.
Methods of syngas production include:
Steam methane reforming (SMR).

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$
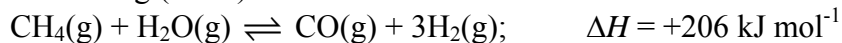
Catalytic partial oxidation (CPOX) of methane

$$2CH_4(g) + O_2(g) \rightleftharpoons 2CO(g) + 4H_2(g); \qquad \Delta H = -76 \text{ kJ mol}^{-1}$$

a.   For both processes, by referring to the effects of temperature and pressure, discuss the conditions that would provide optimum equilibrium yield of syngas. **3 marks**

b.   Both processes benefit from the use of an appropriate catalyst. In which process would the use of a catalyst be of greatest benefit? Explain your answer. **2 marks**

c.   One catalyst used in the CPOX production of syngas contains honeycombs of fused rhenium. Explain, in terms of collision theory, the benefits of such a catalyst. **2 marks**

d. A third method of syngas production is autothermal reforming represented by the equilibrium

$$2CH_4(g) + O_2(g) + CO_2(g) \rightleftharpoons 3CO(g) + 3H_2(g) + H_2O(g) \qquad \Delta H = -31 \text{ kJ mol}^{-1}$$
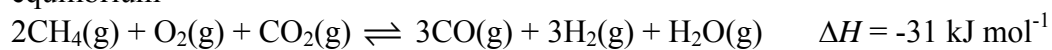
    i. Write the equilibrium constant expression for autothermal reforming. **1 mark**

    ii. What mass of syngas, in tonne, would be produced during the release of 310 MJ of energy in autothermal reforming? **3 marks**

e. Methanol, a liquid fuel, can be produced directly from syngas.

   **i.** Write a balanced equation for the production of methanol from syngas. **1 mark**

    ii. In which method of syngas production is the yield most suited to methanol production? Explain your answer. **1 mark**

iii. Based on your equation in **Question 5 e. i.** and the energy that would be released in combustion of the individual reactants and the product, determine whether the production of methanol from syngas is exothermic or endothermic and the ΔH value, in kJ mol^{-1} for the reaction. The molar enthalpy of combustion of CO is -293.5 kJ mol^{-1}. **3 marks**

iv. Write a balanced thermochemical equation for the combustion of methanol. **1 mark**

v. Write a balanced equation for the reaction occurring at the (-) electrode in a methanol-O_2 fuel cell (acid electrolyte). **1 mark**

Question 6 (10 marks)

In 1829, Johan Büchner, isolated pure salicin from willow bark. Salicin was recognised as the 'active (pain relieving) ingredient' in willow bark. Subsequent derivatives of salicin proved to be more effective than salicin itself.

Shown below is a pathway for the production of a common pain reliever from salicin.
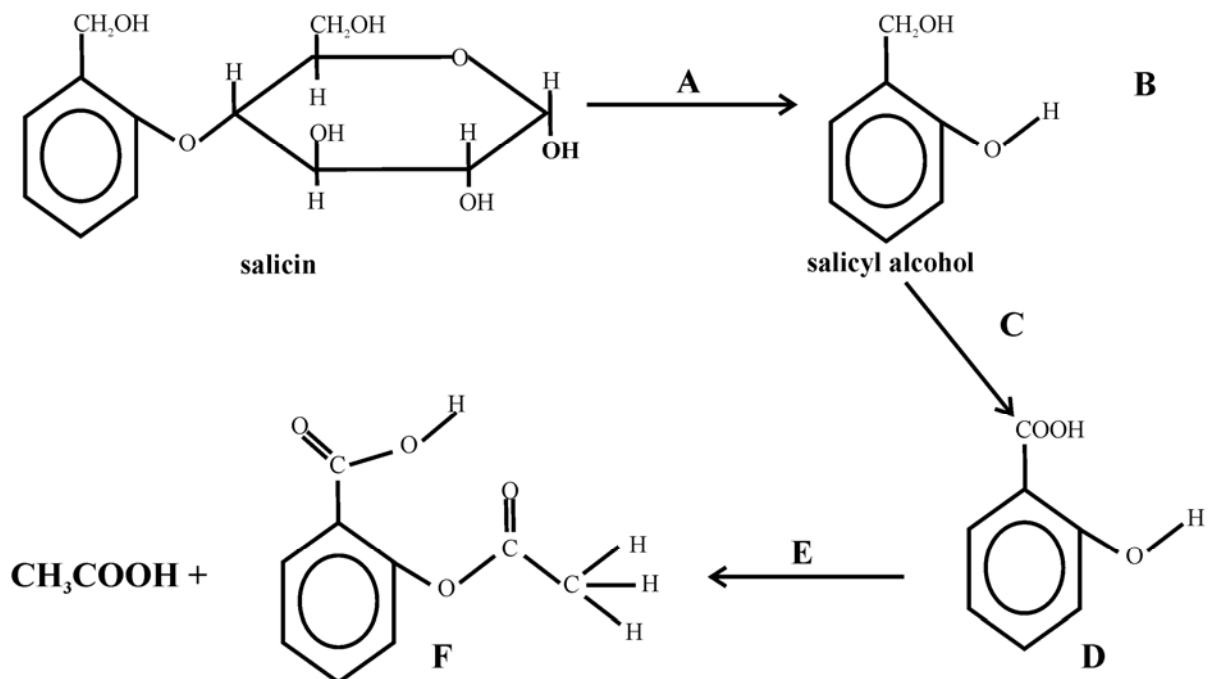
a.   Write the common name of compound F   **1 mark**

b.   Write molecular formulae for compounds A and B.   **2 marks**
        A

        B

c. Write the chemical formula(e) of the species represented by **C.**   **1 mark**

d. Write the name of compound **E.**   **1 mark**

e. Identify the types of reaction occurring in each of the three steps in the pathway.   **1 mark**

f. 2.15 g of compound F was produced from salicin in this pathway where the process was 43 % efficient overall. What mass of salicin was used?   **4 marks**

Question 7 (7 marks)

The electrolyses of water, 1 M LiCl(aq), and molten LiCl, i.e. LiCl(l) were investigated using carbon electrodes and a potential difference of 5 volts.

a. Write balanced half-equations for the reactions expected at

    i. the (+) electrode in the electrolysis of water. **1 mark**

    ii. the (-) electrode in the electrolysis of molten LiCl **1 mark**

    iii. Explain why the pH increases at one of the electrodes during the electrolysis of water. **1 mark**

b. When 8 M LiCl(aq) was electrolysed instead of 1 M LiCl(aq), it was observed that the product at one of the electrodes was the same in the electrolysis of LiCl(l) but different to the product at the same electrode in the electrolysis of 1 M LiCl(aq). Using half equations, explain these observations. **4 marks**

End of Section B

End of Trial Exam

Suggested Answers
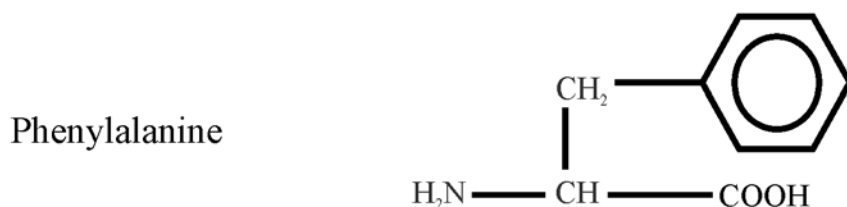
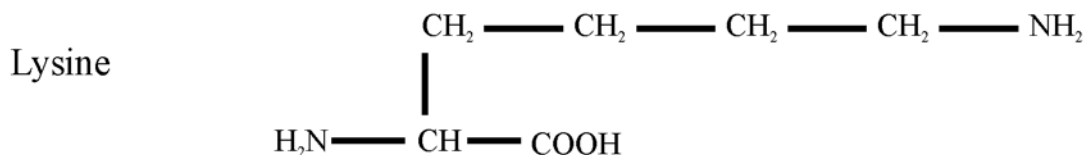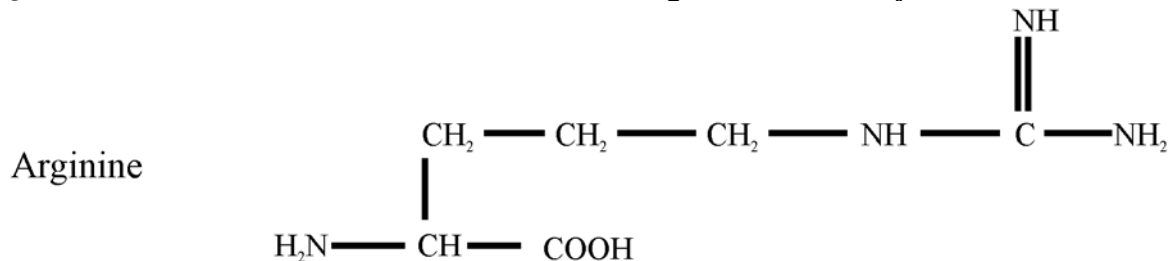# VCE Chemistry 2015 Year 12 Trial Exam Units 3/4

SECTION A – Multiple Choice Answers

Q1. A The chemical formulae and K_a values of the acids are in
Table 12 of the Data Book.
The acids ionise in aqueous solution according to
$C_6H_5COOH(aq) + H_2O(l) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$; $K_a = 6.4 \times 10^{-5}$
$HC_3H_5O_3 + H_2O(l) \rightleftharpoons C_3H_5O_3^-(aq) + H_3O^+(aq)$; $K_a = 1.4 \times 10^{-4}$
At equal concentrations, the weaker acid, benzoic acid C_6H_5COOH, the one with the smaller K_a, is less ionised in aqueous solution and so has the lower $[H_3O^+]$ and higher pH.
 Consider the alternatives:

    A.   On dilution, the extent of ionisation of weak acids increases as the equilibrium shifts to the right, so **the number of H_3O^+ ions present increases**. However the increase in the number of H_3O^+ ions does not fully compensate for the volume increase during dilution and so the $[H_3O^+]$ decreases and the **pH increases**.

    B.   **Benzoic acid** (C_6H_5COOH) has the lower K_a value and so, for equal concentrations of both acids, it is less ionised in aqueous solution and so has the **lower $[H_3O^+]$** and higher pH.

    C.   The amount of strong base, NaOH(aq), required to neutralise an acid depends on acid concentration not acid strength. Continued addition of the strong base to a weak acid pushes the ionisation of the acid further to the right until all the available $H^+(aq)$ has been released. Hence the **same amount of 0.10 M NaOH(aq) would be required** for both acids.

    D.   **Lactic acid** ($HC_3H_5O_3$) has the higher K_a value and so, for equal concentrations of both acids, it is more ionised and so has the higher $[H_3O^+]$ and **lower pH.**

Q2. C Identification of an organic compound commonly involves the following techniques.
Mass Spectroscopy – to obtain the relative molecular mass and the relative mass of molecule fragments.
IR Spectroscopy – to identify bonds and functional groups present.
^{1}H NMR and ^{13}C NMR spectroscopy – to identify carbon and hydrogen molecules in the molecules.

Q3. B For the ratio of O_3 to O_2 to increase the equilibrium $2O_3(g) \rightleftharpoons 3O_2(g)$ must shift to the left. This would be the result of:
- temperature increase: the forward reaction is exothermic and favoured by low temperatures.
- pressure increase: system moves to side with fewer particles to partially compensate.
Lightning releases energy into the atmosphere and so **favours the reverse endothermic reaction.**

Q4. A $K = [O_2]^3/[O_3]^2$
The forward reaction is exothermic. The forward reaction is favoured, and the equilibrium constant increases as the temperature decreases. Alternatively as temperature increases, the equilibrium constant decreases.
The relationship $K = [O_2]^3/[O_3]^2 = \{[O_2]/[O_3]\}^{1.5}$ shows that the increase in the value of K is not linear.
Assuming Y represents K and X represents T, alternative A best represents the relationship for this equilibrium – as X (T) increases, Y (K) decreases.

Q5. D The only change that leads to a change in the value of the equilibrium constant for a specific equilibrium is a change in temperature. So a **change in pressure at constant temperature has no effect** on the K value. This is best represented by alternative D where Y (K) stays constant as X (pressure) increases.

Q6. B The reactions occurring are:
2Mg + **O₂** → 2MgO
MgO + **H₂O** → Mg(OH)₂
Mg(OH)₂ + **CO₂** → MgCO₃ + H₂O
MgCO₃ + **2HCl** → MgCl₂ + H₂O
MgCl₂ → Mg + Cl₂ **Electrolysis**
Four other reactants required: O_2, H_2O, CO_2, HCl

Q7. B Assume that all the energy absorbed by the water is the energy 'lost' from the heated metal sample.
Energy into water = 4.18 J g^{-1} °C^{-1} × 200 g × (29.0-22.6)
$\qquad\qquad\qquad$ = 5.35x10^3 J
Energy lost from metal = SHC × 100 g × (100 – 29.0) °C
$\qquad\qquad$ 5.35x10^{-3} = SHC × 7100
$\qquad\qquad\qquad$ SHC = 5.35x10^3 / 7100
$\qquad\qquad\qquad\qquad$ = **0.754** J g^{-1} °C^{-1}

Q8. **C** Atoms or molecules absorb visible and ultraviolet light if the wavelengths correspond to exact difference between electronic energy levels. Both visible and ultraviolet light contain wavelengths suitable for iodine but only ultraviolet radiation contains wavelengths suitable for nitrogen.

Transitions between vibrational energy levels require wavelengths present in infrared radiation.

Transitions between nuclear spin energy levels require wavelengths present in radiowave radiation.

It is true that breaking the triple bond between N atoms in nitrogen molecules requires more energy than the single bond between I atoms in iodine molecules but that is not the reason for different visible light absorption behaviour.

Q9. **B** The change at t_1 causes an immediate increase in the concentration of both species present in the equilibrium mixture. The most likely cause of such a change is a **decrease in the volume of the container.** For a gaseous system, this will also cause the pressure to increase and the system will move to compensate by favouring the side with fewer particles, i.e. $2O_3$. So the top graph would be the $[O_2]$ and the bottom graph the $[O_3]$. As the system returns to equilibrium the $[O_2]$ decreases, but not back to its original value, whilst the $[O_3]$ increases.

Q10. **A** The reaction between potassium and water can be deduced from the electrochemical series.

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ -0.83 V

$K^+(aq) + e^- \rightarrow K(s)$ -2.93 V

Hence the reaction occurring is

$2K(s) + 2H_2O(l) \rightarrow 2K^+(aq) + H_2(g) + 2OH^-$

The skimming and spinning of the potassium can be attributed to the production of $H_2(g)$ at the potassium-water interface. Heat generated in the exothermic reaction is sufficient to initiate combustion of $H_2(g)$. This in turn generates enough energy to excite the potassium atoms which release energy as lilac light as electrons return to lower energy levels.

Consider the alternatives

A. **Best alternative**: the flame is due to the combustion of H_2; $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

B. **Incorrect**, the lilac flame colour is characteristic of potassium, but is due to the excited electrons dropping back to lower energy levels.

C. **Incorrect**, since $OH^-(aq)$ is produced, the pH increases.

D. Potassium is, according to the electrochemical series, a stronger reductant **than** water – however in the reaction water is the oxidant - but this is not an adequate full explanation of the observations.

Q11. **B** Total peak area $= 32.4 + 47.1 + 40.6 + 27.3$
                                          $= 147.4$

% Norgestrel $=$ [(Peak Area of Norgestrel) / Total Peak Area] $\times$ 100
                    $=$ [40.6 / 147.4] $\times$ 100
                    $=$ **27.5 %**

Q12. D   The structures of the amino acids are given in *Table 8 of the Data Book*.

Arginine

$$CH_2 — CH_2 — CH_2 — NH — \overset{\overset{NH}{\|}}{C} — NH_2$$
$$H_2N — CH — COOH$$

Lysine

$$CH_2 — CH_2 — CH_2 — CH_2 — NH_2$$
$$H_2N — CH — COOH$$

Phenylalanine

$$CH_2 —\!\bigcirc$$
$$H_2N — CH — COOH$$

Since all molecules are amino acids, the determining factor in their separation will be the relative polarity of the side chains. Phenylalanine, the least polar, will be most strongly attracted to the non-polar (hydrophobic) stationary phase and will have the highest retention time. Arginine, the most polar, will be most strongly attracted to the polar (hydrophilic) mobile phase and will have the lowest retention time.

The order of elution will be **arginine**, followed by **lysine**, followed by **phenylalanine**.

Q13. C   Absorbance $0.260 \rightarrow c(Pb^{2+}) = 0.400$ ppb
$\qquad\qquad\qquad\qquad\qquad\quad = 0.400$ µg L^{-1}
All the Pb^{2+} from 2.5 g milk powder ends up in 200 mL of solution
$m(Pb^{2+})$ in 2.5 g milk powder $= m(Pb^{2+})$ in 200 mL
$\qquad\qquad\qquad\qquad\qquad\quad = (0.400 / 1000) \times 200$
$\qquad\qquad\qquad\qquad\qquad\quad = 0.080$ µg
$m(Pb^{2+})$ in 1 g milk powder $\quad = 0.080 / 2.5$
$\qquad\qquad\qquad\qquad\qquad\quad = 0.032$ µg
Data Book Table 4 $\rightarrow 1$ µg $= 1000$ ng
$c(Pb^{2+})$ in milk powder $= 0.032$ µg g$^{-1} \times 1000$ ng µg^{-1}
$\qquad\qquad\qquad\qquad\quad$ **$= 32$ ng g^{-1}**
Hence the correct alternative is C since 32 is closest to 30.

Q14. B   Investigations A and B produce twice as much CO_2 as C and D. Since the $MgCO_3$ is in excess and volume of HNO_3 used is the same in all four, the $c(HNO_3)$ must have been higher – twice as high in fact – for investigations A and B.

The fact that investigation A and C occur at faster initial rates than investigations C and D respectively could be due to
- the use of catalysts in investigations A and C.
- the use of smaller $MgCO_3$ particles in A and C.
- the use of higher temperatures in A and C.
All three of these would increase the proportion – catalyst and higher temperature, or number – smaller particles, of successful collisions and so produce a faster reaction rate.

Q15. A   Propanoic acid is a weak acid and in aqueous solution, is partially ionised according to the equilibrium.
$CH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$; $K_a = 1.3 \times 10^{-5}$
When 20 mL of **0.10 M CH_3CH_2COOH(aq)** is **diluted to 100 mL**, the overall concentration decreases and the **position of equilibrium shifts to the right to produce more particles in the larger volume.**
The **number of H_3O^+ increases** as the system shifts to the right.
Initially the **[$\underline{H_3O^+}$] decreases** due to the volume increase, then increases as the forward reaction is favoured. However when equilibrium is re-established, the **[H_3O^+] is still lower than before the dilution.** This is represented in the concentration-time graph.
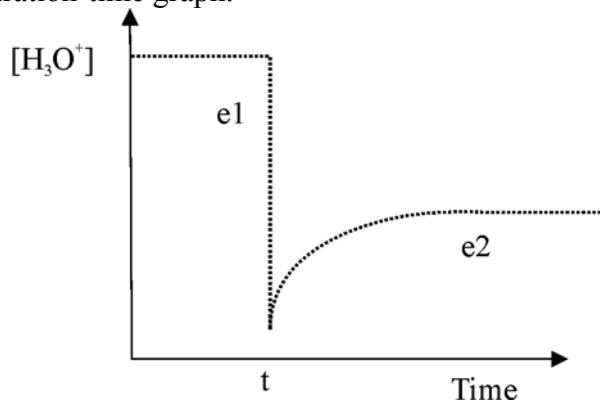
Since the [H_3O^+] decreases as a result of the dilution, the **pH increases**. As the system shifts right to compensate for the volume increase, the **percentage ionisation increases**.

Q16. D The components of the half-cell indicate it is an $Sn^{4+}(aq)$ / $Sn^{2+}(aq)$ half-cell, so the electrode material must be a conducting element which does not react with either $Sn^{4+}(aq)$ or $Sn^{2+}(aq)$, C (graphite) and Pt are elements commonly used where inert electrodes are required.

According to the electrochemical series half-equations

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ +0.80 V

$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$ +0.15 V

$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$ -0.14 V

silver could be used because being a reductant higher on the electrochemical series, it will not react with the oxidant $Sn^{4+}(aq)$ in the half-cell.

Tin could not be used because, as a reductant lower on the electrochemical series, it could react with the oxidant $Sn^{4+}(aq)$ according to

$Sn(s) \ + \ Sn^{4+}(aq) \rightarrow 2Sn^{2+}(aq)$

Q17. B According to the electrochemical series, the only half-cell that can be combined with $Sn^{4+}(aq)/Sn^{2+}(aq)$ to provide a potential difference of 1.53 V is $Au^+(aq)$ / $Au(s)$

$\mathbf{Au^+(aq)} + e^- \rightleftharpoons Au(s)$ +1.68 V

$Sn^{4+}(aq) + 2e^- \rightleftharpoons \mathbf{Sn^{2+}(aq)}$ +0.15 V

E_{cell} = 1.68 – 0.15

    = 1.53 V

The reactions occurring at the electrodes are

X: $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$ ... Anode (-)

Z: $Au^+(aq) + e^- \rightarrow Au(s)$ .... Cathode (+)

Consider the alternatives

A. Incorrect, reduction is occurring at Z

B. **Correct**, cations move towards the cathode

C. Incorrect, X is the anode, Z is the cathode

D. Incorrect, $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$

Q18. B $n(CH_4)$ produced = 2.45×10^5 L / 24.5 L mol^{-1}

                   = 1.00×10^4 mol

Table 13 Data Book $\rightarrow \Delta H_c(CH_4)$ = -889 kJ mol^{-1}

Energy available from methane = 1.00×10^4 mol $\times$ 889 kJ mol^{-1}

                           = 8.89×10^6 kJ

                           = 8.89×10^3 MJ

Volume of heating oil saved = Energy from methane/ Energy per L oil

                           = 8.89×10^3 MJ / 38.5 MJ L^{-1}

                           = **231 L**

Q19. A The calorimeter constant is the energy needed to raise the temperature of the entire calorimeter contents (water and hardware) by 1°C (1 K).

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}

Energy to raise 600 mL water by 1 °C = 4.18 J g^{-1} °C^{-1} $\times$ 600 g $\times$ 1 °C

                                 = 2508 J

Energy needed to raise hardware by 1 °C = 785 J

Calorimeter constant = 2508 + 785

                     = 3.29×10^3 J °C^{-1}

                     = **3.29 kJ °C^{-1}**

Q20. C   Use the data to determine the molar mass of M and use *Table 1 Data Book*.
Reduction half-equation: $M^{2+}(aq) + 2e^- \rightarrow M(s)$

$n(e^-)$ = It / F
        = 2.50 × 35.0x60 / 96500
        = 0.0544 mol
$n(M)$ = ½ × $n(e^-)$
        = ½ × 0.0544
        = 0.0272 mol
$M(M)$ = $m(M) / n(M)$
        = 3.06 / 0.0272
        = **112.5 g mol^{-1}**
Cadmium - Cd

Q21. B   Since the ester groups form from condensation reactions between the hydroxyl, -OH, and carboxyl, -COOH functional groups, the reactants, identifiable from *Tables 9 and 10 in the Data Book*, were
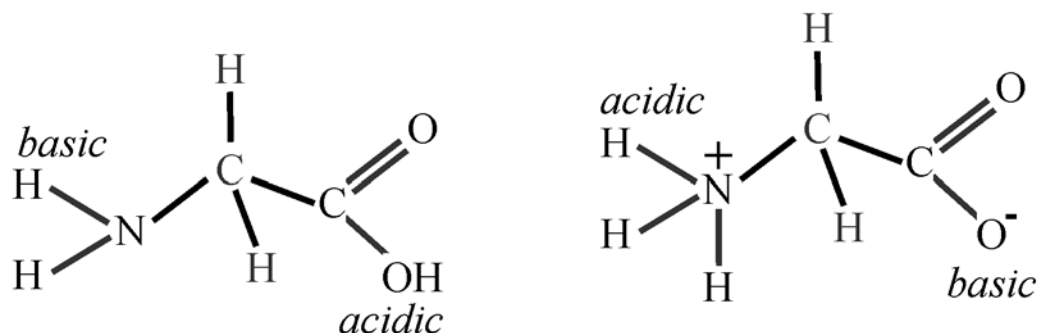$CH_2OHCHOHCH_2OH$ – glycerol
$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$, i.e. $C_{17}H_{33}COOH$ – oleic acid
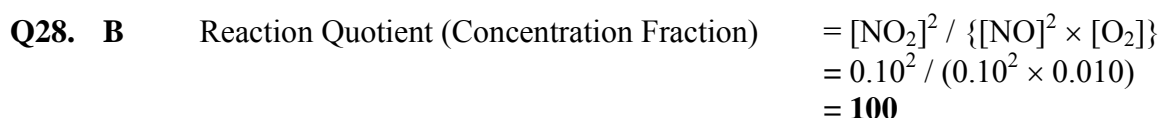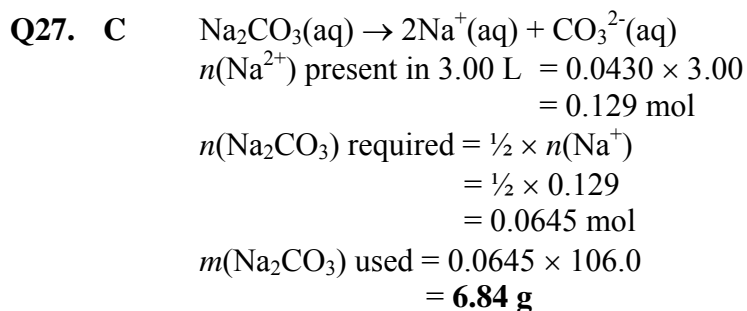$CH_3(CH_2)_4CH=CHCH_2CH=CH (CH_2)_7COOH$ – linoleic acid.
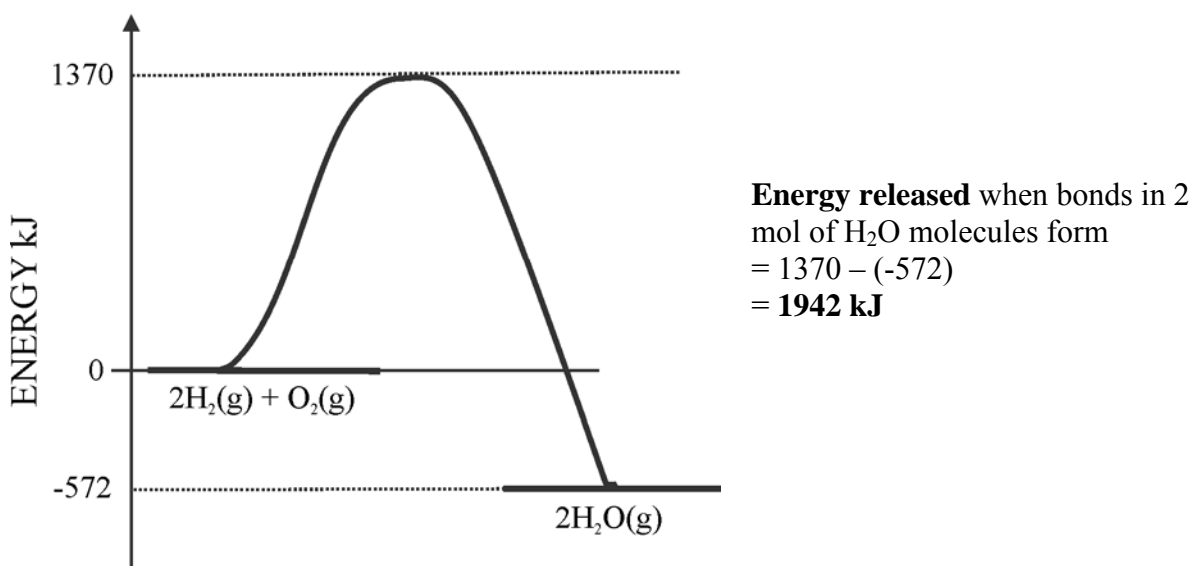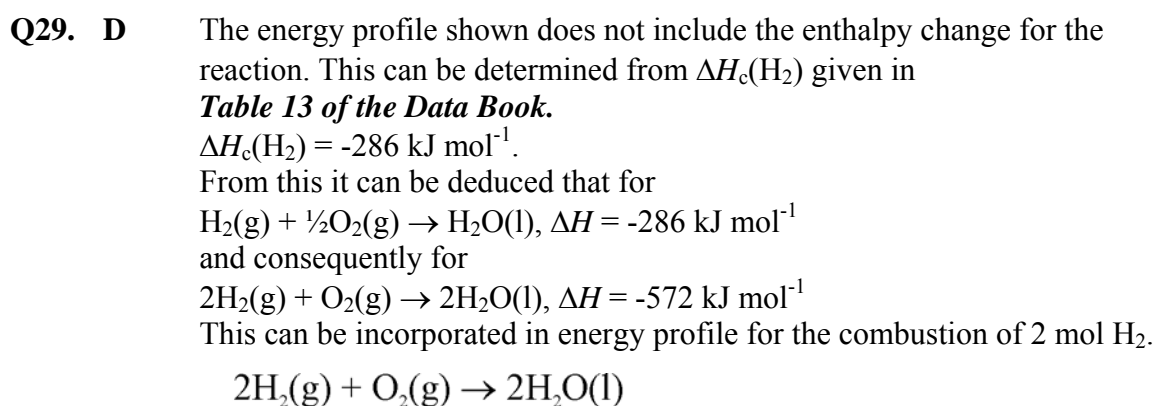Stearic acid, $C_{17}H_{35}COOH$ was not one of the reactants. It is a saturated fatty acid.

Q22. C

In zwitterion formation from amino acid molecules, the acid –COOH group is converted to its conjugate base the –COO$^-$ group and the basic –NH$_2$ group is converted to its conjugate acid –NH$_3^+$.

Q23. B Titrated with H_2SO_4(aq) implies $Ba(OH)_2$(aq) was in the titration flask and H_2SO_4(aq) was added from the burette.

Beyond the equivalence point – 30 mL – **H_2SO_4(aq) was in excess**.

Equation for reaction is $Ba(OH)_2$(aq) + H_2SO_4(aq) → $BaSO_4$(s) + $2H_2O$(l) so Ba^{2+}(aq) ions do not remain in solution but are precipitated out as $BaSO_4$.

$V(H_2SO_4)$ added at equivalence point = 30 mL

$n(H_2SO_4)$ added $= 0.10 \times 30 \times 10^{-3}$

$\qquad\qquad\qquad = 3.0 \times 10^{-3}$ mol

$n(Ba(OH)_2) = n(H_2SO_4) = 3.0 \times 10^{-3}$ mol

$c(Ba(OH)_2) = 3.0 \times 10^{-3}$ mol $/ 25.0 \times 10^{-3}$

$\qquad\qquad = $ **0.12 M**

$[OH^-] = 2 \times [Ba(OH)_2] = 0.24$ M

$[H_3O^+] = 10^{-14} / 0.24$

$\qquad\quad = 4.2 \times 10^{-14}$

$pH = -\log(4.2 \times 10^{-14})$

$\qquad = 13.4$

Q24. A The equation for the titration reaction is

CH_3COOH(aq) + NaOH(aq) → CH_3COO^-(aq) + Na^+(aq) + H_2O(l)

The equivalence point is where exactly the same n(NaOH) has been added as the $n(CH_3COOH)$ in the titration flask. So the only species, other than H_2O, present in significant quantity in the reaction flask are CH_3COO^-(aq) and Na^+(aq). Since **CH_3COO^-(aq)** is the conjugate base of the weak acid CH_3COOH, it is a **weak base** and **makes the pH of the solution at the equivalence point greater than 7.**

Q25. D Electrical energy = VIt

$V = 2.75$ V

$I = 85.6$ μA $= 85.6 \times 10^{-6}$ A

$t = 10.0$ years

$\quad = 10.0 \times 365 \times 24 \times 60 \times 60$ seconds

$\quad = 3.15 \times 10^8$ s

Electrical energy $= 2.75 \times 85.6 \times 10^{-6} \times 3.15 \times 10^8$

$\qquad\qquad\qquad = 7.42 \times 10^4$ J

$\qquad\qquad\qquad = 74.2$ kJ

Q26. C The titration curve is characteristic of the titration of a strong acid by a strong base with the equivalence point at pH 7.0 Sulfuric acid, H_2SO_4(aq), hydrochloric acid, HCl(aq) and nitric acid, HNO_3(aq) are all strong acids. Sulfuric acid is diprotic whilst the other two are monoprotic. Ethanoic acid is a weak acid. The pH of the solution in the titration flask prior to the addition of the base was, according to the titration curve, 1.5

$[H_3O^+] = 10^{-pH} = 10^{-1.5}$

$\qquad\qquad = 0.032$ M

Hence the solution in the flask was most likely **0.030 M HNO_3(aq).**

Q27. C $Na_2CO_3(aq) \rightarrow 2Na^+(aq) + CO_3^{2-}(aq)$
$n(Na^{2+})$ present in 3.00 L $= 0.0430 \times 3.00$
$= 0.129$ mol
$n(Na_2CO_3)$ required $= \frac{1}{2} \times n(Na^+)$
$= \frac{1}{2} \times 0.129$
$= 0.0645$ mol
$m(Na_2CO_3)$ used $= 0.0645 \times 106.0$
$= \textbf{6.84 g}$

Q28. B   Reaction Quotient (Concentration Fraction) $= [NO_2]^2 / \{[NO]^2 \times [O_2]\}$
$= 0.10^2 / (0.10^2 \times 0.010)$
$= \textbf{100}$
Since CF (100) $< K_c$ (3×10^6), the system is not at equilibrium and forward reaction (left to right) will be favoured until equilibrium is established.
As the system moves to equilibrium, the rate of the forward reaction will be greater than the rate of reverse reaction.

Q29. D   The energy profile shown does not include the enthalpy change for the reaction. This can be determined from $\Delta H_c(H_2)$ given in
Table 13 of the Data Book.
$\Delta H_c(H_2) = -286$ kJ mol^{-1}.
From this it can be deduced that for
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$, $\Delta H = -286$ kJ mol^{-1}
and consequently for
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$, $\Delta H = -572$ kJ mol^{-1}
This can be incorporated in energy profile for the combustion of 2 mol H_2.

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

Energy released when bonds in 2 mol of H_2O molecules form
$= 1370 - (-572)$
$= \textbf{1942 kJ}$

Q30. A   Methane is produced in landfill by bacterial (microbial) decomposition of plant and other biomaterial in the garbage in the landfill. Hence it is, in this context, classified as a biofuel.

SECTION B - Short Answer (Answers)

Question 1 (17 marks)

a. Molar mass / relative molecular mass – from the peak with the highest m/z ratio.
$M(\underline{F}) = 74$ g mol^{-1} or $M_r(\underline{F}) = 74$ ❶

b. There are **three different signals – one for each hydrogen environment**. ❶
The **doublet**, at $\delta = 1.2$ ppm, is for hydrogens on the molecule which have **one neighbouring hydrogen**, i.e. **only one hydrogen bonded to an adjacent carbon**. ❶
(This single hydrogen splits the signal for its neighbouring hydrogens into n+1, i.e. 2 peaks).

c. The **absorption** centred around **3350 cm^{-1}** indicates the presence of the hydroxyl, **O-H (alcohol)** functional group – absorption band 3200 – 3550 cm^{-1};
Table 7 of the Data Book. ❶
The absorptions around 2950 cm-1 (C-H) and 1100 cm-1 (C-O) would also be expected to be seen on the spectrum of an alcohol.

d. Compound $\underline{F}$ must be an acid as it reacts with sodium carbonate to produce CO_2.
The carboxylic acid with molar mass of 74 is propanoic acid CH_3CH_2COOH.


❶
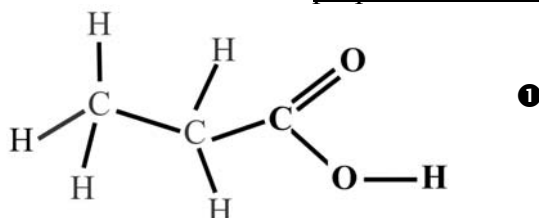
e. Compound $\underline{E}$ is converted to compound $\underline{F}$ in the pathway, hence compound $\underline{E}$ is a primary alcohol with three C atoms, i.e. 1-propanol

i. **$CH_3CH_2CH_2OH$** ❶

ii. Since compounds $\underline{B}$ and $\underline{E}$ are structural isomers with the same functional group, **$\underline{B}$ is 2-propanol**, i.e.


❶
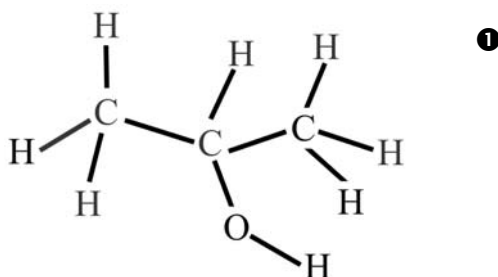
iii. Compound $\underline{E}$, 1-propanol, is oxidised to compound $\underline{F}$, propanoic acid. This requires reaction with an oxidant that is reduced. Acidified dichromate solution $(Cr_2O_7^{2-}(aq)/H^+)$ is commonly used.
In the redox reaction $CH_3CH_2CH_2OH$ is oxidised to CH_3CH_2COOH and $Cr_2O_7^{2-}(aq)$ is reduced to $Cr^{3+}(aq)$. The half-equations are
Oxidation: **$CH_3CH_2CH_2OH(l) + H_2O(l) \rightarrow CH_3CH_2COOH(l) + 4H^+(aq) + 4e^-$** ❶
Reduction: **$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$** ❶

iv. Only primary alcohols, those with the hydroxyl (-OH) group bonded to C-1, can be oxidised to acids.
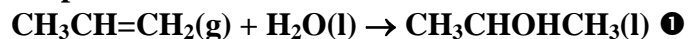**2-propanol has the hydroxyl (-OH) group bonded to C-2.** ❶

f.   i.
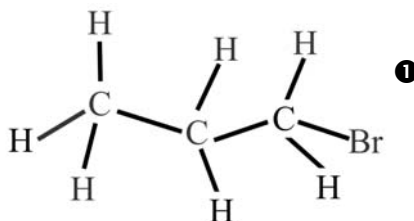
The **three peaks** on the ^{13}C NMR spectrum are reflective of the **three different carbon environments** in each molecule. ❶

ii. $CH_3CH_2CH_3(g)+Br_2(g) \rightarrow CH_3CH_2CH_2Br(g)+HBr(g)$ ❶
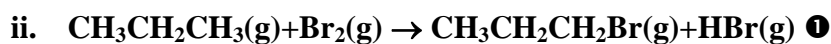
g.   Propene ❶ – different number of carbon atoms to compound <u>C</u> which is propane.
$CH_3CH=CH_2(g) + H_2O(l) \rightarrow CH_3CHOHCH_3(l)$ ❶
This is also consistent with the ^1H NMR spectrum of compound <u>B</u>.
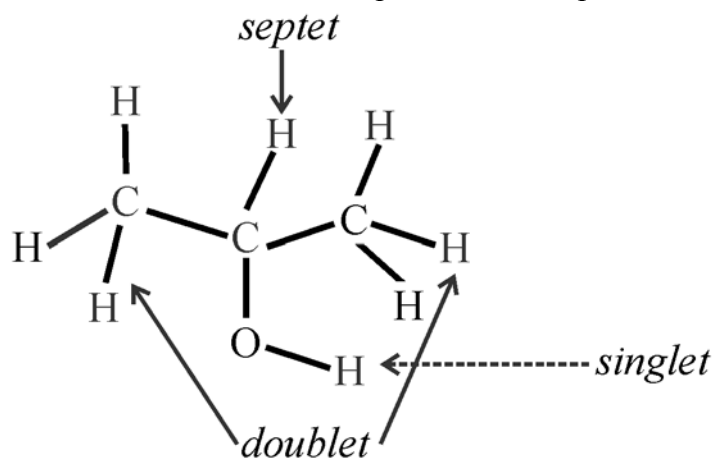
h.   i.   ethyl propanoate ❶
Carboxylic acids and esters with the same number of C atoms are structural isomers and so have the same molar mass. Since pentanoic acid has 5 C atoms, compound G must have 5 C atoms. Since F is propanoic acid, CH_3CH_2COOH, compound G must be an alcohol with 2 C atoms, i.e. ethanol. Acids and alcohols react to produce esters, in this case ethyl propanoate.

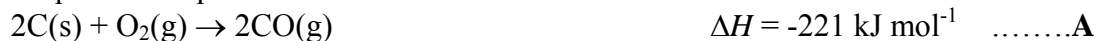**ii. $CH_3CH_2COOH(l) + CH_3CH_2OH(l) \rightarrow CH_3CH_2COOCH_2CH_3(l) + H_2O(l)$** ❶
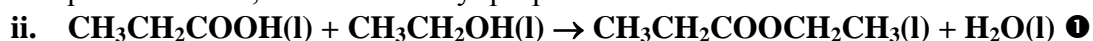
Question 2 (9 marks)

a. $C(s) + O_2(g) \rightarrow CO_2(g)$, $\Delta H = -394$ kJ mol^{-1} ❶ *…. molar enthalpy of combustion from **Table 13** of **Data Book**.*

b. $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$, $\Delta H = -10928$ kJ mol^{-1} *or*
    $C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$, $\Delta H = -5464$ kJ mol^{-1} ❶

c. Requires manipulation of

$2C(s) + O_2(g) \rightarrow 2CO(g)$	$\Delta H = -221$ kJ mol^{-1} ....**A**
$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H = -394$ kJ mol^{-1} ....**B**
$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$,	$\Delta H = -10928$ kJ mol^{-1} ....**C**

to establish $\underline{2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l), \Delta H = ?}$

This requires using equations **A** and **B** to introduce CO into and remove CO_2 from equation **C.** This can be achieved by combining **C** with **16 times** the **reverse** of **B** and **8 times A**, i.e.

$2C_8H_{18}(l) + 25O_2(g) \rightarrow \underline{16CO_2}(g) + 18H_2O(l)$, $\Delta H = -10928$ kJ mol^{-1}**..............C**
$\underline{16CO_2}(g) \rightarrow 16C(s) + 16O_2(g)$, $\Delta H = 16 \times +394 = 6304$ kJ mol^{-1}**.....Reverse** of **B×16** ❶
$16C(s) + 8O_2(g) \rightarrow 16CO(g)$ $\Delta H = 8 \times -221 = -1768$ kJ mol^{-1} **.....Multiply A×8** ❶
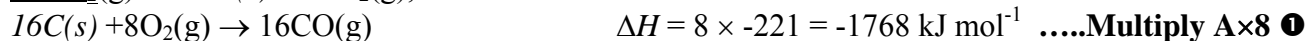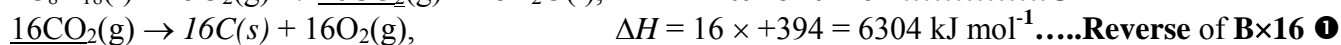
Add these three thermochemical equations together.

$2C_8H_{18}(l) + 25O_2(g) + \underline{16CO_2}(g) + 16C(s) + 8O_2(g) \rightarrow \underline{16CO_2}(g) + 18H_2O(l) + 16C(s) + 16O_2(g) + 16CO(g)$
                              $\Delta H = (-10928$ kJ mol$^{-1}) + (+6304$ kJ mol$^{-1}) + (-1768$ kJ mol$^{-1})$

$2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l)$; $\underline{\Delta H = -6392}$ kJ mol^{-1}   ❶
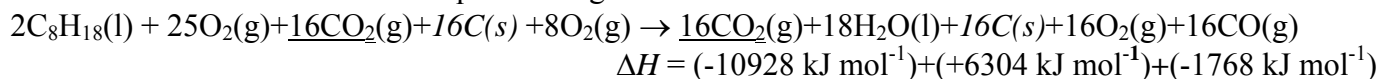
d.

n(CO) collected $= pV / RT$	$= 102.3 \times 100 / (8.31 \times 308)$
	$= 4.00$ mol ❶
$n(C_8H_{18})$ reacting	$= n$(CO) $/ 8 = 4.00 / 8$
	$= 0.500$ mol
$m(C_8H_{18})$ reacting	$= 0.500 \times 114.0$
	$= 57.0$ g ❶
$V(C_8H_{18})$ reacting	$= m(C_8H_{18}) / d(C_8H_{18})$
	$= 57.0$ g $/ 0.703$ g mL^{-1}
	$= 81.1$ mL ❶
% C_8H_{18} reacting	$= [V(C_8H_{18})$ reacting $/ V(C_8H_{18})$ in sample$] \times 100$
	$= (81.1 / 200) \times 100$
	$= \textbf{40.5 \%}$ ❶

Question 3 (18 marks)

a. **i.** ❶
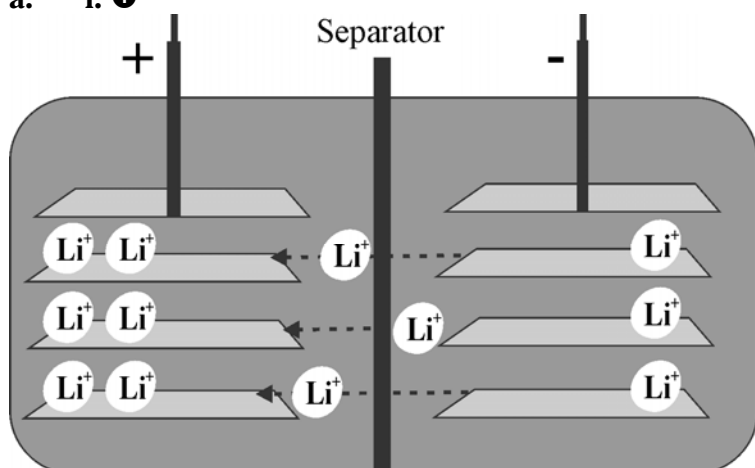
Cations move towards the cathode which is discharging the positive electrode.

    ii. ANODE: $Li_xC_6(s) \rightarrow C_6(s) + xLi^+(aq) + xe^-$ ❶
        CATHODE: $Li_{1-x}MnO_2(s) + xLi^+(aq) + xe^- \rightarrow LiMnO_2(s)$ ❶
    iii. $C_6(s) + xLi^+(aq) + xe^- \rightarrow Li_xC_6(s)$ ❶
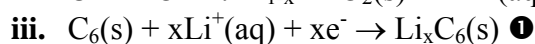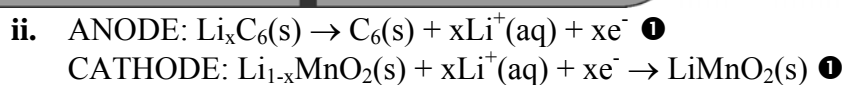
b. **i.** Energy produced $= 7.0 \times 3.6$
                        $= 25.2$ MJ ❶

      $\Delta H_c(C) = -394$ kJ mol^{-1}
      $n(C)$ required = Energy produced / Energy per mol C
                      $= 25.2 \times 10^3 / 394$
                      $= 64$ mol ❶
      Since the power station is only 35 per cent efficient 64 mol is only 35 % of the amount of carbon actually used.
      $64 = 0.35 \times n(C)$ used $\rightarrow n(C)$ used $= 64 / 0.35$
                                          $= 183$ mol ❶

      m(coal used) $= m(C)$ used $= 183 \times 12.0$
                              $= 2.2 \times 10^3$ g
                              $= \textbf{2.2 kg}$. ❶

   **ii.** **Cheaper electricity** since less coal would need to be used to supply the required energy. ❶
        Lowered **environmental impact** because less CO_2 would be produced. ❶

c. No need to pay for electricity used in recharging ❶
    No significant environmental impact since energy is not obtained from a coal fired power station.
    Effective energy storage at night and in times of limited sunlight.

d. **i.** $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$ ❶
    ii. $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ ❶
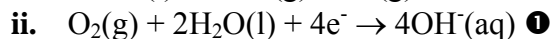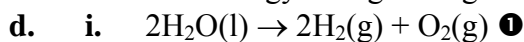
**e.** **i.** $\textbf{C}_{13}\textbf{H}_{11}\textbf{N}_3$ ❶
    ii. Each nucleotide in the **primary structure of DNA** contains **one** of the four **nitrogen bases** (G, C, A, T) **bonded to deoxyribose through a C-N covalent bond**. ❶
        The secondary structure of DNA is maintained by **hydrogen bonds between nitrogen bases** on adjacent strands of the double helix. ❶ The bases pairs formed **are guanine-cytosine (G-C)** with **three sites at which hydrogen bonding occurs** and **adenine-thymine (A-T)** with **two sites at which hydrogen bonding occurs**. ❶
    iii. The presence of the **amino (NH$_2$) groups** means that the **H atoms in those groups** can from **hydrogen bonds with available lone pairs on accessible N and O atoms on the nitrogen bases**. ❶

Question 4 (24 marks)

a. m(I) in 500g iodised salt $= (0.0055 / 100) \times 500$
$= 0.0275$ g
n(I in 500 g iodised salt) $= 0.0275$ g $/ 126.9$ g mol^{-1}
$= 2.17 \times 10^{-4}$ mol ❶
n(KIO$_3$) in 500 g iodised salt $= 2.17 \times 10^{-4}$ mol ❶
m(KIO$_3$) in 500 g iodised salt $= 2.17 \times 10^{-4} \times 214.0$
$= 4.6 \times 10^{-2}$ g
$= \mathbf{46}$ **mg** ❶

b. i. Pb^{2+}(aq) $+ 2I^-$(aq) $\rightarrow PbI_2$(s) ❶

ii. The precipitate is dried, by gentle heating, until all water has been evaporated as indicated by **mass not changing after further drying**.
If the mass of precipitate was based on the first drying it would be higher than its true value and the **iodide content would be calculated to be higher than its true value.** ❶

iii. m(PbI$_2$) produced $= 1.698 - 1.462$
$= 0.236$ g
n(PbI$_2$) produced $= 0.236 / 461.0$
$= 5.12 \times 10^{-4}$ mol ❶
All the iodine (present as I$^-$) in the 0.425 g tablet was precipitated as PbI$_2$
n(I) $= 2 \times n$(PbI$_2$)
$= 2 \times 5.12 \times 10^{-4}$
$= 1.02 \times 10^{-3}$ mol
m(I) $= 1.02 \times 10^{-3} \times 126.9$
$= 0.130$ g ❶
% iodine in tablet $= [m$(I) $/ m$(tablet)$] \times 100$
$= (0.130 / 0.425) \times 100$
$= \mathbf{30.6 \ \%}$ ❶

c. i. Starch, glycogen and 'simple carbohydrates' all have **differences in** their **structures**, with **starch and glycogen both condensation polymers** of glucose. The observations suggest that components of **Lugol's solution interact with complex carbohydrates such as starch and glycogen but not simple carbohydrates**, e.g. monosaccharides and disaccharides. ❶

ii. **Hydrolysis of starch** during digestion **produces glucose**. ❶ Most of this **glucose is converted to glycogen by condensation polymerisation.** ❶

iii. To maintain a steady supply of energy for body process, stored **glycogen is converted to glucose by hydrolysis**. Glucose is then oxidised, and energy released, during respiration. ❶
The thermochemical equation for respiration is
$C_6H_{12}O_6$(aq) $+ 6O_2$(g) $\rightarrow 6CO_2$(g) $+ 6H_2O$(l), $\Delta H = $ -2816 kJ mol^{-1}
(ΔH, *Data Book Table 13).* ❶

d. **i.** Oxidation: $3I^-(aq) \rightarrow I_3^-(aq) + 2e^-$ ❶
Reduction: $3IO_3^-(aq) + 18H^+(aq) + 16e^- \rightarrow I_3^-(aq) + 9H_2O(l)$ ❶
Equalise *electrons by multiplying oxidation half-equation by 8*
Oxidation: $24I^-(aq) \rightarrow 8\ I_3^-(aq) + 16e^-$ then *add it to the reduction half-equation to produce the overall equation for the reaction.*
Overall: $24I^-(aq) + 3IO_3^-(aq) + 18H^+(aq) \rightarrow 9I_3^-(aq) + 9H_2O(l)$ which simplifies to
$8I^-(aq) + IO_3^-(aq) + 6H^+(aq) \rightarrow 3I_3^-(aq) + 3H_2O(l)$ ❶

ii. $2S_2O_3^{2-}(aq) + I_3^-(aq) \rightarrow S_4O_6^{2-}(aq) + 3I^-(aq)$
Assume all the IO_3^- had been reduced to $I_3^-(aq)$ by the excess I^-.
$n(IO_3^-) = n(KIO_3) = 0.0120 \times 25.00 \times 10^{-3}$
$\qquad\qquad\qquad = 3.00 \times 10^{-4}$ mol
$n(I_3^-) = 3 \times n(IO_3^-)$
$\qquad = 3 \times 3.00 \times 10^{-4}$
$\qquad = 9.00 \times 10^{-4}$ mol ❶
$n(S_2O_3^{2-}) = 2 \times n(I_3^-)$
$\qquad\qquad = 2 \times 9.00 \times 10^{-4}$
$\qquad\qquad = 1.80 \times 10^{-3}$ mol ❶
$c(S_2O_3^{2-}) = 1.80 \times 10^{-3} / 35.40 \times 10^{-3}$
$\qquad\qquad = 0.0508$ M
Since $n(Na_2S_2O_3) = n(S_2O_3^{2-})$ then $c(Na_2S_2O_3) = $ **0.0508 M** ❶

e. **i.**
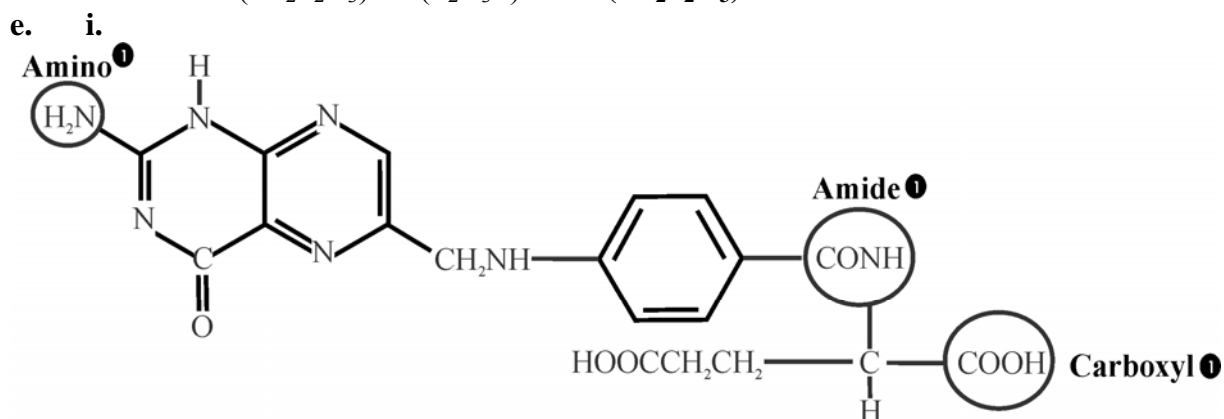
ii. *$C_{19}H_{19}N_7O_6$*
The structure of the folic acid molecule **shows multiple sites (NH₂, NH, CONH, COOH and others) where hydrogen bonds can form with water** suggesting it should be quite soluble. However this is balanced against the **large size** of the molecules. ❶
In 1.0 M NaOH(aq), the carboxyl groups**, -COOH become deprotonated to –COO⁻** (folic acid is converted to folate). This allows for ion-dipole bonding with water molecules. Since this **ion-dipole bonding is stronger than hydrogen bonding this leads to increased solubility.** ❶

Question 5 (18 marks)

a. In **both processes** there are more moles of products (particles) than reactants so the **yield will be higher at lower pressure**. This is because lowering the pressure will cause the system to partially oppose this change by **favouring the side with more moles (particles)**. ❶

From a temperature viewpoint, since **SMR is endothermic,** the **yield of syngas** will **increase as temperature increases** whereas since **CPOX is exothermic** the yield of syngas will **increase as temperature decreases.** ❶

However in the CPOX method, **low temperature** will **lower reaction rate** so the **conditions used** will be those that provide an **economic balance between yield and reaction rate.** ❶

b. **Catalysts speed up the rate of reaction** and so **allow the system to get to equilibrium more quickly** but **do not affect equilibrium yield**. ❶However in the **exothermic CPOX system,** there is a **rate-yield conflict** where the use of **low temperatures decreases the rate of reaction**. Using a **catalyst enables a good reaction rate to be maintained at the lower temperatures used to increase syngas yield**. ❶ *NB It is the lower temperature that is the cause of the increased yield NOT the catalyst.*

c. The **honeycomb structure increases the surface area of the catalyst**. Since the **catalytic effect depends on contact between the reactants and the catalyst surface**, ❶ there will be **more collisions between reactants and the catalyst surface, lowering the activation energy so increasing the proportion of successful collisions** ❶ (those with energy greater than the activation energy) and **giving a faster rate of reaction**.

d. **i.** $K_c = \{[CO]^3[H_2]^3[H_2O]\}/\{[CH_4]^2[O_2][CO_2]\}$. ❶

ii. Syngas contains CO and H_2;

the mass of syngas produced $= m(CO)$ produced $+ m(H_2)$ produced

According to the equation $n(CO) = n(H_2)$

According to the equation production of 3 mol $CO \rightarrow$ releases 31 kJ energy

Total energy released is 310 MJ, so

3 mol $CO \rightarrow$ 31 kJ

'×' mol $CO \rightarrow 310 \times 10^3$ kJ

'×' / 3 $= 310 \times 10^3$ / 31

'×' $= 3 \times (310 \times 10^3 / 31)$

$= 3.0 \times 10^4$ mol

$n(CO)$ produced $= 3.0 \times 10^4$ mol ❶

$n(H_2)$ produced $= 3.0 \times 10^4$ mol

$m(\text{syngas}) = m(CO) + m(H_2)$ ❶

$= (3.0 \times 10^4 \times 28.0) + (3.0 \times 10^4 \times 2.0)$

$= 8.4 \times 10^5 + 6.0 \times 10^4$

$= 9.0 \times 10^5$ g

$= 9.0 \times 10^5 / 10^6$

$= \mathbf{0.90\ tonne}$ ❶

e. **i.** $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$ ❶

  ii. **CPOX** in which the syngas produced has **CO and H_2 in the ratio 1:2,** i.e. the ratio **needed for methanol production.** ❶

  iii. *Table 13. Of the Data Book* gives molar enthalpies of combustion of H_2 (-286 kJ mol^{-1}) and CH_3OH (-725 kJ mol^{-1})

  If the **reactants (1 mol CO and 2 mol H_2) undergo combustion**:

  Total **energy released** $= 293.5 + (2 \times 286)$
  $= \textbf{865.5 kJ}$. ❶

  Energy released in the combustion of **1 mol CH_3OH** $= \textbf{725 kJ}$. ❶

  Difference in energies released $= 865.5 - 725$
  $= \textbf{140.5 kJ}$ ❶

  On combustion, 1 mol CH_3OH releases 140.5 kJ less than is released from the combustion of 2 mol H_2 and 1 mol CO, hence the production of CH_3OH syngas must be **exothermic with ΔH = -141 kJ mol^{-1}**.

  The thermochemical equation for the reaction is

  $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$, ΔH = -142 kJ mol^{-1}

  iv. $\Delta H_c(CH_3OH)$ = -725 kJ mol^{-1} (*Table 13 of Data Book*).

  $CH_3OH(l) + 1.5O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$; ΔH = -725 kJ mol^{-1} ❶ *or*

  $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$; $\Delta H = 2 \times$ -725 = -1450 kJ mol^{-1}

  v. In a fuel cell, oxidation occurs at the negative electrode.

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

Question 6 (10 marks)
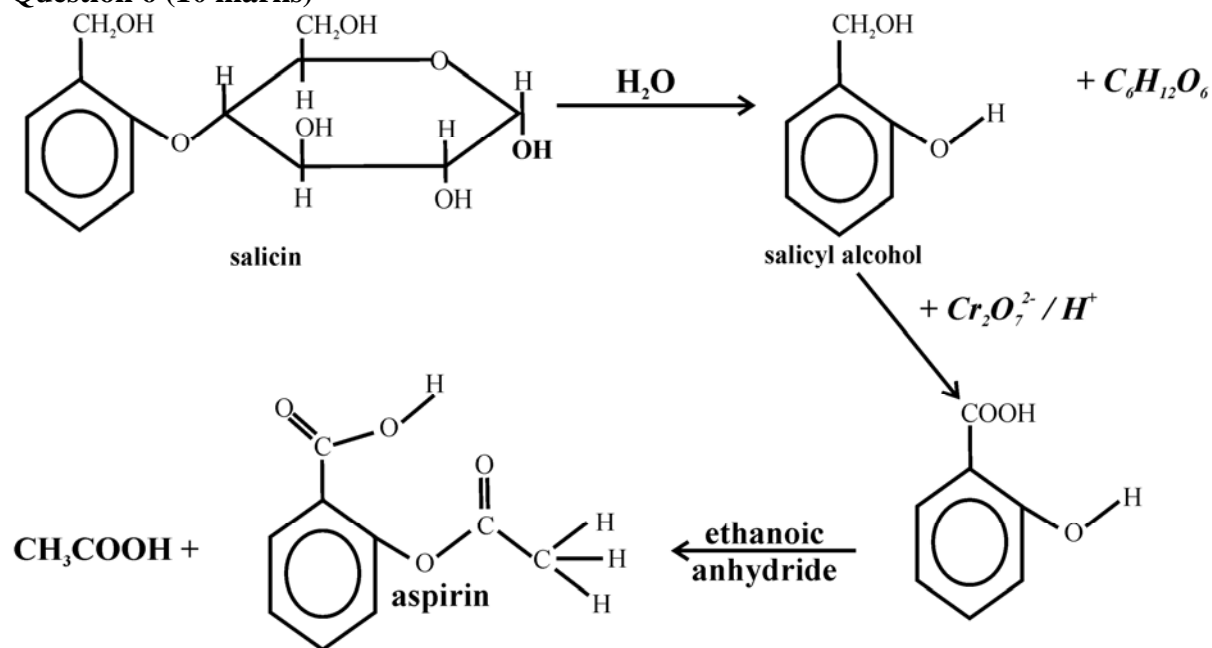
a. **Aspirin ❶**
b. **A – H₂O**, B – **C₆H₁₂O₆ ❶❶**
c. **Cr₂O₇²⁻**(aq) / **H⁺**(aq) **❶**
d. **Ethanoic anhydride ❶**
e. **Hydrolysis, oxidation (redox), condensation (esterification) ❶**
f. Molecular formula of F (aspirin) is $C_9H_8O_4$.
   $M(C_9H_8O_4) = 180.0$ g mol⁻¹
   n(aspirin) produced $= 2.15 / 180.0$
   $= 1.19 \times 10^{-2}$ mol
   n(salicin) converted to aspirin $= n$(aspirin)
   $= 1.19 \times 10^{-2}$ mol **❶**
   This is 43 % of the total n(salicin) used.
   $1.19 \times 10^{-2} = 0.43 \times n$(salicin) used
   n(salicin) used $= 1.19 \times 10^{-2} / 0.43$
   $= 2.78 \times 10^{-2}$ mol **❶**
   Molecular formula of salicin is $C_{13}H_{18}O_7$
   $M(C_{13}H_{18}O_7) = 286.0$ g mol⁻¹ **❶**
   m(salicin) used $= 2.78 \times 10^{-2} \times 286.0$
   $= \mathbf{7.94\ g}$ **❶**

Question 7 (7 marks)

The products of the electrolysis of water and 1 M LiCl(aq)can be deduced from the electrochemical series

$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ *1.36 V*

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

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ *-0.83 V*

$Li^+(aq) + e^- \rightarrow Li(s)$ *-3.02 V*
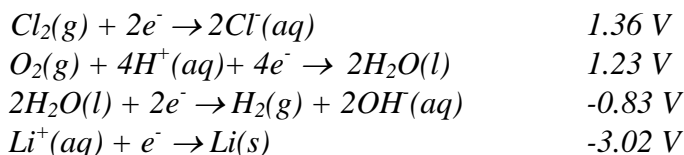
utilising the strongest oxidant reacts with strongest reductant principle.

In $Li\,Cl(l)$ *the only possible reactions are the reduction of* $Li^+(l)$ *at the cathode and the oxidation of* $Cl^-(l)$ *at the anode.*

In electrolysis, oxidation occurs at the (+) electrode and reduction at the (-)

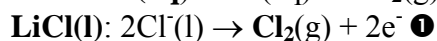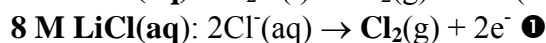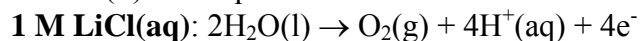**a.**   **i.** $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ ❶

      ii. $Li^+(l) + e^- \rightarrow Li(l)$ ❶

      iii.   **Cathode** (-) $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$.
           pH increases as [OH⁻] increases ❶

b.   In **1 M LiCl(aq) water is oxidised and reduced** because in both cases it is the strongest reductant and the strongest oxidant; the products are $O_2(g)$ – anode, and $H_2(g)$ - cathode.

In molten LiCl, the products are $Cl_2(g)$ – anode, and **Li(l)** – cathode.

In **8 M LiCl(aq)** the high concentration means that **predictions based on the electrochemical series (1 M solutions, 25°C and 101.3 kPa) are less accurate**. ❶
Because **Cl⁻(aq): 1.36 V, and H₂O(l): 1.23) are similar in reducing strength,** the **higher** the **concentration of Cl⁻(aq)** the **greater** the **likelihood of Cl₂(g) being produced at the anode instead of O₂(g),** ❶ i.e. the products are **Cl₂(g)** - anode, and **H₂(g)** - cathode

Anode (+) half-equations:

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

8 M LiCl(aq): $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ ❶

LiCl(l): $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$ ❶

End of Suggested Answers