Name: …… ( ) Class: Sec ……..

St. Gabriel's Secondary School

2024 'O' Preliminary Examination

Subject : Chemistry
Paper : 6092 / 02
Level/Stream : Secondary 4 (Express)
Duration : 1 hour 45 minutes
Date : 21 August 2024

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page 24.

The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
Section A	/70
Section B	/10
TOTAL	/80

Section A

Answer **all** questions.

1 Fig. 1.1 shows part of the Periodic Table. The elements are represented by the letters **M**, **Q**, **R**, **T**, **W**, **X**, **Y** and **Z**.

																Y	
	R												W		X		Z
M						T											
Q																	

Fig. 1.1

Select elements from the Periodic Table to answer the following questions.

You may use each element once, more than once or not at all.

(a) Which **two** elements react together most vigorously?

…….. [1]

(b) Which element forms an ion with a charge of –2?

…….. [1]

(c) Which element has a high density?

…….. [1]

(d) What is the formula of the compound formed when **W** reacts with **Y**?

…….. [1]

(e) Which element constitutes about 1% of dry air?

…….. [1]

[Total: 5]

2 Sodium carbonate ionises in water according to the following equation.

$$Na_2CO_3(s) + H_2O(l) \rightleftharpoons 2Na^+(aq) + HCO_3^-(aq) + OH^-(aq)$$

Fig. 2.1 shows the effect of pressure and temperature on the concentration of hydroxide ions produced per mole of sodium carbonate.

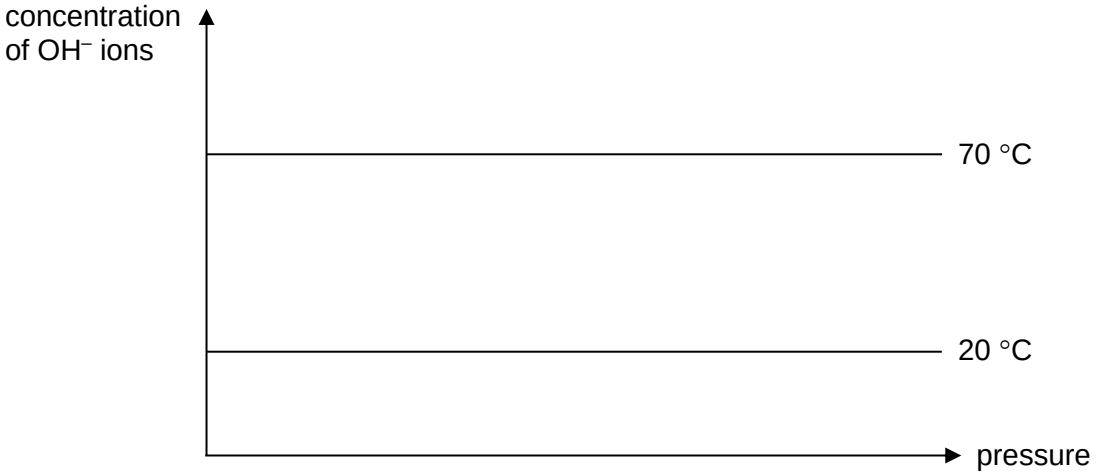


Fig. 2.1

(a) (i) Sodium carbonate is a weak alkali. Explain what a *weak alkali* is.

……..

…… [1]

(ii) State the colour of the resulting mixture when a few drops of Universal Indicator are added to a solution of sodium carbonate.

…… [1]

(b) (i) Describe how temperature and pressure affect the concentration of hydroxide ions produced during the ionisation of sodium carbonate in water.

……..

……..

…… [2]

(ii) Explain the effect of pressure on concentration of hydroxide ions as stated in **(b)(i)**.

……..

…… [1]

(c) Sulfuric acid is a dibasic acid which reacts with the hydroxide ions and hydrogencarbonate ions produced during the ionisation of sodium carbonate.

(i) Write an ionic equation, with state symbols, for the reaction between sulfuric acid and the ions produced.

…… [2]

(ii) Suggest why the formation of the products in **(c)(i)** drives the dissociation of sodium carbonate in water and allows it to react completely with sulfuric acid.

……..

…… [1]

[Total: 8]

3 Fig. 3.1 shows some reactions involving substances **A**, **B**, **C** and **D**.

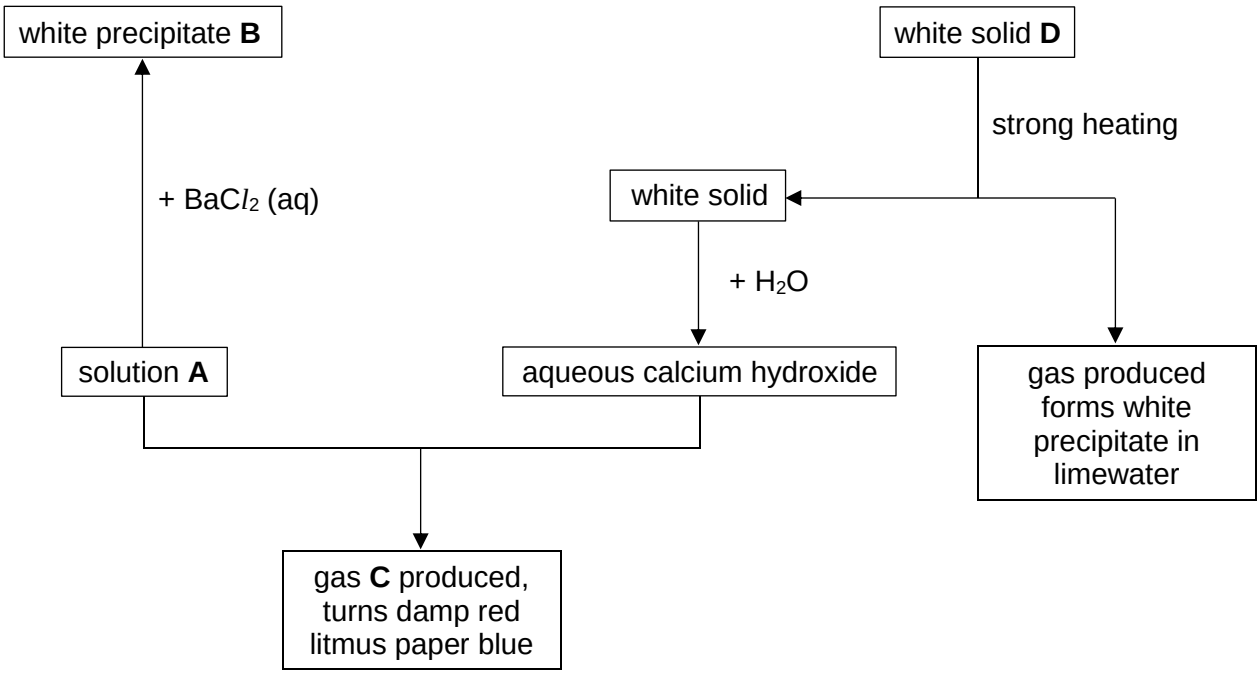


Fig. 3.1

(a) Identify substances **A**, **B** and **D**.

A : ……

B : ……

D : …… [3]

(b) Substance **C** was passed through aqueous copper(II) sulfate until no further change was observed.

Describe and explain the observation(s) seen during the reaction.

……

……

……

……

…….. [3]

[Total: 6]

4 Zinc is mainly obtained from sulfide ores such as zinc blende, ZnS. These sulfides ores typically contain other metal impurities such as cadmium, iron and silver.

Extraction of zinc from zinc blende takes place in a few stages.

Stage 1: Zinc blende is roasted in air to convert zinc sulfide to zinc oxide and sulfur dioxide.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

Stage 2: The roasted oxide is added to a hot solution of sulfuric acid to produce zinc sulfate. Any iron impurities present in the mixture is converted to iron(III) sulfate.

Stage 3: Ammonium sulfate is added to the mixture to remove iron(III) sulfate as a jarosite precipitate, $NH_4Fe_3(SO_4)_2(OH)_6$.

Stage 4: Powdered zinc is added to the mixture to precipitate metal impurities such as cadmium and silver from zinc sulfate solution.

Stage 5: Zinc is extracted through electrolysis of zinc sulfate solution using inert electrodes.

(a) The word equation for the removal of iron(III) sulfate in Stage 2 is as shown.

iron(III) sulfate + ammonium sulfate + water → jarosite + sulfuric acid

Complete the equation for the reaction that takes place. [2]

$3Fe_2(SO_4)_3$

(b) **(i)** Explain how the powdered zinc added in Stage 4 helps to remove the remaining metal impurities.

……..

……..

…… [2]

(ii) State **one** additional process that needs to be carried out in Stage 4 before the products can be used in Stage 5.

…… [1]

(c) **(i)** Write ionic equations, with state symbols, for the reactions occurring at each electrode in Stage 5.

anode: ……..

cathode: …… [2]

(ii) State how the product(s) formed at one of the electrodes in **(c)(i)** is unusual.

……..

…… [1]

(iii) Describe and explain **one** change in the electrolyte during the electrolysis of zinc sulfate solution in Stage 5.

……..

……..

…… [2]

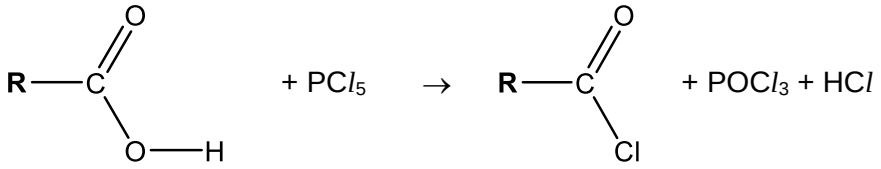
(iv) Describe a simple test that can be conducted to support your explanation in **(c)(ii)**.

……..

…… [1]

[Total: 11]

5 Carboxylic acids readily undergo reaction with phosphorus(V) chloride at room temperature and pressure to form organic compounds known as acid chlorides according to the equation:



R: hydrocarbon chain

Table 5.1 shows information about some acid chlorides.

Table 5.1

number of carbon atoms	name	chemical formula	boiling point / °C
2	ethanoyl chloride	CH_3COCl	51
3	propanoyl chloride	CH_3CH_2COCl	80
4	butanoyl chloride	$CH_3CH_2CH_2COCl$	102
5		$CH_3CH_2CH_2CH_2COCl$	

(a) Complete Table 5.1 by writing the name of the acid chloride with five carbon atoms and predicting its boiling point. [1]

(b) Give **two** pieces of evidence that suggest the acid chlorides constitute a homologous series.

……

……

…….. [2]

(c) **(i)** Draw a 'dot-and-cross' diagram for ethanoyl chloride, CH_3COCl.

Show outer shell electrons only.

[2]

(ii) Use ideas about structure and bonding to account for the boiling point of ethanoyl chloride.

……..

……..

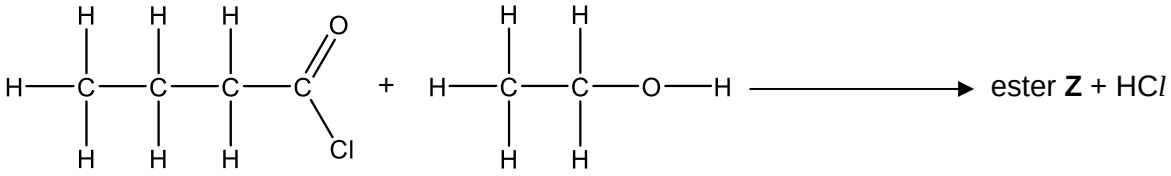
……..

……..

…… [2]

(d) Similar to carboxylic acids, acid chlorides are able to undergo a condensation reaction with alcohols to form esters.

Butanoyl chloride and ethanol react together to form an ester **Z** according to the equation:



butanoyl chloride ethanol

(i) Define *condensation reaction*.

……..

…… [1]

(ii) Draw the full structural formula of ester **Z**.

[1]

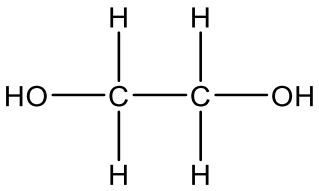
(iii) Suggest why the reaction between butanoyl chloride and ethanol produces a higher yield of the ester compared to the reaction between butanoic acid and ethanol.

……..

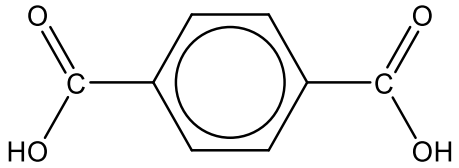
…… [1]

[Total: 10]

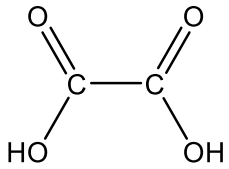
6 Fig. 6.1 shows the structure of four organic compounds which have various uses.



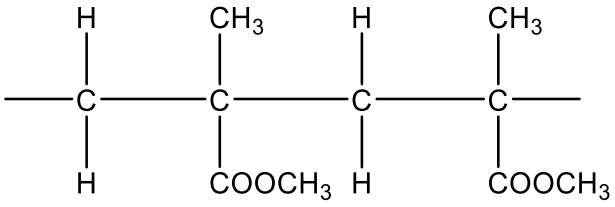
ethylene glycol



terephthalic acid



oxalic acid



Perspex

Fig. 6.1

(a) Terephthalic acid and ethylene glycol undergo polymerisation to produce poly(ethylene terephthalate), commonly known as PET. PET is mainly used to make plastic bottles containing water and beverages.

(i) Draw the full structural formula of PET, showing **two** repeat units.

[2]

(ii) Describe **one** method in which PET can be broken down into its original raw materials.

……..

…… [1]

(iii) Discuss **two** issues related to the recycling of PET.

……..

……..

……..

……..

…… [2]

(b) Oxalic acid is commonly used as a cleaning agent to remove rust and stains on objects. Oxalic acid can theoretically be synthesised from ethylene glycol under laboratory conditions.

State the name of the reagent(s) and condition(s) required for the conversion of ethylene glycol to oxalic acid.

…….. [1]

(c) Perspex is often used as a substitute for glass and has a wide range of applications such as rear lights and instrument clusters for vehicles and appliances.

(i) Name the functional group present in Perspex.

…… [1]

(ii) Draw the structural formula of the monomer used to make Perspex.

[1]

(iii) Calculate the mass of a single polymer molecule of Perspex containing 2500 repeat units.

mass of single polymer molecule of Perspex = …… g [2]

[Total: 10]

7 An experiment was carried out to investigate the effect of particle size and concentration on the rate of reaction.

Fig. 7.1 shows the graph obtained when a 0.138 g lump of potassium carbonate was reacted with 50 cm^3 of 0.05 mol/dm^3 of dilute sulfuric acid (Experiment 1).

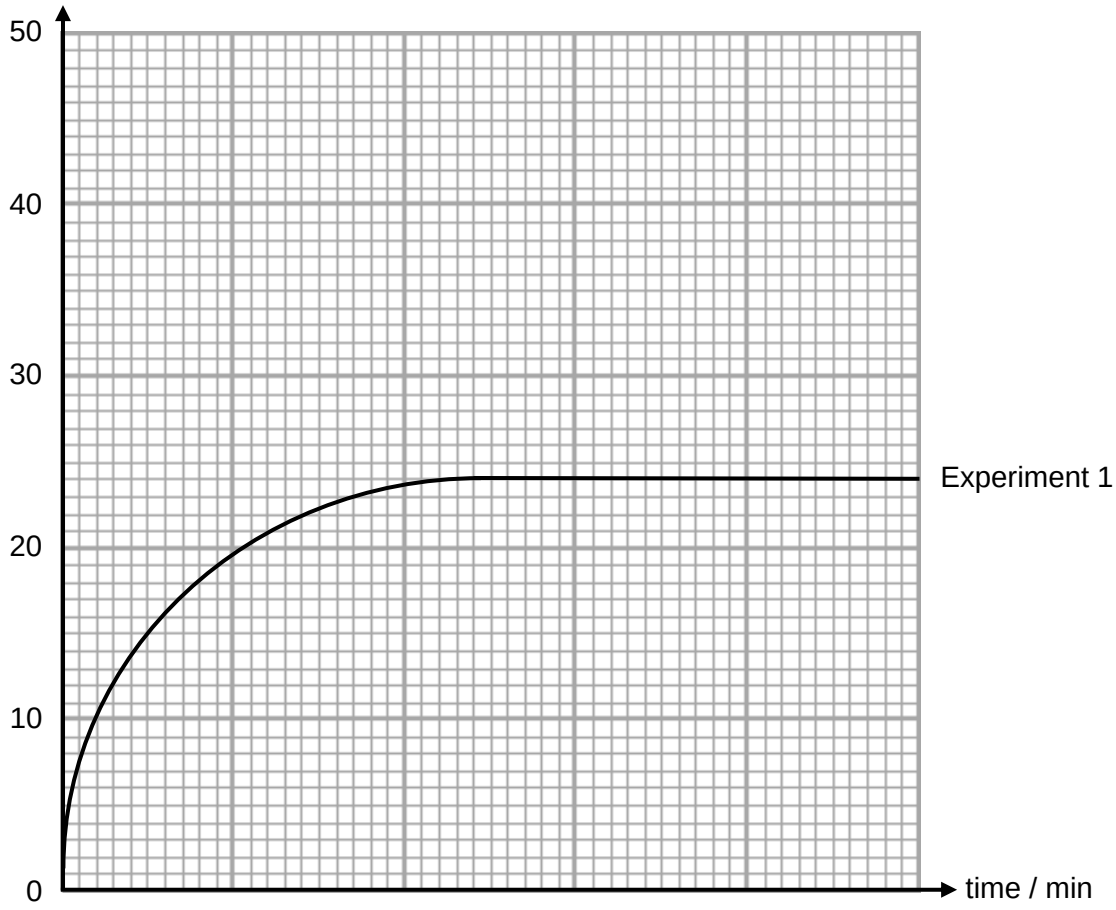


Fig. 7.1

(a) Determine the limiting reactant in this experiment.

Show your working.

[2]

(b) **(i)** The experiment was repeated twice, each with a different reaction condition.

Experiment	reaction conditions
2	0.138 g lump of potassium carbonate 50 cm^3 of 0.025 mol/dm^3 dilute sulfuric acid
3	0.276 g potassium carbonate powder 50 cm^3 of 0.05 mol/dm^3 dilute sulfuric acid

Draw on Fig. 7.1 the graphs for Experiments 2 and 3. Label each graph. [2]

(ii) Explain the shape of the graphs in **(b)(i)**.

Experiment 2 ……..

……..

……..

……..

……..

Experiment 3 ……..

……..

……..

……..

…… [4]

[Total: 8]

8 Electrode Potential

When a metal electrode is placed in a solution containing its aqueous ions, the following equilibrium is established:

$$M^{n+}(aq) + ne^- \rightleftharpoons M(s)$$

At equilibrium, there is a separation of charge between the metal strip and the ions in the solution, giving rise to a potential difference between the metal and the solution. This potential difference is known as the electrode potential and is written as $E_{M^{n+}/M}$.

Standard Electrode Potential, E^θ

The standard electrode potential, E^θ, is a measure of the probability of reduction occurring relative to the standard hydrogen electrode (S.H.E.), which is assigned a value of 0.00 V under standard conditions.

The more positive the E^θ value is, the greater the tendency for reduction to occur.
The more negative the E^θ value is, the greater the tendency for oxidation to occur.

Table 8.1 shows the standard electrode potentials of some elements.

Table 8.1

element	half-equation	E^θ / V
potassium	$K^+ + e^- \rightleftharpoons K$	–2.92
calcium	$Ca^{2+} + 2e^- \rightleftharpoons Ca$	–2.87
sodium	$Na^+ + e^- \rightleftharpoons Na$	–2.71
magnesium	$Mg^{2+} + 2e^- \rightleftharpoons Mg$	–2.38
aluminium	$Al^{3+} + 3e^- \rightleftharpoons Al$	–1.66
zinc	$Zn^{2+} + 2e^- \rightleftharpoons Zn$	–0.76
iron	$Fe^{2+} + 2e^- \rightleftharpoons Fe$	–0.44
tin	$Sn^{2+} + 2e^- \rightleftharpoons Sn$	–0.14
lead	$Pb^{2+} + 2e^- \rightleftharpoons Pb$	–0.13
hydrogen	$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
copper	$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.34
iodine	$I_2 + e^- \rightleftharpoons 2I^-$	+0.54
silver	$Ag^+ + e^- \rightleftharpoons Ag$	+0.80
bromine	$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.07
chlorine	$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36

By comparing E^θ values, scientists are able to deduce the reactivity of each metal relative to other metals. E^θ values also allow scientists to predict whether a chemical reaction would occur by using these values to calculate the standard cell potential, E^θ_{cell}.

Calculation of Standard Cell Potential, E^{θ}_{cell}

The standard cell potential can be calculated by subtracting the standard electrode potential of the oxidation reaction from the standard electrode potential of the reduction reaction, which is represented by the formula

$$E^{\theta}_{cell} = E^{\theta}_{red} - E^{\theta}_{ox}$$

Consider what happens when a strip of calcium metal is introduced into a solution containing dilute nitric acid. Based on a theoretical understanding of reactions of acids, the reaction will occur according to the following equation:

$$Ca(s) + 2H^{+}(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$$

The chemical equation of the reaction can be broken down into two half-equations as shown.

reaction	half-equation	E^{θ} / V
reduction	$2H^{+} + 2e^{-} \rightarrow H_2$	0.00
oxidation	$Ca \rightarrow Ca^{2+} + 2e^{-}$	–2.87

$$E^{\theta}_{cell} = 0.00 - (-2.87) = +2.87 \text{ V}$$

Since the E^{θ}_{cell} value for the reaction is greater than 0.00 V, the reaction is thermodynamically feasible and will likely take place.

Leclanché Cell

The Leclanché cell was invented and patented by the French scientist Georges Leclanché in 1866. The battery contains a carbon cathode surrounded by a layer of manganese(IV) oxide, a zinc anode and ammonium chloride as the electrolyte.

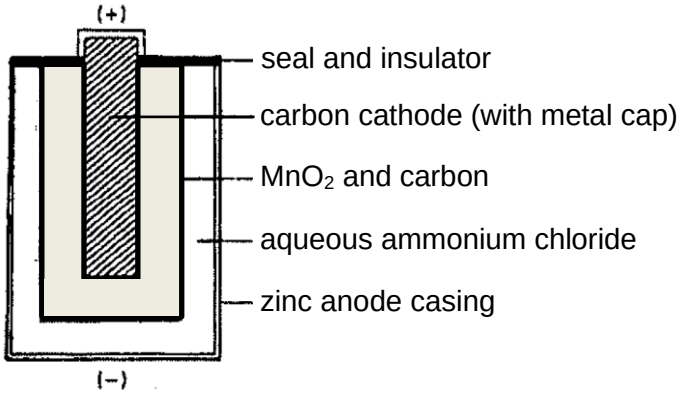


Fig. 8.1

Table 8.2 shows the reactions happening at each electrode and their associated E^{θ} values.

Table 8.2

electrode	half-equation	E^{θ} / V
cathode	$2MnO_2 + 2NH_4^{+} + 2e^{-} \rightarrow 2NH_3 + 2MnO(OH)$	+1.23
anode	$Zn \rightarrow Zn^{2+} + 2e^{-}$	–0.76

The Leclanché cell was used extensively in the 19th century due to its ability to provide intermittent current and low maintenance, but these batteries were found to have short shelf lives. Furthermore, the actual voltage provided by these batteries were lower than calculated due to the internal resistance in the circuit.

Over time, the zinc casing reacts with ammonium chloride to form zinc ions and hydrogen gas. This reaction causes pressures to build up inside the cell and thins the zinc casing, resulting in short shelf lives. Even though the Leclanché cell is no longer in use today, its invention paved the way for the invention of the modern zinc-carbon battery and the alkaline battery.

Alkaline Battery

The alkaline battery was invented after modifications to the Leclanché cell were made. The main modification to the dry cell was the replacement of ammonium chloride as the electrolyte to potassium hydroxide.

Table 8.3 shows the reactions happening at each electrode and their associated E^{θ} values.

Table 8.3

electrode	half-equation	E^{θ} / V
cathode	$2MnO_2 + 2H_2O + 2e^- \rightarrow 2MnO(OH) + 2OH^-$	
anode	$Zn(s) + 2OH^- \rightarrow ZnO + H_2O + 2e^-$	+1.28

Limitations of E^{θ} Values

Although E^{θ} values can be used to predict whether a reaction is thermodynamically feasible, they cannot be used to indicate how fast a reaction proceeds or whether the reaction actually takes place due to other factors such as activation energy.

(a) **(i)** Describe, using E^{θ} values, how the tendency to be reduced changes down the group for Group 17 elements.

……..

…… [1]

(ii) A brown solution is formed when chlorine gas is bubbled into a solution of potassium iodide, but no visible change is observed when iodine gas is bubbled into a solution of potassium chloride.

Calculate the standard cell potential for both reactions to account for this observation.

Show your working.

[2]

(iii) Explain your observation in **(a)(ii)** based on the reactivity of chlorine and iodine.

……..

…… [1]

(b) **(i)** Calculate the standard cell potential, $E^{\theta}_{cell,}$ for the reactions that occur in the Leclanché cell shown in Fig. 8.1 and Table 8.2.

Show your working.

E^{θ}_{cell} = …… [1]

(ii) In practice, the Leclanché cell has a different measured E^{θ}_{cell} value.

Suggest a value for the measured E^{θ}_{cell} and provide a reason to account for this difference between this value and the value obtained in **(b)(i)**.

……..

…… [1]

(c) **(i)** Suggest **one** property of ammonium chloride that enables it to react with zinc.

…… [1]

(ii) Explain, with reference to the shelf life of batteries, why potassium hydroxide is a better electrolyte compared to ammonium chloride.

……..

…… [1]

(d) **(i)** Describe and explain how the concentration of hydroxide ions changes in an alkaline battery.

……..

……..

…… [2]

(ii) The standard cell potential for alkaline batteries is +1.49 V.

Use the information provided in Table 8.3 to calculate the E^{θ} value for the reaction occurring at the cathode.

Show your working.

$E^{\theta}_{cathode}$ = …… [1]

(iii) Suggest why the reactions occurring at the anode and cathode may be slow even though the standard cell potential for alkaline batteries is positive.

……..

…… [1]

[Total: 12]

Section B

Answer **one** question from this section.

9 **(a)** Fig. 9.1 shows some uses of metals in the oil industry.

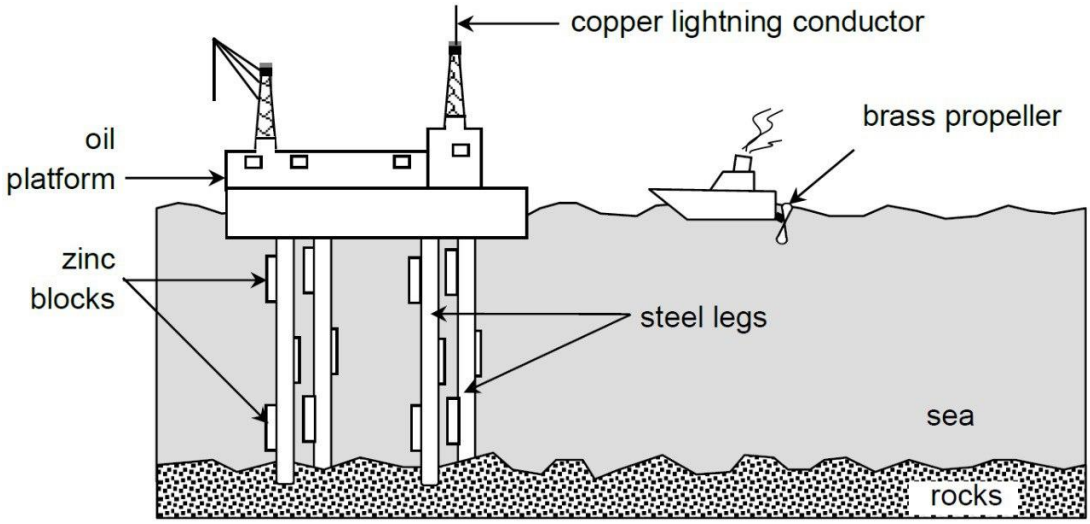


Fig. 9.1

(i) Explain, with reference to structure and bonding, why steel is preferred over iron to construct the legs of the oil platform.

……..

……..

……..

……..

…… [2]

(ii) Explain why zinc blocks are attached to the steel legs of the oil platform.

……..

……..

…… [2]

9 **(b)** Apart from being used in the manufacture of steel, iron is also used to synthesise iron carbonyl, an organometallic compound used as a precursor in the synthesis of many organic molecules.

(i) The chemical formula of iron carbonyl is represented by $Fe(CO)_n$.

Given that iron carbonyl has a relative formula mass of 196, calculate the value of ***n***.

n = …… [1]

(ii) Iron carbonyl undergoes a chemical reaction with sodium to produce Collman's reagent, $Na_2[Fe(CO)_4]$ and carbon monoxide.

Write a chemical equation for this reaction.

…….. [1]

(iii) 5.0 g of iron carbonyl is reacted with sodium in **(b)(ii)**.

Calculate the volume of carbon monoxide produced at room temperature and pressure.

Show your working.

volume of carbon monoxide produced = …… dm^3 [2]

(iv) The oxidation states of iron and carbon monoxide in iron carbonyl are both zero.

Upon reaction with sodium, the oxidation state of iron changes while that of carbon monoxide remains unchanged.

Use oxidation states to show that this reaction is a redox reaction.

……..

……..

……..

……..

…….. [2]

[Total: 10]

10 Ethene undergoes complete combustion according to the equation

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$

(a) The combustion of 1 mole of ethene releases 1074 kJ of heat. Calculate the enthalpy change of combustion when 1 kg of ethene is burned in excess oxygen.

Show your working.

enthalpy change = …… [2]

(b) Complete the energy profile diagram in Fig. 10.1 for the combustion of ethene.

Your diagram should show:
- the products of the reaction
- the energy profile and activation energy for the combustion of ethene, E_a
- the enthalpy change of the reaction, ΔH.

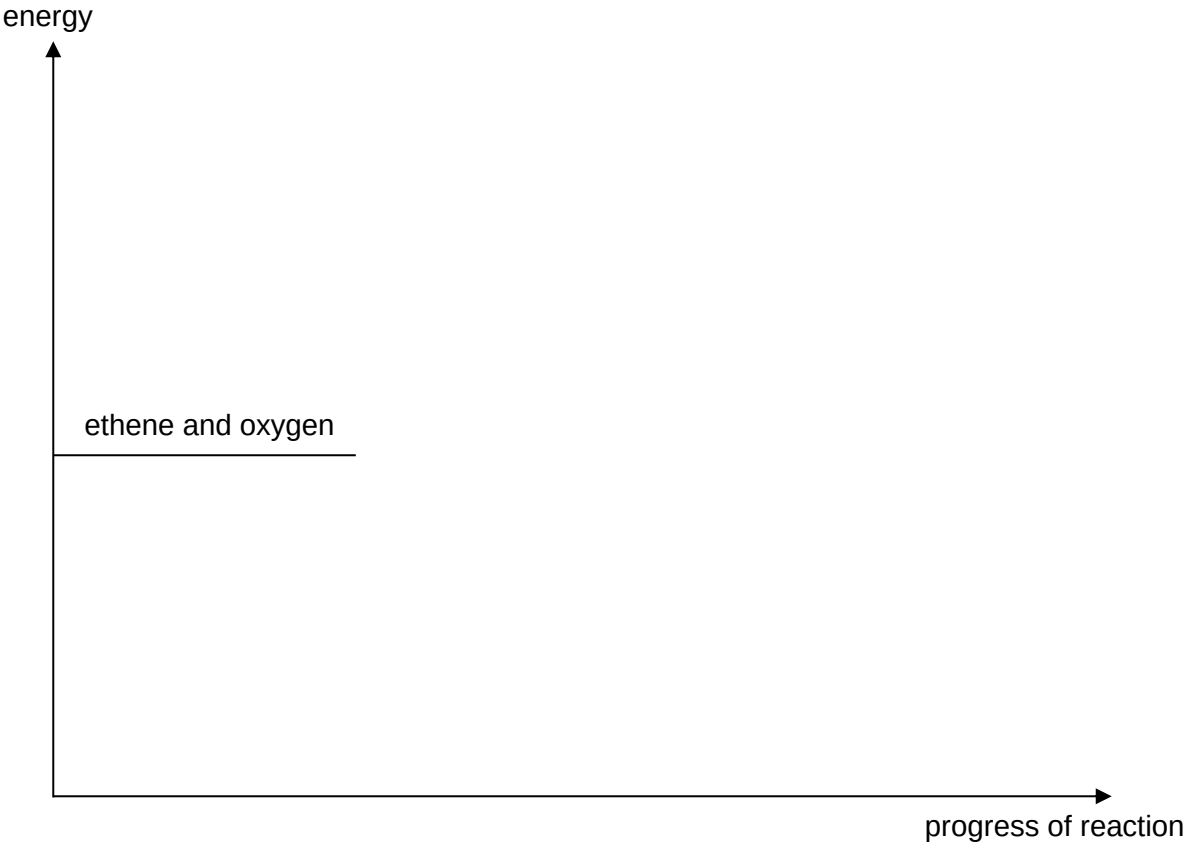


Fig. 10.1

[3]

(c) The Maxwell–Boltzmann distribution shows how the energy of particles within a gas are distributed, as shown in Fig. 10.2. The shaded area under the curve represents the total number of molecules that have energy equal to or above a particular energy level, ***E***.

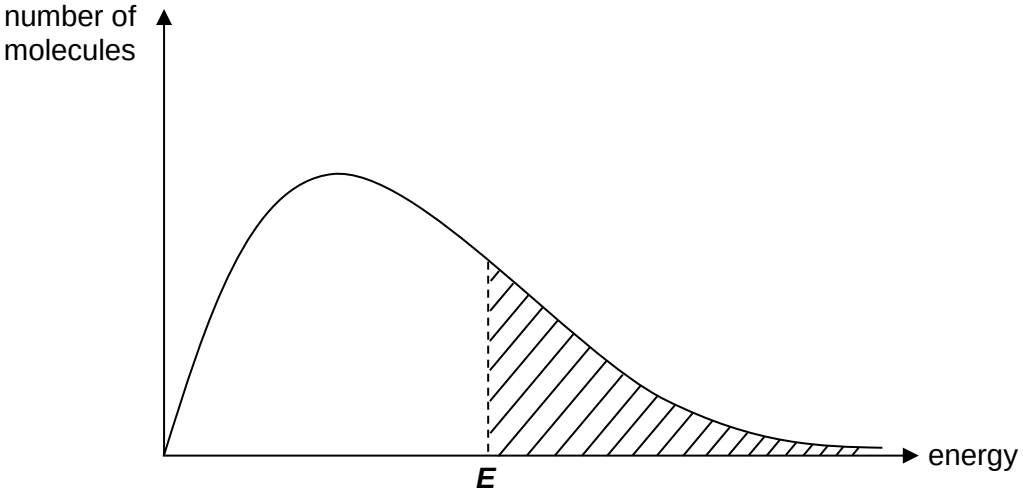


Fig. 10.2

Fig. 10.3 shows how the Maxwell–Boltzmann distribution changes with temperature. The activation energy for the combustion of ethene is marked by E_a.

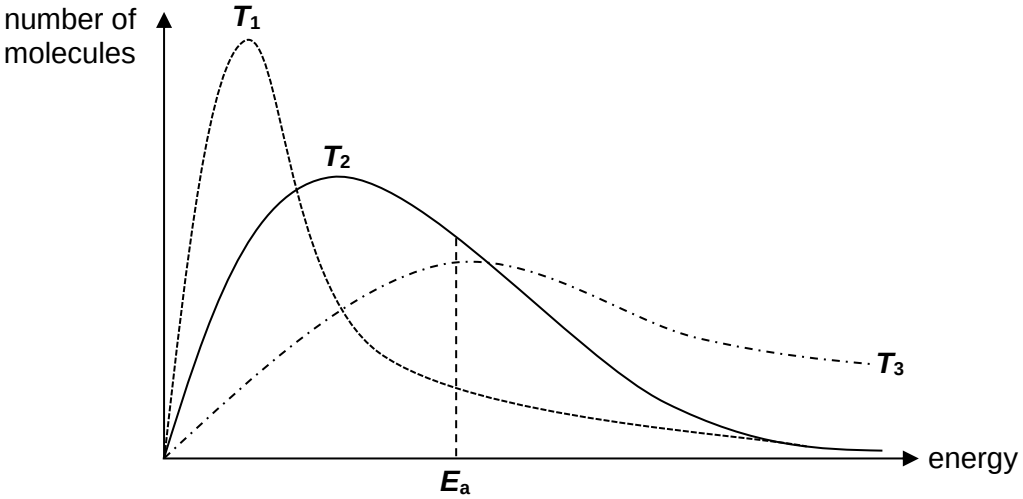


Fig. 10.3

(i) State the temperature – T_1, T_2 or T_3 – at which the average kinetic energy of ethene molecules is the highest.

…… [1]

(ii) Explain, with reference to the Maxwell–Boltzmann distribution and in terms of collisions between reacting particles, why a higher temperature affects the rate of combustion of ethene.

……..

……..

……..

……..

……..

……..

……..

…… [4]

[Total: 10]

End of Paper

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
s87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}.

2024 4E Chemistry Preliminary Examination – Marking Scheme

Paper 1

1	2	3	4	5	6	7	8	9	10
B	**D**	**B**	**B**	**C**	**A**	**D**	**D**	**A**	**C**
11	12	13	14	15	16	17	18	19	20
C	**C**	**C**	**C**	**B**	**B**	**C**	**C**	**C**	**A**
21	22	23	24	25	26	27	28	29	30
D	**D**	**C**	**D**	**D**	**C**	**C**	**B**	**C**	**D**
31	32	33	34	35	36	37	38	39	40
C	**D**	**C**	**B**	**D**	**D**	**A**	**A**	**B**	**D**

Paper 2

A1 **(a)** **Q and Y** [1]

(b) **X** [1]

(c) **T** [1]

(d) **WY_4** [1]

(e) **Z** [1]

[Total: 5]

A2 **(a)** **(i)** **A weak alkali dissociates / ionises partially in water to give a low concentration of hydroxide / OH^- ions.** [1]

(ii) **Blue** [1]

(b) **(i)** **Concentration of hydroxide ions produced remains unchanged as pressure changes.** [1]

Concentration of hydroxide ions produced increases when temperature increases from 20 °C to 70 °C / decreases when temperature decreases from 70 °C to 20 °C. [1]

(ii) **Pressure only affects particles of gases, which are not present in this reaction.** [1]

(c) **(i)** **$2H^+(aq) + OH^-(aq) + HCO_3^-(aq) \rightarrow 2H_2O(l) + CO_2(g)$** [2]

[1]: balanced equation
[1]: correct state symbols (only if formulae is correct)

(ii) **The production of water and carbon dioxide results in a decrease in the concentration of hydrogencarbonate ions and hydroxide ions, causing more sodium carbonate to ionise in water to produce more hydrogencarbonate ions and hydroxide ions to react with the acid.** [1]

OR

Since water is required for dissociation of sodium carbonate, the production of more water causes equilibrium to shift right, causing more sodium carbonate to ionise in water to produce more hydrogencarbonate ions and hydroxide ions to react with the acid.

OR

The formation of water and carbon dioxide in (i) releases energy to the solution and increases its temperature, thereby increasing the extent of dissociation of sodium carbonate to form more hydroxide ions.

[Total: 8]

A3 **(a)** **A: ammonium sulfate / $(NH_4)_2SO_4$** [1]

B: barium sulfate / $BaSO_4$ [1]

D: calcium carbonate / $CaCO_3$ [1]

(b) **A light blue precipitate formed which dissolved in excess aqueous ammonia to form a dark blue solution.** [1]

The light blue precipitate formed due to the formation of copper(II) hydroxide which is insoluble in water. [1]

The precipitate reacted with excess aqueous ammonia to form a soluble metal complex / salt / compound which dissolved in water to give the dark blue solution. [1]

[Total: 6]

A4 **(a)** $3Fe_2(SO_4)_3$ **+ $(NH_4)_2SO_4$ + $12H_2O$ → $2NH_4Fe_3(SO_4)_2(OH)_6$ + $6H_2SO_4$** [2]

[1]: correct chemical formulae
[1]: balanced equation

(b) **(i)** **Zinc is more reactive / higher up in the reactivity series / loses electrons more readily than cadmium and silver,** [1]

hence zinc displaces cadmium and silver from their salt solutions / solutions containing cadmium and silver ions to form zinc sulfate, cadmium and silver. [1]

(ii) **Filtration** [1]

(c) **(i)** anode: **$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$** [1]

cathode: **$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$** [1]

(ii) **Under standard conditions, hydrogen instead of zinc should be formed at the cathode.** [1]

(iii) **The electrolyte becomes more acidic / pH of the electrolyte decreases** [1]

as Zn^{2+} and OH^- ions are discharged at the cathode and anode respectively, leaving behind H^+ and SO_4^{2-} ions / forming sulfuric acid. [1]

(iv) **Add 2 – 3 drops of Universal Indicator. The solution will turn red.** [1]

OR

Dip a piece of blue litmus paper into the solution. The blue litmus paper will turn red. [1]

[Total: 11]

A5 **(a)** **pentanoyl chloride; 119 – 135 (actual: 127)** [1]

(b) **The acid chlorides follow a general formula $C_nH_{2n+1}COCl$ / $C_nH_{2n-1}OCl$** [2]

The boiling point of the acid chlorides increases as the number of carbon atoms increases.

The acid chlorides have the same functional group COCl.

Each member of the series differs from the next member by $–CH_2$.

Any two points.

(c) **(i)** [2]

[1]: correct number of shared electrons
[1]: correct number of electrons around each atom

(ii) **Ethanoyl chloride is a covalent compound with a simple molecular structure. (✓) Ethanoyl chloride molecules are held together by weak intermolecular forces of attraction (✓) which require only a small amount of energy to overcome. (✓) Hence ethanoyl chloride has a low boiling point. (✓)** [2]

[2]: 4 (✓); [1]: 2 – 3 (✓)

(d) **(i)** **Condensation is a reaction in which two molecules react / are joined together / chemically bonded to form a single molecule, usually with the loss of a small molecule such as water.** [1]

(ii) [1]

(iii) **Butanoyl chloride and ethanol react irreversibly to form the ester whereas the reaction between butanoic acid and ethanol is reversible.** [1]

[Total: 10]

A6 (a) (i) [2]

[1]: 3 correct ester linkages
[1]: correct structure

(ii) **PET can be hydrolysed using water in the presence of an acid catalyst.** [1]

OR

PET can be cracked at high temperature in the presence of zeolite catalyst to form short-chain alkanes and / or alkenes.

(iii) **Plastic waste in recycling bins may not eventually get recycled as they are contaminated with leftover food / non-recyclable items are thrown into the recycling bins.** [2]

It is more convenient to dispose of plastics than to recycle them.

Recycling can be expensive due to high cost incurred from transporting waste to the processing plant / sorting and cleaning the waste / high energy consumption.

Recycling plastics may lead to water pollution due to discharge of improperly treated wastewater generated from the recycling into water bodies.

Any two points.

(b) **Aqueous acidified potassium manganate(VII), heat.** [1]

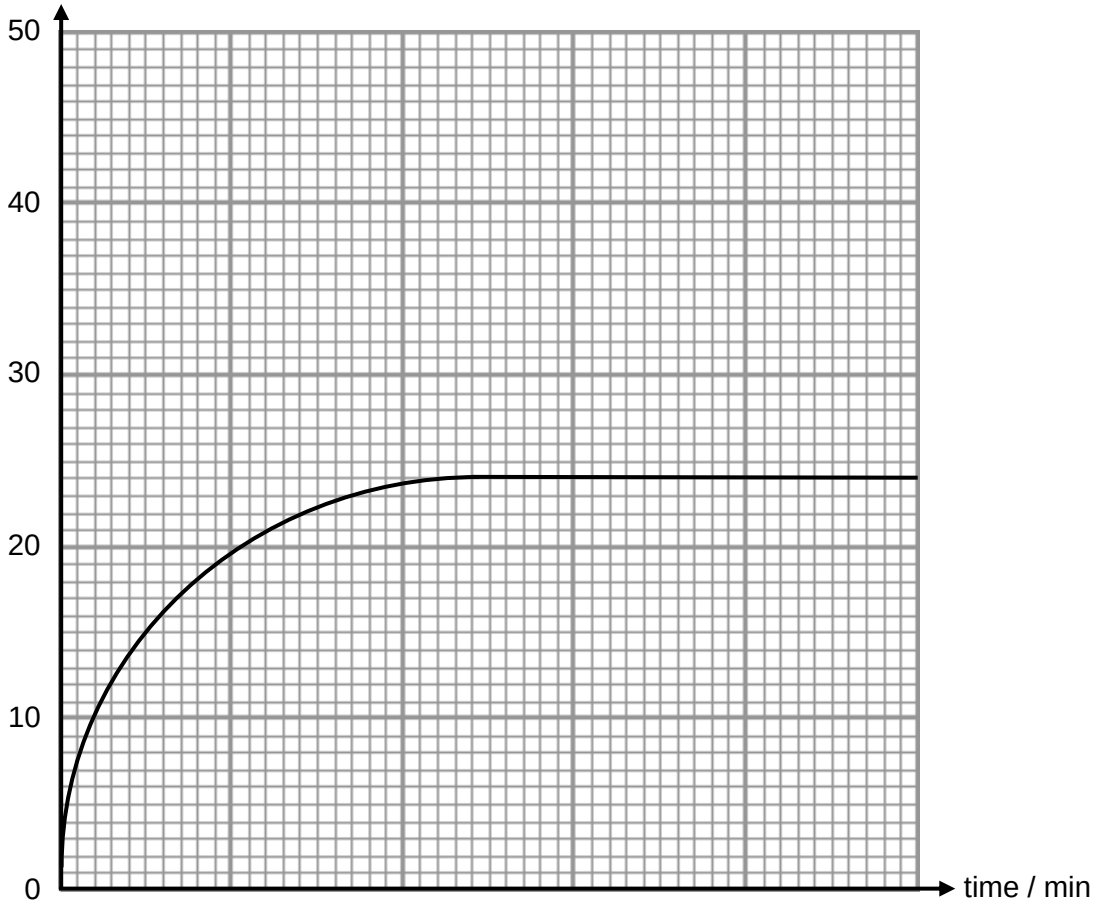
(c) (i) **Ester linkage** [1]

(ii) [1]

(iii) **molar mass of one repeat unit = 5(12) + 2(16) + 8(1) = 100 g/mol**
molar mass of Perspex = 2500 × 100 = 250 000 g/mol [1]
mass of one Perspex molecule = 250 000 ÷ (6.02×10^{23}) = 4.15×10^{-19} g [1]

[Total: 10]

A7 total volume of gas / cm^3



(a) $K_2CO_3 + H_2SO_4 \rightarrow K_2SO_4 + H_2O + CO_2$ [2]

no. of moles of K_2CO_3 = 0.138 ÷ [2(39) + 12 + 3(16)] = 0.001 mol (✓)

no. of moles of H_2SO_4 = (50 ÷ 1000) × 0.05 = 0.0025 mol (✓)

$K_2CO_3 : H_2SO_4 = 1 : 1$

Since 0.001 mol of K_2CO_3 requires only 0.001 mol of H_2SO_4 (✓) which is less than the 0.0025 mol of H_2SO_4 provided, (✓) the limiting reactant is K_2CO_3. (✓)

[2]: 5 (✓); [1]: 2 – 4 (✓)

(b) **(i)** See graph. [2]

(ii) In Experiment 2, concentration of sulfuric acid is halved / decreased, hence rate of reaction is lower and the graph has a gentler initial gradient. [1]

Volume of gas remains the same at 24 cm^3 because mass / number of moles of limiting reactant (potassium carbonate) remains unchanged / dilute sulfuric acid is still in excess. [1]

In Experiment 3, volume of gas doubles because mass / number of moles of limiting reactant / potassium carbonate is doubled. [1]

Initial gradient of graph is steeper indicating higher rate of reaction due to increased surface area to volume ratio of potassium carbonate powder. [1]

[Total: 8]

A8 (a) (i) Tendency to be reduced decreases down the group as the E^{θ} values decrease / become less positive from +1.36V (chlorine) to +0.54V (iodine). [1]

No mark awarded if values are not quoted.

(ii) Cl_2 + KI [2]
$E^{\theta}_{cell} = E^{\theta}_{red} - E^{\theta}_{ox} = +1.36 - (+0.54) = +0.82V$ (✓)
Since $E^{\theta}_{cell} > 0$, the reaction is thermodynamically feasible. (✓)

No mark awarded if '+' sign is missing.

I_2 + KCl
$E^{\theta}_{cell} = E^{\theta}_{red} - E^{\theta}_{ox} = +0.54 - (+1.36) = -0.82V$ (✓)
Since $E^{\theta}_{cell} < 0$, the reaction is not thermodynamically feasible. (✓)

[2]: 4 (✓); [1]: 2 – 3 (✓)

(iii) Chlorine is more reactive than iodine, hence chlorine displaces iodine from potassium iodide to form brown iodine solution. [1]

OR

Chlorine is more reactive than iodine, hence iodine is unable to displace chlorine from potassium chloride and no visible change is observed.

(b) (i) $E^{\theta}_{cell} = +1.23 - (-0.76) = +1.99V$ [1]

No mark awarded if '+' sign is missing.

(ii) +0.5 to +1.98 V, due to internal resistance in the circuit. [1]

(c) (i) Ammonium chloride is acidic / dissolves in water to form H^+ ions. [1]

(ii) Reaction between potassium hydroxide and zinc anode casing will not produce hydrogen gas which damages the battery. [1]

OR

Hydroxide ions that react with zinc are replenished / regenerated at the cathode and can further react with more zinc to continue generating electricity.

OR

Potassium hydroxide reacts with zinc oxide to form solid zinc oxide, hence the casing will not get thinner as quickly and the battery can be used for a longer time.

(d) (i) Concentration of hydroxide ions remains unchanged [1]

because the number of moles of hydroxide ions reacted with zinc / used up at the anode is replenished / regenerated by the same number of moles of hydroxide ions produced at the cathode. [1]

(ii) $E^{\theta}_{cell} = E^{\theta}_{red} - E^{\theta}_{ox}$ [1]
$+1.49 = E^{\theta}_{red} - (+1.28)$
$E^{\theta}_{red} = +1.49 + 1.28 = \underline{+2.77V}$

No mark awarded if '+' sign is missing.

(iii) Activation energy of the reaction is very high. [1]

[Total: 12]

B9 (a) (i) The presence of atoms of different atomic sizes disrupts the orderly arrangement of iron atoms, [1]

hence the layers of atoms do not slide as easily when a force is applied, causing steel to be stronger than iron / able to withstand the weight of the platform better than iron. [1]

(ii) Zinc is more reactive than iron / higher in the reactivity series than iron, [1]

hence it has a higher tendency to form cations / is preferentially oxidised by oxygen and water / will corrode in place of iron in steel to prevent corrosion of the steel legs. [1]

(b) (i) $n = (196 - 56) \div (12 + 16) = \underline{5}$ [1]

(ii) $Fe(CO)_5 + 2Na \rightarrow Na_2[Fe(CO)_4] + CO$ [1]

(iii) no. of moles of iron carbonyl = $5.0 \div 196 = 0.025510$ mol (✓) [2]
$Fe(CO)_5 : CO = 1 : 1$
no. of moles of CO = 0.25510 mol (✓)
volume of CO produced = 0.25510×24 (✓) = $\underline{0.612\ dm^3}$ (✓)

[2]: 5 (✓); [1]: 2 – 4 (✓)

(iv) Sodium is oxidised as the oxidation state of sodium increases from 0 in Na to +1 in $Na_2[Fe(CO)_4]$. [1]

Iron is reduced as the oxidation state of iron decreases from 0 in $Fe(CO)_5$ to –2 in $Na_2[Fe(CO)_4]$. [1]

Since both reduction and oxidation occur simultaneously, this reaction is a redox reaction.

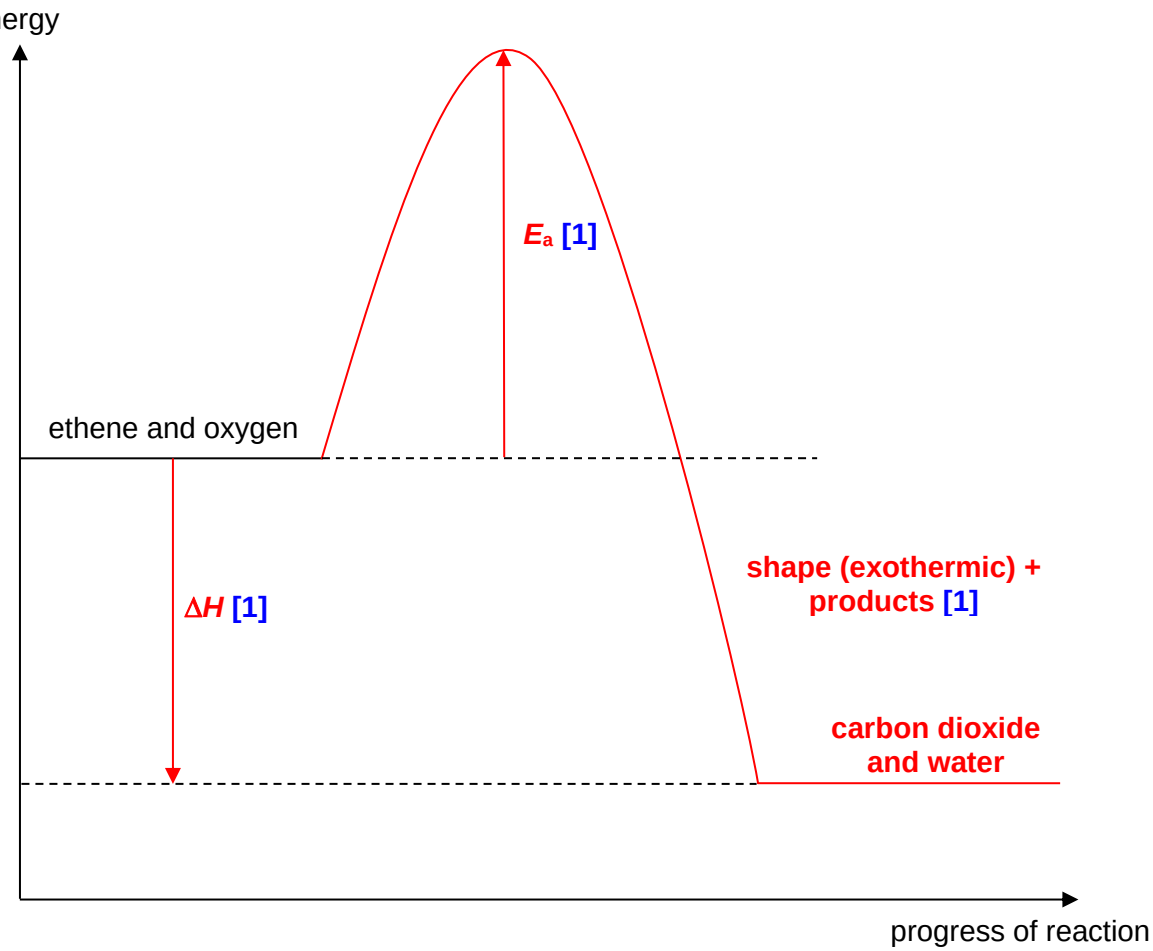
[Total: 10]

B10 **(a)** **no. of moles of ethene = 1 × 1000 ÷ [2(12) + 4(1)] = 35.714 mol** [1]

enthalpy change for 1 kg of ethene = 35.714 × –1074 = –38400 kJ [1]

No mark awarded for wrong units.

(b)



No marks awarded for endothermic graph.

(c) **(i)** T_3 [1]

(ii) **At highest temperature T_3, the area under the Maxwell-Boltzmann distribution curve for energy greater than E_a is largest,** [1]

indicating that the number of ethene and oxygen molecules with energy greater than or equal to the activation energy E_a increases with temperature. [1]

Ethene and oxygen molecules have more kinetic energy, causing them to move faster and collide with each other with greater force / number of collisions to increase. [1]

Frequency of effective collisions increases. Therefore, rate of combustion of ethene increases. [1]

[Total: 10]