Section A

Answer **all** questions.

1 Choose from the following substances to answer the questions.

amphoteric oxide	**A**	aluminium oxide, Al_2O_3
neutral oxide	**B**	carbon monoxide, CO
oxidising agent	**C**	potassium dichromate(VI), $K_2Cr_2O_7$ Cr (transition metal) has O.S. +6
	D	ammonium nitrate, NH_4NO_3
oxidising agent	**E**	potassium manganate(VII), $KMnO_4$ Mn (transition metal) has O.S. +7
(can serve as) oxidising agent	**F**	fluorine, F_2
acidic oxide	**G**	nitrogen dioxide, NO_2

Use the letters **A**, **B**, **C**, **D**, **E**, **F** and **G** to answer the following questions.
Each letter may be used once, more than once or not at all.

Write the symbol for the substance which

(a) is a neutral oxide. B .... [1]

(b) is able to oxidise iodide ions to iodine. C / E / F .... [1]

(c) produces an alkaline gas when warmed with sodium hydroxide. D .... [1]

(d) contains a transition metal with an oxidation state of +6. C .... [1]

(e) is soluble in rainwater, forming acid rain. G .... [1]

[Total: 5]

(c) ammonium salts react with alkalis, producing salt, ammonia gas and water
REF: reaction of alkali with ammonium salts

2 The reaction between ammonium perchlorate, NH_4ClO_4, and aluminium metal is used to propel space shuttles. The reaction produces many substances such as steam and nitrogen gas. The equation shown below represents the reaction.

..6... NH_4ClO_4 (s) + 10Al (s) → ..4.. Al_2O_3 (s) + 2$AlCl_3$ (s) + .12.. H_2O (g) + 3N_2 (g)

(a) Balance and complete the equation by filling in the blanks. [1]

(b) Calculate the oxidation state of chlorine in perchlorate ion, ClO_4^-.

Let oxidation state of Cl be x.

x + 4(-2) = -1 [1]

x = **+**7 [1] REJECT answers without '+'

[2]

(c) The reaction between aluminium and ammonium perchlorate is a redox reaction.

State the role of aluminium in the redox reaction.

Explain your reasoning, using changes in oxidation states of aluminium and chlorine.

Role : reducing agent [1]

Explanation:

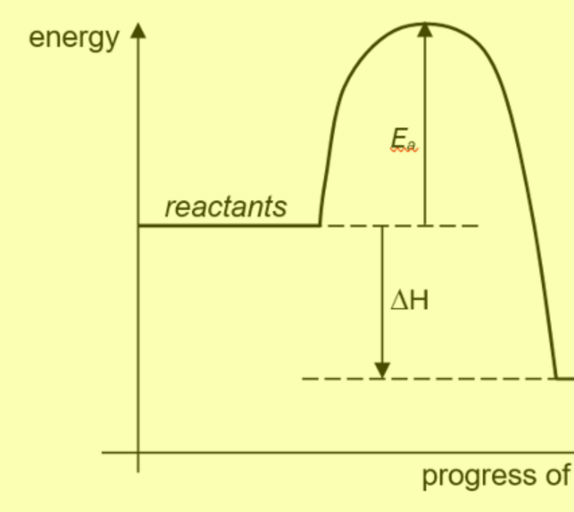
1. oxidation state of Cl decreases from +7 (in chlorate) to -1 (in $AlCl_3$) [1]
2. oxidation state of Al increases from 0 (in Al) to +3 (in Al_2O_3 and/or $AlCl_3$) [1]

Aluminium **reduces Cl**, while itself is oxidised. Hence aluminium is a reducing agent. [3]

(d) Complete the energy profile diagram for this exothermic reaction.

You diagram should show and label

- 'products' of the reaction,
- the activation energy, E_a,
- the enthalpy change, ΔH, of reaction.



[1] **exothermic,** $E_{reactants} > E_{products}$

[1] activation energy, from reactants to peak, **upward** arrow

[1] enthalpy change, from reactant to products, **downward** arrow

[3]

[Total: 9]

(small molecules such as **water**, are removed)

3 Proteins and PET are polymers made by condensation polymerisation.

(a) The diagram in Fig. 3.1 shows the structure of a section of protein.

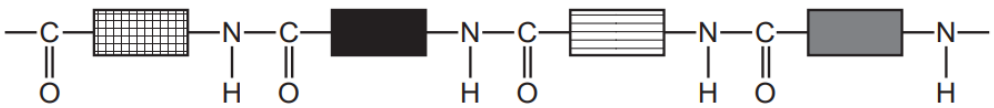
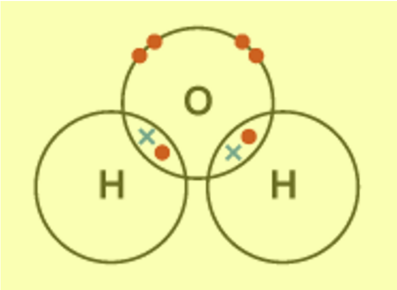


Fig. 3.1

(i) Draw a 'dot-and-cross' diagram of the molecule that is removed during the polymerisation of proteins. Show outer electrons only.



In water
[1] octet for O
[1] duplet for H

[2]

(ii) Proteins are polyamides.

Name one other example of a polyamide.

Nylon .... [1]

(b) PET is a polymer used to make plastic bottles.

The diagram in Fig. 3.2 shows the structure of PET.

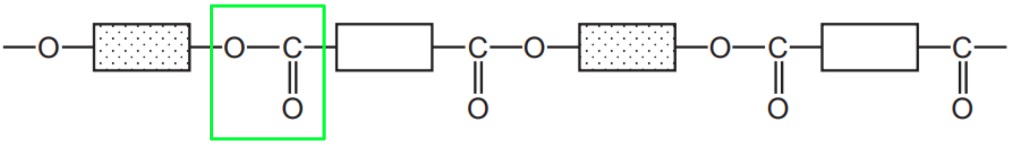
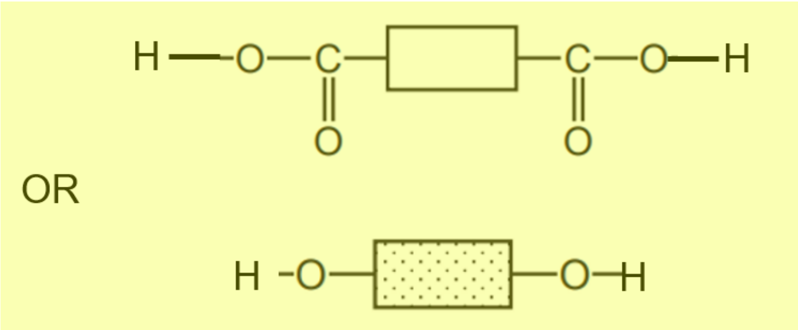


Fig. 3.2

(i) Name the linkage present in PET.

Ester (linkage) .... [1]

(ii) Draw the structure of one of the monomers used to produce PET.



[1]

ACCEPT either one

(iii) Describe **one** environmental issue arising from excessive use of plastics and **one** method in which plastics can be recycled.

Issue: (1) Plastics are **non-biodegradable** and cannot be decomposed by micro-organisms e.g. bacteria (or by natural processes). / (2) Burning plastics can produce heat energy for other processes but incineration of plastics usually **releases acidic/toxic/greenhouse gases**. / (3) Burying plastics require the need to find landfill sites. [1]

Method :
(1) **physical method** (exemplified by melting small pieces of poly(ethene) waste into pellets); (2) **chemical method** (exemplified by depolymerisation and cracking of plastic waste into chemical feedstock and fuel respectively) [1]

(c) Poly(ethene) is a polymer that is made by addition polymerisation.

Describe **two** differences between addition polymerisation and condensation polymerisation.

difference 1: ....

....

.... [1]

difference 2: ....

....

.... [1]

[Total: 9]

Addition polymerisation	*Condensation polymerisation*
• involves one (type of) functional group (C=C)	• involves 2 different functional groups, such as amine ($-NH_2$), carboxyl or hydroxyl
• no loss in atoms before and after polymerisation	• removal / loss of small molecule of water
• empirical formula of monomer same as that of polymer	• empirical formula of monomer different from that of polymer

REJECT all superficial comparison such as
Condensation polymerisation results in ester/amide linkage but addition polymerisation does not.
Condensation polymerisation produces water but addition polymerisation does not.
Addition polymerisation does not produce water but condensation polymerisation does.
Addition polymerisation uses alkenes but condensation polymerisation does not.

4 Sue investigates the reaction of small pieces of zinc with dilute hydrochloric acid at 25°C. The dilute hydrochloric acid is in excess.

Fig. 4.1 shows the volume of hydrogen released as the reaction proceeds.

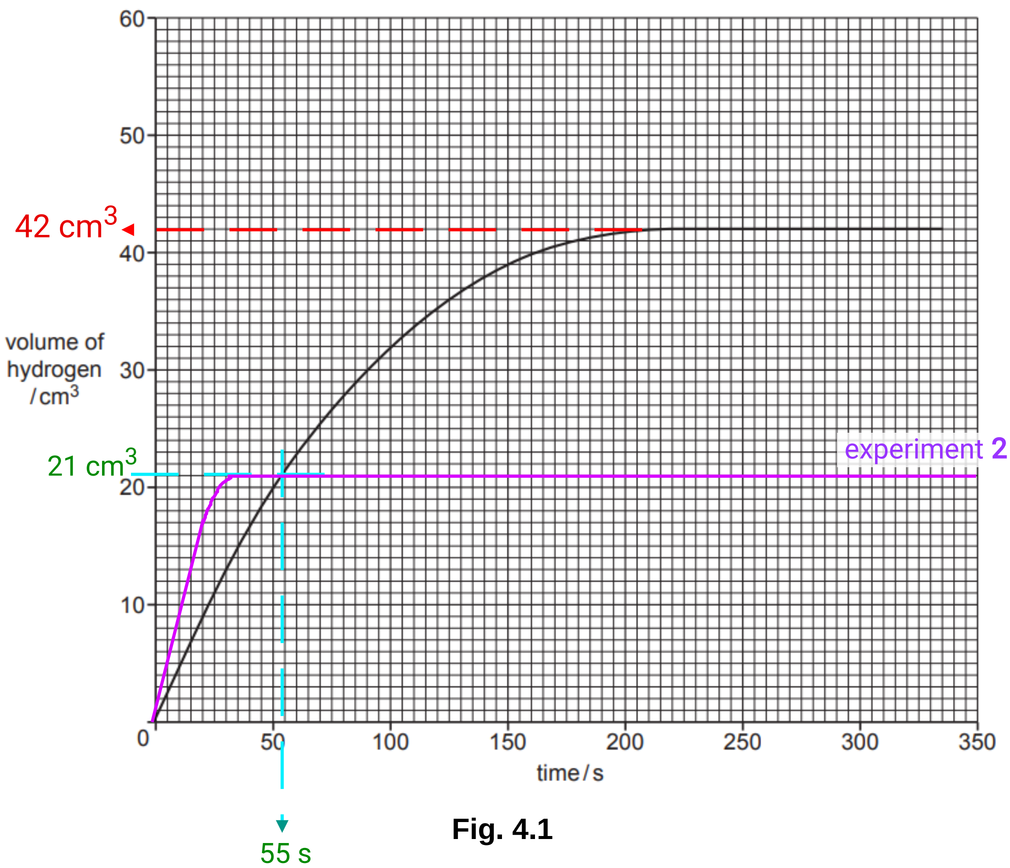


Fig. 4.1

(a) Write a chemical equation, including state symbols, for the reaction.

$Zn\ (s)\ +\ 2HCl\ (aq)\ \text{-->}\ ZnCl_2\ (aq)\ +\ H_2\ (g)$ .... [2]

(b) Calculate the mass of zinc used in the reaction.

mole, Zn used = moles, H_2 produced

= (42/24000) [1]

mass of Zn used = (42/24000) x 65

= 0.114 g (to 3 s.f.) [1]

mass = ...0.114.... g [2]

(c) From Fig. 4.1, how long did it take for half the mass of zinc to be used up?

55 s (+/- 5s) .... [1]

(d) Sketch, on Fig. 4.1, the graph Sue will get if she repeats the experiment with hydrochloric acid in excess, but with half the mass of zinc used, in powdered form.

(half volume of H_2 produced) [1]

faster rate, steeper gradient [1]

Label this graph as '*experiment 2*'. [2]

[Total: 7]

5 Dilute methanoic acid reacts with aqueous calcium hydroxide.

$$2HCOOH + Ca(OH)_2 \rightarrow (HCOO)_2Ca + 2H_2O$$

(a) Write an ionic equation for this neutralisation reaction between methanoic acid and calcium hydroxide.

$H^+ + OH^- \text{-->} H_2O$ .... [1]

(b) Deduce the general equation for the reaction of methanoic acid with Group 2 metals. Use **M** as the symbol for a Group 2 metal.

$2HCOOH + \mathbf{M} \text{-->} (HCOO)_2\mathbf{M} + H_2$ .... [1]

(c) Methanoic acid is a weak acid. It dissociates partially in water, producing methanoate ions and hydrogen ions, as shown.

$$HCOOH\ (aq) \rightleftharpoons HCOO^-\ (aq) + H^+\ (aq)$$

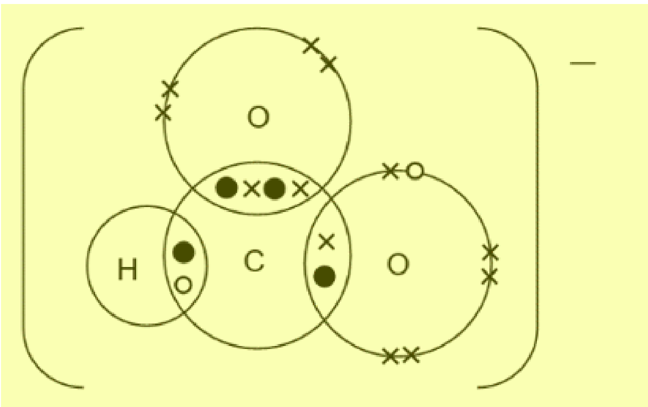
(i) How does the equation show that methanoic acid is a weak acid?

Use of reversible arrow .... [1]

(ii) Complete Fig. 5.1 to show the arrangement of the electrons, in the outer shells, for carbon and oxygen, in a methanoate ion.

Electrons of hydrogen (○) have been completed for you.
You should use the symbols provided for each element in the *key*. [3]

[1] C=O
[1] C-O
[1] correct number of bonding electrons for C and O with octet



key

● C
○ H
× O

Fig. 5.1

[Total: 6]

6 Solvents made up of different mixtures of ethanol and water were used to separate the dyes in a sample of black ink. The black ink contains a mixture of blue, red and yellow dyes.

The coloured dyes have different R_f values in solvents with different compositions of ethanol as shown in Fig. 6.1 below.

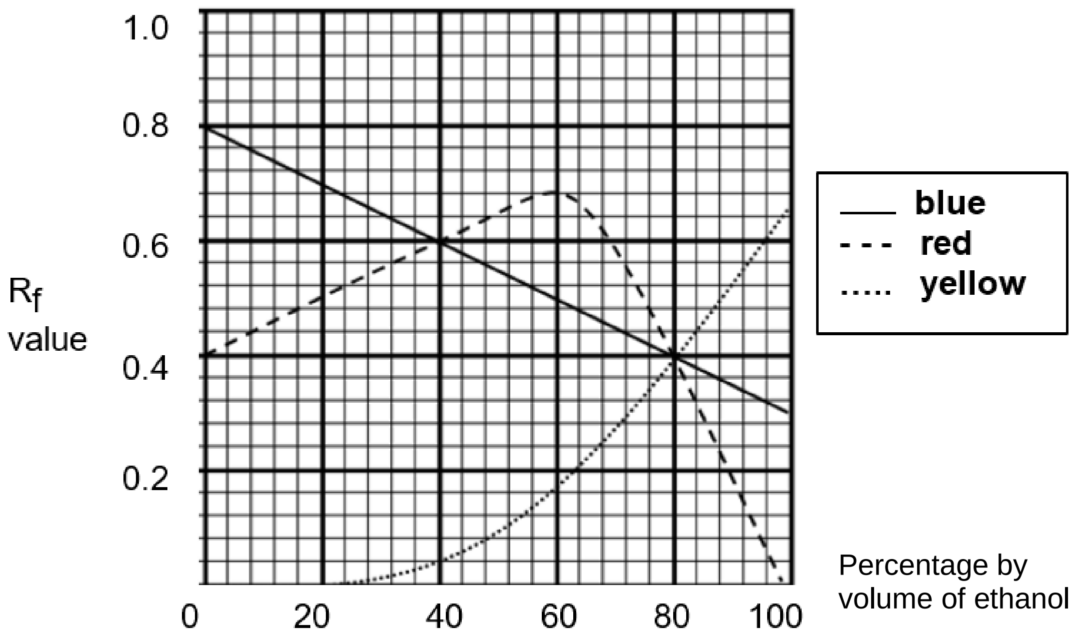


Fig. 6.1

(a) Which coloured dye in black ink is insoluble in a solvent containing 100% ethanol?

Red .... [1]

(b) From Fig. 6.1, which percentage by volume of ethanol <u>cannot</u> be used to separate all the dyes in black ink?

..............80 % [1]

Explain your answer.

All 3 colours have the <u>same</u> / <u>identical</u> R_f value.

(which means all 3 colours travel the same distance / are equally soluble) [1]

(c) What is the R_f value of the blue dye, when the solvent is made up of 96 cm^3 ethanol and 104 cm^3 water?

Show your working clearly.

% by volume of ethanol

$= \frac{96}{96+104} \times 100\%$

$= 48\%$ [1]

R_f of blue dye at 48% ethanol = 0.56 [1]

[2]

[Total: 5]

7 The reactivity series of metals can be compared by their reactions with water, steam and displacement reactions. Some data of these experiments are recorded in Table 7.1 below.

Table 7.1

Metals	**Reaction with water**	**Reaction with steam**	**Displacement reactions**
Mercury	No visible change.	No visible change. Silvery metal remains unchanged.	No visible change.
Magnesium	Slow reaction	Metal burns in steam. Grey solid turns white.	Displaces zinc from $Zn(NO_3)_2$ (aq)
Iron	No visible change.	Reacts slowly with steam. Silvery solid turns black.	Displaces mercury from aqueous $Hg(NO_3)_2$ (aq)
Zinc	No visible change.	Reacts slowly with steam. Grey solid turns yellow when hot.	Displaces iron from $Fe(NO_3)_2$ (aq) zinc > iron

(a) Arrange the metals in Table 7.1, from least reactive to most reactive.

mercury, iron, zinc, magnesium [1]

[1]

(b) Write an ionic equation, with state symbols, for the displacement reaction between zinc powder and aqueous iron(II) nitrate.

$Zn\ \mathbf{(s)} + Fe^{2+}\ \mathbf{(aq)} \rightarrow Zn^{2+}\ \mathbf{(aq)} + Fe\ \mathbf{(s)}$ [2]

(c) Solutions containing chromium(II) ions are usually blue and the reactivity of chromium is between iron and zinc.

Zn > Cr > Fe

Give one observation you would see if a piece of zinc metal is added to aqueous chromium(II) nitrate.

ACCEPT either one:

A layer of grey (chromium) metal deposit on zinc.

Colour of solution changes from **blue** (for chromium(II) solution) to **colourless**. [1]

(d) The apparatus in Fig. 7.2 were set-up. Steam was passed into the first tube containing zinc powder. The zinc powder and iron(II) oxide were then heated.

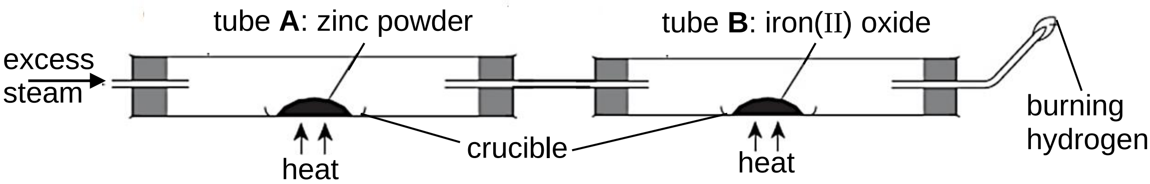


Fig. 7.2

(i) Write a chemical equation for the reaction that occurs in tube **A**.

$H_2O + Zn \rightarrow ZnO + H_2$ .... [1]

(ii) Describe the redox reaction iron(II) oxide undergoes in tube **B**.

(in tube **B**: $H_2 + FeO \rightarrow Fe + H_2O$)

Iron(II) oxide has been **reduced** (by hydrogen gas), while hydrogen has been oxidised. [1]

(e) The following data were obtained from the experiment in Fig. 7.2.

	Mass / g
empty crucible used in tube **B**	10.03
empty crucible + $\boxed{\text{solid residue}}$ (iron) after heating in tube **B**	18.03

Determine the mass of zinc used in tube **A**.

mass of iron (solid residue) = 8.0 g

$FeO + H_2 \rightarrow Fe + H_2O$

mole, H_2 used in tube **B**

= mole, Fe

$= \frac{8}{56} \approx 0.1429$ mole

mole, H_2 produced from tube **A**

≈ 0.1429

mass, Zn = mole, Zn $\times$ A_r of Zn

= 0.1429×65

$\approx$ 9.29 g (to 3 s.f.)

[1] mass of Fe

[1] moles, H_2 (from tube **A**)

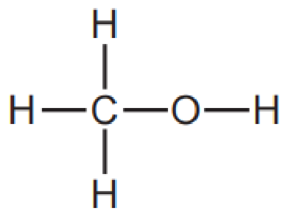
[1] mass, Zn

[3]

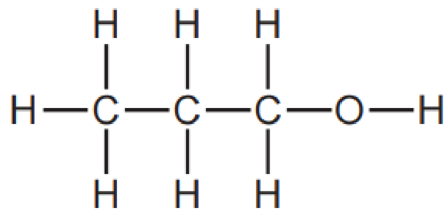
[Total: 9]

8 Methanol and propan-1-ol are alcohols.

The structural formula of methanol and propan-1-ol are shown in Fig. 8.1



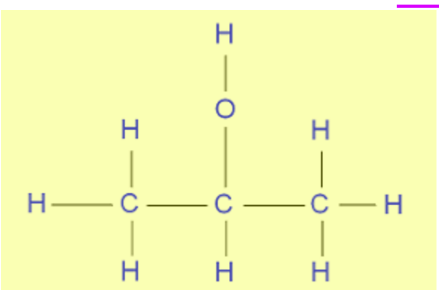
methanol



propan-1-ol

Fig. 8.1

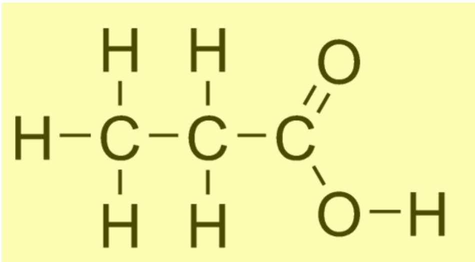
(a) Draw the structural formula of an isomer of propan-1-ol.



[1]

(b) Purple acidified potassium manganate(VII) decolourises when added to a beaker of propan-1-ol.

Explain the observation and draw the structural formula of the product formed by propan-1-ol.



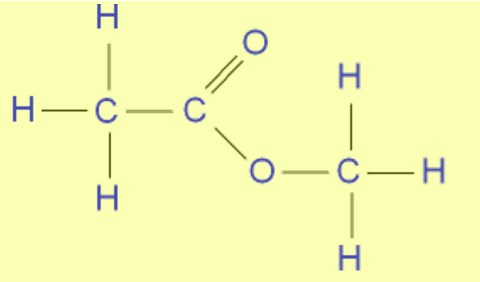
[1] Structural formula of product: propanoic acid

[1] Explanation: Propan-1-ol has been oxidised by acidified $KMnO_4$
(ACCEPT oxidation of propan-1-ol has occurred OWTTE)

[2]

(c) Methanol reacts with ethanoic acid to form a sweet smelling product. (characteristic of ester)

Draw the structural formula of this product.



Product: methyl ethanoate

[1]

(d) **(i)** **X** is an organic acid containing the following composition by mass:
57.1% carbon
4.8% hydrogen
38.1% oxygen

Calculate the empirical formula of **X**.

per 100g	C	H	O
mass	57.1	4.8	38.1
mole	4.758	4.8	2.381
÷ smallest ratio	1.99 ≈ 2	2.02 ≈ 2	1
simplest ratio	2	2	1

Empirical formula of **X** is C_2H_2O.

[1] correctly calculated mole of each element

[1] C_2H_2O

[2]

(ii) A 0.194 g sample of **X** is neutralised by 0.00462 mol of KOH.
Given that one mole of **X** reacts with three moles of KOH, calculate the relative molecular mass of **X**, and hence deduce its molecular formula.

mole ratio X : KOH = 1 : 3

hence 0.194 g of X = 0.00462 / 3 = 0.00154 mole

1 mole of X = (0.194/0.00154) = 126 g (3 s.f.) [1]

Empirical mass = 42; molar mass is **3** times empirical mass
Molecular formula = $\mathbf{C_6H_6O_3}$ [1]

[Total: 8]

9 A news article reported how increasingly frequent hot weather had grounded commercial planes and affected air travel.

How hot weather – and climate change – affect airline flights[1]

High air temperatures affect the physics of how aircraft fly, meaning aircraft takeoff performance can be impaired on hot days. The amount of lift that an airplane wing generates is affected by the density of the air. Air density in turn depends mostly on air temperature and elevation; higher temperatures and higher elevations both reduce density.

Hot air is less dense than cooler air. That affects the amount of lift an airplane can generate. The lower the air density, the faster an airplane must travel to produce enough lift to take off.

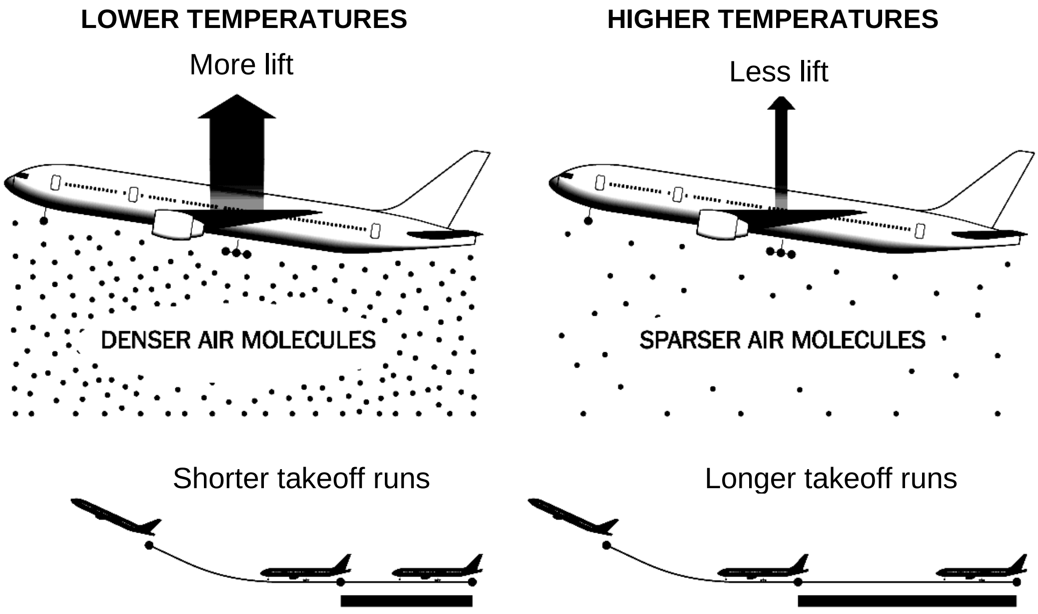


Fig. 9.1[2]

The takeoff distance (in feet) required for a 2550-pound airplane, at different temperatures, is given in Table 9.2. As a safety precaution, pilots typically will add an additional 15% to the required takeoff distance when planning their take offs.
(refer to part (c))

Table 9.2[3]

	Takeoff distance (in feet) at different temperatures				
Altitude (feet)	**0˚C**	**10˚C**	**20˚C**	**30˚C**	**40˚C**
sea level	1465	1575	1690	1810	1945
1000	1600	1720	1850	1990	2135
2000	1755	1890	2035	2190	2355
3000	1925	2080	2240	2420	2605
4000	2120	2295	2480	2685	2880
5000	2345	2545	2755	2975	3205

(refer to part (c))

With the increase in global temperature, at the same altitude, the takeoff distance also increases. This means a longer runway will have to be built for future airports, and more fuel, usually hydrocarbons, will have to be burnt to power the plane. However, environmentalists had put up a study to show that greater fuel usage may further contribute to global warming.

One of the current practices to reduce carbon dioxide emissions is to consider the use of green fuels. Green fuels, also termed synthetic or electrofuels (e-fuels), are liquid, or gaseous fuels produced with electricity from renewable sources. Examples for such e-fuels are synthetic natural gas (SNG), green methanol or ammonia. They are carbon-neutral when burned, emitting only the amount of CO_2 absorbed during its production.[4]

Global ammonia production accounts for 1.3% of energy-related CO_2 emissions, and uses hydrogen obtained from natural gas. The ammonia produced is used to manufacture fertilisers in the Haber Process.

Green ammonia is produced without fossil fuels and could help cut the high emissions associated with synthetic fertiliser production. Hydrogen is first produced via electrolysis of steam using solid oxide electrolysers (SOEs). A typical SOE consists of a cathode, a dense oxide-ion conducting electrolyte material and an anode. A SOE uses electricity to produce hydrogen.

for part (e)

The operating principle of a SOE steam electrolyser is shown in Fig. 9.3.
Steam enters on the cathode side of the cell where it accepts electrons provided by an external power source and is split into hydrogen gas and oxide ions. These oxide ions then migrate through dense electrolyte layer to the anode side of the cell where they are oxidised to form oxygen gas, which exits via the anode outlet.[5]

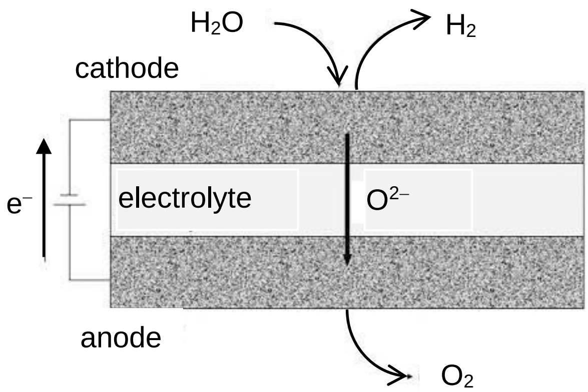


Fig. 9.3

(a) Air density is measured by number of air molecules per unit volume.
Using the Kinetic Particle Theory, explain why there are fewer air molecules per unit volume on a hotter day.

(at higher temperature) particles gain heat / energy [1]

move further apart / push each other further away [1]

....

....

(b) With reference to Table 9.2, describe the relationship between takeoff distance and altitude.

Suggested answer:
At same temperature, takeoff distance **increases** as altitude **increases**.

[1] state one constant (i.e. same temperature)

[1] takeoff ↑ as altitude ↑ AND quote relevant data from Table 9.2

(c) What is the takeoff distance (in metres) required for a 2550 pounds airplane to take off from Kallang Airport (take altitude to be at sea level) at 30°C?
[1 metre ≈ 3.28 feet]

"additional 15%" hence multiply by 1.15

$$\frac{1810 \times 1.15}{3.28} \approx 634.6 \qquad \approx 635 \text{ m (to 3.s.f.)}$$

takeoff distance ≈ 635 m [1]

(d) Suggest why greater fuel usage of planes contributes to global warming.

[1] Combustion of fuel (hydrocarbons) produces carbon dioxide (and water).

[1] Carbon dioxide is a greenhouse gas.

[2]

(e) Write half equations for the processes taking place at the electrodes in the SOE steam electrolyser (Fig. 9.3).

	half equation
cathode	$H_2O + \mathbf{2}e^- \rightarrow H_2 + O^{2-}$
anode	$\mathbf{2}O^{2-} \rightarrow O_2 + \mathbf{4}e^-$

[2]

(f) **(i)** Construct the overall equation in the operation of the SOE steam electrolyser.

$2H_2O \rightarrow 2H_2 + O_2$ [1]

(ii) Using your equation or otherwise, calculate the maximum mass of hydrogen that can be made from 1 tonne of steam.
(1 tonne = 1000 kg)

$$\text{mole, } H_2O\text{ (g)} = \frac{1 \times 10^6}{18} \approx 0.05556 \times 10^6$$

$$\text{mole, } H_2 = 0.05556 \times 10^6$$

$$\text{mass, } H_2 = \frac{0.05556 \times 10^6}{1 \times 10^6} \times 2 \approx 0.111\ tonne$$

[2]

[Total: 12]

Section B

Answer **one** question from this section.

10 Sulfuric acid, H_2SO_4, is neutralised when it is added to aqueous sodium hydroxide, NaOH.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

The reaction is exothermic.

P is 1.25 mol/dm^3 aqueous sodium hydroxide.
Q is dilute sulfuric acid.

To determine the concentration of the sulfuric acid in **Q**, a student conducted six experiments and the results are tabulated in Table 10.1.

Table 10.1

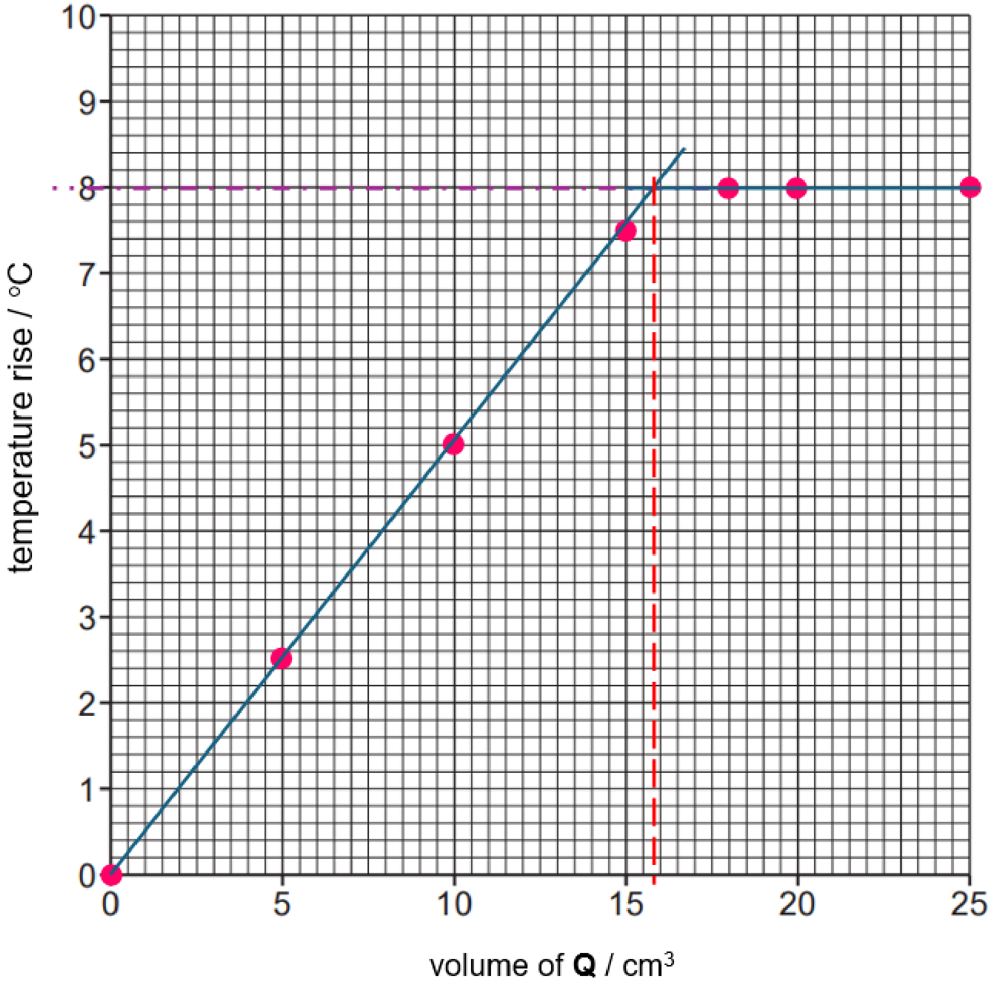
experiment number	volume of **P** / cm^3	volume of water / cm^3	volume of **Q** / cm^3	initial temperature / °C	highest temperature reached / °C	temperature rise / °C
1	25.0	20	5.0	23.0	25.5	2.5
2	25.0	15	10.0	24.5	29.5	5.0
3	25.0	10	15.0	25.0	32.5	7.5
4	25.0	7	18.0	25.0	33.0	8.0
5	25.0	5	20.0	25.5	33.5	8.0
6	25.0	0	25.0	24.5	32.5	8.0

(a) Complete Table 10.1 by filling in the three missing values. [1]

(b) Draw a graph of temperature rise against volume of **Q** on the grid below.

You should:

- plot the point (0,0) as there is no temperature rise when no **Q** is added;
- plot the temperature rises and volumes of **Q** from Table 10.1;
- draw a straight line of best fit for the first four points;
- draw a straight line of best fit for the last three points;
- extend the lines so that they intersect.



[3]

(c) The point where the two lines intersect indicates the volume of **Q** that exactly neutralises 25.0 cm^3 of **P**.

Determine the volume of **Q** where the two lines on the graph intersect.

volume of **Q** ....16.0.......... cm^3 [1]

(+/0 0.5 cm^3)

(d) Use your answer to **(c)** to calculate the concentration of the sulfuric acid in **Q**.

$$\frac{Conc\ of\ Q \times 16.0}{1.25 \times 25.0} = \frac{1}{2}$$

For V_Q = 16.5 cm^3, C_Q = 0.947 mol/dm^3

For V_Q = 15.5 cm^3, C_Q = 1.01 mol/dm^3

concentration of **Q** ....0.977.......... mol/dm^3 [2]

(e) Calculate the mass of sodium sulfate produced in Experiment 5.

NaOH is the limiting reactant.

moles, NaOH = $0.025 \times 1.25 = 0.03125$

moles, Na_2SO_4 = $\frac{1}{2} \times 0.03125 = 0.015625$

mass, Na_2SO_4 = $0.015625 \times (142) \approx 2.22$ g

[3]

[Total: 10]

11 An ionic salt **W** has the chemical formula X_2Y_3.

W is a white solid at room temperature. It is soluble in water to form a colourless solution. The relative formula mass of **W** is 342.

Electrolysis of a solution of **W**, using inert electrodes, gives the observations as shown in Table 11.1.

Table 11.1

	At the anode	At the cathode
Observation	Colourless gas **Q** produced.	Colourless gas **R** produced.

To a sample of solution **W**, the following tests in Table 11.2 are conducted, and the observations are shown in the same table.

Table 11.2

test	Observation
1) Add NaOH (aq) until no further change	White ppt, soluble in excess NaOH (aq), giving a colourless solution
2) Add NH_3 (aq) until no further change	White ppt, insoluble in excess NH_3 (aq)
3) Add acidified barium nitrate solution	White ppt **S** $BaSO_4$
4) Add acidified silver nitrate solution	No visible change

Aluminium ion

W - aluminium sulfate

(a) State the identity of colourless gas **Q** and **R**.

colourless gas **Q** ...... oxygen / O_2

colourless gas **R** ...... hydrogen / H_2

cation **X** ...... aluminium ion / Al^{3+} ion

anion **Y** ...... sulfate ion / SO_4^{2-} ion [4]

(b) Write the ionic equation for the formation of white precipitate **S**.

$Ba^{2+} (aq) + SO_4^{2-} (aq) \rightarrow BaSO_4 (s)$ [1]

(c) **(i)** Write the half equation for the production of colourless gas **Q** at the anode.

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ [1]

(ii) Describe a chemical test for colourless gas **Q**.

Use a glowing splint. Glowing splint relights (in presence of oxygen).

…………………………………………………………………………………… [1]

(d) Electrolysis of molten **W** can be done to extract metal **X**. In the extraction, **W** decomposes to produce metal **X**, oxygen and waste gases that contains an acidic gas that dissolves readily in rain water to form *acid rain*.

(i) Describe one harmful effect of *acid rain*.

Any one of the following:

- Lowers pH of aquatic bodies, killing aquatic plants and animals
- Lowers pH of soil, making the soil unfavorable for healthy plant growth [1]
- Corrodes (carbonate in) cement buildings and metal (i.e. iron) structures

(ii) Suggest a chemical reagent you can use to remove the acidic gas from the waste gases.

Calcium carbonate [specific to syllabus: **12(d)(ii)**]

…………………………………………………………………………………… [1]

(iii) Give the overall chemical equation for the decomposition of molten **W**.

$2Al_2(SO_4)_3$ --> $4Al$ + $6SO_3$ + $3O_2$ [1]

OR $Al_2(SO_4)_3$ --> $2Al$ + $3SO_2$ + $3O_2$

[Total: 10]

End of Paper

Sources:
[1] https://theconversation.com/how-hot-weather-and-climate-change-affect-airline-flights-80795
[2] Infographic from National Oceanic and Atmospheric Administration by The New York Times
[3] https://bruceair.wordpress.com/2022/04/20/takeoff-and-landing-performance/
[4] https://www.engieimpact.com/insights/green-fuels#:~:text=There%20are%20three%20types%20of,and%20e%2Dmethanol%20(green%20hydrogen
[5] https://www.sciencedirect.com/science/article/pii/S0196890423001620