XINMIN SECONDARY SCHOOL
新民中学
SEKOLAH MENENGAH XINMIN

Preliminary Examination 2024

CANDIDATE NAME

CLASS | INDEX NUMBER

CHEMISTRY

6092/01

Secondary 4 Express

28 August 2024

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number on the Question Paper and Answer Sheet in the spaces provided.

There are **forty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C**, **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
A copy of the Periodic Table is printed on page 2.
The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Total	40
Parent's Signature	

This document consists of **16** printed pages.

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 –
87 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

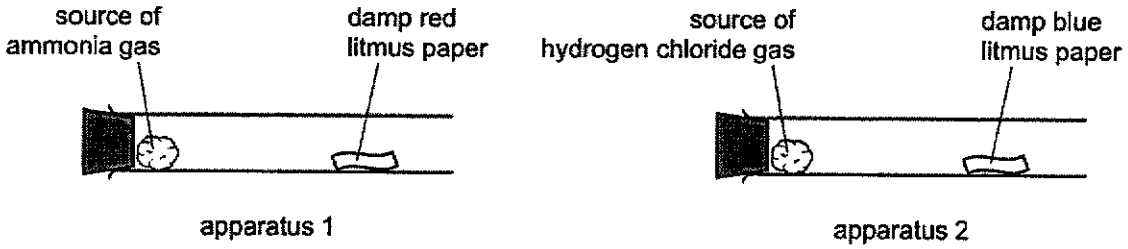
lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
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}

1 A student investigated the diffusion of ammonia gas, NH_3, and hydrogen chloride gas, HCl.

Two sets of apparatus were set up as shown below at room temperature and pressure.



apparatus 1 apparatus 2

The damp red litmus paper in apparatus 1 changed colour after 30 seconds.

How long does it take for the damp blue litmus paper to change colour in apparatus 2?

A about 21 seconds

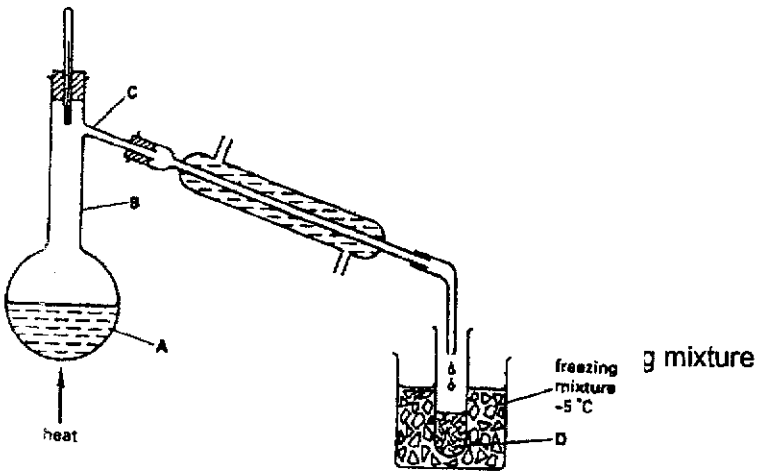
B about 30 seconds

C about 64 seconds

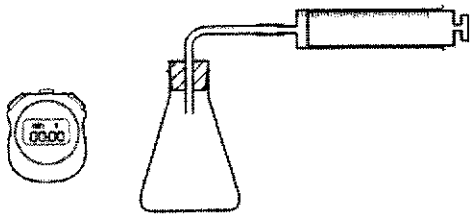
D The blue litmus paper would not change colour.

2 Substance X, melts at 10 °C and boils at 50 °C. It can be purified by distillation as shown in the diagram.

At which point will the particles of X be most regularly arranged?



3 A student wishes to follow the rate of a chemical reaction using the apparatus shown below.



Which of the following reactions allows a student to do so?

A $AgNO_3 + KI$

B $CuSO_4 + NaOH$

C $HCl + Mg$

D $HCl + NaOH$

4 Three separation methods are listed below.

1 obtaining water from sodium chloride solution
2 obtaining solid iodine from a mixture of solid iodine and nickel
3 obtaining solid sodium chloride from aqueous sodium chloride

Which techniques would be involved in these separations?

	1	2	3
A	distillation	sublimation	evaporation
B	distillation	sublimation	filtration
C	filtration	crystallisation	evaporation
D	sublimation	crystallisation	filtration

5 Three particles and their nuclide notations are shown.

particle	1	2	3
nuclide notation	$^{40}_{19}X^{+}$	$^{39}_{19}Y$	$^{34}_{16}Z^{2-}$

Which of the following statements is correct about the particles?

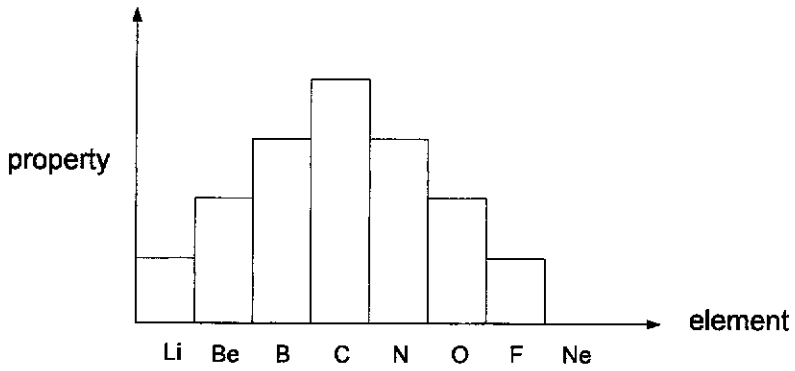
A Particle 1 has more electrons than particle 3.

B Particle 1 and 2 have the same number of neutrons.

C Particle 1 and 3 have the same number of electrons.

D Particle 2 has fewer neutrons than particle 3.

6 The bar chart shows the period of elements from lithium to neon.



Which property of the elements is shown on the chart?

A number of electron shells

B number of electrons used in bonding

C proton number

D relative atomic mass

7 Three elements W, X, Y, and Z have consecutive, increasing proton (atomic) numbers.

Element Y exists as a colourless, monatomic gas at room temperature.

Which will be the chemical formula of a compound formed between W and chlorine?

A W*Cl*

B W_2Cl

C WCl_2

D W_2Cl_3

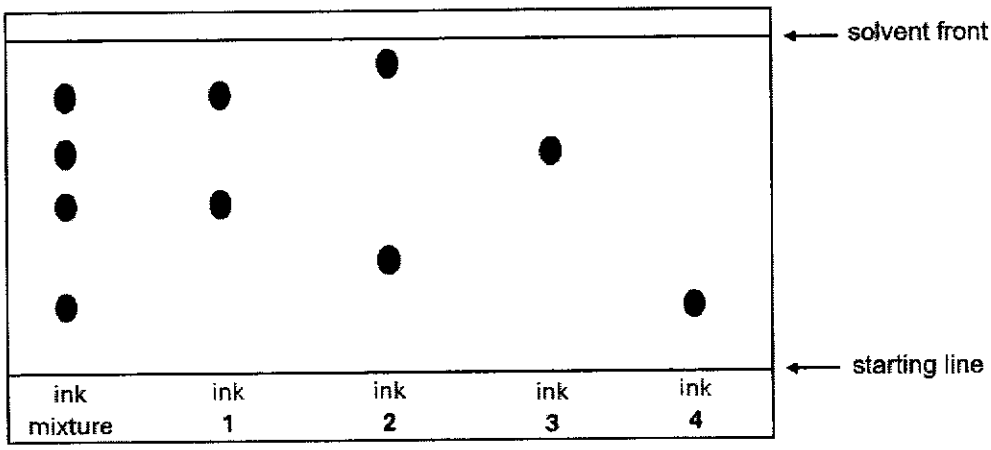
8 The mixtures shown in the table are warmed.

In which mixture does a gas form?

Key: ✓ = gas forms, ✗ = no gas forms

	NaOH(aq) and NH_4Cl(s)	NaOH(aq) and Mg(s)	H_2SO_4(aq) and NaCl(s)
A	✓	✓	✗
B	✓	✗	✓
C	✓	✗	✗
D	✗	✗	✓

9 A paper chromatography experiment was carried out to determine the inks present in a mixture, and the results shown below were obtained.



Which statement about the results is **incorrect**?

A Ink 4 is more soluble than ink 3 in the solvent used.

B Inks 1 and 2 contained more than one colour pigment.

C The ink mixture contained inks 1, 3 and 4.

D The R_f value of ink 3 in the solvent used is more than 0.5.

10 An aqueous solution containing two salts is found.

A series of tests is carried out to identify the ions present. The results are shown.

no	description	observations
1	Add dilute nitric acid followed by aqueous barium nitrate.	No effervescence and white precipitate is observed.
2a	Add aqueous sodium hydroxide followed by warming.	White precipitate is formed and dissolves in excess sodium hydroxide to form a colourless solution. No effervescence is observed.
2b	Add aluminium foil followed by warming.	Effervescence is observed and gas turns moist red litmus paper blue.
3	Add aqueous ammonia.	White precipitate is formed. The mass of the white precipitate decreases by half when excess ammonia is added.

Which of the following salts are present in the aqueous solution?

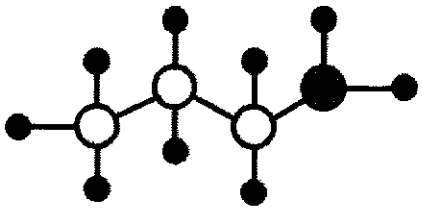
A zinc sulfate and aluminium nitrate

B zinc sulfate and calcium nitrate

C ammonium chloride and aluminium sulfate

D calcium chloride and ammonium sulfate

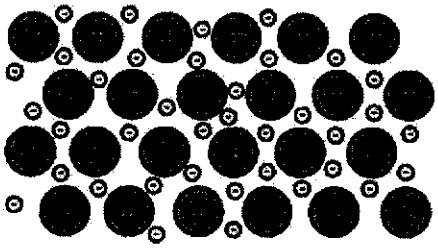
11 The structure of a molecule of a compound containing carbon, nitrogen and hydrogen is shown below.

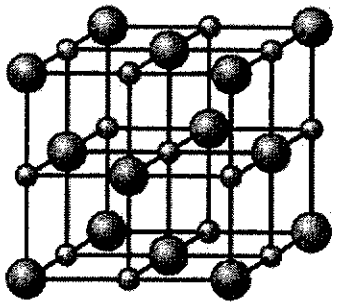


What is the molecular formula of this compound?

A CN_3H_7 **B** CN_3H_9 **C** C_3H_7N **D** C_3H_9N

12 The structures of two materials are shown below.





Which statement is correct?

A Both substances are hard and rigid.

B Both substances are pure compounds.

C Both substances can conduct electricity in the solid state.

D Both substances contain particles held together by strong electrostatic forces of attraction.

13 On adding 50 g of impure limestone, $CaCO_3$ (Mr = 100), to excess hydrochloric acid, 6.0 dm^3 of CO_2 was evolved at room temperature and pressure.

What is the percentage purity of the limestone?

A 25% **B** 50% **C** 75% **D** 100%

14 Hydrogen gas reacts with chlorine gas to form hydrogen chloride gas.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

What is the final volume of the gas mixture when 20 dm^3 of hydrogen is reacted with 30 dm^3 of chlorine gas at 100 °C?

A 40 dm^3 **B** 50 dm^3 **C** 60 dm^3 **D** 70 dm^3

15 Ammonia and excess carbon dioxide can react to form urea and water in a reaction.

$$2NH_3 + CO_2 \longrightarrow CON_2H_4 + H_2O$$

The percentage yield of this reaction is 80 %.

What is the mass of ammonia required for this reaction to obtain 60.0 g of urea?

[M_r: NH_3, 17; CO_2, 44; CON_2H_4, 60; H_2O, 18]

A 10.6 g **B** 27.2 g **C** 34.0 g **D** 42.5 g

16 Aqueous sodium hydroxide reacts with the solution of a certain metal chloride MCl_x, to form a precipitate of the metal hydroxide according to the following equation.

$$MCl_x + x\text{NaOH} \rightarrow M(OH)_x + x\text{NaCl}$$

10.0 cm^3 of 3.0 mol/dm^3 sodium hydroxide solution reacts exactly with 10.0 cm^3 of 1.5 mol/dm^3 MCl_x solution.

What is the formula of the metal chloride?

A MCl **B** MCl_2 **C** MCl_3 **D** MCl_4

17 In which equation does the metal oxide act as an acidic oxide?

A K_2O (s) + H_2O (l) → 2KOH (aq)

B Fe_2O_3 (g) + 3CO (g) → 2Fe (s) + $3CO_2$ (g)

C Al_2O_3 (s) + 6HCl (aq) → $2AlCl_3$ (aq) + $3H_2O$ (l)

D PbO (s) + H_2O (l) + OH^- (aq) → $Pb(OH)_3^-$ (aq)

18 The table below shows the range of colours of an indicator at different pH values.

pH	colour
0 – 2.5	red
2.6 – 5.0	yellow
5.1 – 7.0	orange
7.1 – 14.0	green

Which pair of substances can be distinguished using the indicator above?

A aqueous ammonia and aqueous potassium hydroxide

B dilute hydrochloric acid and dilute sulfuric acid

C dilute hydrochloric acid and water

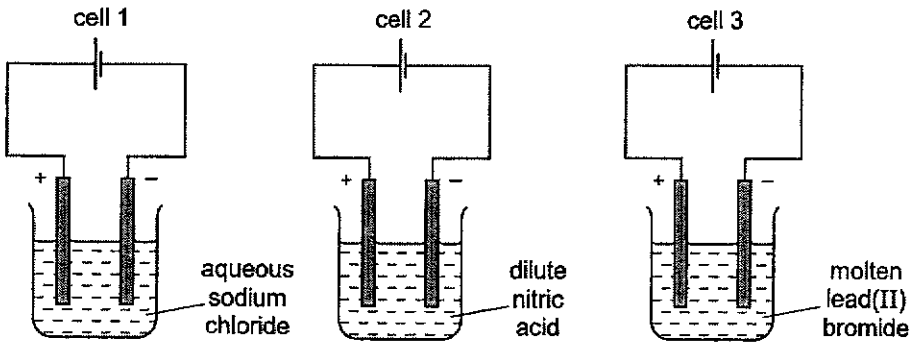
D water and aqueous potassium chloride

19 During an electrolysis experiment, the same amount of charge deposited 32.5 g of zinc and 10.2 g of vanadium.

What was the charge on the vanadium ion?

A 2+ **B** 3+ **C** 4+ **D** 5+

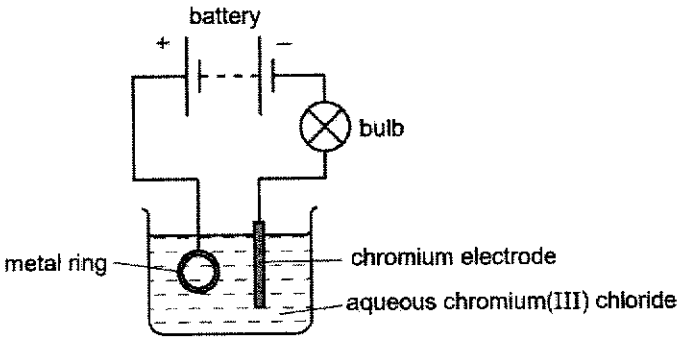
20 Three electrolysis cells are set up. Each cell has platinum electrodes.



In which of these cells is a gas formed at both electrodes?

A 1 and 2 **B** 1 and 3 **C** 2 only **D** 3 only

21 The diagram shows the apparatus used in an attempt to electroplate a metal ring with chromium.



The experiment did not work.

Which change is needed in the experiment to make it work?

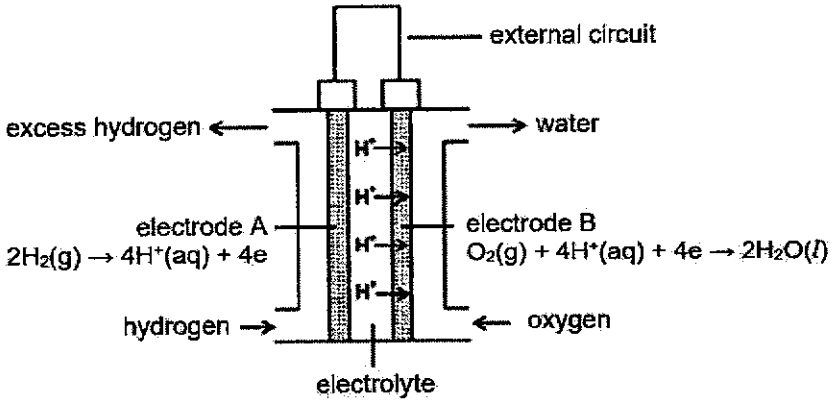
A add solid chromium(III) chloride to the electrolyte

B increase size of the chromium electrode

C increase the temperature of the electrolyte

D switch the ring and the chromium electrode

22 The hydrogen-oxygen fuel cell generates electricity under a continuous supply of hydrogen gas and oxygen gas, as shown in the diagram.

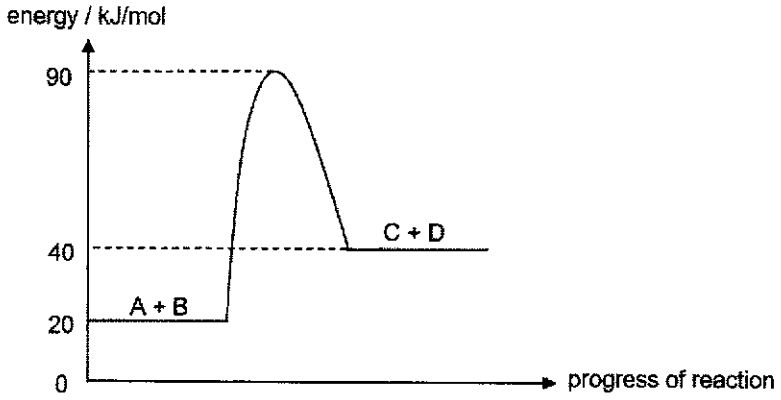


Which of the following correctly shows the direction of electron flow and a suitable electrolyte which can be used in the fuel cell?

	direction of electron flow	electrolyte
A	from electrode A to B	aqueous sodium hydroxide
B	from electrode B to A	aqueous sodium hydroxide
C	from electrode A to B	dilute sulfuric acid
D	from electrode B to A	dilute sulfuric acid

23 The energy profile diagram of a reversible reaction is shown below.

$$A + B \rightleftharpoons C + D$$



What is the value of the activation energy for the backward reaction?

A 20 kJ/mol **B** 50 kJ/mol **C** 70 kJ/mol **D** 90 kJ/mol

24 In which equation is the sign of enthalpy, ΔH, correctly shown?

	equation	ΔH
A	$2AgCl(s) \rightarrow 2Ag(s) + Cl_2(g)$	positive
B	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$	positive
C	$H_2(g) \rightarrow 2H(g)$	negative
D	$H_2O(s) \rightarrow H_2O(l)$	negative

25 Which equations below represent redox reactions?

1 $H^+ + OH^- \rightarrow H_2O$

2 $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

3 $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$

A 1 only

B 3 only

C 1 and 2 only

D 2 and 3 only

26 Small portions of aqueous potassium iodide and acidified aqueous potassium manganate(VII) were added to four different solutions.

The colour changes seen are shown in the table.

solution number	aqueous potassium iodide	acidified potassium manganate(VII)
1	colourless to brown	purple to colourless
2	colourless to brown	no change observed
3	no change observed	purple to colourless
4	no change observed	no change observed

Which solution(s) contained an oxidising agent?

A 2 only **B** 1 and 2 **C** 1 and 3 **D** 3 and 4

27 Antacid tablets neutralise acids. A student investigated the time taken for an antacid tablet to react completely with excess hydrochloric acid under different conditions. The table below shows the results.

experiment number	volume of acid / cm^3	concentration of acid / mol dm^{-3}	temperature of acid / °C	reaction time / s
1	50	1.00	25.0	132
2	50	2.00	25.0	65
3	100	2.00	25.0	65
4	50	2.00	35.0	33

What does the experiment show?

A Increasing the concentration of acid will increase the rate of reaction.

B Increasing the temperature of the reaction does not affect the rate of reaction.

C Increasing the volume of acid will decrease the rate of reaction.

D The addition of a catalyst will increase the rate of reaction.

28 A student has five reagents.

- dilute hydrochloric acid
- dilute sulfuric acid
- dilute nitric acid
- solid calcium carbonate
- solid copper(II) carbonate

How many soluble salts can be prepared?

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

29 The table below gives some information about four metals P, Q, R and S.

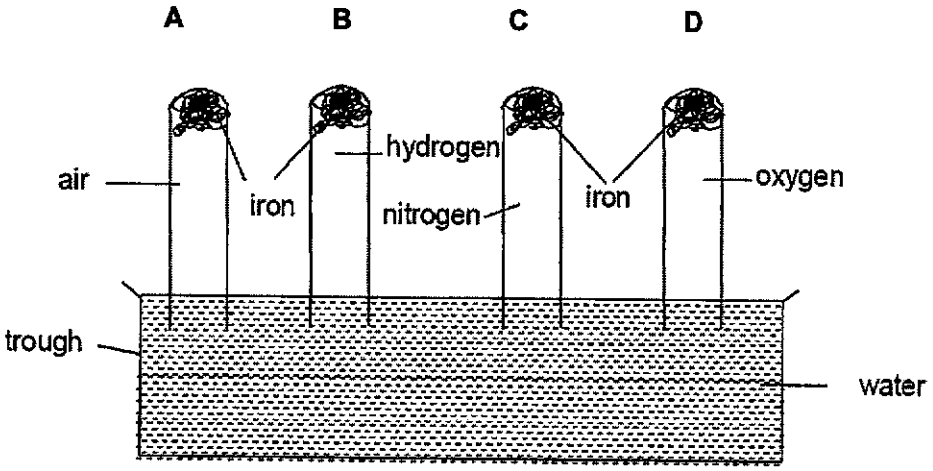
metal	reaction with cold water	reaction with acids	action of heat on carbonate of metal
P	reacts vigorously	reacts vigorously	decomposes to metal oxide
Q	no reaction	reacts moderately	decomposes to metal oxide
R	reacts vigorously	reacts vigorously	no visible reaction
S	no reaction	no reaction	decomposes to metal

What is the order of reactivity of the four metals?

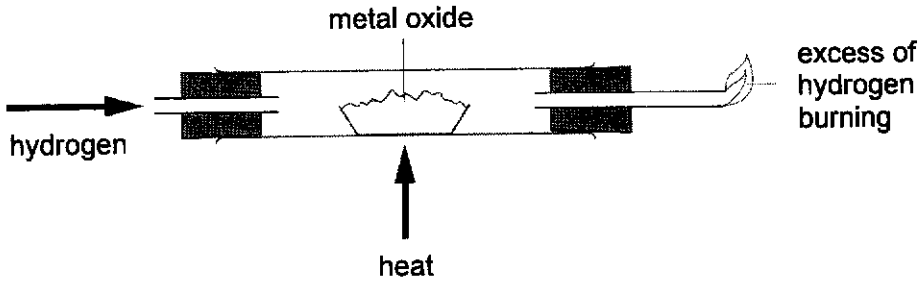
	most reactive →			least reactive
A	P	R	Q	S
B	R	P	Q	S
C	R	Q	P	S
D	S	Q	P	R

30 An experiment was set up as shown in the diagram below.

Which tube will have the highest water level after one month?



31 The experimental set-up below shows the reduction of a metal oxide by hydrogen.



Which of the following oxides cannot be reduced by the method shown above?

A AgO **B** FeO **C** PbO **D** ZnO

32 Elements X, Y and Z are in the same period of the Periodic Table.

Gaseous X exists as diatomic molecules.
Oxides of Y react with both acid and alkali.
Oxides of Z dissolve in water to form solution with pH > 7.

In which order do the elements appear in the Periodic Table?

A X → Y → Z

B Y → X → Z

C Z → X → Y

D Z → Y → X

33 In the equation shown, X and Y represent elements in Group 17 of the Periodic Table.

$$X_2(aq) + 2NaY(aq) \rightarrow Y_2(aq) + 2NaX(aq)$$

	X	Y
1	iodine	chlorine
2	bromine	iodine
3	chlorine	bromine
4	bromine	chlorine

Which pair of elements could be X and Y?

A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

34 How many of the following processes will lead to an increase in greenhouse gas emissions?

decomposition of vegetation	fermentation of glucose	photosynthesis
polymerisation	respiration	neutralisation

A 1 **B** 2 **C** 3 **D** 4

35 Which of the following statements about a homologous series is correct?

A The melting and boiling point increases with increasing relative molecular mass.

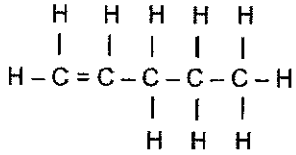
B The members have similar physical properties.

C The members have the same molecular formula.

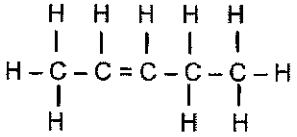
D The relative molecular masses of consecutive members differ by 12.

36 How many different isomers of C_5H_{10} are shown below?

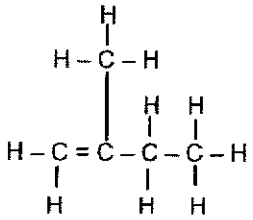
structure 1



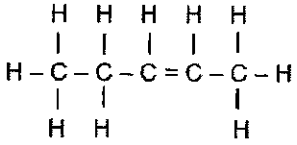
structure 2



structure 3



structure 4



A 0 **B** 2 **C** 3 **D** 4

37 When crude oil is fractionally distilled, which list best describes the mixture of compounds collected at the bottom of the fractionating column?

A Short chain molecules, low viscosity, high flammability

B Short chain molecules, low boiling point, low flammability

C Long chain molecules, high flammability, high boiling point

D Long chain molecules, high viscosity, high boiling point

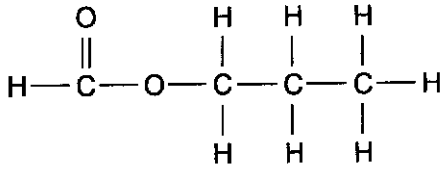
38 The following chemicals are available in the laboratory.

1 aqueous bromine
2 Universal Indicator solution
3 magnesium powder
4 sodium carbonate

Which of these chemicals can be used to distinguish between propene and propanoic acid?

A All of them **B** 1 only **C** 1 and 4 only **D** 1, 2 and 3 only

39 The structure of a compound associated with the smell of raspberries is shown below.



Which reactants are suitable for synthesising the above compound in the laboratory?

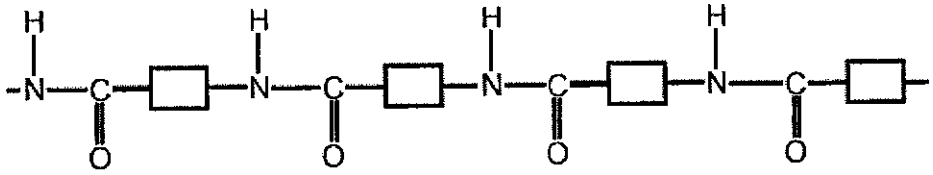
A butanol and methanoic acid

B methanol and butanoic acid

C methanol and propanoic acid

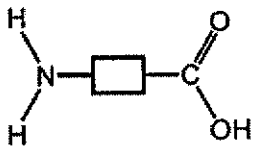
D propanol and methanoic acid

40 The partial structure of a polymer is shown below.

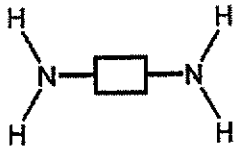


Which monomers would form the above polymer?

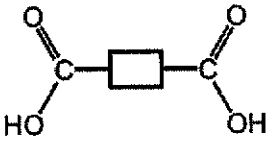
1



2



3



A 1 only **B** 1 and 2 only **C** 2 and 3 only **D** 1, 2 and 3

End of Paper

Section A

Answer **all** questions.

1 Choose from the following substances to answer the questions.

A aluminium oxide, Al_2O_3

B carbon monoxide, CO

C potassium dichromate(VI), $K_2Cr_2O_7$

D ammonium nitrate, NH_4NO_3

E potassium manganate(VII), $KMnO_4$

F fluorine, F_2

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. ..... [1]

(b) is able to oxidise iodide ions to iodine. ..... [1]

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

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

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

[Total: 5]

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.

..... NH_4ClO_4 (s) + 10Al (s) → ..... Al_2O_3 (s) + 2$AlCl_3$ (s) + ... 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^-.

[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.

.....

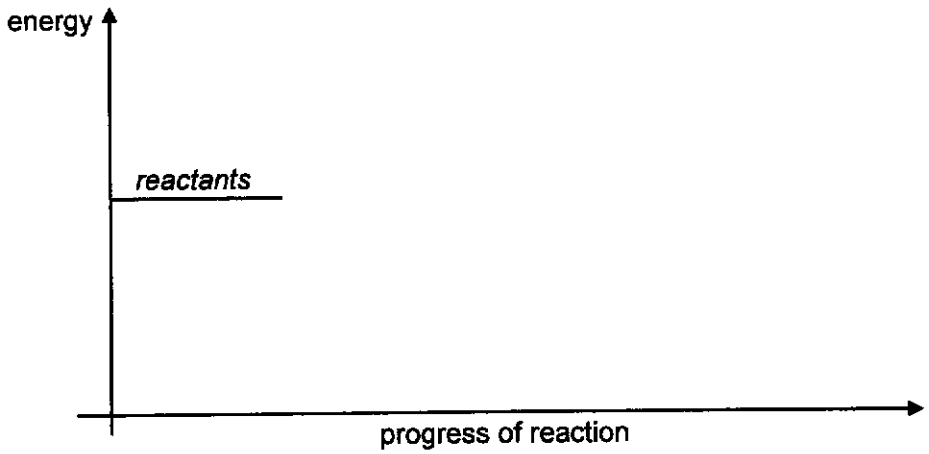
.....

.....

..... [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.



[3]

[Total: 9]

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.

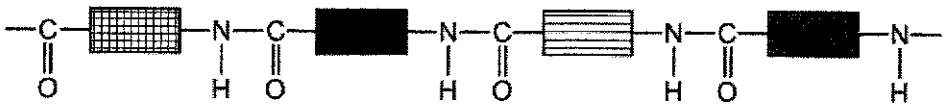


Fig. 3.1

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

[2]

(ii) Proteins are polyamides.

Name one other example of a polyamide.

..... [1]

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

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

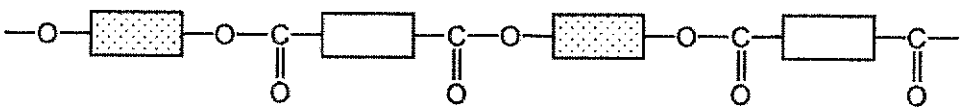


Fig. 3.2

(i) Name the linkage present in PET.

..... [1]

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

[1]

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

Issue: .....

.....

..... [1]

Method : .....

.....

..... [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]

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.

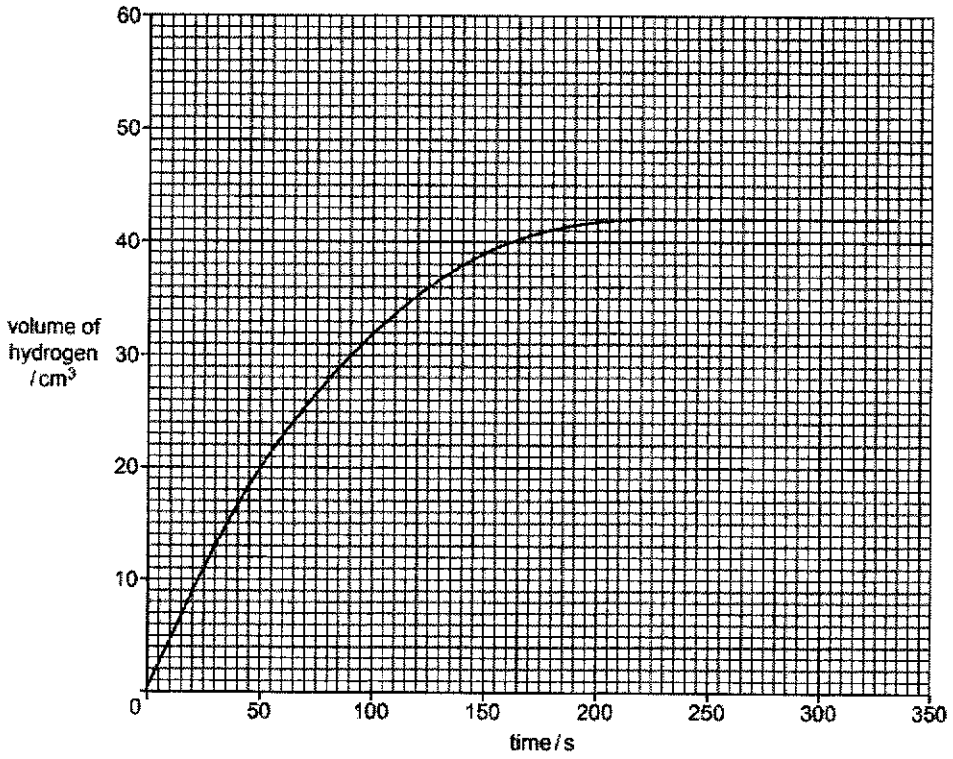


Fig. 4.1

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

..... [2]

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

mass = ... g [2]

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

..... [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.

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.

..... [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.

..... [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?

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

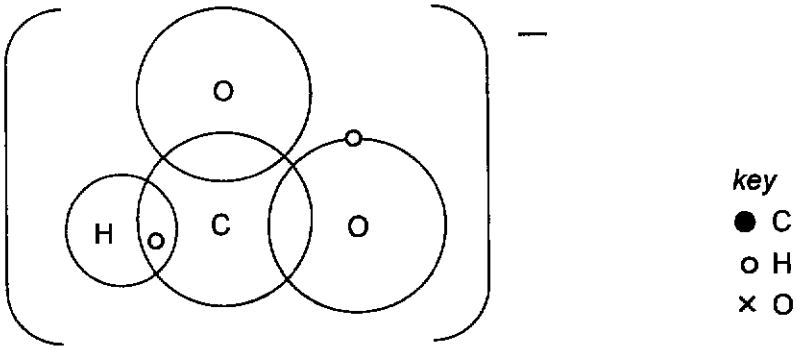


Fig. 5.1

[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.

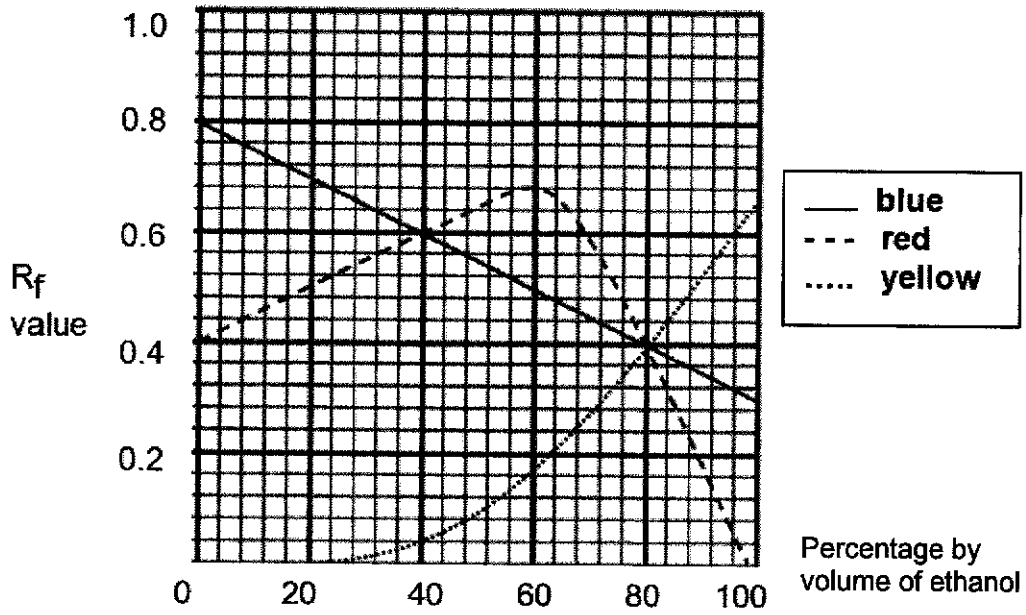


Fig. 6.1

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

..... [1]

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

..... % [1]

Explain your answer.

.....

..... [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.

[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)

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

..... [1]

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

..... [2]

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

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

.....

.....

..... [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.

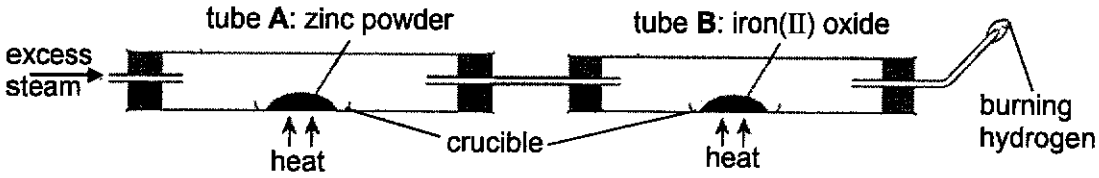


Fig. 7.2

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

..... [1]

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

.....

..... [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 + solid residue after heating in tube **B**	18.03

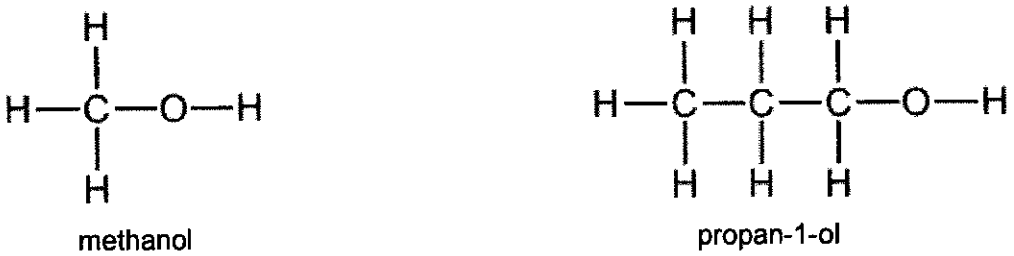
Determine the mass of zinc used in tube **A**.

[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.

.....

.....

..... [2]

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

Draw the structural formula of this product.

[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**.

[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.

[2]

[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.

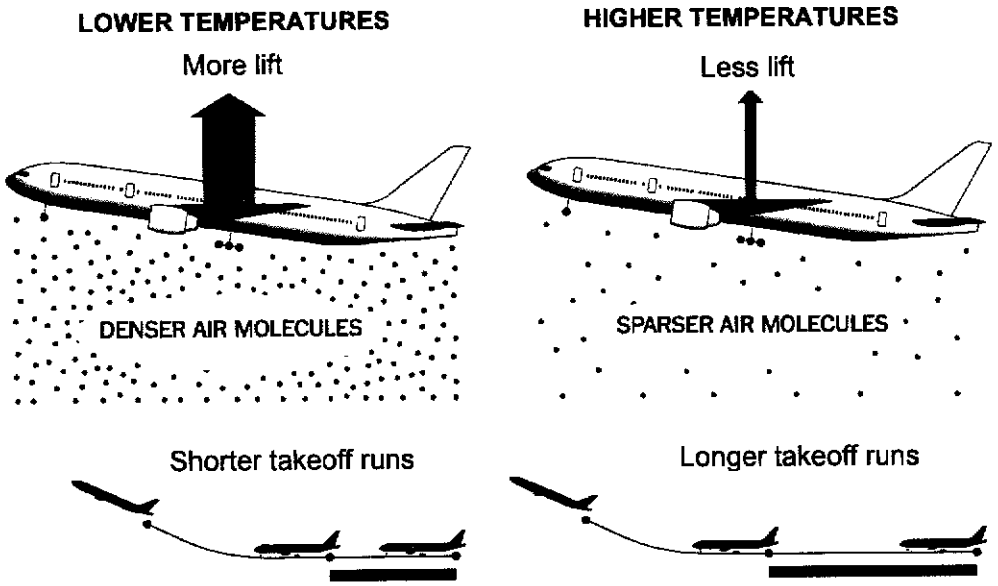


Fig. 9.1[2]

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.

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

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.

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]

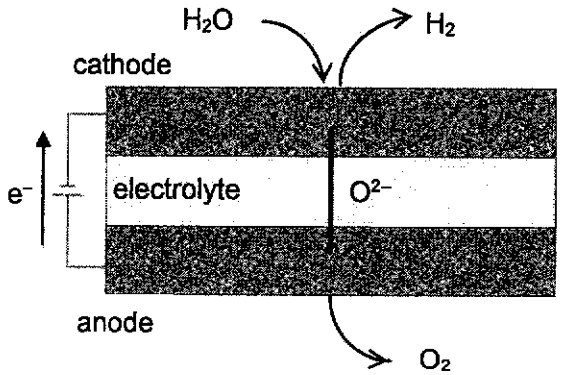


Fig. 9.3

(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.

.....

.....

..... [2]

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

.....

.....

..... [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]

takeoff distance ≈ ..... m [1]

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

.....

.....

..... [2]

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

	half equation
cathode	
anode	

[2]

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

..... [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)

[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

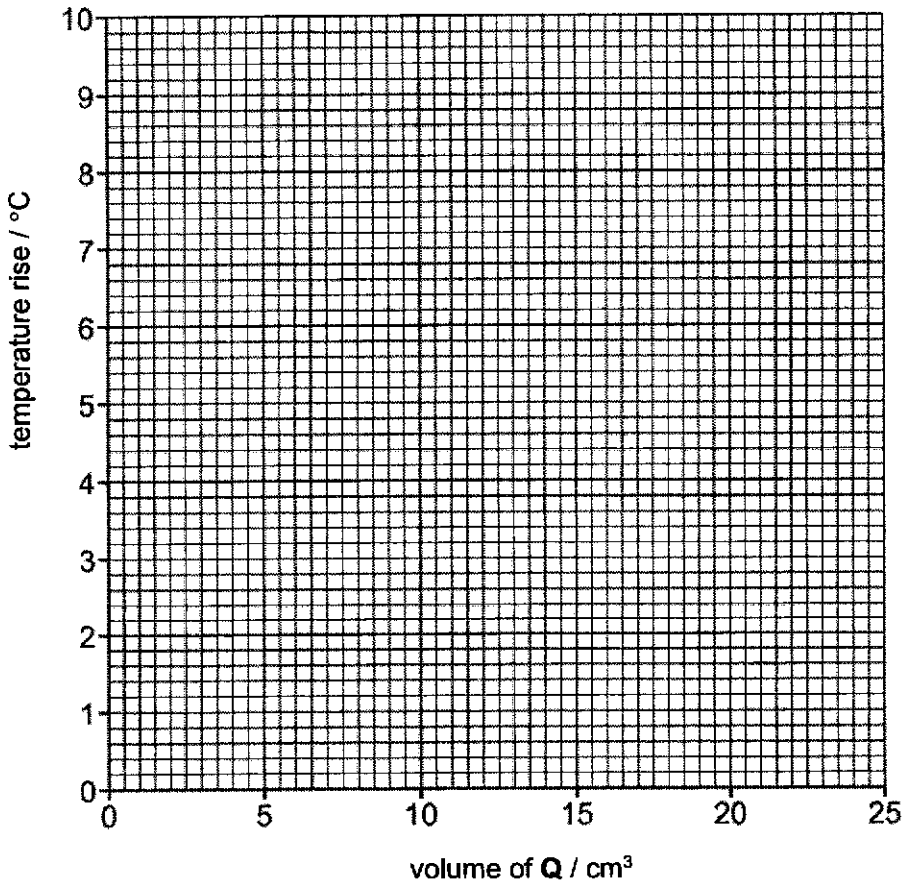
experiment number	volume of **P** /cm^3	volume of water /cm^3	volume of **Q** /cm^3	initial temperature /°C	highest temperature reached /°C	temperature rise /°C
1	25.0	20	5.0	23.0	25.5	
2	25.0	15	10.0	24.5	29.5	5.0
3	25.0	10		25.0	32.5	7.5
4	25.0	7	18.0	25.0	33.0	8.0
5	25.0	5	20.0	25.5	33.5	8.0
6	25.0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

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

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

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

[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**
4) Add acidified silver nitrate solution	No visible change

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

colourless gas **Q** .....

colourless gas **R** .....

cation **X** .....

anion **Y** ..... [4]

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

..... [1]

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

..... [1]

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

.....

..... [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*.

.....

..... [1]

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

.....

..... [1]

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

..... [1]

[Total: 10]

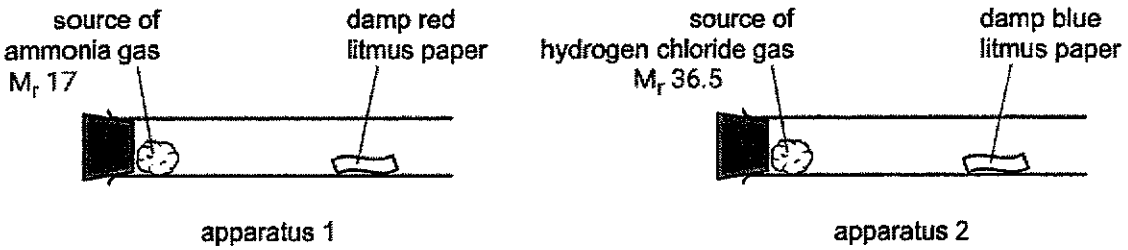
End of Paper

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

Answers

1 A student investigated the diffusion of ammonia gas, NH_3, and hydrogen chloride gas, HCl.

Two sets of apparatus were set up as shown below at room temperature and pressure.



apparatus 1 apparatus 2

The damp red litmus paper in apparatus 1 changed colour after 30 seconds.

How long does it take for the damp blue litmus paper to change colour in apparatus 2?

Heavier M_r, slower rate of diffusion.

In presence of water, HCl (g) dissociates to produce H^+ ions, which turn blue litmus red.

A about 21 seconds

B about 30 seconds

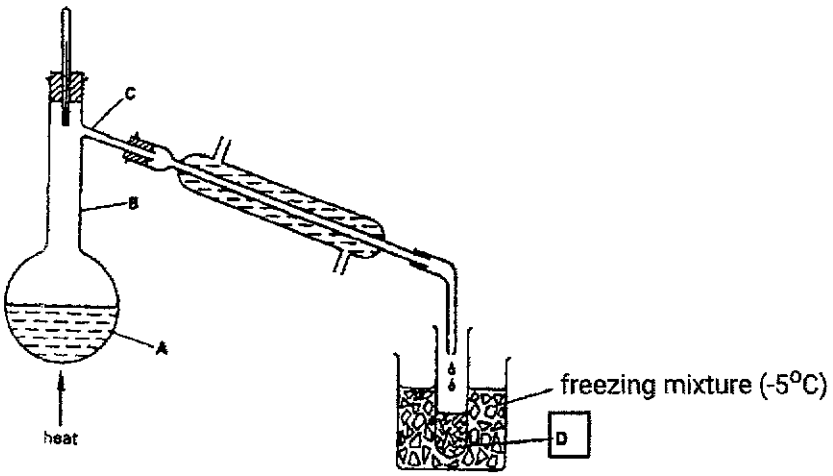
C about 64 seconds

D The blue litmus paper would not change colour.

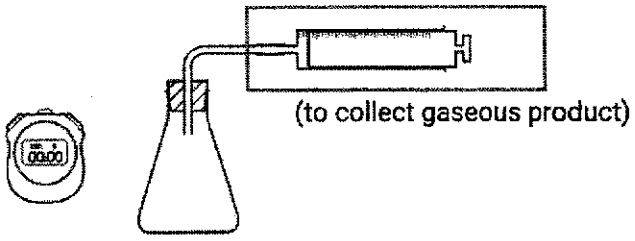
2 Substance X, melts at 10 °C and boils at 50 °C. It can be purified by distillation as shown in the diagram.

At which point will the particles of X be most regularly arranged?

(solid state)



3 A student wishes to follow the rate of a chemical reaction using the apparatus shown below.



Which of the following reactions allows a student to do so?

A $AgNO_3 + KI$

B $CuSO_4 + NaOH$

C $HCl + Mg$

D $HCl + NaOH$

4 Three separation methods are listed below.

1 obtaining water from sodium chloride solution
2 obtaining solid iodine from a mixture of solid iodine and nickel
3 obtaining solid sodium chloride from aqueous sodium chloride

Which techniques would be involved in these separations?

	1	2	3
A	distillation	sublimation	evaporation
B	distillation	sublimation	filtration
C	filtration	crystallisation	evaporation
D	sublimation	crystallisation	filtration

5 Three particles and their nuclide notations are shown.

particle	1	2	3
nuclide notation	$^{40}_{19}X^{+}$	$^{39}_{19}Y$	$^{34}_{16}Z^{2-}$

Which of the following statements is correct about the particles?

A Particle 1 has more electrons than particle 3.

B Particle 1 and 2 have the same number of neutrons.

C Particle 1 and 3 have the same number of electrons.

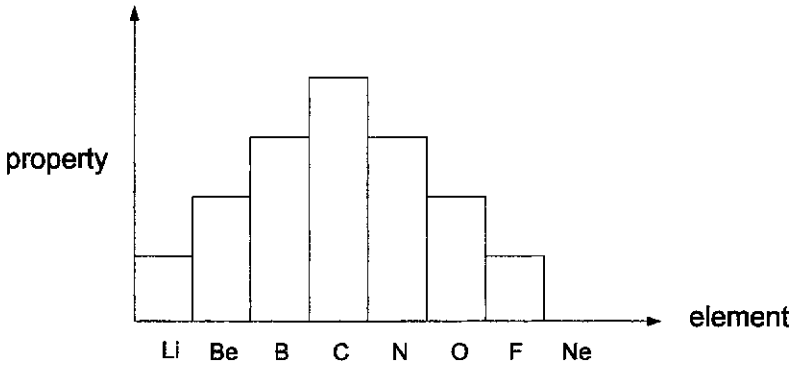
D Particle 2 has fewer neutrons than particle 3.

Particle 1
19p, 21n, 18e

Particle 2
19p, 20n, 19e

Particle 3
16p, 18n, 18e

6 The bar chart shows the period of elements from lithium to neon.



Which property of the elements is shown on the chart?

A number of electron shells

B number of electrons used in bonding

C proton number

D relative atomic mass

7 Three elements W, X, Y, and Z have consecutive, increasing proton (atomic) numbers.

Element Y exists as a colourless, monatomic gas at room temperature.

Which will be the chemical formula of a compound formed between W and chlorine?

Y: Group 18
W: Group16 (non-metal)

A W*Cl*

B W_2Cl

C WCl_2

D W_2Cl_3

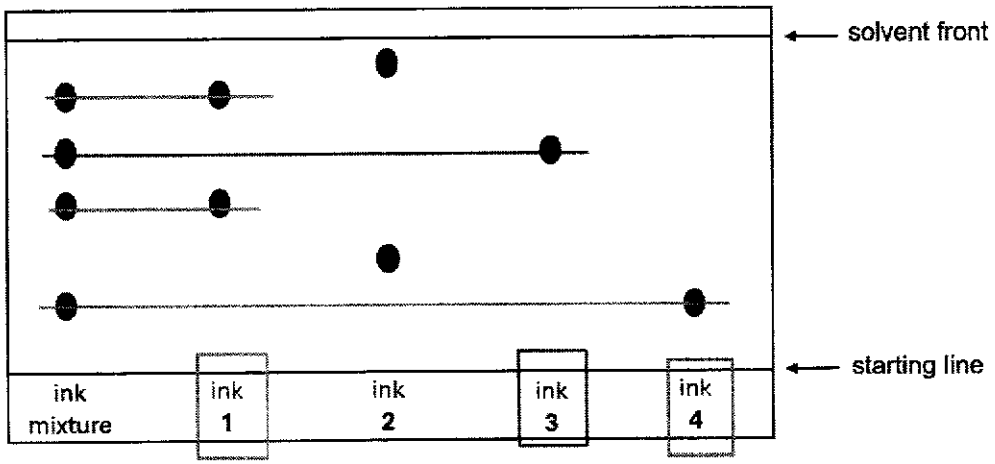
8 The mixtures shown in the table are warmed.

In which mixture does a gas form?

Key: ✓ = gas forms, ✗ = no gas forms

	NH_3 produced	No reaction	No reaction
	NaOH(aq) and NH_4Cl(s)	NaOH(aq) and Mg(s)	H_2SO_4(aq) and NaCl(s)
A	✓	✓	✗
B	✓	✗	✓
C	✓	✗	✗
D	✗	✗	✓

9 A paper chromatography experiment was carried out to determine the inks present in a mixture, and the results shown below were obtained.



Which statement about the results is **incorrect**?

A Ink 4 is more soluble than ink 3 in the solvent used.

B Inks 1 and 2 contained more than one colour pigment.

C The ink mixture contained inks 1, 3 and 4.

D The R_f value of ink 3 in the solvent used is more than 0.5.

10 An aqueous solution containing two salts is found.

A series of tests is carried out to identify the ions present. The results are shown.

no	description	observations
1	Add dilute nitric acid followed by aqueous barium nitrate.	No effervescence and white precipitate is observed. (presence of sulfate ion)
2a	Add aqueous sodium hydroxide followed by warming.	White precipitate is formed and dissolves in excess sodium hydroxide to form a colourless solution. No effervescence is observed.
2b	Add aluminium foil followed by warming.	Effervescence is observed and gas turns moist red litmus paper blue. (presence of nitrate ion)
3	Add aqueous ammonia.	White precipitate is formed. The mass of the white precipitate decreases by half when excess ammonia is added.

Which of the following salts are present in the aqueous solution?

A zinc sulfate and aluminium nitrate

B zinc sulfate and calcium nitrate

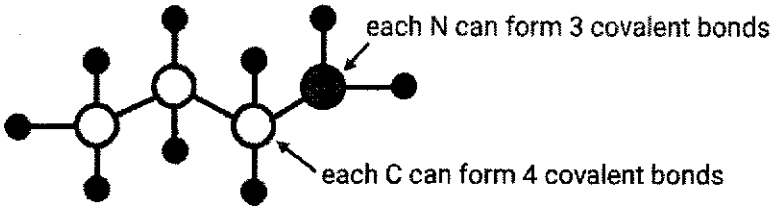
C ammonium chloride and aluminium sulfate

D calcium chloride and ammonium sulfate

Zn^{2+} : white ppt, dissolves in excess NH_3 (aq), producing colourless solution

Al^{3+} : white ppt, insoluble in excess NH_3 (aq)

11 The structure of a molecule of a compound containing carbon, nitrogen and hydrogen is shown below.

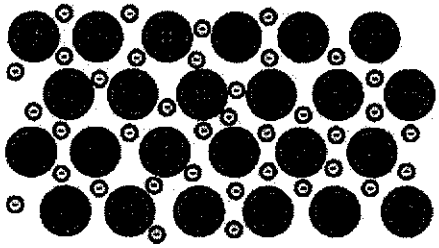


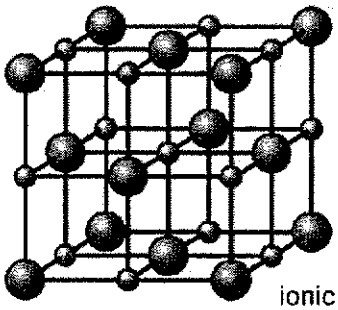
What is the molecular formula of this compound?

A CN_3H_7 **B** CN_3H_9 **C** C_3H_7N **D** C_3H_9N

12 The structures of two materials are shown below.

metallic structure





ionic (crystal) lattice

Which statement is correct?

A Both substances are hard and rigid. (metals are malleable)

B Both substances are pure compounds. (metals are NOT compounds)

C Both substances can conduct electricity in the solid state. (ionic compounds do not conduct electricity as a solid)

D Both substances contain particles held together by strong electrostatic forces of attraction.

13 On adding 50 g of impure limestone, $CaCO_3$ (Mr = 100), to excess hydrochloric acid, 6.0 dm^3 of CO_2 was evolved at room temperature and pressure.

What is the percentage purity of the limestone?

A 25% **B** 50% **C** 75% **D** 100%

moles, CO_2 = 6/24 = 0.25 mole

mole ratio CO_2 : $CaCO_3$ = 1 : 1

mass, $CaCO_3$ = 0.25 mole x 100 g/mol = 25g

%purity = (25/50) X 100% = 50%

14 Hydrogen gas reacts with chlorine gas to form hydrogen chloride gas.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

($10\ dm^3$ excess)

What is the final volume of the gas mixture when $20\ dm^3$ of hydrogen is reacted with $30\ dm^3$ of chlorine gas at 100 °C? ($20\ dm^3\ H_2$ needs only $20\ dm^3\ Cl_2$)

A $40\ dm^3$ **B** $50\ dm^3$ **C** $60\ dm^3$ **D** $70\ dm^3$

mole ratio H_2 (g) : HCl (g) = 1:2 volume of HCl (g) produced = $40\ dm^3$

volume of gas mixture = $40\ dm^3$ HCl (g) + $10\ dm^3$ excess Cl_2 (g)

15 Ammonia and excess carbon dioxide can react to form urea and water in a reaction.

$$2NH_3 + CO_2 \longrightarrow CON_2H_4 + H_2O$$

The percentage yield of this reaction is 80 %.

80% of yield = 60.0g

100% of yield = 75.0g

What is the mass of ammonia required for this reaction to obtain 60.0 g of urea?

[M_r: NH_3, 17; CO_2, 44; CON_2H_4, 60; H_2O, 18]

A 10.6 g **B** 27.2 g **C** 34.0 g **D** 42.5 g

mole ratio NH_3 : urea = 2 : 1

mass, NH_3 required = 2 x [75/M_r of urea] x [M_r of ammonia] = 42.5g

16 Aqueous sodium hydroxide reacts with the solution of a certain metal chloride MCl_x, to form a precipitate of the metal hydroxide according to the following equation.

$$MCl_x + x\text{NaOH} \rightarrow M(OH)_x + x\text{NaCl}$$

(0.03 mole NaOH) (0.015 mole MCl_x)

$10.0\ cm^3$ of $3.0\ mol/dm^3$ sodium hydroxide solution reacts exactly with $10.0\ cm^3$ of $1.5\ mol/dm^3$ MCl_x solution.

What is the formula of the metal chloride?

A MCl **B** MCl_2 **C** MCl_3 **D** MCl_4

(amphoteric oxide - lead(II) oxide, aluminium oxide, zinc oxide)

17 In which equation does the metal oxide act as an acidic oxide?

(reacts with base/alkali to produce salt and water)

A K_2O (s) + H_2O (l) → 2KOH (aq)

B Fe_2O_3 (g) + 3CO (g) → 2Fe (s) + $3CO_2$ (g)

C Al_2O_3 (s) + 6HCl (aq) → $2AlCl_3$ (aq) + $3H_2O$ (l)

D PbO (s) + H_2O (l) + OH^- (aq) → $Pb(OH)_3^-$ (aq)

OH^- = alkali

18 The table below shows the range of colours of an indicator at different pH values.

pH	colour
0 – 2.5	red
2.6 – 5.0	yellow
5.1 – 7.0	orange
7.1 – 14.0	green

Which pair of substances can be distinguished using the indicator above?

A aqueous ammonia and aqueous potassium hydroxide

B dilute hydrochloric acid and dilute sulfuric acid

C dilute hydrochloric acid and water

D water and aqueous potassium chloride

19 During an electrolysis experiment, the same amount of charge deposited 32.5 g of zinc (0.5 mole) and 10.2 g of vanadium. (0.2 mole)

What was the charge on the vanadium ion?

$Zn^{2+} + 2e^- \rightarrow Zn$

1 mole of Zn needed 2 moles of e^-

0.5 mole of Zn means 1 mole of e^- in circuit.

A 2+ **B** 3+ **C** 4+ **D** 5+

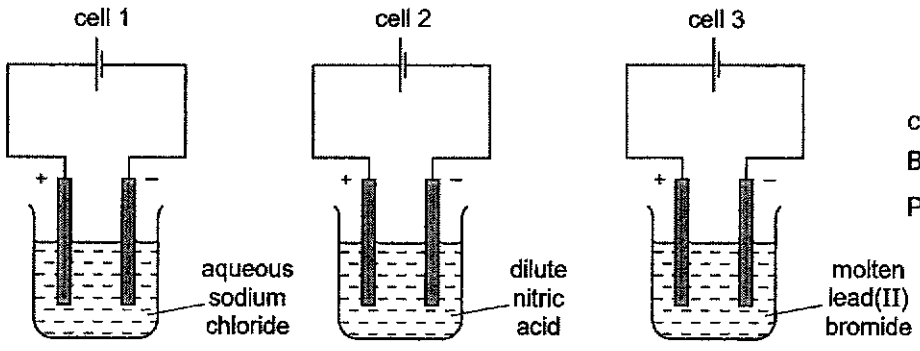
1 mole of e^- in circuit only deposits 0.2 mole V

Hence charge of V ion = 1/0.2 = +5

20 Three electrolysis cells are set up. Each cell has platinum electrodes. (inert electrodes)

cell 1:
H_2 (g) at cathode
O_2 (g) at anode

cell 2:
H_2 (g) at cathode
O_2 (g) at anode



cell 3:
Br_2 (g) at anode
Pb (l) at cathode

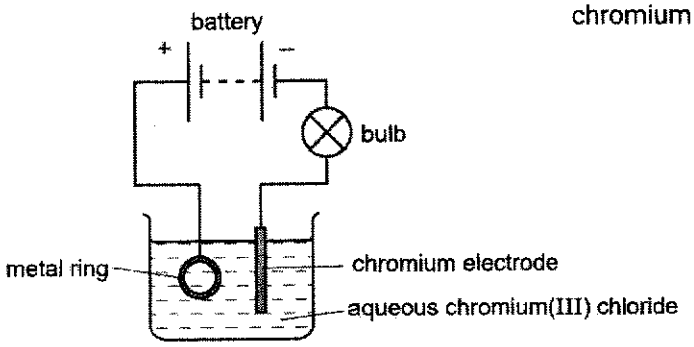
In which of these cells is a gas formed at both electrodes?

A 1 and 2 **B** 1 and 3 **C** 2 only **D** 3 only

21 The diagram shows the apparatus used in an attempt to <u>electroplate</u> a metal ring with chromium.

metal ring at cathode

chromium at anode



The experiment did not work.

Which change is needed in the experiment to make it work?

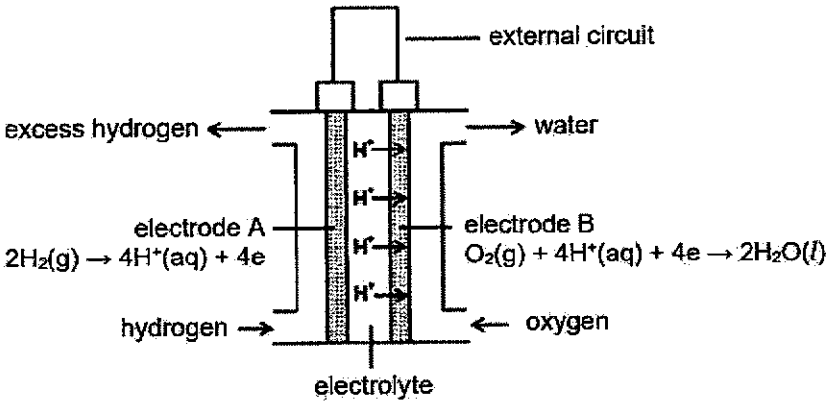
A add solid chromium(III) chloride to the electrolyte

B increase size of the chromium electrode

C increase the temperature of the electrolyte

D switch the ring and the chromium electrode

22 The hydrogen-oxygen fuel cell generates electricity under a continuous supply of hydrogen gas and oxygen gas, as shown in the diagram.

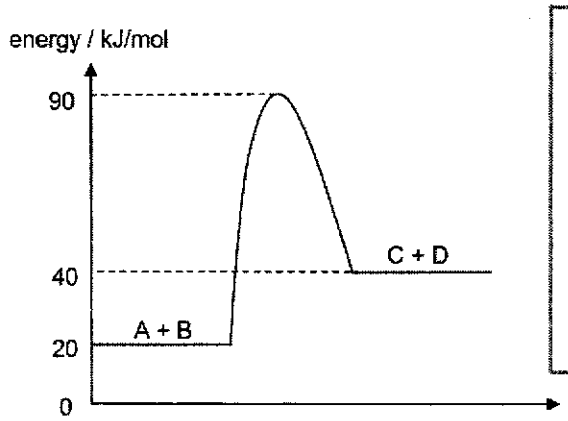


Which of the following correctly shows the direction of electron flow and a suitable electrolyte which can be used in the fuel cell?

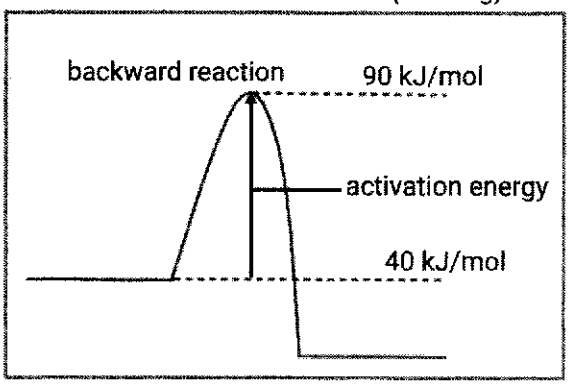
	direction of electron flow	electrolyte
A	from electrode A to B	aqueous sodium hydroxide
B	from electrode B to A	aqueous sodium hydroxide
C	from electrode A to B	dilute sulfuric acid
D	from electrode B to A	dilute sulfuric acid

23 The energy profile diagram of a reversible reaction is shown below.

$A + B \rightleftharpoons C + D$



(working)



What is the value of the activation energy for the backward reaction?

A 20 kJ/mol **B** 50 kJ/mol **C** 70 kJ/mol **D** 90 kJ/mol

24 In which equation is the sign of enthalpy, ΔH, correctly shown?

	equation	ΔH
A	$2AgCl(s) \rightarrow 2Ag(s) + Cl_2(g)$ decomposition, endo (+)	positive
B	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ combustion, exo (-)	positive
C	$H_2(g) \rightarrow 2H(g)$ bond breaking, endo (+)	negative
D	$H_2O(s) \rightarrow H_2O(l)$ melting, endo (+)	negative

25 Which equations below represent redox reactions?

1 $H^+ + OH^- \rightarrow H_2O$ (neutralisation, NOT redox)

2 $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

3 $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$

A 1 only

B 3 only

C 1 and 2 only

D 2 and 3 only

KI = RA. In OA, KI will turn from colourless to brown.
$KMnO_4$ = OA. In RA, $KMnO_4$ will turn from purple to colourless. **12**

26 Small portions of aqueous potassium iodide and acidified aqueous potassium manganate(VII) were added to four different solutions.

The colour changes seen are shown in the table.

solution number	aqueous potassium iodide	acidified potassium manganate(VII)
1	colourless to brown	purple to colourless
2	colourless to brown	no change observed
3	no change observed	purple to colourless
4	no change observed	no change observed

Which solution(s) contained an oxidising agent?

A 2 only **B** 1 and 2 **C** 1 and 3 **D** 3 and 4

27 Antacid tablets neutralise acids. A student investigated the time taken for an antacid tablet to react completely with excess hydrochloric acid under different conditions. The table below shows the results.

experiment number	volume of acid / cm^3	concentration of acid / mol dm^{-3}	temperature of acid / °C	reaction time / s
1	50	1.00	25.0	132
2	50	2.00	25.0	65
3	100	2.00	25.0	65
4	50	2.00	35.0	33

What does the experiment show?

A Increasing the concentration of acid will increase the rate of reaction. (REF: expt 1 & 2. **TRUE**)

B Increasing the temperature of the reaction does not affect the rate of reaction. (REF; expt 2 & 4)

C Increasing the volume of acid will decrease the rate of reaction. (REF: expt 2 & 3)

D The addition of a catalyst will increase the rate of reaction. (no expt to support)

28 A student has five reagents.

- dilute hydrochloric acid
- dilute sulfuric acid
- dilute nitric acid
- solid calcium carbonate
- solid copper(II) carbonate

All **nitrates** are soluble.
All chlorides are soluble except lead(II) chloride, silver chloride.
All sulfates are soluble except lead(II) sulfate, barium sulfate and calcium sulfate.

Salts produced (soluble ones in **bold**):
$CaCl_2$, **$CuCl_2$**, $CaSO_4$, $CuSO_4$, **$Ca(NO_3)_2$**, **$Cu(NO_3)_2$**

How many soluble salts can be prepared?

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

29 The table below gives some information about four metals P, Q, R and S.

P more reactive than Q

metal	reaction with cold water	reaction with acids	action of heat on carbonate of metal
P	reacts vigorously	reacts vigorously	decomposes to metal oxide
Q	no reaction	reacts moderately	decomposes to metal oxide
R	reacts vigorously	reacts vigorously	no visible reaction
S	no reaction	no reaction	decomposes to metal

carbonates of reactive metals are thermally stable (i.e. DO NOT DECOMPOSE when heated)

What is the order of reactivity of the four metals?

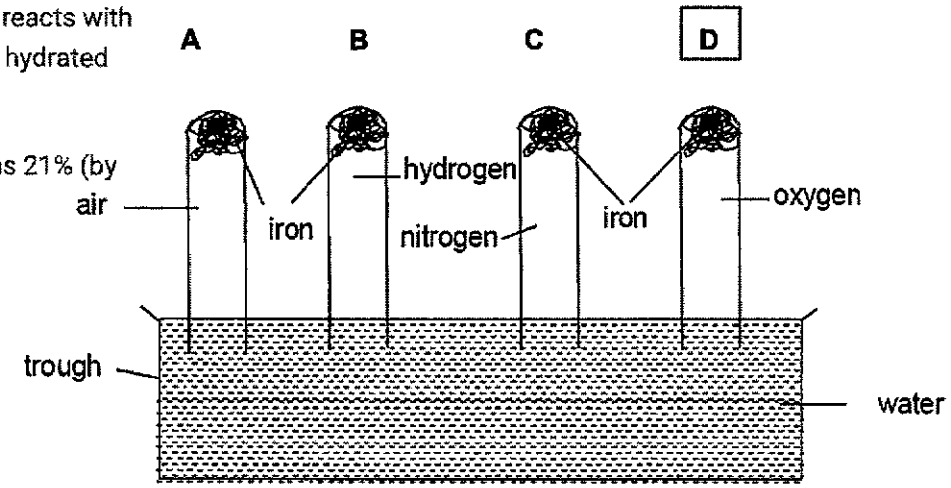
	most reactive →			least reactive
A	P	R	Q	S
B	R	P	Q	S
C	R	Q	P	S
D	S	Q	P	R

30 An experiment was set up as shown in the diagram below.

Which tube will have the highest water level after one month?

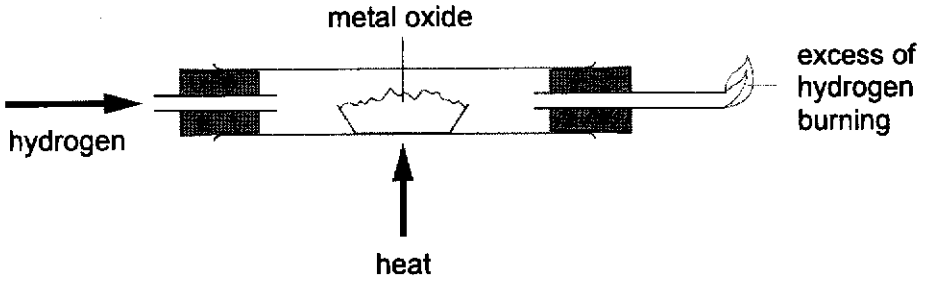
Set up illustrates process of rusting. Rusting occurs when iron reacts with **water and oxygen** to form hydrated iron(III) oxide (rust).

Not (A) as air only contains 21% (by volume) oxygen gas.



(does not occur for metals above zinc in reactivity series)

31 The experimental set-up below shows the reduction of a metal oxide by hydrogen.



Which of the following oxides cannot be reduced by the method shown above?

A AgO **B** FeO **C** PbO **D** ZnO

32 Elements X, Y and Z are in the same period of the Periodic Table.

Gaseous X exists as diatomic molecules.
Oxides of Y react with both acid and alkali.
Oxides of Z dissolve in water to form solution with pH > 7.

In which order do the elements appear in the Periodic Table?

A X → Y → Z

B Y → X → Z

C Z → X → Y

D Z → Y → X

X - to **right** of Periodic Table, could be Group 17, or oxygen
Y - metalloid, in **middle** of Periodic Table
Z - oxide is basic (pH > 7), hence Z is a metal, on **left** of Periodic Table

33 In the equation shown, X and Y represent elements in Group 17 of the Periodic Table.

$$X_2(aq) + 2NaY(aq) \rightarrow Y_2(aq) + 2NaX(aq)$$

Halogen X_2 displaces halogen Y_2 from its salt (NaY).
X is more reactive than Y.

Reactivity of halogens decreases down the group.
X must be above Y in Group 17.

	X	Y
1	iodine	chlorine
2	bromine	iodine
3	chlorine	bromine
4	bromine	chlorine

Which pair of elements could be X and Y?

A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

34 How many of the following processes will lead to an increase in greenhouse gas (methane, carbon dioxide) emissions?

decomposition of vegetation (produces methane)	fermentation of glucose (produces carbon dioxide)	photosynthesis
polymerisation	respiration	neutralisation

A 1 **B** 2 **C** 3 **D** 4

35 Which of the following statements about a homologous series is correct?

A The melting and boiling point increases with increasing relative molecular mass.

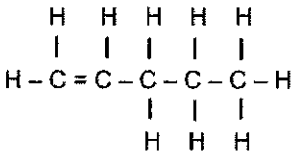
B The members have similar physical properties. (down series, **gradual change** in physical properties)

C The members have the same molecular formula. (same **general** formula)

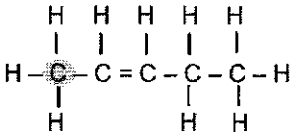
D The relative molecular masses of consecutive members differ by 12. (differs by CH_2, mass diff 14)

36 How many different isomers of C_5H_{10} are shown below?

structure 1

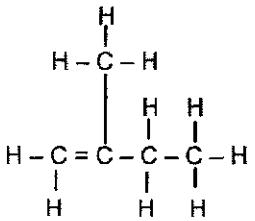


structure 2

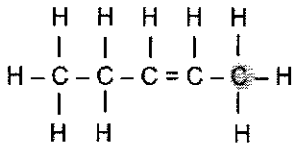


reflect laterally

structure 3



structure 4



Structures 2 and 4 are of the same isomer.

A 0 **B** 2 **C** 3 **D** 4

37 When crude oil is fractionally distilled, which list best describes the mixture of compounds collected at the bottom of the fractionating column? (heavier, high(est) bp, very viscous)

A Short chain molecules, low viscosity, high flammability

B Short chain molecules, low boiling point, low flammability

C Long chain molecules, high flammability, high boiling point

D Long chain molecules, high viscosity, high boiling point

38 The following chemicals are available in the laboratory.

1 aqueous bromine → decolourises in unsaturated hydrocarbon

2 Universal Indicator solution → alkenes are neutral compounds

3 magnesium powder → acid + metal -> salt + H_2 (g)

4 sodium carbonate → acid + carbonate -> salt + H_2O + CO_2 (g)

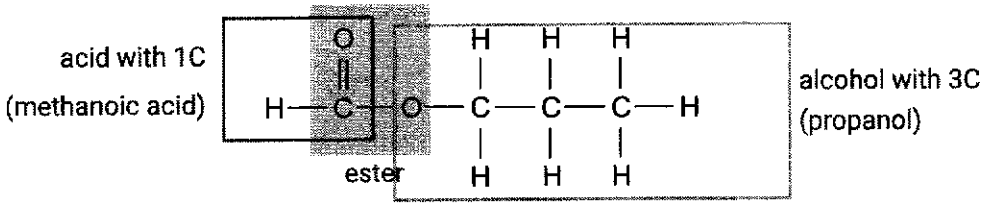
propene = **unsaturated**, hydrocarbon

propanoic acid = carboxylic **acid**

Which of these chemicals can be used to distinguish between propene and propanoic acid?

A All of them **B** 1 only **C** 1 and 4 only **D** 1, 2 and 3 only

39 The structure of a compound associated with the smell of raspberries is shown below.



Which reactants are suitable for synthesising the above compound in the laboratory?

A butanol and methanoic acid

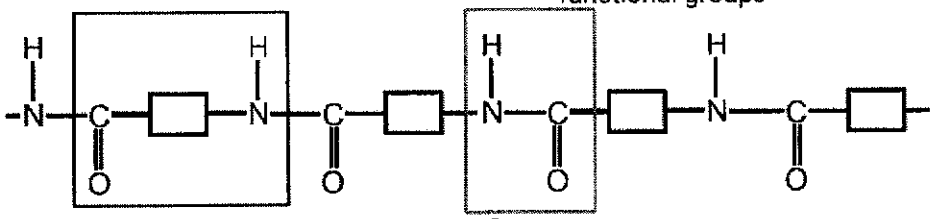
B methanol and butanoic acid

C methanol and propanoic acid

D propanol and methanoic acid

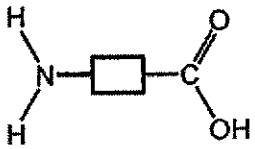
40 The partial structure of a polymer is shown below.

amide linkage, made from -NH_2 and -COOH functional groups



Which monomers would form the above polymer?

1



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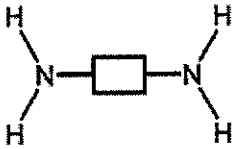
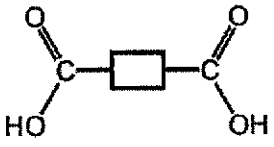


3



A 1 only **B** 1 and 2 only **C** 2 and 3 only **D** 1, 2 and 3

End of Paper

PAPER 2

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.

$\overset{6}{\ldots\ldots} NH_4ClO_4\,(s) + 10Al\,(s) \rightarrow \overset{4}{\ldots\ldots} Al_2O_3\,(s) + 2AlCl_3\,(s) + \overset{12}{\ldots\ldots} H_2O\,(g) + 3N_2\,(g)$

(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.

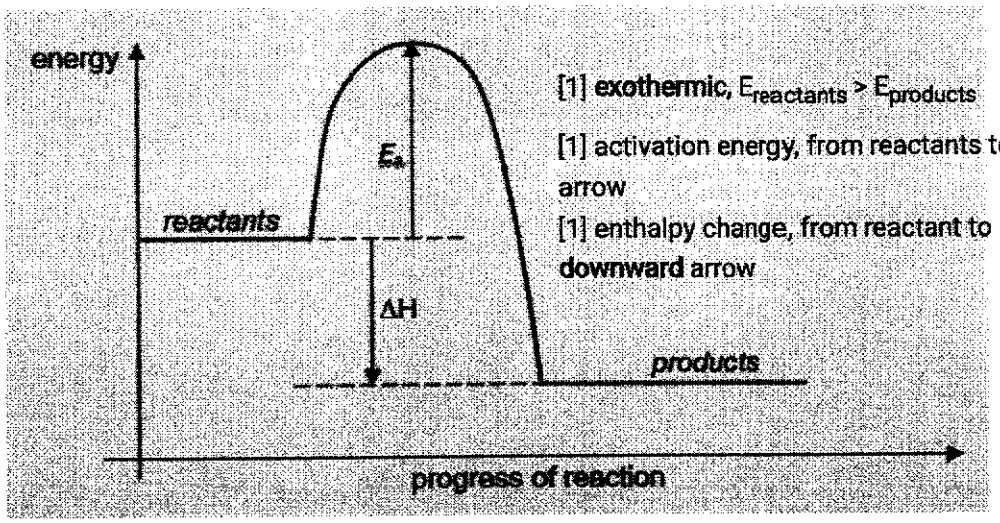
Role : reducing agent [1]

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.

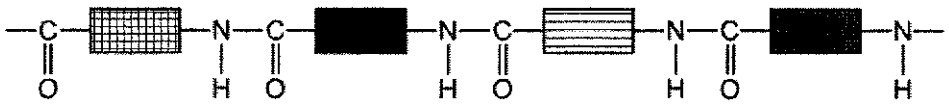
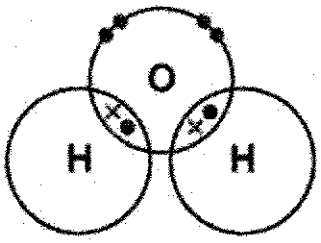


Fig. 3.1

(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.

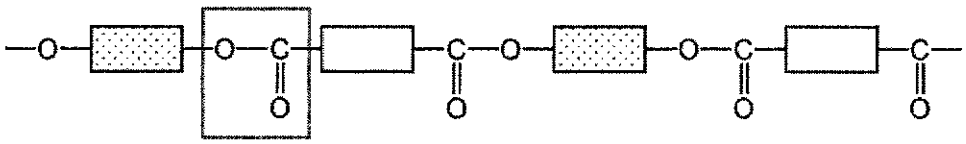
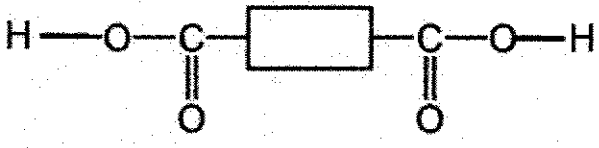


Fig. 3.2

(i) Name the linkage present in PET.

Ester (linkage) ..... [1]

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



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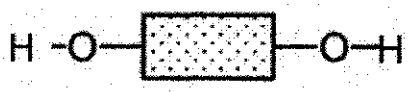


[1]

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: .....

.....

.....

difference 2: .....

.....

.....

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

..... [1]

..... [1]

[Total: 9]

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.

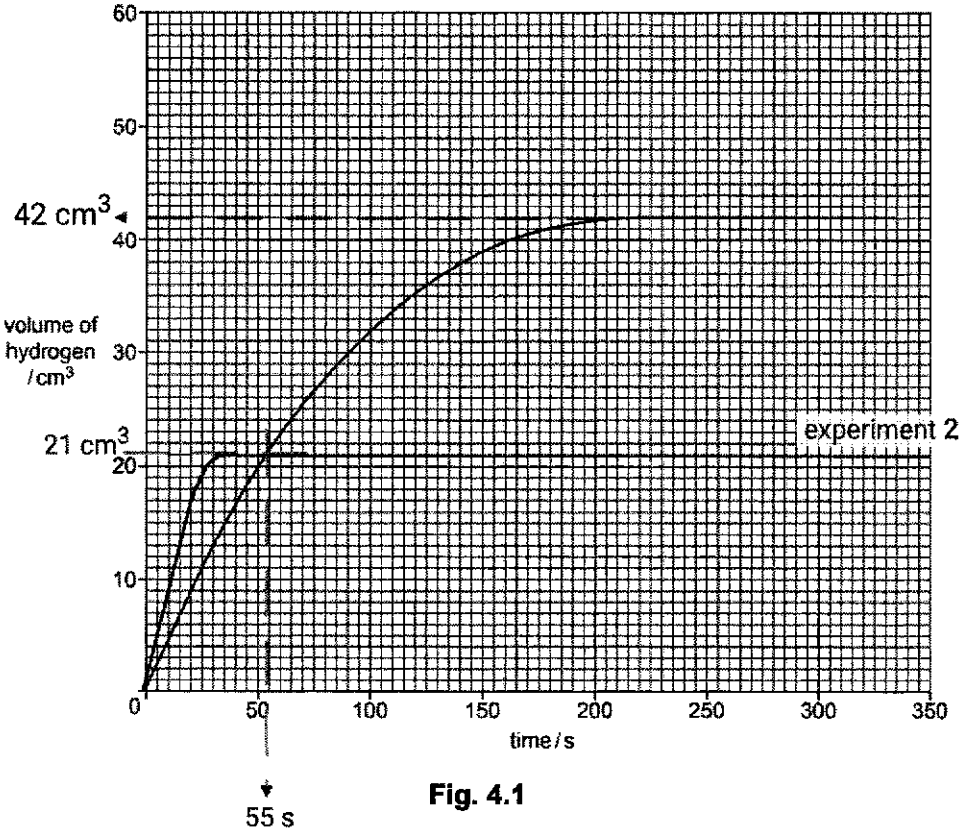


Fig. 4.1

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

$Zn\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$ [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] [2]

Label this graph as '*experiment 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.

$H^+ + OH^- \rightarrow H_2O$ [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.

$2HCOOH + M \rightarrow (HCOO)_2M + H_2$ [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 (o) 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

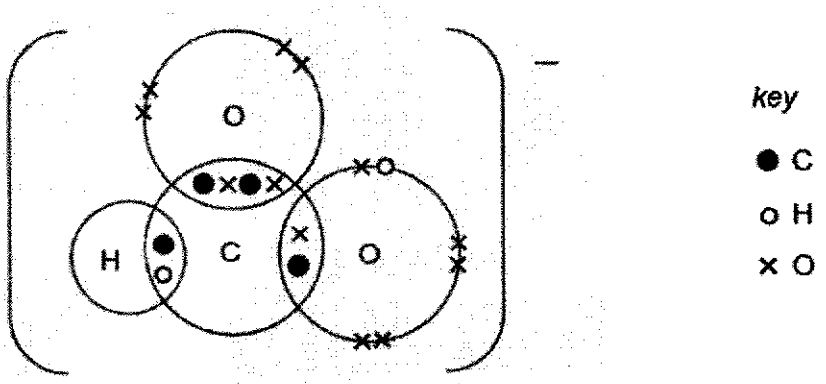


Fig. 5.1

[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.

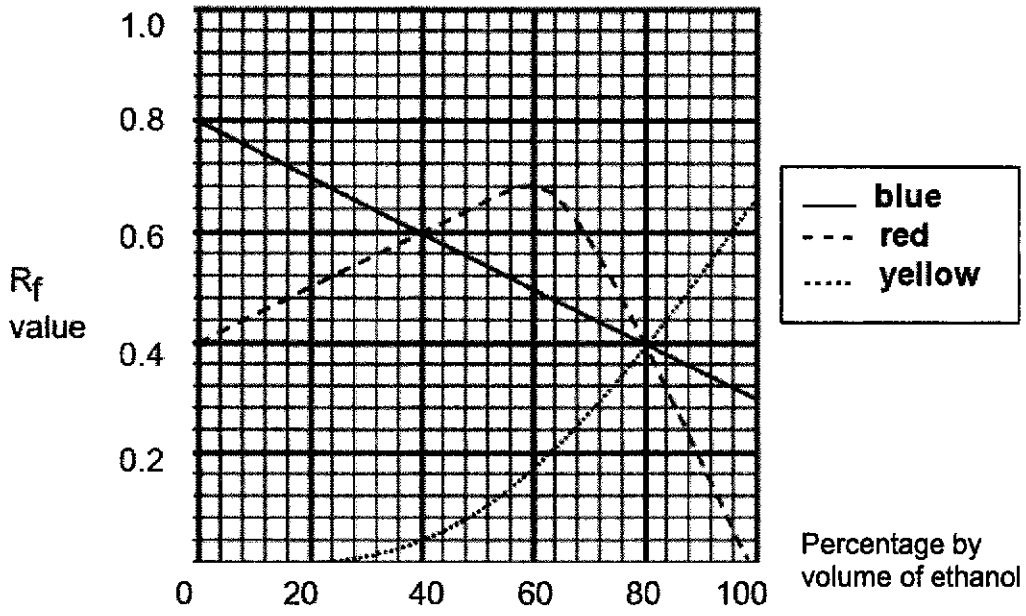


Fig. 6.1

(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 cannot be used to separate all the dyes in black ink?

80 % [1]

Explain your answer.

All 3 colours have the same / identical 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] [2]

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

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

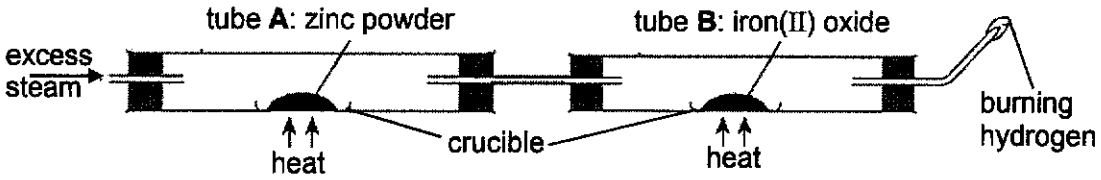


Fig. 7.2

(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 + 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

[1] mass of Fe
[1] moles, H_2 (from tube **A**)
[1] mass, Zn

[3]

mole, H_2 produced from tube **A**
≈ 0.1429

[Total: 9]

mass, Zn = mole, Zn × A_r of Zn
= 0.1429 × 65
≈ 9.29 g (to 3 s.f.)

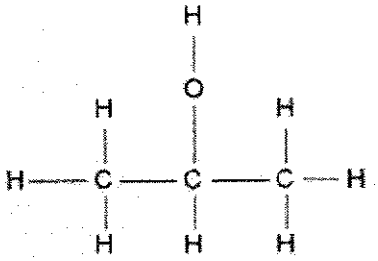
8 Methanol and propan-1-ol are alcohols.

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

methanol propan-1-ol

Fig. 8.1

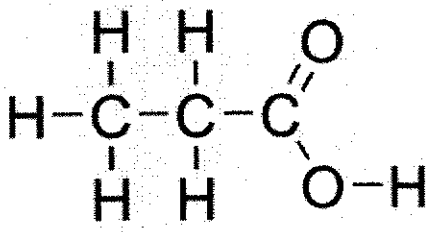
(a) Draw the structural formula of an isomer of propan-1-ol.



[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 $KMnO_4$

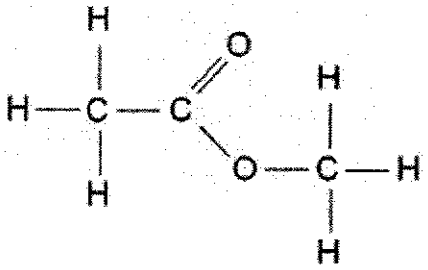
(ACCEPT oxidation of propan-1-ol has occurred OWTTE)

[2]

(characteristic of ester)

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

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

[1] correctly calculated mole of each element

[1] C_2H_2O

Empirical formula of **X** is 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.

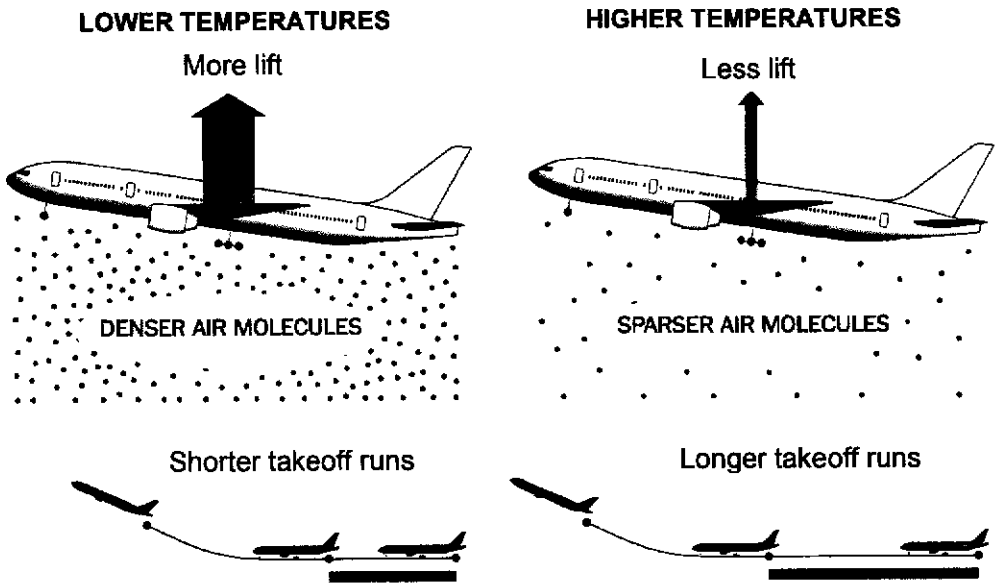


Fig. 9.1[2]

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.

The operating principle of a SOE steam electrolyser is shown in Fig. 9.3.

for part (e)

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]

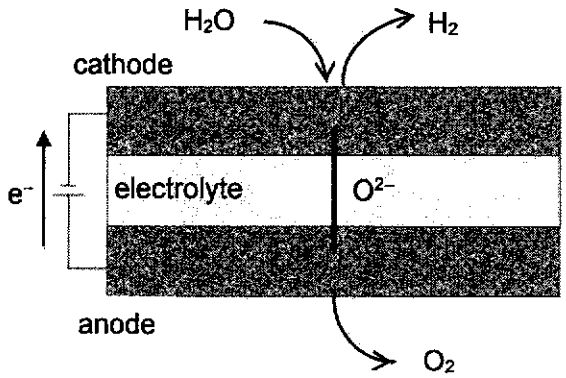


Fig. 9.3

(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	$H_2O + 2e^- \rightarrow H_2 + O^{2-}$
anode	$2O^{2-} \rightarrow O_2 + 4e^-$

[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)

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

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

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

[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

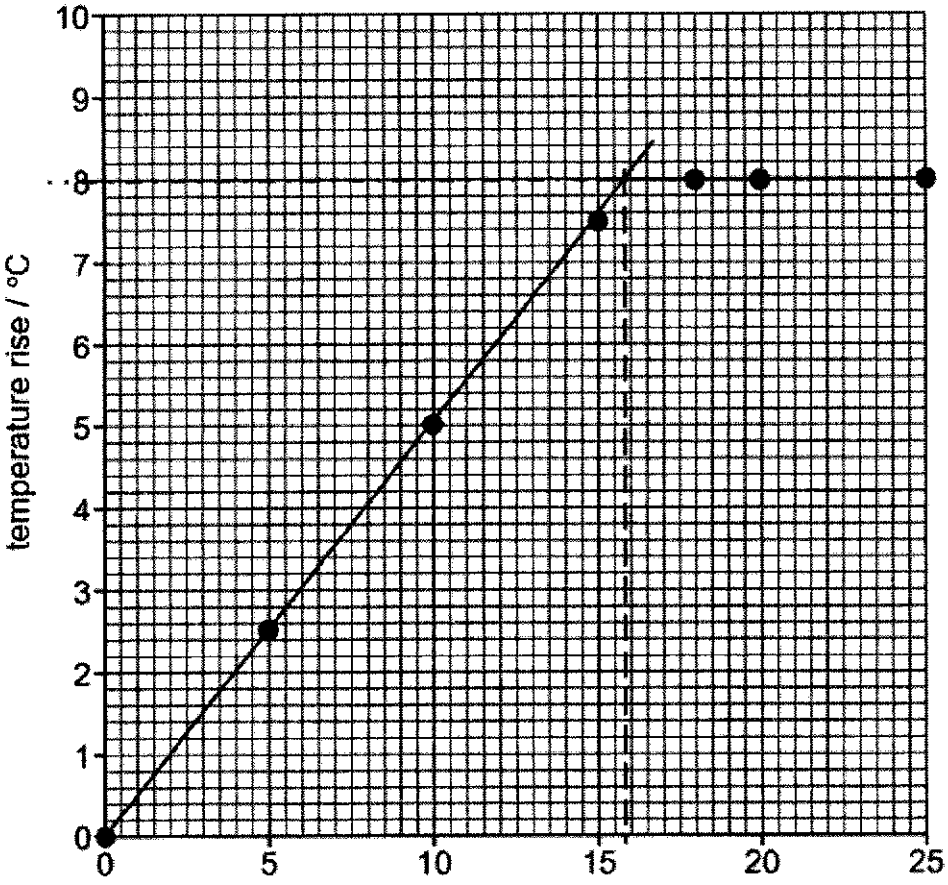
experiment number	volume of **P** /cm^3	volume of water /cm^3	volume of **Q** /cm^3	initial temperature /°C	highest temperature reached /°C	temperature rise /°C
1	25.0	20	5.0	23.0	25.5	2.5
2	25.0	15	10.0	24.5	29.5	5.0
3	25.0	10	15.0	25.0	32.5	7.5
4	25.0	7	18.0	25.0	33.0	8.0
5	25.0	5	20.0	25.5	33.5	8.0
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 = ½ × 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**.

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

OR $Al_2(SO_4)_3 \rightarrow 2Al + 3SO_2 + 3O_2$

[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