



**SINGAPORE CHINESE GIRLS' SCHOOL
PRELIMINARY EXAMINATION
SECONDARY FOUR**

CANDIDATE NAME

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CLASS

4		

REGISTER
NUMBER

CENTRE
NUMBER

INDEX NUMBER

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CHEMISTRY**6092/01****PAPER 1** Multiple Choice**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 register number on the 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.

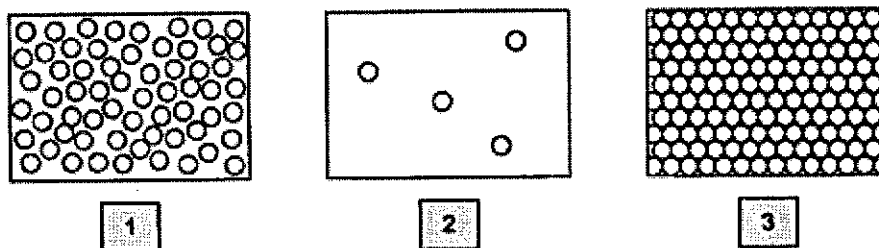
Any rough working should be done in this booklet.

A copy of the Periodic Table is printed on page 17.

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

This question paper consists of **17** printed pages and 1 blank page

- 1 Substance X can occur in three different physical states as shown in the diagram.



Which statement is correct?

- A** In state 1, the particles vibrate in fixed positions.
B Diffusion occurs in the phase change from state 3 to state 2.
C The volume of the substance in state 1 is fixed.
D Condensation occurs in the phase change from state 1 to state 2.

- 2 The rate of diffusion of two gases, methane and propene, is investigated.
 Which gas diffuses at a faster rate and why?

	Faster gas	Reason
A	propene	It is unsaturated so is more reactive.
B	propene	It is lighter so moves faster.
C	methane	It has a lower molecular mass.
D	methane	It has a lower boiling point.

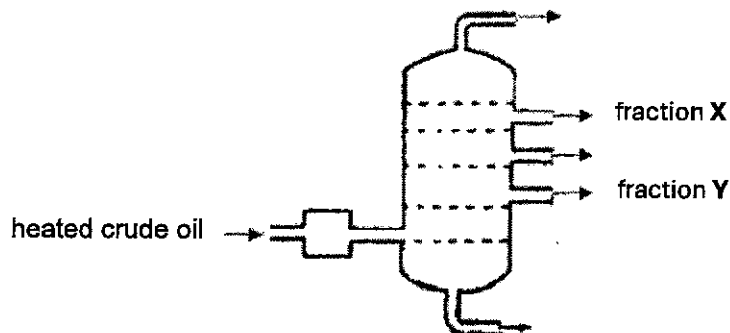
- 3 The table gives the results of chromatography experiments that were carried out on some known food colours, using the same solvent.

Name of food colour	Distance from start line to solvent front (mm)	Distance moved by food colour spot (mm)
Ponceau 4R	60	42
Carmoisine	74	45
Fast red	67	27
Erythrosine	58	17

Which food colour is the most soluble in the solvent used?

- A** Ponceau 4R
B Carmoisine
C Fast red
D Erythrosine

- 4 The diagram shows the fractional distillation of crude oil.

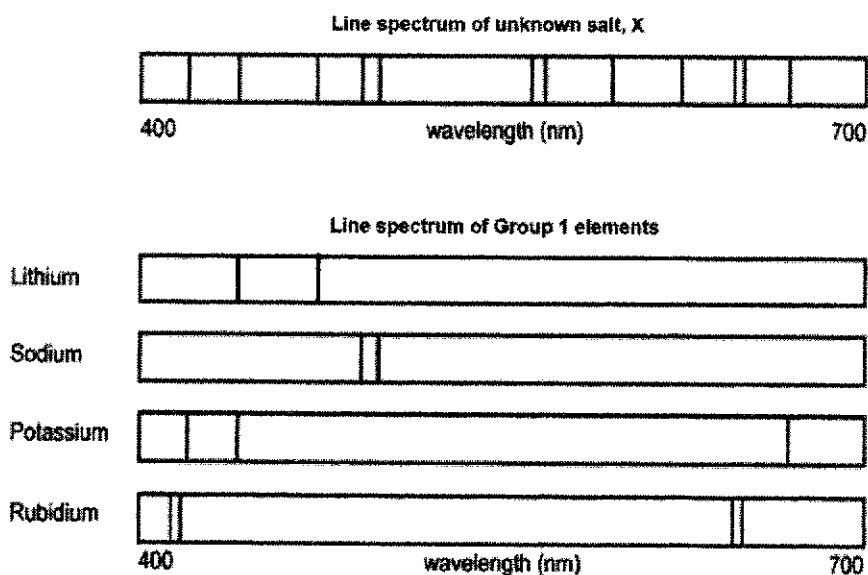


Which statement about fractions X and Y is correct?

- A X is more flammable than Y.
- B X is more viscous than Y.
- C X burns with a sootier flame than Y.
- D X has longer chain molecules than Y.

- 5 An unknown salt sample, X, has been sent off for analysis and identification using flame emission spectroscopy. In this kind of spectroscopy, atoms of an element each give a characteristic pattern of lines which is known as a line spectrum.

A small sample of X loaded into a flame emission spectroscope and its line spectrum was generated. The line spectrum of X was compared to the line spectra of Group 1 elements to see if the metal ions present in X could be identified. The line spectra are shown below.



Which element is not present in X?

- A Lithium
- B Sodium
- C Potassium
- D Rubidium

- 6 A student reacted excess calcium with hydrochloric acid and carried out a series of tests on the reaction mixture. The results of the tests are given in the table.

Which observation does not tell you that this reaction has occurred?

	Test	Observation
A	Add dilute nitric acid followed by aqueous silver nitrate	White precipitate
B	Weigh the reaction mixture at the start and at the end	Mass decreases
C	Test the pH of the mixture at the start and after 30 s	pH increases
D	Add aqueous sodium hydroxide until no further change	White precipitate insoluble in excess sodium hydroxide

- 7 Elements X and Y combine to form an ionic compound.
 Atoms of X have more protons than atoms of Y.
 Atoms of Y have more valence electrons than atoms of X.

Which statement is correct?

- A Ions of X are negatively charged.
 B Atoms of X have more electron shells than atoms of Y.
 C X and Y are in the same period of the Periodic Table.
 D X and Y are in the same group of the Periodic Table.

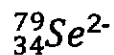
- 8 Iridium has two isotopes, ^{191}Ir and ^{193}Ir . The percentage abundance of each isotope in a sample of iridium is given in the table.

Mass number	191	193
Percentage abundance	62.7%	37.3%

What is the relative atomic mass of the sample of iridium?

- A 191.2
 B 191.6
 C 191.7
 D 192.5

- 9 A selenide ion has the following notation.



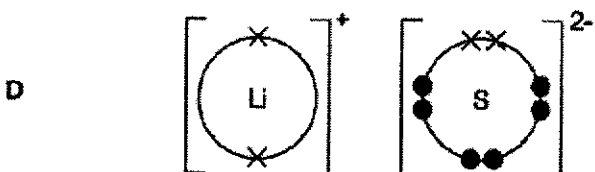
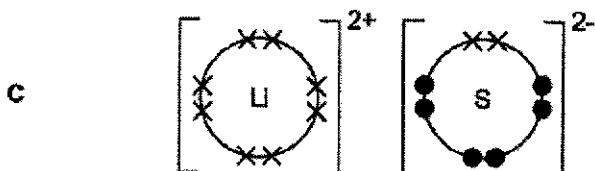
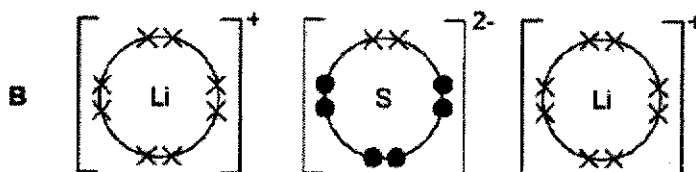
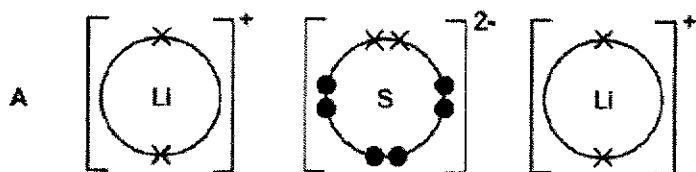
Which row correctly describes the sub-atomic particles in the selenide ion?

	Protons	Neutrons	Electrons
A	32	79	34
B	34	45	32
C	34	45	36
D	45	34	36

- 10 Which element does not form a stable ion with the same electronic configuration as neon?

- A Magnesium
 B Fluorine
 C Sodium
 D Sulfur

- 11 Which of the dot-and-cross diagrams shows the correct arrangement of electrons in the valence shells of lithium sulfide?



- 12 CH_4 , H_2O and HCl are covalent compounds.

Which atoms in these compounds do not use all their outer shell electrons in bonding?

- A C and H
- B C and O
- C O and Cl
- D Cl and C

- 13 An impure sample of calcium carbonate with a mass of 1.70 g was reacted with excess hydrochloric acid and 360 cm^3 of carbon dioxide was collected at room temperature and pressure.

What is the percentage purity of the calcium carbonate?

- A 75%
- B 88%
- C 90%
- D 98%

- 14 The relative molecular masses of four compounds are given. A student has a 1.0 g sample of each compound.

Which sample contains the highest number of moles of oxygen atoms?

	compound	relative molecular mass
A	Al_2O_3	102
B	CuO	80
C	H_2SO_4	98
D	HNO_3	63

- 15 50.0 cm^3 of 0.10 mol/dm^3 silver nitrate, AgNO_3 , is added to 150.0 cm^3 of 0.05 mol/dm^3 of sodium iodide, NaI , in a beaker.

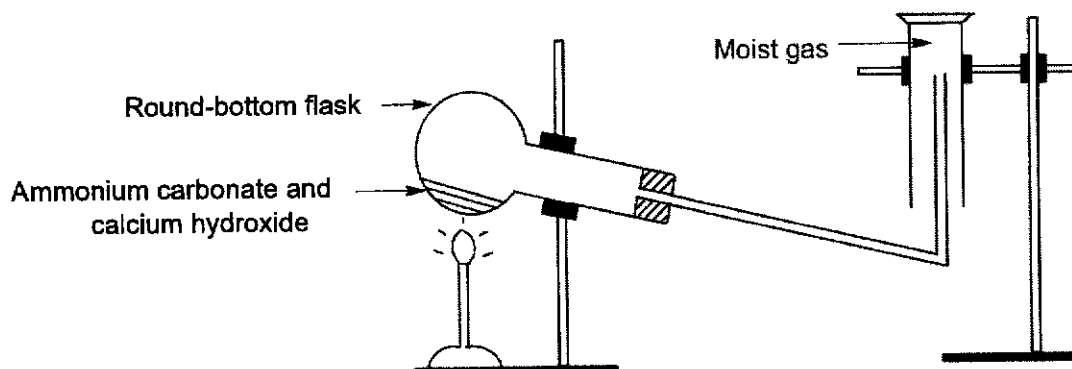
After the reaction, solid silver iodide is present in the beaker. What else is present in the mixture?

- A Ag^+ , Na^+ , NO_3^- only
- B Na^+ , I^- , NO_3^- only
- C Na^+ , I^- only
- D Na^+ , NO_3^- only

- 16 Water is formed when oxygen combines with hydrogen. What mass of oxygen combines with 6 g of hydrogen?
- A 12 g
B 48 g
C 96 g
D 144 g
- 17 Which compound has the lowest percentage by mass of nitrogen?
- A $(\text{NH}_2)_2\text{CO}$
B $(\text{NH}_4)_2\text{SO}_4$
C $(\text{NH}_4)_3\text{PO}_4$
D NH_4NO_3
- 18 Cobalt(II) chloride is a soluble salt. What reactants could be used to produce cobalt(II) chloride and what is a suitable method to produce a pure sample of the salt?

	Reactants	Method
A	cobalt(II) nitrate and hydrochloric acid	excess solid + acid
B	cobalt(II) hydroxide and sodium chloride	titration
C	cobalt(II) sulfate and sodium chloride	precipitation
D	cobalt(II) carbonate and hydrochloric acid	excess solid + acid

- 19 Ammonium carbonate reacts with calcium hydroxide to produce a colourless, pungent gas. The set-up for preparation and collection of a moist sample of the gas is shown.



Which statements about the moist gas are correct? The gas

- 1 turns universal indicator blue
 - 2 is denser than air
 - 3 is very soluble in water
 - 4 can be dried by passing it through concentrated sulfuric acid
- A** 1 and 3 only
B 2 and 4 only
C 1, 3 and 4 only
D 1, 2 and 4 only
- 20 Which property of elements increases from left to right of Period 3 of the Periodic Table?
- A** number of outer shells
B metallic character
C tendency to get reduced
D melting points
- 21 A solution of a lithium halide and a halogen are mixed. A reaction occurs and the mixture darkens in colour.
- What are the reactants?
- A** bromine and lithium chloride
B iodine and lithium fluoride
C chlorine and lithium iodide
D chlorine and lithium fluoride

- 22 Part of the Periodic Table is shown. The letters are not symbols of the elements.

Which statement is correct?

- A I and L can react with oxygen to form neutral oxides.
 B E and K react with acids to form coloured salts.
 C E and M form chlorides that conduct electricity at room temperature.
 D J reacts with M to form a covalent compound with formula MJ.

- 23 The following section of the reactivity series shows a newly discovered element Y.

Ca

Mg

Fe

Y

H

Cu

The carbonate of Y has the formula YCO_3 .

Which of the equations shows a reaction that would take place?

- A $2Y(s) + Cu^{2+}(aq) \rightarrow 2Y^+(aq) + Cu(s)$
 B $3Y(s) + Fe_2O_3(s) \rightarrow 2Fe(s) + 3YO(s)$
 C $YOH(aq) + HCl(aq) \rightarrow YCl(aq) + H_2O(l)$
 D $YO(s) + CO(g) \rightarrow Y(s) + CO_2(g)$

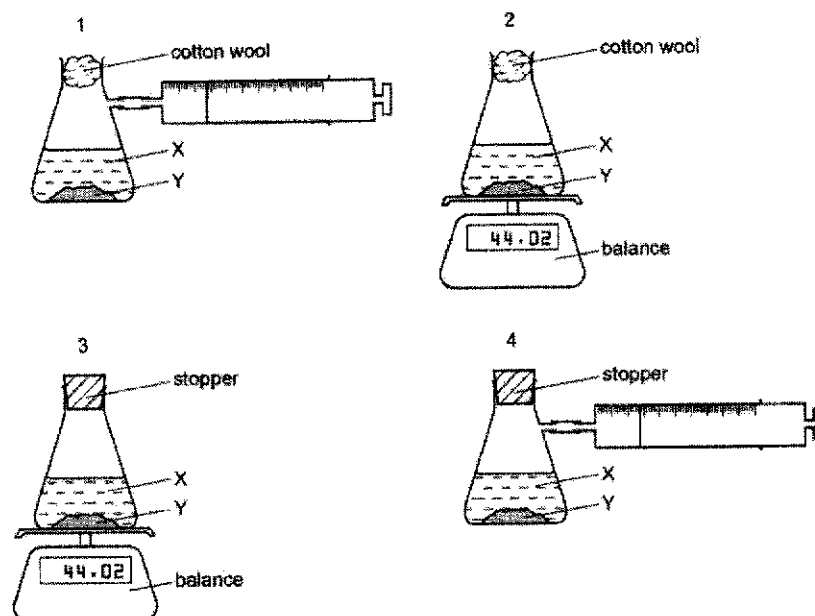
- 24 Solder is an alloy of lead and tin.
 Which statement about solder is correct?

- A It can be represented by the chemical formula, $PbSn$.
 B It has a higher melting point than lead and tin.
 C It consists of positive ions in a sea of delocalised electrons.
 D It is formed by a chemical reaction between lead and tin.

25 Attaching pieces of magnesium to underground iron pipes can protect the iron from corrosion. Which reaction protects the iron from corrosion?

- A $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Fe}(\text{s})$
 B $\text{Fe}(\text{s}) \rightarrow \text{Fe}^{2+}(\text{aq}) + 2\text{e}^{-}$
 C $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Mg}(\text{s})$
 D $\text{Mg}(\text{s}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-}$

26 A liquid X reacts with solid Y to form a gas.



Which two diagrams show suitable methods for investigating the speed of the reaction?

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

- 27 In an experiment, a student reacted excess magnesium with 100 cm³ of 1.0 mol/dm³ of acids **P** and **Q** in separate conical flasks.

The following observations were recorded.

1. Acid **P** produces the gas at a faster rate than acid **Q**.
2. Both reactions produced the same volume of gas at the end of the reaction.

What could acids **P** and **Q** be?

	Acid P	Acid Q
A	hydrochloric acid	propanoic acid
B	sulfuric acid	hydrochloric acid
C	propanoic acid	nitric acid
D	sulfuric acid	propanoic acid

- 28 Four electrolytes are listed. Each is electrolysed using inert electrodes. How many of these electrolytes would produce a colourless gas at both the cathode and anode?

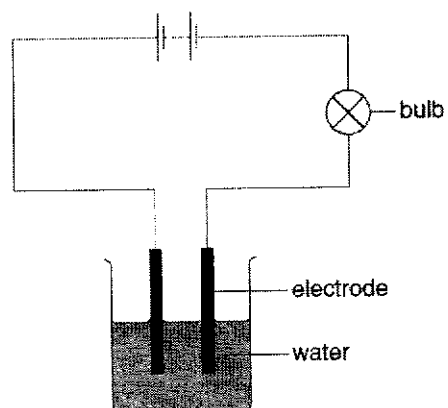
- dilute aqueous copper(II) chloride
- dilute aqueous iron(II) chloride
- concentrated hydrochloric acid
- dilute aqueous sodium hydroxide

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

- 29 Which statement about the electrolysis of molten magnesium chloride is incorrect?

- A** Magnesium ions gain electrons at the cathode.
B Chloride ions are reduced at the anode.
C Electrolysis of 47.5 g of molten magnesium chloride produces 12 dm³ of chlorine.
D The process is endothermic.

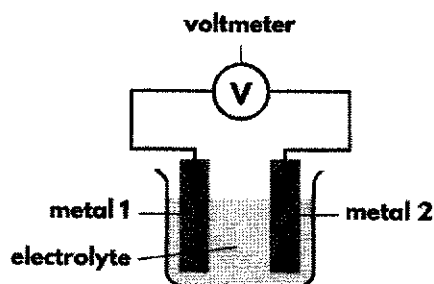
- 30 A student sets up the apparatus shown. The bulb does not light up.



After the student adds substance X to the water, the bulb lights up. What is X?

- A copper(II) carbonate
- B carbon
- C zinc sulfate
- D ethanol

- 31 Two metals and an electrolyte can be used in a simple cell to produce an electric current. The table shows the voltage produced when two different metals are used.



metal 1	metal 2	voltage/ V
copper	zinc	1.10
copper	nickel	0.60
silver	zinc	1.56
silver	nickel	1.06
silver	iron	1.25

- A student made some deductions based on the information given. Which one is correct?
- A** Nickel is more reactive than iron.
B The greater the difference in reactivity between the metals, the smaller the voltage produced.
C The voltage produced when **metal 1** and **2** are copper and iron would be about 0.80V.
D In a simple cell with copper and silver as the metals used, silver will be oxidised.
- 32 These statements refer to hydrogen and its use as a fuel. Which statements are correct?
- Both water and hydrocarbons can be a source of hydrogen.
 - In a fuel cell, hydrogen reacts directly with oxygen to generate electricity.
 - The reaction taking place in a hydrogen fuel cell is a redox reaction.
- A** 1 and 2 only
B 2 and 3 only
C 1 and 3 only
D 1, 2 and 3

33 The formation of liquid water from hydrogen and oxygen may occur in three stages.

- 1 $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 4\text{H}(\text{g}) + 2\text{O}(\text{g})$
- 2 $4\text{H}(\text{g}) + 2\text{O}(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$
- 3 $2\text{H}_2\text{O}(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$

Which stage(s) is/are endothermic?

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

34 Which reactions involve oxidation and reduction?

- 1 chlorine gas reacting with aqueous potassium iodide
- 2 dilute sulfuric acid reacting with magnesium
- 3 dilute hydrochloric acid reacting with aqueous sodium hydroxide

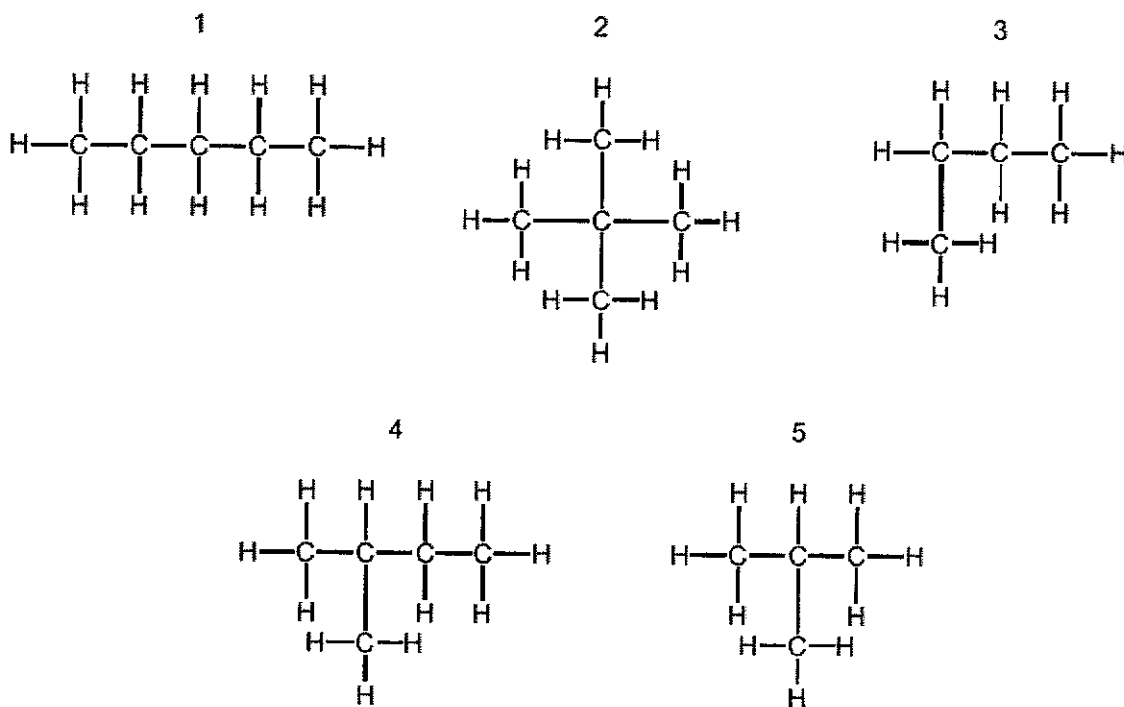
- A 1 and 2 only
- B 1 and 3 only
- C 2 and 3 only
- D 1, 2 and 3

35 Propane, C_3H_8 , reacts with chlorine in the presence of ultra-violet light. What are the possible products of this reaction?

- 1 $\text{C}_3\text{H}_7\text{Cl}$
- 2 $\text{C}_3\text{H}_6\text{Cl}_2$
- 3 HCl
- 4 Cl_2

- A 1 and 3 only
- B 1, 2 and 3 only
- C 1, 2 and 4 only
- D 2, 3 and 4 only

36 The diagrams show the structures of five hydrocarbons.



Which three hydrocarbons are isomers of each other?

- A 1, 2 and 3
- B 1, 2 and 4
- C 2, 3 and 4
- D 3, 4 and 5

37 Which statements about butanol are correct?

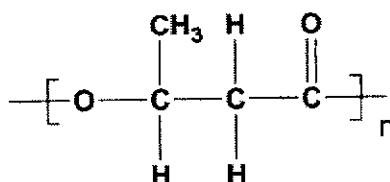
- 1 It is prepared by addition of hydrogen to butene.
- 2 It burns in excess oxygen to form carbon dioxide and steam.
- 3 It is oxidised by oxygen to form butanoic acid.
- 4 It is prepared from glucose by fermentation.

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

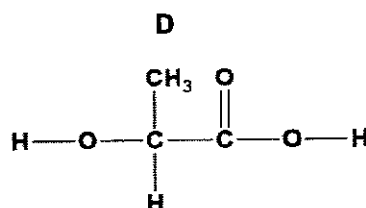
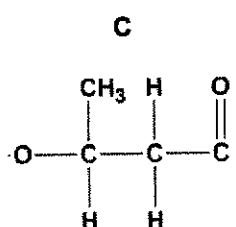
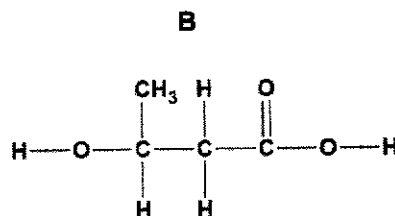
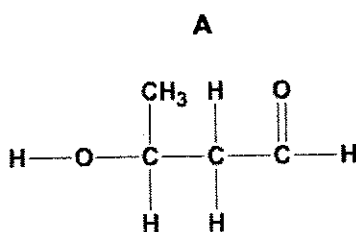
- 38 An ester has the formula $C_2H_5COOC_3H_7$. What are the names of the alcohol and carboxylic acid used to make this ester?

	Alcohol	Carboxylic Acid
A	ethanol	propanoic acid
B	propanol	ethanoic acid
C	propanol	propanoic acid
D	ethanoic acid	butanoic acid

- 39 Polyhydroxybutyric acid is a natural polymer produced by microorganisms as a form of energy storage. The structure of the polymer is as shown in the diagram.



Which diagram represents a monomer of polyhydroxybutyric acid?



- 40 A steel factory and a chemical plant are built near a city. The limestone buildings in the city begin to crumble. Which gas is most likely to have caused this damage?
- A carbon dioxide
 B carbon monoxide
 C oxygen
 D sulfur dioxide

The Periodic Table of Elements

		Group																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18										
		<table border="1" style="margin: auto;"> <tr> <td>1</td> <td>H</td> </tr> <tr> <td></td> <td>hydrogen</td> </tr> <tr> <td></td> <td>1</td> </tr> </table>																1	H		hydrogen		1				
1	H																										
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		<table border="1" style="margin: auto;"> <tr> <th colspan="2">Key</th> </tr> <tr> <td>proton (atomic) number</td> <td></td> </tr> <tr> <td>atomic symbol</td> <td></td> </tr> <tr> <td>name</td> <td></td> </tr> <tr> <td>relative atomic mass</td> <td></td> </tr> </table>																Key		proton (atomic) number		atomic symbol		name		relative atomic mass	
Key																											
proton (atomic) number																											
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3	4	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36										
Li lithium 7	Be beryllium 9	Sc scandium 45	Ti titanium 48	V vanadium 51	Cr chromium 52	Mn manganese 55	Fe iron 56	Co cobalt 59	Ni nickel 59	Cu copper 64	Zn zinc 65	Ga gallium 70	Ge germanium 73	As arsenic 75	Se selenium 79	Br bromine 80	Kr krypton 84										
11	12	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54										
Na sodium	Mg magnesium	Y yttrium	Zr zirconium	Nb niobium	Mo molybdenum	Tc technetium	Ru ruthenium	Rh rhodium	Pd palladium	Ag silver	Cd cadmium	In indium	Sn tin	Sb antimony	Te tellurium	I iodine	Xe xenon										
23	24	89	91	93	96	101	101	103	106	108	112	115	119	122	128	127	131										
K potassium	Ca calcium	La lanthanoids	Zr zirconium	Nb niobium	Mo molybdenum	Tc technetium	Ru ruthenium	Rh rhodium	Pd palladium	Ag silver	Cd cadmium	In indium	Sn tin	Sb antimony	Te tellurium	I iodine	Xe xenon										
37	38	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86										
Rb rubidium	Sr strontium	lanthanoids	Hf hafnium	Ta tantalum	W tungsten	Re rhenium	Os osmium	Ir iridium	Pt platinum	Au gold	Hg mercury	Tl thallium	Pb lead	Bi bismuth	Po polonium	At astatine	Rn radon										
85	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118										
Cs caesium	Ba barium	actinoids	Rf rutherfordium	Db dubnium	Sg seaborgium	Bh bohrium	Hs hassium	Mt meitnerium	Ds darmstadtium	Rg roentgenium	Cn copernicium	Nh nihonium	Fl flerovium	Mc moscovium	Lv livermorium	Ts tennessine	Og oganesson										
133	137	87	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118										
Fr francium	Ra radium	actinoids	Rf rutherfordium	Db dubnium	Sg seaborgium	Bh bohrium	Hs hassium	Mt meitnerium	Ds darmstadtium	Rg roentgenium	Cn copernicium	Nh nihonium	Fl flerovium	Mc moscovium	Lv livermorium	Ts tennessine	Og oganesson										
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	71	71	71										
La lanthanum 139	Ce cerium 140	Pt praseodymium 141	Nd neodymium 144	Pm promethium	Sm samarium 150	Eu europium 152	Gd gadolinium 157	Tb terbium 159	Dy dysprosium 163	Ho holmium 165	Er erbium 167	Tm thulium 169	Yb ytterbium 173	Lu lutetium 175	Lu lutetium 175	Lu lutetium 175	Lu lutetium 175										
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	103	103	103										
Ac actinium	Th thorium	Pa protactinium	U uranium	Np neptunium	Pu plutonium	Am americium	Cm curium	Bk berkelium	Cf californium	Es einsteinium	Fm fermium	Md mendelevium	No nobelium	Lr lawrencium	Lr lawrencium	Lr lawrencium	Lr lawrencium										
			231																								
			238																								

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.)

The Avogadro constant, L = 6.02 x 10²³ mol⁻¹

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SINGAPORE CHINESE GIRLS' SCHOOL
Preliminary Examination
Secondary Four

CANDIDATE
NAME

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CLASS

4		

REGISTER
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NUMBER

INDEX NUMBER

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CHEMISTRY

6092/02

Paper 2 Theory

20 August 2024

1 hour 45 minutes

READ THESE INSTRUCTIONS FIRST

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

Section A

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

Section B

Answer **one** question.
 Answer **all** questions in the spaces provided.

The number of marks is given in brackets [] at the end of each question or part question.
 A copy of the Periodic Table is printed on page 20.

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

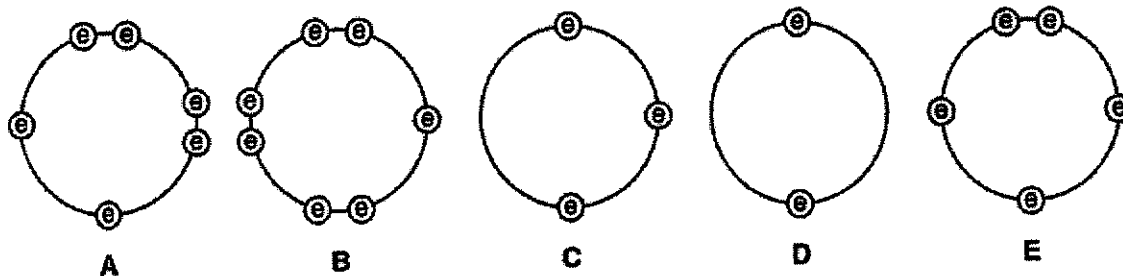
For Examiner's Use	
Section A	70
Section B	10
Total	80

This question paper consists of 20 printed pages.

Section A

Answer all questions

- 1 These diagrams show the electron arrangement in the outer shells of five elements, A to E. All elements are from Period 3 of the Periodic Table.



Use the letters **A** to **E** to answer the following questions.
You may use each letter once, more than once or not at all.

- (a) Which elements are most likely to be non-metals?

..... [1]

- (b) Which elements can act as reducing agents?

..... [1]

- (c) Which element has an atomic number of 16?

..... [1]

- (d) Which element will form three covalent bonds when it forms compounds?

..... [1]

- (e) Which two elements will form a compound with the formula of the type YZ_2 ?

..... [1]

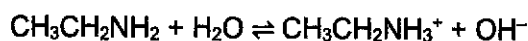
- (f) Which element will form an oxide that reacts with both acids and bases?

..... [1]

[Total: 6]

[Turn over]

- 2 Ethylamine, $\text{CH}_3\text{CH}_2\text{NH}_2$, behaves similarly to ammonia in terms of its chemical properties. The equation below shows what happens when ethylamine is dissolved in water.



- (a) According to the Brønsted-Lowry theory, an acid is defined as a species that can donate protons (H^+), while a base is a species that can accept protons.

Based on the Brønsted-Lowry theory and the given equation, explain whether ethylamine acts as an acid or a base.

.....
[1]

- (b) The pH scale is a method to measure the acidity or alkalinity of a substance. Predict the pH of an aqueous solution of ethylamine.

.....[1]

- (c) Explain, in terms of structure and bonding, why ethylamine has a low boiling point.

.....

[2]

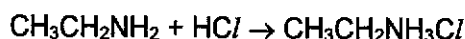
- (d) A student conducted an experiment to measure the electrical conductivity of an aqueous solution of sodium hydroxide and an aqueous solution of ethylamine.

Predict and explain which solution will be a better electrical conductor.

.....

[2]

- (e) Ethylamine can react with acids to form a salt. For example, ethylamine reacts with hydrochloric acid according to the equation below:



Deduce the formula of the salt formed when ethylamine reacts with sulfuric acid.

.....[1]

[Total: 7]

[Turn over]

- 3 Nitrogen oxides in the upper atmosphere cause damage to the ozone layer. Aircraft engines are one source of nitrogen oxides.

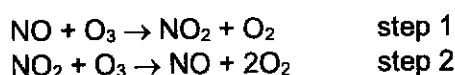
(a) (i) Explain how nitrogen oxides are formed in the engine of an aircraft.

.....
 [1]

(ii) Give one **natural** source of nitrogen oxides in the atmosphere.

..... [1]

- (b) Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two-step reaction.



(i) Use oxidation states to identify which element is **oxidised** in step 1.

element

change in oxidation state [2]

(ii) Write the equation for the overall reaction between nitrogen monoxide and ozone.

..... [1]

(iii) Hence, state the role of NO in the reaction.

..... [1]

- (c) Nitrogen oxides are removed from car exhaust emissions with the aid of the platinum catalyst within catalytic converters.

In a converter, nitrogen monoxide reacts with carbon monoxide.

(i) Briefly explain why carbon monoxide is harmful to humans.

.....

 [1]

(ii) Explain, in terms of colliding particles, how the presence of the platinum catalyst speeds up the reaction between nitrogen monoxide and carbon monoxide.

.....

 [2]

[Turn over]

- (iii) Cars fitted with catalytic converters still give out environmentally harmful gases. Name one environmentally harmful gas that is emitted in large amounts and describe the problem it causes.

.....

.....[1]

[Total: 10]

[Turn over]

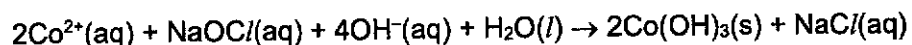
- 4 Cobalt can be extracted from one of its ores, linnæite (a cobalt sulfide compound containing traces of other metal compounds), through a 3-stage process.

Stage 1:

The ore is roasted to form a mixture of metals and metal oxides. The mixture is then heated with dilute sulfuric acid. Copper metal and an aqueous mixture of the sulfates of cobalt and other metals are formed.

**Stage 2:**

Sodium hypochlorite (NaOCl) is then added to the aqueous mixture leading to the formation of cobalt(III) hydroxide.

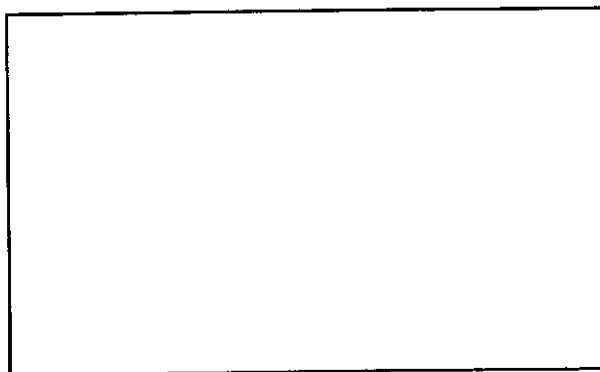
**Stage 3:**

Cobalt(III) hydroxide is decomposed to form cobalt(III) oxide and steam. The cobalt(III) oxide is further reduced by carbon to form cobalt metal.

- (a) (i) Why is copper metal left after treating with sulfuric acid in **Stage 1**?

.....
 [1]

- (ii) Draw a labelled diagram in the box below to show the structure of copper metal.



[1]

- (iii) A sample of cobalt sulfide contain 58% of cobalt and 42% by mass of sulfur. Determine the empirical formula of the cobalt sulfide.

empirical formula [2]

[Turn over]

- (b) (i) Explain using oxidation states whether sodium hypochlorite is an oxidising agent or reducing agent in **Stage 2**.

.....
.....
.....
..... [2]

- (ii) Draw a dot and cross diagram for the hypochlorite ion, ClO^- . It has a single bond between the chlorine atom and oxygen atom.
Show outer electrons only.

[2]

- (c) State how cobalt(III) hydroxide can be separated from the reaction mixture after **Stage 2** is completed.

..... [1]

- (d) Write chemical equations for the two reactions occurring in **Stage 3**.

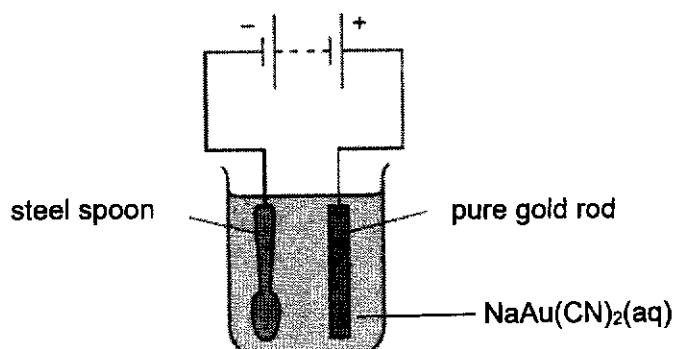
.....
..... [2]

[Total: 11]

[Turn over]

- 5 Electroplating is the process of using an electrical current to deposit a thin layer of metal onto an object. An example of electroplating is gold-plating.

During an experiment to gold-plate a spoon, the apparatus was set up as shown below:



Aqueous sodium dicyanoaurate, $\text{NaAu}(\text{CN})_2$, dissociates in water to form sodium ions, gold ions, and cyanide ions (CN^-).

- (a) Give the formula of all the ions that are attracted to the cathode, after aqueous $\text{NaAu}(\text{CN})_2$ dissociates.
 [1]
- (b) (i) Gold is deposited at the cathode. Write the half-equation for the reaction at the cathode.
 [1]
- (ii) Explain why gold ions are selectively discharged at the cathode.
 [1]
- (c) A student measures the concentration of the $\text{NaAu}(\text{CN})_2$ electrolyte before and after the gold-plating experiment. Predict and explain the results that the student will obtain.
 [2]
- (d) In a separate experiment, the gold electrode was replaced with graphite. Describe and explain a difference in observation during this experiment, compared to the experiment using the gold electrode. Include an equation in your explanation. You may assume that CN^- ions are inert and do not take part in the reaction.
 [3]

[Total: 8]

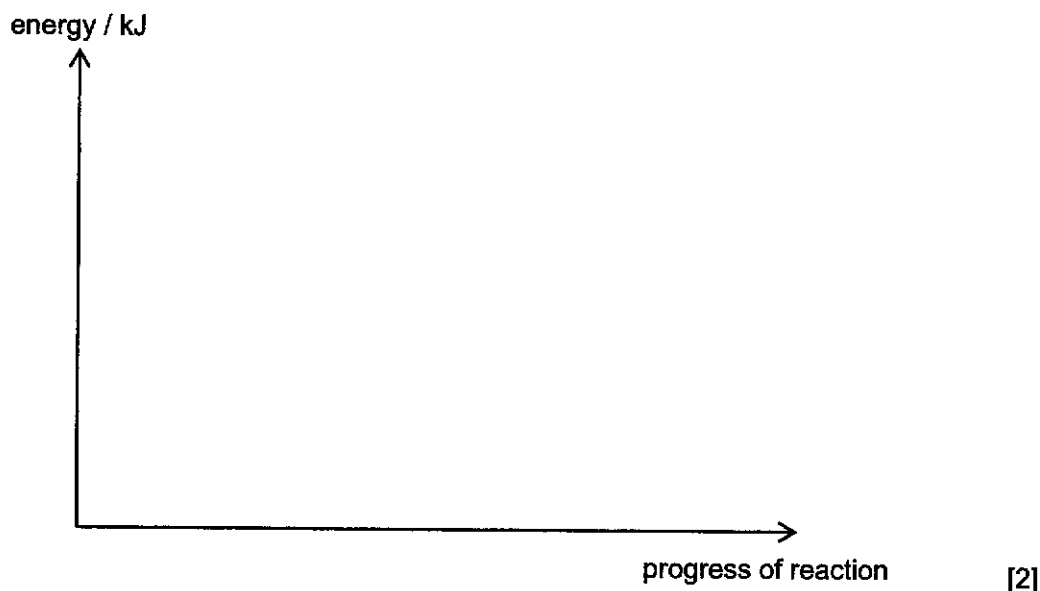
[Turn over]

6 The combustion of ethanol or hydrogen releases energy. This enables them to be used as fuel.

(a) The complete combustion of ethanol is represented by the following equation.



(i) Complete the energy profile diagram below for the combustion of ethanol. Your diagram should include labels for the reaction enthalpy change and activation energy.

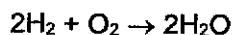


(ii) Explain, in terms of bond breaking and bond making, why this reaction is exothermic.

.....

 [2]

(b) The complete combustion of hydrogen is represented by the following equation.



Use the bond energies given in the table below to calculate the energy released on burning 1 mole of hydrogen.

bond	bond energy / kJ mol^{-1}
H-H	436
O=O	496
O-H	460

Energy released = [2]

[Turn over]

(c) Calculate the energy released when:

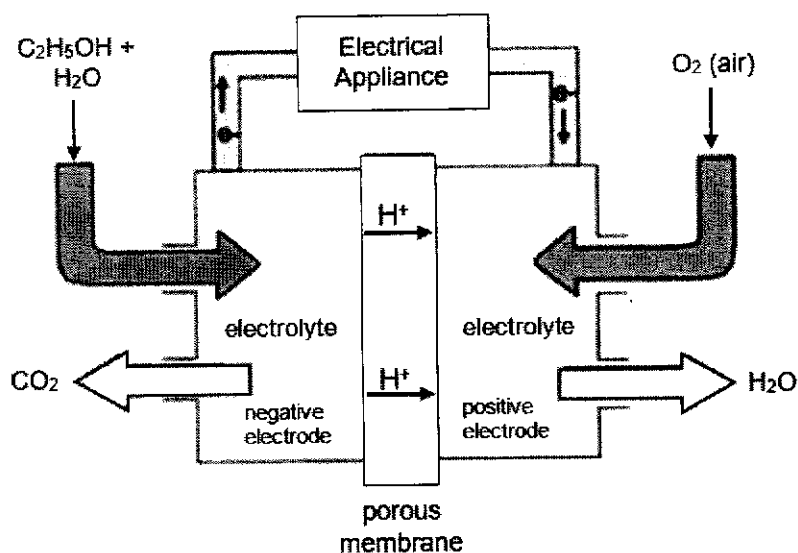
(i) 1 g of hydrogen is burned in excess oxygen.

Energy released = [1]

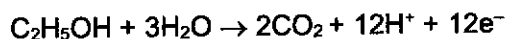
(ii) 1 g of ethanol is burned in excess oxygen.

Energy released = [1]

(d) Hydrogen and ethanol can also be used in fuel cells to power electric cars. The figure below shows a direct ethanol fuel cell (DEFC).



The half-equation for the DEFC at the negative electrode is:



(i) With reference to the diagram, what would be the half-equation at the positive electrode in a DEFC?

..... [1]

(ii) Write the overall equation for the reaction occurring in a DEFC.

..... [1]
[Total: 10]

[Turn over]

- 7 This question is about the chemistry of group 17 elements. Group 17 elements are also known as halogens or "salt-producers", based on their ability to form salts with sodium. Table 7.1 below shows some information regarding the size of the halogen atoms, also known as the atomic radius.

Table 7.1

element	atomic radius / $\times 10^{-12}$ m
fluorine	42
chlorine	79
bromine	94
iodine	140

Group 17 elements have the ability to gain electrons during chemical reactions. One method of measuring how readily elements gain electrons is by measuring their standard electrode potential (E^\ominus). E^\ominus is measured in volts (V) and the more positive the E^\ominus value, the greater the tendency of a species to gain electrons. E^\ominus is represented by half-equations showing the gain of electrons of the respective species. The E^\ominus of some of the halogens are shown in Table 7.2 below.

Table 7.2

element	E^\ominus / V
$F_2 + 2e^- \rightarrow 2F^-$	+2.87
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36
$Br_2 + 2e^- \rightarrow 2Br^-$	
$I_2 + 2e^- \rightarrow 2I^-$	+0.54

The melting points of some salts formed from group 17 elements are shown in Table 7.3 below.

Table 7.3

salt	melting point / $^\circ C$
sodium fluoride	993
sodium iodide	661
magnesium fluoride	1263

Melting an ionic compound involves overcoming the ionic bonds present between the ions. One way of measuring the strength of the ionic bonds in ionic compounds is to compare their Lattice Energy ($L.E.$). The $L.E.$ of ionic compounds can be determined by the formula:

$$L.E. \propto \frac{q^+ \times q^-}{r^+ + r^-}$$

where q^+ is the charge of the cation

q^- is the charge of the anion

r^+ is the radius of the cation

r^- is the radius of the anion

α is the mathematical symbol for "proportionate to"

Besides reacting with metals to form salts, group 17 elements react with hydrogen to form hydrogen halides. The bond energies of the hydrogen-halogen bond of some hydrogen halides are shown below in Table 7.4.

Table 7.4

bond	bond energy / kJ mol ⁻¹
H-F	562
H-Cl	431
H-Br	366
H-I	299

The hydrogen halides can dissolve in water to form aqueous acids. The acids produced can then undergo dissociation according to the general equation:



During the dissociation of the acids, the H-X bond is broken in the process.

The strength of an acid can be quantified by the acid dissociation constant, K_a . The larger the magnitude of K_a , the stronger the acid. Table 7.5 shows the K_a values of some aqueous acids formed from hydrogen halides:

Table 7.5

aqueous acid	K_a / mol dm ⁻³
HF(aq)	6.6×10^{-4}
HCl(aq)	1.4×10^6
HBr(aq)	1.0×10^9
HI(aq)	3.2×10^9

- (a) Describe and explain the trend in atomic radius shown in Table 7.1.

.....

 [2]

- (b) (i) The E^\ominus value for bromine is not given in Table 7.2. State a possible E^\ominus value for bromine.

..... [1]

- (ii) Hence or otherwise, arrange the group 17 elements shown in Table 7.2 based on their strength as oxidising agents, starting with the strongest oxidising agent first.

..... [1]

- (c) Use suitable information provided in the question to explain the differences in melting points of the salts shown in Table 7.3.

.....

 [2]

[Turn over]

- (d) Describe the trend in the strength of the aqueous acids shown in Table 7.5. Use data from Table 7.4 to suggest an explanation for the trend.

.....

.....

.....

..... [2]

The aqueous acids in Table 7.5 can be reacted with magnesium metal to liberate hydrogen gas. 50 cm³ of 0.1 mol/dm³ HBr(aq) was reacted with excess magnesium at room temperature and pressure. The volume of gas evolved over time is plotted in **Figure 7.1** below:

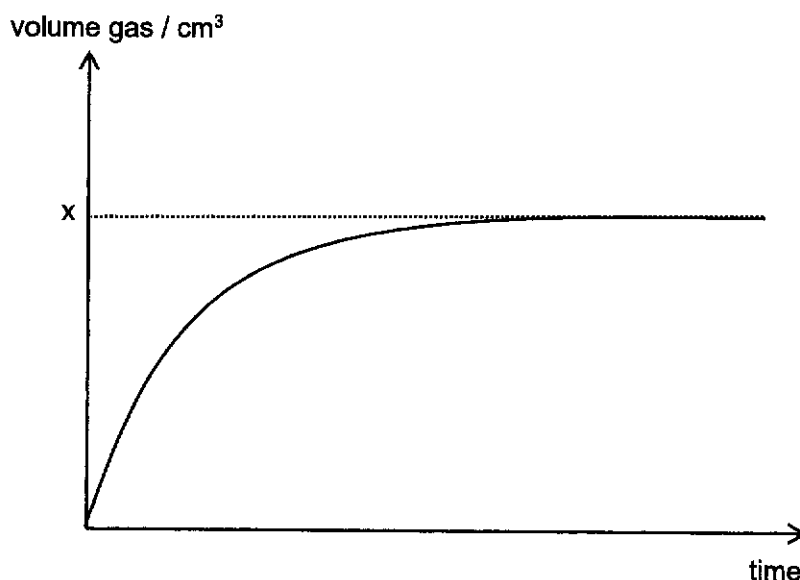


Figure 7.1

- (e) (i) Calculate the volume of hydrogen produced, x , shown in **Figure 7.1**.

[2]

- (ii) Sketch, on **Figure 7.1**, the graph that would be obtained for the reaction between 50 cm³ of 0.1 mol/dm³ HF(aq) and excess magnesium, assuming all other conditions remain the same. Label your graph as HF.

[1]

[Total: 11]

[Turn over]

- 8 A company manufactures polymers. It sells one of its polymers under the trade name of "PB-1".

The table shows some information about PB-1. The term "softening temperature" is used for materials that have no definite melting point.

structure	molecular mass	softening temperature
$\left[\begin{array}{c} \text{CH} - \text{CH}_2 \\ \\ \text{CH}_2\text{CH}_3 \end{array} \right]_n$	5600	115 °C

- (a) (i) Draw the structural formula of the monomer used to make PB-1.

[1]

- (ii) Name this monomer.

.....[1]

- (iii) What type of polymerisation occurs when PB-1 forms from its monomers?

.....[1]

- (b) The company sells two types of PB-1.

The polymer in the table is low molecular mass PB-1.

- (i) Calculate the number of monomer units in each molecule of low molecular mass PB-1.

Number of monomer units [1]

[Turn over]

- (ii) High molecular mass *PB-1* has different properties.

Suggest the softening temperature of high molecular mass *PB-1*.
Explain your answer.

Softening temperature °C

Explanation

.....[2]

- (iii) Explain why *PB-1* has no definite melting point.

.....

.....[1]

[Total: 7]

[Turn over]

Section B

Answer one question from this section.

- 9 The table shows some information about the homologous series of a class of organic compounds called acyl chlorides.

name	condensed formula	displayed formula
ethanoyl chloride	CH_3COCl	
	$\text{C}_2\text{H}_5\text{COCl}$	
butanoyl chloride	$\text{C}_3\text{H}_7\text{COCl}$	

- (a) (i) Fill in the table to show the name and displayed formula of the acyl chloride that occurs between ethanoyl chloride and butanoyl chloride in the homologous series. [1]

- (ii) Explain how you can tell that these molecules are from the same homologous series.

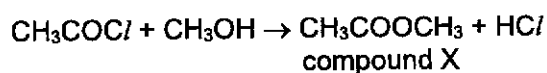
.....

[2]

- (iii) Predict the condensed formula of the acyl chloride that contains 7 carbon atoms.

.....[1]

- (b) Ethanoyl chloride reacts with methanol in the following reaction.



- (i) What is the name of compound X?

.....[1]

- (ii) When 64 g of methanol was reacted with excess ethanoyl chloride, 140 g of compound X was obtained. Calculate the percentage yield of compound X.

[2]

[Turn over]

- (iii) Ethanoic acid also reacts with methanol.
Write an equation for the reaction of ethanoic acid and methanol.

.....[1]

- (iv) Give one similarity and one difference between the reaction of ethanoyl chloride with methanol and the reaction of ethanoic acid with methanol.

similarity

.....

difference

.....[2]

[Total: 10]

[Turn over]

- 10 Table 10.1 shows the formulae of the first three members of the alcohol homologous series.

Table 10.1

alcohol	formula
methanol	CH ₃ OH
ethanol	C ₂ H ₅ OH
propanol	C ₃ H ₇ OH

- (a) State the general formula of the alcohol homologous series.

.....[1]

- (b) Ethanol can be manufactured from either ethene or glucose.

- (i) Write an equation for the production of ethanol from ethene and state the conditions under which the reaction takes place.

.....

[2]

- (ii) The fermentation of glucose can be represented by the following equation.



When 3.6 kg of glucose was fermented, 1.5 kg of ethanol was obtained. Calculate the percentage yield of ethanol.

[3]

- (iii) Explain why ethanol made from ethene is a non-renewable fuel but that made from glucose is a renewable fuel.

.....

[2]

[Turn over]

(c) Propanol reacts in a similar way to ethanol.

- (i) Name the organic product of the reaction between propanol and warm, acidified potassium manganate(VII).

.....[1]

- (ii) Draw the structure of the compound formed when the organic product in (c)(i) reacts with ethanol.

[1]
[Total: 10]

[Turn over]

The Periodic Table of Elements

		Group																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3	Li lithium 7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	Be beryllium 9	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <p>Key</p> <p>proton (atomic) number</p> <p>atomic symbol</p> <p>name</p> <p>relative atomic mass</p> </div>																	
11	Na sodium 23	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
12	Mg magnesium 24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
19	K potassium 39	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
37	Rb rubidium 85	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
55	Cs caesium 133	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
87	Fr francium	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
21	Sc scandium 45	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
39	Y yttrium 89	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
57-71	lanthanoids	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
89-103	actinoids	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
57	La lanthanum 139	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
89	Ac actinium	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

5	B boron 11	6	C carbon 12	7	N nitrogen 14	8	O oxygen 16	9	F fluorine 19	10	Ne neon 20
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
31	Ga gallium 70	32	Ge germanium 73	33	As arsenic 75	34	Se selenium 79	35	Br bromine 80	36	Kr krypton 84
49	In indium 115	50	Sn tin 119	51	Sb antimony 122	52	Te tellurium 128	53	I iodine 127	54	Xe xenon 131
81	Tl thallium 204	82	Pb lead 207	83	Bi bismuth 209	84	Po polonium	85	At astatine	86	Rn radon
113	Nh nihonium	114	Fl flerovium	115	Mc moscovium	116	Lv livermorium	117	Ts tennessine	118	Og oganesson
67	Ho holmium 165	68	Er erbium 167	69	Tm thulium 169	70	Yb ytterbium 173	71	Lu lutetium 175		
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 dm³ at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

2024 4OLP Preliminary Exam Chemistry 6092 Paper 1 answers

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



SINGAPORE CHINESE GIRLS' SCHOOL
Preliminary Examination
Secondary Four

CANDIDATE
NAME

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CLASS

4		
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REGISTER
NUMBER

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CENTRE
NUMBER

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INDEX NUMBER

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CHEMISTRY

6092/02

Paper 2 Theory

20 August 2024

1 hour 45 minutes

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Section A

Answer **all** questions.

Write your answers in the spaces provided.

Section B

Answer **one** question.

Answer **all** questions in the spaces provided.

The number of marks is given in brackets [] at the end of each question or part question.

A copy of the Periodic Table is printed on page 20.

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

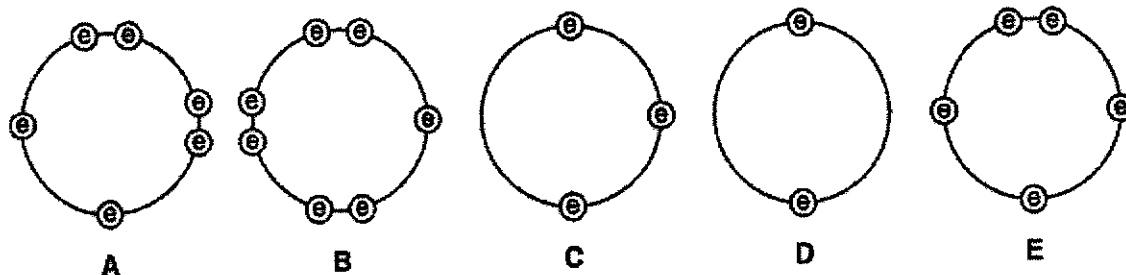
For Examiner's Use	
Section A	70
Section B	10
Total	80

This question paper consists of 20 printed pages.

Section A

Answer all questions

- 1 These diagrams show the electron arrangement in the outer shells of five elements, A to E. All elements are from Period 3 of the Periodic Table.



Use the letters A to E to answer the following questions. You may use each letter once, more than once or not at all.

- (a) Which elements are most likely to be non-metals?

A, B, E [1]

- (b) Which elements can act as reducing agents?

C, D [1]

- (c) Which element has an atomic number of 16?

A [1]

- (d) Which element will form three covalent bonds when it forms compounds?

E [1]

- (e) Which two elements will form a compound with the formula of the type YZ_2 ?

D and B / A and B [1]

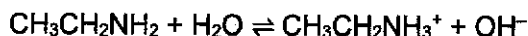
- (f) Which element will form an oxide that reacts with both acids and bases?

C [1]

[Total: 6]

[Turn over]

- 2 Ethylamine, $\text{CH}_3\text{CH}_2\text{NH}_2$, behaves similarly to ammonia in terms of its chemical properties. The equation below shows what happens when ethylamine is dissolved in water.



- (a) According to the Brønsted-Lowry theory, an acid is defined as a species that can donate protons (H^+), while a base is a species that can accept protons.

Based on the Brønsted-Lowry theory and the given equation, explain whether ethylamine acts as an acid or a base.

Ethylamine acts as a base as it accepts a proton from water.

.....[1]

- (b) The pH scale is a method to measure the acidity or alkalinity of a substance. Predict the pH of an aqueous solution of ethylamine.

8–11

.....[1]

- (c) Explain, in terms of structure and bonding, why ethylamine has a low boiling point.

Only a small amount of energy is required to overcome the weak intermolecular forces of

attraction [1] in ethylamine's simple molecular structure. [1]

.....[2]

- (d) A student conducted an experiment to measure the electrical conductivity of an aqueous solution of sodium hydroxide and an aqueous solution of ethylamine.

Predict and explain which solution will be a better electrical conductor.

NaOH [1] will be a better electrical conductor as it is a strong base that is fully ionised to

produce more mobile ions [1].

.....[2]

- (e) Ethylamine can react with acids to form a salt. For example, ethylamine reacts with hydrochloric acid according to the equation below:



Deduce the formula of the salt formed when ethylamine reacts with sulfuric acid.

$(\text{CH}_3\text{CH}_2\text{NH}_3)_2\text{SO}_4$

.....[1]

[Total: 7]

[Turn over]

- 3 Nitrogen oxides in the upper atmosphere cause damage to the ozone layer. Aircraft engines are one source of nitrogen oxides.

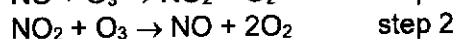
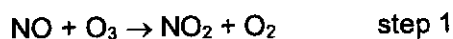
(a) (i) Explain how nitrogen oxides are formed in the engine of an aircraft.

At the high operating temperature of an aircraft engine, nitrogen and oxygen from air react to form nitrogen oxides. [1]

(ii) Give one **natural** source of nitrogen oxides in the atmosphere.

Lightning activity [1]

- (b) Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two-step reaction.



(i) Use oxidation states to identify which element is **oxidised** in step 1.

element N [1]

change in oxidation state +2 to +4 [1] [2]

(ii) Write the equation for the overall reaction between nitrogen monoxide and ozone.



(iii) Hence, state the role of NO in the reaction.

Catalyst [1] [1]

- (c) Nitrogen oxides are removed from car exhaust emissions with the aid of the platinum catalyst within catalytic converters.

In a converter, nitrogen monoxide reacts with carbon monoxide.

(i) Briefly explain why carbon monoxide is harmful to humans.

CO binds irreversibly / binds more readily to haemoglobin in blood and reduces the ability of blood to transport oxygen in the body. [1]

[1]

(ii) Explain, in terms of colliding particles, how the presence of the platinum catalyst speeds up the reaction between nitrogen monoxide and carbon monoxide.

The catalysts on a catalytic converter lower the activation energy of the reaction by providing an alternative reaction pathway [1]. More particles possess energy greater than or equal to activation energy, resulting in a higher frequency of effective collisions. [1] [2]

[Turn over]

- (iii) Cars fitted with catalytic converters still give out environmentally harmful gases. Name one environmentally harmful gas that is emitted in large amounts and describe the problem it causes.

Carbon dioxide is emitted in large quantities, which leads to global warming and
causes the melting of polar ice caps and flooding of low-lying areas.[1]

[Total: 10]

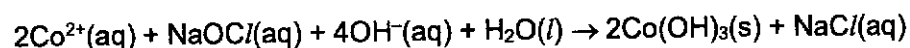
- 4 Cobalt can be extracted from one of its ores, linnaeite (a cobalt sulfide compound containing traces of other metal compounds), through a 3-stage process.

Stage 1:

The ore is roasted to form a mixture of metals and metal oxides. The mixture is then heated with dilute sulfuric acid. Copper metal and an aqueous mixture of the sulfates of cobalt and other metals are formed.

Stage 2:

Sodium hypochlorite (NaOCl) is then added to the aqueous mixture leading to the formation of cobalt(III) hydroxide.

**Stage 3:**

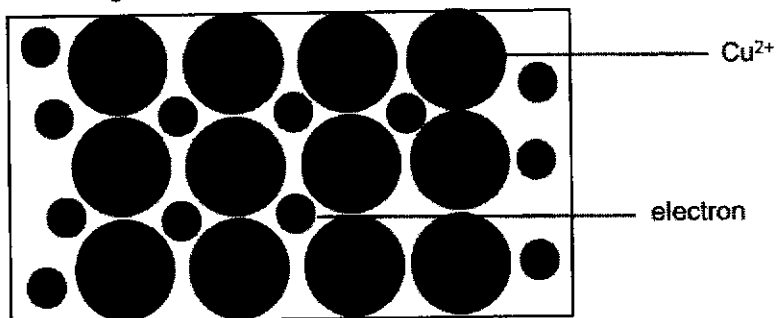
Cobalt(III) hydroxide is decomposed to form cobalt(III) oxide and steam. The cobalt(III) oxide is further reduced by carbon to form cobalt metal.

- (a) (i) Why is copper metal left after treating with sulfuric acid in **Stage 1**?

Copper is unreactive and does not react with acids. [1]

..... [1]

- (ii) Draw a labelled diagram in the box below to show the structure of copper metal.



[1]

- (iii) A sample of cobalt sulfide contain 58% of cobalt and 42% by mass of sulfur. Determine the empirical formula of the cobalt sulfide.

element	Co	S
Percentage by mass / %	58	42
Number of moles in 100 g / mol	0.9831	1.313
Mole ratio	3	4

empirical formula Co_3S_4 [2]

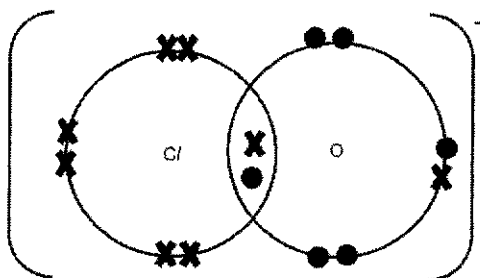
[Turn over]

- (b) (i) Explain using oxidation states whether sodium hypochlorite is an oxidising agent or reducing agent in **Stage 2**.

It is an oxidising agent as it was reduced. The oxidation number of chlorine decreased from +1 in NaOCl to -1 in NaCl / Cobalt has been oxidised as the oxidation number of cobalt increased from +2 in Co^{2+} to +3 in $\text{Co}(\text{OH})_3$.

[2]

- (ii) Draw a dot and cross diagram for the hypochlorite ion, ClO^- . It has a single bond between the chlorine atom and oxygen atom. Show outer electrons only.



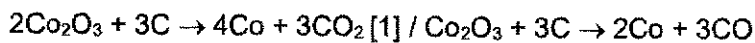
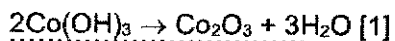
[2]

- (c) State how cobalt(III) hydroxide can be separated from the reaction mixture after **Stage 2** is completed.

Filtration.

[1]

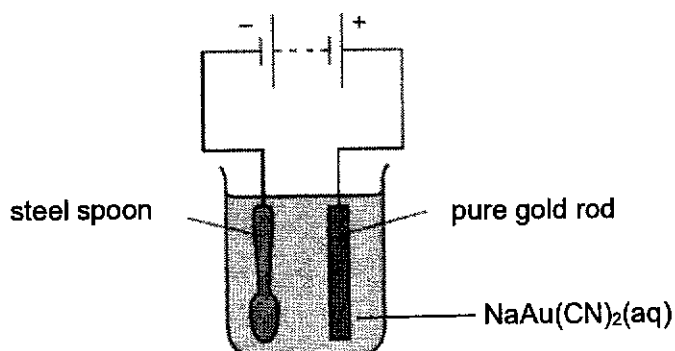
- (d) Write chemical equations for the two reactions occurring in **Stage 3**.



[Total: 11]

- 5 Electroplating is the process of using an electrical current to deposit a thin layer of metal onto an object. An example of electroplating is gold-plating.

During an experiment to gold-plate a spoon, the apparatus was set up as shown below:



Aqueous sodium dicyanoaurate, $\text{NaAu}(\text{CN})_2$, dissociates in water to form sodium ions, gold ions, and cyanide ions (CN^-).

- (a) Give the formula of all the ions that are attracted to the cathode, after aqueous $\text{NaAu}(\text{CN})_2$ dissociates.

H^+ , Na^+ , Au^+ [1]

- (b) (i) Gold is deposited at the cathode. Write the half-equation for the reaction at the cathode.

H^+ , Na^+ , Au^+ [1]

- (ii) Explain why gold ions are selectively discharged at the cathode.

$\text{Au}^+ + \text{e}^- \rightarrow \text{Au}$ [1]

..... [1]

- (c) A student measures the concentration of the $\text{NaAu}(\text{CN})_2$ electrolyte before and after the gold-plating experiment. Predict and explain the results that the student will obtain.

The concentration remains the same. [1] The rate at which Au^+ is reduced at the cathode is

equal to the rate at which the Au is ionising to form Au^+ . [1]

..... [2]

- (d) In a separate experiment, the gold electrode was replaced with graphite. Describe and explain a difference in observation during this experiment, compared to the experiment using the gold electrode. Include an equation in your explanation.

You may assume that CN^- ions are inert and do not take part in the reaction.

The anode does not dissolve, but instead an effervescence of O_2 gas is observed at the anode.

[1] As the graphite anode does not undergo oxidation unlike the Au anode, OH^- ions are

discharged to form O_2 instead. [1] $4\text{OH}^- \rightarrow 2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^-$ [1]

..... [3]

[Total: 8]

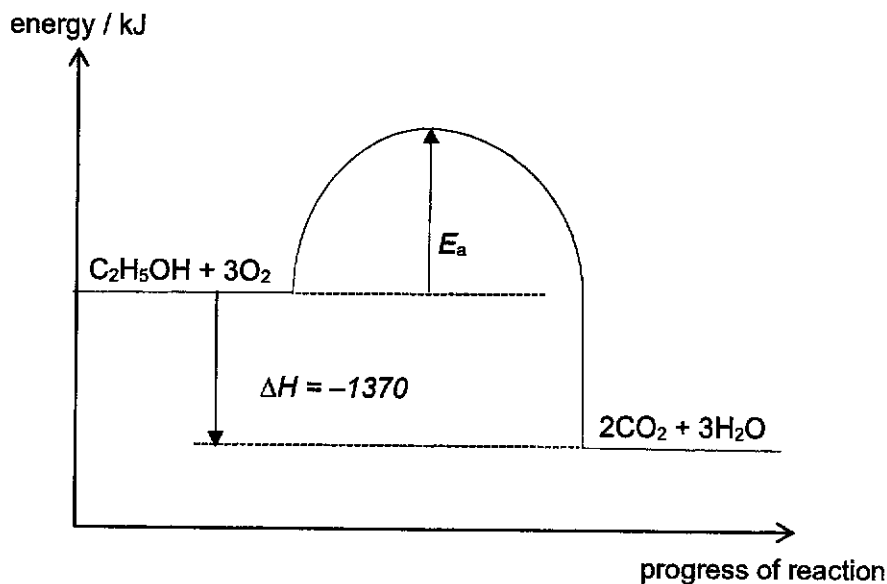
[Turn over]

6 The combustion of ethanol or hydrogen releases energy. This enables them to be used as fuel.

(a) The complete combustion of ethanol is represented by the following equation.



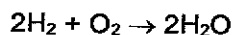
(i) Complete the energy profile diagram below for the combustion of ethanol. Your diagram should include labels for the reaction enthalpy change and activation energy.



[2]

(ii) Explain, in terms of bond breaking and bond making, why this reaction is exothermic. More energy is released during bond formation in CO_2 and H_2O [1], compared to the energy absorbed during bond breaking in $\text{C}_2\text{H}_5\text{OH}$ and O_2 . [1] hence there is a net release of energy to the surroundings, causing a rise in temperature. [2]

(b) The complete combustion of hydrogen is represented by the following equation.



Use the bond energies given in the table below to calculate the energy released on burning 1 mole of hydrogen.

bond	bond energy / kJ mol^{-1}
H-H	436
O=O	496
O-H	460

$$\text{Energy change} = 2(436) + 496 - 4(460) [1] = -472 \text{ kJ/mol}$$

$$\text{Energy released per mole of H}_2 = 472 + 2 = 236 \text{ kJ/mol [1]}$$

$$\text{Energy released} = \dots\dots\dots 236 \text{ kJ/mol} \dots\dots\dots [2]$$

[Turn over]

(c) Calculate the energy released when:

(i) 1 g of hydrogen is burned in excess oxygen.

$$\text{energy released} = 236 \div 2 = 118 \text{ kJ}$$

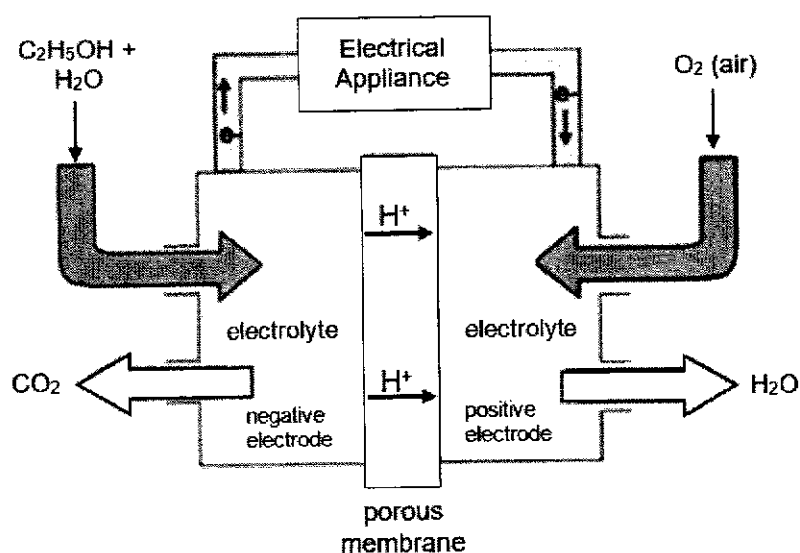
$$\text{Energy released} = \dots 118 \text{ kJ} \dots [1]$$

(ii) 1 g of ethanol is burned in excess oxygen.

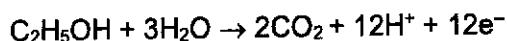
$$\text{energy released} = 1370 \div 46 = 29.8 \text{ kJ (3 s.f.)}$$

$$\text{Energy released} = \dots 29.8 \text{ kJ (3 s.f.)} \dots [1]$$

(d) Hydrogen and ethanol can also be used in fuel cells to power electric cars. The figure below shows a direct ethanol fuel cell (DEFC).



The half-equation for the DEFC at the negative electrode is:



(i) With reference to the diagram, what would be the half-equation at the positive electrode in a DEFC?



(ii) Write the overall equation for the reaction occurring in a DEFC.



[Total: 10]

[Turn over]

- 7 This question is about the chemistry of group 17 elements. Group 17 elements are also known as halogens or "salt-producers", based on their ability to form salts with sodium. Table 7.1 below shows some information regarding the size of the halogen atoms, also known as the atomic radius.

Table 7.1

element	atomic radius / $\times 10^{-12}$ m
fluorine	42
chlorine	79
bromine	94
iodine	140

Group 17 elements have the ability to gain electrons during chemical reactions. One method of measuring how readily elements gain electrons is by measuring their standard electrode potential (E^\ominus). E^\ominus is measured in volts (V) and the more positive the E^\ominus value, the greater the tendency of a species to gain electrons. E^\ominus is represented by half-equations showing the gain of electrons of the respective species. The E^\ominus of some of the halogens are shown in Table 7.2 below.

Table 7.2

element	E^\ominus / V
$\text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^-$	+2.87
$\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$	+1.36
$\text{Br}_2 + 2\text{e}^- \rightarrow 2\text{Br}^-$	
$\text{I}_2 + 2\text{e}^- \rightarrow 2\text{I}^-$	+0.54

The melting points of some salts formed from group 17 elements are shown in Table 7.3 below.

Table 7.3

salt	melting point / $^\circ\text{C}$
sodium fluoride	993
sodium iodide	661
magnesium fluoride	1263

Melting an ionic compound involves overcoming the ionic bonds present between the ions. One way of measuring the strength of the ionic bonds in ionic compounds is to compare their Lattice Energy ($L.E.$). The $L.E.$ of ionic compounds can be determined by the formula:

$$L.E. \propto \frac{q^+ \times q^-}{r^+ + r^-}$$

where q^+ is the charge of the cation

q^- is the charge of the anion

r^+ is the radius of the cation

r^- is the radius of the anion

α is the mathematical symbol for "proportionate to"

Besides reacting with metals to form salts, group 17 elements react with hydrogen to form hydrogen halides. The bond energies of the hydrogen-halogen bond of some hydrogen halides are shown below in Table 7.4.

Table 7.4

bond	bond energy / kJ mol^{-1}
H-F	562
H-Cl	431
H-Br	366
H-I	299

The hydrogen halides can dissolve in water to form aqueous acids. The acids produced can then undergo dissociation according to the general equation:



During the dissociation of the acids, the H-X bond is broken in the process.

The strength of an acid can be quantified by the acid dissociation constant, K_a . The larger the magnitude of K_a , the stronger the acid. Table 7.5 shows the K_a values of some aqueous acids formed from hydrogen halides:

Table 7.5

aqueous acid	$K_a / \text{mol dm}^{-3}$
HF(aq)	6.6×10^{-4}
HCl(aq)	1.4×10^6
HBr(aq)	1.0×10^9
HI(aq)	3.2×10^9

- (a) Describe and explain the trend in atomic radius shown in Table 7.1.

The atomic radius increases down the group [1] due to an increase in the number of electron shells. [1]

..... [2]

- (b) (i) The E^\ominus value for bromine is not given in Table 7.2. State a possible E^\ominus value for bromine. any value between ± 0.55 and ± 1.35 V [1]

- (ii) Hence or otherwise, arrange the group 17 elements shown in Table 7.2 based on their strength as oxidising agents, starting with the strongest oxidising agent first.

$\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$ [1]

- (c) Use suitable information provided in the question to explain the differences in melting points of the salts shown in Table 7.3.

The melting point of NaI is lower than NaF due to the larger radius of I^- which decreases the magnitude of the L.E. [1]. The melting point of MgF_2 is higher than NaF as Mg^{2+} has a higher charge than Na^+ . [1]

..... [2]

[Turn over]

- (d) Describe the trend in the strength of the aqueous acids shown in Table 7.5. Use data from Table 7.4 to suggest an explanation for the trend.

The strength of the acids increase from $\text{HF} < \text{HCl} < \text{HBr} < \text{HI}$. [1] This is due to the decreasing strength of the H-X bonds, exemplified by the decrease in B.E. from H-F to H-I shown in table 7.4. Thus, the extent of dissociation increases / as less energy is required to break the H-X bond. [1] [2]

The aqueous acids in Table 7.5 can be reacted with magnesium metal to liberate hydrogen gas. 50 cm³ of 0.1 mol/dm³ HBr(aq) was reacted with excess magnesium at room temperature and pressure. The volume of gas evolved over time is plotted in Figure 7.1 below:

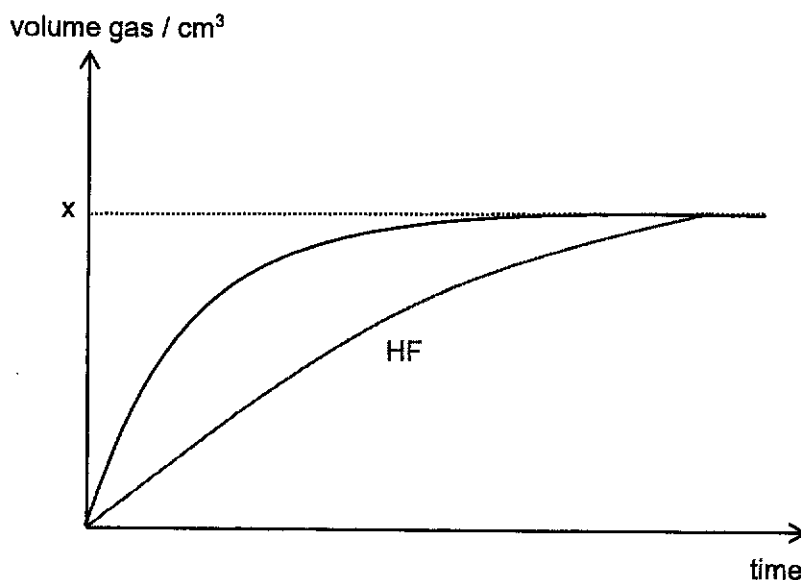
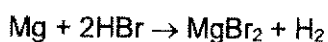


Figure 7.1

- (e) (i) Calculate the volume of hydrogen produced, x, shown in Figure 7.1.



$$\text{No. of moles of HBr} = (50/1000) \times 0.1 = 0.005 \text{ mol [1]}$$

$$\text{Volume of H}_2, x = (0.005/2) \times 24000 = 60 \text{ cm}^3 \text{ [1]}$$

[2]

- (ii) Sketch, on Figure 7.1, the graph that would be obtained for the reaction between 50 cm³ of 0.1 mol/dm³ HF(aq) and excess magnesium, assuming all other conditions remain the same. Label your graph as HF. [1]

[Total: 11]

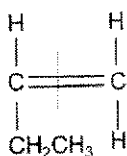
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- 8 A company manufactures polymers. It sells one of its polymers under the trade name of "PB-1".

The table shows some information about PB-1. The term "softening temperature" is used for materials that have no definite melting point.

structure	molecular mass	softening temperature
$\left[\begin{array}{c} \text{CH} - \text{CH}_2 \\ \\ \text{CH}_2\text{CH}_3 \end{array} \right]_n$	5600	115 °C

- (a) (i) Draw the structural formula of the monomer used to make PB-1.



[1]

- (ii) Name this monomer.

Butene. [1]

- (iii) What type of polymerisation occurs when PB-1 forms from its monomers?

Addition polymerisation [1]

- (b) The company sells two types of PB-1.

The polymer in the table is low molecular mass PB-1.

- (i) Calculate the number of monomer units in each molecule of low molecular mass PB-1.

$$M_r \text{ of monomer} = 12(4) + 8(1) = 56$$

$$\text{No. of monomer units} = \underline{5600 \div 56 = 100}$$

Number of monomer units 100 [1]

[Turn over]

- (ii) High molecular mass *PB-1* has different properties.

Suggest the softening temperature of high molecular mass *PB-1*.
Explain your answer.

Softening temperature Between 116 to 500 °C

Explanation With a higher molecular mass, the intermolecular forces are stronger and
..... require more energy to overcome.[2]

- (iii) Explain why *PB-1* has no definite melting point.

They are mixtures [1] consisting of macromolecules of different chain lengths.
.....

.....[1]

[Total: 7]

Section B

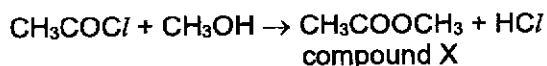
Answer **one** question from this section.

- 9 The table shows some information about the homologous series of a class of organic compounds called acyl chlorides.

name	condensed formula	displayed formula
ethanoyl chloride	CH ₃ COCl	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C} \begin{array}{l} // \text{O} \\ \backslash \text{Cl} \end{array} \\ \\ \text{H} \end{array}$
propanoyl chloride	C ₂ H ₅ COCl	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
butanoyl chloride	C ₃ H ₇ COCl	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{O} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{Cl} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$

- (a) (i) Fill in the table to show the name and displayed formula of the acyl chloride that occurs between ethanoyl chloride and butanoyl chloride in the homologous series. [1]
- (ii) Explain how you can tell that these molecules are from the same homologous series. They have the same COCl functional group and successive members differ in formulae by a -CH₂- group / same general formula C_nH_{2n+1}COCl. [2]
- (iii) Predict the condensed formula of the acyl chloride that contains 7 carbon atoms. C₆H₁₃COCl [1]

- (b) Ethanoyl chloride reacts with methanol in the following reaction.



- (i) What is the name of compound X? Methyl ethanoate [1]
- (ii) When 64 g of methanol was reacted with excess ethanoyl chloride, 140 g of compound X was obtained. Calculate the percentage yield of compound X.

$$\text{No. of moles of methanol} = 64 \div 32 = 2 \text{ mol [1]}$$

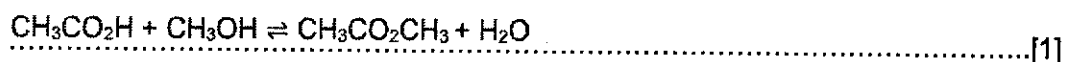
$$\text{Theoretical mass of X} = 2 \times 74 = 148 \text{ g}$$

$$\text{Percentage yield} = (140 \div 148) \times 100\% = \underline{94.6\%} \text{ (3 s.f.) [1]}$$

[2]

[Turn over]

- (iii) Ethanoic acid also reacts with methanol.
Write an equation for the reaction of ethanoic acid and methanol.



- (iv) Give one similarity and one difference between the reaction of ethanoyl chloride with methanol and the reaction of ethanoic acid with methanol.

similarity Both produce the same ester / an ester is formed as the product / a small
molecule is removed during the reaction / both are condensation reactions

difference The side product is H_2O and HCl respectively for the reaction between
ethanoic acid and methanol, and the reaction between ethanoyl chloride [2]

and methanol.

[Total: 10]

- 10 Table 10.1 shows the formulae of the first three members of the alcohol homologous series.

Table 10.1

alcohol	formula
methanol	CH ₃ OH
ethanol	C ₂ H ₅ OH
propanol	C ₃ H ₇ OH

- (a) State the general formula of the alcohol homologous series.

C_nH_{2n+1}OH / C_nH_{2n+2}O[1]

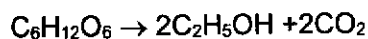
- (b) Ethanol can be manufactured from either ethene or glucose.

- (i) Write an equation for the production of ethanol from ethene and state the conditions under which the reaction takes place.

C₂H₄ + H₂O → C₂H₅OH. [1] High temperature and pressure in the presence of H₃PO₄ catalyst. [1]

.....[2]

- (ii) The fermentation of glucose can be represented by the following equation.



When 3.6 kg of glucose was fermented, 1.5 kg of ethanol was obtained. Calculate the percentage yield of ethanol.

no. of moles of glucose = 3600 ÷ 180 = 20 mol

theoretical no. of moles of C₂H₅OH = 2 x 20 = 40 mol [1]

theoretical mass of C₂H₅OH produced = 40 x 46 = 1840 g [1]

percentage yield = (1500 ÷ 1840) x 100% = 81.5% (3 s.f.) [1]

[3]

- (iii) Explain why ethanol made from ethene is a non-renewable fuel but that made from glucose is a renewable fuel.

Ethene is obtained from fossil fuels, which is a finite and non-renewable resource.

glucose is obtained from crops that have a relative short life cycle and thus can be considered to be renewable resources.

.....[2]

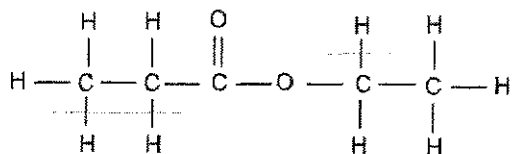
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(c) Propanol reacts in a similar way to ethanol.

- (i) Name the organic product of the reaction between propanol and warm, acidified potassium manganate(VII).

propanoic acid.[1]

- (ii) Draw the structure of the compound formed when the organic product in (c)(i) reacts with ethanol.



[1]
[Total: 10]

[Turn over]

