Name: _____ Class: _____

Anglo-Chinese School (Barker Road)

PRELIMINARY EXAMINATION 2023

SECONDARY FOUR EXPRESS

CHEMISTRY PAPER 1
6092/1

1 HOUR

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Read the instructions on the OTAS answer sheet carefully.

Write your index number, subject code and paper number clearly on the OTAS answer sheet provided for you.

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

INFORMATION FOR CANDIDATES
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 18.
The use of an approved scientific calculator is expected, where appropriate.

*This paper consists of **18** printed pages inclusive of this page.*

1 Different volumes of alkalis were separately added to a fixed volume of acid.

The highest temperature reached was measured.

The experiment was designed to determine the exact volume of alkali needed to completely neutralise the acid.

In addition to the thermometer, the following pieces of apparatus are available.

1 burette
2 electronic balance
3 gas syringe
4 pipette
5 styrofoam cup

Which pieces of apparatus are needed for this experiment?

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

2 A student heats a sample of ammonium chloride in a test-tube.

Moist red and blue litmus papers were placed at the mouth of the test-tube.

What would be observed?

A Both the red and blue litmus papers changed colour at the same time.
B Only the blue litmus paper turned red.
C Only the red litmus paper turned blue.
D The red litmus paper turned blue followed by the blue litmus paper turning red.

3 The melting points of three substances, P, Q and R, are shown below.

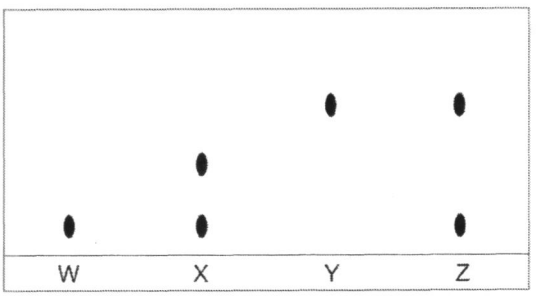
substance	melting point / °C
P	45
Q	55
R	65-80

P, Q and R are used to make different substances, W, X, Y and Z. The composition of these substances are found in the table below.

substance	composition
W	contains P only
X	contains P and Q only
Y	contains R only
Z	contains P and R only

Which chromatogram will be obtained when substances W, X, Y and Z are dissolved in a suitable solvent?

A



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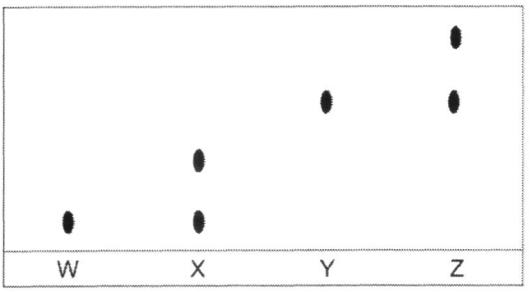

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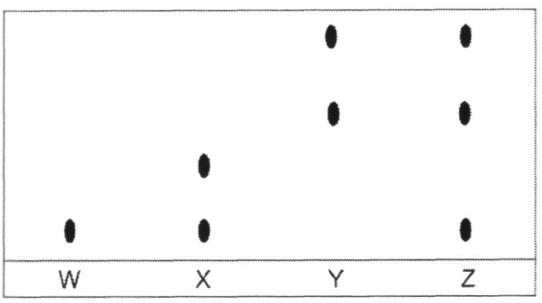

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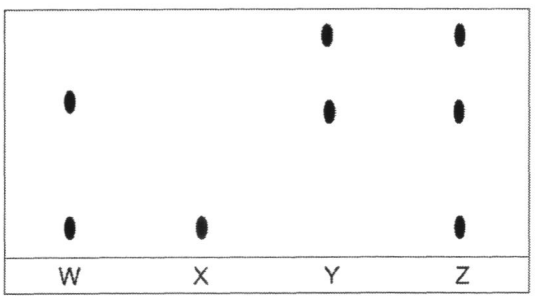


4 An impurity commonly found in coke is burnt in excess oxygen, producing gases X and Y.

X is an element while Y is a compound.

Gas X was tested with a lighted splint.
Gas Y was tested with a piece of filter paper soaked in acidified potassium manganate(VII).

Which results would be observed for X and Y?

	gas X	gas Y
A	Lighted splint burns brightly.	Purple paper decolourises.
B	Lighted splint burns brightly.	There are no visible changes.
C	Lighted splint extinguishes with a 'pop' sound.	There are no visible changes.
D	Lighted splint extinguishes.	Purple paper decolourises.

5 An atom of element G can be written as $^{16}_{8}G$.

Particle H has four less neutrons, the same number of protons and two more electrons than this atom of G.

What is the correct symbol of H?

A $^{12}_{8}H$

B $^{12}_{8}H^{2-}$

C $^{16}_{8}H^{2+}$

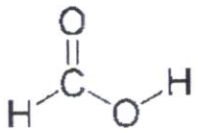
D $^{16}_{4}H$

6 An ion X^{3-} has *m* neutrons and *n* electrons.

What is the atomic and nucleon number of this ion?

	atomic number	nucleon number
A	n	m + n
B	n - 3	m + n
C	n - 3	m + n - 3
D	n + 3	m + n - 3

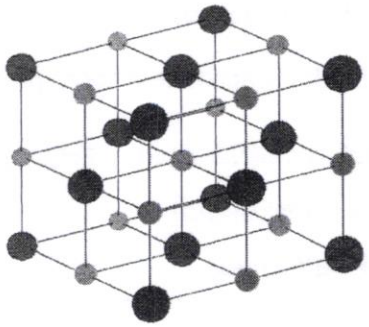
7 The structural formula of methanoic acid, HCOOH is shown below.



Which information about the molecule of methanoic acid is correct?

	total number of electrons in molecule	number of electrons involved in bonding
A	18	5
B	18	10
C	24	5
D	24	10

8 A group I compound has the structure shown in the diagram below.



Which physical properties will this compound have?

	state at room temperature	electrical conductivity at room temperature	electrical conductivity when molten	electrical conductivity when added to water
A	liquid	✗	✗	✗
B	solid	✓	✓	✓
C	solid	✗	✓	✗
D	solid	✗	✓	✓

9 Sodium hydrogen phosphate has the formula Na_2HPO_4.

What is the formula of the compound, iron(III) hydrogen phosphate?

A $FeHPO_4$

B Fe_2HPO_4

C $Fe_2(HPO_4)_3$

D Fe_3HPO_4

10 Which statement does **not** describe the property of a weak alkali?

A It has a pH range of around 8 to 11.

B It has good electrical conductivity in the presence of water.

C It reacts with ammonium salts to produce a gas.

D It turns Universal Indicator solution blue.

11 Slaked lime is added to soil that is too acidic.

What is the ionic equation for the reaction that takes place?

A $Ca(OH)_2(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$

B $Ca^{2+}(aq) + 2NO_3^-(aq) \rightarrow Ca(NO_3)_2(aq)$

C $Ca^{2+}(aq) + 2OH^-(aq) \rightarrow Ca(OH)_2(s)$

D $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

12 Element Q reacts with chlorine to form a compound, QCl_3.

Q also reacts with oxygen to form a compound that exists as a gas at room temperature.

Which information about Q is correct?

	group number	type of oxide formed
A	III	amphoteric
B	III	basic
C	V	acidic
D	V	basic

13 Which pair of reactants can be used to form lead(II) chloride?

	reactant 1	reactant 2
A	lead	hydrochloric acid
B	lead(II) carbonate	hydrochloric acid
C	lead(II) nitrate	sodium chloride
D	lead(II) sulfate	sodium chloride

14 A substance contains elements with the following composition by mass.

element	percentage by mass (%)
carbon	41.9
hydrogen	3.1
chlorine	55.0

What is the molecular formula of this compound?

A C_2H_2Cl

B $C_4H_9Cl_4$

C $C_8H_4Cl_9$

D $C_9H_8Cl_4$

15 Ammonium salts are common fertilisers and a rich source of nitrogen.

Which ammonium salt provides the highest content of nitrogen?

A $(NH_4)_2SO_4$

B $(NH_4)_3PO_4$

C NH_4Cl

D NH_4NO_3

16 70 cm^3 of butane was burnt with 300 cm^3 of oxygen according to the equation below.

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$$

The reaction was then cooled to room temperature and the gases collected.

What is the volume of gases collected?

A 200 cm^3

B 220 cm^3

C 400 cm^3

D 560 cm^3

17 Ammonia is produced industrially using the Haber process according to the equation below.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Which statements are correct?

1 Nitrogen is reduced to form ammonia.

2 The finely-divided iron catalyst helps to increase the yield of the reaction.

3 The percentage yield of the reaction is near 100%.

4 The reaction is carried out at 450 °C and 250 atmospheric pressure.

A 1 and 2 only

B 1 and 4 only

C 2 and 3 only

D 2 and 4 only

18 An atom of an element Q has the symbol $^{5}_{2}Q$.

Which group and period does element Q belong to?

	group	period
A	II	1
B	III	1
C	0	1
D	0	2

19 Five statements about five different elements, iron, iodine, aluminium, zinc and potassium are listed below.

1 black solid at room temperature

2 burns with a lilac flame when placed in water

3 forms an oxide that reacts with hydrochloric acid and sodium hydroxide

4 forms compound with the formula XCl_2 and XCl_3

5 used in making brass

Which statement correctly describes each element?

	iron	iodine	aluminium	zinc	potassium
A	3	4	1	2	5
B	4	1	3	5	2
C	5	1	4	3	2
D	5	4	3	1	2

20 Arc welding is a process which uses electricity to make high temperatures to melt two pieces of metal so that they can be joined.

Argon is blown onto the surface where the molten metals are joining.

Why is argon used?

A It reacts with oxygen releasing heat which helps the metals to melt.

B It gives off a lot of light to help the welder see what they are doing.

C It is a good electrical conductor and so creates a high temperature.

D It is an inert gas and so prevents the metals from oxidising.

21 In which equation is chromium being oxidised?

1 $Cr^{3+} + MnO_4^- + 2H_2O \rightarrow CrO_4^{2-} + MnO_2 + 4H^+$

2 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

3 $Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$

4 $4Cr + 3O_2 \rightarrow 2Cr_2O_3$

A 1 and 2

B 1 and 4

C 2 and 3

D 3 and 4

22 An unknown substance Q exhibits the following properties.

melting point	1500 °C
solubility in water	insoluble
electrical conductivity	good electrical conductor in the solid state
density	high

The halide salt of Q is pale-green in colour.

What is Q?

A barium

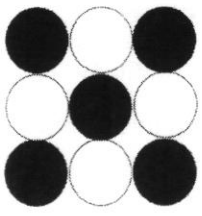
B calcium

C graphite

D iron

23 Which diagram shows the correct arrangement of particles in steel?

A



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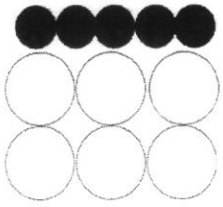

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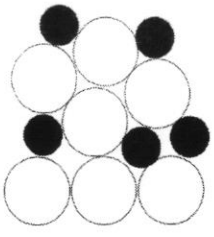

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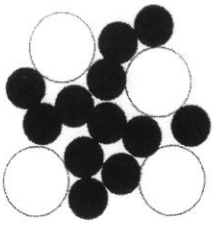


24 A recycling company uses information to decide which metals to recycle.

Which metal is **least** likely to be recycled?

	abundance of metal	ease of extraction	cost of recycling
A	high	low	moderate
B	low	high	high
C	low	high	low
D	moderate	high	high

25 Which reactions take place in the production of iron in the blast furnace?

1 $C + O_2 \rightarrow CO_2$

2 $CO_2 + C \rightarrow 2CO$

3 $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

4 $CaCO_3 \rightarrow CaO + CO_2$

5 $CaO + SO_2 \rightarrow CaSO_3$

A 1 and 2 only

B 1, 2 and 4 only

C 1, 2, 3 and 4 only

D All of the above

26 Which statements about galvanising in rust-prevention are correct?

1 Galvanising can be carried out using any metal that is more reactive than iron.

2 Galvanising involves zinc metal corroding in place of the iron.

3 Galvanising is not effective once there is a scratch on the surface of the paint.

4 Galvanising prevents oxygen and water from coming into contact with the iron.

A 1 and 2 only

B 2 and 3 only

C 2 and 4 only

D 3 and 4 only

27 A bicycle is electroplated with chromium to make it more resistant to scratches and rusting.

Chromium lies above zinc in the reactivity series of metals.

Which set-up will allow the chromium to be plated onto the bicycle?

	anode	cathode	electrolyte
A	bicycle	chromium	molten chromium(III) sulfate
B	chromium	bicycle	aqueous copper(II) chloride
C	chromium	bicycle	aqueous chromium (III) sulfate
D	chromium	bicycle	molten chromium(III) sulfate

28 The complete combustion of propane is an exothermic reaction.

Which statement explains this?

A More bonds are broken than are formed.

B More bonds are formed than are broken.

C The total enthalpy of the bonds broken is greater than the total enthalpy of the bonds formed.

D The total enthalpy of the bonds broken is less than the total enthalpy of the bonds formed.

29 When ammonia is burnt in oxygen, it produces nitrogen and water vapour.

$$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$$

The bond energies of the reactants and products of a reaction are shown in the table below.

bond	bond energy in kJ/mol	bond	bond energy in kJ/mol
N-H	391	O–O	204
N=N	418	O=O	498
N≡N	945	O–H	467

What is the enthalpy change of the reaction?

A – 4692 kJ

B –2025 kJ

C –1308 kJ

D +2667 kJ

30 Petroleum can be separated into fractions using fractional distillation.

Which statements are correct?

1 The fractions obtained at a particular point in the fractionating column always contains the same compounds in the same ratio.

2 The densities of the compounds obtained near the bottom of the fractionating column are higher than those near the top.

3 The compounds found in naphtha can be used to manufacture other macromolecules.

4 All the fractions can be used as fuels.

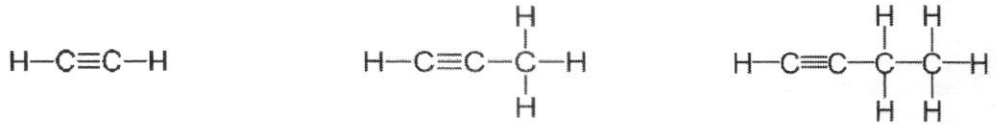
A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 3 and 4 only

31 The structures of three compounds are shown below.



1 The boiling point and flammability of the compounds increases with the number of carbon atoms.

2 They all have the same general formula of C_nH_{2n}.

3 They are all hydrocarbons.

4 They are members of the same homologous series.

Which statements about these compounds is correct?

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 3 and 4 only

32 Which pair of diagram represent two isomers of pentane?

1 

2 

3 

A 1 and 2 only

B 2 only

C 2 and 3 only

D 3 only

33 What are the reagents and reaction conditions to convert vegetable oil to margarine?

	reagent	reaction conditions
A	bromine	room temperature
B	hydrogen	200 °C, iron catalyst
C	hydrogen	200 °C, nickel catalyst
D	steam	300 °C, phosphoric acid catalyst, 60 atm pressure

34 The cracking of an alkane W is shown in the equation below.

$$W \rightarrow X + Y + C_4H_8$$

Compound X is a saturated compound that is fully substituted when it reacts with 10 moles of chlorine gas under UV light.

Compound Y undergoes an addition reaction to form ethanol.

What are W, X and Y?

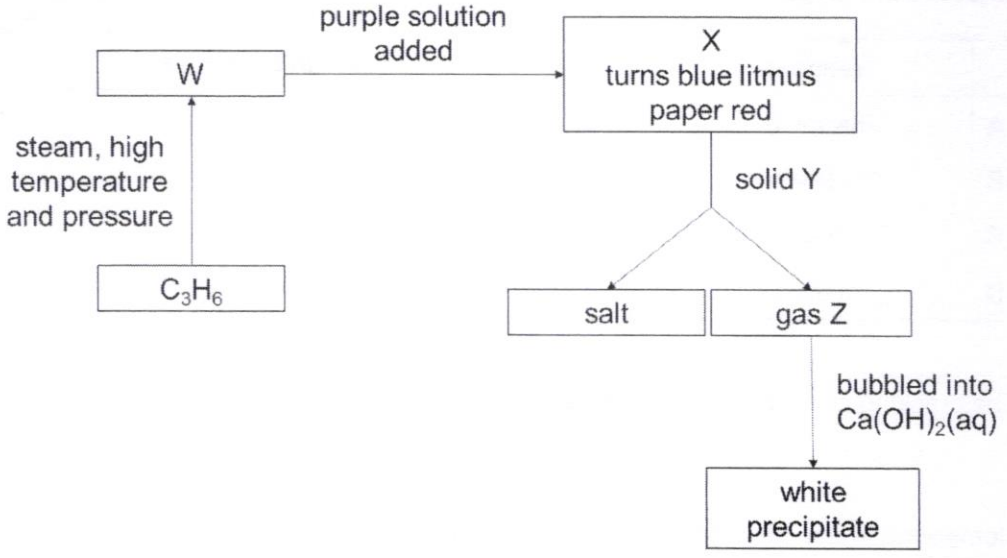
	W	X	Y
A	C_6H_{16}	butane	ethene
B	$C_{10}H_{22}$	butane	ethene
C	$C_{12}H_{24}$	decane	ethane
D	$C_{12}H_{26}$	decane	ethene

35 Ethanol is produced in a fermentation reaction involving glucose and yeast under specific conditions.

Which row shows the changes to the mass of ethanol, glucose and yeast at the end of the reaction?

	mass of ethanol	mass of glucose	mass of yeast
A	increase	decrease	decrease
B	increase	decrease	remains the same
C	increase	increase	remains the same
D	decrease	decrease	decrease

36 The flow chart shows some reactions of organic compounds.



What are W, X, Y and Z?

	W	X	Y	Z
A	ethanol	ethanoic acid	sodium carbonate	carbon dioxide
B	propanol	propanoic acid	magnesium	carbon dioxide
C	propanol	propanoic acid	magnesium	hydrogen
D	propanol	propanoic acid	sodium carbonate	carbon dioxide

37 Which statements are true for nylon and terylene?

1 Nylon and terylene are strong and can be used to make sleeping bags and fishing lines.

2 Nylon is an addition polymer while terylene is a condensation polymer.

3 Nylon is made from the reaction of dicarboxylic acid and diol while terylene is made from the reaction of dicarboxylic acid and diamine.

4 The relative molecular masses of nylon and terylene is less than the sum of the relative molecular masses of their monomers.

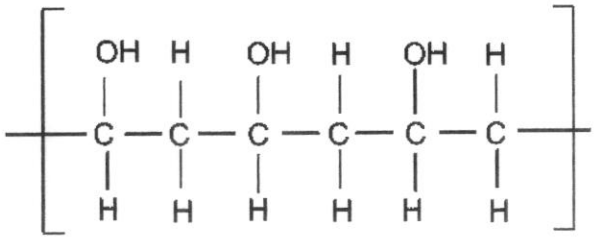
A 1 and 2 only

B 1 and 3 only

C 1 and 4 only

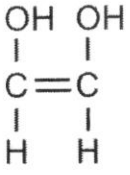
D 2, 3 and 4 only

38 The structure of a polymer is shown below.



What is the monomer unit for this polymer?

A



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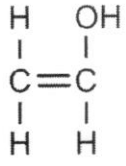

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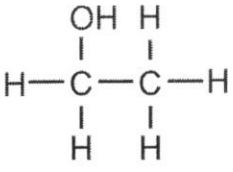

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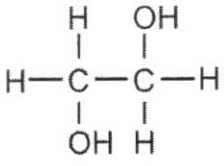


39 Which reaction takes place when in the catalytic converter of a car engine?

A $C + NO \rightarrow \frac{1}{2} N_2 + CO$

B $CO + NO \rightarrow CO_2 + \frac{1}{2} N_2$

C $CO + NO_2 \rightarrow NO + CO_2$

D $CO_2 + NO \rightarrow CO + NO_2$

40 Which pair of pollutants are produced from the combustion of petrol in the engine of vehicles?

A carbon dioxide and nitrogen dioxide

B methane and nitrogen dioxide

C ozone and carbon dioxide

D sulfur dioxide and methane

NAME: ..... CLASS: ..... INDEX NUMBER: .....

Anglo-Chinese School (Barker Road)

PRELIMINARY EXAMINATION 2023

SECONDARY FOUR EXPRESS

CHEMISTRY
PAPER 2

6092/2

1 HOUR 45 MINUTES

INSTRUCTIONS TO CANDIDATES:

Do not open this booklet until you are told to do so.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.

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

Sections B
Answer all **three** questions, the last question is in the form either/or.
Write your answers in the spaces provided.

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

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

A copy of the Periodic Table is printed on Page 22.

FOR EXAMINER'S USE ONLY	
Section A	/ 50
Section B	/ 30
Total Score	**/ 80**

This paper consists of **22** printed pages including the cover page.

Section A

Answer **all** questions in this section.

A1 Different metal ores may contain impurities of lead, zinc or aluminium.

The reaction of a sample of ore with nitric acid results in the formation of a solution containing one of these metal ions.

(a) Explain why aqueous ammonia can be used to identify only **one** of the ions in solution.

.....

.....

..... [2]

(b) Describe another test that can be used to distinguish between the other two ions.

Include the expected results of the test in your answer.

.....

..... [2]

[Total: 4]

A2 Magnesium chloride was prepared by reacting magnesium carbonate powder with dilute hydrochloric acid.

(a) Construct a balanced chemical equation, with state symbols, for the reaction above.

..... [2]

(b) Outline the steps taken to prepare magnesium chloride solution in the laboratory, including the apparatus needed.

.....

.....

.....

.....

..... [3]

(c) A student wants to obtain magnesium chloride crystals from the solution. He heats up the magnesium chloride solution strongly for a few minutes.

(i) Explain why heating the solution strongly is **not** advised.

.....

..... [1]

(ii) Hence, describe the steps that he should take to obtain the crystals instead.

.....

..... [1]

[Total: 7]

A3 Lithium, sodium and potassium are elements in Group I of the Periodic Table. Rubidium, Rb, is another element in Group I.

(a) Explain why rubidium is placed in the same group as lithium, sodium and potassium.

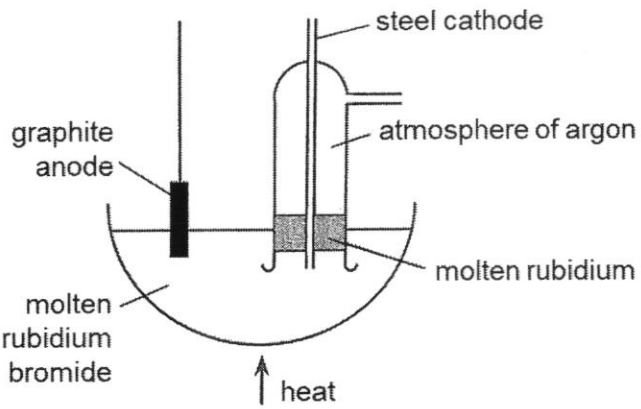
.....

..... [1]

(b) State one physical property that is unique to Group I metals.

..... [1]

(c) Rubidium metal can be obtained by the electrolysis of molten rubidium bromide, using the apparatus shown below.



(i) Construct the ionic half-equations for the reactions at the anode and cathode.

anode: .....

cathode: ..... [2]

(ii) Suggest why an atmosphere of argon is used around the cathode.

.....

..... [2]

(d) The graphite anode, molten rubidium bromide and molten rubidium can all conduct electricity.

Explain, in terms of their structures, how each substance conducts electricity.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

(e) Explain why it is **not** possible to extract rubidium by electrolysis of aqueous rubidium bromide.

.....

.....

..... [1]

[Total: 11]

A4 Crystals of a salt produced was found to have the following composition by mass: 31.5% K, 25.6% Cu and the remaining *Cl*.

(a) Calculate the empirical formula of the salt crystal formed.

Show all your workings.

[3]

(b) The ion of an isotope of copper has the formula $^{66}_{29}Cu^{2+}$.

Complete the table with information about this ion.

subatomic particles	number of subatomic particles
protons	
neutrons	
electrons	

[2]

(c) Fluorine gas was bubbled into a separate solution of copper(II) chloride, forming a solution of copper(II) fluoride.

(i) Explain the chemistry behind the reaction described.

.....

.....

..... [1]

(ii) Explain, in terms of changes in oxidation states, why the reaction is a redox reaction.

.....

.....

.....

..... [2]

(iii) Copper(II) fluoride reacts with hot water to form fluoride ions, hydrogen ions and one other ion.

Deduce the formula of the other ion produced.

..... [1]

[Total: 9]

A5 (a) Shale is a sedimentary rock which contains a variety of iron compounds. Table 5.1 shows the colours of these iron compounds.

Table 5.1

name of iron compound	colour
iron(III) oxide	red
iron(II) hydroxide	dirty-green
iron(III) hydroxide	reddish-brown
iron(II) oxide	black

Shale is found in areas where there is also a significant quantity of carbon present. Carbon acts as a reducing agent when reacting with the iron compounds in the shale, causing shale to have a multi-coloured appearance.

(i) When a sample of shale was dug up, it was observed that the sample contained only two different colours.

What were the two possible colours of the sample of shale which was dug up?

Explain your answer.

.....

.....

.....

..... [2]

(ii) A sample of shale that was left exposed to air for many years was found to contain two different colours.

Suggest which two colours were found in this sample of shale and explain your answer.

.....

.....

.....

..... [2]

(b) Iron can be extracted from iron(III) oxide. Since shale contains iron(III) oxide, it is possible to extract iron from shale.

(i) Write the chemical equation, including state symbols, for the extraction of pure iron from iron(III) oxide in the blast furnace.

..... [2]

(ii) If 100 tonnes of shale was placed in the blast furnace, and 30 tonnes of pure iron was extracted, calculate the percentage composition of iron(III) oxide in the sample of shale.

(1 tonne = 1 000 000 g)

[Relative atomic masses, A_r: Fe, 56; O, 16]

[3]

[Total: 9]

A6 When an acid dissolves in water, the hydrogen ions produced by the acid bonds with water molecules to form hydronium ions, H_3O^+. In the formation of the hydronium ion, a dative covalent bond is formed between the hydrogen ion and one pair of unbonded electrons in the oxygen atom of water.

Fig. 6.1 shows a simplified representation of how a water molecule forms a dative covalent bond with a hydrogen ion.

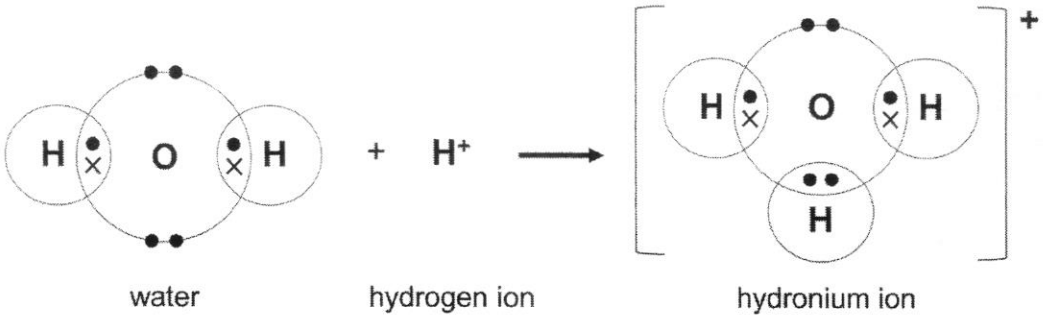


Fig. 6.1

(a) The formation of an ammonium ion is another example which involves the formation of a dative covalent bond.

With the help of Fig. 6.1, draw the 'dot-and-cross' diagram of an ammonia molecule and an ammonium ion.

Show outer electrons only.

[3]

(b) Using your answers in **(a)**, state one similarity and one difference between the two structures.

similarity .....

.....

.....

difference .....

.....

.....

..... [2]

[Total: 5]

A7 Solid barium hydroxide is placed in a beaker. Solid ammonium chloride is then added into the beaker and the mixture is stirred. The equation below shows the reaction between barium hydroxide and ammonium chloride.

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4Cl(s) \longrightarrow BaCl_2 \cdot 2H_2O(s) + 2NH_3(g) + 8H_2O(l)$$

The beaker is then placed on a wooden block with a small pool of water. After a few minutes, the pool of water turned to ice, as shown in Fig. 7.1 below.

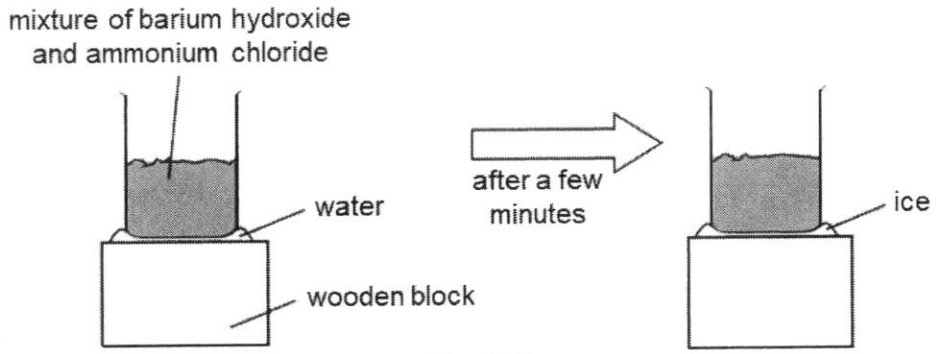


Fig. 7.1

(a) Suggest an explanation for the observations seen after the beaker was placed on the wooden block for a few minutes.

.....

.....

.....

..... [2]

(b) Draw the energy profile diagram for the reaction.

Your diagram should show:

- the reactants and products of the reaction
- the energy profile and activation energy, E_a, for the reaction
- the enthalpy change of reaction, ΔH.

[3]

[Total: 5]

Section B

Answer all **three** questions in this section.
The last question is in the form of an either/or and only one of the alternatives should be attempted.

B8 The chemistry of rocket science

To get a rocket into outer space, it must first be able to generate sufficient thrust (moving force) to overcome Earth's gravitational field. Most rocket engines make use of either solid or liquid propellants to generate thrust.

Structure of rocket engines

Engines that use solid propellants consist of a single steel casing filled with a solid propellant mixture that burn at a rapid rate, expelling hot gases to produce thrust. Once ignited, solid propellant engines cannot be shut down and the mixture continues to burn until all the propellant is used up.

In a liquid propellant engine, the liquid propellant mixture is fed through a system of pipes, valves, and pumps to a combustion chamber where they are burned to produce thrust. The type of materials used to build the engine varies, depending on the properties of the propellant chosen. For example, when corrosive liquid propellants are used, the engine needs to be made with more expensive corrosion-resistant materials, otherwise, the operational lifetime of the engine is significantly reduced. While liquid propellant engines are more complex to build than their solid propellant counterparts, however, they are able to control the rate of flow of propellant to the combustion chamber, hence the engine can be slowed down, sped up, stopped, or restarted.

Solid versus liquid propellants

An example of a common solid propellant is a mixture of finely grounded ammonium perchlorate, NH_4ClO_4, mixed with aluminium powder. The mixture burns to produce large volumes of gases and a hard, rubber-like waste product. This waste product must be safely disposed of and cannot be released into outer space. The equation below shows the reaction when the solid propellant reacts in the rocket engine.

$$3NH_4ClO_4(s) + 3Al(s) \longrightarrow Al_2O_3(s) + AlCl_3(s) + 3NO(g) + 6H_2O(g)$$

A common liquid propellant used is RP-1 or refined petroleum-1. RP-1 is formulated from the kerosene fraction of crude oil and processed further to remove sulfur-containing impurities that can corrode the engine tank. The remaining hydrocarbons in the processed kerosene are mostly straight-chain alkanes. When RP-1 is ignited with oxygen, the alkanes undergo combustion, giving off a large amount of energy to heat up and expand the gases. As the hot gases rush out of the combustion chamber, they generate a significant amount of thrust. However, engines that use RP-1 generates significant amounts of soot that limit operational lifetime of engine.

Liquid hydrogen is another liquid propellant that is very attractive as it produces water vapour as the only product. However, it is difficult to store due to its low density. To liquefy hydrogen gas, engineers must first cool it to –253°C. The rocket must also be thoroughly insulated to prevent liquid hydrogen from boiling off and expanding dangerously.

Table 8.1 summarises some key factors that affect the choice of liquid propellants.

Table 8.1

factors	impact	concerns
density of the propellant	Low-density propellants require larger storage tanks.	increased mass of launch vehicle
storage temperature	Propellants with low storage temperature will require thermal insulation.	increased mass of launch vehicle
toxicity of propellant	Propellants that are toxic needs to be safely handled, transported, and stored.	potential safety hazard

Propulsion in outer space

Once a rocket has escaped Earth's gravitational field, they still need a means of propulsion, which can be obtained in two ways – chemical propulsion or electric propulsion.

Table 8.2 compares the two ways of propulsion in outer space.

Table 8.2

	chemical propulsion	electric propulsion
fuel used	liquid hydrazine (N_2H_4)	noble gases, such as xenon
type of reaction	reactions that produce large volumes of hot gas to propel the rocket	reactions that use electricity to ionise the fuel, then the ions repel one another to propel the rocket
fuel efficiency*	lower	higher
other information	highly toxic fuel, ignites very readily, duration of propulsion is limited by fuel capacity of spacecraft	limited supply of fuel on Earth, inert fuel with lower risk of exploding accidentally
estimated cost	$75.80/kg	$3000/kg

*A lower fuel efficiency means that the fuel is used up more quickly, which limits the duration of the space mission.

(Information modified from: https://cen.acs.org/physical-chemistry/astrochemistry/Periodic-Graphics-Fuels-space-travel/100/i43
http://www.braeunig.us/space/propel.htm
https://chemnotcheem.com/the-chemistry-of-rocket-science/
https://spaceimpulse.com/2023/06/13/how-much-does-rocket-fuel-cost/)

(a) Use the data provided to suggest one advantage and one disadvantage of solid propellant engines over liquid propellants engines.

advantage .....

.....

.....

disadvantage .....

.....

..... [2]

(b) Explain, using ideas of collision theory, why the propellant mixture used in solid propellant engines tend to be in powdered form.

.....

..... [1]

(c) **(i)** When a batch of RP-1 was heated, the liquid boiled from 206 °C to 256 °C.

Suggest why this is so.

.....

..... [1]

(ii) The enthalpy change of combustion of RP-1 is –7091 kJ/mol, while that of hydrogen is –286 kJ/mol.

Assuming that RP-1 is mainly composed of dodecane, $C_{12}H_{26}$, calculate the enthalpy change when 1 g of each propellant is burnt.

[Relative atomic masses, A_r: H, 1; C, 12]

enthalpy change of combustion of RP-1 = ... kJ/g

enthalpy change of combustion of hydrogen = ... kJ/g [2]

(iii) Use the data provided and your answer from **(c)(ii)** to suggest one advantage and one disadvantage of using hydrogen as a liquid propellant over RP-1.

advantage .....

.....

.....

disadvantage .....

.....

..... [2]

(d) **(i)** In electric propulsion, electricity is used to remove an electron from a xenon atom, producing gaseous ions.

Using information in Table 8.2 and ideas about kinetic particle theory, explain how electric propulsion of xenon works to propel the rocket in outer space.

Support your answer with an ionic equation.

.....

.....

.....

..... [2]

(ii) Other noble gases, such as krypton and argon, are also popular fuels used in electric propulsion.

With reference to Table 8.2, give two reasons why electric propulsion is still preferred over chemical propulsion despite its high cost.

.....

.....

.....

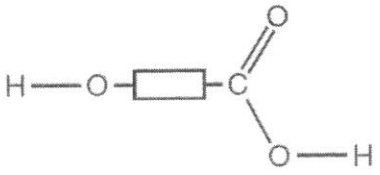
.....

.....

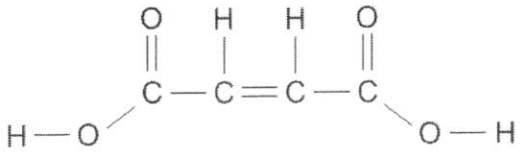
..... [2]

[Total: 12]

B9 A liquid mixture contains two organic compounds, **A** and **B**. The structures of compounds **A** and **B** are shown below.



A



B

(a) Name the three different functional groups present in the mixture of **A** and **B** and describe the chemical tests that can be carried out to confirm the presence of each of these three functional groups in the mixture.

Your answer should include:

- the required reaction conditions, if any,
- the expected observations for each of the tests described.

.....

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.....

..... [5]

(b) Monomers of compound **A** can self-polymerise to form a polymer.

Monomers of compound **B** can also self-polymerise to form a different polymer.

For each compound, state the type of polymerisation it undergoes and draw the structural formula of the polymer formed, showing two repeat units.

type of polymerisation that compound **A** undergoes:

.....

polymer of compound **A**:

type of polymerisation that compound **B** undergoes:

.....

polymer of compound **B**:

[3]

[Total: 8]

EITHER

B10 Fig. 10.1 shows the set-ups of two experiments, 1 and 2, that were carried out using a piece of magnesium, a piece of iron and dilute zinc nitrate solution in a beaker.

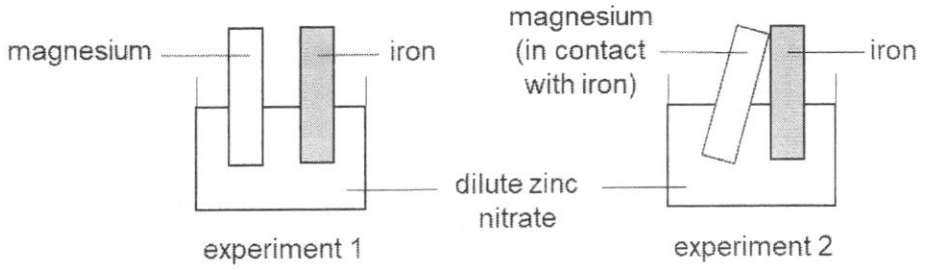


Fig. 10.1

(a) At the end of experiment 1, some newly-formed grey deposits were seen on the surface of the piece of magnesium.

With the help of an ionic equation, explain the observations at the end of experiment 1.

.....

.....

..... [2]

(b) Predict and explain the expected observations for experiment 2.

Your answer should:

- describe the expected observations at each piece of metal
- explain why each change occurs
- give half-equations for each change.

.....

.....

.....

.....

.....

.....

.....

.....

.....

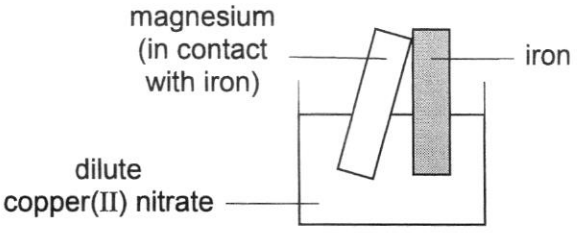
..... [5]

(c) The set-up used in experiment 2 is similar to one method of rust prevention.

Name this method of rust prevention.

..... [1]

(d) In a separate experiment, experiment 2 was repeated using copper(II) nitrate solution, as shown below.



Describe two changes observed at the end of this experiment.

.....

.....

..... [2]

[Total: 10]

OR

B10 The acid dissociation constant, K_a, is a quantitative measure of the strength of an acid in solution. The larger the K_a value, the greater the ease of dissociation of the acid molecules in solution and thus the stronger the acid. For strength of bases, it is measured using K_b, the base dissociation constant. The larger the K_b value, the greater the ease of dissociation of the base molecules in solution and thus the stronger the base.

The dissociation constants for some acids and bases are given in Table 10.1 and Table 10.2 respectively.

Table 10.1

type of acid	name and formula of acid	dissociation constant, K_a
inorganic	hydrochloric acid, HC*l*	1.3×10^{6}
	nitric acid, HNO_3	2.5×10^{1}
organic	methanoic acid, HCOOH	1.8×10^{-4}
	ethanoic acid, CH_3COOH	1.75×10^{-5}
	propanoic acid C_2H_5COOH	1.34×10^{-5}
	oxalic acid, HOOCCOOH	5.9×10^{-2}

Table 10.2

name of base	chemical formula of base	dissociation constant, K_b
ammonia	NH_3	1.8×10^{-5}
methylamine	CH_3NH_2	4.4×10^{-4}
ethylamine	$CH_3CH_2NH_2$	5.6×10^{-4}

(a) Use the information in Table 10.1 to describe the general difference in the dissociation constants of organic and inorganic acids.

Explain the difference in values with reference to the extent of dissociation.

.....

.....

.....

.....

..... [2]

(b) Use the data in Table 10.1 and Table 10.2 to describe the effect of carbon chain length on the strength of an acid and the strength of a base.

.....

.....

.....

.....

.....

..... [3]

(c) Sulfuric acid is a dibasic acid which has two dissociation constants: 1.0×10^{3} and 1.0×10^{-2}. The equations for the dissociation of sulfuric acid are as shown.

$$H_2SO_4(aq) \longrightarrow H^+(aq) + HSO_4^-(aq)$$

$$HSO_4^-(aq) \longrightarrow H^+(aq) + SO_4^{2-}(aq)$$

(i) Use the equations to explain the meaning of the term *dibasic*.

.....

..... [1]

(ii) Hence, explain what each dissociation constant measures.

.....

.....

..... [1]

(d) A student made the following statement.

"Oxalic acid is a member of the carboxylic acid homologous series."

Give one piece of evidence that agrees and disagrees with the statement above.

agree .....

.....

.....

disagree .....

.....

..... [2]

(e) Draw the full structural formula of the organic compound formed when oxalic acid reacts with excess ethanol.

[1]

[Total: 10]

END OF PAPER

2023 Secondary 4 Express 6092 Chemistry Preliminary Examinations Paper 1 Answers

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

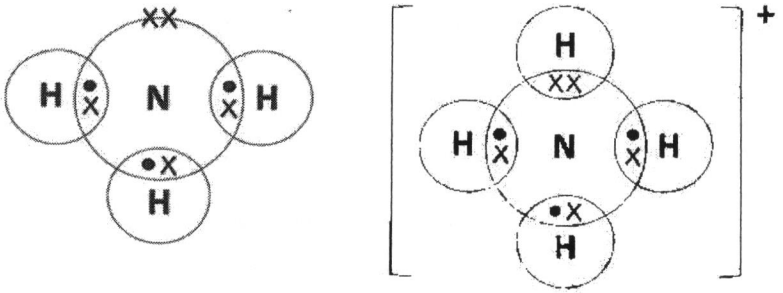
ACS (Barker Road)
6092 4E Chemistry Prelim Exam 2023 Marking Scheme

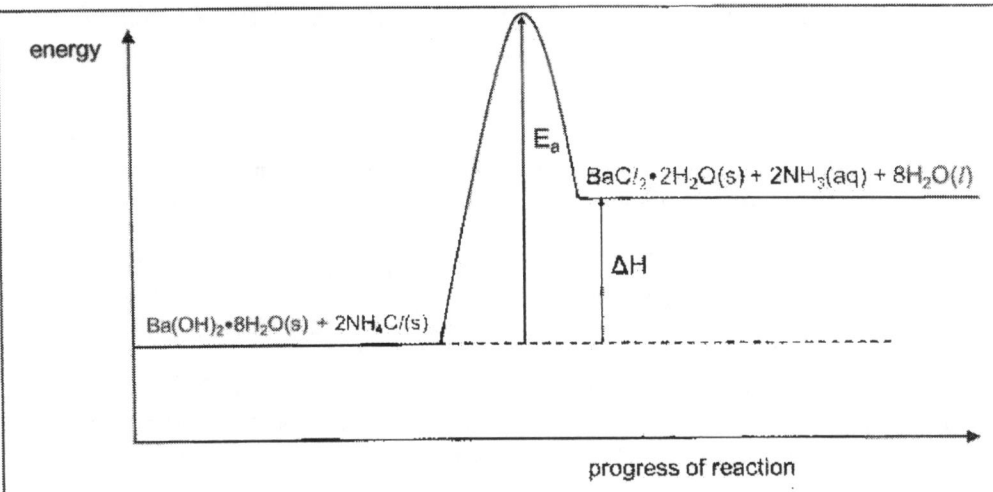
Paper 2

Question		Answer	Mark	Remarks
A1	(a)	Aqueous ammonia would form a white precipitate with lead, zinc and aluminium ion / all 3 cations. The white ppt that is formed with zinc ion dissolves in excess aqueous ammonia to form a colourless solution.	1 1	
	(b)	Add aqueous sodium sulfate / sulfuric acid / potassium sulfate / any aqueous sulfate. The solution containing Pb^{2+} will form a white ppt ($PbSO_4$) The solution containing $A\beta^{+}$ will not form any ppt.	1 1	
A2	(a)	$MgCO_3$ (s) + 2HCl (aq) → $MgCl_2$ (aq) + CO_2 (g) + H_2O (l) ;	2	
	(b)	1. Add excess $MgCO_3$ to a beaker containing dilute hydrochloric acid. 2. Stir until no more effervescence is seen / no more solid dissolves. 3. Filter the mixture, using a filter paper and funnel, to obtain the filtrate.	1 1 1	
	(c)	(i) The salt may decompose or become anhydrous.	1	
		(ii) Heat the solution to saturation and allow it to cool.	1	
	(c)	The percentage yield will decrease. The water that was present in the magnesium chloride would evaporate, causing the mass of magnesium chloride to decrease.	1 1	
A3	(a)	Their atoms have the same number of valence electrons/1 valence electron.	1	
	(b)	Soft / low melting points / low density	1	
	(c)	Anode: $2Br^{-}$ (l) → Br_2 (g) + $2e^{-}$ Cathode: Rb^{+} (l) + e^{-} → Rb (l)	1 1	

<table>
<tr><td></td><td>(d)</td><td>Argon is inert/unreactive;
and prevents the highly reactive rubidium from reacting readily/explosively/vigorously with oxygen/air.;</td><td>1</td><td>OWTTE</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>(e)</td><td>Graphite anode: Macromolecular structure where each C atom uses 3 valence electrons to bond with 3 other C atoms and delocalises 1 valence electron, which can carry charge.
Molten RbCl: giant ionic lattice structure with mobile ions to carry charge.
Molten Rb: metallic lattice structure with mobile ions and electrons to carry charge.</td><td>1
1
1
1</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>(f)</td><td>Hydrogen ions will be preferentially discharged over rubidium ions and reduced at the cathode to produce hydrogen gas, instead of rubidium metal.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>A4</td><td>(a)</td><td><table><tr><td>Element</td><td>K</td><td>Cu</td><td>Cl</td></tr><tr><td>Mass</td><td>31.5</td><td>25.6</td><td>100-31.5-25.6 = 42.9;</td></tr><tr><td>A_r</td><td>39</td><td>64</td><td>35.5</td></tr><tr><td>Mol</td><td>31.5/39 = 0.80769</td><td>25.6/64 = 0.4</td><td>42.9/35.5 = 1.2084;</td></tr><tr><td>;implest ratio</td><td>0.80769/0.4 = 2.0192
= 2</td><td>0.4/0.4
= 1</td><td>1.2084/0.4 = 3.02
= 3</td></tr></table>
Empirical formula is K_2CuCl_3 ;</td><td>3</td><td>If empirical formula is not written, deduct 1 mark.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td>Protons: 29;
Neutrons: 37;
Electrons: 27;</td><td>2</td><td>1 correct – 1m
All correct – 2m</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i) Fluorine is more reactive than chlorine and can displace chloride ions ;from copper(II) chloride to form copper(II) fluoride and chlorine.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>(ii) Oxidation state of F decreases from 0 in F_2 to -1 in CuF_2, hence F_2 is reduced.
Oxidation state of Cl increases from -1 in $CuCl_2$ to 0 in Cl_2, hence $CuCl_2$ is oxidised.
Since oxidation and reduction happens at the same time, reaction is redox.</td><td>1
1</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

		(iii)	$CuOH^+$	1	Students need to write out and balance the equation in terms of the number of each atom and the total charges on each side of the equation. $CuF_2 + H_2O \rightarrow 2F^- + H^+ + \mathbf{CuOH^+}$ Only 1 other ion was produced, hence no other answers are accepted.
A5	**(a)**	**(i)**	Black and dirty-green.; Carbon reduces iron(III) hydroxide to iron(II) hydroxide AND Reduces iron(III) oxide in haematite to iron(II) oxide. ;	2	
		(ii)	Reddish-brown and red ; Oxygen in the air oxidises iron(II) hydroxide to iron(III) hydroxide AND oxidises iron(II) oxide to iron(III) oxide. ;	2	
	(b)	**(i)**	Fe_2O_3 (s) + 3 CO (g) → 2 Fe (*l*) + 3 CO_2 (g)	2	
		(ii)	Moles of Fe extracted = $30 \times 10^6 / 56 = 5.36 \times 10^5$ mol ; Moles of PURE Fe_2O_3 reacted = $5.36 \times 10^5 / 2 = 2.68 \times 10^5$ mol Mass of PURE $Fe_2O_3 = 2.68 \times 10^5 \times 160 = 42.88 \times 10^6$ g = 42.88 tonnes ; % purity of Fe_2O_3 = 42.88/100 x 100 % = 42.88 % ~ 42.9 %;	3	

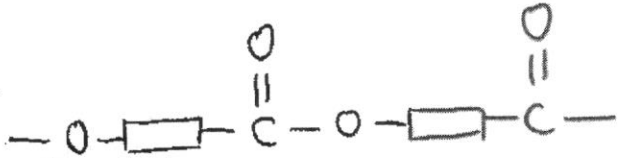
A6	**(a)**	 AMMONIA, NH_3 AMMONIUM ION, NH_4^+	3	Dot and cross of NH_3 – 1m Dot and cross of NH_4^+ – 1m Dative bond in NH_4^+ – 1m
	(b)	Similarity: Both bonds are formed by the sharing of (valence) electrons between two atoms. Difference: A covalent bond is formed when each atom shares 1 (valence) electron, while a dative covalent bond is formed when two/both/pair of shared electrons come from the same atom.	1 1	
A7	**(a)**	Reaction (between barium hydroxide and ammonium chloride) is endothermic/takes in or away heat from the surroundings/water. Causing water to freeze/cool to below 0 °C OR temperature of water to decrease below melting/freezing point (of 0 °C).	1 1	

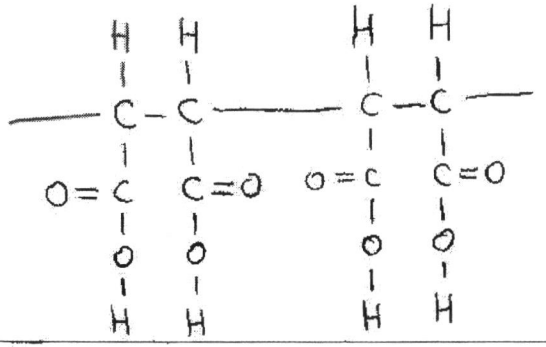
	(b)		3	Single-head arrow ΔH – 1m Single-head arrow E_a – 1m Correct energy levels + reactants and products (accept names or formula, no need state symbols) – 1m

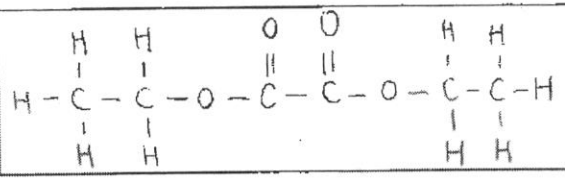
Section B

Question		Answer	Mark	Remarks
B8	(a)	Disadvantage: Solid propellant engine cannot be stopped/restarted, cannot control movement/speed/motion of spacecraft. OR Solid waste product must be properly disposed of / stored in engine, increasing mass of engine. Advantage: Solid propellant engines are easier to build due to its less complex structure/less components or parts needed in the engine or more considerations based on properties of chosen propellant OR Solid propellant engines are cheaper to build as there is no need to use corrosion-resistant materials / have higher operational lifetime (because fuel is not corrosive.)	2	OWTTE

	(b)	Increased surface area in contact, increased frequency of effective collisions, faster reaction.		1	
	(c)	**(i)**	RP-1 is impure/a mixture, hence boils over a range of temperatures.	1	
		(ii)	Mass of 1 mole (i.e M_r) of $C_{12}H_{26}$ = 12(12) + 26(1) = 170 ΔH of RP-1 = –7091 / 170 = –41.7 kJ/g ; Mass of 1 mole (i.e M_r) of H_2 = 2 ΔH of hydrogen = –286 / 2 = –143 kJ/g ;	2	
		(iii)	Advantage: Produce water (can be used for drinking or is a clean/pollution-free product) vs soot (pollutant or limit engine operation) (can be phrased as a disadvantage also) OR More energy per mass of propellant burnt for hydrogen (143 vs 41.7) / less propellant burnt per unit energy produced. OR hydrogen propellant do not contain impurities that can corrode the engine tank. Disadvantage: need to insulate engine because need to cool down to liquefy hydrogen propellant, resulting in increased mass of launch vehicle / need for larger storage tank for hydrogen due to its low density vs no need to liquefy/insulate RP-1	2	
	(d)	**(i)**	$Xe(g) \rightarrow Xe^+(g) + e^-$; Gaseous positive ions are produced, which collide and repel one another at high speeds, generating thrust. ;	2	
		(ii)	In electric propulsion, noble gases are unreactive/chemically stable, hence safe to store compared to hydrazine, which ignites readily and is dangerous to store. OR not as toxic as hydrazine, safer to use. OR In electric propulsion, there is higher fuel efficiency so can be used for longer space missions / less volume of fuel is needed for same distance travelled.	2	Any two

B9	**(a)**	<u>Hydroxyl group:</u> Test: add acidified potassium manganate(VII) or acidified $KMnO_4$ into the sample and heat (under reflux). Observations: if purple $KMnO_4$ solution decolourises, hydroxyl group is present. <u>Carbon-carbon double bond:</u> Test: Add aqueous bromine to the sample Observations: If reddish-brown aq. Br_2 decolourises, C=C bond is present. <u>Carboxyl group:</u> Test: add Universal Indicator/litmus paper. Observations: if U.I turns orange/yellow OR litmus turns red, carboxyl group is present. OR Test: add any reactive metal OR metal carbonate Observations: if effervescence of a colourless, odourless gas that extinguishes lighted splint with 'pop' sound is produced OR forms white ppt in limewater, carboxyl group is present.	5	Correct name of any 1 func group – 1m Correct names of all 3 func group – 2m Max: [2] Test for – OH : reagent + heat + obs [1] Test for C=C : Reagent + obs [1] Test for – COOH: reagent + obs [1] Max: [3]
	(b)	type of polymerisation that compound **A** undergoes: condensation polymer of compound **A**: 	3	Structural formula of polymer A [1] Structural formula of polymer B [1] Correct type of polymerisation for both A and B [1]

		type of polymerisation that compound **B** undergoes: addition polymer of compound **B**: 		
EITHER				
B10	**(a)**	Magnesium is more reactive than zinc and displaces the zinc ions to form magnesium nitrate and grey Zn metal. ; $Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$;	2	
	(b)	Mass of **Mg** will decrease as magnesium is more reactive than iron and oxidises in place of iron. ; (Mg is the anode.) **[1]** $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$; [1] Effervescence/bubbles of a colourless, odourless gas is observed at iron metal in Expt 2. ; [1] Hydrogen ions in zinc nitrate solution is preferentially discharged and reduced at the iron (cathode) to form hydrogen gas. ; [1] $2H^+(aq) + 2e^- \rightarrow H_2(g)$; [1]	5	
	(c)	sacrificial protection	1	
	(d)	Reddish-brown/pink/pink-brown copper residue/metal forms on Mg metal/bottom of beaker. ; Blue solution (gradually) decolourises. ;	2	

OR					
B10	**(a)**	The dissociation constants of inorganic acids are much higher than that of organic acids. [1] Inorganic acids can dissociate/ ionise fully in water while organic acids can only dissociate/ ionise partially to form H^+ ions. [1]		2	
	(b)	The longer the carbon chain length, the weaker the acid. AND The longer the carbon chain length, the stronger the base. [1] Data: As the carbon chain increases from 1 C atom for methanoic acid to 3 C atoms for propanoic acid, K_a decreases from 1.8×10^{-4} to 1.34×10^{-5}. [1] Data: As the carbon chain increases from 1 C atom for methylamine to 2 C atoms for ethylamine, K_b increases from 4.4×10^{-4} to 5.6×10^{-4}. [1]		3	
	(c)	**(i)**	Sulfuric acid is dibasic, dissociates in water to produce two H^+ ions per acid molecule / dissociates two times to produce two H^+ ions per acid molecule. OR 1 mole of acid produces two moles of H^+ ions in water.	1	
		(ii)	Larger K_a (of 1.0×10^3) measures the ease of the first dissociation of H_2SO_4 to produce one H^+ ion, while the smaller K_a (of 1.0×10^{-2}) measures the ease of dissociation of HSO_4^- to produce the second H^+ ion.	1	
	(d)	Agree: oxalic acid contains the carboxyl functional group OR –COOH. [1] Reject: each member differs from the next by a CH_2 unit (unable to infer from information given) Disagree: oxalic acid does not follow the general formula $C_nH_{2n+1}COOH$ [1]		2	
	(e)			1	Esterification reaction