Name and Index Number: ( )	Class:

SENG KANG SECONDARY SCHOOL
PRELIMINARY EXAMINATION

CHEMISTRY — 6092/01

Secondary 4 Express — 29 August 2023

Paper 1 Multiple Choice — 1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your index number and name on all the work you hand in.

There are **forty** questions in 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 Multiple Choice 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 question paper.
A copy of the Periodic Table is printed on page 16.
The use of an approved scientific calculator is expected, where appropriate.

Parent's / Guardian's Signature: .....

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

Do not turn over the page until you are told to do so.

1 The statements describe two changes of state.

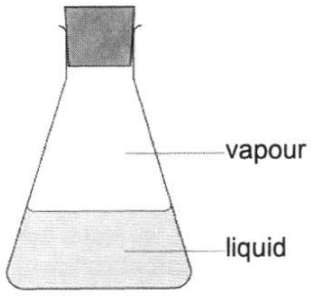
1 The molecules of substance X are arranged randomly. During the change of state, they lose energy and become more ordered. The molecules can still move freely.

2 The molecules of substance Y are arranged in a regular lattice. During the change of state, they gain energy and become less ordered. The molecules are still close together.

Which changes of state are described by the statements?

	1	2
A	condensation	evaporation
B	condensation	melting
C	freezing	evaporation
D	freezing	melting

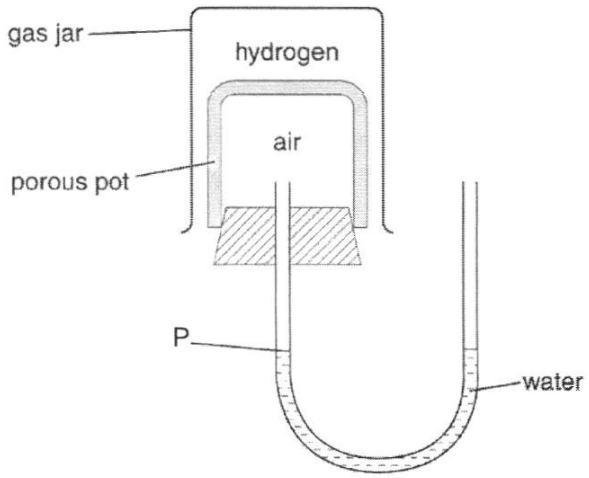
2 A sealed conical flask contains a liquid and its vapour, as shown.



What happens when a molecule in the vapour enters the liquid?

	the molecule stops moving	the molecule becomes smaller
A	✓	✓
B	✓	×
C	×	✓
D	×	×

3 The apparatus shown in the diagram was set up.



How will the water level at P change over a period of time?

A It will fall, then rise and return to P.

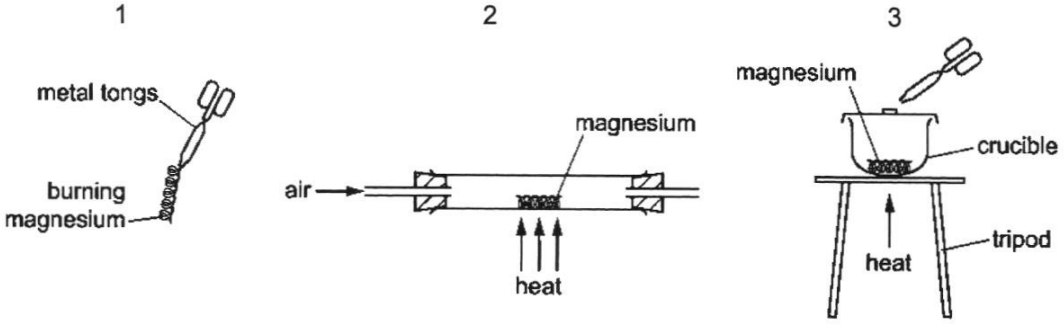
B It will fall and remain at a lower level.

C It will rise, then fall and return to P.

D It will rise and remain at a higher level.

4 When heated, magnesium reacts with oxygen in the air to form magnesium oxide, a white powder.

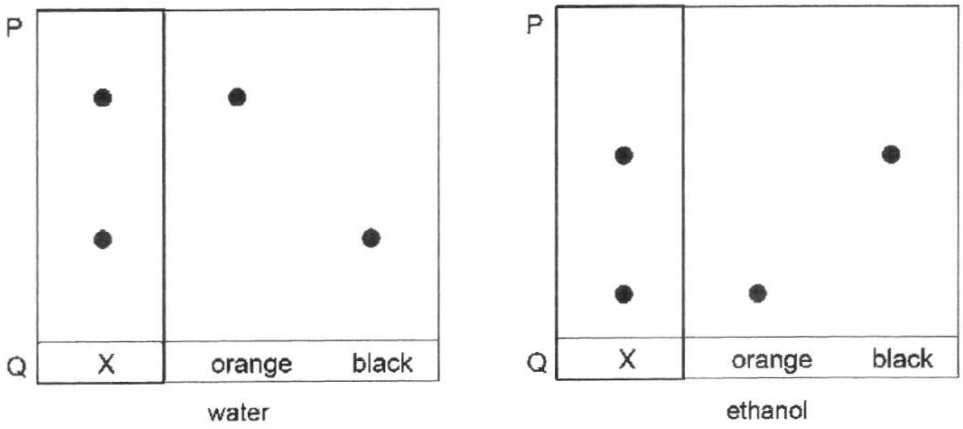
A student investigates the change in mass that occurs during this reaction. He is given a balance and the three sets of apparatus shown.



Which set(s) of apparatus is/are suitable for this investigation?

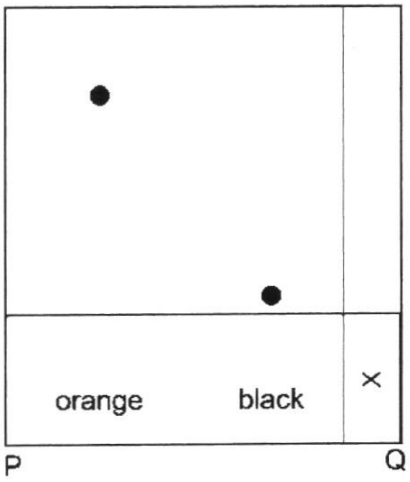
A 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 2 only

5 The colours in a soft drink, X, was analysed by chromatography. The experiment was performed using two different solvents, water and ethanol. The results are shown.

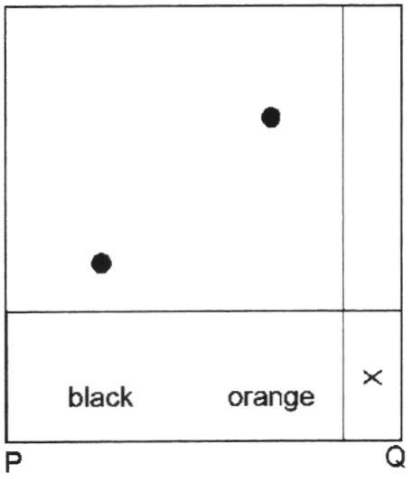


How would the final chromatogram appear if mixture X was first developed in water, then turned through 90° anticlockwise and edge PQ was placed in ethanol?

A



C



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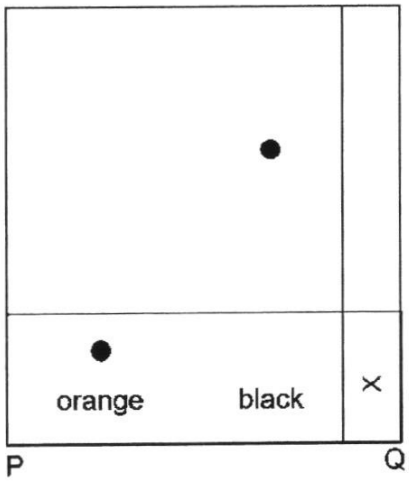

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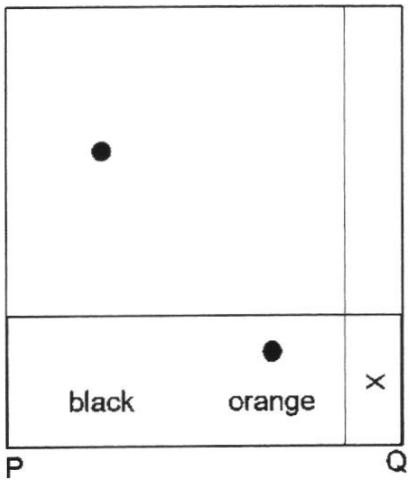
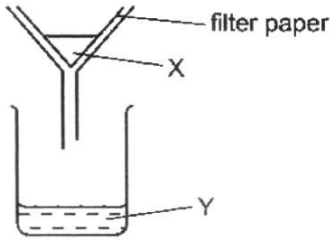


6 The diagram shows a method for separating a substance that contains X and Y.



Which types of substance can be separated by the method shown?

A compounds
B elements
C mixtures
D molecules

7 Four substances are heated gently. The temperatures at which they start and finish melting are recorded.

substance	temperature	
	initial melting / °C	final melting / °C
1	0	0
2	36	40
3	101	105
4	117	117

Which statement about the substances is correct?

A Substance 2 and substance 3 are impure.
B Substance 3 is water.
C Substance 4 is the only pure substance.
D They are all solids at room temperature.

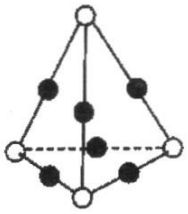
8 Which statement describes isotopes?

A Isotopes of the same element have different electron arrangements.
B Isotopes of the same element have different nuclear charges.
C Isotopes of the same element have nuclei with masses that are the same.
D Isotopes of the same element have the same number of protons.

9 What is the nucleon number of the isotope of uranium, $^{235}_{92}U$?

A 143 **B** 235 **C** 238 **D** 327

10 The diagram represents one molecule of a compound.



key
○ = an atom of X
● = an atom of Y

What is the molecular formula of this compound?

A X_2Y_3 **B** X_3Y_2 **C** X_4Y_6 **D** X_6Y_4

11 The statements describe elements P and Q.

An atom of P has more protons than an atom of Q.
An atom of Q has more valence electrons than an atom of P.
Particles of P and Q combine to form an ionic structure.

What can be deduced based on the statements?

A An atom of P has more electron shells than an atom of Q.
B P forms negatively charged ions.
C P and Q are in the same period of the Periodic Table.
D P and Q are in the same Group of the Periodic Table.

12 What is the percentage, by mass, of nitrogen in the fertiliser $(NH_4)_3PO_4$?

A 9.4% **B** 18.8% **C** 28.2% **D** 37.6%

13 A volume of ethane, C_2H_6, at r.t.p. has a mass of 20 g.

What is the mass of an equal volume of propene, C_3H_6, at r.t.p.?

A 20 g **B** 21 g **C** 28 g **D** 42 g

14 Three elements X, Y and Z belong to the same period in the Periodic Table.

The properties of the oxide formed by the three elements are shown.

oxide of X	insoluble in water and aqueous sodium hydroxide but dissolves readily in dilute hydrochloric acid
oxide of Y	has low boiling point and does not react with both aqueous sodium hydroxide and dilute hydrochloric acid
oxide of Z	insoluble in water but dissolves in both aqueous sodium hydroxide and dilute hydrochloric acid

What is the arrangement of elements X, Y and Z, in order of increasing atomic number, on the Periodic Table based on the properties?

	increasing atomic number →		
A	X	Y	Z
B	X	Z	Y
C	Y	X	Z
D	Y	Z	X

15 The results of some experiments with sulfur dioxide are shown.

experiment	description	result
1	mix with dilute hydrochloric acid	does not react
2	mix with concentrated sodium hydroxide	a salt is formed
3	add Universal Indicator	Universal Indicator turns violet
4	add acidified aqueous potassium manganate(VII)	purple solution turns colourless

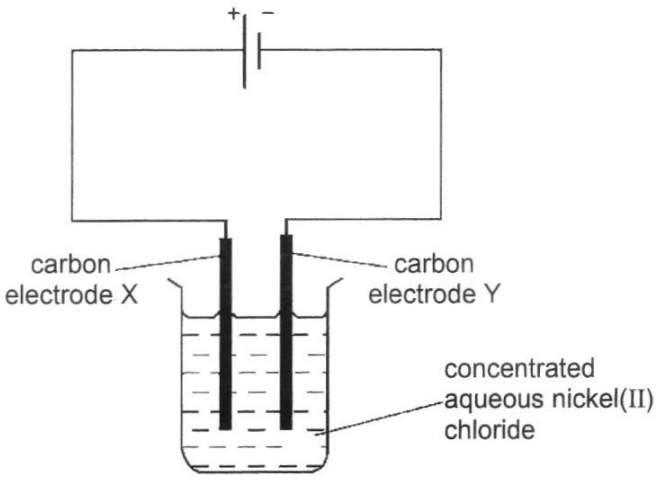
Which results are correct?

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

16 Which substance, when added to water, makes a solution that is a good conductor of electricity?

A calcium carbonate
B copper
C ethanol
D sodium hydroxide

17 Apparatus is set up as shown in the diagram.



What occurs at electrode X?

A Chloride ions are oxidised.

B Chloride ions are reduced.

C Nickel ions are oxidised.

D Nickel is deposited.

18 When ammonium nitrate is added to water the temperature of the water decreases.

The ammonium nitrate can be recovered by evaporating the water added.

Which statement explains these observations?

A The ammonium nitrate dissolves in the water and the process is endothermic.

B The ammonium nitrate dissolves in the water and the process is exothermic.

C The ammonium nitrate reacts with the water and the process is endothermic.

D The ammonium nitrate reacts with the water and the process is exothermic.

19 It has been suggested that the cars of the future could be powered by fuel cells. One type of fuel cell uses the chemical reaction between oxygen and hydrogen to produce electricity.

What would be a **disadvantage** of using this type of fuel cell to power a car?

A A car cannot be powered by electricity.

B The hydrogen tank might split in an accident, leading to an explosion.

C The product of the reaction between oxygen and hydrogen is toxic.

D The oxygen would need to be obtained from air.

20 Calcium, on the left of period 4 of the Periodic Table, is more metallic than bromine on the right of this period.

Why is this so?

A Calcium has fewer electrons than bromine.

B Calcium has fewer full shells of electrons than bromine.

C Calcium has fewer outer shell electrons than bromine.

D Calcium has fewer protons than bromine.

21 Sulfur and selenium, Se, are in the same Group of the Periodic Table.

What would we expect the formulae to be when selenium form compounds?

A Se_2O, Na_2Se and $NaSeO_4$

B SeO_2, Na_2Se and $NaSeO_4$

C SeO_2, Na_2Se and Na_2SeO_4

D SeO_3, NaSe and $NaSeO_4$

22 The equation shows the reaction between a halogen and aqueous bromide ions.

$$\underset{\ldots 1\ldots}{X_2} + \underset{\ldots 2\ldots}{2Br^-} \rightarrow 2X^- + \underset{\ldots 3\ldots}{Br_2}$$

Which words describe gaps 1, 2 and 3?

	1	2	3
A	chlorine	brown	colourless
B	chlorine	colourless	brown
C	iodine	brown	colourless
D	iodine	colourless	brown

23 An inert gas R is used to fill weather balloons.

Which descriptions of R are correct?

	number of outer shell electrons in atoms of R	structure of gas R
A	2	diatomic molecules
B	2	single atoms
C	8	diatomic molecules
D	8	single atoms

24 Three chemical reactions are represented as shown in the equations.

$$Cl_2 + 2H_2O + SO_2 \rightarrow 2HCl + H_2SO_4$$
$$Cl_2 + H_2S \rightarrow 2HCl + S$$
$$SO_2 + 2H_2S \rightarrow 2H_2O + 3S$$

Which row shows the reducing power of the reducing agents in a decreasing order?

	most reducing power ⟶ least reducing power		
A	Cl_2	H_2S	SO_2
B	Cl_2	SO_2	H_2S
C	H_2S	SO_2	Cl_2
D	SO_2	H_2S	Cl_2

25 Which statement about the alkali metals is true?

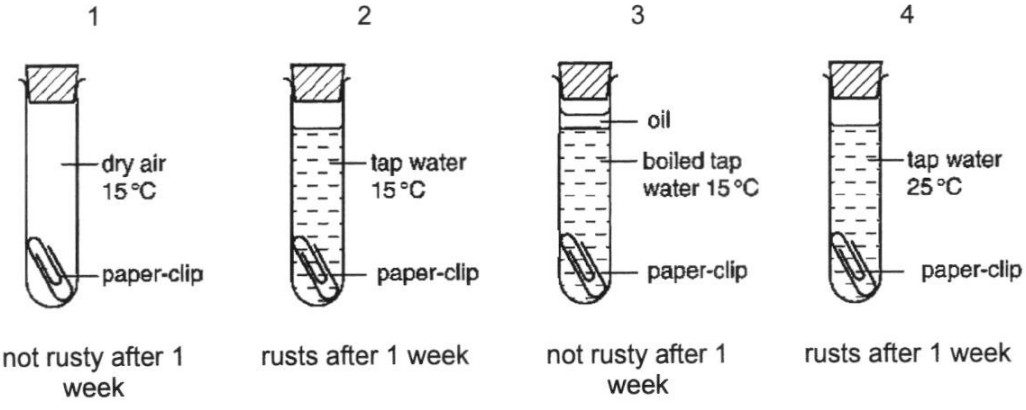
A They form covalent bonds with Group VII elements.

B They form oxides on reacting with water.

C Their melting points decrease on descending Group I.

D Their reactivities decrease on descending Group I.

26 Four experiments on rusting are shown.



Which two experiments can be used to show that air is needed for iron to rust?

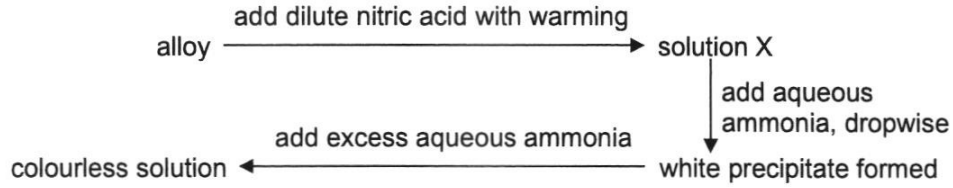
A 1 and 3 **B** 1 and 4 **C** 2 and 3 **D** 2 and 4

27 The metals iron, lead and zinc can each be manufactured by the reduction of the oxides with coke.

What is the correct order of the ease of reduction of the metal oxides?

	oxides becoming more difficult to reduce →		
A	iron	lead	zinc
B	iron	zinc	lead
C	lead	iron	zinc
D	zinc	iron	lead

28 A student conducted the following tests on a sample of alloy containing two metals.



What are the two possible metals present in the alloy?

A aluminium and copper
B lead and iron
C zinc and copper
D zinc and iron

29 The table gives information about five metals.

metal	percentage in the Earth's crust	cost per tonne / $
aluminium	8.1	750
copper	0.0007	1080
iron	5.0	300
tin	0.0002	9500
zinc	0.015	575

The general pattern suggest that the higher the percentage in the Earth's crust, the lower the cost.

Which metal does **not** fit this pattern?

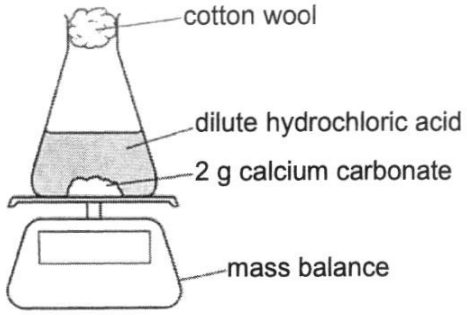
A aluminium **B** copper **C** iron **D** tin

30 Which metallic element, represented by M, has the following characteristics?

- It can be prevented from corroding by attaching a piece of magnesium to it.
- Two of its oxides have the formulae MO and M_2O_3.
- It has the highest percentage by mass of all the metals present in stainless steel.

A Fe **B** Na **C** Pb **D** Zn

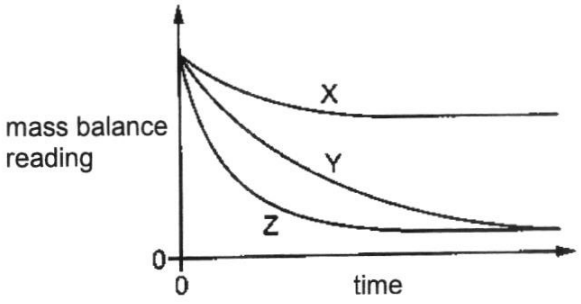
31 The rate of reaction between calcium carbonate and hydrochloric acid is measured in three separate experiments.



The conditions at which each experiment is performed are as follows.

experiment	particle size of calcium carbonate	moles of hydrochloric acid provided for reaction
1	powdered	in excess
2	lumps	in excess
3	lumps	insufficient

The results of these experiments are shown.



Which statement is correct?

A Experiment 1 is shown by curve X.

B Experiment 1 is shown by curve Y.

C Experiment 2 is shown by curve Y.

D Experiment 3 is shown by curve Z.

32 Nitrogen and hydrogen react in a closed vessel as shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

How do the speeds of the forward and reverse reactions change, if the pressure in the vessel is increased but the temperature is kept constant?

	speed of forward reaction	speed of reverse reaction
A	decreases	does not change
B	decreases	increases
C	does not change	does not change
D	increases	increases

33 Magnesium reacts with hydrochloric acid.

Which solution would give the fastest initial rate of reaction?

A 40 g of hydrochloric acid in 1000 cm^3 of water

B 20 g of hydrochloric acid in 1000 cm^3 of water

C 10 g of hydrochloric acid in 100 cm^3 of water

D 4 g of hydrochloric acid in 50 cm^3 of water

34 A sample of fertiliser is tested by warming it with aqueous sodium hydroxide.

A colourless gas is produced which turns moist red litmus paper blue.

Which element, essential for plant growth, is present in the sample?

A nitrogen **B** phosphorus **C** potassium **D** sulfur

35 Solid ammonium chloride is heated. The gases ammonia and hydrogen chloride are formed. This is reaction 1.

Ammonia gas is mixed with hydrogen chloride gas. Solid ammonium chloride is formed. This is reaction 2.

Which statement is correct?

A Both reaction 1 and reaction 2 are exothermic.

B Reaction 2 is reversible.

C The equation for reaction 1 is $NH_5Cl \rightarrow NH_4 + HCl$.

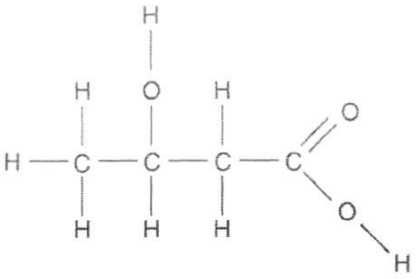
D The three substances involved in each reaction all have a simple molecular structure.

36 The table shows the results of tests carried out on compound Z.

test	result
bromine water added	decolourised
sodium carbonate added	colourless and odourless gas evolved

Which formula represents compound Z?

A



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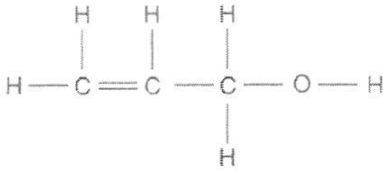

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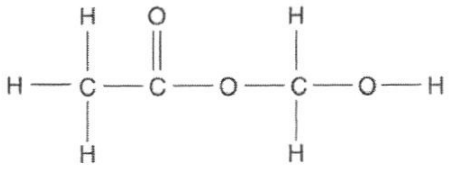

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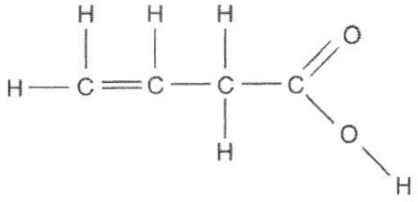
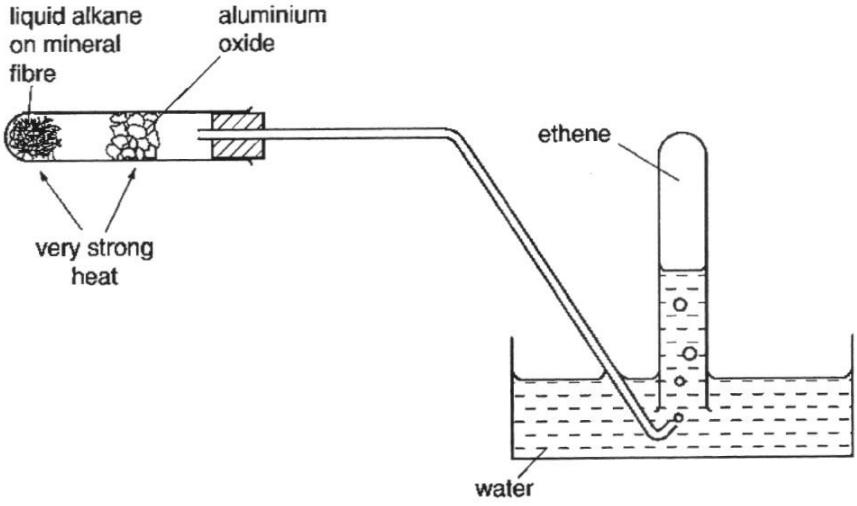


37 The experiment shown is carried out.



What process occurs?

A cracking

B dehydrogenation

C distillation

D polymerisation

38 What is the general formula of the homologous series of carboxylic acids?

methanoic acid	HCO_2H
ethanoic acid	CH_3CO_2H
propanoic acid	$C_2H_5CO_2H$
butanoic acid	$C_3H_7CO_2H$

A CHO **B** $C_nH_{2n}O$ **C** $C_nH_nO_n$ **D** $C_nH_{2n}O_2$

39 An ester is formed from a carboxylic acid and an alcohol.

How does the number of carbon, hydrogen and oxygen atoms in an ester differ from the total number of these atoms in the carboxylic acid and alcohol from which the ester is formed?

	carbon atoms	hydrogen atoms	oxygen atoms
A	fewer	fewer	fewer
B	fewer	same	fewer
C	same	fewer	fewer
D	same	same	same

40 Which statement about vegetable oil and the margarine made from it is correct?

A Both are liquids at room temperature.

B Both occur naturally.

C Margarine has higher melting point than vegetable oil.

D Vegetable oil has fewer carbon-carbon double bonds than margarine.

END OF PAPER

Name and Index Number: ( )	Class:

SENG KANG SECONDARY SCHOOL
PRELIMINARY EXAMINATION

CHEMISTRY — 6092/02

Secondary 4 Express — 23 August 2023

Paper 2 Theory — 1 hour 45 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

Section B
Answer all **three** questions, the last question is in the form either/or.

At the end of the examination, fasten all your work securely together.
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 22.
The use of an approved scientific calculator is expected, where appropriate.

For Examiner's use	
Section A	**/ 50**
1	/ 6
2	/ 6
3	/ 8
4	/ 8
5	/ 10
6	/ 6
7	/ 6
Section B	**/ 30**
8	/ 12
9	/ 8
Either 10	/ 10
Or 10	/ 10
Total	**/ 80**

Parent's / Guardian's Signature: .....

This document consists of **22** printed pages.

Do not turn over the page until you are told to do so.

Section A

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

1 Fig. 1.1 shows part of the Periodic Table.

I	II											III	IV	V	VI	VII	0
													C	N	O	F	
	Mg											Al				Cl	Ar
K	Ca				Cr		Fe			Cu	Zn					Br	
																I	
									Pt								

Fig. 1.1

Answer the following questions using only the symbols of the elements in Fig.1.1.

Each symbol may be used once, more than once or not at all.

Give the **symbol** of the element that

(a) forms an ion with a charge of 2–, ... [1]

(b) can displace magnesium from its salt solution safely in the laboratory,

..... [1]

(c) is extracted from haematite, ... [1]

(d) is used to make food containers because of its resistance to corrosion,

..... [1]

(e) is about one percent by volume of dry air, ... [1]

(f) is a catalyst found in the catalytic converter. ..... [1]

[Total: 6]

2 Most living things need oxygen to survive. Oxygen helps organisms grow, reproduce, and turn food into energy.

(a) Naturally occurring oxygen is composed of three stable isotopes, as shown in the mass spectrum in Fig. 2.1.

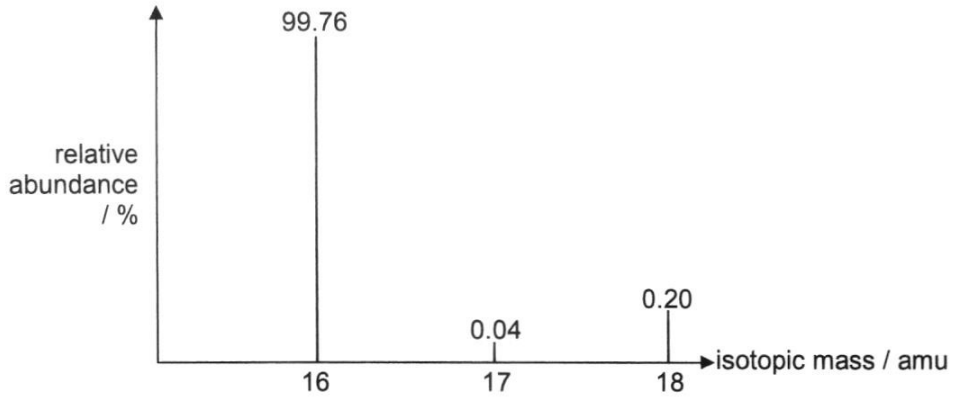


Fig. 2.1

Using the mass spectrum in Fig. 2.1, show that the relative atomic mass of oxygen is 16.0. Show your working **clearly**.

[1]

(b) Fig. 2.2 shows an experimental set-up to investigate the percentage of oxygen in air by passing 50.0 cm^3 of air over copper wire continuously over the two gas syringes.

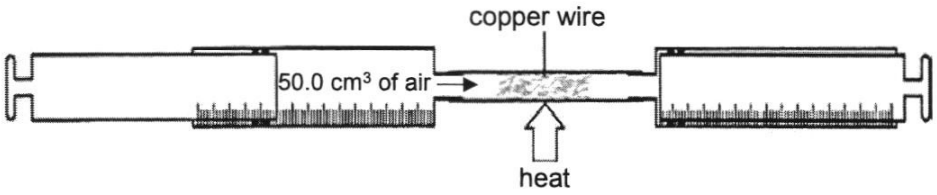


Fig. 2.2

(i) At the end of the experiment, the remaining volume of air is 39.5 cm^3.

Prove that the percentage of oxygen in air is 21.0%. Show your working **clearly**.

[1]

(ii) Write an equation for the reaction between the copper wire and air in Fig. 2.2.

..... [1]

(c) Table 2.3 gives the boiling points of argon, nitrogen and oxygen, which are commonly found in clean air.

Table 2.3

gas	boiling point / °C
argon	−186
nitrogen	−196
oxygen	−182

Oxygen can be separated from liquefied air as shown in Fig. 2.4.

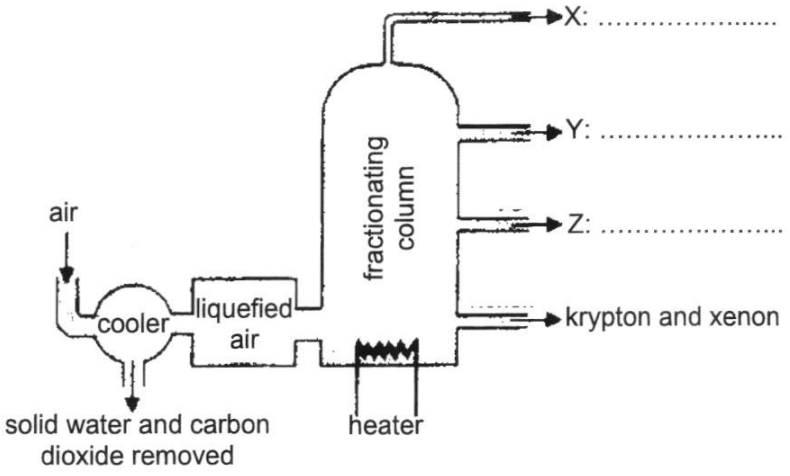


Fig. 2.4

(i) On Fig. 2.4, identify the gases X, Y and Z in the fractionating column of liquefied air using the data in Table 2.3. [2]

(ii) During the separation process, the mixture of argon, nitrogen and oxygen is allowed to cool from room temperature to −200 °C at the cooler.

Which substance will turn into liquid state first? ..... [1]

[Total: 6]

3 Fig. 3.1 shows the structures of two molecules, K and L, formed between three non-metallic elements, P, Q and R.

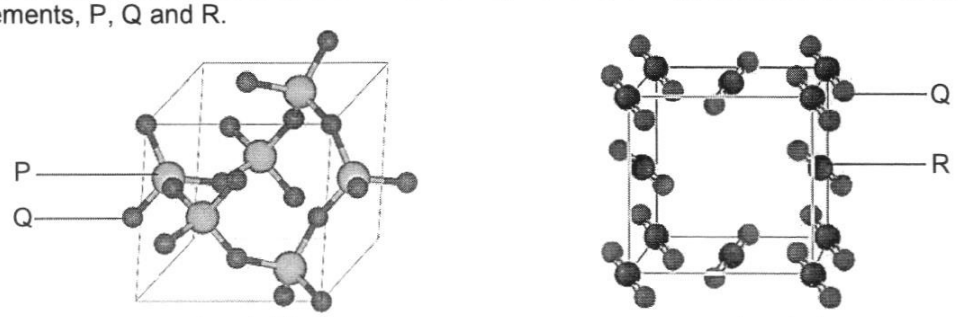


Fig. 3.1

(a) Both elements P and R belong to the same Group in the Periodic Table.

Deduce the Group in the Periodic Table which elements P and R belong to. Justify your answer using the structures in Fig. 3.1.

Group .....

justification ..... [2]

(b) Explain, in terms of bonding and structure, why molecule K exists as a solid while molecule L exists as a gas at room temperature and pressure.

.....

.....

.....

.....

.....

..... [4]

(c) Two students talk about the electrical conductivities of molecules K and L.

Student 1: Molecule K cannot conduct electricity in any physical states.

Student 2: Molecule L can conduct electricity due to the free-moving molecules that act as charged carriers.

Do you agree with each student? Explain your reasoning.

.....

.....

.....

..... [2]

[Total: 8]

4 **(a)** Magnesium carbonate reacts with dilute hydrochloric acid.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$$

When 25.0 cm^3 of dilute hydrochloric acid is added to excess magnesium carbonate, the volume of carbon dioxide gas produced, at room temperature and pressure, is 120 cm^3.

(i) Calculate the concentration, in mol/dm^3, of the dilute hydrochloric acid.

concentration ..... [3]

(ii) The reaction is repeated at a higher temperature. All other conditions stay the same.

Using ideas about collisions between particles, explain how the rate of reaction changes.

.....

.....

..... [2]

(b) Duralumin, an alloy of aluminium, magnesium, copper and manganese, is used in the construction of aircrafts.

(i) State the meaning of the term *alloy*.

..... [1]

(ii) Suggest **one** advantage of using duralumin in the construction of aircrafts.

..... [1]

(iii) To extract copper for the manufacture of duralumin, copper is required to be purified by electrolysis using an impure copper anode and a pure copper cathode.

Construct the ionic equation for the reaction taking place at the cathode.

cathode ..... [1]

[Total: 8]

5 Fig. 5.1 shows a toilet cleaner that contains an acid salt, sodium dihydrogen phosphate, NaH_2PO_4.

Fig. 5.1

Sodium dihydrogen phosphate is manufactured by reacting sodium hydroxide with phosphoric acid.

$$NaOH(aq) + H_3PO_4(aq) \rightarrow NaH_2PO_4(aq) + H_2O(l)$$

Sodium dihydrogen phosphate can react with excess sodium hydroxide to form sodium hydrogen phosphate, Na_2HPO_4.

$$NaH_2PO_4(aq) + NaOH(aq) \rightarrow Na_2HPO_4(aq) + H_2O(l)$$

(a) Using the information given, explain why sodium dihydrogen phosphate is considered both an 'acid' and a 'salt'.

.....

.....

.....

..... [2]

(b) **(i)** State the ionic equation for the reaction between sodium hydroxide and phosphoric acid. Include state symbols.

..... [1]

(ii) Suggest the name and formula of **another** possible salt produced from sodium hydroxide and phosphoric acid.

name .....; formula ..... [2]

(c) Table 5.2 shows information on two other dibasic acidic compounds.

Table 5.2

name of dibasic acid	pH of a 0.5 mol/dm^3 solution	
ethanedioic acid	3.0	↓ increasing acid strength
sulfuric acid	1.0	

(i) Using the information in Table 5.2, explain why sulfuric acid behaves as a strong acid but ethanedioic acid behaves as a weak acid.

.....

.....

.....

..... [2]

(ii) Describe an experiment, other than measuring pH or using indicators, which you could carry out to show that sulfuric acid is a strong acid but ethanedioic acid is a weak acid.

In your answer, state the measurements you would make and what results you would expect.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 10]

6 Fig. 6.1 shows the percentage yield of ammonia during the Haber process.

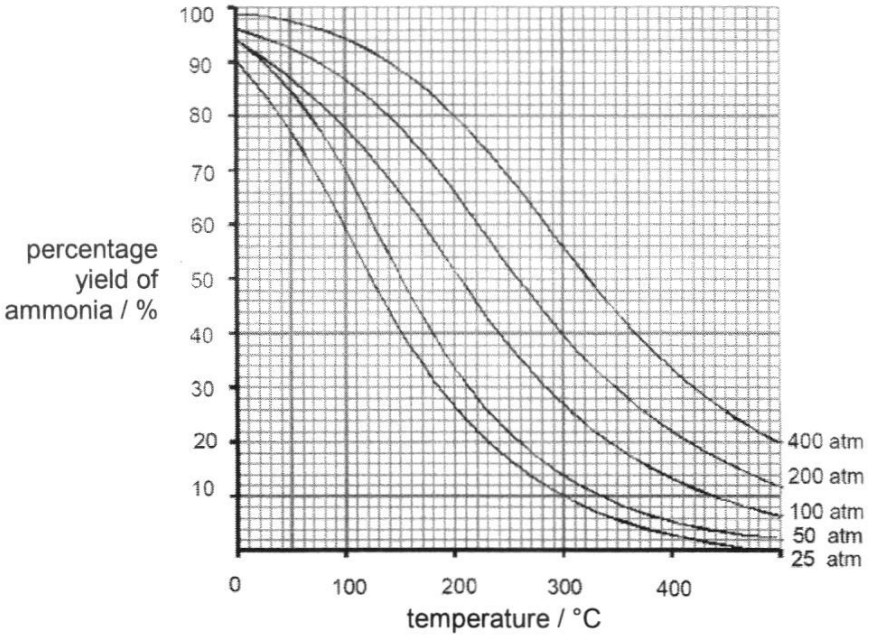


Fig. 6.1

(a) **(i)** Based on Fig. 6.1, state the conditions under which the percentage yield is highest.

temperature ..... pressure ..... [1]

(ii) State the industrial conditions that are used in the Haber process.

temperature ..... pressure ..... [1]

(iii) Explain why the industrial conditions are used, despite **not** giving the highest yield.

.....

..... [2]

(b) Iron is also used in the manufacturing process of ammonia.

A student made this comment.

'The iron is used to increase the percentage yield of ammonia.'

State the role of iron in the manufacture of ammonia, and explain whether you agree with the student's comment.

role of iron .....

explanation .....

..... [2]

[Total: 6]

7 Ethanol can be manufactured from the action of yeast on sugars found in grapes to produce wine in 40 days.

Fig. 7.1 shows how the composition of ethanol and grape juice change over 40 days.

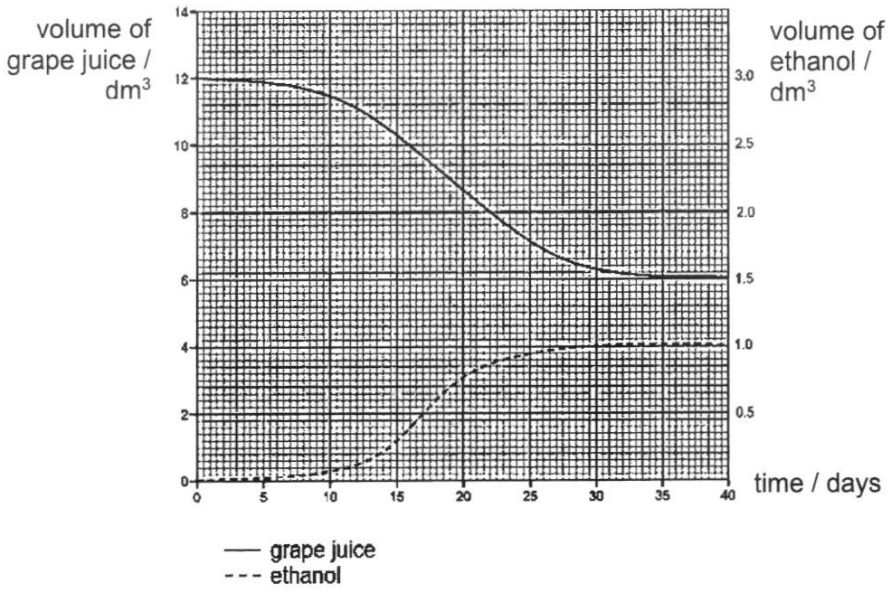


Fig. 7.1

(a) State **two** other conditions needed for this manufacturing process.

..... [2]

(b) Grape juice is known to contain glucose.

With the help of a chemical equation, explain the changes in composition of ethanol and grape juice as shown in Fig. 7.1.

.....

.....

.....

.....

.....

..... [3]

(c) Upon warming, ethanol is oxidised by acidified potassium manganate(VII) to produce a carboxylic acid.

Write an equation for this reaction.

..... [1]

[Total: 6]

Section B

Answer all **three** questions in this section in the spaces provided.

The last question is in the form of an either/or and only one of the alternatives should be attempted.

8 Plastic Polymers

Plastics are commonly made up of polymers. The properties of plastic polymers depend on the monomers they are made up from, and all plastic polymers have their own characteristic physical properties, depending on their specific molecular structure.

Table 8.1 shows the molecular structure of two plastic polymers, **A** and **B**, and some of their physical properties.

Table 8.1

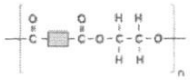
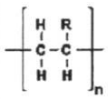
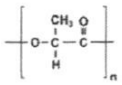
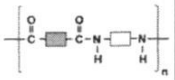
molecular structure	melting point / °C	density in g/cm^3	relative tensile strength
 plastic polymer **A**	115	0.91 – 0.94	half the strength of plastic polymer **B**
 plastic polymer **B**	135	0.95 – 0.97	double the strength of plastic polymer **A**

Plastic Recycling

Plastic recycling is the processing of plastic waste into new and useful products. To ensure the quality and value of the recycled plastic, plastics of different polymer types have to be sorted out before they can be recycled. The Resin Identification Code (RIC) was introduced so that plastic item can be labelled for easier sorting.

Plastics usually consist of polymer chains of varying lengths. Table 8.2 shows the names of the polymers that fall under the seven different RIC, the general range of molar masses of the different plastics and their percentages of plastic waste generated.

Table 8.2

RIC	polymer name	chemical structure	molar mass / (g/mol)	% of plastic waste
1 PETE	poly(ethylene terephthalate)		8000 – 31 000	18.8
2 HDPE	high density poly(ethene)		100 000 – 250 000	19.8
3 V	poly(vinyl chloride)		50 000 – 120 000	5.3
4 LDPE	low density poly(ethene)		100 000 – 250 000	13.9
5 PP	poly(propene)		75 000 – 700 000	19.1
6 PS	poly(styrene)	 where **R** represents a hydrocarbon branch	100 000 – 400 000	5.9
7 OTHER	other plastics, such as polycarbonate, polyamides	 poly(lactic acid)  nylon	—	17.2

Two methods of Plastic Recycling, Mechanical Recycling and Depolymerisation

Mechanical recycling is a physical method that melts plastics of the same polymer before making them into small pellets to be used again, while depolymerisation is a chemical method that uses either heat or chemical reactions to convert the polymers back into its monomers. Since each polymer has its unique chemical properties, the method of recycling is based on the RIC.

Fig. 8.3 shows the journey of plastic trash from recycling bin to becoming a new plastic product.

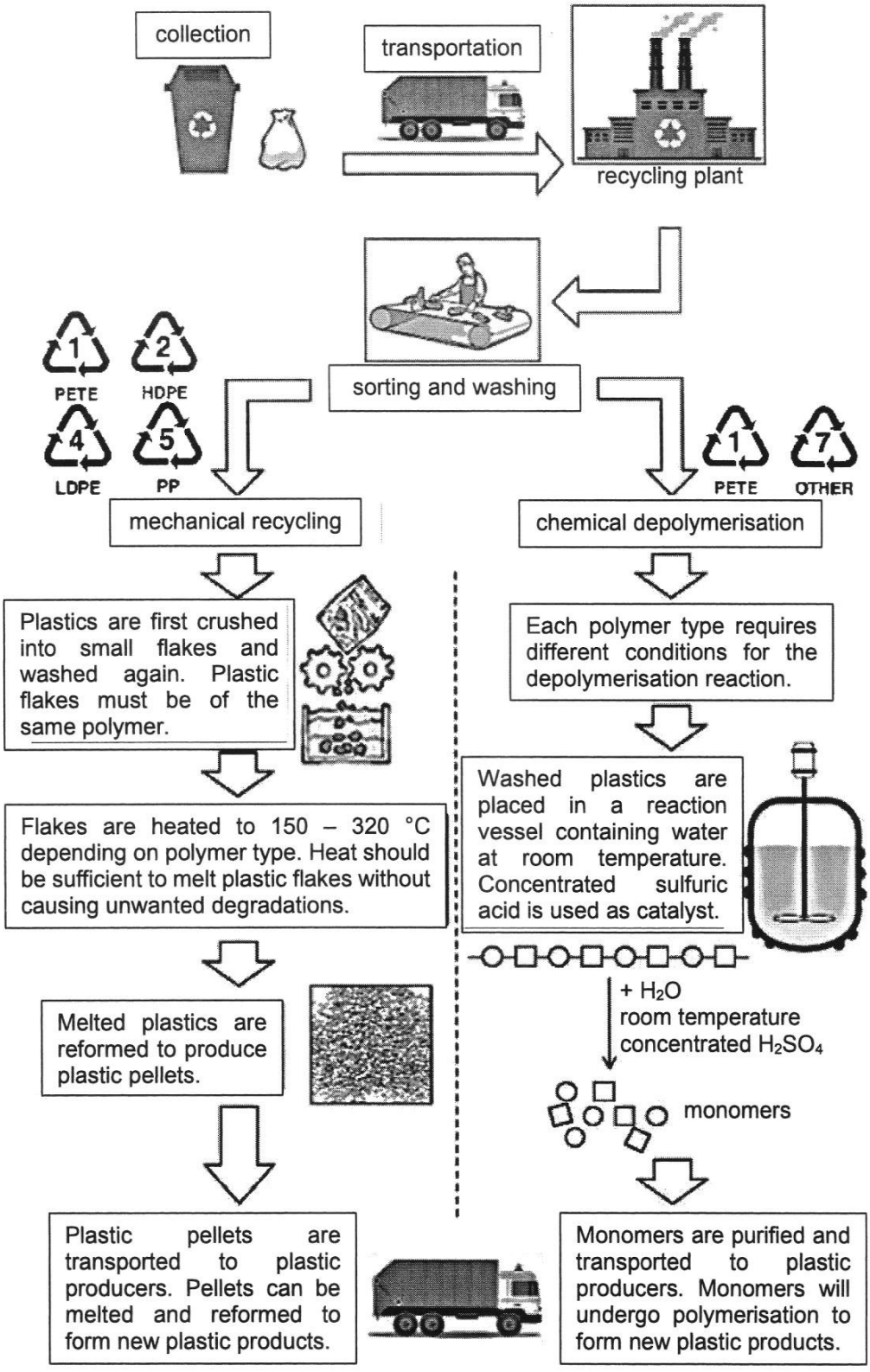


Fig. 8.3

Acknowledgement:
1) https://www.ghs.sg/recyclables/plastic-recycling/plastic-identification-codes/
2) https://onlinelibrary.wiley.com/doi/full/10.1002/pol.20230154
3) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7866858/

(a) With reference to the information in Table 8.1, describe and explain the relationship between the specific molecular structure and its physical properties.

.....

.....

.....

.....

.....

..... [3]

(b) **(i)** Draw the full structural formula of the monomer of poly(propene).

[1]

(ii) Explain, in terms of bonding and structure, why the melting point of a polymer is always higher than its monomer.

.....

.....

.....

..... [2]

(c) The shortest chain of poly(styrene) consists of 962 repeating units. Elemental analysis of poly(styrene) found that the polymer contains 92.3% of carbon and 7.7% of hydrogen by mass.

Calculate and deduce the formula of **R** in poly(styrene) in Table 8.2.

formula of **R** in poly(styrene) ..... [3]

(d) **(i)** Referring to data in Table 8.2 and Fig. 8.3, a student suggests that mechanical recycling can only recycle addition polymers while depolymerisation only recycles condensation polymers.

Do you agree with this student? Use the data to support your answer.

.....

..... [1]

(ii) Most recycling companies find that it is more cost-effective to develop mechanical recycling methods as compared to depolymerisation recycling methods.

With reference to Table 8.2 and/or Fig. 8.3, suggest a reason why this is so.

.....

..... [1]

(e) Based on the information given, suggest **one** reason why recycling plastic is **not** entirely environmentally friendly.

.....

..... [1]

[Total: 12]

9 Fig. 9.1 shows the Clark Sensor. It is an electrolytic cell that is used to measure the concentration of oxygen gas dissolved in samples of water, such as from rivers and seas.

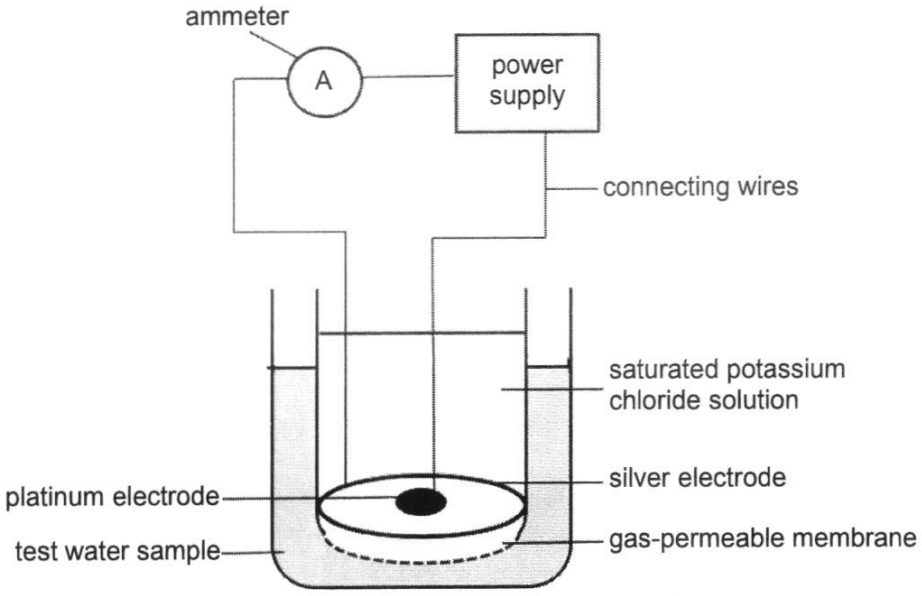


Fig. 9.1

Oxygen gas, dissolved in the water sample, can diffuse across the gas-permeable membrane.

A constant voltage is applied and the rate of flow of electrons produced is measured by the ammeter.

The half-equations at the electrode reactions are as shown.

anode: $Ag \rightarrow Ag^+ + e^-$

cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

(a) Using the half-equations, write the overall equation for the reaction in the electrolytic cell. State symbols are **not** required.

..... [1]

(b) Based on the information given, identify the direction of electron flow in the electrolytic cell by placing a tick (✓) in the correct box.

platinum to silver	
silver to platinum	

[1]

(c) The number of moles of electrons that flow through the silver electrode per minute is 5.20×10^{-4} mol.

Calculate the number of oxygen molecules used up per minute.

[2]

(d) Describe a test to identify the presence of oxygen gas.

.....

..... [2]

(e) Suggest why the water sample needs to be stirred constantly during the measurement.

.....

..... [1]

(f) One of the electrodes is cleaned regularly to remove a white solid that is formed during the reaction.

Suggest the identity of the white solid.

..... [1]

[Total: 8]

Either

10 The ethers are a homologous series.

Table 10.1 shows the data about the enthalpy change when 1 mole and 1 g of each ether is completely combusted.

Table 10.1

name of ether	chemical formula	enthalpy change of combustion (kJ/mol)	enthalpy change of combustion (kJ/g)
methoxymethane	CH_3OCH_3	−1460	−31.7
methoxyethane	$CH_3OC_2H_5$	−2107	−35.1
ethoxyethane	$C_2H_5OC_2H_5$	−2726	

(a) Calculate the enthalpy change of combustion when 1 g of ethoxyethane burns. Show your working **clearly**.

[2]

(b) Using ideas about breaking and forming bonds, explain why **all** of the values in Table 10.1 are negative.

.....

.....

.....

..... [2]

(c) The enthalpy change of combustion in kJ/mol increases from methoxymethane to ethoxyethane.

Using the chemical formulae in Table 10.1, suggest a reason why.

.....

..... [1]

(d) One characteristic of a homologous series is that the properties show a trend.

Describe the trends you would expect for **two** properties of the ethers as the molecules increase in molecular size. Enthalpy change of combustion must **not** be one of the properties you choose.

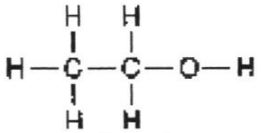
.....

.....

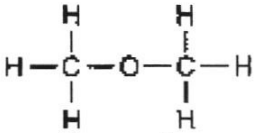
.....

..... [2]

(e) Ethanol is an isomer of methoxymethane.



ethanol



methoxymethane

Table 10.2 show the enthalpy changes of combustion for ethanol and methoxymethane.

Table 10.2

isomer	ethanol	methoxymethane
enthalpy change of combustion (kJ/mol)	−1371	−1460

(i) Draw the 'dot and cross' diagram of methoxymethane. Show only the outermost shells.

[2]

(ii) Suggest why the enthalpy changes of combustion for the two isomers are different.

.....

..... [1]

[Total: 10]

Or

10 From 1976 through 1989, an automobile manufacturer equipped vehicles with lean-burn engines. Lean-burn engine is a type of car engine that allows the combustion of fuel with an excess of air.

Table 10.3 shows some information about lean-burn engine compared to normal car engine.

Table 10.3

type of engine	ratio of air:fuel	operating temperature	concentration of carbon monoxide in exhaust gases	concentration of nitrogen oxides in exhaust gases
lean-burn	65:1	lower	lower	lower
normal	15:1	higher	higher	higher

Acknowledgement:
1) https://en.wikipedia.org/wiki/Lean-burn
2) https://studentlesson.com/definition-applications-diagram-working-advantages-of-lean-burn-engines/

(a) Using the information in Table 10.3, suggest why lean-burn engine produces smaller amounts of carbon monoxide and nitrogen oxides as compared to normal engine.

.....

.....

.....

..... [2]

(b) An older method of reducing the amounts of carbon monoxide and nitrogen oxides from vehicles is the use catalytic converters.

The equation shows the reaction that takes place in a catalytic converter.

$$2CO + 2NO \rightarrow 2CO_2 + N_2$$

(i) Use oxidation states to show that this reaction is redox.

.....

.....

.....

..... [2]

(ii) When catalytic converters were first invented, some advertisements claimed that they 'solved all car pollution problems'.

Explain why this is **not** true.

.....

..... [1]

(c) An alternative is the use of methane as fuel for vehicles.

The complete combustion of methane can be represented by the equation.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad \Delta H = -890 \text{ kJ/mol}$$

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

.....

.....

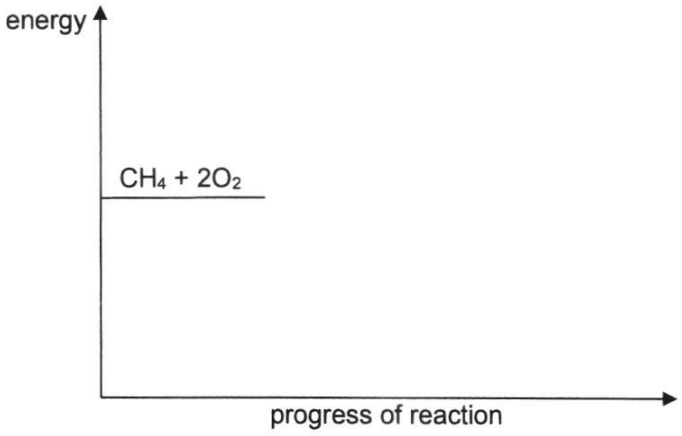
.....

..... [2]

(ii) Complete the energy profile diagram for the combustion of methane.

Your diagram should show and label the

- activation energy for the reaction,
- enthalpy change of reaction,
- products from the reaction.



[3]

[Total: 10]

END OF PAPER

MARK SCHEME for 2023 4E Pure Chemistry Prelim Paper 1 & 2

PAPER 1 [40 marks]

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

PAPER 2
Section A [50 marks]

1 Note to marker: Minus only 1m if students never write chemical symbol for one or any part of this question.

(a) O [1] **(b)** Ca **[1]** [reject: K] **(c)** Fe **[1]** *[memory work]*
(d) Al/Cu [1] **(e)** Ar **[1]** *[memory work]* **(f)** Pt [1] *[memory work]*

2 **(a)** A_r of O = $\left(\frac{99.76}{100} \times 16\right) + \left(\frac{0.04}{100} \times 17\right) + \left(\frac{0.20}{100} \times 18\right)$ [1m for showing correct working]
= 16.0044
= 16.0 (3 sig. fig.)

(b) **(i)** % of O_2 in air = $\frac{(50.0-39.5)}{50} \times 100\%$ [1m for showing correct working]
= 21.0%

(ii) $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$ [all state symbols must be correct to award mark **if** students choose to indicate the state symbols] [1]

(c) **(i)** [**1m** for **2** correct answers; 2m for 3 correct answers]
X: nitrogen; Y: argon; Z: oxygen

(ii) Oxygen [1]

3 **(a)** Group IV [reject **4**] [1]
justification: Both elements **P** and **R** forms four covalent bonds / shares four pairs of electrons in molecules **K** and **L**. [1]

(b) *[This part of the question relying on memory work after the candidates are able to infer that molecule **K** is a giant covalent molecule and molecule **L** is a simple covalent molecule.]*
A large amount of energy is needed to break/overcome the extensive (network of) strong covalent bonds [1]
in the giant (three dimensional) molecular structure of molecule K, hence it has a high melting point and exists as a solid. [1]
A small amount of / little energy is needed to **OVERCOME** the weak intermolecular forces of attraction between molecules / weak van der Waals forces of attractions between molecules [1]
in the simple molecular structure, hence it has a low boiling point and exists as a gas. [1]

Setter: Ms Kwok Honey

[reject break to describe the forces of attraction]

(c) ['explain' means your answer must be supported with scientific concepts/facts/phrases]
Agree with student 1 that **K** does not conduct electricity in any states as there is no mobile / free moving charged carriers / ions and electrons in the molecule.
OR Agree with student 1 because all the valence/outermost electrons are used up for (covalent) bonding, (hence no mobile electrons as charged carriers). [1]
Disagree with student 2 that **L** can conduct electricity as the molecules are electrically neutral / no free electrons and ions, (thus will not be able to act as charged carriers). [1]

4 (a) (i) *[Step 2: Find the no. of moles of "given" using the 'vol. of gas' formula]*
No. of moles of CO_2 gas = $\frac{\frac{120}{1000}}{24}$ = 0.005 mol.
[Standard procedure: Always convert volume in cm^3 to dm^3 by dividing by 1000] **[1]**
[Step 4: Compare mole ratio of "given" and "to find"]
Mole ratio = CO_2 : HC*l*
= 1 : 2
= 0.005 : 0.01 **[1]**
[Step 5: Answer to the question.]
Concentration of HC*l* = $\frac{0.01}{(\frac{25}{1000})}$ = 0.400 mol/dm^3
[ensure unit is included in 3 s.f.] **[1]**

(ii) *[apply 'FCS' in your explanation]*
At higher temperature, the (reacting) particles gain kinetic energy. More particles possess energy equal to or greater than the activation energy. [F] **[1]**
The particles move faster and collide with each other more often. Thus, there are more effective collisions [C], leading to higher rate/speed of reaction [S]. **[1]**

(b) (i) *[This part of the question is relying purely on memory work.]*
Mixture of a/one metal with one or few other elements. **[1]**
[reject: mixture of 2 or more metals]

(ii) *[This part of the question is relying purely on memory work.]*
Harder / stronger / resistant to corrosion / lowers melting point / [any other scientifically answer] **[1]**

(iii) Cathode attracts cations (hence reduction occurs):
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ [must include correct state symbols for any ionic or half equations] **[1]**

5 (a) In equation 2, sodium dihydrogen phosphate is neutralised by an alkali, sodium hydroxide to produce/form/give salt, sodium hydrogen phosphate, and water. Hence, it is an acid. **[1]**
OR
An acid is a substance that produces hydrogen ions in aqueous solution. Sodium dihydrogen phosphate has two hydrogen atoms in its chemical formula and hence can produce/form/gives hydrogen ions in solution and hence is an acid.
Recall: Salt is any ionic compound where a metallic ion or an ammonium ion replaces one or more hydrogen ions of an acid.

Sodium has replaced one of the hydrogen ions in phosphoric acid to form the salt, sodium dihydrogen phosphate. [1]

OR

In equation 1, phosphoric acid reacts/neutralises with sodium hydroxide to produce/form/gives the salt, sodium dihydrogen phosphate, and water.

(b) (i) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ [must include correct state symbols for any ionic or half equations]
[standard ionic equation for a neutralisation reaction] [1]

(ii) sodium phosphate [1]; Na_3PO_4 [1]

(c) (i) ['Explain why' means your answer must be supported with scientific concepts/facts/phrases. In this case, relate the answer to the definition of strong and weak acids, followed by supporting the concentration of hydrogen ions dissociated by clearly indicating the value using the data from Table 5.2.]
Marking point: 1m for stating complete and partial dissociation of the strong and weak acids respectively; 1m for mentioning the concentration of hydrogen ions in each acid. [2]

Sulfuric acid is a strong acid which completely ionises/dissociates in water/aqueous solution *[definition of strong acid]*. Hence, the (effective) concentration of hydrogen ions is (0.5 × 2=)1.0 mol/dm^3 *[infer the value from Table 5.2]*.

Ethanedioic acid is a weak acid which only partially ionises/dissociates in water/aqueous solution *[definition of strong acid]*. Hence, the (effective) concentration of hydrogen ions will be much less than 1.0 mol/dm^3 *[compare the concentration with sulfuric acid to showcase why ethanedioic acid is a weak acid]*.

(ii) Marking point: 2m for procedure whereby award 1m for every two correct steps; 1m for correct result [3]

[apply 'C': chemicals;
'Q': quantities (volume, length, mass, concentration);
'A': apparatus (measuring cylinder, burette, pipette, electronic balance, gas syringe);
'A': action (filter, measure, pipette, transfer, record, repeat, calculate)

Procedure 1:

Measure 30 cm^3 of 1.0 mol/dm^3 [Note: Students can quote any value for volume and concentration regardless if the value is logical or not] sodium hydroxide using a measuring cylinder and transfer into a styrofoam cup. Record the initial temperature, T_i.

Measure 20 cm^3 of 0.5 mol/dm^3 [Note: Students can quote any value for volume and concentration regardless if the value is logical or not] sulfuric acid using a measuring cylinder and add to the sodium hydroxide in the styrofoam cup. Observe and record the highest temperature reached, T_h. Calculate the temperature change by subtracting T_i from T_h.

Repeat the experiment but this time replace the sulfuric acid with ethanedioic acid.

Result:

The higher/greater/bigger temperature change indicates that it is a stronger acid.

OR

Procedure 2:

Measure 10.0 cm^3 of 0.5 mol/dm^3 [Note: Students can quote any value for volume and concentration regardless if the value is logical or not] sulfuric acid using a measuring cylinder and transfer into a boiling tube.
Measure 1.0 g [Note: Students can quote any value for mass regardless if the value is logical or not] reactive metal/metal carbonate (powder) [must state a specific chemical to use] using an electronic balance and transfer to the acid.
Record the time taken for the volume of gas evolved to reach constant in the gas syringe. [Note to marker: Ignore the idea of whether the volume of gas collected will go beyond 100 cm^3 because the important point is to showcase that data needs to be collected for making conclusion] *OR* Record the time taken to collect 5/10 cm^3 [Note: Student can quote any value below 100 cm^3] of gas evolved. *OR* Record the time taken for the reactive metal/ carbonate (powder) to dissolve into the acid.
Repeat the experiment but this time replace the sulfuric acid with ethanedioic acid.
[reject if there is no mention of time taken for Procedure 2 because both are dibasic acids and will produce the same volume of H_2/CO_2 gas t the end of the reaction.]
Result:
The shorter time taken for the reaction to end indicates that it is a stronger acid.
[reject the method of titration because both dibasic acids have the same number of moles of hydrogen ions]

6 **(a)** Note to marker: Minus only 1m if missing unit(s) for any part in **6(a)**.

(i) *[This part of the question is to test if candidates are able to infer from the graphs.]*
0 °C; 400 atm [1]

(ii) *[This part of the question is relying purely on memory work.]*
450 °C; 250 atm [1]

(iii) *[This part of the question is relying purely on memory work.]*
A higher temperature is used to increase rate/speed of reaction.
OR A low temperature will reduce/lower/decrease the rate/speed of reaction. [1]
A lower pressure is used as it is less costly/expensive / safer.
OR A high pressure will be costly to maintain. [1]

(b) Role of iron: catalyst [1]
['explain' means your answer must be supported with scientific concepts/facts/phrases]
Disagree because a catalyst only increases the rate of production of the same amount of ammonia.
OR Disagree because iron can only provide an alternative pathway to lower the activation energy to increase the rate of ammonia formed but unable to increase the amount of ammonia produced. [1]

7 **(a)** *[This part of the question is relying purely on memory work.]*
37 °C [1]; absence of oxygen/air [1]
[reject yeast/enzymes because it is already given in the question]

(b) *[Writing of this equation is purely on memory work. This part of the question requires the candidates to recall on the process of fermentation and relating this process to the graphs.]*

$C_6H_{12}O_6$ (aq) → $2C_2H_5OH$ (aq) + $2CO_2$ (g) [all state symbols must be correct to award mark if students choose to indicate the state symbols] [1]

At the start/beginning/initially [there should be indication of data quoted from graph], glucose in the grape juice undergoes fermentation in the presence of yeast to produce ethanol resulting in a drop in/decrease volume of grape juice and a rise in/increase volume of ethanol. [1]

After 35 days [there should be indication of data quoted from graph], fermentation stops (as the concentration of ethanol denature the enzymes in yeast) resulting in a constant volume [there should be indication of data quoted from graph] of ethanol of 1.0 dm^3. [1]

(c) *[Writing of this equation is purely on memory work.]*

$C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$ [1]

Section B [30 marks]

[First 2 questions are compulsory; only attempt one Q10. If students attempt both Q10, only 'Either 10' will be marked]

8 *[Data-based question whereby candidates have to apply comprehension skill, analytical skill, inference and deduction skills. Candidates must write answers based on information given and NOT based on their own experience or knowledge.]*

(a) description: The more orderly the molecule / plastic polymer, the higher the melting point, density and (tensile) strength.

OR The less orderly the molecule / plastic polymer, the lower the melting point, density and (tensile) strength.

OR The straighter chain the molecule / plastic polymer, the higher the melting point, density and (tensile) strength. *OR* The more branched the molecule / plastic polymer, the lower the melting point, density and (tensile) strength. [1]

explanation: Stronger intermolecular / van der Waals forces of attraction between the orderly arranged / straight chain molecules / plastic polymer [1]

due to the larger surface area in contact between molecules / plastic polymers. [1]

OR

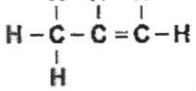
Weaker intermolecular / van der Waals forces of attraction between the less orderly arranged / branched molecules / plastic polymer.

due to smaller surface area in contact between molecules / plastic polymers.

[Note to marker: Ensure the explanation matches the description.]

[reject if explanation contradicts the description]

(b) **(i)**



*[This part of the question asks about '**MONOMER**'!]* [1]

(ii) Macromolecule / Polymer has a higher molar mass / (relative) molecular mass than the monomer, [1]

[Note to marker: Ensure comparison is clearly stated]

thereby more (heat) energy is needed to **OVERCOME** the stronger intermolecular forces / van der Waals forces between the polymers. [1]

[reject break to describe the attractive forces]

(c) *From Table 8.2, minimum M_r of the polymer = 100 000*

From 1st sentence of part (c), there are 962 repeating units.

M_r of ONE repeat unit = $\frac{100000}{962}$ = 103.95

[Note to candidates: Whenever you see percentages of several elements, always draw such table to obtain empirical formula.]

	C	H
percentage / %	92.3	7.7
no. of moles	$\frac{92.3}{12}$ = 7.691	$\frac{7.7}{1}$ = 7.7
ratio (strategy: divide by the smallest value from the 'no. of moles)	$\frac{7.691}{7.691}$ = 1	$\frac{7.7}{7.691}$ = 1.0011

Empirical formula = CH [1]

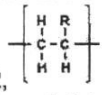
M_r of CH = 12 + 1 = 13

Let the molecular formula of one repeat unit of poly(styrene) be $(CH)_n$.

$n = \frac{relative\ molecular\ mass}{M_r\ of\ empirical\ formula}$

$= \frac{103.95}{13}$ = 7.99 = 8 (round off to whole no.)

Molecular formula of one repeat unit = C_8H_8 [1]

From Table 8.2, 

∴ formula of **R** in poly(styrene) = $C_8H_8 - 2C - 3H = \underline{C_6H_5}$ [1]

(d) **(i)** Disagree, PETE is a condensation polymer so mechanical recycling can also recycle condensation polymers, other than addition polymers. [1]

(ii) Mechanical recycling recycles more types of plastics as compared to chemical depolymerisation. [1]

OR

Mechanical recycling recycles a higher percentage of plastic waste as compared to chemical depolymerisation.

(e) *Any **one** possible suggestion that is logical and based on information given:* [1]

- transportation requires fossil fuels to be burnt
- mechanical recycling requires plastic to be heated and that requires fossil fuels to be burnt to provide the energy
- chemical depolymerisation requires concentrated sulfuric acid which will harm the environment when released
- washing of the plastic requires water to be used which will deplete the world's water supply

9 **(a)** Equation 1: $Ag \rightarrow Ag^+ + e^-$

Equation 1 × 4: $4Ag \rightarrow 4Ag^+ + 4e^-$

Equation 2: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Equation 1 × 4 + Equation 2: $\underline{4Ag + O_2 + 4H^+} \rightarrow \underline{4Ag^+ + 2H_2O}$ [1]

[Note to candidates: Solve it like simultaneous equations, learnt in Mathematics, by getting rid of e^- through cancellation.]

(b) *[This part of the question is to test if candidates are able to infer from the 2 half-equations given.]*

silver to platinum [1]

(c) Mole ratio = e^- : O_2
= 4 : 1 (from cathode half equation)
= 5.2×10^{-4} : 1.3×10^{-4} [1]
No. of oxygen molecules = $1.3 \times 10^{-4} \times 6 \times 10^{23}$
= 7.80×10^{19} [1]

(d) Test: Insert a glowing splint into the mouth of the test-tube [1]
Observation: The glowing splint relights. [1]

(e) Ensures a constant rate of diffusion of oxygen to the platinum electrode / constant supply of oxygen to the electrode. [1]

(f) Silver chloride / AgCl [reject silver/Ag because silver is silver in colour and will never exist as white solid.] [1]

Either

10 (a) M_r of $C_2H_5OC_2H_5$ = 12 + 12 + 5 + 16 + 12 + 12 + 5 = 74
No. of moles in 1 g $C_2H_5OC_2H_5$ = $\frac{1}{74}$ = 0.0135135 mol. [1]
Enthalpy change of combustion = 0.0135135 × −2726 = −36.8 kJ/g (3 sig. fig.) [1]
OR
Enthalpy change of combustion 1 g $C_2H_5OC_2H_5$ = $\frac{-2726}{12+12+5+16+12+12+5}$ [1]
= −36.8 kJ/g (3 sig. fig.) [1]

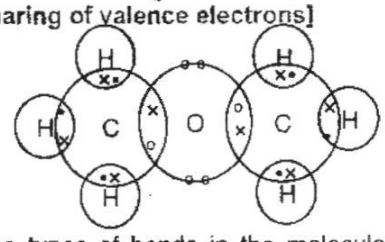
(b) There are more energy released/given off from bond forming [1]
than energy absorbed/taken in for bond breaking, hence the net energy change is exothermic. [1]
[reject: required/needed/used to describe the energy]

(c) Going down the members of the homologous series, the molecular size increases.
There are more C and H atoms to form more CO_2 and H_2O molecules, so the enthalpy change for combustion is more negative as energy from forming bonds in products is more than energy for breaking bonds in reactants. [1]

(d) *[modified from O Level 2014 P2A Q4d]*
Any two correct answers: [2]
As the number of carbon atoms in the molecule increases / As the molecular size in the homologous series increases,
- flammability decreases
- boiling point increases
- viscosity increases
- flashpoints increases

(e) *[modified from O Level 2014 P2A Q4e]*

(i) **[1m for showing correct number of atoms; 1m for showing correct sharing of valence electrons]**



[2]

(ii) The types of bonds in the molecules that need to be overcome are different (ethanol has C-C and O-H bonds, but dimethylether C-O bonds), so different amount of energy are needed when these bonds are broken. [1]

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Or

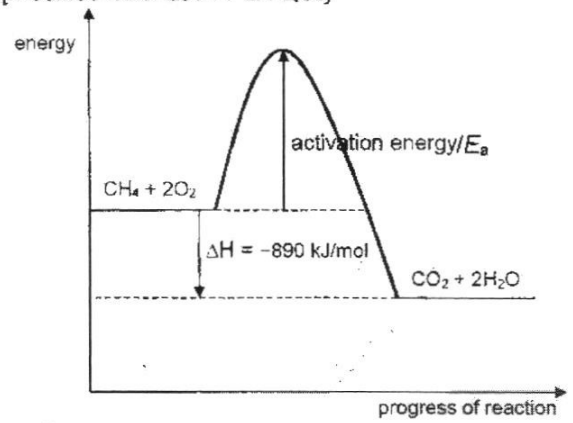
10 (a) *explanation on why smaller amount of CO is produced:*
Lean-burn engine has more air (oxygen) present to allow for more complete combustion of carbon-containing fuels. [1]
OR
Lean-burn engine has more air (oxygen) present, leading to fewer incomplete combustion of carbon-containing fuels.
explanation on why smaller amount of NO_x is produced:
At lower temperature, there will be fewer reactions between nitrogen and oxygen to form nitrogen oxides, leading to smaller amount of nitrogen oxides formed. [1]

(b) (i) CO is oxidised due to an increase in oxidation state of C in CO from +2 to +4 in CO_2. [1]
NO is reduced due to a decrease in oxidation state of N in NO from +2 to 0 in N_2. **[1]**
Since oxidation and reduction occur at the same time, this reaction is redox.
[reject: change to describe oxidation state; use of gain/loss of oxygen]

(ii) Carbon dioxide is a greenhouse gas that traps heat on the Earth's surface, leading to global warming. **[1]**

(c) (i) More (heat) energy is released/given off in the formation of 2 C = O bonds and 4 O – H bonds **[1]**
than absorbed to break 4 C – H bonds and 2 O = O bonds. [1]
[reject: required/needed/used to describe the energy]

(ii) *[modified from 2014 P2A Q6c]*



[Marking points:
1m for correct labelling of activation energy;
1m for correct labelling of ΔH with correct direction of the arrow head, correct values and unit;
1m for correct labelling of the two products written in chemical formulae] **[3]**