

NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 1

---

**CHEMISTRY**

Paper 1 Multiple Choice

**8873/01****18 September 2020****1 hour**

Additional Materials:      Multiple Choice Answer Sheet  
   Data Booklet

---

**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

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

Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** 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 Answer Sheet.

**Read the instructions on the Answer Sheet very carefully.**

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

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

This document consists of **14** printed pages and **2** blank pages.

**[Turn over**



## 2

- 1 Use of the Data Booklet is relevant to this question.

A typical solid fertiliser for use with household plants and shrubs contains the elements N, P and K in the ratio of 15 g : 30 g : 15 g per 100 g of fertiliser. The recommended usage of fertiliser is 14 g of fertiliser per 5 dm<sup>3</sup> of water.

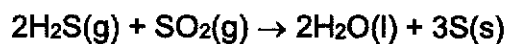
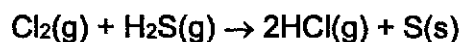
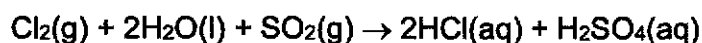
What is the concentration of nitrogen atoms in this solution?

- A 0.015 mol dm<sup>-3</sup>  
 B 0.030 mol dm<sup>-3</sup>  
 C 0.075 mol dm<sup>-3</sup>  
 D 0.149 mol dm<sup>-3</sup>
- 2 Compounds J and K each contain 40.0% carbon by mass.

What could J and K be?

	J	K
A	hexose, C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	starch, (C <sub>6</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>n</sub>
B	pentose, C <sub>5</sub> H <sub>10</sub> O <sub>5</sub>	hexose, C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>
C	pentose, C <sub>5</sub> H <sub>10</sub> O <sub>5</sub>	sucrose, C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>
D	starch, (C <sub>6</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>n</sub>	sucrose, C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>

- 3 The equations for three reactions are given below.



What is the correct order of strength of the three reacting gases as reducing agents?

- |   |                  |                  |                  |
|---|------------------|------------------|------------------|
|   | <i>strongest</i> |                  | <i>weakest</i>   |
| A | hydrogen sulfide | sulfur dioxide   | chlorine         |
| B | sulfur dioxide   | hydrogen sulfide | chlorine         |
| C | chlorine         | hydrogen sulfide | sulfur dioxide   |
| D | chlorine         | sulfur dioxide   | hydrogen sulfide |

## 3

- 4 Beams of charged particles are deflected by an electric field.

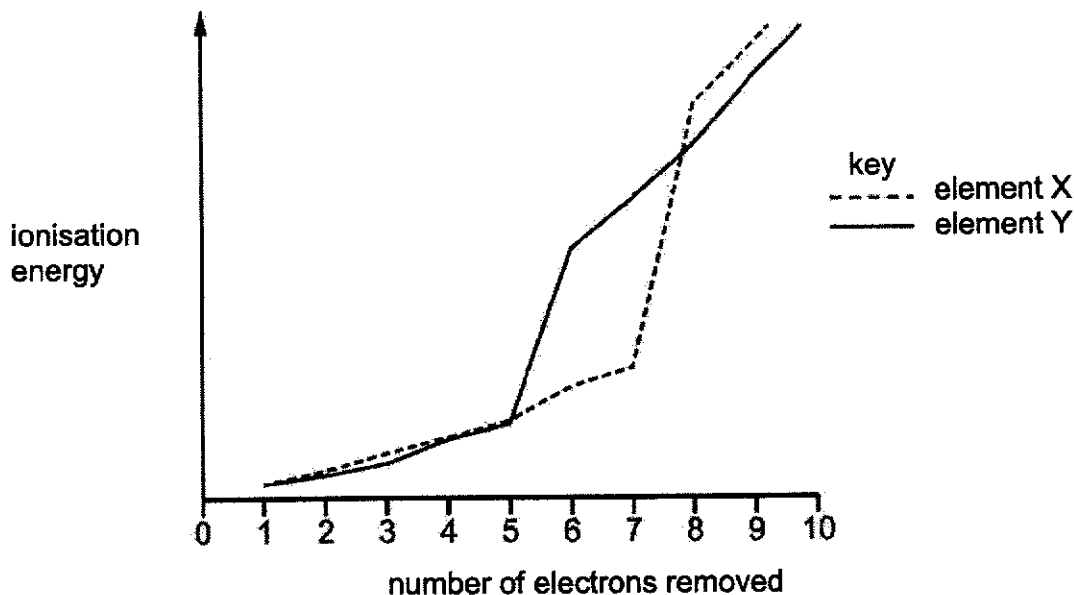
In an experiment, protons are deflected by an angle of  $+15^\circ$ . In another experiment under identical conditions, particle Y is deflected by an angle of  $+5^\circ$ .

What could be the composition of particle Y?

	no. of protons	no. of neutrons	no. of electrons
<b>A</b>	1	2	1
<b>B</b>	3	3	5
<b>C</b>	4	5	1
<b>D</b>	4	5	3

- 5 *Use of the Data Booklet is relevant to this question.*

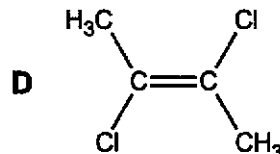
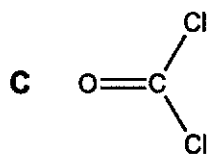
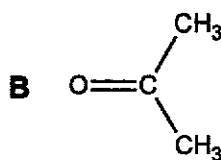
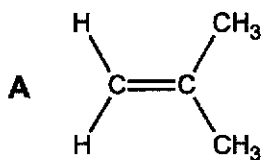
The graph shows the successive ionisation energies of element X and element Y. Both elements are in Period 3.



Which statement is **not** correct?

- A An atom of element Y has three electrons in the 3p subshell.
- B The ion of element of X is smaller than that of Y.
- C Y is more electronegative than X.
- D The total number of occupied orbitals in  $Y^+$  is one less than that in an atom of X.

6 Which molecule has the largest overall dipole moment?



7 Which types of bonding are present in lithium nitrate,  $\text{LiNO}_3$ ?

- 1 ionic
- 2 covalent
- 3 co-ordinate (dative covalent)

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

8 Which statement is not correct?

- A The hydrogen bonds in ice are more regularly arranged than in water.
- B Two electrons from each oxygen are involved in forming hydrogen bonds in ice.
- C All the bond angles surrounding each oxygen atom in ice are  $109.5^\circ$ .
- D The open structure of ice causes ice to be less dense than water.

- 9 The table gives the lattice energies of sodium chloride and magnesium oxide.

	sodium chloride	magnesium oxide
lattice energy	-787 kJ mol <sup>-1</sup>	-3795 kJ mol <sup>-1</sup>

Which of the following statements are true?

- 1 Sodium chloride has a longer bond length than magnesium oxide.
  - 2 Both magnesium ion and oxide ion have smaller ionic radii than sodium ion and chloride ion.
  - 3 Sodium oxide is predicted to have a more exothermic lattice energy than sodium chloride.
- A 1 only  
 B 1, 2 and 3  
 C 1 and 2 only  
 D 2 and 3 only

- 10 The standard enthalpy change of combustion of but-1-ene, C<sub>4</sub>H<sub>8</sub>(g), is x kJ mol<sup>-1</sup>.

The standard enthalpy change of the reaction 2C<sub>2</sub>H<sub>4</sub>(g) → C<sub>4</sub>H<sub>8</sub>(g) is y kJ mol<sup>-1</sup>.

What is the standard enthalpy change of combustion of ethene, C<sub>2</sub>H<sub>4</sub>(g)?

- A  $\frac{x}{2} + y$  kJ mol<sup>-1</sup>  
 B  $x + \frac{y}{2}$  kJ mol<sup>-1</sup>  
 C  $\frac{x+y}{2}$  kJ mol<sup>-1</sup>  
 D  $\frac{x-y}{2}$  kJ mol<sup>-1</sup>

11 Use of the Data Booklet is relevant to this question.

A butane burner is used to heat water. The  $M_r$  of butane is 58.

- $\Delta H_c$  of butane is  $-2877 \text{ kJ mol}^{-1}$ .
- 250 g of water is heated from  $12^\circ\text{C}$  to  $100^\circ\text{C}$ .
- The burner transfers 47% of the heat released from the burning fuel to the water.

Assume that the butane undergoes complete combustion and none of the water evaporates.

What is the mass of butane that was burnt?

- A 0.071 g      B 1.85 g      C 3.94 g      D 4.48 g

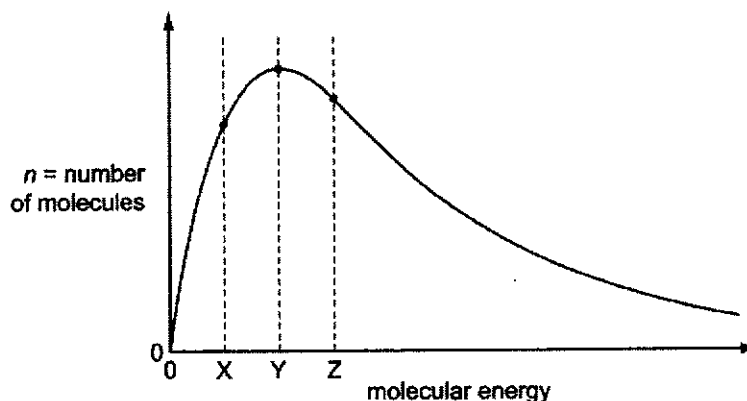
12 Excess magnesium powder is added to  $25 \text{ cm}^3$  of dilute hydrochloric acid. The total volume of hydrogen gas evolved was measured.

In a second experiment, magnesium powder of the same mass was used. This was added to  $25 \text{ cm}^3$  of dilute ethanoic acid. The total volume of hydrogen gas evolved was measured.

If the same concentration of acids were used in both experiments, how will the initial rate of reaction, total volume of hydrogen evolved and initial pH in the second experiment compare to that of the first experiment?

	initial rate of reaction	total volume of hydrogen evolved	initial pH
A	decrease	no change	higher
B	decrease	decrease	lower
C	no change	decrease	higher
D	no change	no change	lower

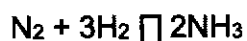
- 13 The Maxwell-Boltzmann distribution for a gas at constant temperature is shown below.



If a catalyst is added to the reaction, what happens to the number of molecules for energy X, Y and Z?

	X	Y	Z
A	higher	lower	lower
B	higher	higher	higher
C	lower	lower	lower
D	no change	no change	no change

- 14 The percentage yield and rate of chemical reactions is an important consideration in industrial applications like the Haber Process.

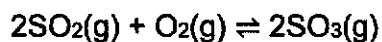


Which of the following changes made to the Haber Process increases both the rate and percentage yield?

- A Increase in temperature
- B Add a catalyst
- C Increase in pressure
- D Increase the volume of reaction vessel



- 15 At 500 K, 0.80 mol SO<sub>2</sub> and 0.30 mol O<sub>2</sub> were introduced into a 10 dm<sup>3</sup> vessel. The amount of SO<sub>3</sub> formed at equilibrium was 0.50 mol.



What is the value for  $K_c$ ?

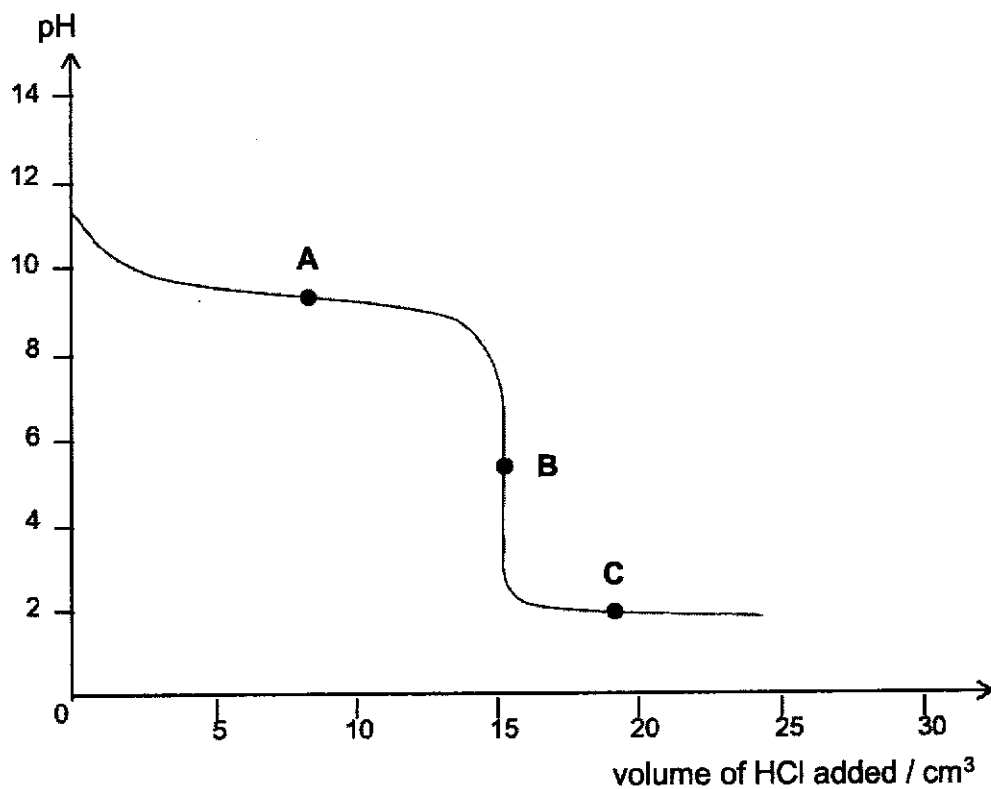
- A 0.0180  
B 33  
C 56  
D 556
- 16 A specified volume of water was heated. The different values of the ionic product of water,  $K_w$ , was obtained at two different temperatures.

Temperature / °C	25	62
$K_w / \text{mol}^2 \text{dm}^{-6}$	$1.0 \times 10^{-14}$	$1.0 \times 10^{-13}$

Which of the following is true for water at 65 °C?

- A It is neutral and its pH is 7.  
B It is neutral and its pH is less than 7.  
C It is not neutral and pH is less than 7.  
D It is not neutral and its pH is less than its pOH.

- 17 15.0 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> NH<sub>3</sub> was titrated against 0.100 mol dm<sup>-3</sup> HCl. The following pH-volume graph was obtained.

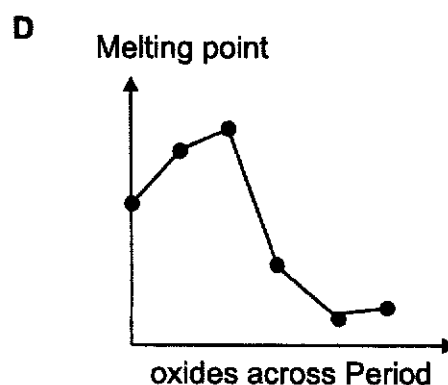
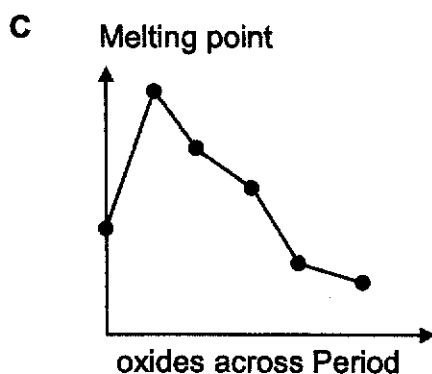
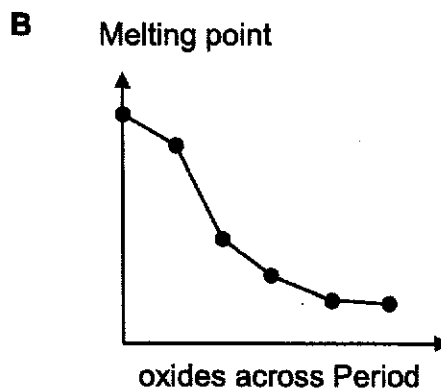
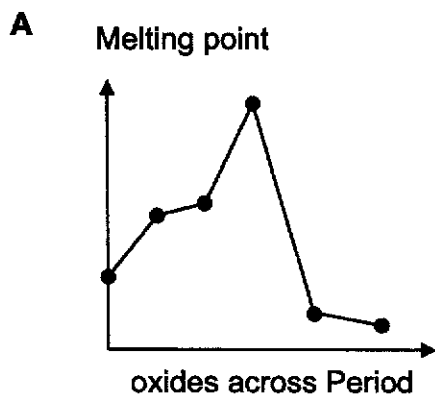


Which statement about the titration is correct?

- 1 A buffer exists at point A.
- 2 The solution at point B contains NH<sub>3</sub>.
- 3 Methyl orange indicator can be used for this titration.
- 4 The solution at point C only contains HCl.

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

- 18 Which of the following graphs best represents the variation in melting points of the oxides of period 3 elements (Na to S)?



- 19 A diagonal relationship is said to exist between certain pairs of diagonally adjacent elements in the second and third periods of the Periodic Table. The compounds of Be and B display similar physical and chemical properties with those of Al and Si respectively.

Which of the following conclusions can be made?

- 1 Both  $\text{BeCl}_2$  and  $\text{BCl}_3$  produce white fumes in moist air.
- 2  $\text{BeO}$  reacts with  $\text{HCl}$  but  $\text{B}_2\text{O}_3$  does not.
- 3 Both  $\text{BeO}$  and  $\text{B}_2\text{O}_3$  react with water to form basic solutions.

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

20 **W**, **X**, **Y** and **Z** are elements in Period 3.

**W** has greater electrical conductivity than **Y** but lower first ionisation energy than **X**. **Y** has higher melting point than **W**, and **Z** has a greater atomic radius than **W**.

Based on the above information, which of the following correctly identifies these elements?

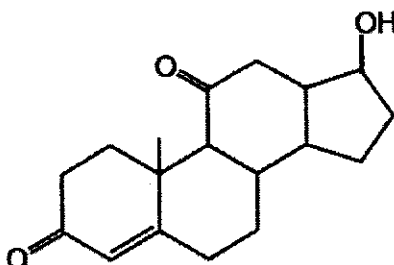
	<b>W</b>	<b>X</b>	<b>Y</b>	<b>Z</b>
<b>A</b>	Al	P	Si	Mg
<b>B</b>	Na	Mg	S	Si
<b>C</b>	Si	S	Al	Na
<b>D</b>	Si	Mg	P	Na

21 In which molecules do all the carbon atoms lie in the same plane?

- 1 2,3-dimethylbut-2-ene
- 2 propane
- 3 benzene

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

22 The derivative of drug cortisone has the formula shown.



What is the molecular formula of the compound?

- A** C<sub>17</sub>H<sub>20</sub>O<sub>3</sub>      **B** C<sub>17</sub>H<sub>22</sub>O<sub>3</sub>      **C** C<sub>18</sub>H<sub>22</sub>O<sub>3</sub>      **D** C<sub>18</sub>H<sub>24</sub>O<sub>3</sub>

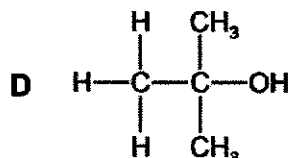
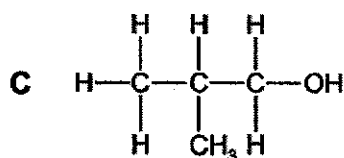
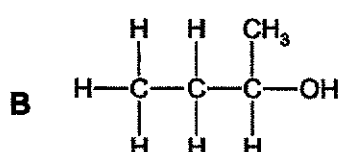
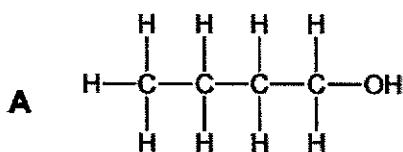
- 23 In the substitution of 2-methylbutane with bromine, a mixture of mono-brominated compounds were obtained.

What is the statistical ratio of the two mono-brominated compounds with the highest yields?

- A 1 : 6                      B 1 : 4                      C 1 : 3                      D 1 : 2
- 24 Aqueous silver nitrate was added at the same time to separate solutions of chloropropane and iodopropane. The signs of a precipitate were first seen in the sample containing iodopropane.

Why did a precipitate appear in iodopropane first?

- A The chloropropane also reacted with the aqueous silver nitrate but gave a soluble product.
- B The chloropropane reacted more slowly because the carbon-chlorine bond is less polar than carbon-iodine bond.
- C The chloropropane reacted more slowly because the carbon-chlorine bond is longer than carbon-iodine bond.
- D The iodopropane reacted more quickly because the carbon-iodine bond is weaker than carbon-chlorine bond.
- 25 Which alcohol can be dehydrated to give a mixture of products?

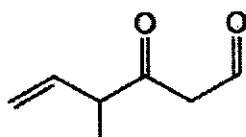


26 A sample of pentan-1,5-diol is completely oxidised by acidified  $\text{KMnO}_4$ .

What is the mass of the product formed from oxidation of 1.00 g of pentan-1,5-diol?

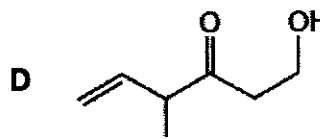
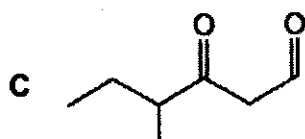
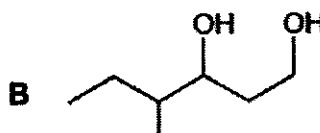
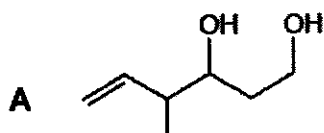
- A 0.962 g
- B 1.12 g
- C 1.27 g
- D 1.37 g

27 The diagram shows the structure of compound Z.

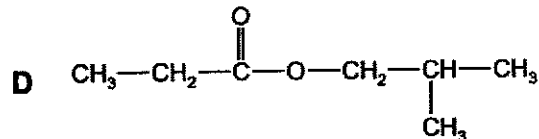
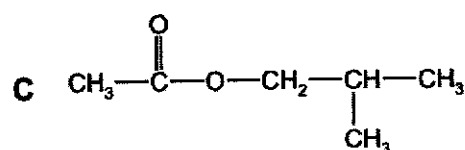
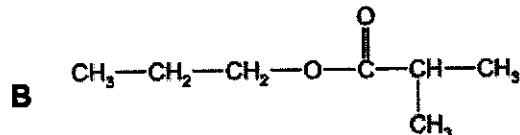
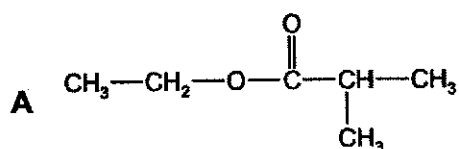


Z

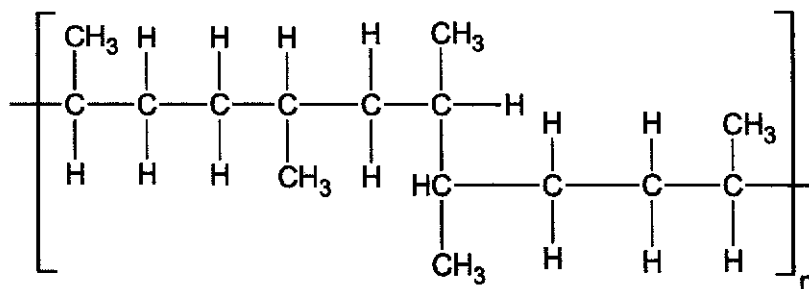
What is the product of the reaction between compound Z and an excess of  $\text{NaBH}_4$ ?



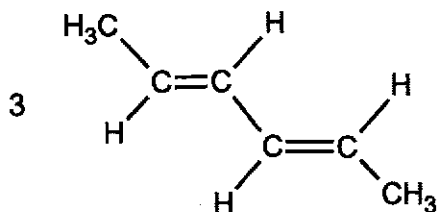
28 Ethyl propanoate is heated under reflux with aqueous sodium hydroxide. The alcohol produced is then reacted with 2-methylpropanoic acid to make a second ester. What is the structural formula of this second ester?



29 Which monomer will react to give a polymer with the repeat unit shown below?

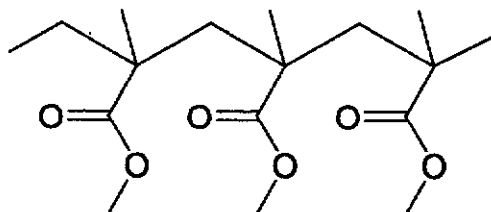


- 1  $\text{CH}_2=\text{CH}-\text{CH}_3$   
 2  $\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$



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

30 Poly(methyl methacrylate) is used to make hard contact lenses. Part of its polymer chain is shown.



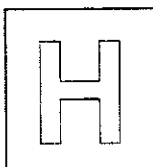
Which statement about poly(methyl methacrylate) is correct?

- A A small molecule of water is lost when polymerisation took place.  
 B Its monomer includes a dicarboxylic acid and a diol.  
 C It can undergo alkaline hydrolysis.  
 D It can form hydrogen bonds between two polymer chains.

**15**  
**BLANK PAGE**



16  
BLANK PAGE



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 1

CANDIDATE  
NAME

--

CLASS

1	9		
---	---	--	--

TUTOR'S  
NAME

--

CENTRE  
NUMBER

S			
---	--	--	--

INDEX  
NUMBER

--	--	--	--

## CHEMISTRY

**8873/02**

Paper 2

**31 August 2020**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials:                      Data Booklet

### READ THESE INSTRUCTIONS FIRST

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

**Section A**  
Answer all the questions.

**Section B**  
Answer one question.

The use of an approved scientific calculator is expected, where appropriate.  
A Data Booklet is provided.

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

For Examiner's Use	
<b>A1</b>	<b>/7</b>
<b>A2</b>	<b>/12</b>
<b>A3</b>	<b>/12</b>
<b>A4</b>	<b>/23</b>
<b>A5</b>	<b>/6</b>
<b>B</b>	<b>/20</b>
<b>Total</b>	<b>/80</b>

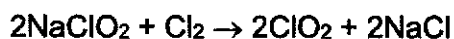
This document consists of 24 printed pages and 2 blank pages.

**Section A**

Answer all questions in this section in the spaces provided.

For  
examiner's  
use only

- 1 In each of these reactions, different chlorine-containing compounds are formed in a redox reaction.
- (a) State the oxidation number of chlorine in each of the chlorine-containing species for the following equation.



	Species	Oxidation number	Species	Oxidation number
Reactants	NaClO <sub>2</sub>		Cl <sub>2</sub>	
Products	ClO <sub>2</sub>		NaCl	

[2]

- (b) 6.13 g sample of the salt KClO<sub>3</sub> was dissolved in water. The solution was acidified and made up to 100 cm<sup>3</sup>. A 10 cm<sup>3</sup> portion of this solution was completely reduced by 12.5 cm<sup>3</sup> of 0.200 mol dm<sup>-3</sup> H<sub>2</sub>O<sub>2</sub>(aq).
- (i) Calculate the final oxidation number of chlorine.

[3]

3

- (ii) Using your answer in (b)(i) and the table in (a), deduce the chlorine-containing product of this reaction.

*For  
examiner's  
use only*

.....[1]

- (iii) Hence, construct a balanced equation for the reaction between  $\text{H}_2\text{O}_2$  and acidified  $\text{ClO}_3^-$ .

.....[1]

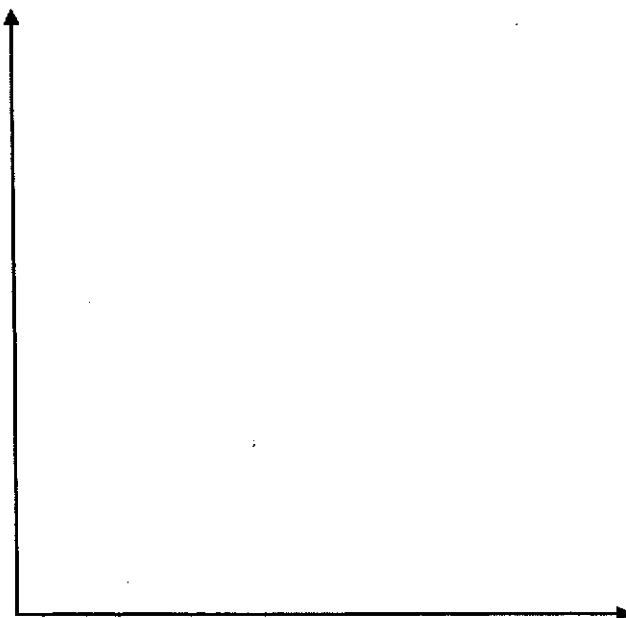
[Total: 7]

- 2(a)**  $\text{H}_2\text{O}_2$  is unstable and slowly decomposes in the presence of light to form water and oxygen. The decomposition of  $\text{H}_2\text{O}_2$  is an exothermic reaction and the numerical value for the enthalpy change of decomposition of  $\text{H}_2\text{O}_2$  is  $98.2 \text{ kJ mol}^{-1}$ . The activation energy of the forward reaction is  $+75 \text{ kJ mol}^{-1}$ .

*For  
examiner's  
use only*



- (i) Draw the reaction pathway diagram for the decomposition of  $\text{H}_2\text{O}_2$  on the axes below.



[2]

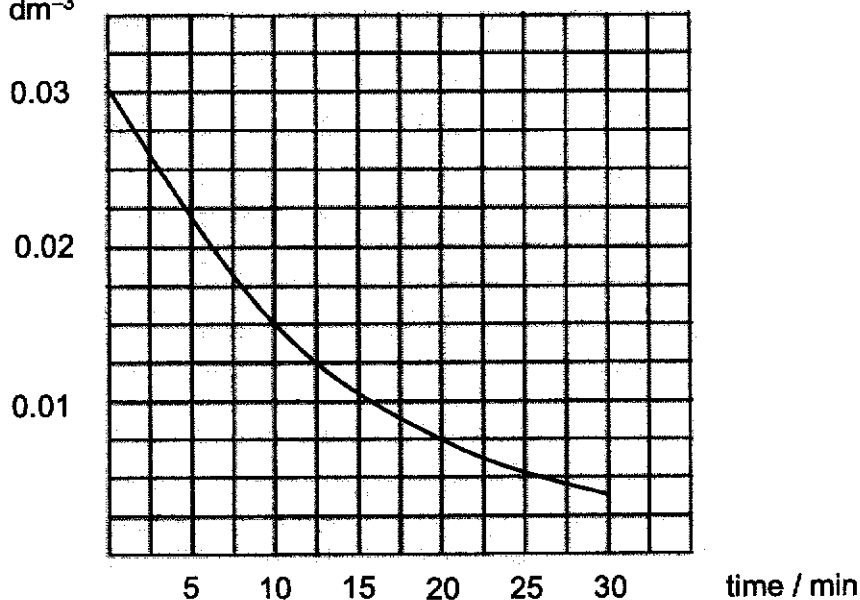
In the presence of a catalyst, the activation energy of the reaction is lowered by  $50 \text{ kJ mol}^{-1}$ .

- (ii) Determine the activation energy of the backward reaction when a catalyst is added and label this in the diagram in (i).

[1]

- (b) The graph shows how the concentration of  $\text{H}_2\text{O}_2$  changes with time.

$[\text{H}_2\text{O}_2] / \text{mol dm}^{-3}$



For  
examiner's  
use only

- (i) Deduce, showing your working, the order of reaction with respect to  $\text{H}_2\text{O}_2$ . Hence write the rate equation for this reaction.

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

- (ii) By drawing a tangent at  $t = 0$  min, calculate the initial rate. Hence, calculate the rate constant for this reaction, stating its units.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 ..... [3]

(iii) Sketch a graph of rate of reaction against  $[H_2O_2]$  for this reaction.

*For  
examiner's  
use only*

[1]

(c) With an aid of a labelled diagram, explain the effect on the rate of the reaction when the temperature was increased.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[3]

[Total: 12]





(iii) Using relevant data from the *Data Booklet*, explain why the resulting solutions of magnesium chloride and aluminium chloride with water give rise to different pH values.

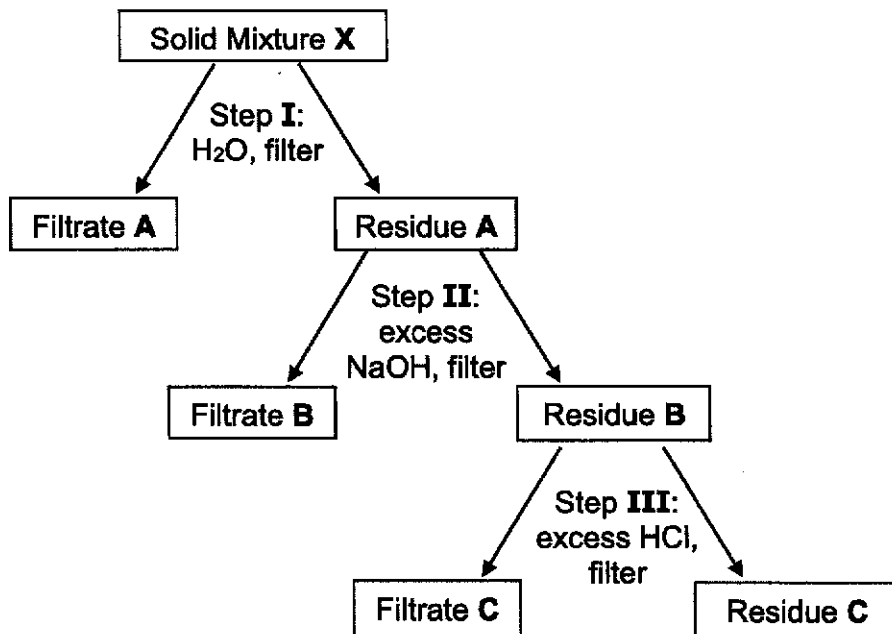
.....

.....

.....

.....[1]

(b) A solid mixture X containing magnesium oxide, magnesium chloride, aluminium oxide and silicon chips was required to be separated. The following procedure was carried out on the mixture.



(i) Write the balanced equations of the reactions that occurred in steps II and III, given that only one reaction occurred at each step.

Step II.....

Step III.....[2]

(ii) State the substance(s) present in

Residue A.....

Residue B.....

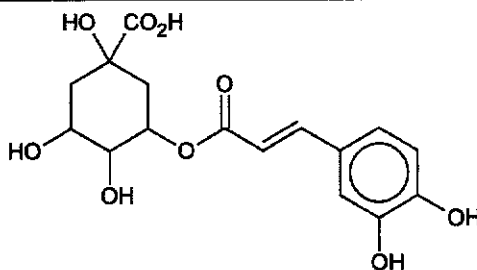
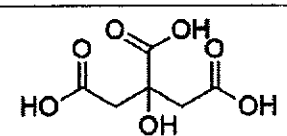
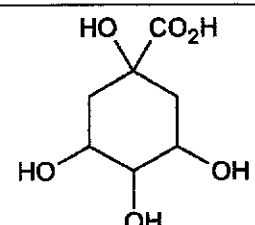
Residue C.....

Filtrate C.....[3]

[Total: 12]

- 4 Coffee is an acidic beverage as the brewing process releases acids from the coffee beans. The perceived acidity in coffee drinks is found to correlate to its pH. The table below shows some of the weak acids that are commonly found in a typical medium roast coffee.

For  
examiner's  
use only

acid	structure	$K_a / \text{mol dm}^{-3}$
ethanoic acid	$\text{CH}_3\text{COOH}$	$1.8 \times 10^{-5}$
chlorogenic acid		$4.0 \times 10^{-4}$
citric acid		$(K_{a1}) 7.2 \times 10^{-4}$ $(K_{a2}) 1.7 \times 10^{-5}$ $(K_{a3}) 4.1 \times 10^{-7}$
malic acid	$\text{HO}_2\text{CCH}_2\text{CH}(\text{OH})\text{CO}_2\text{H}$	$(K_{a1}) 4.0 \times 10^{-4}$ $(K_{a2}) 7.8 \times 10^{-6}$
quinic acid		$4.0 \times 10^{-4}$

- (a) (i) Explain the meaning of the terms *acid* and *weak acid*, in terms of the Brønsted-Lowry theory of acids.

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

- (ii) By considering the  $K_a$  values, suggest which acid will contribute the most to the acidity in coffee (ignore the effect of  $K_{a2}$  and  $K_{a3}$ ). Explain your answer.

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

- (iii) Malic acid is a diprotic acid.

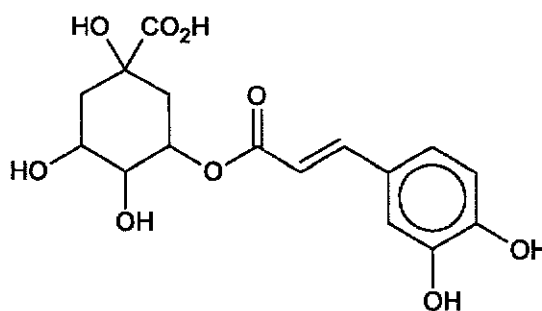
Write an equation to represent the second acid dissociation,  $K_{a2}$  of malic acid, and hence write an expression for  $K_{a2}$ .

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

- (iv) Suggest a reason why the value of  $K_{a2}$  of malic acid is smaller than its  $K_{a1}$  value.

.....  
 .....[1]

- (b) It was found that the acid present in the largest quantity in coffee beans is chlorogenic acid,  $C_{16}H_{18}O_9$ . It is believed to be the main acid that causes the coffee acidity and it is also partly responsible for the bitterness in coffee.



chlorogenic acid

An experiment was conducted to determine the concentration of chlorogenic acid in the coffee drinks that were brewed by coffee powder of different grind sizes. The following results was obtained when the coffee powder was brewed for 5 min.

	coarse grind	fine grind	extra fine grind
[chlorogenic acid] / $\text{mg dm}^{-3}$	700	1060	1180

- (i) With reference to its structure, suggest a reason why chlorogenic acid can dissolve in water when the coffee powder was brewed.

.....  
 .....  
 .....[1]

- (ii) State and explain the relationship between the grind sizes and concentration of chlorogenic acid in coffee drinks.

*For  
examiner's  
use only*

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

- (iii) A cup of coffee brewed using the fine grind coffee powder was found to have a pH of 3.04.

Assuming that the acidity is due to chlorogenic acid **only**, calculate the concentration of the acid in mol dm<sup>-3</sup> and hence the degree of ionisation of chlorogenic acid.

[3]

**[Turn over**

- (c) The percentage by mass of chlorogenic acid in the different types of coffee powder is shown below.

For  
examiner's  
use only

	Green Robusta	Roasted Arabica	Instant Coffee
% by mass of chlorogenic acid	8.8	2.3	5.8

In the experiment in (b), 10.0 g of fine ground coffee powder was brewed in 200 cm<sup>3</sup> of water. The chlorogenic acid in the coffee powder was assumed to dissolve in water completely during the brewing.

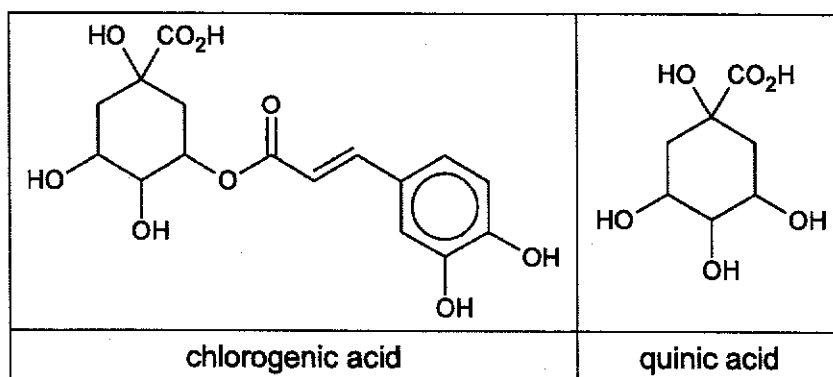
- (i) Calculate the percentage by mass of chlorogenic acid in the coffee powder used.

[1]

- (ii) Hence, state the type of coffee powder used in the experiment.

[1]

- (d) Excessive quinic acid has been associated with unfavourable sourness when brewed coffee is left on a heater plate. It was also found that the concentration of quinic acid in coffee increases inversely with chlorogenic acid.



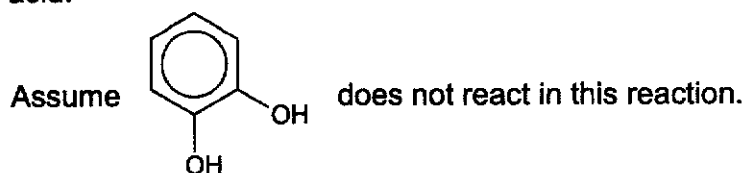
- (i) Suggest a reason why the concentration of quinic acid increases when brewed coffee was left on a heater plate.

[1]

13

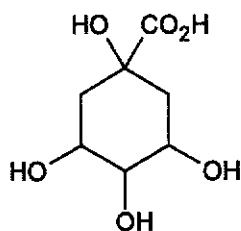
- (ii) Suggest the structure of the other product obtained together with quinic acid.

*For  
examiner's  
use only*



[1]

- (e) Draw the product obtained and state the type of reaction when quinic acid reacts with the following reagents.



quinic acid

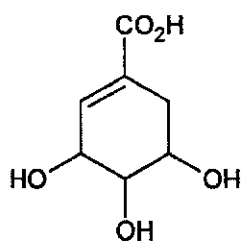
(i) NaOH(aq), room temperature	(ii) Ethylamine, DCC
Type of reaction:	Type of reaction:

[4]

14

- (f) Quinic acid can be converted into shikimic acid using a biocatalyst.

*For  
examiner's  
use only*



shikimic acid

Suggest a simple chemical test that can check if the conversion is successful, stating clearly the reagents and conditions, and the expected observations.

.....

.....

.....

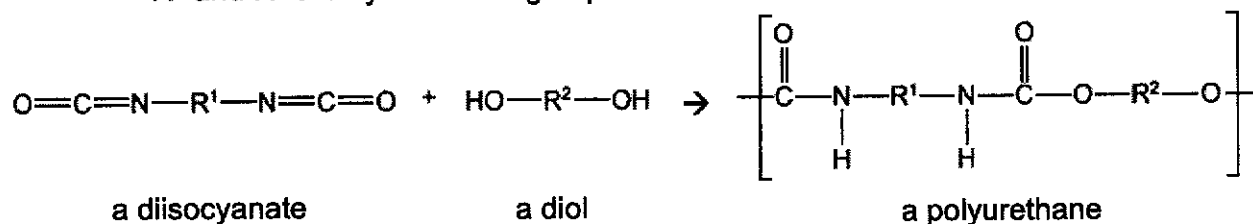
.....[2]

[Total: 23]

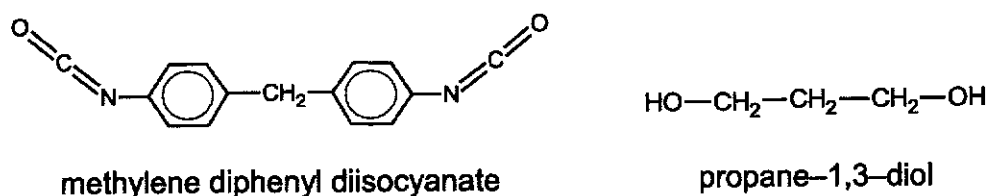
5 Polyurethanes are polymers composed of organic units joined by urethane links.

The reaction of a diisocyanate with a diol to form polyurethanes is as shown.  $R^1$  and  $R^2$  are hydrocarbon groups.

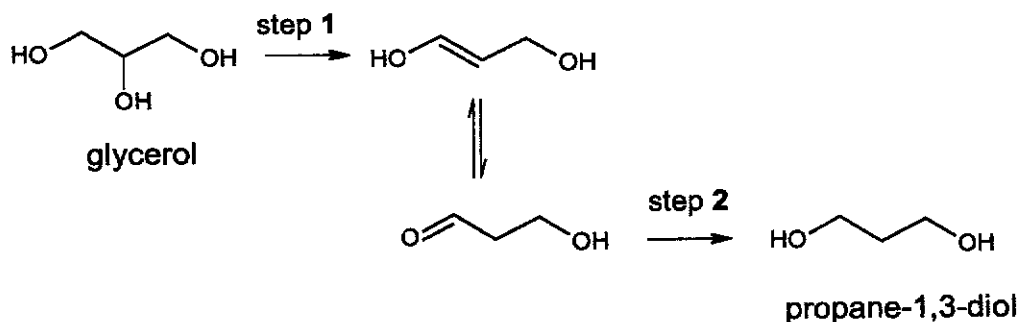
For  
examiner's  
use only



Lycra® is a polyurethane which is made up of two monomers, methylene diphenyl diisocyanate and propane-1,3-diol.



(a) Propane-1,3-diol can be synthesised using glycerol. The following synthesis pathway shows how propane-1,3-diol is formed from glycerol.



Suggest the type of reaction and the reagents and conditions involved in step 1 and step 2.

Step 1:

type of reaction.....

reagents and conditions.....

Step 2:

type of reaction.....

reagents and conditions.....[4]



(b) With reference to the structure and bonding of polyurethane, predict whether fabrics made of Lycra® are prone to creasing after they are washed and dried.

*For  
examiner's  
use only*

.....

.....

.....

.....

.....

.....

.....

.....

.....

[2]

[Total: 6]

**Section B**

Answer **one** question from this section, in the spaces provided.

For  
examiner's  
use only

**6** The elements in Group 17 of the Periodic Table often form stable compounds with both metals and non-metals.

**(a)** When  $\text{Cl}_2(\text{g})$  is passed over hot iron,  $\text{FeCl}_3(\text{s})$  is formed.

**(i)** The iron and chlorine in  $\text{FeCl}_3$  exist as the  $\text{Fe}^{3+}$  and  $\text{Cl}^-$  ions.

State the full electronic configuration of an iron ion,  $\text{Fe}^{3+}$ , and a chloride ion,  $\text{Cl}^-$ .

$\text{Fe}^{3+}$  .....

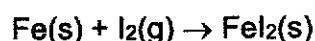
$\text{Cl}^-$  ..... [2]

**(ii)** Use the *Data Booklet* to state and compare the values of the atomic and ionic radii of chlorine.

Explain why they differ.

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

**(iii)** However, when  $\text{I}_2(\text{g})$  is passed over hot iron, the following reaction occurs.



State what you would observe during the reaction between Fe and  $\text{I}_2$ . Explain why  $\text{FeI}_2(\text{s})$  is formed rather than  $\text{FeI}_3(\text{s})$ .

Observation.....

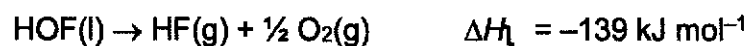
Explanation.....

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

- (b) HOF is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

For  
examiner's  
use only

HOF is an unstable compound and decomposes to form HF and O<sub>2</sub>.



- (i) Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of HOF.

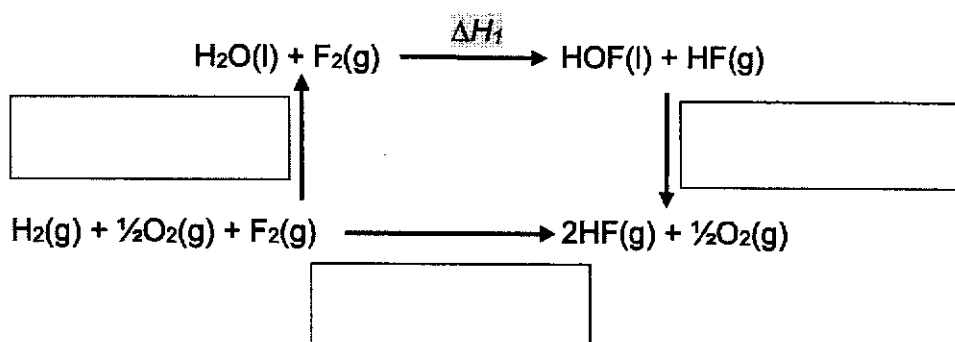
[1]

- (ii) Using values from the *Data Booklet*, calculate the enthalpy change of the reaction,  $\frac{1}{2} \text{H}_2\text{(g)} + \frac{1}{2} \text{F}_2\text{(g)} \rightarrow \text{HF(g)}$ .

[2]

- (iii) Using  $\Delta H_f(\text{H}_2\text{O}) = -285.8 \text{ kJ mol}^{-1}$  and the above given and calculated values, fill in the boxes in the energy cycle below.

Hence, calculate the enthalpy change of the reaction,  $\Delta H_1$ .



[2]

- (c) Hydrogen reacts with iodine in a reversible reaction.



For  
examiner's  
use only

An enclosed vessel containing 2.50 mol of hydrogen and 2.00 mol of iodine was allowed to reach dynamic equilibrium. The equilibrium mixture was found to contain 3.38 mol of hydrogen iodide.

- (i) Explain the term *dynamic equilibrium*.

.....  
 .....  
 ..... [1]

- (ii) Use the information given to complete the table below.

Amount / mol	$\text{H}_2(\text{g})$	+	$\text{I}_2(\text{g})$	$\rightleftharpoons$	$2\text{HI}(\text{g})$
Initial					
Change					
Equilibrium					

[2]

- (iii) Write the expression for the equilibrium constant,  $K_c$ . Use your answers in the table above to calculate the value of  $K_c$ .

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

(iv) Explain the effect on the position of equilibrium and the value of  $K_c$  when

*For  
examiner's  
use only*

I the temperature is increased.

.....  
.....  
.....  
.....  
.....  
.....

II the vessel volume is halved.

.....  
.....  
.....  
.....  
.....  
.....

[4]

[Total: 20]

7(a) Poly(ethene) is one of the most widely produced plastics in the world. It is formed by the polymerisation of ethene.

(i) Describe the bonding in ethene in terms of orbital overlap. You may draw a diagram to illustrate your answer.

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....[3]

(ii) Describe the changes in chemical bonding that occur during the polymerisation of ethene.

.....  
.....  
.....[1]

(iii) The C-C bond angle in ethene changes when the polymer is formed.

State and explain how the C-C bond angle differs between a molecule of ethene and the polymer.

bond angle changes from ..... to .....

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

Poly(ethene) exists as low density poly(ethene) (LDPE) which has a lot of side-chains, and high density poly(ethene) (HDPE) in which there are fewer and shorter side-chains.

*For  
examiner's  
use only*

- (iv) Explain, with the aid of diagrams, why the presence of side-chains causes a difference in density in poly(ethene).

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

- (v) Suggest one difference in their physical properties.

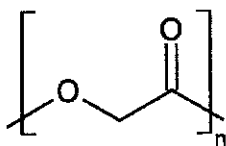
.....  
.....  
.....[1]

- (vi) Poly(ethene) bags pollute the environment for a long time because they are non-biodegradable. Suggest why.

.....  
.....  
.....  
.....[1]

- (b) Over the years, there has been considerable research into biodegradable plastics such as poly(glycolic acid) (PGA). Along with its thermoplastic properties, PGA has been manufactured into various medical applications. An example is in surgical sutures which is used to close the edges of a wound and to repair damaged tissue. It degrades as a wound heals. The repeat unit for poly(glycolic acid) (PGA), is shown below.

*For  
examiner's  
use only*



- (i) Draw the displayed formula of the monomer for PGA.

[2]

- (ii) Suggest the reagent and condition needed to prepare PGA from the monomer identified in (i) in the school laboratory.

.....[1]

- (iii) Suggest how PGA degrades as the wound in the body heals.

.....  
 .....  
 .....[1]

- (iv) Suggest why PGA would **not** be a suitable containers for food.

.....  
 .....  
 .....[1]



(c) Poly(ethene) and poly(glycolic acid) are synthesised from their respective monomers by different reactions.

(i) State the different types of reaction that took place in the polymerisation.

.....  
 .....[1]

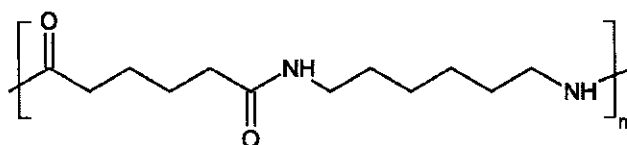
(ii) Suggest one difference in the polymerisation reactions identified in (c)(i).

.....  
 .....  
 .....[1]

(d) The table shows the melting points of three polymers.

polymer	melting point / °C
poly(ethene)	135
poly(glycolic acid)	230
nylon 6,6	269

The repeat unit for nylon 6,6, is shown below.



Explain the differences in melting point of these three polymers in terms of intermolecular forces between the chains.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....[3]

[Total: 20]

25  
BLANK PAGE

*For  
examiner's  
use only*

26  
BLANK PAGE

*For  
examiner's  
use only*

*For  
examiner's  
use only*

Nanyang JC J2 Preliminary Examination 2020  
H1 Chemistry 8873/01  
Paper 1 MCQ Answers

Ans	Ans	Ans	Ans
B	B	C	C
B	D	A	A
A	B	D	A
C	D	C	A
C	C	D	A
C	C	D	C

1 B  
There is 15 g of N per 100 g of fertiliser.

$n(N)$  in 100g fertiliser =  $\frac{15}{14.0}$

$\therefore n(N)$  in 14g fertiliser =  $\left(\frac{15}{14.0} + 100\right) \times 14 = 0.1500$  mol

0.1500 mol is dissolved in 5 dm<sup>3</sup>.

Hence conc of N atoms =  $\frac{0.1500}{5} = 0.0300$  mol dm<sup>-3</sup>

2 B  
% mass of C in hexose

$$\frac{12 \times 6}{6 \times 12.0 + 12 \times 1.0 + 6 \times 16.0} = \frac{72}{180} = 40.0\%$$

% mass of C in pentose  
$$\frac{12 \times 5}{5 \times 12.0 + 10 \times 1.0 + 5 \times 16.0} = \frac{60}{150} = 40.0\%$$

3 A  
 $Cl_2 + 2H_2O + SO_2 \rightarrow 2HCl + H_2SO_4$

Cl is reduced from 0 in  $Cl_2$  to -1 in HCl while S is oxidised from +4 in  $SO_2$  to +6 in  $H_2SO_4$ .

$SO_2$  is a stronger reducing agent than  $Cl_2$ .

$Cl_2 + H_2S \rightarrow 2HCl + S$

Cl is reduced from 0 in  $Cl_2$  to -1 in HCl while S is oxidised from -2 in  $H_2S$  to 0 in S.

$H_2S$  is a stronger reducing agent than  $Cl_2$ .

$2H_2S + SO_2 \rightarrow 2H_2O + 3S$

S is reduced from +4 in  $SO_2$  to 0 in S while S is oxidised from -2 in  $H_2S$  to 0 in S.  
 $H_2S$  is a stronger reducing agent than  $SO_2$ .

4 C

For protons,  $\frac{\text{charge}}{\text{mass}} = 1$

angle of deflection =  $k \frac{\text{charge}}{\text{mass}}$

+15 =  $k(1)$

$k = 15$

For particle Y which is deflected by an angle of +5°,

$\frac{\text{charge}}{\text{mass}} = + \frac{5}{15} = + \frac{1}{3}$

	p	n	e	charge	mass	charge/mass
A	1	2	1	0	3	no deflection
B	3	3	5	-2	6	$-\frac{1}{3}$
C	4	5	1	+3	9	$+\frac{1}{3}$
D	4	5	3	+1	9	$+\frac{1}{9}$

5 C  
From the graph, X has 7 valence electrons, is in group 17 while Y has 5 valence electrons, is in group 15.  
X is Cl and Y is P.

A Correct. Phosphorus:  $1s^2 2s^2 2p^6 3s^2 3p^3$

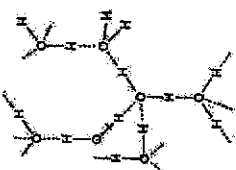
B Correct. The ions of X and Y are  $X^-$  and  $Y^-$  respectively.  $X^-: 1s^2 2s^2 2p^6 3s^2 3p^6$  and  $Y^-: 1s^2 2s^2 2p^6 3s^2 3p^6$

$X^-$  and  $Y^-$  are isoelectronic. X has a larger nuclear charge than  $Y^-$  as X has more protons than  $Y^-$ . The outermost electrons are more attracted to the nucleus of X.

C NOT correct. Cl is more electronegative than P.

D Correct.  $Y^-: 1s^2 2s^2 2p^6 3s^2 3p^2$  and  $X: 1s^2 2s^2 2p^6 3s^2 3p^5$ . One of the p orbital in  $Y^-$  is not occupied.

8 B



A: In the liquid state, the molecules have enough energy to overcome the hydrogen bonds. Hence, they are able to roll and slide over one another. There is no regular arrangement of the water molecules.

B: Four electrons from each oxygen are involved in forming hydrogen bonds in ice.

C: The structure of ice consists of a giant lattice of  $H_2O$  molecules with each oxygen atom surrounded tetrahedrally (109.5°) by four hydrogen atoms. 2 of these hydrogen atoms are covalently bonded and the other 2 hydrogen atoms are attracted via hydrogen bonding.

D: The open lattice in ice possess many empty spaces between molecules and there are less molecules per unit volume in ice, causing ice to be less dense than water.

9 D

$$LE|e| \frac{Z^+Z^-}{r^+ + r^-} |$$

Lattice energy measures the strength of ionic bonds.

1 NaCl and MgO are ionic compounds, we do not measure bond length.

2  $Mg^{2+}$ ,  $O^{2-}$  ions have higher charges and smaller ionic radii than  $Na^+$  and  $Cl^-$  hence MgO has a more exothermic lattice energy than NaCl.

3  $O^{2-}$  has higher charge and smaller ionic radius than  $Cl^-$ , hence  $Na_2O$  has a more exothermic lattice energy than NaCl.

10 C

$$\Delta H_f = \sum a\Delta H_f(\text{reactants}) - \sum b\Delta H_f(\text{products})$$

$$y = 2 \times \Delta H_f(\text{ethene}) - x$$

$$2 \times \Delta H_f(\text{ethene}) = y + x$$

$$\Delta H_f(\text{ethene}) = (y + x)/2$$

11 C

Energy absorbed by water

$$= 250 \times 4.18 \times (100 - 12) \times 10^{-3}$$

$$= 91.96 \text{ kJ}$$

Energy evolved by combustion of butane

$$= 91.96 \times \frac{100}{47}$$

$$= 195.6 \text{ kJ}$$

$$195.6 = 2877 \times \frac{m(\text{butane})}{58}$$

$$m(\text{butane}) = 3.944 \approx 3.94 \text{ g}$$

12 A

First experiment



Second experiment

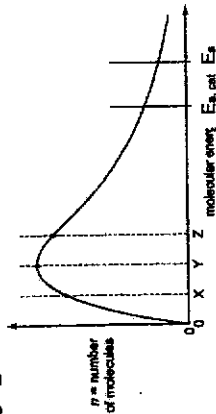


Since the acid is the limiting reagent in both experiments, with the same concentration and volume of acid used, the same  $n(\text{acid})$  will be reacted and hence the same  $n(\text{H}_2)$  is produced. The total  $V(\text{H}_2)$  evolved remains the same in the second experiment because the weak acid will be completely dissociated during the reaction with Mg to produce the same amount of  $\text{H}^+$  as the strong acid.

Ethanoic acid is a weak acid while hydrochloric acid is a strong acid. Given that both the acids are of the same concentration and weak acid only partially dissociates, the initial concentration of  $[\text{H}^+]$

present in the second experiment is smaller than that of the first experiment, thus the initial rate of reaction should decrease while the initial pH for the experiment using  $\text{CH}_3\text{COOH}$  is higher than that of HCl.

13 D



An addition of catalyst will only cause a lowering in the value of activation energy. Hence, the number of molecules with energy X, Y and Z should not increase.

14 C

Change made	
A	Increase temperature <ul style="list-style-type: none"> <li>Increases both forward and backward rate</li> <li>Favors endothermic reaction, so backward reaction is favoured, percentage yield decreases</li> </ul>
B	Add a catalyst <ul style="list-style-type: none"> <li>Increases both forward and backward rate</li> <li>No effect on POE, hence percentage yield remains unchanged</li> </ul>
C	Increase pressure <ul style="list-style-type: none"> <li>Increases both forward and backward rate</li> <li>Favors reaction that produces lesser moles of gas, hence forward reaction favoured, yield increases</li> </ul>
D	Increase volume of reaction vessel will decrease the pressure of the system <ul style="list-style-type: none"> <li>Decreases both forward and backward rate</li> <li>Favors reaction that produces more moles of gas, hence backward reaction favoured, yield decreases</li> </ul>

15 D

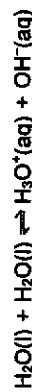


I	0.8	0.3	0
C	-0.5	-0.25	+0.5
E	0.3	0.05	0.5

$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{0.5^2}{(0.3)^2 (0.05)} = 556$$

16 B

$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$  is derived from the self-ionisation of water



At all temperatures,  $[\text{H}_3\text{O}^+] = [\text{OH}^-]$  so

$$\text{pH} = \text{pOH}$$

Water is neutral at all temperatures.

At 65 °C,  $[\text{H}_3\text{O}^+]$  and  $[\text{OH}^-]$  are greater but are still equal.

$$[\text{H}_3\text{O}^+] = 3.16 \times 10^{-7} \text{ mol dm}^{-3}$$

$$\text{pH} = 6.5$$

17 A

Titration is between a strong acid and weak base.

1. An basic buffer exist at point A – solution contains unreacted weak base,  $\text{NH}_3$  and its salt,  $\text{NH}_4\text{Cl}$ .

2. There is no  $\text{NH}_3$  at point B as stoichiometric amount of HCl had been added to neutralise all the  $\text{NH}_3$ .

3. The pH range of methyl orange (3–4) lies within the pH change at the equivalence point (pH 3–7 for a strong acid-weak base titration).

4. The solution at point C contains both the salt,  $\text{NH}_4\text{Cl}$  formed and excess strong acid HCl.

18 C

**$\text{Na}_2\text{O}$ ,  $\text{MgO}$  &  $\text{Al}_2\text{O}_3$ :**

Giant ionic structure where strong ionic bonds exist between oppositely charged ions. Large amount of energy required to

overcome strong ionic bonds hence they have high melting points.

$\text{MgO}$  has higher melting point than  $\text{Na}_2\text{O}$ . Lattice energy of  $\text{MgO}$  is more exothermic than  $\text{Na}_2\text{O}$  as  $\text{Mg}^{2+}$  has greater charge and smaller ionic radius than  $\text{Na}^+$ .

$\text{Al}_2\text{O}_3$  has lower melting point than  $\text{MgO}$ . Lattice energy of  $\text{Al}_2\text{O}_3$  is less exothermic than  $\text{MgO}$  as it has a marked degree of covalent character due to the high charge density of  $\text{Al}^{3+}$  ion which polarised  $\text{O}^{2-}$  ion easily.

**$\text{SiO}_2$ :**

Giant molecular structure where strong covalent bonds exist between Si and O atoms in a rigid 3D network.

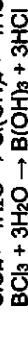
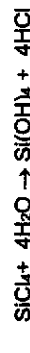
Large amount of energy required to overcome the strong covalent bonds.

**$\text{P}_4\text{O}_{10}$  &  $\text{SO}_3$ :**

Simple molecular structure where weak instantaneous dipole-induced dipole forces exist between molecules.

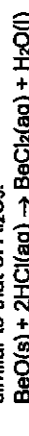
Small amount of energy required to overcome these forces and melting points are generally very low.

19 B

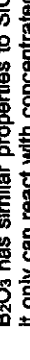


The production of HCl is observed as white fumes when  $\text{BeCl}_2$  and  $\text{BCl}_3$  is hydrolysed by water like  $\text{AlCl}_3$  and  $\text{SiCl}_4$ .

2  $\text{BeO}$  exhibits amphoteric characteristics, similar to that of  $\text{Al}_2\text{O}_3$ .



$\text{B}_2\text{O}_3$  has similar properties to  $\text{SiO}_2$ , thus it only can react with concentrated bases.



3 Both are insoluble in water (like  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$ ) to give solutions of pH = 7.

20 A

W has greater electrical conductivity than Y (compare electrical conductivity  $Al > Mg > Na > Si > P$  or S) **Eliminate Option C**

W has lower first ionisation energy than X. (compare first ionisation energy  $P > Si > Mg > Al > Na$ ) **Eliminate Option D**

Y has higher melting point than W. (compare melting point  $Si > Al > Se > Na > Na$ ) **Options A and B are correct**

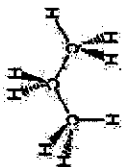
Z has a greater atomic radius than W. (Atomic radii decreases across the period, element Z must be earliest in the period)

21 A



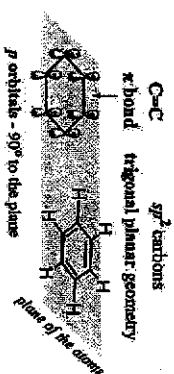
1 Correct. The shape is trigonal planar with respect to each of the circled carbons. Therefore all the 6 carbons will lie in the same plane.

2 Correct. Since there are only 3 carbon atoms in propane, the three of them will lie in the same plane.

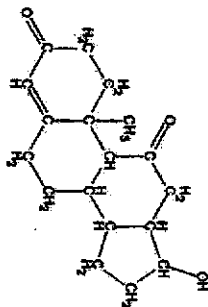


3 Correct. Benzene is a planar molecule, having the shape of a hexagon.

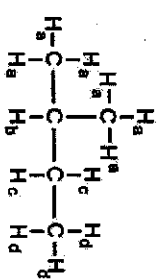
The Structure of Benzene



22 D  
 $C_{18}H_{24}O_3$



23 D



There are 4 possible ways you can substitute a hydrogen atom with bromine. Hydrogens with same chemical environments are labelled above.

Monobrominated product	Number of H that can be substituted to get the same product
	6
	1
	2
	3

Hence the 2 products with highest yield is 3 : 6 (1 : 2).

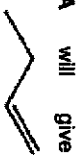
24 D

A is incorrect as chloropropane will react more slowly with the aqueous silver nitrate but gave an Insoluble product, AgCl.

B is incorrect carbon-chlorine bond is more polar than carbon-iodine bond. However the rate of hydrolysis is not dependent on the polarity of the bond.

C is incorrect as chloropropane reacted more slowly because the carbon-chlorine bond is shorter than carbon-iodine bond. Hence the carbon-chlorine bond is stronger and needs more energy to break. Rate of reaction is slower.

25 B



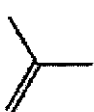
A will give only one product.

B will give rise to two products that are structural isomers

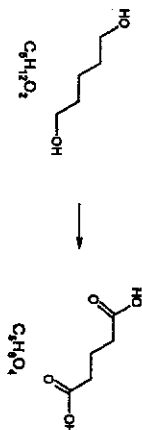


The second product on the right will give rise to a pair of cis-trans isomers, however they are not taken into account as the question only asked for structural isomers which exclude cis trans isomer.

C and D will both give the only one product after dehydration.



26 C



$$M(C_6H_{12}O_2) = 104.0$$

$$M(C_6H_{14}O_2) = 132.0$$

$$n(C_6H_{12}O_2) = 1.00 / 104.0 = 0.009615 \text{ mol}$$

$$m(C_6H_{14}O_2) = 0.009615 \times 132.0 = 1.27 \text{ g}$$

27 A

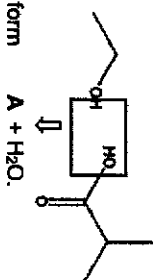
In the reaction with  $NaBH_4$ , ketones will be reduced to secondary alcohol and aldehyde will be reduced to primary alcohol. Alkene will not be reduced.

28 A

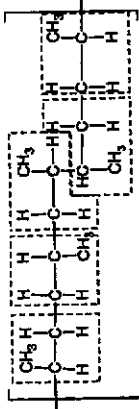


Ethyl propanoate will undergo hydrolysis with aqueous sodium hydroxide as shown.

The alcohol produced will be ethanol which will then react with 2-methylpropanoic acid to form

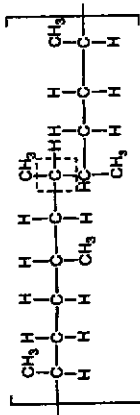
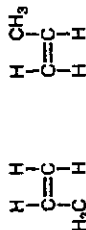
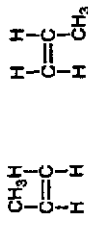


29 A



All the circled parts in the addition polymer above represent the same repeating unit. Hence, the monomer must be propene.

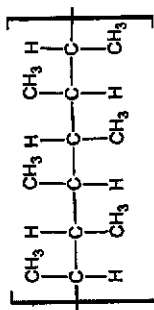
These are propene molecules in different orientations:



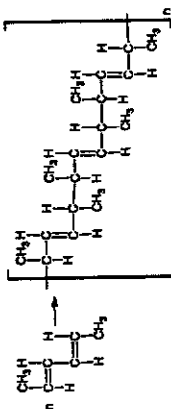
The polymer shown above is also a result of the free rotation about the single bonds. For example, the single bond about the circled C of monomer propene can rotate to achieve the polymer as shown above.

Option 1: The propene molecules in different orientation shown above undergo addition polymerisation to form the poly(propene) shown in the question.

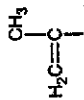
Option 2: The monomer present is a but-2-ene which will not yield the given polymer when it undergoes addition polymerisation. Poly(but-1-ene) will yield a polymer with a methyl group on every C atom involved in the backbone chain.



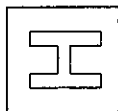
Option 3: The monomer will yield the following polymer:



30 C



The monomer  $\text{H}_2\text{C}=\text{C}(\text{COOCH}_3)\text{CH}_3$  undergoes addition polymerisation to form poly(methyl methacrylate). Hence, there is no loss of small molecules of water. In the polymer, there is no hydrogen atom bonded to F/O/N atoms, hence, there is no hydrogen available for hydrogen bonding with the neighbouring chain. The presence of an ester group in the side chain causes the polymer to hydrolyse when alkali is added.



NANYANG JUNIOR COLLEGE  
JC 2 PRELIMINARY EXAMINATION  
Higher 1

CANDIDATE  
NAME

CLASS

CENTRE  
NUMBER

1 9

S

TUTOR'S  
NAMEINDEX  
NUMBER

CHEMISTRY

Paper 2

8873/02

31 August 2020

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Section A  
Answer all the questions.Section B  
Answer one question.

The use of an approved scientific calculator is expected, where appropriate.  
A Data Booklet is provided.

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

For Examiner's Use	
A1	/7
A2	/12
A3	/12
A4	/23
A5	/6
B	/20
Total	/80

This document consists of 24 printed pages and 2 blank pages.

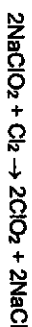
[Turn over



Section A  
Answer all questions in this section in the spaces provided.

- 1 In each of these reactions, different chlorine-containing compounds are formed in a redox reaction.

- (a) State the oxidation number of chlorine in each of the chlorine-containing species for the following equation.



Species	Oxidation number	Species	Oxidation number
Reactants	$\text{NaClO}_2$	$\text{Cl}_2$	
Products	$\text{ClO}_2$	$\text{NaCl}$	

[2]

$\text{NaClO}_2$ : +3,  $\text{ClO}_2$ : +4,  $\text{Cl}_2$ : 0,  $\text{NaCl}$ : -1  
[2] for 4 correct, [1] for 2 correct,

- (b) 6.13 g sample of the salt  $\text{KClO}_3$  was dissolved in water. The solution was acidified and made up to 100  $\text{cm}^3$ . A 10  $\text{cm}^3$  portion of this solution was completely reduced by 12.5  $\text{cm}^3$  of 0.200  $\text{mol dm}^{-3}$   $\text{H}_2\text{O}_2(\text{aq})$ .

- (i) Calculate the final oxidation number of chlorine.

$$n(\text{KClO}_3) \text{ in } 100 \text{ cm}^3 = \frac{6.13}{39.1+35.5+16.0 \times 3} = 5.000 \times 10^{-2} \text{ mol}$$

$$n(\text{KClO}_3) \text{ in } 10 \text{ cm}^3 = 5.000 \times 10^{-2} \times \frac{10}{100} = 5.000 \times 10^{-3} \text{ mol}$$

$$n(\text{H}_2\text{O}_2) = 0.0125 \times 0.200 = 2.500 \times 10^{-3} \text{ mol}$$



Method 1:

$$n(\text{e}^-) \text{ lost by } \text{H}_2\text{O}_2 = 2 \times 2.500 \times 10^{-3} = 5.000 \times 10^{-3} \text{ mol}$$

$$n(\text{e}^-) \text{ lost} = n(\text{e}^-) \text{ gained by } \text{KClO}_3 = 5.000 \times 10^{-3} \text{ mol}$$

$$n(\text{e}^-) \text{ gained by per mol of } \text{KClO}_3 = \frac{5.000 \times 10^{-3}}{5.000 \times 10^{-3}} = 1$$

Since the initial oxidation number of Cl in  $\text{ClO}_3^-$  = +5 and 1 mole of electrons was gained

- Final oxidation number of chlorine = +5 - 1 = +4

For  
examiner's  
use only

Method 2:

Initial oxidation number of Cl in  $\text{ClO}_3^-$  = +5



$$n(\text{e}^-) \text{ gained by } \text{ClO}_3^- = 5.000 \times 10^{-3} (5-x)$$

$$n(\text{e}^-) \text{ lost by } \text{H}_2\text{O}_2 = n(\text{e}^-) \text{ gained by } \text{ClO}_3^- = 5.000 \times 10^{-3} \text{ mol}$$

$$5.000 \times 10^{-3} (5-x) = 5.000 \times 10^{-3}$$

$$5-x = 1$$

$$x = 4$$

6 points - 3 m, 3 to 5 points - 2 m, 2 points - 1 m

- (ii) Using your answer in (b)(i) and the table in (a), deduce the chlorine-containing product of this reaction.



- (iii) Hence, construct a balanced equation for the reaction between  $\text{H}_2\text{O}_2$  and acidified  $\text{ClO}_3^-$ .



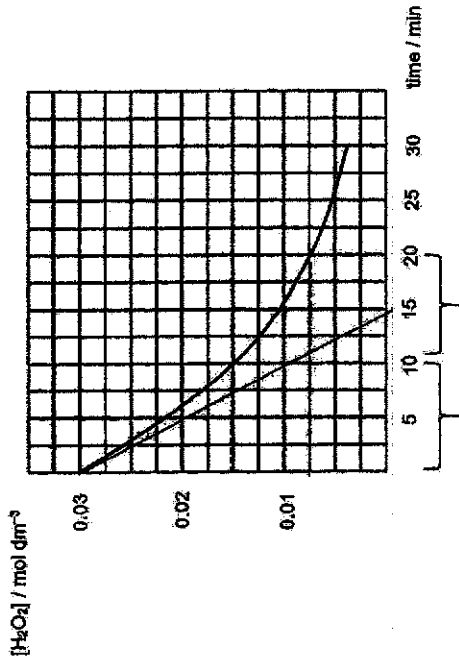
[Total: 7]

For  
examiner's  
use only

For  
examiner's  
use only

5

(b) The graph shows how the concentration of  $\text{H}_2\text{O}_2$  changes with time.



$t_{1/2} = 10 \text{ min}$   $t_{1/2} = 10 \text{ min}$

(i) Deduce, showing your working, the order of reaction with respect to  $\text{H}_2\text{O}_2$ . Hence write the rate equation for this reaction.

From 0.03 to 0.015  $\text{mol dm}^{-3}$ ,  $t_{1/2} = 10 \text{ min}$

From 0.015 to 0.0075  $\text{mol dm}^{-3}$ ,  $t_{1/2} = 10 \text{ min}$

Half-life remains constant at 10 min, hence order wrt  $\text{H}_2\text{O}_2$  is 1.

Working for 2 constant  $t_{1/2}$  (either on graph or writing) [1]

Rate =  $k[\text{H}_2\text{O}_2]$  [1]

(ii) By drawing a tangent at  $t = 0 \text{ min}$ , calculate the initial rate. Hence, calculate the rate constant for this reaction, stating its units.

Initial rate = Gradient at  $t=0 = 0.03/15 = 0.002 \text{ mol dm}^{-3} \text{ min}^{-1}$

Drawing of tangent at  $t=0$  and correct calculation [1]

Rate =  $k[\text{H}_2\text{O}_2]$   
 $0.002 = k(0.03)$   
 $k = 0.0667 \text{ min}^{-1}$

Correct calculation and value of  $k$  [1] and correct units of  $k$  [1]

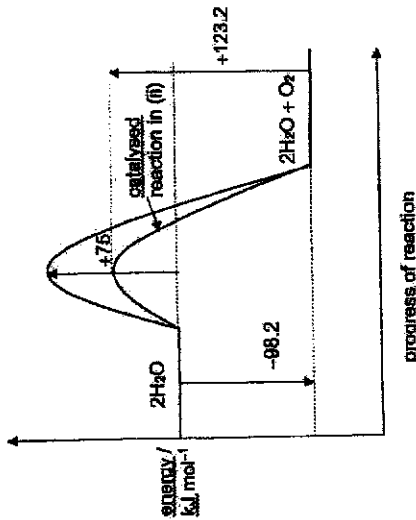
For  
examiner's  
use only

4

2(a)  $\text{H}_2\text{O}_2$  is unstable and slowly decomposes in the presence of light to form water and oxygen. The decomposition of  $\text{H}_2\text{O}_2$  is an exothermic reaction and the numerical value for the enthalpy change of decomposition of  $\text{H}_2\text{O}_2$  is  $-98.2 \text{ kJ mol}^{-1}$ . The activation energy of the forward reaction is  $+75 \text{ kJ mol}^{-1}$ .



(i) Draw the reaction pathway diagram for the decomposition of  $\text{H}_2\text{O}_2$  on the axes below.



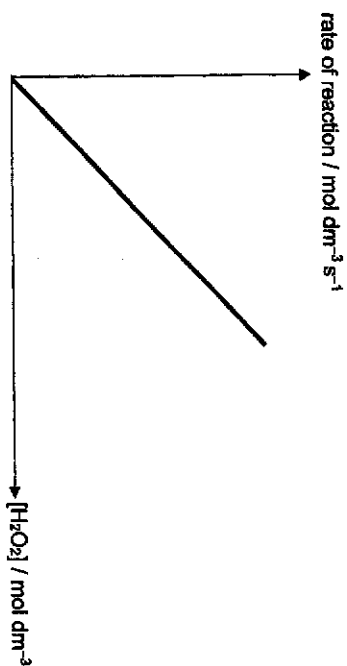
- Axis labelled correctly
  - Shape of graph
  - Correctly written reactants and products
  - Correctly identify  $E_a$  and  $\Delta H$
- 4 points - 2 marks 2 to 3 points - 1 mark

In the presence of a catalyst, the activation energy of the reaction is lowered by  $50 \text{ kJ mol}^{-1}$ .

(ii) Determine the activation energy of the backward reaction when a catalyst is added and label this in the diagram in (i).

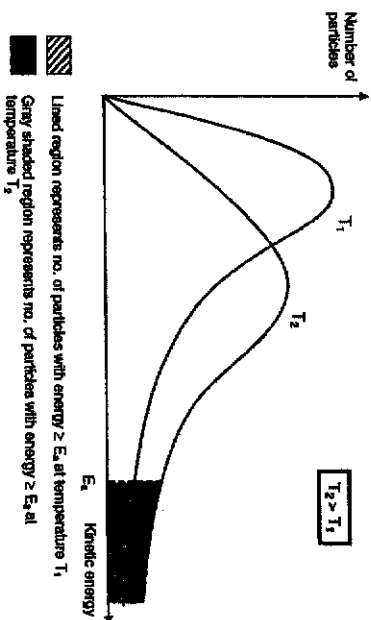
$$(+98.2 + 75) - 50 = +123.2 \text{ kJ mol}^{-1} [1]$$

(iii) Sketch a graph of rate of reaction against  $[H_2O_2]$  for this reaction.



[1] for shape and correct x and y axes

(c) With an aid of a labelled diagram, explain the effect on the rate of the reaction when the temperature was increased.



[1] for labelled diagram

- When temperature was increased, the average kinetic energy of the reactants increased.
  - More reactants will have energy greater than or equals to the activation energy.
  - The frequency of effective collisions increased. Rate constant increased, hence rate increased.
- 3 points [2]; 1 – 2 points [1]

For examiner's use only

3(a) (i) The boiling points of three chlorides are given in the following table.

compound	boiling point / °C
magnesium chloride	1412
aluminium chloride	178
phosphorus pentachloride	166

Explain the differences in the boiling points of the above compounds in terms of structure and bonding.

MgCl<sub>2</sub> has a giant ionic structure. More energy is required to overcome the strong ionic bonds between the Mg<sup>2+</sup> and Cl<sup>-</sup> ions. Thus, MgCl<sub>2</sub> has the highest boiling point. Both AlCl<sub>3</sub> and PCl<sub>5</sub> have simple molecular structures. Less energy is required to overcome the weak instantaneous dipole-induced dipole forces between molecules.

At the boiling point, AlCl<sub>3</sub> exists as a dimer, Al<sub>2</sub>Cl<sub>6</sub> (Mr = 266.7), which has a larger number of electrons / larger electron cloud than PCl<sub>5</sub> (Mr = 208) and is more polarised.

More energy is required to overcome the stronger instantaneous dipole-induced dipole forces between Al<sub>2</sub>Cl<sub>6</sub> molecules than that between PCl<sub>5</sub> molecules. Thus, Al<sub>2</sub>Cl<sub>6</sub> has a higher boiling point than PCl<sub>5</sub>.

- Structure, bonding, particles for MgCl<sub>2</sub>
- Structure, bonding, particles for AlCl<sub>3</sub> and PCl<sub>5</sub>
- Energy required
- AlCl<sub>3</sub> dimerises
- larger electron cloud / larger no. of electrons than PCl<sub>5</sub>
- Stronger id-id for Al<sub>2</sub>Cl<sub>6</sub>

6 pts – [3]  
4-5 pts – [2]  
2-3 pts – [1]

(ii) Explain the reaction of magnesium chloride with water, suggesting the pH of the resulting solution and writing equations, where appropriate.

The resulting pH is 6.5. [1]

- Mg<sup>2+</sup> has relatively high charge density and it undergoes slight hydrolysis is able to polarise the water molecules.
  - MgCl<sub>2</sub>(s) + 6H<sub>2</sub>O(l) → [Mg(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup>(aq) + 2Cl<sup>-</sup>(aq) (resulting in breakage of O-H bond to form H<sub>3</sub>O<sup>+</sup> ion, which is acidic.)
  - [Mg(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup>(aq) + H<sub>2</sub>O(l) ⇌ [Mg(H<sub>2</sub>O)<sub>5</sub>(OH)]<sup>+</sup>(aq) + H<sub>3</sub>O<sup>+</sup>(aq)
- 3pts – [2], 2 or 1 pts – [1]

For examiner's use only

For  
examiner's  
use only

9

(II) State the substance(s) present in

Residue A: Si(s), MgO(s), Al<sub>2</sub>O<sub>3</sub>(s)

Residue B: Si(s), MgO(s)

Residue C: Si(s)

Filtrate C: MgCl<sub>2</sub>(aq)

7-8 correct species - [3]

4-6 correct species - [2]

1-3 correct species - [1]

For  
examiner's  
use only

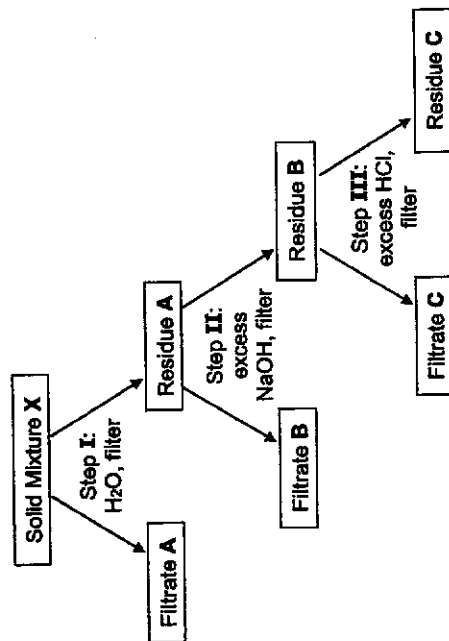
8

(III) Using relevant data from the Data Booklet, explain why the resulting solutions of magnesium chloride and aluminium chloride with water give rise to different pH values.

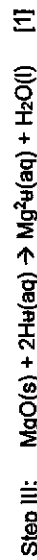
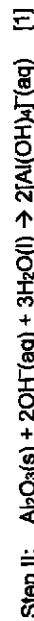
Ionic radius of Al<sup>3+</sup> = 0.050 nm, ionic radius of Mg<sup>2+</sup> = 0.065 nm,ionic charge of Al<sup>3+</sup> = +3, ionic radius of Mg<sup>2+</sup> = +2charge density of Al<sup>3+</sup> ( $\frac{3}{0.050}$ ) is higher thanMg<sup>2+</sup> ( $\frac{2}{0.065} = 30.8$ )Hence Al<sup>3+</sup> is able to polarise the water molecules to a greater extent, resulting in a higher concentration of H<sub>3</sub>O<sup>+</sup>.

2 pts - [1]

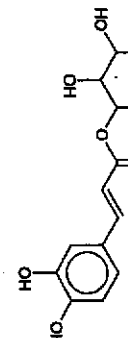
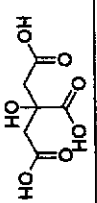
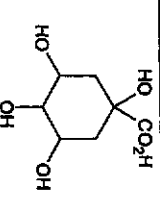
(b) A solid mixture X containing magnesium oxide, magnesium chloride, aluminium oxide and silicon chips was required to be separated. The following procedure was carried out on the mixture.



(i) Write the balanced equations of the reactions that occurred in steps II and III, given that only one reaction occurred at each step



- 4 Coffee is an acidic beverage as the brewing process releases acids from the coffee beans. The perceived acidity in coffee drinks is found to correlate to its pH. The table below shows some of the weak acids that are commonly found in a typical medium roast coffee.

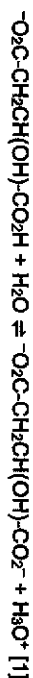
acid	structure	$K_a$ / mol dm <sup>-3</sup>
ethanoic acid	<chem>CH3COOH</chem>	$1.8 \times 10^{-5}$
chlorogenic acid		$4.0 \times 10^{-4}$
citric acid		( $K_{a1}$ ) $7.2 \times 10^{-4}$ ( $K_{a2}$ ) $1.7 \times 10^{-5}$ ( $K_{a3}$ ) $4.1 \times 10^{-7}$
malic acid	<chem>HO2CCH2CH(OH)CO2H</chem>	( $K_{a1}$ ) $4.0 \times 10^{-4}$ ( $K_{a2}$ ) $7.8 \times 10^{-6}$
quinic acid		$4.0 \times 10^{-4}$

- (a) (i) Explain the meaning of the terms *acid* and *weak acid*, in terms of the Brønsted-Lowry theory of acids.  
An acid is a proton donor. [1]  
A weak acid is a proton donor that partially ionises, forming less  $H_3O^+$ . [1]
- (ii) By considering the  $K_a$  values, suggest which acid will contribute the most to the acidity in coffee (ignore the effect of  $K_{a2}$  and  $K_{a3}$ ). Explain your answer.  
Citric acid. [1]  
The  $K_a$  value is the largest, hence it is the strongest acid. The extent of dissociation is the largest. [1]

For  
examiner's  
use only

- (iii) Malic acid is a diprotic acid.

Write an equation to represent the second acid dissociation,  $K_{a2}$  of malic acid, and hence write an expression for  $K_{a2}$ .

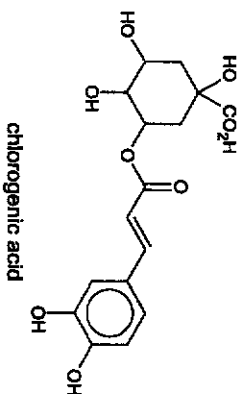


$$K_{a2} = \frac{[O_2CCH_2CH(OH)CO_2^-][H_3O^+]}{[O_2CCH_2CH(OH)CO_2H]} \quad [1]$$

- (iv) Suggest a reason why the value of  $K_{a2}$  of malic acid is smaller than its  $K_{a1}$  value.

It is electrostatically unfavourable to remove a proton from an anion than a neutral molecule. [1]

- (b) (i) It was found that the acid present in the largest quantity in coffee beans is chlorogenic acid,  $C_{16}H_{16}O_9$ . It is believed to be the main acid that causes the coffee acidity and it is also partly responsible for the bitterness in coffee.



An experiment was conducted to determine the concentration of chlorogenic acid in the coffee drinks that were brewed by coffee powder of different grind sizes. The following results were obtained when the coffee powder was brewed for 5 min.

[chlorogenic acid] / mg dm <sup>-3</sup>	coarse grind	fine grind	extra fine grind
	700	1060	1180

- (i) With reference to its structure, suggest a reason why chlorogenic acid can dissolve in water when the coffee powder was brewed.  
Energy release from the formation of hydrogen bonds between chlorogenic acid molecules and water molecules is more than energy absorbed to overcome hydrogen bonding between chlorogenic acid molecules and between water molecules. [1]

For  
examiner's  
use only

12

(ii) State and explain the relationship between the grind sizes and concentration of chlorogenic acid in coffee drinks.

As the grind size decreases, concentration of chlorogenic acid increases. [1]

The smaller particle size provide a larger surface area (to volume ratio). Hence increasing the rate of chlorogenic acid dissolving into the water / more chlorogenic acid dissolve in water. [1]

(iii) A cup of coffee brewed using the fine grind coffee powder was found to have a pH of 3.04.

Assuming that the acidity is due to chlorogenic acid only, calculate the concentration of the acid in mol dm<sup>-3</sup> and hence the degree of ionisation of chlorogenic acid.

$$[H^+] = 10^{-3.04} = 9.120 \times 10^{-4} \text{ mol dm}^{-3} \text{ [1]}$$

$$M_r \text{ of chlorogenic acid} = 16 \times 12.0 + 18 \times 1.0 + 9 \times 16.0 = 354.0$$

$$[\text{chlorogenic acid}] = 1060 \times 10^{-3} / 354.0 = 2.994 \times 10^{-3} \text{ mol dm}^{-3} \text{ [1]}$$

$$\text{Degree of ionisation} = \frac{9.120 \times 10^{-4}}{2.994 \times 10^{-3}} = 0.305 \text{ [1]}$$

Alternative (using H2 method):

$$[H^+] = 10^{-3.04} = 9.120 \times 10^{-4} \text{ mol dm}^{-3}$$

$$K_a = \frac{[H^+]^2}{[\text{chlorogenic acid}]}$$

$$4.0 \times 10^{-4} = \frac{[9.120 \times 10^{-4}]^2}{[\text{chlorogenic acid}]}$$

$$[\text{chlorogenic acid}] = 2.079 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{Degree of ionisation} = \frac{9.120 \times 10^{-4}}{2.079 \times 10^{-3}} = 0.439$$

For  
examiner's  
use only

13

(c) The percentage by mass of chlorogenic acid in the different types of coffee powder is shown below.

	Green Robusta	Roasted Arabica	Instant Coffee
% by mass of chlorogenic acid	8.8	2.3	5.8

In the experiment in (b), 10.0 g of fine ground coffee powder was brewed in 200 cm<sup>3</sup> of water. The chlorogenic acid in the coffee powder was assumed to dissolve in water completely during the brewing.

(i) Calculate the percentage by mass of chlorogenic acid in the coffee powder used.

$$[\text{chlorogenic acid}] = 1060 \text{ mg dm}^{-3}$$

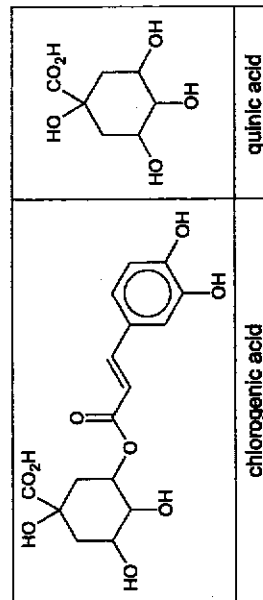
$$\text{Mass of chlorogenic acid} = 1060 \times 200 / 1000 = 212 \text{ mg} = 212 \times 10^{-3} \text{ g}$$

$$\text{Percentage by mass of chlorogenic acid} = \frac{212 \times 10^{-3}}{10.0} \times 100 \% = 2.12 \% \text{ [1]}$$

(ii) Hence, state the type of coffee powder used in the experiment.

Roasted Arabica [1]

(d) Excessive quinic acid has been associated with unfavourable sourness when brewed coffee is left on a heater plate. It was also found that the concentration of quinic acid in coffee increases inversely with chlorogenic acid.



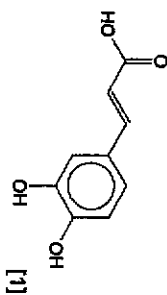
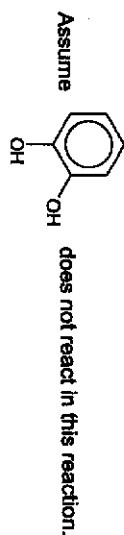
(i) Suggest a reason why the concentration of quinic acid increases when brewed coffee was left on a heater plate.

Heat increases the rate of hydrolysis of chlorogenic acid. [1]

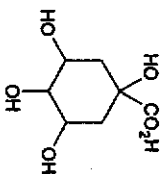
For  
examiner's  
use only

14

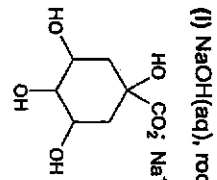
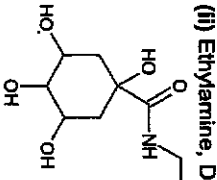
- (ii) Suggest the structure of the other product obtained together with quinic acid.



- (e) Draw the product obtained and state the type of reaction when quinic acid reacts with the following reagents.



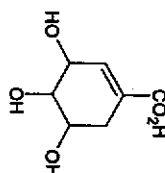
quinic acid

(i) NaOH(aq), room temperature	(ii) Ethylamine, DCC
 [1]	 [1]
Type of reaction: acid-base [1]	Type of reaction: condensation [1]

For examiner's use only

15

- (f) Quinic acid can be converted into shikimic acid using a biocatalyst.



shikimic acid

Suggest a simple chemical test that can check if the conversion is successful, stating clearly the reagents and conditions, and the expected observations.

Add Br<sub>2</sub> in CCl<sub>4</sub> to a small sample of the reaction mixture. [1]  
If conversion is successful, orange-red Br<sub>2</sub> decolourises.  
If conversion is not successful, orange-red Br<sub>2</sub> remains. [1]

For examiner's use only

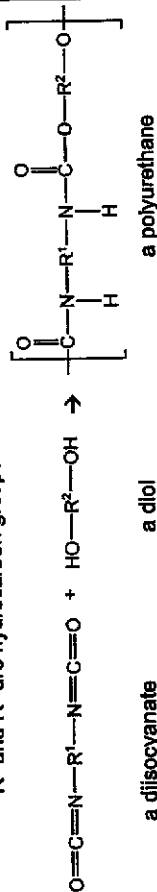
(b) With reference to the structure and bonding of polyurethane, predict whether fabrics made of Lycra® are prone to creasing after they are washed and dried.

- Lycra® is prone to creasing.
- When the material is wet, the hydrogen bonds between the polymer chains that were present initially will be broken and the water molecules form hydrogen bonds with the polymer chain.
- When the material is dried, the polymer move to new positions and realign in a different arrangement, forming new hydrogen bonds which are strong enough to hold them in their new positions.

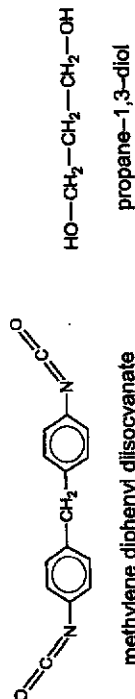
3 points – 2 marks; 2 points – 1 mark

5 Polyurethanes are polymers composed of organic units joined by urethane links.

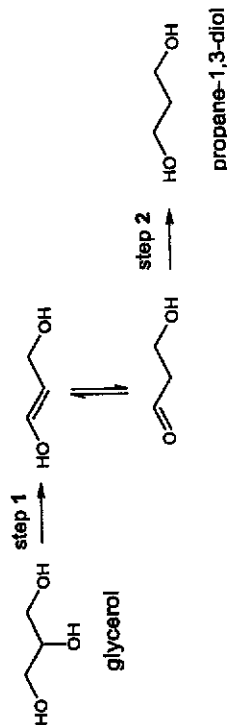
The reaction of a diisocyanate with a diol to form polyurethanes is as shown.



Lycra® is a polyurethane which is made up of two monomers, methylene diphenyl diisocyanate and propane-1,3-diol.



(a) Propane-1,3-diol can be synthesised using glycerol. The following synthesis pathway shows how propane-1,3-diol is formed from glycerol.



Suggest the type of reaction and the reagents and conditions involved in step 1 and step 2.

Step 1

type of reaction Elimination [1]

reagents and conditions  $\text{Al}_2\text{O}_3$  at  $350^\circ\text{C}$  or excess conc  $\text{H}_2\text{SO}_4$  at  $170^\circ\text{C}$  [1]

Step 2

type of reaction Reduction [1]

reagents and conditions  $\text{LiAlH}_4$  in dry ether, room temperature or  $\text{NaBH}_4(\text{aq})$  or  $\text{NaBH}_4$  in methanol, room temperature or  $\text{H}_2(\text{g})$ , Ni catalyst, heat or  $\text{H}_2(\text{g})$ , Pt/Pd at room temperature [1]



## Section B

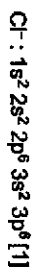
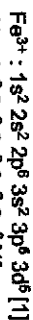
Answer one question from this section, in the spaces provided.

- 6 The elements in Group 17 of the Periodic Table often form stable compounds with both metals and non-metals.

(a) When  $\text{Cl}_2(\text{g})$  is passed over hot iron,  $\text{FeCl}_3(\text{s})$  is formed.

(i) The iron and chlorine in  $\text{FeCl}_3$  exist as the  $\text{Fe}^{3+}$  and  $\text{Cl}^-$  ions.

State the full electronic configuration of an iron ion,  $\text{Fe}^{3+}$ , and a chloride ion,  $\text{Cl}^-$ .



(ii) Use the *Data Booklet* to state and compare the values of the atomic and ionic radii of chlorine.

Explain why they differ.

For chlorine, the ionic radius (0.181 nm) is larger than the atomic radius (0.099 nm). [1]

Anions are bigger than their respective atoms because of the extra repulsion of the added electron(s). Since the nuclear charge remains the same, the outermost electrons are now less attracted to the nucleus. [1]

(iii) However, when  $\text{I}_2(\text{g})$  is passed over hot iron, the following reaction occurs.



State what you would observe during the reaction between Fe and  $\text{I}_2$ . Explain why  $\text{FeI}_2(\text{s})$  is formed rather than  $\text{FeI}_3(\text{s})$ .

Purple gas disappears / decolourises. [1]

Iodine is not a strong enough oxidising agent compared to  $\text{Cl}_2$ . [1]

For  
examiner's  
use only

(b)  $\text{HOF}$  is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

$\text{HOF}$  is an unstable compound and decomposes to form  $\text{HF}$  and  $\text{O}_2$ .



(i) Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of  $\text{HOF}$ .



(ii) Using values from the *Data Booklet*, calculate the enthalpy change of the reaction,  $\frac{1}{2} \text{H}_2(\text{g}) + \frac{1}{2} \text{F}_2(\text{g}) \rightarrow \text{HF}(\text{g})$ .

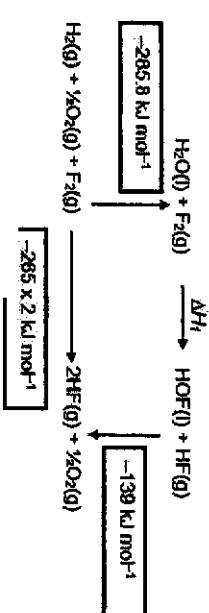
$\Delta H_f^\ominus$  = 8.15 (reactants) – 8.15 (products)

$$= \frac{1}{2}(436) + \frac{1}{2}(158) - 562 \quad [1] \text{ correct citation of values from D.B.}$$

$$= -265 \text{ kJ mol}^{-1} [1] \text{ correct final ans}$$

(iii) Using  $\Delta H_f^\ominus$  ( $\text{H}_2\text{O}$ ) =  $-285.8 \text{ kJ mol}^{-1}$  and the above given and calculated values, fill in the boxes in the energy cycle below.

Hence, calculate the enthalpy change of the reaction,  $\Delta H_f^\ominus$ .



Correct values [1], allow ECF from (ii)

$$\Delta H_f^\ominus = 285.8 - 285 (2) + 139 = -105.2 = -105 \text{ kJ mol}^{-1}$$

Correct final answer [1], allow ECF from (ii)

For  
examiner's  
use only

- (c) Hydrogen reacts with iodine in a reversible reaction.



An enclosed vessel containing 2.50 mol of hydrogen and 2.00 mol of iodine was allowed to reach dynamic equilibrium. The equilibrium mixture was found to contain 3.38 mol of hydrogen iodide.

- (i) Explain the term dynamic equilibrium.

Rates of the forward and backward reactions of a reversible reaction are the same. There is no net change in the concentration of the reactants and products. [1]

- (ii) Use the information given to complete the table below.

Amount / mol	$\text{H}_2(\text{g})$	+	$\text{I}_2(\text{g})$	$\rightleftharpoons$	$2\text{HI}(\text{g})$
Initial	2.50		2.00		0
Change	$-\frac{3.38}{2}$		$-\frac{3.38}{2}$		+3.38
Equilibrium	0.810		0.310		3.38

[1] correct change amount and [1] all values correct

- (iii) Write the expression for the equilibrium constant,  $K_c$ . Use your answers in the table above to calculate the value of  $K_c$ .

Let the volume of the enclosed vessel be  $V \text{ dm}^3$

$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{(3.38/V)^2}{(0.810/V)(0.310/V)} = \frac{3.38^2}{0.810 \times 0.310} = 45.49 = 45.5 \text{ [1]}$$

- (iv) Explain the effect on the position of equilibrium and the value of  $K_c$  when

- By Le Chatelier's principle, the system reacts to compensate / reduce some of the excess heat.
  - The position of equilibrium will shift to the right, favouring the forward endothermic reaction.
  - [Product] increases while [reactants] decreases. Value of  $K_c$  increases.
- 2 points for [1], 4 points for [2]

- Pressure increases by two times when vessel volume is halved. By Le Chatelier's principle, the system reacts to reduce the pressure.
- However, there are equal number of moles of gaseous reactants and products.
- Hence, there is no shift in position of equilibrium.
- [Product] and [reactants] remain constant. Value of  $K_c$  does not change.

- 2 points for [1], 4 points for [2]

- 7(a) Poly(ethene) is one of the most widely produced plastics in the world. It is formed by the polymerisation of ethene.

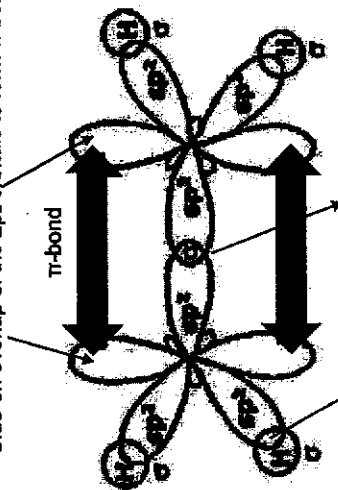
- (i) Describe the bonding in ethene in terms of orbital overlap. You may draw a diagram to illustrate your answer.

Two  $sp^2$  hybrid orbitals on each carbon overlap head-on with two 1s orbitals of H to form two C-H  $\sigma$ -bonds.  
[1] for explanation and diagram  
Accept if p orbital of carbon is used instead

One  $sp^2$  hybrid orbital on each carbon overlaps head-on with the  $sp^2$  orbital of the other carbon to form a C-C  $\sigma$ -bond.  
[1] for explanation and diagram  
Accept if p orbital of carbon is used instead

One  $2p_z$  orbital on each carbon overlap side-on with the  $2p_z$  orbital of the other carbon to form a C-C  $\pi$ -bond.  
[1] for explanation and diagram

Side-on overlap of the  $2p_z$  orbitals to form  $\pi$  bond



Head-on overlap of the  $sp^2$  orbital and s orbital to form  $\sigma$  bonds

Head-on overlap of the  $sp^2$  orbitals to form  $\sigma$  bonds

- (ii) Describe the changes in chemical bonding that occur during the polymerisation of ethene.

C=C / double /  $\pi$  bond is broken and new C-C / single /  $\sigma$  bonds are formed with other monomers. [1]

- (iii) The C-C bond angle in ethene changes when the polymer is formed.

State and explain how the C-C bond angle differs between a molecule of ethene and the polymer.

120° to 109.5° [1]

due to the change from a trigonal planar carbon (or carbon with 3 bond pairs and 0 lone pair) to a tetrahedral carbon (or carbon with 4 bond pairs and 0 lone pair) [1]

Poly(ethene) exists as low density poly(ethene) (LDPE) which has a lot of side-chains, and high density poly(ethene) (HDPE) in which there are fewer and shorter side-chains.

- (iv) Explain, with the aid of diagrams, why the presence of side-chains causes a difference in density in poly(ethene).

**LDPE**



Polymer chains are highly branched. They cannot pack together closely and regularly or are more irregularly tangled together.

The empty space between polymer chains resulting in weaker instantaneous dipole-induced dipole between chains.

**HDPE**



Polymer chains have minimal or no branching. They can pack closely together, giving a more regular structure with less empty space between adjacent chains.

There are more surface area of contact between adjacent chains for intermolecular instantaneous dipole-induced dipole forces of attraction to form.

[1] for diagram and [1] for packing and IMF

For  
examiner's  
use only

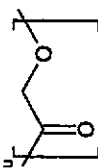
- (v) Suggest one difference in their physical properties.

LDPE is softer while HDPE is harder [1]  
or LDPE is more flexible while HDPE is stiffer

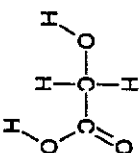
- (vi) Poly(ethene) bags pollute the environment for a long time because they are non-biodegradable. Suggest why.

Its bonds are non-polar or poly(ethene) is non-polar (or there is absence of polar ester or amide bonds), hence they cannot be broken down by microorganisms or enzymes. [1]

- (b) Over the years, there has been considerable research into biodegradable plastics such as poly(glycolic acid) (PGA). Along with its thermoplastic properties, PGA has been manufactured into various medical applications. An example is in surgical sutures which is used to close the edges of a wound and to repair damaged tissue. It degrades as a wound heals. The repeat unit for poly(glycolic acid) (PGA) is shown below.



- (i) Draw the displayed formula of the monomer for PGA.



[1] for glycolic acid and [1] for showing all bonds

- (ii) Suggest the reagent and condition needed to prepare PGA from the monomer identified in (i) in the school laboratory.

concentrated H<sub>2</sub>SO<sub>4</sub>, heat under reflux for a few hours [1]

- (iii) Suggest how PGA degrades as the wound in the body heals.

The ester functional group / linkage / bond in PGA undergoes hydrolysis or reacts with water. [1]

- (iv) Suggest why PGA would not be a suitable containers for food.

Acid present in food would hydrolyse PGA. [1]  
or Hot contents would soften the container as PGA is a thermoplastic.

For  
examiner's  
use only

25

Nylon 6,6, a polyamide has the strongest hydrogen bonding between the polar amide linkages of neighbouring chains. [1]

The amount of energy required to overcome the intermolecular forces between the chains decreases from nylon 6,6 to poly(glycolic acid) and to poly(ethene).

For  
examiner's  
use only

(c) Poly(ethene) and poly(glycolic acid) are synthesised from their respective monomers by different reactions.

(i) State the different types of reaction that took place in the polymerisation. Poly(ethene) and poly(glycolic acid) are synthesised by addition and condensation polymerisation respectively. [1]

(ii) Suggest one difference in the polymerisation reactions identified in (c)(i).

The ethene monomers form saturated polymers without loss of any molecule whereas the glycolic acid monomers react together releasing a small water molecule. [1]

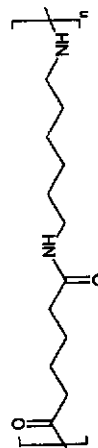
or  
Ethene monomers consist of unsaturated molecules whereas the glycolic acid monomers consist of saturated monomers.

or  
Ethene monomers consist of multiple bonds (e.g. double bonds) react to form saturated polymers while glycolic acid monomers consist of bifunctional monomers with two functional groups react to form a polymer (with ester linkages)

(d) The table shows the melting points of three polymers.

polymer	melting point / °C
poly(ethene)	135
poly(glycolic acid)	230
nylon 6,6	269

The repeat unit for nylon 6,6, is shown below.



Explain the differences in melting point of these three polymers in terms of intermolecular forces between the chains.

Poly(ethene) has the weakest instantaneous dipole-induced dipole between the non-polar chains. [1]

Poly(glycolic acid) has the stronger permanent dipole-permanent dipole forces of attraction between the polar ester linkages of neighbouring chains. [1]

For  
examiner's  
use only