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ST ANDREW'S JUNIOR COLLEGE



JC2 Preliminary Examination

H1 Chemistry (8873/01)

18 Sep 2020

Paper 1 Multiple Choice

1 hour

Additional Materials: Multiple Choice Answer Sheet, Data Booklet

READ THESE INSTRUCTIONS:

Write in soft pencil.

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

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.

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 **12** printed pages (including this page).

1 *Use of Data Booklet is relevant to this question*

Hydrogen polyoxides are chemical compounds that consist only of hydrogen and oxygen atoms, bonded exclusively by single bonds.

One such hydrogen polyoxide contains 97.56% by mass of oxygen.

What could be the identity of this hydrogen polyoxide?

- A H₂O₂ B H₂O₃ C H₂O₄ D H₂O₅

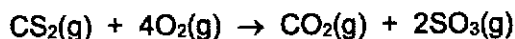
2 *Use of Data Booklet is relevant to this question*

A 5g sample of a diatomic gas was found to contain 3.76×10^{22} atoms.

What is the relative molecular mass of this gas?

- A 40 B 80 C 120 D 160

3 Carbon disulfide vapour burns in oxygen according to the following equation.



A sample of 10 cm³ of carbon disulfide was burned in 50 cm³ of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again. All measurements were made at the same temperature and pressure in which carbon disulfide was gaseous.

What were the measured volumes?

	volume of gas after burning / cm ³	volume of gas after adding NaOH(aq) / cm ³
A	30	0
B	30	10
C	40	10
D	40	30

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

Two moles of an oxidising agent, WO_3^{2-} , in the presence of excess acid oxidised 68.1 dm³ of sulfur dioxide gas at standard temperature and pressure to SO_4^{2-} .

What is the number of moles of electrons accepted by one mole of WO_3^{2-} ?

- A 1 B 2 C 3 D 4

[Turn over

- 5 G^{3-} has a relative atomic mass of 75 and contains 45 electrons.

Which of the following is an isotope of G ?

	Number of protons	Number of electrons	Number of neutrons
A	42	42	33
B	42	42	35
C	48	48	27
D	48	48	30

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

The valence electronic configuration of 4 elements, **J**, **L**, **M** and **Q** are listed below.

Element	Valence Electronic Configuration
J	$1s^2$
L	$2s^2 2p^5$
M	$3s^2$
Q	$3s^2 3p^5$

Which of the following statements about these elements are true?

- Element **J** and **M** are in the same group but different period.
- Element **L** and **Q** are in the same group but different period.
- Element **M** and **Q** are in different group but the same period.
- Element **J** and **L** are in different group but the same period.

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

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

Which of the following species has the same number of unpaired electrons as Cu in CuI ?

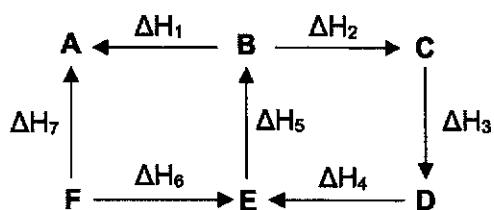
- A** Na
B Mn^{2+}
C Cr^{5+}
D V^{3+}

[Turn over

- 8 Which of the following species contain a co-ordinate bond?
- 1 $AlCl_4^-$
 - 2 CO
 - 3 NO_2^+
 - 4 SO_4^{2-}
- A 1 and 2 only
B 2 and 3 only
C 3 and 4 only
D 1 and 4 only
- 9 Which of the following molecules are planar?
- 1 BCl_3
 - 2 ICl_4^-
 - 3 H_3O^+
- A 1,2 and 3
B 1 and 2 only
C 2 and 3 only
D 1 only
- 10 Which of the following gases requires the least amount of pressure to liquefy?
- A CO_2 B CH_3CH_3 C CH_3CH_2F D CH_3CH_2OH
- 11 Which of the following equations represents the lattice energy of MgO?
- A $Mg(s) + \frac{1}{2} O_2(g) \longrightarrow MgO(s)$
B $Mg^{2+}(g) + \frac{1}{2} O_2^{2-}(g) \longrightarrow MgO(g)$
C $Mg^{2+}(g) + O^{2-}(g) \longrightarrow MgO(s)$
D $2Mg^{2+}(g) + O_2^{2-}(g) \longrightarrow 2 MgO(s)$

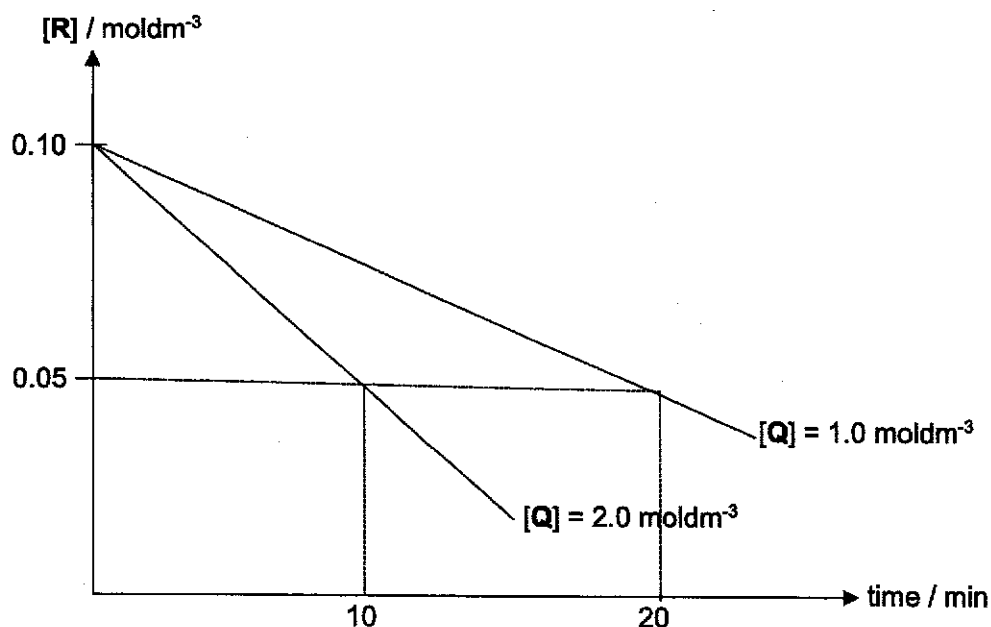
[Turn over

- 12 Consider the following energy cycle.



Which of the following is the ΔH of A to D?

- A $\Delta H_1 + \Delta H_2 + \Delta H_3$
 B $\Delta H_1 + \Delta H_4 + \Delta H_5$
 C $\Delta H_3 - \Delta H_2 - \Delta H_1$
 D $\Delta H_6 - \Delta H_4 - \Delta H_7$
- 13 To monitor the kinetics of a reaction between Q and R, two experiments were conducted to monitor the concentration of R over time with different concentrations of Q. The graph below shows the results obtained.



Based on the graph above, which of the following is the rate equation of the reaction between Q and R?

- A rate = k
 B rate = k[Q]
 C rate = k[R]
 D rate = k[Q][R]

[Turn over

Q14 and 15 will make reference to the reversible reaction between X and Y to produce Z

14 Given that the K_c for the following equilibrium is 9,



What is the mole ratio of Y : Z at equilibrium?

- A 1 : 1 B 1 : 3 C 3 : 1 D 9 : 1

15 When the same reaction between X and Y was repeated at a higher temperature, the K_c value was found to be 12.

Which of the following statements about this equilibrium are correct?

- 1 The production of Z is an endothermic process.
- 2 When the pressure of reaction is reduced, more Y is produced.
- 3 Adding more Z after equilibrium has been established will lead to a decrease in the K_c value.
- 4 Adding a catalyst to the equilibrium will speed up the rate of the forward and backward reaction but the value of K_c remains unchanged.

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

16 Boric acid, $B(OH)_3$, is often used as an antiseptic and as a precursor to other chemical compounds. The following equilibrium illustrates the acidity of boric acid.



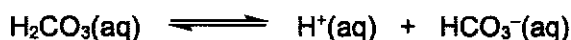
Which of the following statements about the above equilibrium are **incorrect**?

- 1 Boric acid accepted a lone pair of electrons from OH^- .
- 2 Boric acid is a weak monobasic acid.
- 3 Boric acid is a Brønsted-Lowry acid.
- 4 Boric acid is an Arrhenius acid.

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

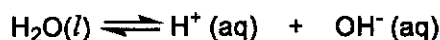
[Turn over

- 17 Human plasma is buffered mainly by dissolved CO_2 which has reacted to form carbonic acid, H_2CO_3 .



Given that the ratio of $[\text{HCO}_3^-]$ to $[\text{H}_2\text{CO}_3]$ in human plasma is 20 : 1 and the acid dissociation constant, K_a , of carbonic acid is $8 \times 10^{-7} \text{ mol dm}^{-3}$, which of the following statements is **incorrect**?

- A The pH of human plasma is 7.4.
 - B The concentration of H_2CO_3 will decrease while the concentration of HCO_3^- will increase when a small amount base is added to human plasma.
 - C This buffer is more efficient in removing acid than base.
 - D This buffer system can be prepared by mixing suitable amounts of sodium hydrogencarbonate and sodium hydroxide.
- 18 The dissociation of water is an endothermic process and has the following equation.



$K_w = [\text{H}^+][\text{OH}^-]$ and it represents the ionic product of water.

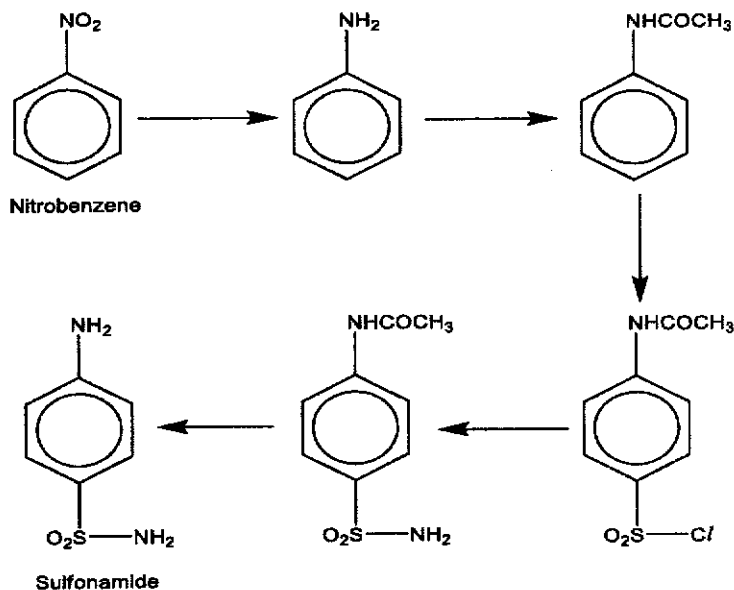
Which if the following statements is correct?

- A Water is not neutral when temperature of water is increased.
 - B The pH of water is 7 at all temperatures.
 - C When the temperature of water is decreased, pH of water will increase.
 - D When the temperature of water is increased, a pH of 7 is considered acidic.
- 19 Which of the following statements about Period 3 elements and their oxides is **incorrect**?
- A The covalent character of Period 3 oxides increase across the period.
 - B The melting points of Period 3 elements decrease across the period.
 - C The resultant pH of the oxides in water decrease across the period.
 - D The maximum oxidation state of Period 3 elements increases across the period.
- 20 Which of the following elements has a giant lattice structure with its chloride readily undergoing hydrolysis?
- A Mg B Na C Si D S

[Turn over

Q21 and 22 will make reference to the structure of sulfonamide and its synthesis.

- 21 Sulfonamides are one of the earliest antimicrobial drugs developed in the laboratory. Below shows its synthesis from nitrobenzene.



Which of the following types of reactions were involved in the above synthesis?

- 1 Addition
- 2 Condensation
- 3 Hydrolysis
- 4 Reduction

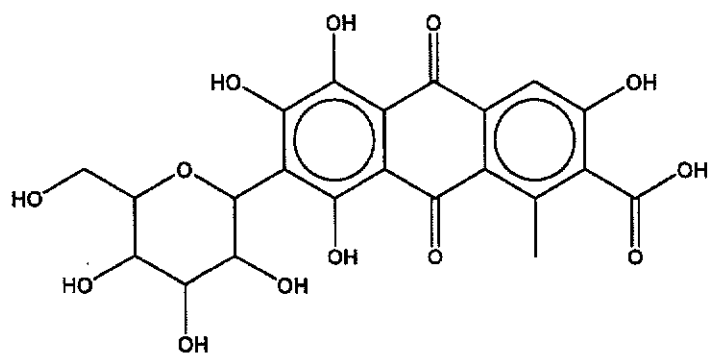
- A 1 and 2 only
 B 3 and 4 only
 C 1, 2 and 3 only
 D 2, 3 and 4 only

- 22 Which of the following bond angle is **not** seen in sulfonamide?

- A 105°
 B 107°
 C 109.5°
 D 120°

[Turn over

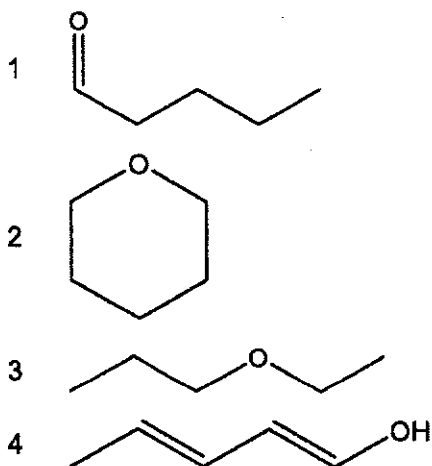
- 23 The classic red colour from many lipsticks are obtained from pigments and dyes such as Carmine Red, whose structure is given below.



Carmine Red

Which of the following functional groups is **not** found in Carmine Red?

- A Carboxylic Acids
 - B Ester
 - C Ketone
 - D Primary alcohol
- 24 Which of the following molecules are constitutional (structural) isomers?



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

[Turn over

- 25 Compound T is an alkene with an M_r of 94. When it reacts with hydrogen, the product has an M_r of 100.

What is the maximum number of cis-trans isomers possible for compound T?

- A 2 B 4 C 6 D 8

- 26 Alkanes can undergo free radical substitution with limited liquid bromine to produce mono-substituted bromoalkanes.

Which row gives the correct number of possible mono-substituted bromoalkanes and their ratio when 2,4-dimethylpentane reacts with limited bromine?

	No. of possible mono-substituted bromoalkanes	Ratio between the products
A	3	1:1:6
B	3	2:3:3
C	4	1:1:6:6
D	4	1:2:3:3

- 27 Equal amounts of 3 halogenoalkanes were treated with ethanolic silver nitrate and the time taken for a precipitate (ppt) to appear are recorded in the table below.

Alkylhalide	Time taken for ppt to appear
Bromoethane	3 minutes
Chloroethane	5 minutes
Iodoethane	Almost immediately

Which of the following statements best explains this observation?

- A Iodoethane contains the most number of electrons.
 B Chlorine is the most electronegative atom.
 C The bond between carbon and iodine is the weakest.
 D The bond between chlorine atoms is the strongest.

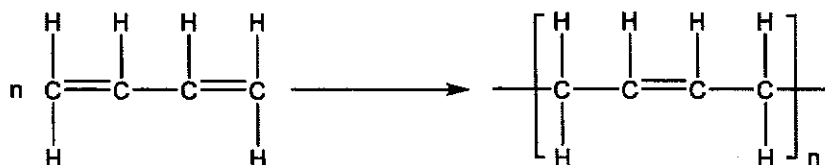
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28 Which of the following statements correctly describe the difference between low density poly(ethane) (LDPE) and high density poly(ethane) (HDPE)?

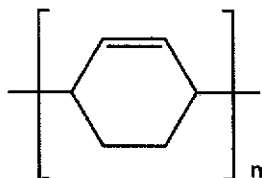
- 1 The average polymer chain for HDPE is shorter than LDPE.
- 2 LDPE chains are branched while HDPE chains are linear.
- 3 LDPE has a lower flexibility than HDPE.

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

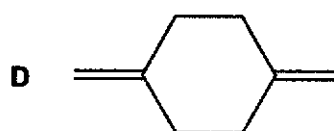
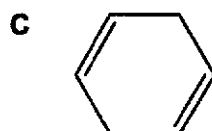
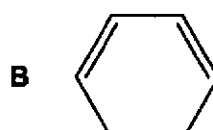
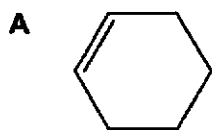
29 1,3-butadiene can undergo addition polymerisation according to the following equation.



An addition polymer, X, has the following structure.

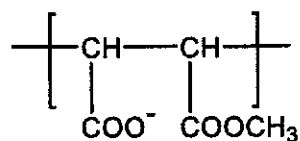


Using the information given above, which of the following is the monomer of polymer X?



[Turn over

30 Polymer Z has the following repeat unit.



Which of the following statements about this polymer is correct?

- A It is formed from 2 monomers.
- B It is a condensation polymer.
- C It is a water soluble polymer.
- D The structure of the monomer contains only 1 π bond.

-END OF PAPER-

Name: _____

Class: _____

ST ANDREW'S JUNIOR COLLEGE**JC2 Preliminary Examinations****Chemistry****8873/02****Higher 1****2 September 2020****Paper 2 Structured Questions****0800 – 1000**

Additional Materials: Data Booklet

2 Hours**READ THESE INSTRUCTIONS FIRST**

Write your name and civics group on all the work you hand in.

Write in dark blue or black pen.

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

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

Section A [60 marks]Answer **all** the questions.**Section B [20 marks]**Answer **one** question.

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

At the end of the examination, fasten all your work securely together.

You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [] at the end of each question or part question.

For Examiners' use only:

Section A			
Question 1	10	Question 2	14
Question 3	18	Question 4	10
Question 5	8		
Section B			
Question 6 / 7	20		
TOTAL			80

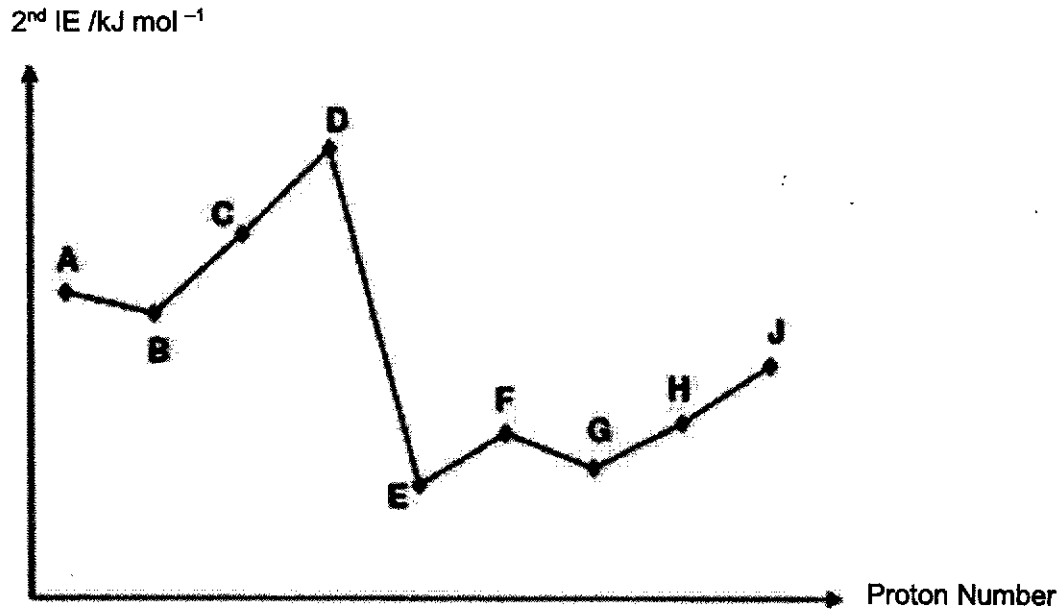
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Section A

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

- 1 The second ionisation energies of nine consecutive elements A to J in Periods 2 and 3 of the Periodic Table are as shown.



- (a) (i) A and J are in the same group. Explain why the second ionisation energy of J is lower than that of A. [1]

.....

- (ii) Explain why element A is in Group 16. [1]

.....

- (iii) Explain the dip in second ionisation energy from A to B. [2]

.....

1 (b) The oxide of **G** is insoluble in water while its chloride reacts completely with aqueous sodium hydroxide to give a resulting mixture which is neutral.

(i) Write 2 equations to justify the formation of the resulting neutral mixture. [2]

.....
.....

There is another element which forms an insoluble oxide.

(ii) Identify this element. [1]

.....

(iii) State the nature of the oxide of the element in (b)(ii) and that of **G**. [1]

Oxide of element in (b)(ii):

Oxide of **G**:

(iv) There are two unlabelled samples of white solids which could either be a sample of the oxide of the element in (b)(ii) or the oxide of **G**. Describe the reactions you could carry out on the solids to determine its identity. In your answers, include the reagents used for each test and describe the observations. [2]

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[Total: 10]

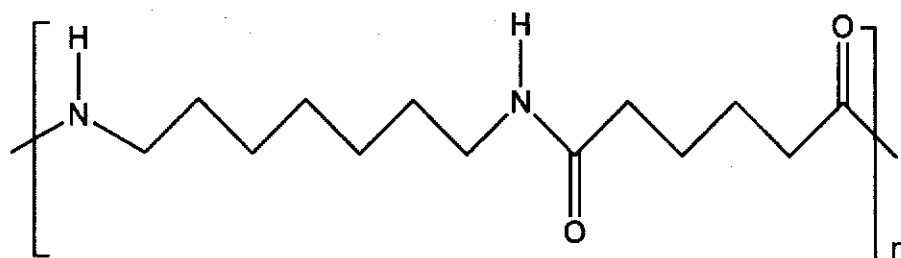
[Turn over

- 2 Synthetics polymers are macromolecules which have many uses. They are made from monomers which combine together in polymerisation reactions.

In a chemical reaction, if **all** of the product molecules are useful, then the reactant molecules is said to have a 100% *atom economy* where there is no waste to dispose of and so no pollution from the products. If one or more of the product molecules are not useful, the *atom economy* is less than 100% where there is waste to dispose of and the process is polluting. Reactions with 100% atom economy are less wasteful of resources.

Polymers can be designed to have specific properties so that they can be used for specific purposes.

Polyamides, **PA** are polymers which are often used in packaging materials. An example of **PA** has the following structure.



PA

- (a) (i) Draw the structural formulae of the two monomers used to make **PA**. [2]

- (ii) State the type of polymerisation for **PA**. [1]

.....

- (iii) State the reagents and conditions other than the two monomers needed for the above reaction to make **PA**. [1]

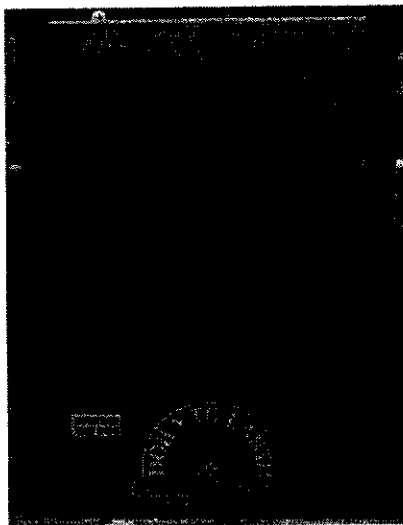
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[Turn over

- 2 (a) (iv) Suggest whether or not the atom economy of the production of PA is 100%.
Explain your answer. [1]

.....

(v)



It was suggested to use PA as a material for the packaging of the above mentioned fertilizer. Explain if it is suitable for PA to be used. [2]

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[Turn over

- 2 (a) (vi) Predict whether **PA** is a thermosetting or a thermoplastic polymer. Explain your answer with the aid of a suitable diagram, and your knowledge of the structure and bonding in polymers. [3]

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[Turn over

- 2 (b) When choosing a polymer for a specific use, the properties of the polymer must be considered carefully.

The table below shows properties of 4 polymers labelled A to D.

polymer	melting point/ $^{\circ}\text{C}$	chemical reactivity	strength	rigidity
A	200	low	medium	medium
B	500	high	medium	high
C	1000	low	high	low
D	Decompose upon heating	high	high	high

State which polymer would be the most suitable for making a bullet-proof vest that can withstand a bomb blast in a chemical warfare.

Explain your choice by considering each of the 4 properties listed in the table above. **[4]**

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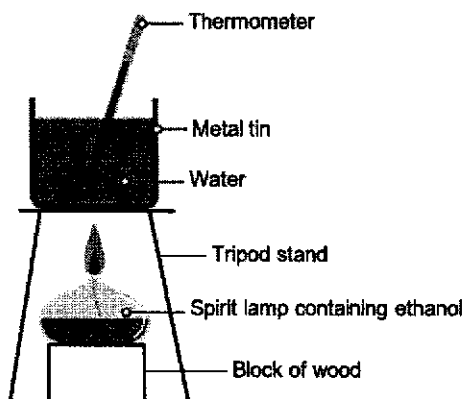
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[Total: 14]

[Turn over

3 Use of Data Booklet is relevant to this question.

Ethanol, C_2H_5OH , is an important industrial chemical and is used as a solvent and a fuel. A student used the apparatus shown below to find the enthalpy change of combustion of ethanol, $\Delta H_c(\text{ethanol})$.



The measurements recorded by the student are shown in Table 3.1.

Mass of water /g	Initial temperature of water / °C	Final temperature of water /°C	Initial mass of spirit burner and ethanol /g	Final mass of spirit burner and ethanol /g
200	27.6	59.5	113.25	112.22

Table 3.1

- (a) (i) Define, with the aid of an equation, the term *standard enthalpy change of combustion* of ethanol. [2]

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[Turn over

- 3 (a) (ii) Using the data from **Table 3.1**, calculate a value for the enthalpy change of combustion of ethanol, $\Delta H_c(\text{ethanol})$. Hence, calculate the efficiency of the heating process given that the theoretical value of the standard enthalpy change of combustion of ethanol is $-1367 \text{ kJ mol}^{-1}$. **[3]**

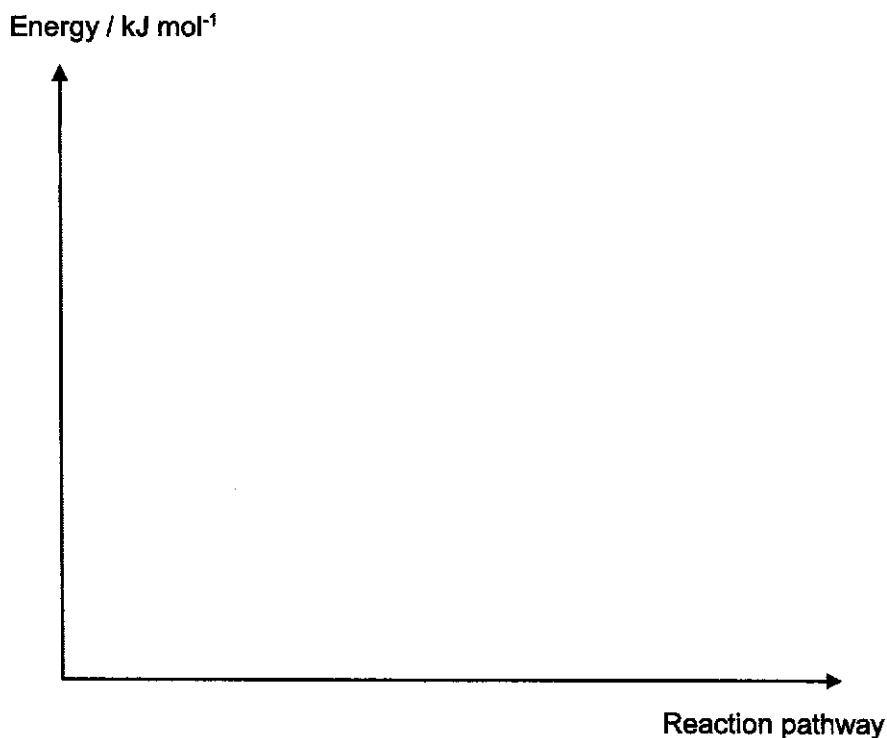
- (iii) Use the bond energies given in the *Data Booklet* to calculate another value for the standard enthalpy change of combustion of ethanol. **[2]**

- (iv) Suggest an explanation for the difference between the theoretical value and your value in (a)(iii). **[1]**

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.....

[Turn over

- 3 (a) (v) Given that the activation energy is 335 kJ mol^{-1} , sketch a clearly labelled reaction pathway diagram for the combustion reaction of ethanol using the theoretical value of the enthalpy change of combustion of ethanol from (a)(ii). [2]



- (b) Ethanol can be oxidised using hot acidified potassium dichromate(VI).
- (i) Draw the displayed formula of the organic product formed and give the IUPAC name. [2]

IUPAC Name:

- (ii) Write a balanced equation for the oxidation of ethanol using [O] to represent the oxidising agent. State the colour change observed. [2]

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- 3 (b) (iii) Other than using oxidising agents, suggest a simple chemical test to distinguish ethanol from the organic product obtained in (b)(i). [2]

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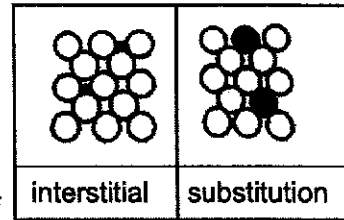
- (iv) Infrared spectroscopy can be used to identify molecules by their different functional groups. Ethanol and the product in (b)(i) have different infrared absorption spectra. With reference to the *Data Booklet*, state two differences in the infra-red absorption spectra of ethanol and the product in (b)(i). [2]

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[Total: 18]

[Turn over

- 4 Steel is an *interstitial* alloy, as carbon atoms fit in between iron atoms in the lattice. Brass is a *substitution* alloy, as zinc atoms replace the copper atoms in the lattice. Stainless steel is a combination of interstitial and substitution alloys, because carbon atoms fit in between the lattice, but some of the iron atoms are replaced with nickel atoms.



The alloy's structure will determine properties such as *hardness*, which measures the material's resistance to permanent shape change when a force is applied. These properties rely on how much electrostatic attraction is present between ions and electrons in any given volume of the lattice.

$$\text{Lattice Strength} \propto \frac{q^+}{r}$$

- (a) The ionic radius and ionic charge of the following element are given in the following table.

Element	C	V	Cr	Fe	Ni	Cu	Zn	W
ionic radius (10^{-12} m)	16	64	62	64	60	73	74	66
ionic charge	+4	+3	+3	+3	+3	+2	+2	+4

- (i) Adding a small amount of which **metallic** element is likely to increase the lattice strength of iron most? Give a reason for your answer. [1]

.....

- (ii) From the table above, suggest another element, other than nickel, that can be added to iron to form a substitution alloy. [1]

.....

- (iii) An aqueous solution of Fe^{3+} is known to be acidic due to its high charge density, similar to Al^{3+} . Write an equation to justify the acidity of an aqueous solution of Fe^{3+} . [1]

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[Turn over

- 4 (b) (i) With the aid of a labelled diagram, describe the structure and bonding in iron. [2]

.....
.....

- (ii) Metals are malleable because they can be hammered or pressed into shapes without breaking the metallic bond. The hardness of iron is enhanced when carbon atoms are added to iron atoms in the lattice. With reference to your answer in (b)(i), explain how adding carbon atoms enhance the hardness of iron in steel. [1]

.....
.....

- (c) Cations of some of the metals such as Fe and Cr can act as catalysts for specific reactions.

- (i) Define the term, catalyst. [1]

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.....

[Turn over

- 4 (c) (ii) With the aid of a suitable diagram, explain how catalysts increase the rate of reactions. [3]

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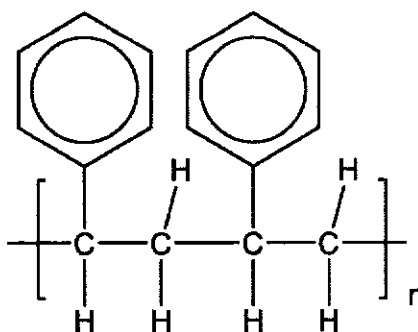
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[Total: 10]

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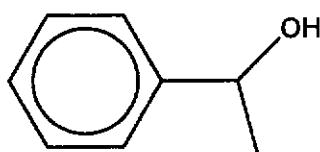
- 5 (a) Polystyrene (PS) is a type of polymer used to make foam box for food packaging and has the following structure.



- (i) Draw the skeletal formula of the monomer and state its IUPAC name. [2]

IUPAC Name:

- (ii) State the reagents and conditions on how the monomer can be synthesized from 1-phenylethanol. Write a balanced equation for the reaction.



1-phenylethanol

[2]

Reagent and condition:

Balanced Equation:

.....

[Turn over

- 5 (a) (iii) The progress of the reaction can be monitored by following the concentration of 1-phenylethanol. Describe how the completion of this reaction can be confirmed by means of a simple chemical test. [2]

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- (b) Suggest an advantage and disadvantage of using polystyrene as a food packaging. [2]

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[Total: 8]

[Turn over

Section B

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

- 6 Phosgene is a toxic gas prepared by the reaction of carbon monoxide with chlorine.



- (a) (i) Write the K_c expression for the preparation of phosgene. [1]

.....

- (ii) If the equilibrium concentration of chlorine and phosgene are the same at 300°C , calculate the equilibrium concentration of carbon monoxide in the reaction. [1]

- (iii) Given that the enthalpy change of the above reaction is exothermic, deduce how the K_c will change when temperature increases. [2]

.....

.....

.....

[Turn over

- 6 (b) The reaction between carbon monoxide and chlorine in the preparation of phosgene is studied at constant temperature.

The initial concentration and rate data obtained for each experiment is given in **Table 6.1**.

Experiment	Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	Initial [CO] / mol dm^{-3}	Initial [Cl ₂] / mol dm^{-3}
1	1.29×10^{-29}	1.00	0.10
2	1.33×10^{-30}	0.10	0.10
3	1.30×10^{-29}	0.10	1.00
4	1.32×10^{-31}	0.10	0.01

Table 6.1

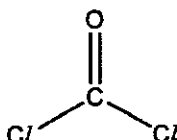
- (i) Determine the order of reaction with respect to each reactant and hence deduce the rate equation for this reaction. Use data from **Table 6.1** to explain your answers. [3]

- (ii) Using experiment 1, calculate the value of the rate constant, stating its units. [2]

[Turn over

- 6 (b) (iii) Using your answer in (b)(i), sketch a graph of 1 mol dm^{-3} carbon monoxide against time when chlorine is in excess. [2]

- (c) The structure of phosgene is as shown below.



Draw labelled diagrams to show how orbitals overlap to form a sigma (σ) bond and a pi (π) bond in the C=O bond. [2]

[Turn over

- 6 (d) Table 6.2 shows the electronegativity values of the atoms in phosgene.

Atom	Electronegativity / Pauling units
C	2.5
Cl	3.0
O	3.5

Table 6.2

Predict all possible intermolecular forces which could exist between phosgene molecules. Explain how these forces arise. [3]

.....

.....

.....

.....

.....

.....

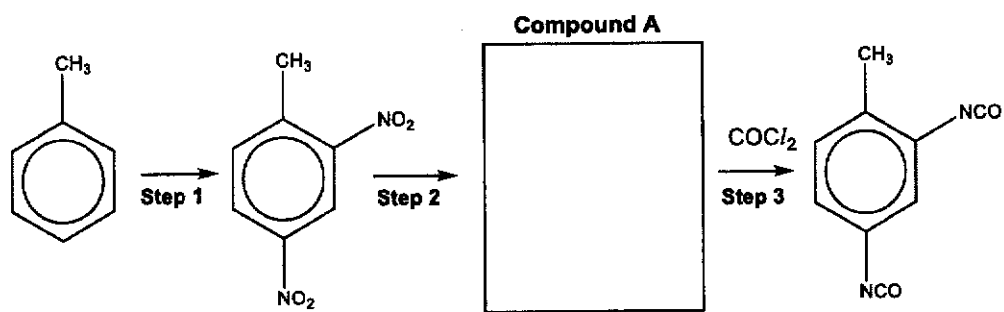
- (e) Phosgene reacts with methylamine to form methyl isocyanate.



Draw the dot-and-cross diagram of methyl isocyanate given that it has two double bonds. [1]

[Turn over

- 6 (f) 2,4-diisocyanato-1-methylbenzene is used to make polyurethane foams. It can be made in the following three-step process.



- (i) Using the information in (e), suggest the structural formula of A. [1]

- (ii) Step 2 is a reduction reaction. Write an equation for Step 2 using [H] to represent the reducing agent. [1]

- (iii) State the type of reaction in Step 1. [1]

[Total: 20]

[Turn over

7 Fumaric acid is an organic compound with the formula $\text{HO}_2\text{CCH}=\text{CHCO}_2\text{H}$. A white solid, fumaric acid occurs widely in nature.

(a) (i) Write the IUPAC name of the compound formed when fumaric acid is reacted with hydrogen gas in the presence of nickel catalyst. [1]

.....

(ii) Draw skeletal diagrams to show cis-trans isomerism in fumaric acid and explain how this isomerism arises. [2]

.....

.....

(iii) Define the term constitutional isomer and draw the structural formula of a constitutional isomer of fumaric acid that does not contain a carboxylic acid functional group. [2]

.....

.....

(b) Fumaric acid is a weak acid that dissociates in water to form a mono-anion, hydrogen fumarate, $\text{HO}_2\text{CCH}=\text{CHCO}_2^-$.

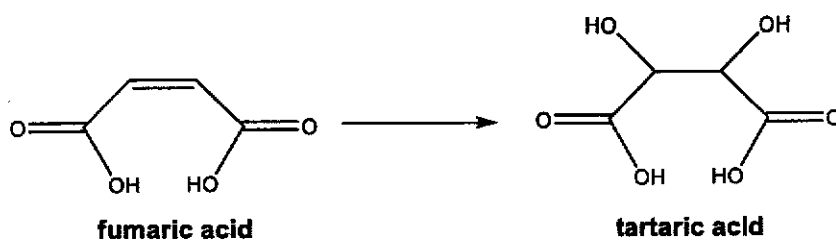
(i) Write an equation for the equilibrium between fumaric acid and water. Label the conjugate acid and conjugate base in your equation. [2]

.....

.....

[Turn over

- 7 (b) (ii) Fumaric acid is reacted with cold acidified potassium manganate to form tartaric acid.



0.20 mol dm⁻³ of fumaric acid has a pH of 5.0 whilst 0.060 mol dm⁻³ of tartaric acid has a pH of 5.5. With the aid of relevant calculations, predict if tartaric acid or fumaric acid is a weaker acid. [2]

- (iii) With the aid of a suitable diagram, explain how sodium hydrogen fumarate is soluble in water. [2]

.....

.....

[Turn over

7 (c) Fumaric acid ($M_r = 116$) has been used as a food additive since 1946 in the EU, USA, Australia and New Zealand. As a food additive, it is used as a pH regulator and can be denoted by the E number, E297. It is generally used in beverages and baking powders.

(i) An equimolar mixture of fumaric acid and hydrogen fumarate ion is an acidic buffer. Write an equation to show how the buffer regulates the pH on the addition of H^+ ions. [1]

.....
(ii) The ingredient label of a brand of baking powder has been found to contain E297.

A 1g sample of baking powder is dissolved in 15 cm³ of excess 0.0535 mol dm⁻³ sodium hydroxide. The impurities in the baking powder are insoluble and do not react with sodium hydroxide. The solution is filtered into a 250 cm³ graduated flask. Deionised water is added so that the total volume of the solution is 250 cm³. This is solution Z. 10 cm³ of solution Z required 15.60 cm³ of 0.001 mol dm⁻³ sulfuric acid for complete neutralisation.

Calculate the percentage by mass of E297 in the sample of baking powder.

[3]

[Turn over

- 7 (d) Predict and explain whether magnesium hydrogen fumarate or sodium hydrogen fumarate has a higher melting point. [2]
-
-
-

- (e) Fumaric acid undergoes complete combustion to form carbon dioxide gas and water.

- (i) Define the term *standard enthalpy change of formation* of fumaric acid with the aid of a balanced chemical equation. [1]
-

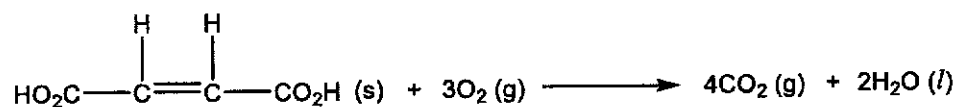
- (ii) Relevant values of ΔH_f^\ominus are given in Table 7.1.

Compound	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
Fumaric acid	- 811
Carbon dioxide	- 394
Water	- 286

Table 7.1

Using relevant values from Table 7.1, calculate the standard enthalpy change of combustion of fumaric acid. [2]

Equation for the combustion of fumaric acid:



[Total: 20]

-END OF PAPER-

NAME		Class	
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ST ANDREW'S JUNIOR COLLEGE



JC2 Preliminary Examination [Worked Solutions]

H1 Chemistry (8873/01)

18 Sep 2020

Paper 1 Multiple Choice

1 hour

Additional Materials: Multiple Choice Answer Sheet, Data Booklet

READ THESE INSTRUCTIONS:

Write in soft pencil.

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

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.

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 **5** printed pages (including this page).

Answers:

1	D	7	C	13	B	19	B	25	D
2	D	8	A	14	B	20	C	26	A
3	C	9	B	15	A	21	D	27	C
4	C	10	D	16	A	22	A	28	B
5	B	11	C	17	D	23	B	29	B
6	C	12	D	18	C	24	A	30	C

1 Use of Data Booklet is relevant to this question

Hydrogen polyoxides are chemical compounds that consist only of hydrogen and oxygen atoms, bonded exclusively by single bonds.

One such hydrogen polyoxide contains 97.56% by mass of oxygen.

What could be the identity of this hydrogen polyoxide?

- A H_2O_2 B H_2O_3 C H_2O_4 D H_2O_5

Ans: D

Since the compound only contain hydrogen and oxygen, the % by mass of hydrogen = $100 - 97.56 = 2.44\%$

H : O

2.44 : 97.56 (%)

2.44 : 6.0975 (divide by Ar)

1 : 2.5 (divide by smallest number)

2 : 5

2 Use of Data Booklet is relevant to this question

A 5g sample of a diatomic gas was found to contain 3.76×10^{22} atoms.

What is the relative molecular mass of this gas?

- A 40 B 80 C 120 D 160

Ans: D

Since the gas is diatomic, the number of molecules of this gas in the 5 g sample

= $(3.76 \times 10^{22}) / 2 = 1.88 \times 10^{22}$

Therefore, the number of moles of this gas = $(1.88 \times 10^{22}) / (6.02 \times 10^{23}) = 0.03125$

Thus, Mr of the gas = $5 / (0.03125) = 160$

3 Carbon disulfide vapour burns in oxygen according to the following equation.



A sample of 10 cm³ of carbon disulfide was burned in 50 cm³ of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again. All measurements were made at the same temperature and pressure in which carbon disulfide was gaseous.

What were the measured volumes?

	volume of gas after burning / cm ³	volume of gas after adding NaOH(aq) / cm ³
A	30	0
B	30	10
C	40	30
D	40	30

Ans: C

Volume of gas before burning = 60 cm³

Volume of gas used = 10 + 30 = 40 cm³

Volume of gas produced after burning = 30 cm³

Volume of gas remaining = 60 - 40 + 30 = 50 cm³

CO₂ and SO₂ are both acidic gases hence both will react with aq NaOH.

Hence vol of gas after adding aq NaOH = 50 - 30 = 20 cm³

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

Two moles of an oxidising agent, WO_3^{2-} , in the presence of excess acid oxidised 68.1 dm³ of sulfur dioxide gas at standard temperature and pressure to SO_4^{2-} .

What is the number of moles of electrons accepted by one mole of WO_3^{2-} ?

- A 1 B 2 C 3 D 4

Ans: C

$n(SO_2) = 68.1 / 22.7 = 3$

$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$

$WO_3^{2-} = SO_2$

2 : 3

3 mol of SO_2 donate 6 mol of electrons which is accepted by 2 mol of WO_3^{2-}

Hence 1 mol of WO_3^{2-} accepts 3 mol of electrons

- Ans: C
 Element J is H and its in period 1 Group 18
 Element L is in period 2 Group 17
 Element M is in period 3 Group 2
 Element Q is in period 3 Group 17

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

Which of the following species has the same number of unpaired electrons as Cu in CuI?

- A Na
 B Mn²⁺
 C Cr³⁺
 D V⁵⁺

Ans: C

Cu in CuI is Cu⁺. Thus, its electronic configuration is [Ar] 3d¹⁰ (from [Ar] 3d¹⁰4s¹). Thus is has no unpaired electrons.

Electronic configuration of Cr³⁺ is [Ne]3s² with no unpaired electrons. Na would be [Ne]3s¹ with 1 unpaired electron; V³⁺ [Ar]3d² with 2 unpaired electrons; Mn²⁺ [Ar]3d⁵ with 5 unpaired electrons.

8 Which of the following species contain a co-ordinate bond?

- 1 AlCl₄⁻
 2 CO
 3 NO₂⁺
 4 SO₄²⁻

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

Ans: A

Option 1 has a dative bond from Cl to Al while option 2 has a dative bond from O to C. The rest have no dative bond present.

5 G³⁺ has a relative atomic mass of 75 and contains 45 electrons.

Which of the following is an isotope of G?

	Number of protons	Number of electrons	Number of neutrons
A	42	42	33
B	42	42	34
C	48	48	27
D	48	48	30

Ans: B

For element G, number of electrons it has = 45 - 3 = 42

Hence, it would also have 42 protons.

Given that isotopes have the same number of protons and electrons, the answer is either A or B

No of neutrons in the species mentioned in the question = 75 - 42 = 33

Hence the number of neutrons in the isotope must differ from 33, hence 35.

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

The valence electronic configuration of 4 elements, J, L, M and Q are listed below.

Element	Valence Electronic Configuration
J	1s ²
L	2s ² 2p ⁵
M	3s ²
Q	3s ² 3p ⁵

Which of the following statements about these elements are true?

- 1 Element J and M are in the same group but different period.
 2 Element L and Q are in the same group but different period.
 3 Element M and Q are in different group but the same period.
 4 Element J and L are in different group but the same period.

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

9 Which of the following molecules are planar?

- 1 BCl_3
- 2 ICl_4^-
- 3 H_3O^+

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

Ans: B

Option 1 is 3bp, 0lp so trigonal planar; Option 2 is 4bp, 2 lp so square planar and Option 3 is 3bp, 1lp so its trigonal pyramidal. Hence only Option 1 and 2 are planar

10 Which of the following gases requires the least amount of pressure to liquefy?

- A CO_2
- B CH_3CH_3
- C CH_3CH_2F
- D CH_3CH_2OH

Ans: D

When liquefying gas, the one with the strongest intermolecular force would require the least amount of pressure. A and B have 1d-1d, C has pd-pd while D has H-bond. H bond being the strongest among the 4 will allow D to require the least amount of pressure to liquefy.

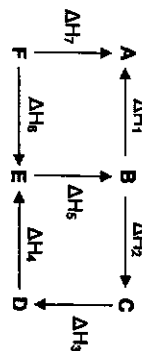
11 Which of the following equations represents the lattice energy of MgO ?

- A $Mg(s) + \frac{1}{2} O_2(g) \longrightarrow MgO(s)$
- B $Mg^{2+}(g) + \frac{1}{2} O_2^{2-}(g) \longrightarrow MgO(g)$
- C $Mg^{2+}(g) + O^{2-}(g) \longrightarrow MgO(g)$
- D $2Mg^{2+}(g) + O_2^{2-}(g) \longrightarrow 2 MgO(s)$

Ans: C

By definition, lattice energy is the energy evolved when one mole of the solid ionic compound is formed from its gaseous ions at 298K and 1 bar.

12 Consider the following energy cycle.



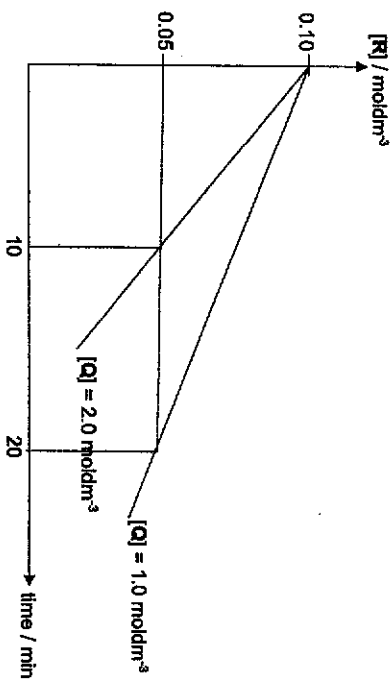
Which of the following is the ΔH of A to D?

- A $\Delta H_1 + \Delta H_2 + \Delta H_3$
- B $\Delta H_1 + \Delta H_4 + \Delta H_5$
- C $\Delta H_3 - \Delta H_2 - \Delta H_1$
- D $\Delta H_3 - \Delta H_2 - \Delta H_1$

Ans: D

There are many ways to get from A to D. Its either $-\Delta H_1 + \Delta H_2 + \Delta H_3$ OR $-\Delta H_1 - \Delta H_5 - \Delta H_4$ OR $-\Delta H_7 + \Delta H_6 + \Delta H_5 + \Delta H_3$ OR $-\Delta H_7 + \Delta H_6 - \Delta H_4$ which when rearranged is option D.

13 To monitor the kinetics of a reaction between Q and R, two experiments were conducted to monitor the concentration of R over time with different concentrations of Q. The graph below shows the results obtained.



Based on the graph above, which of the following is the rate equation of the reaction between Q and R?

- A rate = k
- B rate = k [Q]
- C rate = k [R]
- D rate = k [Q][R]

Option 3 is also wrong as only temperature can cause a change in the value of K_c .
 Option 4 is correct as catalyst will increase the rate of the forward and backward reaction but not the value of K_c . [MA]

16 Boric acid, $B(OH)_3$, is often used as an antiseptic and as a precursor to other chemical compounds. The following equilibrium illustrates the acidity of boric acid.



Which of the following statements about the above equilibrium are incorrect?

- 1 Boric acid accepted a lone pair of electrons from OH^- .
- 2 Boric acid is a weak monobasic acid.
- 3 Boric acid is a Brønsted-Lowry acid.
- 4 Boric acid is an Arrhenius acid.

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

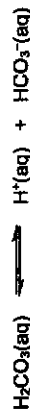
Ans: A

Option 1 is correct: Boric acid accepts a lone pair from OH^- to form $B(OH)_4^-$
 Option 2 is correct: Monobasic acid as each mole of $B(OH)_3$ forms 1 mole of H_3O^+ and dissociates partially.

Option 3 is incorrect: Not a Brønsted-Lowry acid: H^+ donor; $B(OH)_3$ accepts a OH^- and does not donate H^+

Option 4 is correct: Arrhenius acid: Produces $H^+(aq)$ in water

Human plasma is buffered mainly by dissolved CO_2 which has reacted to form carbonic acid, H_2CO_3 .



Given that the ratio of $[HCO_3^-]$ to $[H_2CO_3]$ in human plasma is 20 : 1 and the acid dissociation constant, K_a , of carbonic acid is $8 \times 10^{-7} \text{ mol dm}^{-3}$, which of the following statements is incorrect?

- A The pH of human plasma is 7.4.
- B The concentration of H_2CO_3 will decrease while the concentration of HCO_3^- will increase when a small amount base is added to human plasma.
- C This buffer is more efficient in removing acid than base.

D

Ans: B

The graph given is one of conc of R against time. Hence, the gradient of each graph will give the rate of the reaction. Given that it's a straight line, gradient is constant which mean rate is constant when conc of R is changing. Hence order of reaction w.r.t. R is 0
 When conc of Q was doubled from 1 to 2 mol dm^{-3} , initial rate, which is the grad of the graph, doubled from $[(0.1-0.05)/(0-20) = 0.0025]$ to $[(0.1-0.05)/(0-10) = 0.005]$. Hence order of reaction w.r.t. Q is 1

Q14 and 15 will make reference to the reversible reaction between X and Y to produce Z

14 Given that the K_c for the following equilibrium is 9,



What is the mole ratio of Y : Z at equilibrium?

- A 1 : 1 B C 3 : 1 D 9 : 1

Ans: B

$$K_c = \frac{[Z]^2}{[Y]^2} = 9$$

$$\frac{[Z]}{[Y]} = 3$$

$$[Y] : [Z] \text{ is } 1 : 3$$

15 When the same reaction between X and Y was repeated at a higher temperature, the K_c value was found to be 12.

Which of the following statements about this equilibrium are correct?

- 1 The production of Z is an endothermic process.
- 2 When the pressure of reaction is reduced, more Y is produced.
- 3 Adding more Z after equilibrium has been established will lead to a decrease in the K_c value.
- 4 Adding a catalyst to the equilibrium will speed up the rate of the forward and backward reaction but the value of K_c remains unchanged.

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

Ans: A

Option 1 is correct. When temperature increase, value of K_c increased. This implied that the forward reaction was favoured to produce more Z when temperature increase.

Hence, forward reaction is endothermic in order to absorb the excess heat.

Option 2 is wrong as both sides have the same no. of moles of gas. Hence an increase in pressure will not shift the position of equilibrium.

Ans: D

A is correct: $K_a = [\text{HCO}_3^-][\text{H}^+]/[\text{H}_2\text{CO}_3] = (20)[\text{H}^+]/(1)$

Thus $[\text{H}^+] = K_a/20 = 4 \times 10^{-8}$, $\text{pH} = -\lg(4 \times 10^{-8}) = 7.39 \approx 7.4$

B is correct: When OH^- is added to the buffer, H_2CO_3 will react with it and produce HCO_3^- . Hence $[\text{HCO}_3^-]$ will increase while $[\text{H}_2\text{CO}_3]$ will decrease.

C is correct: Given the ratio of $[\text{HCO}_3^-] : [\text{H}_2\text{CO}_3]$ is 20:1, there are more HCO_3^- present to remove H^+ .

D is incorrect: The proposed mixture would produce a buffer of CO_3^{2-} and HCO_3^- .

Hence, This buffer system can be prepared by mixing suitable amounts of carbonic acid and sodium hydroxide OR sodium hydrogencarbonate and hydrochloric acid

- 18 The dissociation of water is an endothermic process and has the following equation.



$K_w = [\text{H}^+][\text{OH}^-]$ and it represents the ionic product of water.

Which if the following statements is correct?

- A Water is not neutral when temperature of water is increased.
 B The pH of water is 7 at all temperatures.
 C ~~When the temperature of water is increased, the pH of water increases.~~
 D When the temperature of water is increased, a pH of 7 is considered acidic.

Ans: C

Option A is wrong as at all temperatures, $[\text{H}^+] = [\text{OH}^-]$ which makes water neutral at all temperatures.

When the temperature of water increases, position of equilibrium will shift to the right given the dissociation of water is endothermic. Hence, $[\text{H}^+]$ will increase. With that, pH is expected to fall and hence option B is wrong.

Due to the same reason, the neutral pH of water will fall below 7 when temperature is increased and hence a pH of 7 is seen as basic and not acidic, making option D wrong. When temperature falls, the reverse will happen and $[\text{H}^+]$ in the solution will decrease causing pH to increase. Hence option C is correct.

- 19 Which of the following statements about Period 3 elements and their oxides is incorrect?
 A The covalent character of Period 3 oxides increase across the period.
 B ~~The maximum oxidation state of Period 3 elements increases across the period.~~
 C The resultant pH of the oxides in water decrease across the period.
 D The maximum oxidation state of Period 3 elements increases across the period.

Ans: B

Option A is true as Period 3 oxides change from ionic to covalent with covalent character to covalent across the period.

Option B is false as there is an increase in melting point from Na to Si before decreasing.

Option C is true as the pH of the oxides in water changes from basic to acidic.

Option D is true as the oxidation state of the cation changes from +1 to +6 for oxides.

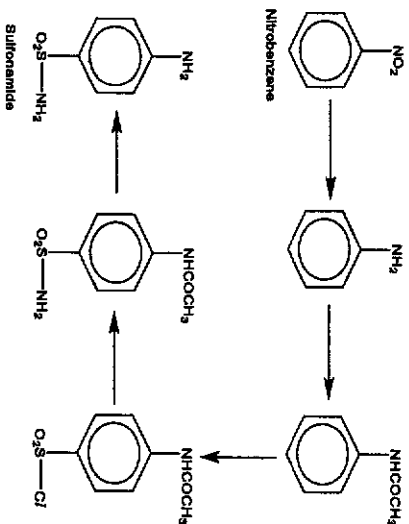
- 20 Which of the following elements has a giant lattice structure with its chloride readily undergoing hydrolysis?
 A Mg B Na ~~C Al~~ D S

Ans: C

Since the element has a giant lattice structure, it means its either a metal or a giant covalent molecule. This rules out option D.

Chloride of Na don't hydrolyse in water while that of Mg only partially hydrolyse in water. Chloride of Si however undergoes complete hydrolysis in water.

- Q21 and 22 will make reference to the structure of sulfonamide and its synthesis.
 21 Sulfonamides are one of the earliest antimicrobial drugs developed in the laboratory. Below shows its synthesis from nitrobenzene.

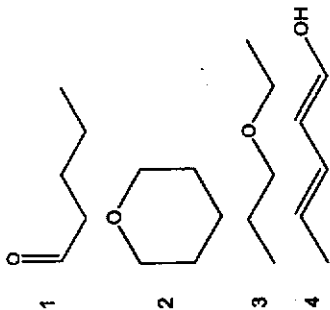


Which of the following types of reactions were involved in the above synthesis?

- 1 Addition
- 2 Condensation
- 3 Hydrolysis
- 4 Reduction

13

24 Which of the following molecules are constitutional (structural) isomers?



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

Ans: A

Constitutional isomers have the same molecular formula but different structural formula. Both option 1 and 2 have the molecular formula of C_4H_8O . Option 3 has a molecular formula of $C_4H_{10}O$ while option 4 has a molecular formula of C_4H_8O .

25 Compound T is an alkene with an M_r is 94. When it reacts with hydrogen, the product has an M_r of 100.

What is the maximum number of cis-trans isomers possible for compound T?

- A 2 B 4 C 6 D 8

Ans: D

When an alkene with 1 $C=C$ reacts with hydrogen, its M_r will increase by 2 (2 H atoms added). Hence, with an increase in M_r of 6, it means compound T has 3 $C=C$.

If all of them are able to exhibit cis-trans isomers, then the maximum no of cis-trans isomers possible for compound T = $2^3 = 8$

12

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

Ans: D

The types of reaction reflected above (in sequence) are reduction, condensation, substitution, substitution and hydrolysis.

22 Which of the following bond angle is not seen in sulfonamide?

A 109.5°

B 107°

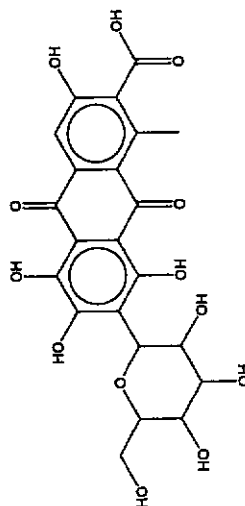
C 109.5°

D 120°

Ans: A

Bond angle around C in benzene is 120° . Bond angle around S is 109.5° . Bond angle around N is 107° .

23 The classic red colour from many lipsticks are obtained from pigments and dyes such as Carmine Red, whose structure is given below.



Carmine Red

Which of the following functional groups is not found in Carmine Red?

A Carboxylic Acids

B Ketone

C Ketone

D Primary alcohol

Ans: B

There is no ester functional group ($RCOOR'$) in the structure of Carmine Red.

26 Alkanes can undergo free radical substitution with limited liquid bromine to produce mono-substituted bromoalkanes.

Which row gives the correct number of possible mono-substituted bromoalkanes and their ratio when 2,4-dimethylpentane reacts with limited bromine?

	No. of possible mono-substituted bromoalkanes	Ratio between the products
A	3	1:1:1
B	3	2:3:3
C	4	1:1:6:6
D	4	1:2:3:3

Ans: A

For free radical substitution of 2,4-dimethylpentane, there are only 3 possible products as the molecule is symmetrical.

Equal amounts of 3 haloalkanes were treated with ethanolic silver nitrate and the time taken for a precipitate (ppt) to appear are recorded in the table below.

Alkylhalide	Time taken for ppt to appear
Bromoethane	3 minutes
Chloroethane	5 minutes
Iodoethane	Almost immediately

Which of the following statements best explains this observation?

- A Iodoethane contains the most number of electrons.
 B Chlorine is the most electronegative atom.
 C ~~Chlorine is the most electronegative atom.~~
 D The bond between chlorine atoms is the strongest.

Ans: C

The rate of the reaction between alkylhalides is dependant on the bond strength between carbon and the halogen. The weaker the bond, the faster the reaction and hence, the faster the ppt will appear.

28 Which of the following statements correctly describe the difference between low density poly(ethane) (LDPE) and high density poly(ethane) (HDPE)?

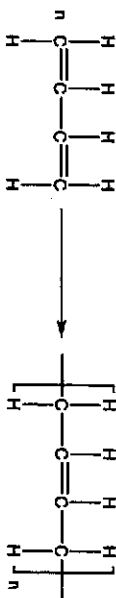
- The average polymer chain for HDPE is shorter than LDPE.
- LDPE chains are branched while HDPE chains are linear.
- LDPE has a lower flexibility than HDPE.

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

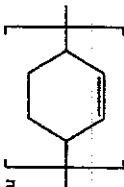
Ans: B

Only option 2 correctly points out the difference between LDPE and HDPE. HDPE has a longer average polymer chain than LDPE. HDPE is more rigid and stiff and hence less flexible than LDPE.

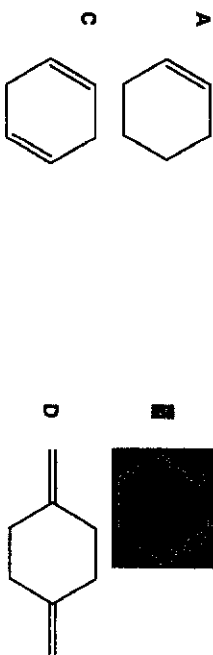
29 1,3-butadiene can undergo addition polymerisation according to the following equation.



An addition polymer, X, has the following structure.

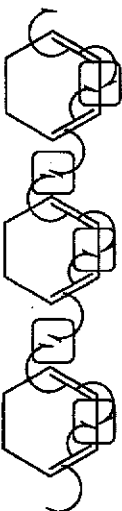


Using the information given above, which of the following is the monomer of polymer X?



Ans: B

How the polymer is formed



(Focusing on the middle monomer in red)

- One of the bond of the C=C will break and the 2 electrons that make up the bond will split and move in opposite directions as indicated by the arrows (each arrow represent one electron)
- Where the arrows meet (as indicated by the red square) is where a new bond is formed and the polymer below is formed

Name: _____ Class: _____

ST ANDREW'S JUNIOR COLLEGE



JC2 Preliminary Examinations [SOLUTIONS]

Chemistry 9873/02
 Higher 1 2 September 2020
 Paper 2 Structured Questions 0800 - 1000
 Additional Materials: Data Booklet 2 Hours

READ THESE INSTRUCTIONS FIRST

Write your name and civics group on all the work you hand in.

Write in dark blue or black pen.

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

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

Section A [60 marks]

Answer all the questions.

Section B [20 marks]

Answer one question.

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

At the end of the examination, fasten all your work securely together.

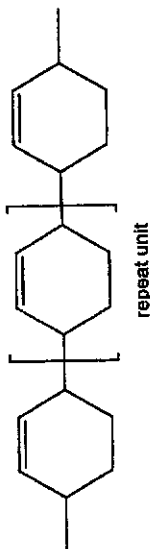
You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [] at the end of each question or part question.

For Examiners' use only:

Section A		
Question 1	10	Question 2
Question 3	18	Question 4
Question 5	8	
Section B		
Question 6 / 7	20	TOTAL
		80

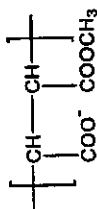
This document consists of 26 pages including a blank page.

16



The polymer above reflect what is formed with the new bonds seen in red with the red monomer in the middle showing how the repeat unit is derive as seen in the question.

30 Polymer Z has the following repeat unit.

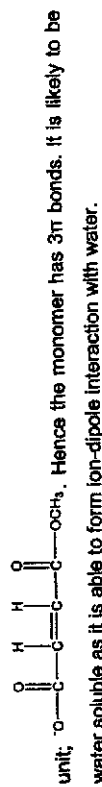


Which of the following statements about this polymer is correct?

- A It is formed from 2 monomers.
- B It is a condensation polymer.
- C It is a water soluble polymer.
- D The structure of the monomer contains only 1 π bond.

Ans: C

Based on the repeat unit, this polymer is an addition polymer with the following repeat



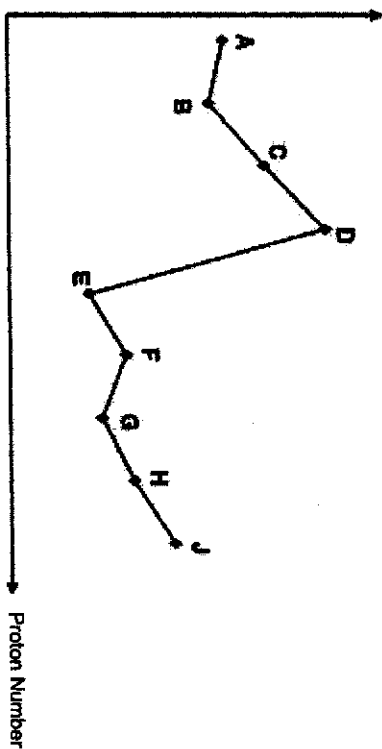
-END OF PAPER-

Section A

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

- 1 The second ionisation energies of nine consecutive elements A to J in Periods 2 and 3 of the Periodic Table are as shown.

2nd IE (kJ mol⁻¹)



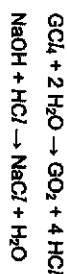
- (a) (i) A and J are in the same group. Explain why the second ionisation energy of J is lower than that of A.
 J has an extra quantum shell; the valence electrons are further away from nucleus and less strongly attracted and thus a lower I.E. [1]

- (ii) Explain why element A is in Group 16.
 Element D must be from Group 1 as it has the highest 2nd IE because the 2nd electron is removed from the inner quantum shell. Since A - D are consecutive elements, A must be in Group 16. [1]

- (iii) Explain the dip in second ionisation energy from A to B.
 The second ionisation of A involves the removal of the singly-occupied 2p electron while that in B involves the removal of a paired 2p electron. Paired p electron experiences inter-electronic repulsion and hence require lesser energy to remove it. [2]

- 1 (b) The oxide of G is insoluble in water while its chloride reacts completely with aqueous sodium hydroxide to give a resulting mixture which is neutral.

(i) Write 2 equations to justify the formation of the resulting neutral mixture. [2]



*Can represent G as Si

There is another element which forms an insoluble oxide.

(ii) Identify this element. [1]

F (symbol) or Al

(iii) State the nature of the oxide of the element in (b)(ii) and that of G. [1]

Oxide of element in (b)(ii): amphoteric

Oxide of G: acidic

(iv) There are two unlabelled samples of white solids which could either be a sample of the oxide of the element in (b)(ii) or the oxide of G. Describe the reactions you could carry out on the solids to determine its identity. In your answers, include the reagents used for each test and describe the observations. [2]

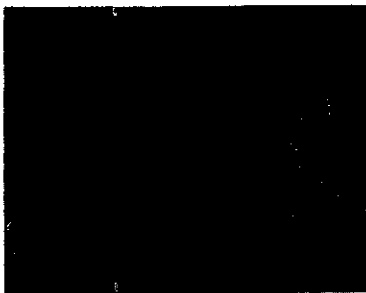
I would dissolve both solids in two separate portions of aqueous nitric acid (or any acid). The one which dissolved to give a colourless solution will be the oxide of F while the one which stay undissolved will be the oxide of G.
 OR

I would dissolve both solids in two separate portions of aqueous/dilute sodium hydroxide. The one which dissolved to give a colourless solution will be the oxide of F while the one which stay undissolved will be the oxide of G. [1]

[Total: 10]

- 2 Synthetics polymers are macromolecules which have many uses. They are made from monomers which combine together in polymerisation reactions.

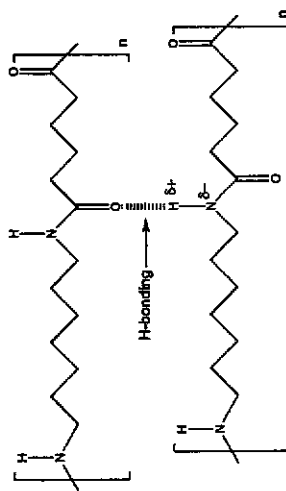
In a chemical reaction, if all of the product molecules are useful, then the reactant molecules is said to have a 100% atom economy where there is no waste to dispose of and so no pollution from the products. If one or more of the product molecules are not useful, the atom economy is less than 100% where there is waste to dispose of and the process is polluting. Reactions with 100% atom economy are less wasteful of resources.



(v)

It was suggested to use PA as a material for the packaging of the above mentioned fertiliser. Explain if it is suitable for PA to be used. [2]
The fertiliser is acidic and the presence of moisture and heat in a humid environment in Singapore will result in hydrolysis to possibly occur and thus causing PA to break down. Hence, PA is not suitable for use as the packaging material.

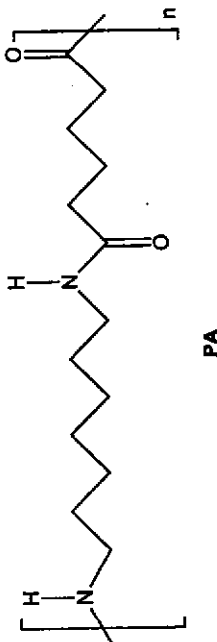
(vi) Predict whether PA is a thermosetting or a thermoplastic polymer. Explain your answer with the aid of a suitable diagram, and your knowledge of the structure and bonding in polymers. [3]



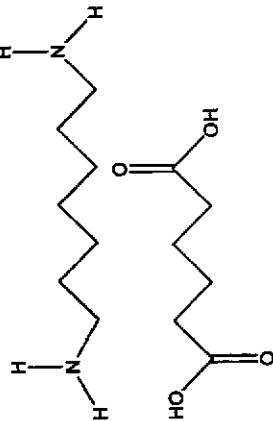
Thermoplastic polymer. The hydrogen bonding between the polymer chains will be broken when heated.

Polymers can be designed to have specific properties so that they can be used for specific purposes.

Polyamides, PA are polymers which are often used in packaging materials. An example of PA has the following structure.



(a) (i) Draw the structural formulae of the two monomers used to make PA. [2]



(ii) State the type of polymerisation for PA. [1]
Condensation

(iii) State the reagents and conditions other than the two monomers needed for the above reaction to make PA. [1]
DCC

2 (a) (iv) Suggest whether or not the atom economy of the production of PA is 100%. Explain your answer. [1]

It will not be 100% as water molecules are lost in the production of PA.
Or
It is 100% as water molecule is a harmless side product.

- 2 (b) When choosing a polymer for a specific use, the properties of the polymer must be considered carefully.

The table below shows properties of 4 polymers labelled A to D.

polymer	melting point/ $^{\circ}\text{C}$	chemical reactivity	strength	rigidity
A	200	low	medium	medium
B	500	high	medium	high
C	1000	low	high	low
D	Decompose upon heating	high	high	high

State which polymer would be the most suitable for making a bullet proof vest that can withstand a bomb blast in a chemical warfare.

Explain your choice by considering each of the 4 properties listed in the table above. [4]

C Melting point High to withstand bomb blast

Chemical Reactivity: To prevent chemical from reacting with the vest

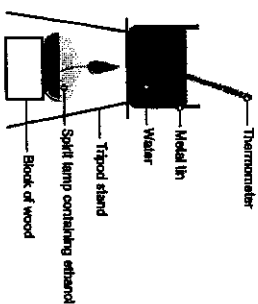
Strength: High strength required to prevent the strap/ribs from cutting through the vest

Rigidity: Low rigidity so as to have a better fit when wearing the vest

[Total: 14]

- 3 Use of Data Booklet is relevant to this question

Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is an important industrial chemical and is used as a solvent and a fuel. A student used the apparatus shown below to find the enthalpy change of combustion of ethanol, $\Delta H_c(\text{ethanol})$.



The measurements recorded by the student are shown in Table 3.1.

Mass of water /g	Initial temperature of water / $^{\circ}\text{C}$	Final temperature of water / $^{\circ}\text{C}$	Initial mass of spirit burner and ethanol /g	Final mass of spirit burner and ethanol /g
200	27.6	59.5	113.25	112.22

Table 3.1

- (a) (i) Define, with the aid of an equation, the term *standard enthalpy change of combustion* of ethanol. [2]

Standard enthalpy change of combustion of ethanol is the energy released/change when one mole of ethanol is burnt/oxidised in excess oxygen under standard conditions of 298K and 1 bar.



- (ii) Using the data from Table 3.1, calculate a value for the enthalpy change of combustion of ethanol, $\Delta H_c(\text{ethanol})$. Hence, calculate the efficiency of the heating process given that the theoretical value of the standard enthalpy change of combustion of ethanol is $-1367 \text{ kJ mol}^{-1}$. [3]

Mass of ethanol burnt = $113.25 - 112.22 = 1.03 \text{ g}$

Amount of ethanol burnt = $1.03 / 46 = 0.02239 \text{ mol}$

$Q = mc\Delta T = 200 \times 4.18 \times (59.5 - 27.6) = 26668.4 \text{ J} = 26.6684 \text{ kJ}$

$\Delta H_c(\text{ethanol}) = (-26.6684 / 0.02239)$
 $= -1191.1 \text{ kJ mol}^{-1}$
 $= -1190 \text{ kJ mol}^{-1} \text{ (3 s.f.)}$

efficiency = $(1191.1/1367) \times 100\% = 87.1\%$

- 3 (a) (iii) Use the bond energies given in the Data Booklet to calculate another value for the standard enthalpy change of combustion of ethanol. [2]

Bonds Broken: 5 C-H, 1 C-C, 1 C-O, 1 O-H, 3 O=O

Bonds Formed: 4 C=O (CO_2), 6 O-H

$$\begin{aligned} \Delta H_c(\text{ethanol}) &= [5(410) + (350) + (380) + (460) + 3(496)] \\ &\quad - [4(805) + 6(460)] \\ &= 4708 - 5980 = -1272 \text{ kJ mol}^{-1} \end{aligned}$$

- (iv) Suggest an explanation for the difference between the theoretical value and your value in (a)(iii). [1]

The bond energy values in the Data Booklet are average values

or

The heat change for the conversion of water from liquid to gaseous state is not considered in the calculation using bond energies.

9

- (iv) Infrared spectroscopy can be used to identify molecules by their different functional groups. Ethanol and the product in (b)(i) have different infrared absorption spectra. With reference to the *Data Booklet*, state two differences in the infra-red absorption spectra of ethanol and the product in (b)(i). [2]

Ethanol : $970 - 1260 \text{ cm}^{-1}$ (C-O), $3580 - 3650 \text{ cm}^{-1}$ (O-H)

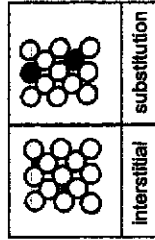
Product in b(i): $1210 - 1440 \text{ cm}^{-1}$ (C-O), $1680 - 1730 \text{ cm}^{-1}$ (C=O), $2500 - 3000 \text{ cm}^{-1}$ (C-H)

Accept ecf for aldehyde

Product in b(i): $1670 - 1740 \text{ cm}^{-1}$ (C=O)

Any two difference [1] each.

[Total: 18]



- 4 Steel is an *interstitial* alloy, as carbon atoms fit in between iron atoms in the lattice. Brass is a *substitution* alloy, as zinc atoms replace the copper atoms in the lattice. Stainless steel is a combination of interstitial and substitution alloys, because carbon

atoms fit in between the lattice, but some of the iron atoms are replaced with nickel atoms.

The alloy's structure will determine properties such as *hardness*, which measures the material's resistance to permanent shape change when a force is applied. These properties rely on how much electrostatic attraction is present between ions and electrons in any given volume of the lattice.

Lattice Strength $\propto \frac{q^+}{r}$

- (a) The ionic radius and ionic charge of the following element are given in the following table.

Element	C	V	Cr	Fe	Ni	Cu	Zn	W
Ionic radius (10^{-12} m)	16	64	62	64	60	73	74	66
Ionic charge	+4	+3	+3	+3	+3	+2	+2	+4

- (i) Adding a small amount of which metallic element is likely to increase the lattice strength of iron most? Give a reason for your answer. [1]

W. It has the highest $\frac{q^+}{r}$ value

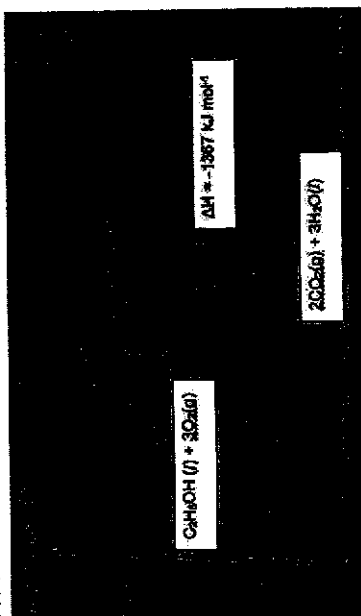
- (ii) From the table above, suggest another element, other than nickel, that can be added to iron to form a substitution alloy. [1]

V or Cr

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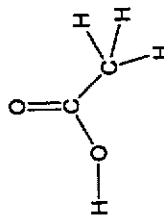
8

- (v) Given that the activation energy is 335 kJ mol^{-1} , sketch a clearly labelled reaction pathway diagram for the combustion reaction of ethanol using the theoretical value of the enthalpy change of combustion of ethanol from (a)(ii). [2]



- 3 (b) Ethanol can be oxidised using hot acidified potassium dichromate(VI).

- (i) Draw the displayed formula of the organic product formed and give the IUPAC name. [2]



IUPAC Name: Ethanoic acid

- (ii) Write a balanced equation for the oxidation of ethanol using [O] to represent the oxidising agent. State the colour change observed. [2]



Colour change: orange to green.

- (iii) Other than using oxidising agents, suggest a simple chemical test to distinguish ethanol from the organic product obtained in (b)(i). [2]

Reagents and conditions: $\text{Na}_2\text{CO}_3 (\text{aq})$

Observations: Effervescence observed for ethanoic acid, gas evolved formed white ppt with limewater.

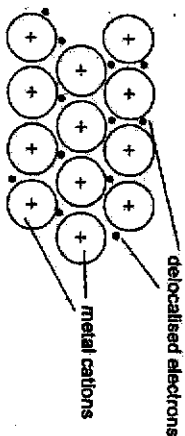
No effervescence for ethanol.

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- (iii) An aqueous solution of Fe^{3+} is known to be acidic due to its high charge density, similar to Al^{3+} . Write an equation to justify the acidity of an aqueous solution of Fe^{3+} .



- 4 (b) (i) With the aid of a labelled diagram, describe the structure and bonding in iron. [2]



Giant metallic structure with strong electrostatic forces of attraction between cations and sea of delocalised electrons.

- (ii) Metals are malleable because they can be hammered or pressed into shapes without breaking the metallic bond. The hardness of iron is enhanced when carbon atoms are added to iron atoms in the lattice. With reference to your answer in (b)(i), explain how adding carbon atoms enhance the hardness of iron in steel. [1]

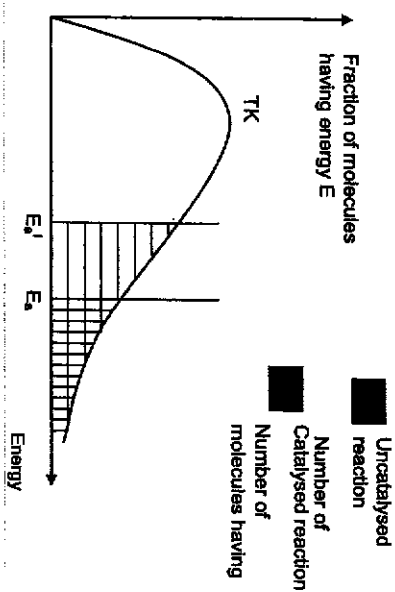
Adding carbon atoms into the space between the iron atoms in the lattice will prevent the iron atoms from sliding over each other easily and hence do not go out of shape easily.

- (c) Cations of some of the metals such as Fe and Cr can act as catalysts for specific reactions.

- (i) Define the term, catalyst. [1]

Catalyst is a substance that increases the rate of a chemical reaction with itself chemically unchanged at the end of the reaction.

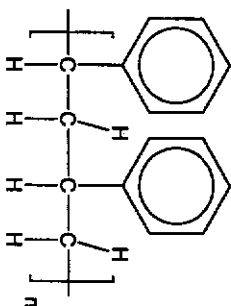
- 4 (c) (ii) With the aid of a suitable diagram, explain how catalysts increase the rate of reactions. [3]



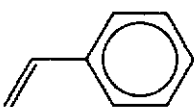
A catalyst lowers the activation energy of a reaction by providing an alternative reaction pathway. There will be then an increase in the number of molecules having energy greater than or equal to the lowered activation energy, which results in the frequency of effective collisions increases. This will cause the rate of the reaction to increase.

[Total: 10]

- 5 (a) Polystyrene (PS) is a type of polymer used to make foam box for food packaging and has the following structure.

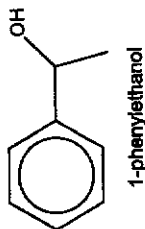


- (i) Draw the skeletal formula of the monomer and state its IUPAC name. [2]



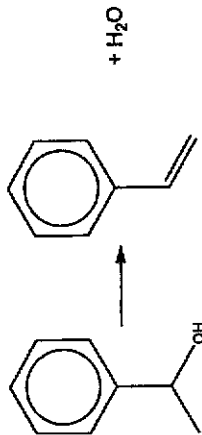
IUPAC name: phenylethene / benzene ethene

- (ii) State the reagents and conditions on how the monomer can be synthesized from 1-phenylethanol. Write a balanced equation for the reaction.



[2]

Reagents and Conditions: excess concentrated H_2SO_4 , 170°C /heat



- 5 (a) (iii) The progress of the reaction can be monitored by following the concentration of 1-phenylethanol. Describe how the completion of this reaction can be confirmed by means of a simple chemical test. [2]

Reagents and Conditions: KMnO_4 (aq), H_2SO_4 (aq), heat
 Reaction is complete when the purple KMnO_4 remains purple, implying that the alcohol is no longer present.

OR

Reagents and Conditions: $\text{K}_2\text{Cr}_2\text{O}_7$ (aq), H_2SO_4 (aq), heat
 Reaction is complete when the orange $\text{K}_2\text{Cr}_2\text{O}_7$ remains orange, implying that the alcohol is no longer present.

- (b) Suggest an advantage and disadvantage of using polystyrene as a food packaging. [2]

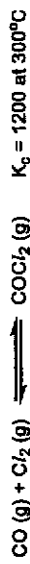
Advantage: It is inert and hence will not cause any food poisoning. / It is a good insulator and thus can keep food warm.
 Disadvantage: It is non-biodegradable so it remains in the landfill for prolonged period of time/ it can affect the marine ecosystem as it floats on water / It is flammable.

[Total: 8]

Section B

Answer one question from this section in the spaces provided.

- 6 Phosgene is a toxic gas prepared by the reaction of carbon monoxide with chlorine.



- (a) (i) Write the K_c expression for the preparation of phosgene. [1]

$$K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]}$$

- (ii) If the equilibrium concentration of chlorine and phosgene are the same at 300°C , calculate the equilibrium concentration of carbon monoxide in the reaction. [1]

$$K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]} = \frac{1}{K_c} \quad \text{Hence, } [\text{CO}] = \frac{1}{K_c} = 8.33 \times 10^{-4} \text{ mol dm}^{-3}$$

- (iii) Given that the enthalpy change of the above reaction is exothermic, deduce how the K_c will change when temperature increases. [2]

When T increases, position of equilibrium will shift to the left to favour the endothermic reaction OR to remove excess heat.

Hence the backward rate increases more than the forward rate.

Since, $K_c = \frac{k_f}{k_r}$, K_c decreases.

- 6 (b) The reaction between carbon monoxide and chlorine in the preparation of phosgene is studied at constant temperature.

The initial concentration and rate data obtained for each experiment is given in Table 6.1.

Experiment	Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	Initial $[\text{CO}] / \text{mol dm}^{-3}$	Initial $[\text{Cl}_2] / \text{mol dm}^{-3}$
1	1.29×10^{-28}	1.00	0.10
2	1.33×10^{-30}	0.10	0.10
3	1.30×10^{-28}	0.10	1.00
4	1.32×10^{-31}	0.10	0.01

Table 6.1

- (i) Determine the order of reaction with respect to each reactant and hence deduce the rate equation for this reaction. Use data from Table 6.1 to explain your answers. [3]

Comparing experiment 1 and 2, when $[\text{CO}] \times 10$, rate $\times 10$. Hence order with respect to $[\text{CO}]$ is 1.

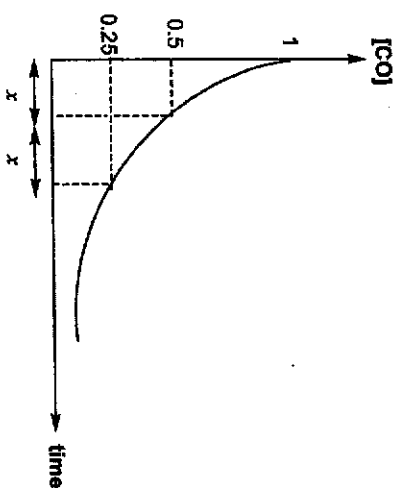
Comparing experiment 2 and 3, when $[\text{Cl}_2] \times 10$, rate $\times 10$. Hence order with respect to $[\text{Cl}_2]$ is 1.

$$\text{Rate} = k [\text{CO}][\text{Cl}_2]$$

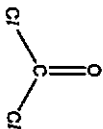
(ii) Using experiment 1, calculate the value of the rate constant, stating its units. [2]

Using experiment 1, $k = \frac{1.29 \times 10^{-8}}{[I][O]} = 1.29 \times 10^{-28} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$

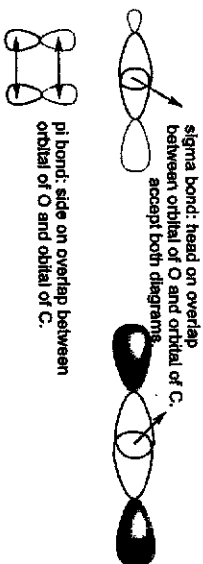
6 (b) (iii) Using your answer in (b)(i), sketch a graph of 1 mol dm⁻³ carbon monoxide against time when chlorine is in excess. [2]



(c) The structure of phosgene is as shown below.



Draw a labelled diagram to show how orbitals overlap to form a sigma (σ) bond and a pi (π) bond in the C=O bond. [2]



6 (d) Table 6.2 shows the electronegativity values of the atoms in phosgene.

Atom	Electronegativity / Pauling units
C	2.5
Cl	3.0
O	3.5

Table 6.2

Predict all possible intermolecular forces which could exist between phosgene molecules. Explain how these forces arise. [3]

There is instantaneous dipole-induced dipole (d-d) interaction and permanent dipole-permanent dipole interaction in phosgene.

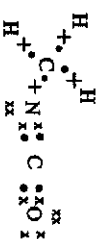
Since there is a larger difference in electronegativity between the chlorine and oxygen than between carbon and chlorine, phosgene has an overall dipole moment OR is a polar molecule.

In phosgene, the electrons are constantly moving thus resulting in a temporary uneven distribution of electrons i.e. instantaneous dipole. The instantaneous dipole attract/repel neighbouring molecules, hence creating an induced dipole.

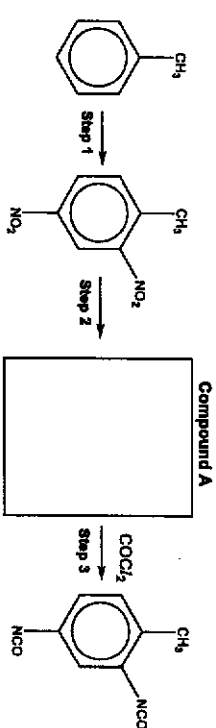
(e) Phosgene reacts with methylamine to form methyl isocyanate.



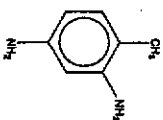
Draw the dot-and-cross diagram of methyl isocyanate given that it has two double bonds. [1]



6 (f) 2,4-disocyanato-1-methylbenzene is used to make polyurethane foams. It can be made in the following three-step process.



(i) Using the information in (e), suggest the structural formula of A. [1]

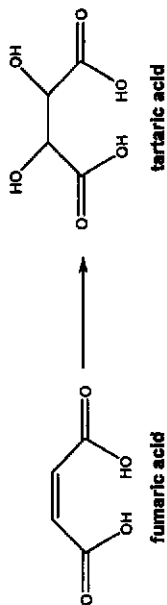


(b) Fumaric acid is a weak acid that dissociates in water to form a mono-anion, hydrogen fumarate, $\text{HO}_2\text{CCH}=\text{CHCO}_2^-$.

(i) Write an equation for the equilibrium between fumaric acid and water. Label the conjugate acid and conjugate base in your equation. [2]



(ii) Fumaric acid is reacted with cold acidified potassium manganate to form tartaric acid.



0.20 mol dm^{-3} of fumaric acid has a pH of 5.0 whilst 0.080 mol dm^{-3} of tartaric acid has a pH of 5.5. With the aid of relevant calculations, predict if tartaric acid or fumaric acid is a weaker acid. [2]

$$[\text{H}^+] = 10^{-5} = 1 \times 10^{-5} \text{ mol dm}^{-3}$$

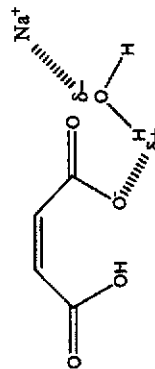
$$[\text{H}^+] = 10^{-5.5} = 3.16 \times 10^{-6} \text{ mol dm}^{-3} \text{ [1] together with correct conclusion}$$

$$K_{\text{fumaric acid}} = 1 \times 10^{-5} / 0.20 = 5 \times 10^{-5}$$

$$K_{\text{tartaric acid}} = 3.16 \times 10^{-6} / 0.08 = 5.27 \times 10^{-6}$$

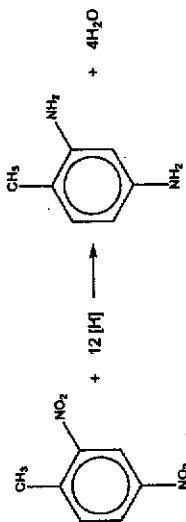
Hence fumaric acid is a weaker acid since $K_{\text{fumaric acid}} < K_{\text{tartaric acid}}$.

(iii) With the aid of a suitable diagram, explain how sodium hydrogen fumarate is soluble in water. [2]



The ion dipole interaction between sodium hydrogen fumarate releases sufficient energy to overcome the hydrogen bonding between water and the ionic bonds between sodium hydrogen fumarate.

(ii) Step 2 is a reduction reaction. Write an equation for Step 2 using [H] to represent the reducing agent. [1]



(iii) State the type of reaction in Step 1. [1]

Substitution

[Total: 20]

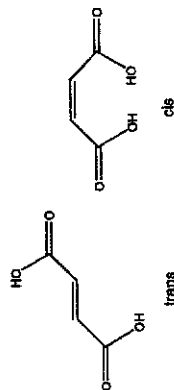
7 Fumaric acid is an organic compound with the formula $\text{HO}_2\text{CCH}=\text{CHCO}_2\text{H}$. A white solid, fumaric acid occurs widely in nature.

(a) (i) Write the IUPAC name of the compound formed when fumaric acid is reacted with hydrogen gas in the presence of nickel catalyst. [1]

Butenedioic acid

(ii) Draw skeletal diagrams to show cis-trans isomerism in fumaric acid and explain how this isomerism arises. [2]

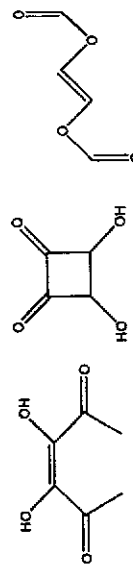
There is restricted rotation about the C=C bond and each C of the alkene is connected to different groups



(iii) Define the term constitutional isomer and draw the structural formula of a constitutional isomer of fumaric acid that does not contain a carboxylic acid functional group. [2]

Constitutional isomer is an isomer with the same molecular formula but different structural formula.

Possible structures:



7 (c) Fumaric acid ($M_r = 116$) has been used as a food additive since 1946 in the EU, USA, Australia and New Zealand. As a food additive, it is used as an acidity regulator and can be denoted by the E number, E297. It is generally used in beverages and baking powders.

(i) An equimolar mixture of fumaric acid and hydrogen fumarate ion is an acidic buffer. Write an equation to show how the buffer behaves as an acidity regulator. [1]



(ii) The ingredient label of a brand of baking powder has been found to contain E297.

A 1g sample of baking powder is dissolved in 15 cm³ of excess 0.0535 mol dm⁻³ sodium hydroxide. The impurities in the baking powder are insoluble and do not react with sodium hydroxide. The solution is filtered into a 250 cm³ graduated flask. Deionised water is added so that the total volume of the solution is 250 cm³. This is solution Z. 10 cm³ of solution Z required 15.60 cm³ of 0.001 mol dm⁻³ sulfuric acid for complete neutralisation.

Calculate the percentage by mass of E297 in the sample of baking powder. [3]

Moles of sulfuric acid = 1.56×10^{-5} mol

Since mole of sulfuric acid : NaOH = 1 : 2

Moles of excess NaOH = 3.12×10^{-5} mol in 10cm³

Moles of excess NaOH = 7.8×10^{-4} mol in 250cm³

Moles of NaOH reacted with E297 = $(15/1000 \times 0.0535) - 7.8 \times 10^{-4}$

= $8.025 \times 10^{-4} - 7.8 \times 10^{-4} = 2.25 \times 10^{-5}$ mol

Since mole of E297 : NaOH = 1 : 2

Moles of E297 = 1.125×10^{-5}

Mass of E297 = $1.125 \times 10^{-5} \times 116 = 1.31 \times 10^{-3}$ g

% by mass of E297 = $(1.31 \times 10^{-3} / 1) \times 100\% = 0.131 \%$

7 (d) Predict and explain whether magnesium hydrogen fumarate or sodium hydrogen fumarate has a higher melting point. [2]

Magnesium hydrogen fumarate has a magnesium cation with a larger charge and smaller size than sodium cation in sodium hydrogen fumarate.

Hence, sodium hydrogen fumarate has a smaller magnitude of ionic lattice energy than magnesium hydrogen fumarate. Thus magnesium hydrogen fumarate has a higher melting point.

(e) Fumaric acid undergoes complete combustion to form carbon dioxide gas and water.

(i) Define the term *standard enthalpy change of formation of fumaric acid* with the aid of a balanced chemical equation. [1]



(ii) Relevant values of ΔH_f^\ominus are given in Table 7.1.

Compound	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
Fumaric acid	-811
Carbon dioxide	-394
Water	-286

Table 7.1

Using relevant values from Table 7.1, calculate the standard enthalpy change of combustion of fumaric acid. [2]

Equation for the combustion of fumaric acid:



$$\Delta H_c^\ominus = [4(-394) + 2(-286)] - (-811) = -1337 \text{ kJ mol}^{-1}$$

[Total: 20]

-END OF PAPER-

