VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **24 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, highlighters, glue or correction fluid.
Write your name, CT group and VJC exam number on the Answer Sheet in the spaces provided unless this has been done for you. Do not shade your NRIC number.
DO **NOT** WRITE IN ANY BARCODES.

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 choices in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. No mark will 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 **10** printed pages.

1 Which of the following species will experience the largest angle of deflection when passing through an electric field?

A $^{12}_{6}C^{2+}$ **B** $^{4}_{2}He^{+}$ **C** $^{3}_{1}H^{+}$ **D** $^{14}_{7}N^{3-}$

2 Which ion has less electrons than neutrons and less neutrons than protons?

Ion	Neutrons	Nucleons
W^-	18	37
X^{2+}	17	34
Y^{3+}	16	33
Z^{3-}	16	31

A W^- **B** X^{2+} **C** Y^{3+} **D** Z^{3-}

3 X and Y are elements of period 3. The successive ionisation energies, in kJ mol^{-1}, of elements X and Y are given below.

X	580	1980	2970	6500	8300	10870	13590	16390
Y	941	1050	2060	4140	6590	7900	15000	17750

Which of the following statements about elements X and Y are true?

1 Y has an outer electronic configuration $ns^2\ np^4$.

2 X and Y forms a compound with the formula X_3Y_2.

3 Atomic radius of X is greater than Y.

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

C 1 and 3 only **D** 2 and 3 only

4 What is the number of σ and π bonds in the molecule, $(CN)_2CC(CN)_2$?

	σ	π
A	5	9
B	9	5
C	9	9
D	13	5

5 Which statement explains why silicon dioxide has a high melting point?

A It has a giant ionic structure with strong electrostatic forces of attraction between ions.

B It has a giant molecular structure with strong covalent bonds between atoms.

C It has a simple molecular structure with strong forces of attraction between molecules.

D It has a giant metallic structure with a strong electrostatic attraction between positive ions and the sea of delocalised electrons.

6 The boiling points of ammonia, hydrogen bromide and hydrogen chloride are given below.

Gas	Formula	Boiling Point / °C
Ammonia	NH_3	–33
Hydrogen bromide	HBr	–66
Hydrogen chloride	HCl	–85

Which statement best explains the above data?

A The strength of the instantaneous dipole – induced dipole interactions increases in the order NH_3 < HCl < HBr.

B The strength of the permanent dipole – permanent dipole interactions increases in the order HCl < HBr < NH_3.

C More covalent bonds are broken in ammonia compared to those in hydrogen chloride and hydrogen bromide.

D The instantaneous dipole – induced dipole interactions in HBr is stronger than the instantaneous dipole – induced dipole interactions in HCl but weaker than the hydrogen bonds in NH_3.

7 In which sequence are the molecules arranged in increasing bond angle?

1 $H_2O < NH_3 < CH_4$

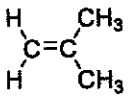
2 $H_2O < BF_3 < CO_2$

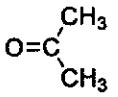
3 $CH_4 < CO_2 < SF_6$

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

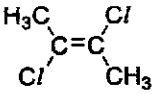
C 2 and 3 only **D** 1 only

8 Which molecule has the largest overall dipole?

A 

B 

C 

D 

9 Which of the following pairs of solutions would produce a buffer when mixed together?

A HNO_3 and $NaNO_3$ **B** HCN and NaCN

C NaOH and NaCl **D** HCl and NaOH

10 Hypobromous acid can react with water as shown in the equation below.

$$HOBr(aq) + H_2O(aq) \rightleftharpoons H_3O^+(aq) + OBr^-(aq)$$

Which of the following statements correctly describe the above reaction?

1 H_2O and OBr^- are acting as Bronsted bases.

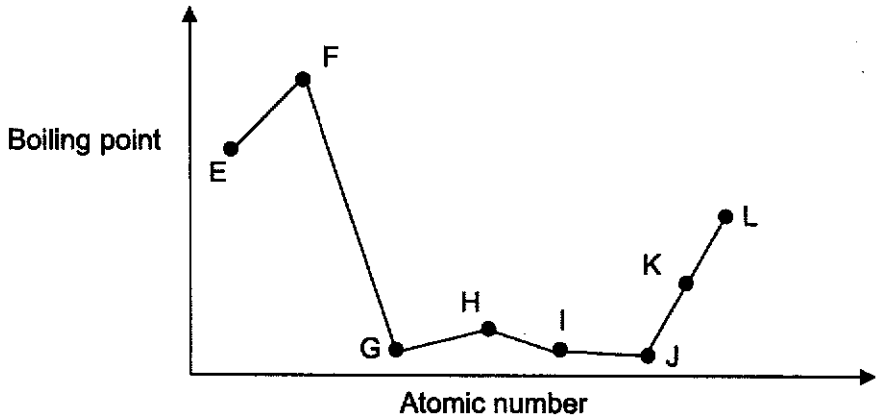
2 HOBr is acting as an Arrhenius acid.

3 HOBr and H_2O are conjugate acid–base pairs.

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

C 1 only **D** 2 and 3 only

11 The graph below shows the variation in the boiling point for eight consecutive elements in the Periodic Table, all with atomic number less than 21.



Which statements are correct?

1 The chloride of E reacts with aqueous sodium hydroxide to give a precipitate which is soluble in excess sodium hydroxide.

2 The oxide of F is neutral in aqueous solution.

3 The oxide of K dissolves readily in water to give a strongly alkaline solution.

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

C 1 only **D** 2 and 3 only

12 L, M and N are elements in Period 3. L has a smaller ionic radius than M, and M has a more endothermic first ionisation energy than N.

What are elements L, M and N?

	L	M	N
A	P	S	*Al*
B	P	*Al*	S
C	*Al*	S	P
D	*Al*	P	S

13 Which statement explains why HI has a lower thermal stability than HCl and HBr?

A The enthalpy change of formation of HI is the most exothermic.

B The HI bond has the lowest bond energy.

C The HI bond has the shortest length.

D The HI molecule has the lowest polarity.

14 Diamond is a pure form of carbon. The mass of a diamond can be measured in carats. One carat is 0.200 g of carbon.

Which expression gives the number of carats that contain 6.02×10^{23} carbon atoms?

A 0.200×12.0

B $12.0 / 0.200$

C $0.200 / 12.0$

D $(0.200 / 6.02 \times 10^{23}) \times 12.0$

15 Which statement about 1 mol of sodium metal is correct?

A It contains 6.02×10^{23} electrons.

B It contains the same number of atoms as 0.5 mol of hydrogen gas.

C It contains the same number of atoms as $\frac{1}{12}$ mol of ^{12}C atoms.

D It has the same number of atoms as 24 dm^3 of chlorine gas at r.t.p.

16 Washing powder, $Na_2CO_3.10H_2O$, loses some of its water of crystallisation when exposed to the atmosphere, this process is known as efflorescence. When 3.17 g of washing powder was left in the open for some time, the mass of the powder decreased to 2.17 g. The formula of effloresced washing powder is $Na_2CO_3.xH_2O$.

What is the value of x?

A 2 B 3 C 4 D 5

17 Assuming that they have similar lattice structures, which ionic solid would require the most energy to form gaseous ions?

A Na_2S B CaO C MgF_2 D MgO

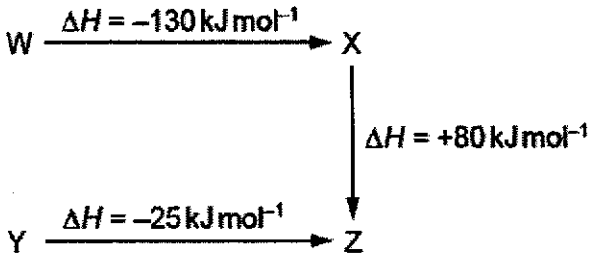
18 In a calorimetric experiment, 1.60 g of a fuel is burnt. The energy released is absorbed by 200 g of water and the temperature rose from 18 °C to 68 °C. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

What is the total energy released per gram of fuel burnt?

A 16300 J B 26100 J

C 35500 J D 169000 J

19 The diagram represents the energy changes for some reactions.



What are the natures of the conversions W → Y, Y → X and Z → W?

	W → Y	Y → X	Z → W
A	Exothermic	Endothermic	Endothermic
B	Exothermic	Exothermic	Endothermic
C	Endothermic	Exothermic	Exothermic
D	Endothermic	Endothermic	Exothermic

20 Which statement best explains why a small increase in temperature can lead to a significant increase in the rate of a gaseous reaction?

A The frequency of collisions between the molecules is significantly greater at a higher temperature.

B The average kinetic energy of the molecules is significantly greater at a higher temperature.

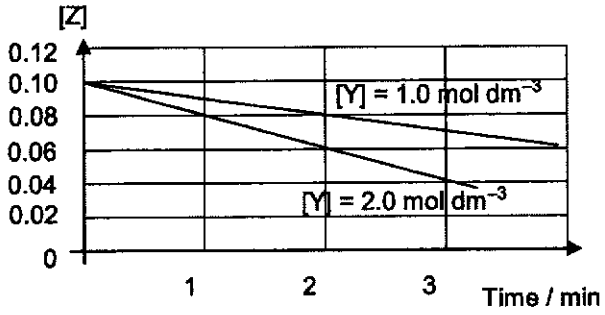
C The activation energy of the reaction is significantly lower when the gases are at a higher temperature.

D The frequency of effective collisions between molecules with kinetic energy equal or greater than the activation energy is significantly greater at a higher temperature.

21 Substances Y and Z react according to the following reaction:

$Y(aq) + Z(aq) \rightarrow T(aq) + U(aq)$

The graph below shows the variation of [Z] with time of two separate experiments carried out by varying the initial concentration of reactant Y.



How will the reaction rate be affected when concentration of Z is halved and Y is doubled?

A The rate remains unchanged.

B The rate increases by a factor of two.

C The rate decreases by a factor of two.

D The rate increases by a factor of four.

22 The dissociation of X_3Y is shown below.

$$X_3Y(s) \rightleftharpoons 3X^+(aq) + Y^{3-}(aq)$$

What is the expression for the equilibrium constant, K_c?

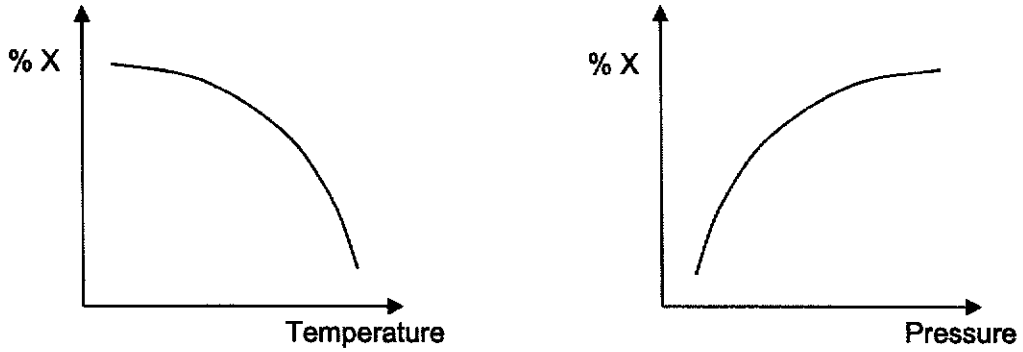
A $\frac{[X^+]^3[Y^{3-}]}{[X_3Y]}$

B $[X^+]^3[Y^{3-}]$

C $[3X^+]^3[Y^{3-}]$

D $\frac{[X_3Y]}{[X^+]^3[Y^{3-}]}$

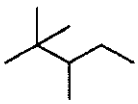
23 A compound X is formed during a gas phase reaction. The graphs below show how the percentage of a compound X present at equilibrium varies with temperature and pressure.

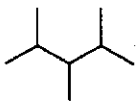


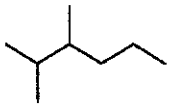
Which of the following responses concerning the equilibrium is correct?

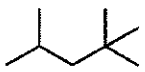
	Enthalpy change of reaction	*No. of gaseous particles in product / No. of gaseous particles in reactant*
A	Exothermic	> 1
B	Exothermic	< 1
C	Endothermic	> 1
D	Endothermic	< 1

24 What is the skeletal formula for 2,2,3-trimethylpentane?

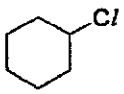
A 

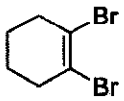
B 

C 

D 

25 Which structure will exhibit cis-trans isomerism?

A 

B 

C $CH_2CHCH_2CHCH_2$

D $CH_2CHCH_2CHCH(CH_3)$

26 Which statement about an ethene molecule is **not** correct?

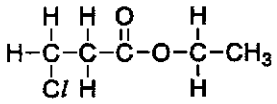
A It forms a polymer that has the same percentage of carbon as itself.

B It has all its atoms in the same plane.

C It decolourises liquid bromine.

D It has an empirical formula of C_2H_4.

27 What would be the products formed when the following compound is boiled with aqueous sodium hydroxide?



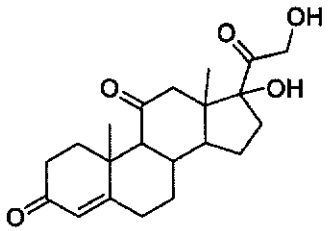
A CH_3CH_2OH and $HOCH_2CH_2CO_2^-Na^+$

B CH_3CH_2OH and $ClCH_2CH_2CO_2^-Na^+$

C $CH_3CH_2O^-Na^+$ and $ClCH_2CH_2CO_2^-Na^+$

D $CH_3CH_2O^-Na^+$ and $HOCH_2CH_2CO_2^-Na^+$

28 Cortisone is one of the main hormones that are released in response to stress.



cortisone

Which statement about this compound is correct?

1 It turns hot acidified $Cr_2O_7^{2-}$ ions from orange to green.

2 It reacts with an amine in the presence of DCC to form an amide.

3 It undergoes condensation with ethanoic acid.

4 It undergoes a subsitution reaction with chlorine gas.

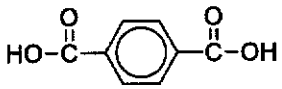
A 1, 2 and 3 only

B 1, 3 and 4 only

C 3 and 4 only

D 1 and 4 only

29 The polymer poly(ethylene terephthalate), also known as PET, is a polymer formed from the following monomers.



benzene-1,4-dicarboxylic acid

$HOCH_2CH_2OH$

ethan-1,2-diol

Which statement is correct?

A PET is biodegradable.

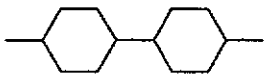
B PET is an addition polymer.

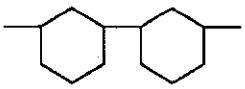
C PET is a thermoplastic polymer.

D PET polymer chains are held by hydrogen bonds.

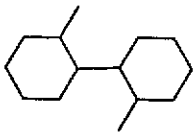
30 Cyclohexene, shown below, can form an addition polymer.

Which of the following shows a section of the polymer?

A 

B 

C 

D 

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY

8873/02

Paper 2

15 September 2020

Candidates answer on the Question Paper.

2 hours

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and CT 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, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

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

For Examiner's Use		
Section A	1	/ 13
	2	/ 17
	3	/ 20
	4	/ 10
Section B	5 / 6	/ 20
Total		/ 80

This document consists of **17** printed pages and **1** blank page.

[Turn over

Section A

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

1 (a) An experiment was conducted to determine the percentage by mass of Na_3CrO_4 in a solid sample. 2.05 g of this sample was first reacted with 25 cm^3 of dilute H_2SO_4 to give a solution containing Cr^{3+} and $Cr_2O_7^{2-}$. The resultant solution was then transferred to a 100 cm^3 volumetric flask which was topped up to the mark with deionised water.

10.0 cm^3 of the solution in the volumetric flask was pipetted out and reacted with excess KI. $Cr_2O_7^{2-}$ was converted into Cr^{3+} and I_2 was liberated as shown below.

$$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightarrow 2Cr^{3+} + 7H_2O + 3I_2$$

The amount of I_2 formed in the above reaction was found to be 8.90×10^{-4} mol.

(i) Identify the species which is being oxidised and the species which is being reduced for the reaction of CrO_4^{3-} with H_2SO_4. Explain your answers using oxidation numbers.

.....

.....

.....

..... [2]

(ii) Write half-equations to show the oxidation and reduction processes that occurred in the reaction of CrO_4^{3-} with H_2SO_4. Hence, write a balanced equation for this reaction.

.....

.....

.....

..... [2]

(iii) Calculate the amount of $Cr_2O_7^{2-}$ formed in the 100 cm^3 volumetric flask.

[2]

(iv) Hence, determine the percentage by mass of Na_3CrO_4 in the sample.

[2]

(v) A student conducted this experiment but KI was not added in excess. Explain the effect that this error will have on percentage by mass of Na_3CrO_4 determined.

.....

.....

..... [1]

(vi) State the electronic configuration of Cr^{3+}.

$1s^2$..... [1]

(b) The relative atomic mass of an element depends on the percentage abundance of each isotope present.

A sample of chromium contains four isotopes, as shown below.

isotope	relative isotopic mass	Percentage abundance / %
^{50}Cr	49.95	4.35
^{52}Cr	51.94	83.79
^{53}Cr	*x*	*y*
^{54}Cr	53.94	2.36

(i) Define the term *isotopes*.

.....

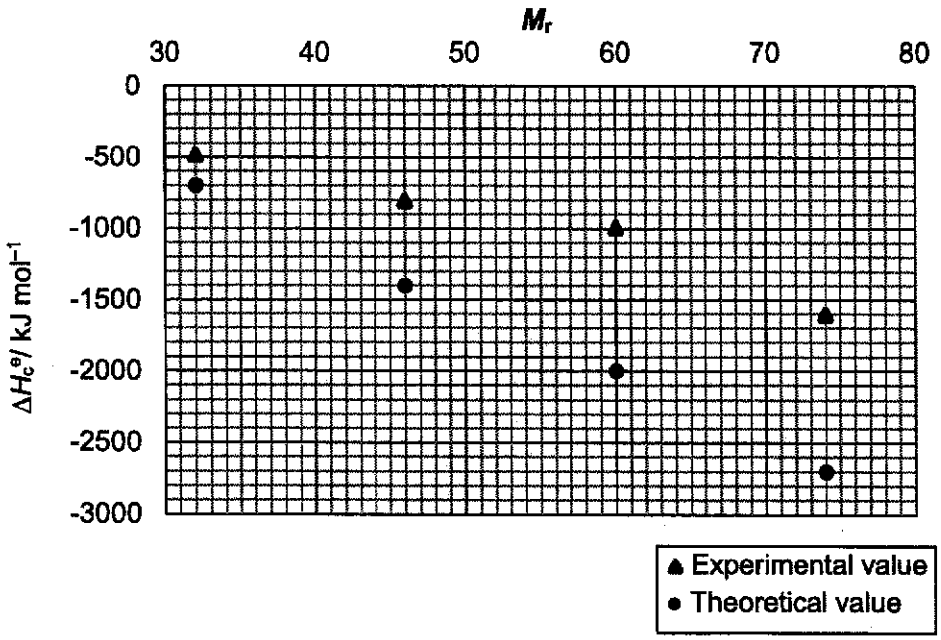
..... [1]

(ii) Calculate the value for *x* and *y*, giving your answers to **two** decimal places.

[2]

[Total:13]

2(a) Experiments were conducted to determine the enthalpy change of combustion for a series of primary alcohols. These experimental values were compared with the theoretical values as shown in the graph below.



(i) Define the standard enthalpy change of combustion of butanol.

.....

..... [1]

(ii) Suggest why there is a regular change in the enthalpy change of combustion of this series of primary alcohols.

.....

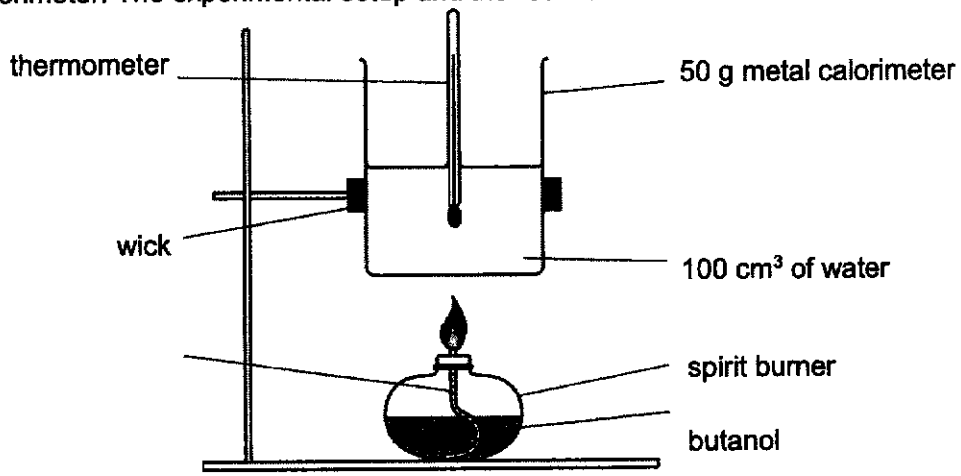
..... [1]

(iii) Explain one reason why the experimental values are different from the theoretical values.

.....

..... [1]

(iv) Another experiment was conducted to determine the specific heat capacity of a calorimeter. The experimental setup and the results are shown below.



temperature of water before heating = 25.0 °C
temperature of water after heating = 50.1 °C
mass of spirit burner before heating = 81.50 g
mass of spirit burner after heating = 80.76 g

With reference to the graph on page 4 and relevant information in the data booklet, determine the specific heat capacity of the metal calorimeter.

[3]

(b) The combustion of alcohols produces a greenhouse gas, carbon dioxide. A mineral serpentine, $Mg_3Si_2O_5(OH)_4$, has the potential to capture carbon dioxide. After carbon dioxide is captured, magnesium carbonate, water and an acidic oxide are formed.

(i) Write a balanced equation for the reaction of $Mg_3Si_2O_5(OH)_4$ with CO_2.

..... [1]

(ii) Draw the dot-and-cross diagram for $MgCO_3$.

[1]

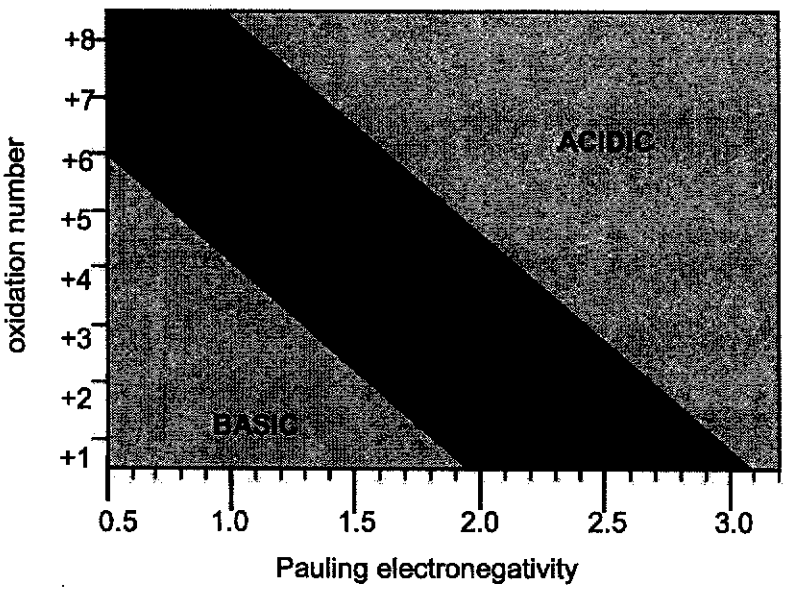
(iii) $MgCO_3$ can be decomposed under high heat to form MgO. Explain whether $MgCO_3$ or MgO will have a higher melting point.

.....

.....

..... [2]

(c) The diagram below illustrates the acid-base behaviour of oxides, $\mathbf{M_xO_y}$ based on the electronegativity and oxidation state of the element **M**. The larger the value of the Pauling electronegativity is, the more electronegative the element **M** is.



Using Na_2O as an example, Na in Na_2O has an oxidation state of +1 and a Pauling electronegativity of 0.93 which leads to the conclusion that Na_2O is a basic oxide based on the graph.

(i) Given that the Pauling electronegativity of gallium is 1.81, predict whether Ga_2O_3 is an acidic oxide, basic oxide or amphoteric oxide.

..... [1]

(ii) Write an equation for any reaction(s) of Ga_2O_3 with NaOH and HC*l* respectively. If there's no reaction with either NaOH or HC*l*, state that there's no reaction.

with NaOH: .....

with HC*l*: .....[2]

(iii) As_2O_5 is an acidic oxide and As_2O_3 is an amphoteric oxide. Suggest a value for the electronegativity of As.

..... [1]

(iv) For elements with the same oxidation number, suggest and explain how their electronegativity affects the acid-base bahaviour of their oxides.

.....

.....

.....

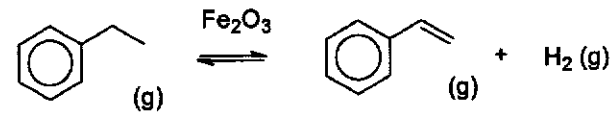
.....

.....

..... [3]

[Total: 17]

3 (a) *Styrofoam* is the trade name for the polymer polystyrene. To obtain styrene, ethylbenzene undergoes a reaction at 600 °C, in the presence of Fe_2O_3 catalyst.



ethylbenzene styrene

(i) State the type of reaction that ethylbenzene undergoes.

..... [1]

(ii) Describe a simple chemical test to distinguish between styrene and ethylbenzene. State what you would observe.

.....

.....

.....

..... [2]

(iii) With the aid of an equation, define the bond energy of the H–H bond.

.....

.....

.....

..... [2]

(iv) Using the bond energy values in the *Data Booklet*, calculate the enthalpy change of reaction.

[2]

(v) Hence, sketch an energy profile diagram for the reaction, indicating clearly the reactants, products, activation energy and enthalpy change, ΔH.

[2]

(vi) On the same axes as **(a)(v)**, sketch the energy profile diagram for the reaction when Fe_2O_3 was not used, clearly labelling your sketch as *without* Fe_2O_3. [1]

(vii) Using a sketch of a Maxwell-Boltzmann distribution, explain how the addition of the Fe_2O_3 affects the rate of reaction.

.....

.....

.....

..... [2]

(b) At 600 °C, a pure sample of 0.50 mol ethylbenzene and a fixed mass of Fe_2O_3 catalyst was placed in an evacuated gas syringe that has a volume of 0.50 dm^3. When equilibrium was established at t = 5 min, 30% of the resultant mixture is ethylbenzene.

At t =10 min, the temperature of the syringe was increased to 800 °C and a new equilibrium was established at t = 15 min.

At t = 20 min, the volume of syringe was decreased to 0.25 dm^3, and a new equilibrium was established at t = 25 min.

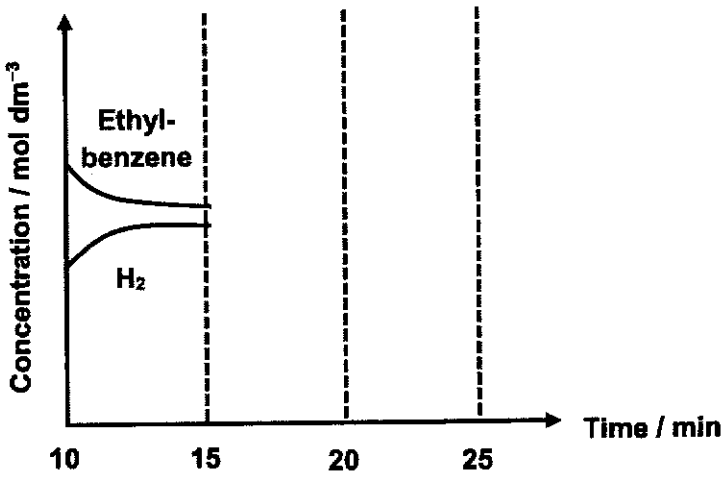
(i) Write an expression for K_c for the reaction.

..... [1]

(ii) Calculate the value of K_c at t = 5 min, stating the units.

[1]

(iii) On the axes provided, complete the graphs to show how the concentrations of ethylbenzene and H_2 varies from t =15 min to t = 25 min. Label your graphs clearly.



[2]

(c) Humidity can affect the synthesis of polystyrene. To monitor the humidity levels in the factory that manufactures polystyrene, a humidity meter was made by soaking filter paper in an aqueous solution of cobalt(II) chloride. The paper was dried so that the original pink colour was replaced and the filter paper became pale blue. The equation for the equilibrium reaction representing the colour change is as follows:

$$\underset{\text{pink}}{[Co(H_2O)_6]^{2+}} + 4Cl^- \rightleftharpoons \underset{\text{blue}}{[CoCl_4]^{2-}} + 6H_2O \qquad \Delta H = +50 \text{ kJ mol}^{-1}$$

The dry filter paper was then left in the factory for the day.

(i) How would the use of this meter indicate that the factory was humid during the day? Explain your answer.

.....

.....

.....

..... [2]

(ii) Suggest, with an explanation, **two** reasons why the paper turned blue when heated with a hairdryer.

.....

.....

.....

..... [2]

[Total: 20]

4 Ethanedioic acid, $H_2C_2O_4$ is a dibasic acid. The two acid dissociation constants, K_{a1} and K_{a2} of ethanedioic acid are 5.4×10^{-2} and 5.4×10^{-5} respectively.

(a) (i) Write an expression for the second acid dissociation constant, K_{a2}, stating the units.

[2]

(ii) Suggest a reason why K_{a1} is higher than K_{a2}.

.....

..... [1]

(iii) In a 0.100 mol dm^{-3} $H_2C_2O_4$ solution, the percentage dissociation of $H_2C_2O_4$ is 3.98%, calculate the pH of this solution.

[1]

(b) A mixture containing 0.50 mol dm^{-3} of $HC_2O_4^-$ and 0.50 mol dm^{-3} of $C_2O_4^{2-}$ can serve as a buffer solution.

(i) Define the term *buffer solution.*

.....

..... [1]

(ii) Explain, with the aid of equations, how the above mixture can serve as a buffer solution.

.....

.....

.....

..... [2]

(c) A reaction between the reagents **A**, **B**, and **C** is studied at a constant temperature and the results are shown in the table below.

The rate equation is found to be rate = $k[B]^2[C]$

Complete the table.

Experiment	Initial [**A**] / mol dm^{-3}	Initial [**B**] / mol dm^{-3}	Initial [**C**] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.025	0.0125	0.040	1.51×10^{-8}
2	0.050	0.0125	0.040	
3	0.010	0.0375		1.02×10^{-7}
4	0.025		0.040	6.00×10^{-8}

[3]

[Total: 10]

Section B

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

5 (a) Natural rubber is a polymer which is made from 2-methyl-1,3-butadiene, $CH_2=C(CH_3)CH=CH_2$. Natural rubber can be vulcanized to improve the elasticity by the addition of sulfur cross links. Without the crosslinks, the rubber cannot return to its original shape after being stretched over a limit. Figure 1 shows how the polymer chains change during stretching.

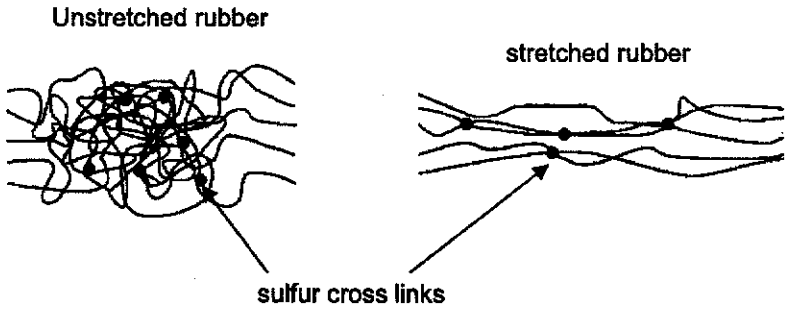


Figure 1

Figure 2 shows the how the length of a rubber and a few other polymers, **W**, **X**, **Y** and **Z** changes when a force is applied to them until it is broken.

For the rubber, it can retain its shape after being stretched from point **0** to point **A**. From point **A** to point **B**, it starts to lose its ability to return to its original shape.

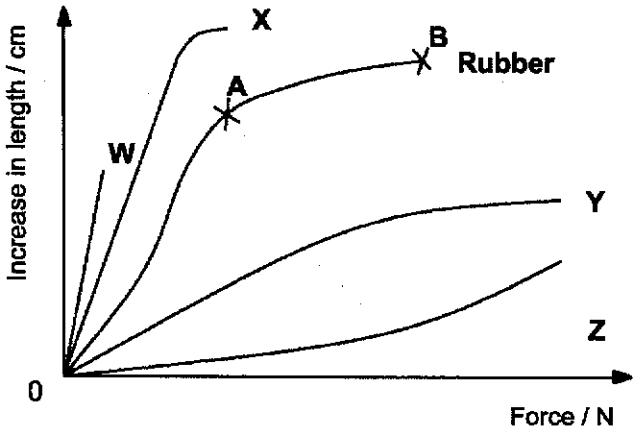


Figure 2

(i) Suggest which bonds or interactions are broken from point **0** to point **A**, from point **A** to point **B** and at point **B**.

from point **0** to point **A**: .....

from point **A** to point **B**: .....

at point **B**: .....[2]

(ii) With reference to Figure 1, suggest why rubber gives off heat to the surroundings when it is stretched.

.....

..... [1]

(iii) A belaying rope is used for rock climbing. It prevents the climber from falling to the ground when one slips. It is strong enough to carry the weight of the climber. It also stretches to reduce the impact of the fall experienced by the climber to a limit. After that, it should not stretch any further to break the fall.

With reference to Figure 2, state and explain which polymer can be used to make a belaying rope.

.....

.....

.....

..... [2]

(iv) Poly(styrene-butadiene-styrene), or SBS, is a rubber that is produced for the soles of shoes. It is made from styrene, $C_6H_5CH{=}CH_2$ and butadiene, $CH_2{=}CHCH{=}CH_2$.

Draw **one** repeat unit of this polymer which is made up of two monomers of styrene and 1 monomer of butadiene which is arranged in the order of styrene, butadiene, styrene.

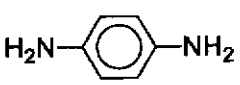
[1]

(v) Suggest how further reaction could help the polymer have higher tensile strength.

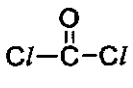
.....

..... [1]

(b) A polyamide **X** was made from the monomers shown. Similar to carboxylic acid, phosgene also reacts with 1,4-phenylenediamine to form polymer X with the loss of HCl.



1,4-phenylenediamine



Phosgene

(i) Draw **two** repeat units of **X**.

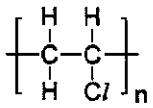
[1]

(ii) In a big industrial city, there is air pollution from factories emitting SO_2 gas. Polymer **X** undergoes degradation when it is exposed to the rain for a prolonged period of time.

State the type of reaction that occurred when **X** underwent degradation.

..... [1]

(iii) PVC has the structure as shown below.



PVC

Even in an unpolluted city, explain why PVC is still favoured over **X** as a material to manufacture rain coats.

.....

.....

.....

..... [2]

(c) (i) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that does not react with acidified potassium manganate(VII).

..... [1]

(ii) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that can give 3 possible organic products, including stereoisomers, when heated with excess concentrated H_2SO_4.

..... [1]

(iii) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that does not react with excess hot concentrated H_2SO_4.

..... [1]

(iv) Draw the skeletal formula and name the organic product formed when $CH_3CH_2CH_2CH_2CH_2OH$ reacts with CH_3CO_2H in the presence of a catalyst.

[2]

(v) Suggest and explain whether $CH_3CH_2CH_2CH_2CH_2OH$ or $CH_3CH_2CH_2CH_2CHO$ has a higher boiling point.

.....

.....

.....

..... [2]

(d) Draw a diagram to illustrate the shape of ClF_3. Hence, explain whether ClF_3 is a polar molecule.

.....

..... [2]

[Total: 20]

6 (a) Acrylonitrile, CH_2=CHCN, is a colourless, volatile organic liquid.

(i) Draw a diagram to illustrate the shape of CH_2=CHCN, clearly indicating the bond angles around all the carbon atoms.

[2]

(ii) State and explain if acrylonitrile can exhibit cis-trans isomerism.

.....

.....

.....

..... [2]

The synthesis of acrylonitrile involves a reaction between propene, ammonia, and oxygen. Besides acrylonitirile, water is also formed in the reaction.

(iii) Write a balanced equation for the synthesis of acrylonitrile.

..... [1]

(iv) Propene, ammonia, and oxygen exist as gases during the synthesis of acrylonitrile. The reaction is catalysed by a solid catalyst, bismuth phoshphomolybdate, $Bi_9PMo_{12}O_{52}$. Outline the mode of the catalytic action for the synthesis of acrylonitrile.

.....

.....

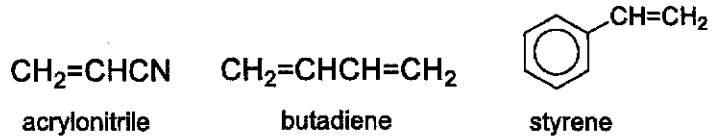
.....

.....

.....

..... [3]

(b) Acrylonitrile is one of the monomers used in the production of the copolymer, *Acrylonitrile Butadiene Styrene (ABS)*, which is used to manufacture *Lego*™. The structures of the 3 monomers used to form *ABS* are shown below.



(i) Butadiene can be synthesised from butanedial, $CHOCH_2CH_2CHO$ via a 2-step reaction as shown below.

Suggest the structure of compound **F**, and the reagents and conditions for steps 1 and 2.

Compound **F**: .....

Step 1: .....

Step 2: .....[3]

(ii) Define the term *polymer*.

.....

..... [1]

(iii) Draw one repeat unit of the polymer *ABS*.

[1]

(iv) Explain why *Lego*™ can withstand masses up to 400 kg before it breaks.

.....

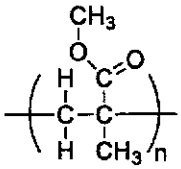
..... [1]

(v) Suggest and explain whether *Lego*™ is likely to be recyclable.

.....

..... [1]

(c) Traditional *Lego*™ pieces are usually brightly coloured and hence are attractive to children. In addition, the variety of colours support a wide variety of design options for constructing *Lego*™ masterpieces. Nonetheless, certain *Lego*™ designs require transparent pieces. These transparent *Lego*™ pieces are made of poly(methyl methacrylate).
The structure of poly(methyl methacrylate) is shown below:



Poly(methyl methacrylate)

(i) Draw the monomer of poly(methyl methacrylate).

[1]

(ii) Suggest whether bottles made of poly(methyl methacrylate) is suitable for storing dilute acid solutions.

.....

..... [1]

A group of researchers are trying to find a suitable polymer to be used as the screen for a foldable mobile phone. The screen needs to be foldable and resistance to scratches.

Four polymers, **A**, **B**, **C** and **D** have been shortlisted for this purpose. Their properties are shown below.

Table 2.1

polymer	strength	water resistance	rigidity	chemical reactivity
A	medium	low	high	low
B	strong	medium	low	medium
C	strong	high	low	low
D	low	medium	medium	medium

(iii) One of the monomers use to synthesis polymer **A** is $CH_3CH_2CH(OH)CH_2CH(OH)CH_3$.

Name the monomer used to synthesise **A**.

..... [1]

(iv) State which polymer would be most suitable for making this foldable screen. Explain your choice by considering the properties listed in table 2.1.

.....

.....

.....

.....[2]

[Total: 20]

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY **8873/01**

Paper 1 Multiple Choice **24 September 2020**

1 hour

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

BP~745

VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME .....

CT GROUP .....

CHEMISTRY **8873/02**

Paper 2 **15 September 2020**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and CT 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, glue or correction fluid.

Section A
Answer all the questions.

Section B
Answer one question.

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

For Examiner's Use		
Section A	1	/ 13
	2	/ 17
	3	/ 20
	4	/ 10
Section B	5 / 6	/ 20
Total		/ 80

This document consists of 16 printed pages and 0 blank page.

Section A

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

1 (a) An experiment was conducted to determine the percentage by mass of Na_3CrO_4 in a solid sample. 2.05 g of this sample was first reacted with 25 cm^3 of dilute H_2SO_4 to give a solution containing Cr^{3+} and $Cr_2O_7^{2-}$. The resultant solution was then transferred to a 100 cm^3 volumetric flask which was topped up to the mark with deionised water.

10.0 cm^3 of the solution in the volumetric flask was pipetted out and reacted with excess KI. $Cr_2O_7^{2-}$ was converted into Cr^{3+} and I_2 was liberated as shown below.

$$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightarrow 2Cr^{3+} + 7H_2O + 3I_2$$

The amount of I_2 formed in the above reaction was found to be 8.90×10^{-4} mol.

(i) Identify the species which is being oxidised and the species which is being reduced for the reaction of CrO_4^{3-} with H_2SO_4. Explain your answers using oxidation numbers.

CrO_4^{3-} is reduced as the oxidation number of Cr decreases from +5 in CrO_4^{3-} to +3 in Cr^{3+}.
CrO_4^{3-} is oxidised as the oxidation number of Cr increases from +5 in CrO_4^{3-} to +6 in $Cr_2O_7^{2-}$.

[2]

(ii) Write half-equations to show the oxidation and reduction processes that occurred in the reaction of CrO_4^{3-} with H_2SO_4. Hence, write a balanced equation for this reaction.

Reduction half-equation: $CrO_4^{3-} + 8H^+ + 2e^- \rightarrow Cr^{3+} + 4H_2O$
Oxidation half-equation: $2CrO_4^{3-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O + 2e^-$

$3CrO_4^{3-} + 10H^+ \rightarrow Cr^{3+} + 5H_2O + Cr_2O_7^{2-}$

[2]

(iii) Calculate the amount of $Cr_2O_7^{2-}$ formed in the 100 cm^3 volumetric flask.

Amount of $Cr_2O_7^{2-}$ in 10 cm^3 of the solution $= 8.90 \times 10^{-4} \div 3$
$= 2.97 \times 10^{-4}$ mol

Amount of $Cr_2O_7^{2-}$ in 100 cm^3 of the solution $= 2.97 \times 10^{-4} \times (100/10)$
$= 2.97 \times 10^{-3}$ mol

[2]

(iv) Hence, determine the percentage by mass of Na_3CrO_4 in the sample.

Amount of Na_3CrO_4 reacted with $H_2SO_4 = 2.97 \times 10^{-3} \times 3$
$= 8.90 \times 10^{-3}$ mol
Mass of $Na_3CrO_4 = 8.90 \times 10^{-3} \times (23.0 \times 3 + 52.0 + 16.0 \times 4)$
$= 1.65$ g
Percentage by mass of Na_3CrO_4 $= 1.65 \div 2.05 \times 100\%$
$= 80.5\%$

[2]

(v) A student conducted this experiment but KI was not added in excess. Explain the effect that this error will have on percentage by mass of Na_3CrO_4 determined.

Not all the dichromate reacted to give I_2, thus the calculated amount of Na_3CrO_4 will be smaller than expected leading to a smaller percentage purity.

[1]

(vi) State the electronic configuration of Cr^{3+}.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

[1]

(b) The relative atomic mass of an element depends on the percentage abundance of each isotope present.

A sample of chromium contains four isotopes, as shown below.

Isotope	relative isotopic mass	Percentage abundance / %
^{50}Cr	49.95	4.35
^{52}Cr	51.94	83.79
^{53}Cr	*x*	*y*
^{54}Cr	53.94	2.36

(i) Define the term *isotopes*.

Isotopes are atoms of the same element that have the same number of protons but different number of neutrons.

[1]

(ii) Calculate the value for *x* and *y*, giving your answers to **two** decimal places.

y = 100 – 4.35 – 83.79 – 2.36
= 9.50

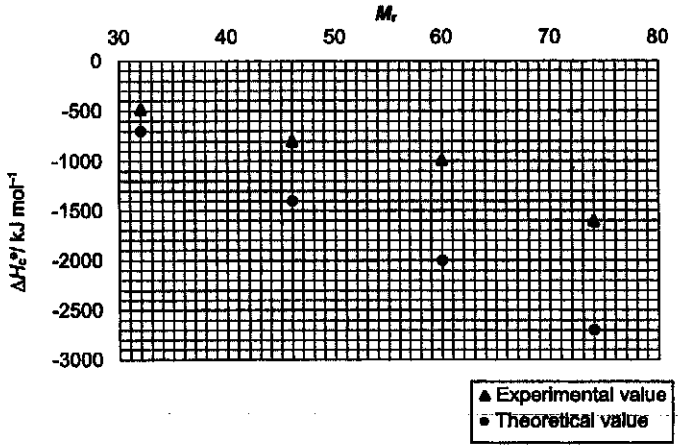
$$\textbf{52.0} = \frac{(49.95\times4.35)+(51.94\times83.79)+(9.50x)+(53.94\times2.36)}{4.35+83.79+9.50+2.36}$$

x = 52.99

[2]

[Total:13]

2 (a) Experiments were conducted to determine the enthalpy change of combustion for a series of primary alcohols. These experimental values were compared with the theoretical values as shown in the graph below.



(i) Define the standard enthalpy change of combustion of butanol.

(ii)

The standard enthalpy change of combustion of butanol is the energy released when one mole of butanol is completely burnt in excess oxygen at 298K and 1 bar.

[1]

(ii) Suggest why there is a regular change in the enthalpy change of combustion of this series of primary alcohols.

Progressively, there is a regular addition of CH_2 in the alcohol. The increase in the number of bonds broken and formed during the combustion is the same, leading a regular change in the enthalpy change of combustion.

[1]

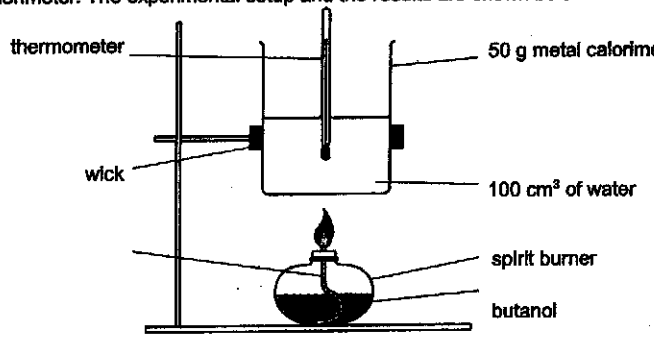
(iii) Explain one reason why the experimental values are different from the theoretical values.

Due to heat loss to surroundings, the temperature change recorded is lower leading to a less exothermic experimental value.

OR Water formed in the experiment is in gaseous state and additional heat was used to vapourise water so temperature change recorded was smaller, leading to a less exothermic experimental value.

[1]

(iv) Another experiment was conducted to determine the specific heat capacity of a calorimeter. The experimental setup and the results are shown below.



temperature of water before heating = 25.0 °C
temperature of water after heating = 50.1 °C
mass of spirit burner before heating = 81.50 g
mass of spirit burner after heating = 80.76 g

With reference to the graph on page 4 and relevant information in the data booklet, determine the specific heat capacity of the metal calorimeter.

Let y be the specific heat capacity of the metal calorimeter.
Amount of butanol combusted = (81.50 – 80.76 / 74.0)
= 0.010 mol

Heat evolved = $m_{water}c_{water}\Delta T + m_{calorimeter}c_{calorimeter}\Delta T$
= (100)(4.18)(50.1 – 25.0) + (50)(y)(50.1 – 25.0)
= (10491 + 1255y) J

$$1600 \times 10^3 = \frac{10491+1255y}{0.010}$$

y= 4.39
The specific heat capacity of the metal calorimeter is 4.39 J g^{-1} $°C^{-1}$

[3]

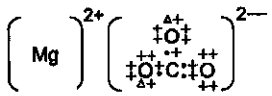
(b) The combustion of alcohols produces a greenhouse gas, carbon dioxide. A mineral serpentine, $Mg_3Si_2O_5(OH)_4$, has the potential to capture carbon dioxide. After carbon dioxide is captured, magnesium carbonate, water and an acidic oxide are formed.

(i) Write a balanced equation for the reaction of $Mg_3Si_2O_5(OH)_4$ with CO_2.

$Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + 2H_2O$

[1]

(ii) Draw the dot-and-cross diagram for $MgCO_3$.



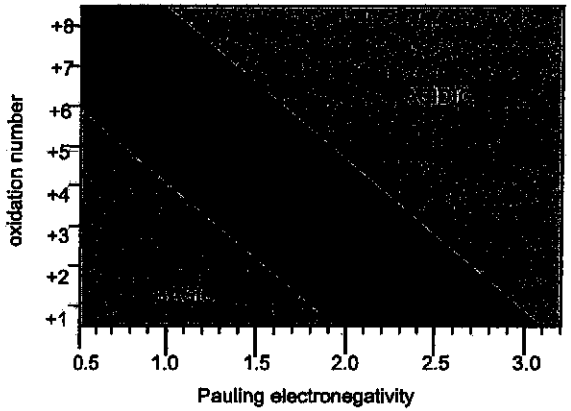
[1]

(iii) $MgCO_3$ can be decomposed under high heat to form MgO. Explain whether $MgCO_3$ or MgO will have a higher melting point.

O^{2-} and CO_3^{2-} have the same charges. However, O^{2-} is smaller than CO_3^{2-}.
Lattice energy $\propto \frac{q_+ \times q_-}{r_+ + r_-}$
(or since lattice energy is directly proportional to the product of charges and inversely proportional to the sum of radii),
hence MgO will have a more exothermic lattice energy and stronger ionic bonds which requires more energy to break.

[2]

(c) The diagram below illustrates the acid-base behaviour of oxides, M_xO_y based on the electronegativity and oxidation state of the element M. The larger the value of the Pauling electronegativity is, the more electronegative the element M is.



Using Na_2O as an example, Na in Na_2O has an oxidation state of +1 and a Pauling electronegativity of 0.93 which leads to the conclusion that Na_2O is a basic oxide based on the graph.

(i) Given that the Pauling electronegativity of gallium is 1.81, predict whether Ga_2O_3 is an acidic oxide, basic oxide or amphoteric oxide.

Ga_2O_3 is an amphoteric oxide.

[1]

(ii) Write an equation for any reaction(s) of Ga_2O_3 with NaOH and HCl respectively. If there's no reaction with either NaOH or HCl, state that there's no reaction.
$Ga_2O_3 + 6HCl \rightarrow 2GaCl_3 + 3H_2O$
$Ga_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaGa(OH)_4$

[2]

(iii) As_2O_5 is an acidic oxide and As_2O_3 is an amphoteric oxide. Suggest a value for the electronegativity of As.
Pauling electronegativity of As= 2.2

[1]

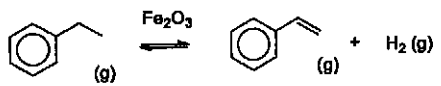
(iv) For elements with the same oxidation number, suggest and explain how their electronegativity affects the acid-base behaviour of their oxides.
When the electronegativity of the element is low, its oxide is basic. When the electronegativity increases, it becomes increasingly more acidic.

With electronegativity increases, the difference in the electronegativity between the element and oxygen decreases, leading to a greater covalent character. With a greater covalent character (or less ionic), their oxides become increasingly more acidic.

[3]

[Total:17]

3 (a) *Styrofoam* is the trade name for the polymer polystyrene. To obtain styrene, ethylbenzene undergoes a reaction at 600 °C, in the presence of Fe_2O_3 catalyst.



ethylbenzene styrene

(i) State the type of reaction that ethylbenzene undergoes.

- **Elimination**

[1]

(ii) Describe a simple chemical test to distinguish between styrene and ethylbenzene. State what you would observe.

- **Add Br_2(aq) (in the dark) to separate test tubes containing styrene and ethylbenzene respectively.**
- **Styrene decolourises orange Br_2(aq) while ethylbenzene does not.**

[2]

(iii) With the aid of an equation, define the bond energy of the H–H bond.

- **$H_2(g) \rightarrow 2H(g)$**
- **Bond energy is defined as average energy absorbed to break 1 mol of H–H covalent bonds in the gaseous state to form gaseous H atoms.**

[2]

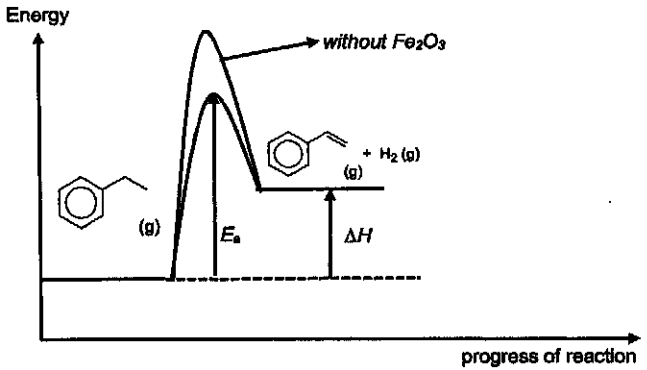
(iv) Using the bond energy values in the *Data Booklet*, calculate the enthalpy change of reaction.

ΔH = $\sum$BE(bonds broken) − $\sum$BE(bonds formed)
= [2BE(C–H) + BE(C–C)] − [BE (C=C) + BE(H–H)]
- **= [2(410) + 350] − [610 + 436]**
- **= +124 kJ mol^{-1}**

[2]

[Turn over

(v) Hence, sketch an energy profile diagram for the reaction, indicating clearly the reactants, products, activation energy and enthalpy change, ΔH.

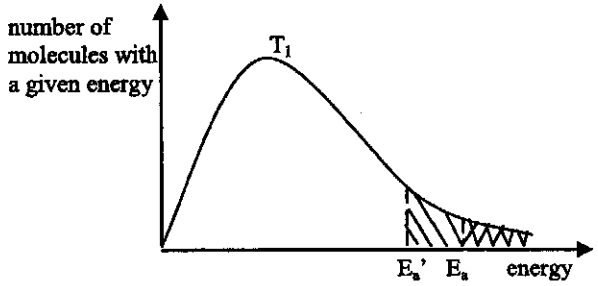


[2]

(vi) On the same axes as (a)(v), sketch the energy profile diagram for the reaction when Fe_2O_3 was not used, clearly labelling your sketch as *without* Fe_2O_3.

[1]

(vii) Using a sketch of a Maxwell-Boltzmann distribution, explain how the addition of the Fe_2O_3 affects the rate of reaction.



- **The addition of Fe_2O_3 catalyst lowers the Ea to Ea', and so a larger proportion of molecules (larger shaded area) have at least activation energy, leading to a higher frequency of effective collisions and hence an increased rate of reaction.**

[2]

(b) At 600 °C, a pure sample of 0.50 mol ethylbenzene and a fixed mass of Fe_2O_3 catalyst was placed in an evacuated gas syringe that has a volume of 0.50 dm^3. When equilibrium was established at t = 5 min, 30% of the resultant mixture is ethylbenzene.

At t =10 min, the temperature of the syringe was increased to 800 °C and a new equilibrium was established at t = 15 min.

At t = 20 min, the volume of syringe was decreased to 0.25 dm^3, and a new equilibrium was established at t = 25 min.

(i) Write an expression for K_c for the reaction.

$$K_c = \frac{[\text{styrene}][H_2]}{[\text{ethylbenzene}]}$$

[1]

(ii) Calculate the value of K_c at t = 5 min, stating the units:

	(g)	⇌	(g)	+	H_2 (g)
Initial / mol	0.5		0		0
Change / mol	−x		+x		+x
Equilibrium / mol	0.5 − x		x		x

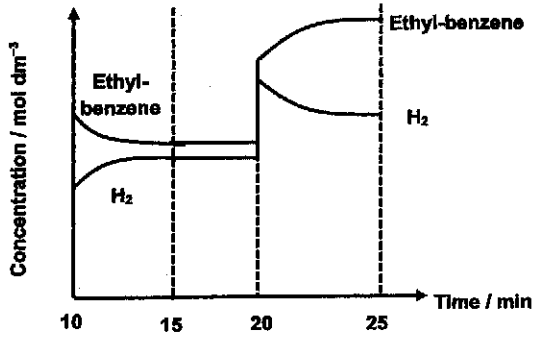
$$\frac{0.5-x}{0.5-x+x+x} = 0.3$$

$$x = 0.269$$

- $K_c = \frac{[\text{styrene}][H_2]}{[\text{ethylbenzene}]} = \frac{(\frac{0.269}{0.5})(\frac{0.269}{0.5})}{(\frac{0.5-0.269}{0.5})} = 0.627 \text{ mol dm}^{-3}$

[1]

(iii) On the axes provided, complete the graphs to show how the concentrations of ethylbenzene and H_2 varies from t =15 min to t = 25 min. Label your graphs clearly.



- **1m for compression of gas at t = 20 min**
- **1m for equilibrium position change from t = 20 to t = 25 min.**

[2]

(c) Humidity can affect the synthesis of polystyrene. To monitor the humidity levels in the factory that manufactures polystyrene, a humidity meter was made by soaking filter paper in an aqueous solution of cobalt(II) chloride. The paper was dried so that the original pink colour was replaced and the filter paper became pale blue. The equation for the equilibrium reaction representing the colour change is as follows:

$$\underset{\text{pink}}{[Co(H_2O)_6]^{2+}} + 4Cl^- \rightleftharpoons \underset{\text{blue}}{[CoCl_4]^{2-}} + 6H_2O \qquad \Delta H = +50 \text{ kJ mol}^{-1}$$

The dry filter paper was then left in the factory for the day.

(i) How would the use of this meter indicate that the factory was humid during the day? Explain your answer.

- **When the laboratory was humid during the day, more water vapour adsorbs on the paper.**
- **Thus, by Le Chatelier's principle (LCP), the position of the above equilibrium is shifted to the left, which caused the paper to turn from blue to pink.**

[2]

(ii) Suggest, with an explanation, two reasons why the paper turned blue when heated with a hairdryer.

- **When heated with a hairdryer, the temperature of the paper increased. By LCP, the forward endothermic reaction was favoured to absorb excess heat. As a result, the paper turned blue.**
- **When heated with a hairdryer, water on the filter paper evaporates. By LCP, the forward reaction is favoured to replenish water and thus the paper turned blue.**

[2]

[Total: 20]

4 Ethanedioic acid, $H_2C_2O_4$ is a dibasic acid. The two acid dissociation constants, K_{a1} and K_{a2} of ethanedioic acid are 5.4×10^{-2} and 5.4×10^{-5} respectively.

(a) (i) Write an expression for the second acid dissociation constant, K_{a2}, stating the units.

- $K_{a_2} = \frac{[H^+][C_2O_4^{2-}]}{[HC_2O_4^-]}$
- **Units: mol dm^{-3}**

[2]

(ii) Suggest a reason why K_{a1} is higher than K_{a2}.

- **More energy is needed to remove the positive H^+ from a negatively charged $HC_2O_4^-$ for K_{a2} compared to uncharged $H_2C_2O_4$ for K_{a1}. Hence, $H_2C_2O_4^-$ dissociates to a smaller extent.**

[1]

(iii) In a 0.100 mol dm^{-3} $H_2C_2O_4$ solution, the percentage dissociation of $H_2C_2O_4$ is 3.98%, calculate the pH of this solution.

- $[H^+] = \frac{3.98}{100} \times 0.1 = 3.98 \times 10^{-3}$ mol dm^{-3}
- **pH = $-\lg(3.98 \times 10^{-3})$ = 2.40**

[1]

(b) A mixture containing 0.50 mol dm^{-3} of $HC_2O_4^-$ and 0.50 mol dm^{-3} of $C_2O_4^{2-}$ can serve as a buffer solution.

(i) Define the term *buffer solution*.

- **A buffer solution is able to maintain a fairly constant pH when a small amount of acid or base is added.**

[1]

(ii) Explain, with the aid of equations, how the above mixture can serve as a buffer solution.

- $HC_2O_4^- + OH^- \rightarrow C_2O_4^{2-} + H_2O$
  $C_2O_4^{2-} + H^+ \rightarrow HC_2O_4^-$
- **Large reservoirs of $HC_2O_4^-$ and $C_2O_4^{2-}$ neutralise small amounts of OH^- and H^+ added respectively, keeping pH relatively constant.**

[2]

(c) A reaction between the reagents **A**, **B**, and **C** is studied at a constant temperature and the results are shown in the table below.

The rate equation is found to be rate = $k[B]^2[C]$

Complete the table.

Experiment	Initial [A] / mol dm^{-3}	Initial [B] / mol dm^{-3}	Initial [C] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.025	0.0125	0.040	1.51×10^{-8}
2	0.050	0.0125	0.040	**1.51×10^{-8}**
3	0.010	0.0375	**0.030**	1.02×10^{-7}
4	0.025	**0.0250**	0.040	6.00×10^{-8}

[3]

Compare experiment 1 and 2, since [B] and [C] are the same and [A] is not in the rate equation, both experiments have the same initial rate.

Using data from experiment 1, rate = $k[B]^2[C]$
$1.51 \times 10^{-8} = k[0.0125]^2[0.040]$
$k = 2.42 \times 10^{-3}$ mol^{-2}dm^{6}s^{-1}

To find [C] for experiment 3, $1.06 \times 10^{-7} = 2.42 \times 10^{-3}[0.0375][C]$
[C] = 0.030 mol dm^{-3}

To find [B] for experiment 4, $6.0 \times 10^{-8} = 2.42 \times 10^{-3}[B]^2[0.040]$
[B] = 0.0250 mol dm^{-3}

[Total: 10]

Section B

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

5 (a) Natural rubber is a polymer which is made from 2-methyl-1,3-butadiene, $CH_2=C(CH_3)CH=CH_2$. Natural rubber can be vulcanized to improve the elasticity by the addition of sulfur cross links. Without the crosslinks, the rubber cannot return to its original shape after being stretched over a limit. Figure 1 shows how the polymer chains change during stretching.

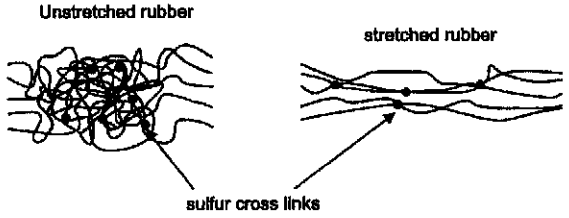


Figure 1

Figure 2 shows the how the length of a rubber and a few other polymers, **W**, **X**, **Y** and **Z** changes when a force is applied to them until it is broken.

For the rubber, it can retain its shape after being stretched from point **0** to point **A**. From point **A** to point **B**, it starts to lose its ability to return to its original shape.

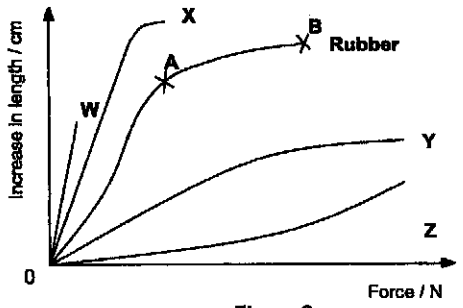


Figure 2

(i) Suggest which bonds or interactions are broken from point **0** to point **A**, from **A** to **B** and at **B**.

From 0 to A: the instantaneous dipole-induced dipole interactions between the polymer chain breaks.
From A to B: the sulfur cross links breaks.
At B: the covalent bonds in the polymer chain breaks.

[2]

(ii) With reference to Figure 1, suggest why rubber gives off heat to the surroundings when it is stretched.

There is more extensive instantaneous dipole-induced dipole interactions formed due to greater surface area between the linear polymer chains which releases energy.

[1]

(iii) A belaying rope is used for rock climbing. It prevents the climber from falling to the ground when one slips. It is strong enough to carry the weight of the climber. It also stretches to reduce the impact of the fall experienced by the climber to a limit. After that, it should not stretch any further to break the fall.

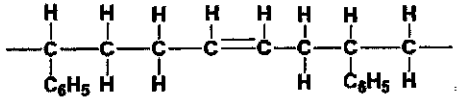
With reference to Figure 2, state and explain which polymer can be used to make a belaying rope.

Polymer Y
It has high tensile strength as it only breaks when a large force is applied. When a force is applied, there is an initial increase in the length to reduce the impact. When the force is increased over a limit, the length remains almost the same.

[2]

(iv) Poly(styrene-butadiene-styrene), or SBS, is a rubber that is produced for the soles of shoes. It is made from styrene, $C_6H_5CH{=}CH_2$ and butadiene, $CH_2{=}CHCH{=}CH_2$.

Draw one repeat unit of this polymer which is made up of two monomers of styrene and 1 monomer of butadiene which is arranged in the order of styrene, butadiene, styrene.



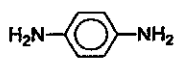
[1]

(v) Suggest how further reaction could help the polymer have higher tensile strength.

There are still C=C bonds in the polymer chain which can undergo further addition reactions to form strong covalent cross links, hence more energy is needed to break the polymer.

[1]

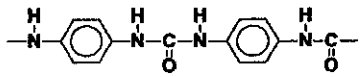
(b) A polyamide **X** was made from the monomers shown. Similar to carboxylic acid, phosgene also reacts with 1,4-phenylenediamine to form polymer X with the loss of HCl.



1,4-phenylenediamine

Phosgene

(i) Draw **two** repeat units of **X**.



[1]

(ii) In a big industrial city, there is air pollution from factories emitting SO_2 gas. Polymer **X** undergoes degradation when it is exposed to the rain for a prolonged period of time.

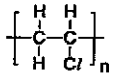
State the type of reaction that occurred when **X** underwent degradation.

It can undergo acid hydrolysis.

[1]

[Turn over

(iii) PVC has the structure as shown below.



PVC

Even in an unpolluted city, explain why PVC is still favoured over **X** as a material to manufacture rain coats.

PVC is more water resistant.
PVC forms weaker permanent dipole-permanent dipole interactions with water which makes it more water resistant unlike polymer X which can form stronger hydrogen bonds with water.

[2]

(c) (i) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that does not react with acidified potassium manganate(VII).
$CH_3CH_2C(OH)(CH_3)_2$

[1]

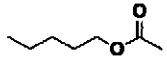
(ii) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that can give 3 possible organic products, including stereoisomers, when heated with excess concentrated H_2SO_4.
$CH_3CH_2CH_2CH(OH)CH_3$

[1]

(iii) Write down the structural formula of an isomer with the molecular formula $C_5H_{12}O$ that does not react with excess hot concentrated H_2SO_4.
$(CH_3)_3CCH_2OH$

[1]

(iv) Draw the skeletal formula and name the organic product formed when $CH_3CH_2CH_2CH_2CH_2OH$ reacts with CH_3CO_2H in the presence of a catalyst.



Pentyl ethanoate

[2]

(v) Suggest and explain whether $CH_3CH_2CH_2CH_2CH_2OH$ or $CH_3CH_2CH_2CHO$ has a higher boiling point.

Pentanol forms stronger hydrogen bonds between its molecules as compared to pentanal which forms weaker permanent dipole-permanent dipole interactions between its molecules and so it requires lesser energy to break.
Pentanol has higher boiling point as more energy is required to break its stronger intermolecular forces of attraction.

[2]

(d) Draw a diagram to illustrate the shape of ClF_3. Hence, explain whether ClF_3 is a polar molecule.

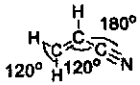
It is polar as it has polar C/-F bonds and a net dipole moment.

[2]

[Total:20]

6 (a) Acrylonitrile, CH_2=CHCN, is a colourless, volatile organic liquid.

(i) Draw a diagram to illustrate the shape of CH_2=CHCN, clearly indicating the bond angles around all the carbon atoms.



[2]

(ii) State and explain if acrylonitrile can exhibit cis-trans isomerism.

- **Acrylonitrile cannot exhibit cis-trans isomerism**
- **This is because two H atoms (or two identical atoms) are bonded to one of the C atoms in the C=C.**

[2]

The synthesis of acrylonitrile involves a reaction between propene, ammonia, and oxygen. Besides acrylonitirile, water is also formed in the reaction.

(iii) Write a balanced equation for the synthesis of acrylonitrile.

- **$2CH_2$=$CHCH_3 + 2NH_3 + 3O_2 \rightarrow 2CH_2CHCN + 6H_2O$**

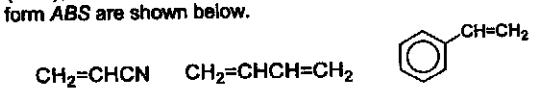
[1]

(iv) Propene, ammonia, and oxygen exist as gases during the synthesis of acrylonitrile. The reaction is catalysed by a solid catalyst, bismuth phoshphomolybdate, $Bi_9PMo_{12}O_{52}$. Outline the mode of the catalytic action for the synthesis of acrylonitrile.

The reaction involves heterogeneous catalysis.
The reactant molecules are adsorbed onto the active sites of the catalyst surface by forming weak bonds between reactant molecules and the surface catalyst atoms.
This increases the surface concentration of reactant molecules and allows them to come into proper orientation for reaction.
The adsorption also weakens the covalent bonds within the reactant molecules and adjacent reactant molecules react to form products.
The product molecule eventually desorbs from the catalyst surface.

[3]

(b) Acrylonitrile is one of the monomers used in the production of the copolymer, *Acrylonitrile Butadiene Styrene (ABS)*, which is used to manufacture *Lego™*. The structures of the 3 monomers used to form *ABS* are shown below.



(i) Butadiene can be synthesised from butanedial, $CHOCH_2CH_2CHO$ via a 2-step reaction as shown below.

Suggest the structure of compound F, and the reagents and conditions for steps 1 and 2.

- **Compound F: $CH_2(OH)CH_2CH_2CH_2OH$**
- **Step 1: $NaBH_4$(aq)**
  or $NaBH_4$ in ethanol or H_2, Pt or H_2, Ni, heat or $LiAlH_4$ in dry ether
- **Step 2: excess conc. H_2SO_4, heat**

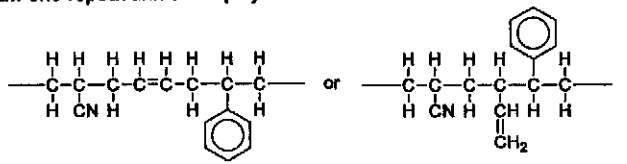
[3]

(ii) Define the term *polymer*.

- **A polymer is a macromolecule built up from monomers, with average molar mass of at least 1000, or at least 100 repeat units.**

[1]

(iii) Draw one repeat unit of the polymer *ABS*.



[1]

(iv) Explain why *Lego™* can withstand masses up to 400 kg before it breaks.

- **The presence of C=C bonds in the polymer allows the formation of strong covalent cross-links, giving it strength.**

[1]

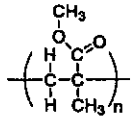
(v) Suggest and explain whether *Lego™* is likely to be recyclable.

- **As a large amount of energy is required to break the strong covalent cross links, Lego™ is not likely to be recyclable as it does not soften upon heating.**

[1]

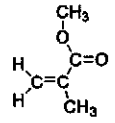
(c) Traditional *Lego™* pieces are usually brightly coloured and hence are attractive to children. In addition, the variety of colours support a wide variety of design options for constructing *Lego™* masterpieces.

Nonetheless, certain *Lego™* designs require transparent pieces. These transparent *Lego™* pieces are made of poly(methyl methacrylate). The structure of poly(methyl methacrylate) is shown below:



Poly(methyl methacrylate)

(i) Draw the monomer of poly(methyl methacrylate).

- 

[1]

(ii) Suggest if bottles made of poly(methyl methacrylate) is suitable for storing dilute acid solutions.

It is not a suitable material as the ester groups can undergo acid hydrolysis.

[1]

A group of researchers are trying to find a suitable polymer to be used as the screen for a foldable mobile phone. The screen needs to be foldable and resistance to scratches.

Four polymers, **A**, **B**, **C** and **D** have been shortlisted for this purpose. Their properties are shown below.

Table 2.1

polymer	strength	water resistance	rigidity	chemical reactivity
A	medium	low	high	low
B	strong	medium	low	medium
C	strong	high	low	low
D	low	medium	medium	medium

(iii) One of the monomers use to synthesis polymer **A** is $CH_3CH_2CH(OH)CH_2CH(OH)CH_3$.

Name the monomer used to synthesise **A**.

- **Hexane-2,4-diol**

[1]

(iv) State which polymer would be most suitable for making this foldable screen. Explain your choice by considering the properties listed in table 2.1.

- **Polymer C is most suitable for making foldable screen. This is because it has high water resistance which will prevent water getting into the phone.**
  It has a low rigidity and hence can be folded easily. The material is strong and so it will not be easily scratched. It has low chemical reactivity and so it will not undergo degradation easily when it is exposed to corrosive materials in daily life.

[2]

[Total: 20]