Class	Adm No

Candidate Name: _____

H

millennia institute

2020 End-of-Year Examinations
Pre-University 2

H1 CHEMISTRY **8873/01**

Paper 1 Multiple Choice **17th Sep 2020**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

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 Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

This question paper consists of **12** printed pages and **2** blank pages.
PartnerInLearning

1 20 cm^3 of a hydrocarbon was completely combusted in 110 cm^3 of oxygen gas. The resultant gases, when cooled to room temperature, was passed through aqueous potassium hydroxide, and the total volume decreased by 60 cm^3 to 10 cm^3.

What is the molecular formula of the hydrocarbon?

A C_2H_6 **B** C_3H_6 **C** C_3H_8 **D** C_4H_8

2 Which of the following statements about 1 mole of carbon dioxide gas is correct?

A It contains 1.81×10^{24} atoms.
B It contains 2 moles of O^{2-} ions.
C It has a relative molecular mass of 44 grams per mol
D It occupies a volume of 68.1 dm^3 at standard temperature and pressure.

3 25.0 cm^3 of 1.00 mol dm^{-3} $KMnO_4$ was reacted against 1.00 mol dm^{-3} potassium iodide, KI, in an alkaline medium to form brown precipitates MnO_2 and I_2.

What volume of potassium iodide was required for a complete reaction?

A 25.0 cm^3 **B** 37.5 cm^3 **C** 75.0 cm^3 **D** 125 cm^3

4 *Use of the Data Booklet is relevant to this question.*
Which of the following species are isoelectronic with $^{22}Na^+$?

A $^{17}O^{2-}$ **B** $^{19}F^{3-}$ **C** $^{22}Ne^+$ **D** $^{23}Mg^+$

5 When a beam of lithium-6 ions, $^6Li^+$, were passed through an electric field, the beam deflected by an angle of 6.0°.
What is the angle of deflection when a beam of $^{14}N^{3-}$ ions was passed through the same electric field?

A 0.9°
B 7.7°
C 14.0°
D 42.0°

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

The energy required for the following ionisation process of **A** was found to be +2366 kJ mol^{-1}.

$$A(g) \rightarrow A^{2+}(g) + 2e^-$$

What is the identity of element **A**?

A Magnesium
B Aluminium
C Silicon
D Phosphorus

7 Which of the following best explains why graphite has a high melting point?

A Graphite has a giant covalent structure.
B The electrons in graphite are delocalised.
C There are extensive intermolecular forces of attraction between the layers of graphite.
D The covalent bonds between carbon atoms are very strong.

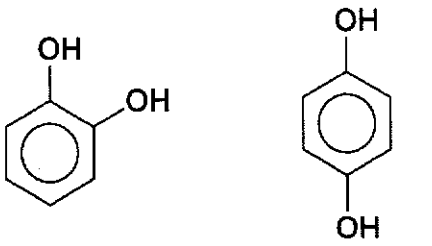
8 Which of the following has the largest bond angle?

A CCl_4 **B** NO_2 **C** SF_6 **D** SO_2

9 Which of the following compounds has the least exothermic lattice energy?

A LiF **B** MgO **C** NaCl **D** Na_2O

10 Catechol and hydroquinone have the following structures.



catechol hydroquinone

Which of the following statements are correct?

1 Hydroquinone has a higher boiling point than catechol as the –OH groups are further apart in hydroquinone than in catechol.

2 Hydroquinone has a higher melting point than catechol as the molecules of hydroquinone can stack closer together in the solid state.

3 Both catechol and hydroquinone are able to conduct electricity as they have delocalised electrons.

A 1 only

B 2 only

C 1 and 2 only

D 1, 2 and 3

11 Which of the following equations correctly represents the standard enthalpy change of neutralisation?

A $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

B $HCl(aq) + H_2O(aq) \rightarrow H_3O^+(aq) + Cl^-(aq)$

C $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

D $HCl(aq) + \frac{1}{2} Na_2CO_3(aq) \rightarrow NaCl(aq) + \frac{1}{2} H_2O(l) + \frac{1}{2} CO_2(g)$

12 Sulfur molecules exist as S_8 molecules. The enthalpy change of combustion of $S_8(s)$ to $SO_2(g)$ is -2376 kJ mol^{-1}.

What is the enthalpy change of formation of sulfur dioxide?

A $+2376$ kJ mol^{-1}

B $+297$ kJ mol^{-1}

C -297 kJ mol^{-1}

D -2376 kJ mol^{-1}

13 Isopropyl alcohol, C_3H_8O, is commonly used as a disinfectant but is highly flammable. To determine its enthalpy change of combustion, 6 g of isopropyl alcohol was completely burnt under a copper can filled with 1000 cm^3 of water and its temperature rose by 47.9 °C.

Assuming no heat loss to surroundings, what is the enthalpy change of combustion of isopropyl alcohol, in **kJ mol^{-1}**?
[relative molecular mass of C_3H_8O = 60.0]

A $-\frac{1000 \times 4.18 \times 47.9}{0.1}$

B $-\frac{4.18 \times 47.9}{0.1}$

C $-\frac{4.18 \times 47.9}{6}$

D $-\frac{1000 \times 4.18 \times 47.9}{60}$

14 Chlorate ions, ClO^-, dissolved into swimming pool water can react with chloride ions, Cl^-, to release the characteristic smell of chlorine gas.

$$ClO^- + Cl^- + 2H^+ \rightarrow Cl_2 + H_2O$$

In an experiment to find out the rate in which chlorine gas is released, the concentrations were varied and the following data was collected.

Experiment	$[ClO^-]$ / mol dm^{-3}	$[Cl^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} h^{-1}
1	0.10	0.10	0.10	1.3×10^{-3}
2	0.20	0.10	0.10	2.6×10^{-3}
3	0.20	0.20	0.20	5.2×10^{-3}
4	0.20	0.20	0.40	5.2×10^{-3}

Which of the following statements are true?

1 The order of reaction with respect to $[ClO^-]$ is one

2 The order of reaction with respect to $[Cl^-]$ is one

3 The order of reaction with respect to $[H^+]$ is zero

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

15 The reaction between $(CH_3)_3Br$ and OH^- is first order with respect to the concentration of $(CH_3)_3Br$. In one experiment, it was found that 2 minutes was taken for the concentration of $(CH_3)_3Br$ to decrease from 1.0 mol dm^{-3} to 0.25 mol dm^{-3}.

How much time does it take for the concentration of $(CH_3)_3Br$ to decrease to 0.25 mol dm^{-3} if the starting concentration was doubled to 2.0 mol dm^{-3}?

A 1 minute
B 2 minutes
C 3 minutes
D 4 minutes

16 Which of the following affects the equilibrium position of the reversible reaction below?

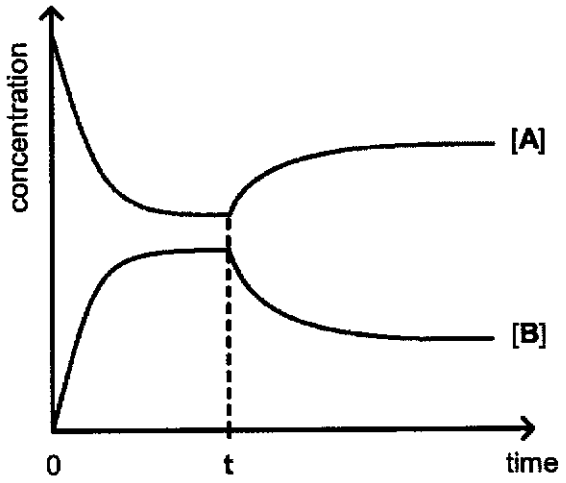
$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H < 0$$

1 Concentration
2 Pressure
3 Temperature
4 Catalyst

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

17 The concentration-time graph of a reversible reaction is shown below.

$$\mathbf{A}(g) \rightleftharpoons \mathbf{B}(g)$$



What is a possible change made to the reaction at time t?

A Change in concentration of reactant

B Change in volume of the reaction vessel

C Change in surface area of reactants

D Change in temperature of the system

18 The thermal decomposition of ammonium chloride is an endothermic reaction.

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

A 0.1 mol sample of NH_4Cl was placed in an evacuated gas syringe and allowed to reach equilibrium at room temperature and pressure, during which the total volume increased by 1440 cm^3. It was found that 0.07 mol of the NH_4Cl sample remained.

Calculate the value of the equilibrium constant, K_c, for the decomposition reaction.

A 4.34×10^{-4}

B 9.00×10^{-4}

C 1.00×10^{-2}

D 2.08×10^{-2}

19 Which of the following underlined species is acting as an Arrhenius acid?

1 $\underline{H_2O}(l) + NH_3(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$

2 $\underline{AlCl_3}(g) + NH_3(g) \rightarrow AlCl_3{\cdot}NH_3(s)$

3 $\underline{HCl}(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 3 only

20 Carbonic acid is known as a diprotic acid as it can dissociate twice in water.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq) \qquad K_{a1}$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq) \qquad K_{a2}$$

Given that $K_{a1} > K_{a2} > K_w$, which of the following species is the strongest acid?

A H_2CO_3

B HCO_3^-

C CO_3^{2-}

D H_2O

21 Which of the following has a pH of 1?

1 A solution of 1 mol dm^{-3} of $HCl(aq)$

2 A solution of 0.1 mol dm^{-3} $H_2SO_4(aq)$

3 A solution of which the hydroxide ion concentration is 10^{-13} mol dm^{-3}.

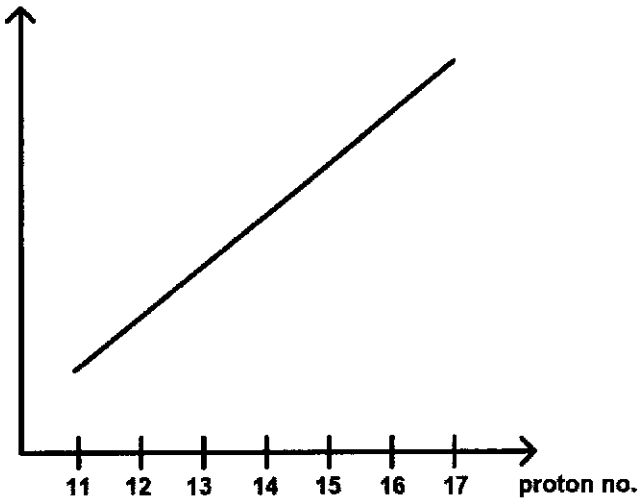
A 2 only

B 1 and 3 only

C 2 and 3 only

D 3 only

22 The following graph shows a certain trend of Period 3 elements.



Which of the following is the correct label for the *y*-axis?

A atomic radius
B electronegativity
C first ionisation energy
D ionic radius

23 Which of the following elements form chlorides that will produce an acidic solution when dissolved in water?

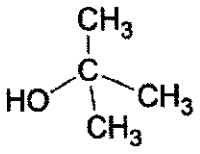
1 sodium
2 magnesium
3 aluminium
4 phosphorus

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

24 Which of the following statements helps to explain why hydrogen bromide is unstable to heat and breaks down but not hydrogen fluoride?

A The bond energy of the F–F bond is higher than that of the Br–Br bond
B The bond length of the F–F bond is shorter than that of the Br–Br bond
C The bond energy of the H–F bond is higher than that of the H–Br bond
D The bond length of the H–F bond is longer than that of the H–Br bond

25 Which of the following is the IUPAC name for the following structure of $C_4H_{10}O$?



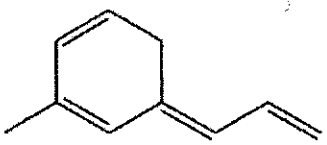
A 2-methylpropan-2-ol

B 2-hydroxypropane

C 2-hydroxypropanol

D trimethylmethanol

26 How many *cis-trans* isomers does the following compound exhibit?



A 2

B 4

C 8

D 16

27 Which of the following reactions will **not** give ethene, $H_2C{=}CH_2$, as the product?

1 CH_3CH_2Br, ethanolic KOH, heat

2 CH_3CH_2OH, $H_2SO_4(aq)$, heat

3 CH_3CH_3, excess O_2, heat

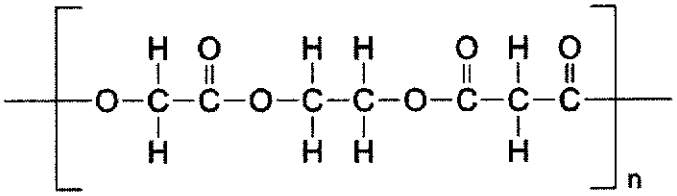
A 1 only

B 3 only

C 1 and 2 only

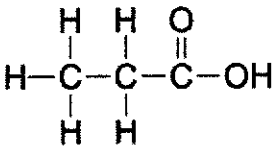
D 2 and 3 only

28 The following shows a repeating unit of a polymer.



Which of the following are possible identities of the monomers?

1



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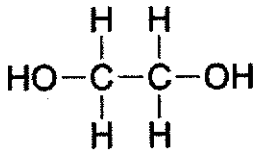

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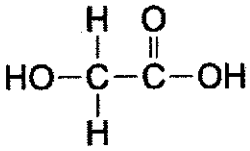

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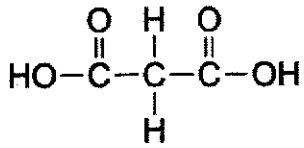


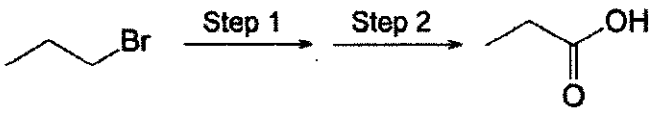
A 1 and 2 only

B 2 and 3 only

C 3 and 4 only

D 2, 3 and 4 only

29 1-bromopropane can undergo a two-step reaction to form propanoic acid.



1-bromopropane propanoic acid

What are the possible reagent and conditions for steps 1 and 2?

	Step 1	Step 2
A	alkaline $KMnO_4$, cold	aqueous NaOH, heat
B	aqueous KOH, heat	acidified $KMnO_4$, heat
C	NaOH in ethanol, heat	acidified $KMnO_4$, heat
D	$LiAlH_4$, r.t.	HBr, r.t.

30 Car tyres are made from a type of polymer. They are strong enough to withstand high pressures and the heavy weight of the car, yet are able to deform slightly when the wheels encounter bumps in the road.

Which of the following statements are **incorrect** about the polymer in car tyres?

A It is a thermoset

B There are strong covalent crosslinks

C It can be remoulded when heated to a high temperature

D Used car tyres are usually incinerated and not recycled

END OF PAPER 1

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Class Adm No

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millennia institute

2020 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **16 Sep 2020**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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

Answer **all** questions in Section **A** and answer **any one** of the two questions in Section **B**.

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

A Data Booklet is provided.

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

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

Question	1	2	3	4	Section B	Total
Marks	/11	/18	/14	/17	/20	/80

For Examiners' Use

Section A

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

1 The Chernobyl disaster was one of the worst nuclear disaster in history near the city of Pripyat at Ukraine. The accident started during a safety test on a reactor. On one of the tests, a large amount of energy was suddenly released, rupturing the reactor core in a highly destructive steam explosion.

The reaction involved in the first explosion reaches dynamic equilibrium as shown below, involving two flammable gases, $H_2(g)$ and $CO(g)$.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131 \text{ kJ mol}^{-1}$$

(a) **(i)** Define *dynamic equilibrium*. [1]

.....

.....

(ii) State *Le Chatelier's principle*. [1]

.....

.....

(b) The explosion was due to the increased outflow of water from the reactor. However, the rate of heat removal from the reactor was slowed down due to low water level in the steam separator and that caused a large increase in temperature.

The high temperature and the surplus of steam produced caused the first explosion as shown in the equation above. With the containment broken, air began to enter the reactor. Graphite reacted with the air to cause a second explosion. Following the days of explosion, liquid nitrogen was injected to reduce further explosion risk.

(i) Explain why the high temperature of the reactor and the surplus of steam caused the first explosion. [3]

.....

.....

.....

.....

(ii) Suggest, with the aid of an equation, how the second explosion could have occurred. [2]

.....

.....

.....

(c) Suggest the purpose of injecting liquid nitrogen into the reactor. [1]

.....

.....

(d) (i) Write the expression for the equilibrium constant, K_c for the reaction involved in the first explosion. [1]

(ii) At 730 °C, the percentage conversion of steam was found to be 30%.
Given that the initial concentration of steam was 0.1 mol dm^{-3}, calculate the value of K_c at 730 °C. [2]

[Total: 11]

2 **Figure 1** shows the set-up of how values of energy changes of combustion for different substances can be obtained in a school laboratory.

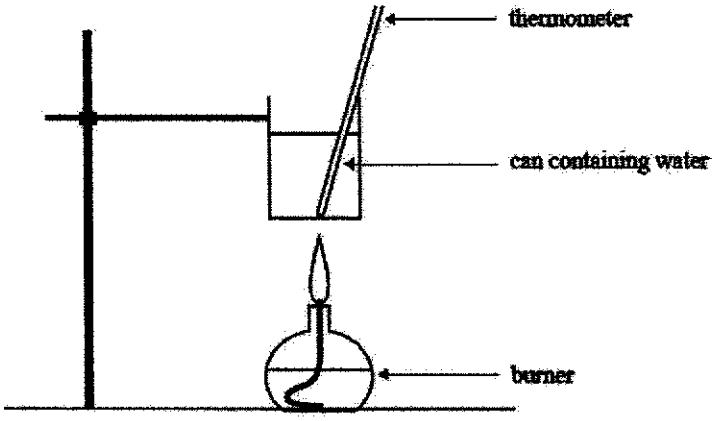


Figure 1

The higher heating value (HHV) can be measured by knowing the initial mass of the fuel sample. HHV of a fuel is defined as the amount of heat released per mass of fuel once the fuel is combusted and the products have returned to the temperature of 25 °C.

The HHV of solid hexanedioic acid, $C_6H_{10}O_4(s)$, was investigated and the data collected is found in **Table 1** and **Figure 2**.

Table 1

Mass of empty beaker / g	137.5
Mass of beaker and hexanedioic acid / g	140.1
Volume of water / cm^3	400

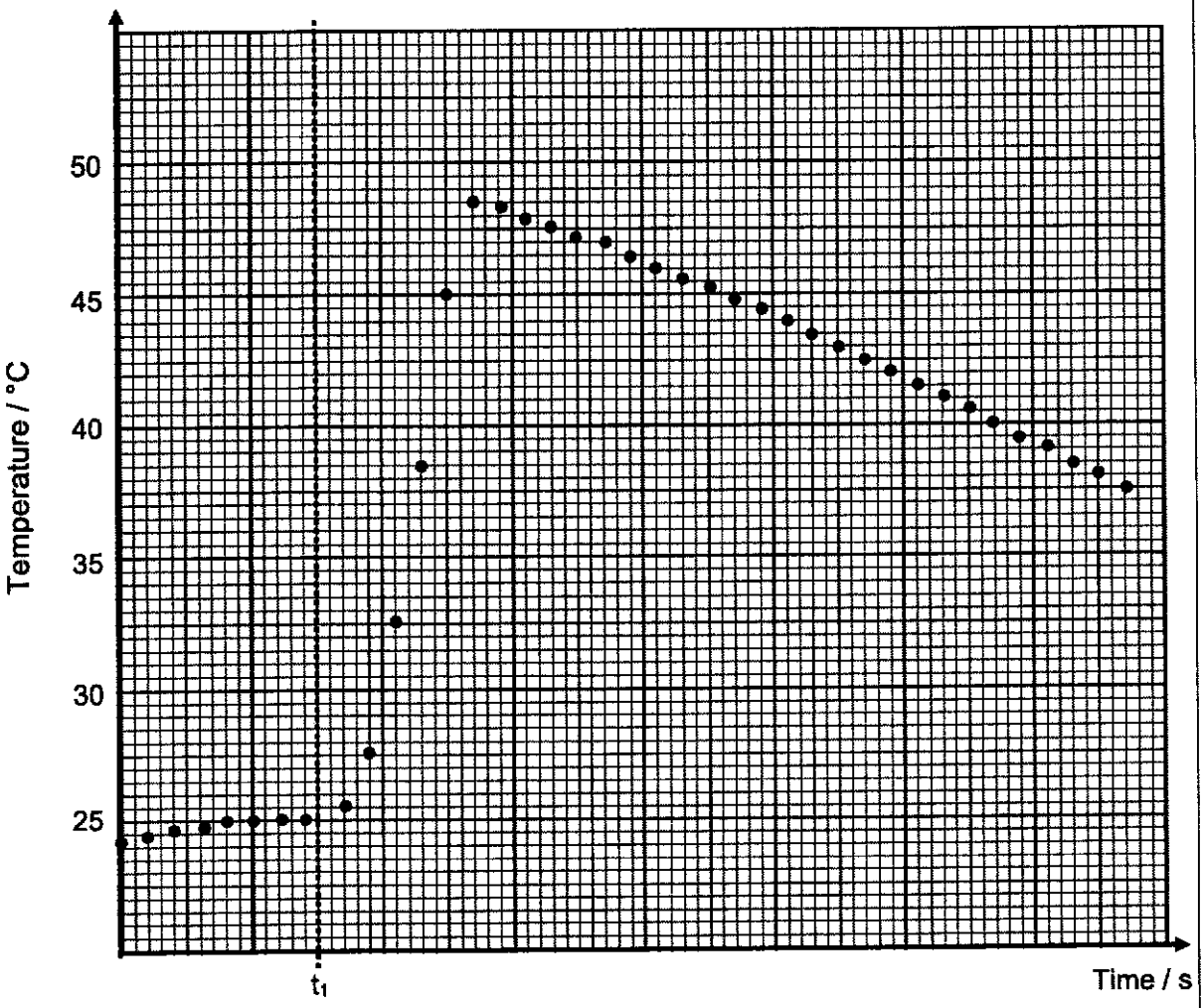


Figure 2

(a) **(i)** Write the equation for the combustion of 1 mole of solid hexanedioic acid, including state symbols. [2]

.....

(ii) **Figure 2** shows the cooling curve of the combustion of hexanedioic acid. In order to determine the maximum temperature, the cooling portion of the curve is extrapolated to the point at t_1.

Determine the maximum change in temperature based on **Figure 2** by extrapolation. [2]

maximum change in temperature:.....

(iii) Calculate the heat evolved from the reaction. [1]

(iv) Hence, calculate the higher heating value (HHV), in kJ g^{-1}, of hexanedioic acid. [1]

(v) State and explain the impact on the HHV value calculated in **(a)(iv)** if extrapolation was not carried out. [2]

.....

.....

.....

(vi) Suggest a data which is necessary to obtain an accurate HHV value if extrapolation was not carried out. [1]

.....

.....

(b) Nylon-66 is a polymer which is most common for textile and plastic industries. It is made from the two monomers, hexanedioic acid and 1,6-diaminohexane.

(i) Draw the skeletal formula of the two monomers. [2]

hexanedioic acid	1,6-diaminohexane.

(ii) Draw one repeat unit of Nylon-66. [1]

(iii) State the type of polymerisation that produces Nylon-66 and name the bond formed during this polymerisation. [2]

.....

.....

(iv) Based on your answer in **(b)(iii)**, suggest and explain the disadvantage of using nylon-66 to make fabric, in terms of bonding, with the aid of a diagram. [3]

.....

.....

(v) Given that nylon is a thermoplastic polymer, state one property which makes it a good material to be used in clothings. [1]

.....

.....

[Total:18]

3 Aluminium makes up about 8% of the Earth's crust by mass, where it is the third most abundant element and also the most abundant metal.

(a) State the number of protons, neutrons and electrons in an atom of ^{27}Al. [1]

.....

(b) **(i)** State the full electronic configurations of an aluminium ion and $^{27}_{13}Al^{3+}$ and $^{19}_{9}F^{-}$. [1]

$^{27}_{13}Al^{3+}$ .....

$^{19}_{9}F^{-}$ .....

(ii) Based on the answer in **(b)(i)**, state the relationship between the two ions. [1]

.....

(iii) Draw labelled lines to Figure 3 to represent the path of beams of aluminium ions and fluoride ions in an electric field, showing the relative angle of each species.

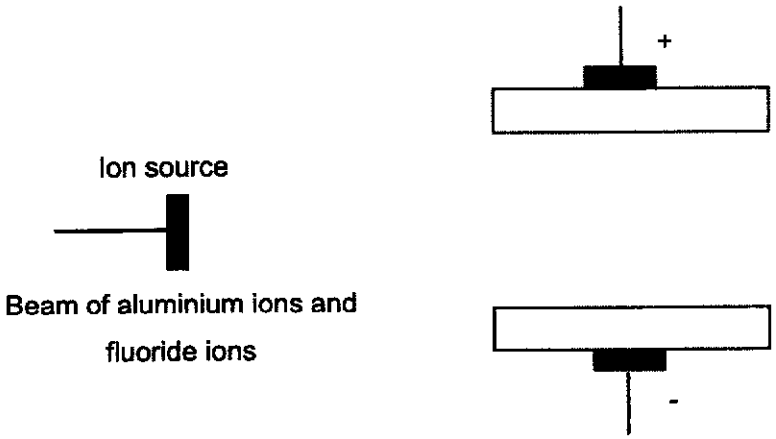


Figure 3

[2]

(c) Magnesium and aluminium react with chlorine to form magnesium chloride and aluminium chloride respectively.

(i) Write equations to show what happens when samples of each of these chlorides are added separately to water. In each case, state the likely pH of the resulting solution. [3]

.....

.....

.....

.....

.....

.....

(ii) Account for the difference in pH of magnesium chloride and aluminium chloride. [2]

.....

.....

.....

(d) A diagonal relationship exists between certain pairs of diagonally adjacent elements in the second and third periods of the Periodic Table. An example of a pair of such elements is Be and Al.

(i) Based on the position in the Periodic Table, describe the structure and bonding of beryllium chloride. [2]

.....

.....

.....

(ii) Predict the pH of beryllium chloride and explain the reason. [2]

.....

.....

[Total: 14]

Question 4 starts on the next page.

4 (a) Photochemical oxidation of arsenic, As(III) ion, to the less toxic As(V) ion, using peroxydisulfate ions, $S_2O_8^{2-}$, as the oxidising agent proved to be a simple and efficient method.

The oxidation takes place according to the following equation.

$$S_2O_8^{2-} + H_3AsO_3 + H_2O \rightarrow 2SO_4^{2-} + H_3AsO_4 + 2H^+$$

20 cm^3 of 0.5 mol dm^{-3} solution of potassium peroxydisulfate was mixed with 200 cm^3 of a solution of arsenic(III) acid, H_3AsO_3 of the same concentration. At fixed time intervals, small portions of the reaction mixture were analysed to determine the concentration of peroxydisulfate ion.

The results are shown in **Table 2.**

Table 2

Time / min	$[S_2O_8^{2-}]$ / mol dm^{-3}
0	0.50
4	0.38
8	0.27
12	0.20
16	0.16
20	0.11

(i) Write the ion-electron equations for the reaction in an acidic medium. [2]

Reduction: .....

Oxidation: .....

(ii) On **Figure 4**, plot the graph of the concentration of peroxydisulfate ion against time.

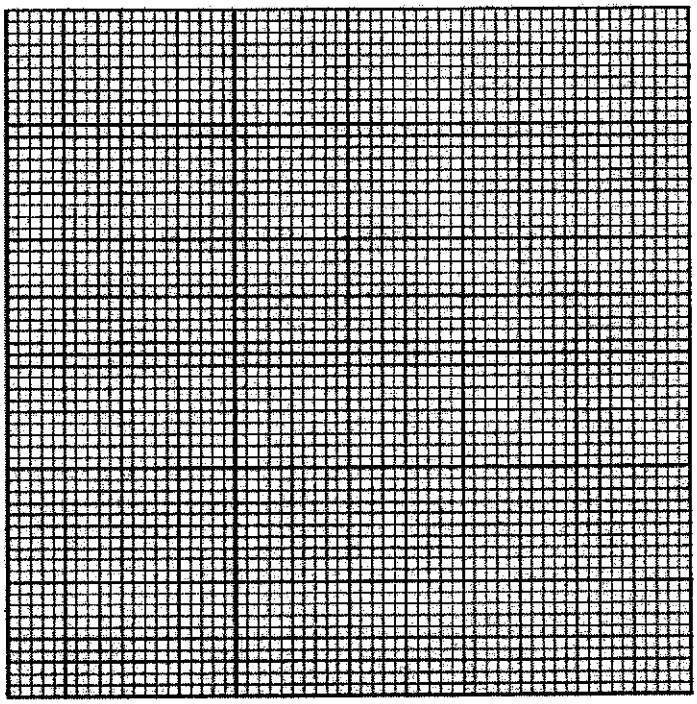


Figure 4

[2]

(iii) Hence, deduce the order of reaction with respect to potassium peroxydisulfate based on **(a)(ii)**. [2]

(iv) The experiment was repeated using 20 cm^3 of H_3AsO_3 and 20 cm^3 of $K_2S_2O_8$ at different concentrations.

Table 3

$[S_2O_8^{2-}]$ / mol dm^{-3}	$[H_3AsO_3]$ / mol dm^{-3}	Initial Rate / mol dm^{-3} min^{-1}
0.5	1.0	0.120
0.5	0.5	0.060

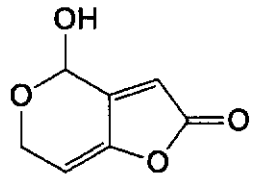
Using the information given in Table 3, deduce the order of reaction with respect to H_3AsO_3. [1]

(v) Hence, write the rate equation. [1]

.....

(vi) Calculate the value of rate constant, including its units. [1]

(b) The Singapore Food Agency (SFA) has recalled Pure Tassie Organic Apple & Raspberry Juice on 30 April 2020 as the samples were found to contain patulin at levels exceeding the maximum limit as stated in the Singapore Food Regulations.



Patulin

The lethal dose of patulin on human is 25 mg kg^{-1} body weight. The maximum limit for patulin in fruit juice as stated in the Singapore Food Regulations is 50 parts per billion (ppb).

[1 ppb = 10^{-6} g per litre]

(i) A sample of 1.5 litre bottle of apple juice from another brand was found to contain 0.047 mg of patulin.

Determine if this sample is within the safety limit suggested by the Singapore Food Regulations. [2]

(ii) Determine the maximum number of bottles of apple juice that a 50 kg woman can consume before the lethal dose kicks in. [2]

(iii) The purity of patulin can be determined by reacting patulin with aqueous bromine or phosphorus pentachloride.

Name the type of reaction between patulin and aqueous bromine. [1]

.....

(iv) Draw the structure of the product for the reaction between patulin and aqueous bromine. [1]

(v) $ROH + PCl_5 \rightarrow RCl + POCl_3 + HCl$ where ROH refers to patulin

Calculate the percentage purity of a sample containing patulin if 2.45 g of the sample reacts with 0.015 mol of PCl_5. [M_r of patulin = 154.0] [2]

[Total: 17]

END OF SECTION A

Section B

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

For Examiners' Use

5 (a) Chlorous acid, $HClO_2$, is a weak acid which is unstable and will be converted to hypochlorous acid, HClO, and chloric acid, $HClO_3$.

$$2HClO_2 \rightarrow HClO + HClO_3$$

(i) State the oxidation states of chlorine in

$HClO_2$: .....

HClO : .....

$HClO_3$: ..... [2]

(ii) State the type of reaction which chlorous acid undergoes. Explain your reasoning. [2]

.....

.....

.....

(iii) With the aid of an equation, explain what is meant by weak acid, using $HClO_2$ as an example. [1]

.....

.....

(iv) Write an expression for the acid dissociation constant, K_a, for $HClO_2$. [1]

(v) The pH of a 2.0 mol dm^{-3} solution of $HClO_2$ is 0.83.
Calculate the concentration of H^+ ions. [1]

(vi) Given that $[H^+] = [ClO_2^-]$, calculate the value of K_a for $HClO_2$. [1]

(vii) A mixture of chlorous acid and its salt, sodium chlorite forms a buffer solution. Explain what is meant by a buffer solution. [1]

.....

(viii) Write two equations to show how a mixture of chlorous acid and sodium chlorite act as a buffer system. [2]

.....

.....

(b) Concentrated sulfuric acid plays an important role in many organic reactions. Other than acting as an acid, concentrated sulfuric acid also catalyses the conversion of alcohol to alkene.

(i) Define the term *catalyst*. [1]

.....

.....

(ii) Explain how the concentrated sulfuric acid catalyst affects the rate of reaction, with the aid of a labelled Boltzmann distribution curve. [3]

.....

.....

.....

.....

(iii) State the type of reaction that an alcohol undergoes to form an alkene. [1]

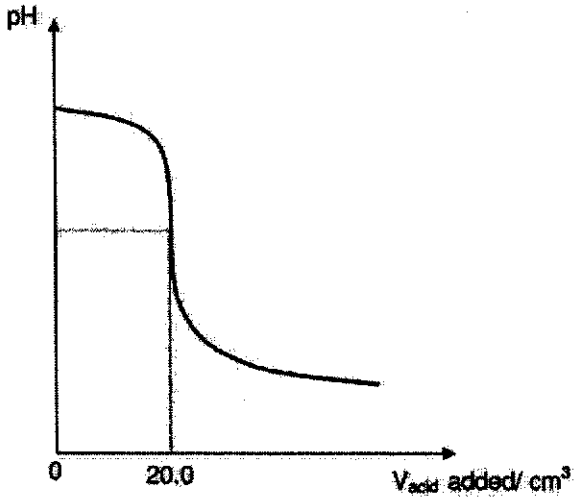
.....

(iv) Pentan-2-ol forms alkene with the presence of concentrated sulfuric acid and heat. Name and draw the structures of all the possible products and their isomers, where relevant. [4]

[Total: 20]

For Examiners' Use

6 (a) Potassium hydroxide, KOH, is a strong base. When 30.0 cm^3 of 0.125 mol dm^{-3} KOH was titrated against an aqueous solution of ethanoic acid, CH_3COOH, the following graph was obtained.



(i) Calculate the pH of a 0.125 mol dm^{-3} solution of KOH. [2]

(ii) Calculate the concentration of the ethanoic acid solution. [2]

(iii) Explain, in terms of structure and bonding, why potassium hydroxide is a solid while ethanoic acid is a liquid at room temperature. [2]

.....

.....

.....

(iv) Suggest and explain how the boiling point of calcium hydroxide compares with that of potassium hydroxide. [3]

.....

.....

.....

.....

.....

(b) (i) Identify the Period 3 element that forms a sparingly soluble amphoteric oxide. [1]

.....

(ii) Write an ionic equation to illustrate the reaction between the oxide of the element identified in (b)(i) and aqueous sodium hydroxide. [1]

.....

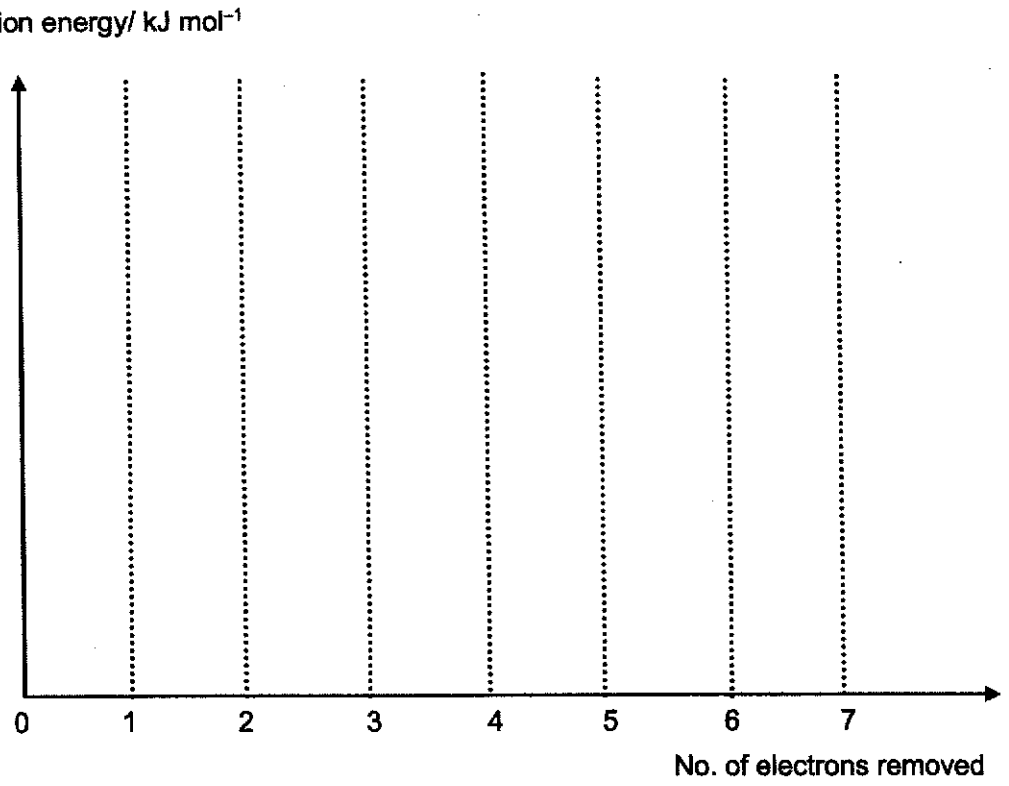
(c) (i) Explain why the ionic radius of phosphorus is larger than its atomic radius. [1]

.....

.....

.....

(ii) On the axis below, sketch the graph for the first seven ionisation energies of phosphorus against the number of electrons removed. [2]



(iii) Explain why the first ionisation energy of phosphorus is higher than that of silicon. [2]

.....

.....

.....

(d) (i) I_2 is not very soluble in water. However when I_2 reacts with KI(aq), it forms highly soluble KI_3.

Draw the dot and cross diagram of the I_3^- ion (including all lone pairs of electrons), and deduce its shape and bond angle. [2]

Shape:..... Bond angle:.....

(ii) Explain why I_3^- ion is more soluble in water than I_2. [2]

.....

.....

.....

.....

.....

[Total: 20]

END OF PAPER 2

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BP~361

Class | Adm No

Candidate Name: _____

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millennia institute

2020 End-of-Year Examinations
Pre-University 2

H1 CHEMISTRY **8873/01**

Paper 1 Multiple Choice **17th Sep 2020**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

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 Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

This question paper consists of ■ printed pages and ■ blank pages.
PartnerInLearning
402

1 20 cm^3 of a hydrocarbon was completely combusted in 110 cm^3 of oxygen gas. The resultant gases, when cooled to room temperature, was passed through aqueous potassium hydroxide, and the total volume decreased by 60 cm^3 to 10 cm^3.

What is the molecular formula of the hydrocarbon?

A C_2H_6 **B** C_3H_6 [redacted] **D** C_4H_8

$$C_xH_y + (x + {}^y/_4)O_2 \rightarrow xCO_2 + ({}^y/_2)H_2O$$

Note 1: when gases are cooled to room temperature, H_2O is condensed to a liquid and does not contribute to total volume of resultant gases.
Note 2: passing the gases through potassium hydroxide (base) will remove acidic gases, in this case CO_2 (60 cm^3) leaving only neutral O_2 (10 cm^3) behind.

The key to answering this question is to find x and y in terms of [redacted] (compared with the original 20 cm^3 hydrocarbon).

C_xH_y + $(x + {}^y/_4)O_2$ → xCO_2 + $({}^y/_2)H_2O$

Used 110 – 10 = 100cm^3 x = [redacted] = **3** ignored as liquid

$(x + {}^y/_4)$ = [redacted] = 5

Since $x = 3$, $(3 + {}^y/_4) = 5$

$y = (5 - 3) \times 4 = \underline{8}$

2 Which of the following statements about 1 mole of carbon dioxide gas is correct?

A [redacted]

B It contains 2 moles of O^{2-} ions.

C It has a relative molecular mass of 44 grams per mol

D It occupies a volume of 68.1 dm^3 at standard temperature and pressure.

Avogadro's constant, 1 mole = 6.02×10^{23}
Each CO_2 molecule contains 1 C atom and 2 O atoms → total 3 atoms.
1 mole of CO2 will then contain 3 moles of atoms.
3 moles = $3 \times 6.02 \times 10^{23} = 1.806 \times 10^{24}$ atoms (3 s.f. will become 1.81×10^{24})

B is incorrect as the C and O atoms are covalently bonded and do not exist as ions.
C is incorrect as relative molecular mass does not have units. It is molar mass that has units of g mol^{-1} (grams per mol)
D is incorrect as 1 mole of any gas occupies 22.7 dm^3 at s.t.p.

3 25.0 cm^3 of 1.00 mol dm^{-3} $KMnO_4$ was reacted against 1.00 mol dm^{-3} potassium iodide, KI, in an alkaline medium to form brown precipitates MnO_2 and I_2.

What volume of potassium iodide was required for a complete reaction?

A 25.0 cm^3 **B** 37.5 cm^3 [redacted] **D** 125 cm^3

Oxidation number of Mn in MnO_4^- goes from +7 to +4 in MnO_2, meaning it **gains 3 e^-**.
Oxidation number of I in I^- goes from –1 to 0 in I_2, meaning it **loses 1 e^-** for each I^-.
Thus **based on the amt of electrons** transferred, mol ratio of MnO_4^- : I^- = 1 :3

Volume of KI = $[(\frac{25.0}{1000}) \times 1.00 \times \frac{3}{1} + 1.00] \times 1000 = 25.0 \times 3 = \underline{75.0\ cm^3}$

Vol $KMnO_4$ in dm^3 · conc $KMnO_4$ · mol ratio · conc KI · $dm^3 \rightarrow cm^3$

Alternatively, refer to the equation of acidic medium to find the number of electrons gained by MnO_4^-.
[H]: $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$
You may convert to alkali medium if this was a structured question, but this is not necessary.
[H]: $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$ ×2
[O]: $2I^- \rightarrow I_2 + 2e^-$ ×3
Overall: $2MnO_4^- + 4H_2O + 6I^- \rightarrow 2MnO_2 + 8OH^- + 3I_2$
You will still arrive at the conclusion of mol ratio of MnO_4^- : I^- = 1 :3

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

Which of the following species are isoelectronic with $^{22}Na^+$?

[redacted] **B** $^{19}F^{3-}$ **C** $^{22}Ne^+$ **D** $^{23}Mg^+$

Ignore the mass number given on the top left corner of the chemical symbol.
Number of electrons = number of protons ± the electrons it gained/lost
Number of electrons in $^{22}Na^+$ = 11 – 1 = 10 e^-

Number of electrons in $^{17}O^{2-}$ = 8 + 2 = 10 e^- ✓
Number of electrons in $^{19}F^{3-}$ = 9 + 3 = 12 e^-
Number of electrons in $^{22}Ne^+$ = 10 – 1 = 9 e^-
Number of electrons in $^{23}Mg^+$ = 12 – 1 = 11 e^-

5 When a beam of lithium-6 ions, $^6Li^+$, were passed through an electric field, the beam deflected by an angle of 6.0°.

What is the angle of deflection when a beam of $^{14}N^{3-}$ ions was passed through the same electric field?

A 0.9°

[redacted]

C 14.0°

D 42.0°

The angle of deflection is $\propto \frac{\text{charge}}{\text{mass}}$

Compared to $^6Li^+$, charge of $^{14}N^{3-}$ is three times as large, but mass is $\frac{14}{6}$ times.

Angle of deflection of $^{14}N^{3-}$ = $6° \times \left(\frac{3}{(\frac{14}{6})}\right) = 7.7°$

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

The energy required for the following ionisation process of **A** was found to be +2366 kJ mol^{-1}.

$$A(g) \rightarrow A^{2+}(g) + 2e^-$$

What is the identity of element **A**?

A Magnesium

B Aluminium

[redacted]

D Phosphorus

Based on the equation, the energy needed is the sum of the 1st and 2nd ionisation energies. By referring to the Data Booklet for the 4 elements listed, the sum of the 1st and 2nd I.E. are as follows:

Mg	738	+	1450	= +2186
Al	577	+	1820	= +2397
Si	786	+	1580	= +2366 ✓
P	1060	+	1900	= +2960

7 Which of the following best explains why graphite has a high melting point?

A Graphite has a giant covalent structure.

B The electrons in graphite are delocalised.

C There are extensive intermolecular forces of attraction between the layers of graphite.

[redacted]

The C-C covalent bonds have strong electrostatic forces of attraction between the positive nuclei of C atoms and shared pair of electrons (localised in sigma bonds) and require large amounts of energy to overcome.

Although A is true, it does not explain the bonding.

B: Although graphite has delocalised electrons (which helps it to conduct electricity due to mobile charge carriers), BUT this does not help to explain the bonding.

C: Although the intermolecular forces (instantaneous dipole-induced dipole) are extensive, it is still weak enough for the layers to easily slide across each other and for the layers to separate. Hence, the id-id in graphite is not the dominant force of attraction that is being overcome during melting and not the contributing factor to the high melting point.

8 Which of the following has the largest bond angle?

A CCl_4 [redacted] C SF_6 D SO_2

CCl_4 has 4 bond pairs and 0 lone pairs → tetrahedral 109.5°
SF_6 has 6 bond pairs and 0 lone pairs → octahedral 90°
SO_2 has 2 bond pairs and 1 lone pair → bent, <120°
as lone pair-bond pair repulsion is > bond pair-bond pair repulsion.
NO_2 has 2 bond pairs and 1 lone electron → bent, > 120°
The repulsion by the 1 lone electron will be less than the repulsion of 1 pair of electrons (two electrons), hence the bond pairs will spread out further.

9 Which of the following compounds has the least exothermic lattice energy?

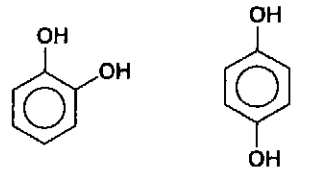
A LiF B MgO [redacted] D Na_2O

Lattice energy is always exothermic.
Least exothermic means the smallest in value or magnitude.

Magnitude of lattice energy $\propto \left|\frac{q^+.q^-}{r_+ + r_-}\right|$

Out of all the cations, Na^+ has the largest cationic radius and smallest charge.
Out of all the anions, Cl^- has the largest anionic radius and smallest charge.
Hence, magnitude of lattice energy of NaCl will be the smallest.

10 Catechol and hydroquinone have the following structures.



catechol hydroquinone

Which of the following statements are correct?

[redacted]

3 Both catechol and hydroquinone are able to conduct electricity as they have delocalised electrons.

A 1 only

B 2 only

[redacted]

D 1, 2 and 3

1: intramolecular hydrogen bonding in catechol reduces the intermolecular hydrogen bonding between catechol molecules, thus less energy needed → lower melting point for catechol
2: hydroquinone is more symmetrical than catechol, the molecules can stack more closely in the solid state and the IMF (id-id and H-bonding) attraction will be stronger.
3: the electrons are only delocalised across 6 carbon atoms and are restricted to within the molecule – electrons do not move from one molecule to the next, and hence, not considered to be mobile charge carrers.

11 Which of the following equations correctly represents the standard enthalpy change of neutralisation?

[Turn over

A $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

B $HCl(aq) + H_2O(aq) \rightarrow H_3O^+(aq) + Cl^-(aq)$

[redacted]

D $HCl(aq) + \frac{1}{2} Na_2CO_3(aq) \rightarrow NaCl(aq) + \frac{1}{2} H_2O(l) + \frac{1}{2} CO_2(g)$

The standard enthalpy change of neutralisation is defined as the heat energy change when 1 mol of water is formed from the reaction between an acid and a base.

Hence, option C is the correct answer as all the other equations do not form 1 mol of water

12 Sulfur molecules exist as S_8 molecules. The enthalpy change of combustion of $S_8(s)$ to $SO_2(g)$ is -2376 kJ mol^{-1}.

What is the enthalpy change of formation of sulfur dioxide?

A +2376 kJ mol^{-1}

B +297 kJ mol^{-1}

[redacted]

D -2376 kJ mol^{-1}

The enthalpy change of combustion of S_8 to SO_2 involves 8 mol of SO_2 being formed.

$$S_8(s) + 8O_2(g) \rightarrow 8SO_2(g)$$

Hence, the ΔH when 1 mol of $SO_2(g)$ is formed is just $-2376 \div 8 = -297$ kJ mol^{-1}

13 Isopropyl alcohol, C_3H_8O, is commonly used as a disinfectant but is highly flammable. To determine its enthalpy change of combustion, 6 g of isopropyl alcohol was completely burnt under a copper can filled with 1000 cm^3 of water and its temperature rose by 47.9 °C.

Assuming no heat loss to surroundings, what is the enthalpy change of combustion of isopropyl alcohol, in **kJ mol^{-1}**?

[relative molecular mass of C_3H_8O = 60.0]

A $-\dfrac{1000 \times 4.18 \times 47.9}{0.1}$

[redacted]

C $-\dfrac{4.18 \times 47.9}{6}$

D $-\dfrac{1000 \times 4.18 \times 47.9}{60}$

$q = mc\Delta T = (1000)(4.18)(47.9)$ J (units in Joules)

amount of C_3H_8O burned = 6.0 / 60.0 = 0.1 mol

ΔH = -q / amt LR = [redacted] J mol^{-1} = [redacted] kJ mol^{-1}

= [redacted] kJ mol^{-1}

14 Chlorate ions, ClO^-, dissolved into swimming pool water can react with chloride ions, Cl^-, to release the characteristic smell of chlorine gas.

$$ClO^- + Cl^- + 2H^+ \rightarrow Cl_2 + H_2O$$

In an experiment to find out the rate in which chlorine gas is released, the concentrations were varied and the following data was collected.

Experiment	$[ClO^-]$ / mol dm^{-3}	$[Cl^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} h^{-1}
1	0.10	0.10	0.10	1.3×10^{-3}
2	0.20	0.10	0.10	2.6×10^{-3}
3	0.20	0.20	0.20	5.2×10^{-3}
4	0.20	0.20	0.40	5.2×10^{-3}

Which of the following statements are true?

1 The order of reaction with respect to $[ClO^-]$ is one

2 The order of reaction with respect to $[Cl^-]$ is one

3 The order of reaction with respect to $[H^+]$ is zero

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

[redacted]

Rate equation:
Rate = $k [ClO^-]^x [Cl^-]^y [H^+]^z$

Comparing expts 1 and 2,
when **$[ClO^-]$ doubled** from 0.10 to 0.20 (times 2) while $[Cl^-]$ & $[H^+]$ remained the same,
initial rate also doubled (times 2) from 1.3 to 2.6×10^{-3}.
Since rate $\propto [ClO^-]^x$, (2) = $[2]^x$, x = 1 → **first order** w.r.t. $[ClO^-]$ → **option 1 is true.**

Comparing expts 3 and 4,
When **$[H^+]$ doubled** from 0.20 to 0.40 (times 2) while $[Cl^-]$ & $[ClO^-]$ remained the same,
initial rate remained the same (times 1) at 5.2×10^{-3}.
Since rate $\propto [H^+]^z$, (2) = $[1]^z$, z = 0 → **zero order** w.r.t. $[H^+]$ → **option 3 is true.**

Comparing expts 2 and 3,
When **$[Cl^-]$ doubled** from 0.10 to 0.20 (times 2) while $[ClO^-]$ remained the same, and it is already established that rate is independent of $[H^+]$ (zero order)
initial rate also doubled (times 2) from 2.6 to 5.2×10^{-3}.
Since rate $\propto [Cl^-]^y$, (2) = $[2]^y$, y = 1 → **first order** w.r.t. $[Cl^-]$ → **option 2 is true.**

15 The reaction between $(CH_3)_3Br$ and OH^- is first order with respect to the concentration of $(CH_3)_3Br$. In one experiment, it was found that 2 minutes was taken for the concentration of $(CH_3)_3Br$ to decrease from 1.0 mol dm^{-3} to 0.25 mol dm^{-3}.

How much time does it take for the concentration of $(CH_3)_3Br$ to decrease to 0.25 mol dm^{-3} if the starting concentration was doubled to 2.0 mol dm^{-3}?

A 1 minute

B 2 minutes

[redacted]

D 4 minutes

Half-life is defined as the time taken for concentration of reactant to half its initial concentration. For a first order reaction, the half-life (time to halve) is constant.

In this question from 1.0 to 0.25 mol dm^{-3}, the concentration has halved twice.
i.e. $0.25 = 1.0 \times (\frac{1}{2})^n$, where n = number of half-lives = 2
This process takes 2 minutes so $2 \times$ half-life = 2 min $\rightarrow$ $1 \times$ half-life = 1 min

In the second reaction, we calc the number of half-lives, n
$0.25 = 2.0 \times (\frac{1}{2})^n \rightarrow n = 3$ (2.0 half once = 1.0, half twice = 0.5, half thrice = 0.25)
Since one half-life is 1 min, 3 half-lives is 3 minutes.

16 Which of the following affects the equilibrium position of the reversible reaction below?

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H < 0$$

1 Concentration
2 Pressure
3 Temperature
4 Catalyst

A 4 only

B 1 and 3 only

[redacted]

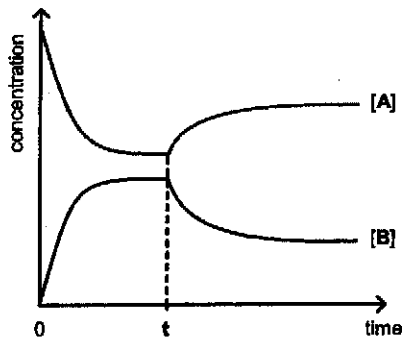
D 1, 2, 3 and 4

A reversible reaction is at dynamic equilibrium if the rate of the forward reaction = rate of the backward reaction.

Option 1 – increasing [rxt] or decreasing [pdt] will shift POE to the right, and vice versa
Option 2 – increasing pressure will shift POE to right with less gaseous particles and vice versa
Option 3 – increasing temperature will favour endothermic (backward) reaction and shift POE left and vice versa.
Option 4 - Since a catalyst speeds up the rate of the forward and backward reaction to the same extent, a catalyst does not affect the position of an equilibrium.

17 The concentration-time graph of a reversible reaction is shown below.

$$A(g) \rightleftharpoons B(g)$$



What is a possible change made to the reaction at time t?

A Change in concentration of reactant

B Change in volume of the reaction vessel

C Change in surface area of reactants

[redacted]

At time t, there is no sharp change to either [A] or [B]. Hence it is a temperature change.

If it was a conc change, **either** adding or removing either **A** or **B**, there will be a sharp change to **either A** or **B** (vertical straight line up if conc increase or down if conc decrease)

A change in volume of reaction will affect **both** [A] or [B] simultaneously. Hence there will be a sharp change (vertical straight line up or down) observed for **both A** and **B.**

Surface area is not applicable to gaseous reactants and is usually only applicable to solids

18 The thermal decomposition of ammonium chloride is an endothermic reaction.

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

A 0.1 mol sample of NH_4Cl was placed in an evacuated gas syringe and allowed to reach equilibrium at room temperature and pressure, during which the total volume increased by 1440 cm^3. It was found that 0.07 mol of the NH_4Cl sample remained.

Calculate the value of the equilibrium constant, K_c, for the decomposition reaction.

[redacted]

B 9.00×10^{-4}

C 1.00×10^{-2}

D 2.08×10^{-2}

Evacuated (vacuum) gas syringe means the initial volume is assumed to be zero as there are no gases inside the gas syringe

Hence, the volume increase is due solely to the amt of gases produced from the decomposition.

amt NH_3 produced = amt HCl produced = amt NH_4Cl reacted = 0.1 – 0.07 = 0.03 mol

---

Alternatively,
At r.t.p. amt of gases = 1440 ÷ 24000 = 0.06 mol
Since NH_3 and HCl gas is produced in a 1:1 mole ratio,
amt NH_3 = amt HCl = 0.06 ÷ (1+1) = 0.03 mol

---

since the reactant is a solid, the [reactant] is constant
converting 1440 cm^3 to 1.44 dm^3,
$K_c = [NH_3][HCl] = [0.03 \div 1.44]^2 = \mathbf{4.34 \times 10^{-4}\ mol\ dm^{-3}}$

19 Which of the following underlined species is acting as an Arrhenius acid?

1 $\underline{H_2O}(l) + NH_3(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$

2 $\underline{AlCl_3}(g) + NH_3(g) \rightarrow AlCl_3{\cdot}NH_3(s)$

3 $\underline{HCl}(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

A 1 and 2 only

B [redacted]

C 2 and 3 only

D 3 only

Arrhenius acid dissociates to produce H^+.
Option 1 – H_2O has produced (lost) H^+ (the H^+ combined with NH_3 to form NH_4^+) and formed OH^- the conjugate base. **(True)**
Option 2 – there is no transfer or production of H^+ **(false)**
Option 3 – HCl has produced (lost) H^+ (the H^+ combined with OH^- to form H_2O) and formed Cl as the conjugate base. **(True)**

20 Carbonic acid is known as a diprotic acid as it can dissociate twice in water.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq) \qquad K_{a1}$$

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq) \qquad K_{a2}$$

Given that $K_{a1} > K_{a2} > K_w$, which of the following species is the strongest acid?

A [redacted]

B HCO_3^-

C CO_3^{2-}

D H_2O

(The acid dissociation constant, K_a, is a measure of the extent of dissociation of an acid. The larger the K_a, the greater the extent of dissociation.)

Equation 1 describes **H_2CO_3 acting as an acid** (in the forward reaction)
and HCO_3^- acting as a base (in the backward reaction)
Equation 2 describes **HCO_3^- acting as an acid** (in the forward direction)
and CO_3^{2-} acting as a base (in the backward reaction)
In both equations H_2O is acting as a base (accepting H^+)

Ignoring the bases (since bases can just be considered as extremely weak acids)
$K_{a1} > K_{a2}$ means that the extent of acid dissociation of H_2CO_3 is greater than that of HCO_3^-
→ Therefore H_2CO_3 is the strongest acid.

21 Which of the following has a pH of 1?

1 A solution of 1 mol dm^{-3} of HCl(aq)

2 A solution of 0.1 mol dm^{-3} H_2SO_4(aq)

3 A solution of which the hydroxide ion concentration is 10^{-13} mol dm^{-3}.

A 2 only

B 1 and 3 only

C 2 and 3 only

D [redacted]

Option 1: 1 mol dm^{-3} of HCl(aq) produces 1 mol dm^{-3} of H^+
pH = - lg $[H^+]$ = -lg 1 = 0 **(incorrect)**

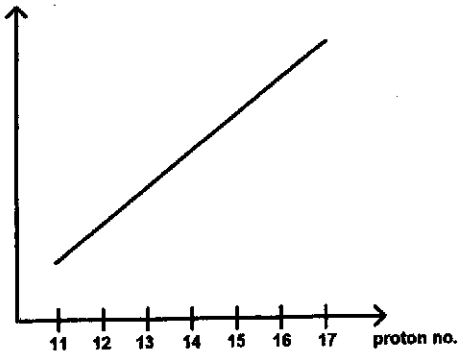
Option 2: 0.1 mol dm^{-3} of H_2SO_4(aq) produces 0.2 mol dm^{-3} of H^+
pH = - lg $[H^+]$ = -lg 0.2 = 0.699 **(incorrect)**

Option 3:
$K_w = 10^{-14} = [H^+][OH^-]$
$10^{-14} = [H^+][10^{-13}]$
$[H^+] = 0.1$
pH = - lg $[H^+]$ = -lg 0.1 = 1 **(correct)**

22 The following graph shows a certain trend of Period 3 elements.

[Turn over

12



Which of the following is the correct label for the *y*-axis?

A atomic radius

B [redacted]

C first ionisation energy

D ionic radius

Option A - Atomic radius decreases across the Period **(Incorrect)**

Option B - electronegativity increases across the Period **(correct)**

Option C – first I.E. generally increases but has dips / irregularities between proton numbers 12 & 13 and between proton numbers 15 & 16 **(Incorrect)**

Option D – ionic radius decreases from proton numbers 11 to 14, then jumps up to 15, before decreasing from 15 to 17 (anionic radius is larger than cationic radius in the same period due to having an extra valence shell of electrons)

23 Which of the following elements form chlorides that will produce an acidic solution when dissolved in water?

1 sodium

2 magnesium

3 aluminium

4 phosphorus

A 1, 2 and 3 only

B 1, 3 and 4 only

C [redacted]

D 1, 2, 3 and 4

Option 1:
$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ (no hydrolysis, neutral, pH = 7) **(incorrect)**

Option 2:
$MgCl_2(s) + 6H_2O(l) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + 2Cl^-(aq)$

$[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5OH]^+(aq) + H^+(aq)$ (weakly acidic, pH ≈ 3)

Option 3:
$AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$
$[Al(H_2O)_6]^{3+}(aq) \rightarrow [Al(H_2O)_5OH]^{2+}(aq) + H^+(aq)$ (strongly acidic, pH ≈ 2)

Option 4:
$PCl_3(s) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$ (strongly acidic, pH ≈ 2)
Or
$PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$ (strongly acidic, pH ≈ 2)

24 Which of the following statements helps to explain why hydrogen bromide is unstable to heat and breaks down but not hydrogen fluoride?

A The bond energy of the F–F bond is higher than that of the Br–Br bond

B The bond length of the F–F bond is shorter than that of the Br–Br bond

C [redacted]

D The bond length of the H–F bond is longer than that of the H–Br bond

For the thermal decomposition of hydrogen halide

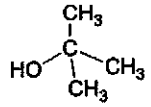
$2\ H\text{–}F \rightarrow H\text{–}H + F\text{–}F$
$2\ H\text{–}Br \rightarrow H\text{–}H + Br\text{–}Br$

Bond breaking requires energy, the easier the bond is broken, the more reactive (unstable) the hydrogen halide. (looking at options C and D)

The factor that affects how easily the H-X bond is broken is the **extent of orbital overlap. The larger the halogen, the longer the bond length, the lower extent of orbital overlap and the weaker the bond is (lower bond energy).**
Thus **Option C is correct** and not Option D as H-Br is longer than H-F bond.

Looking at options A and B,
The more exothermic the reaction, the more likely it is to happen.
Looking at the bonds formed, F-F bond is stronger and releases more energy (more exothermic) than forming Br-Br bond.
Hence, this **does not help to explain** why HBr is more unstable (more reactive) than HF.

25 Which of the following is the IUPAC name for the following structure of $C_4H_{10}O$?



A [redacted]

B 2-hydroxypropane

C 2-hydroxypropanol

D trimethylmethanol

The longest carbon chain is 3 carbons: the stem of the name is '**prop**', there are not alkenes so the stem becomes 'prop**an**'

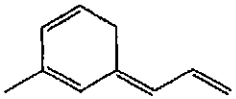
[Turn over

There is an –OH group and $-CH_3$ group connected to carbon number 2, but since –OH has higher priority, the name will go into the suffix as '**-2-ol**'

The $-CH_3$ group then goes into the prefix as '**2-methyl**'

B and C are both incorrect as the $-CH_3$ (methyl) group is not accounted for.
In addition, option C counts the –OH group twice: once in the prefix and once in the suffix
D is incorrect as the longest carbon chain is 3, but the stem 'meth' only counts 1 carbon.

26 How many *cis-trans* isomers does the following compound exhibit?

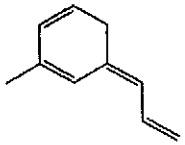


A [redacted]
B 4
C 8
D 16

The two C=C in the cyclic ring cannot exhibit cis-trans, as the trans isomer will cause the ring to break.

The terminal C=C on the right has two identical –H groups and does not exhibit cis-trans

Only the middle C=C can exhibit cis-trans, the other isomer being



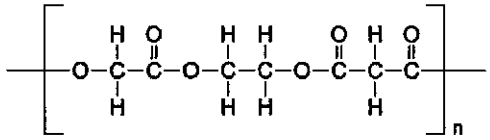
27 Which of the following reactions will **not** give ethene, $H_2C=CH_2$, as the product?

1 CH_3CH_2Br, ethanolic KOH, heat
2 CH_3CH_2OH, H_2SO_4(aq), heat
3 CH_3CH_3, excess O_2, heat

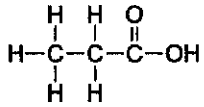
A 1 only
B 3 only
C 1 and 2 only
D [redacted]

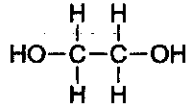
Option 1 is the correct reagent and conditions for elimination – not the answer
Option 2 is incorrect as concentrated H_2SO_4 is needed for elimination, not aq H_2SO_4
Option 3 is incorrect as it is the combustion of alkanes to form CO_2 and H_2O.

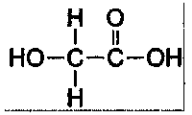
28 The following shows a repeating unit of a polymer.

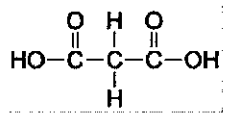


Which of the following are possible identities of the monomers?

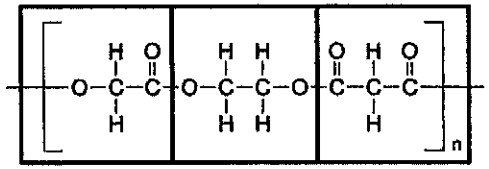
1 

[redacted] 

[redacted] 

[redacted] 

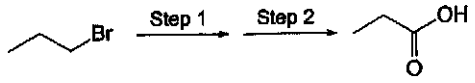
A 1 and 2 only
B 2 and 3 only
C 3 and 4 only
D [redacted]



Analysing where the ester linkages are and drawing a line in the middle of the ester linkages, we are able to see that there are three different monomers.
On the left we have a 2-carbon monomer with alcohol and carboxyl group – option C

In the middle we have a 2-carbon monomer with both alcohol groups – option B
On the right we have a 3-carbon monomer with two carboxyl groups – option D

29 1-bromopropane can undergo a two-step reaction to form propanoic acid.



1-bromopropane propanoic acid

What are the possible reagent and conditions for steps 1 and 2?

	Step 1	Step 2
A	alkaline $KMnO_4$, cold	aqueous NaOH, heat
B	[redacted]	[redacted]
C	NaOH in ethanol, heat	acidified $KMnO_4$, heat
D	$LiAlH_4$, r.t.	HBr, r.t.

Step 1 is the substitution (hydrolysis) of alkyl bromide to propan-1-ol.
Step 2 is the oxidation of propan-1-ol to propanoic acid.
$KMnO_4$ is the reagent for oxidation
aqueous NaOH or KOH is the reagent for substitution of alkyl halides

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ethanolic NaOH or KOH is the reagent for elimination of alkyl halides to form alkenes
$LiAlH_4$ is a reducing agent (to reduce carboxylic acid / ketone / aldehydes to alcohols)
HBr is used for substitution of alcohols to form alkyl bromides.

30 Car tyres are made from a type of polymer. They are strong enough to withstand high pressures and the heavy weight of the car, yet are able to deform slightly when the wheels encounter bumps in the road.

Which of the following statements are **incorrect** about the polymer in car tyres?

A It is a thermoset

B There are strong covalent crosslinks

C [redacted]

D Used car tyres are usually incinerated and not recycled

Based on the description and from general knowledge, car tyres are rigid and strong, and can hence be classified as a thermoset and not a thermoplastic.
In this case, option B and D fits the description of a thermoset and not option C, which describes a thermoplastic.

END OF PAPER 1

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BP~371

Class | Adm No

Candidate Name: _____

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millennia institute

2020 End-of-Year Exams
Pre-University 2

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **16 Sep 2020**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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

Answer **all** questions in Section A and answer **any one** of the two questions in Section B.

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

A Data Booklet is provided.

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

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

Question	1	2	3	4	Section B	Total
Marks	/11	/18	/14	/17	/20	/80

This question paper consists of [redacted] printed pages and [redacted] blank page.

Section A

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

For Examiner's Use

1 The Chernobyl disaster was one of the worst nuclear disaster in history near the city of Pripyat at Ukraine. The accident started during a safety test on a reactor. On one of the tests, a large amount of energy was suddenly released, rupturing the reactor core in a highly destructive steam explosion.

The reaction involved in the first explosion reaches dynamic equilibrium as shown below, involving two flammable gases, $H_2(g)$ and $CO(g)$.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131 \text{ kJ mol}^{-1}$$

(a) (i) Define *dynamic equilibrium*. [1]

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Dynamic equilibrium refers to a reversible reaction in which the rates of the forward and backward reactions have become equal and there is no change in the concentrations of the products and reactants.

(ii) State *Le Chatelier's principle*. [1]

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Le Chatelier's Principle states that if a system in equilibrium is disturbed, the equilibrium position will shift in the direction that tends to reduce that change so as to re-establish the equilibrium.

(b) The explosion was due to the increased outflow of water from the reactor. However, the rate of heat removal from the reactor was slowed down due to low water level in the steam separator and that caused a large increase in temperature.

The high temperature and the surplus of steam produced caused the first explosion as shown in the equation above. With the containment broken, air began to enter the reactor. Graphite reacted with the air to cause a second explosion. Following the days of explosion, liquid nitrogen was injected to reduce further explosion risk.

(i) Explain why the high temperature of the reactor and the surplus of steam caused the first explosion. [3]

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When temperature increases, by LCP, the system opposes the change by shifting the equilibrium position to the right as the forward reaction is endothermic(;) which absorbs heat. As a result, more hydrogen gas which is flammable was produced;

When there is a surplus of steam, by LCP, the system opposes the change by shifting the equilibrium position to the right (;) to produce more hydrogen gas which is flammable.

(ii) Suggest, with the aid of an equation, how the second explosion could have occurred. [2]

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$C + O_2 \rightarrow CO_2$. Reaction is highly exothermic. OR

$C + O_2 \rightarrow CO$. CO is a flammable gas

(c) Suggest the purpose of injecting liquid nitrogen into the reactor. [1]

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Liquid nitrogen is used to cool down the reactor as it has a very low boiling point.

(d) (i) Write the expression for the equilibrium constant, K_c for the reaction involved in the first explosion. [1]

$K_c = \frac{[H_2][CO]}{[H_2O]}$

(ii) At 730 °C, the percentage conversion of steam was found to be 30%.

Given that the initial concentration of steam was 0.1 mol dm^{-3}, calculate the value of K_c at 730 °C. [2]

[Turn over

	C(s)	+ $H_2O(g)$	⇌	$H_2(g)$	+ CO(g)
Initial conc	-	0.1		0	0
Change in conc	-	-0.03		+0.03	+0.03
Eqm conc	-	0.07		0.03	0.03

$K_c = \frac{[H_2][CO]}{[H_2O]} = \frac{0.03 \times 0.03}{0.07}$

$K_c = 0.0129$ mol dm^{-3}

[Total: 11]

2 Figure 1 shows the set-up of how values of energy changes of combustion for different substances can be obtained in a school laboratory.

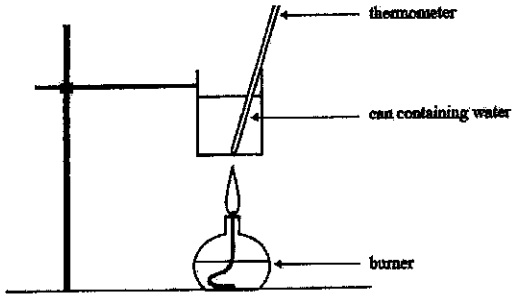


Figure 1

The higher heating value (HHV) can be measured by knowing the initial mass of the fuel sample. HHV of a fuel is defined as the amount of heat released per mass of fuel once the fuel is combusted and the products have returned to the temperature of 25 °C.

The HHV of solid hexanedioic acid, $C_6H_{10}O_4(s)$, was investigated and the data collected is found in Table 1 and Figure 2.

Mass of empty beaker / g	137.5
Mass of beaker and hexanedioic acid / g	140.1
Volume of water / cm^3	400

Table 1

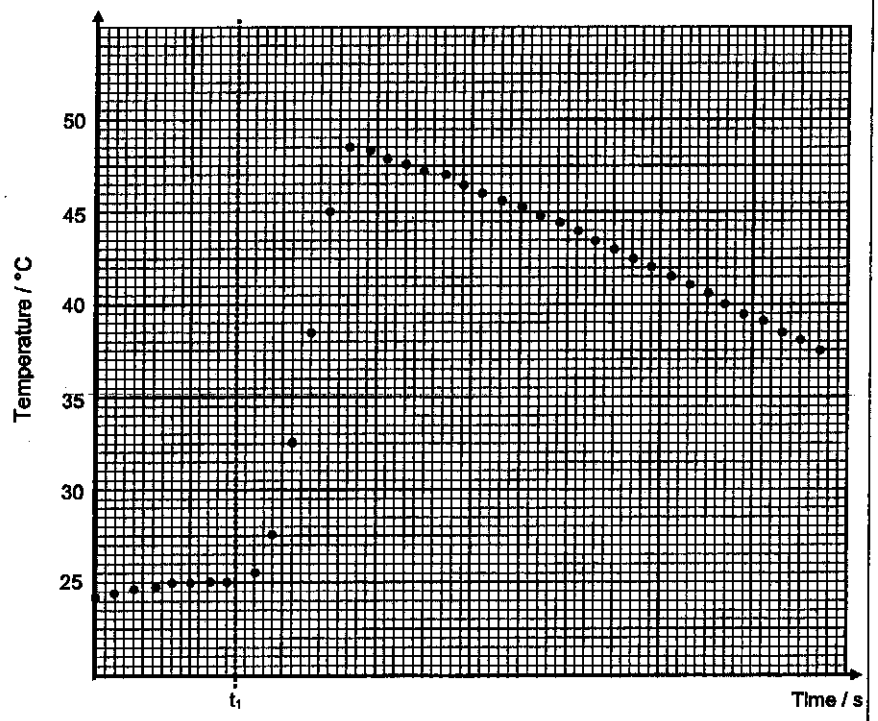


Figure 2

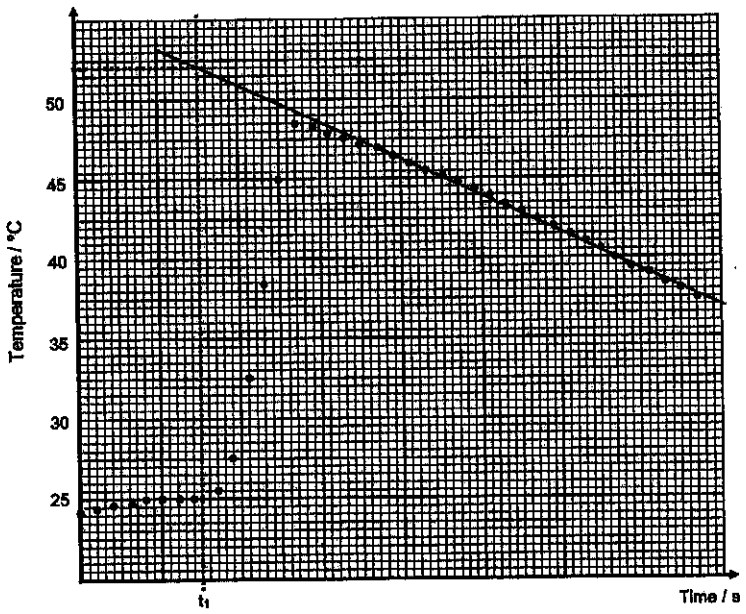
(a) (i) Write the equation for the combustion of 1 mole of solid hexanedioic acid, including state symbols. [2]

.....

$C_6H_{10}O_4(s) + 6.5O_2(g) \rightarrow 6CO_2(g) + 5H_2O(l)$

(ii) Figure 2 shows the cooling curve of the combustion of hexanedioic acid. In order to determine the maximum temperature, the cooling portion of the curve is extrapolated to the point at t_1.

Determine the maximum change in temperature based on Figure 2 by extrapolation. [2]



Maximum temperature: 52 °C

Maximum change = 52 – 25 = 27.0 °C

(iii) Calculate the heat evolved from the reaction. [1]

$Q = mc\Delta T$

$= 400 \times 4.18 \times 27 = 45144$ J

(iv) Hence, calculate the higher heating value, in kJ g^{-1}, of hexanedioic acid. [1]

Mass of hexanedioic acid = 140.1-137.5 = 2.6 g

HVV = 45144 / 2.6 = 17.4 kJ g^{-1}

[Turn over

(v) State and explain the impact on the HVV value calculated in **(a)(iv)** if extrapolation was not carried out. [2]

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The HVV value will be lower (;) due to the unaccounted heat loss(;) to the surroundings.

(vi) Suggest a data which is necessary to obtain an accurate HVV value if extrapolation was not carried out. [1]

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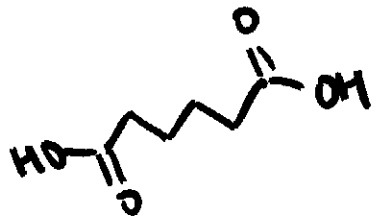
.....

the heat capacity of the can material

(b) Nylon-66 is a polymer which is most common for textile and plastic industries. It is made from the two monomers, hexanedioic acid and 1,6-diaminohexane.

(i) Draw the skeletal formula of the two monomers. [2]

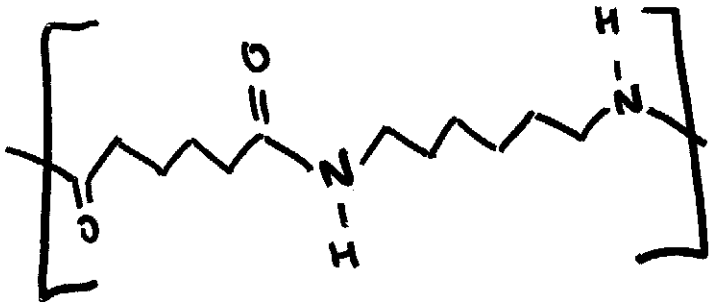
hexanedioic acid	1,6-diaminohexane.



hexanedioic acid

hexanediamine

(ii) Draw one repeat unit of Nylon-66. [1]



(iii) State the type of polymerisation that produces Nylon-66 and name the bond formed during this polymerisation. [2]

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Condensation polymerisation. The bond formed is amide bond.

(iv) Based on your answer in (b)(iii), suggest and explain the disadvantage of using nylon-66 to make fabric, in terms of bonding, with the aid of a diagram. [3]

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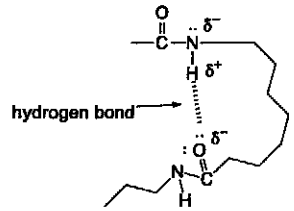

It is prone to creasing. When it is wet, H-bonds is formed between amide and water molecules but when it is dried, the water molecules leave and the H-bonds will form between amide groups in the polymer, forming creases.

(v) Given that nylon is a thermoplastic polymer, state one property which makes it a good material to be used in clothings. [1]

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It is not rigid which adds to the comfort.

[Total:18]

3 Aluminium makes up about 8% of the Earth's crust by mass, where it is the third most abundant element and also the most abundant metal.

(a) State the number of protons, neutrons and electrons in an atom of ^{27}Al. [1]

.....

13 protons, 14 neutrons and 13 electrons

(b) (i) State the full electronic configurations of an aluminium ion and $^{27}_{13}Al^{3+}$ and $^{19}_{9}F^{-}$. [1]

$^{27}_{13}Al^{3+}$ .....

$^{19}_{9}F^{-}$ .....

$1s^2\ 2s^2\ 2p^6$ for both

(ii) Based on the answer in (b)(i), state the relationship between the two ions. [1]

.....

isoelectronic

(iii) Draw labelled lines to Figure 3 to represent the path of beams of aluminium ions and fluoride ions in an electric field, showing the relative angle of each species.

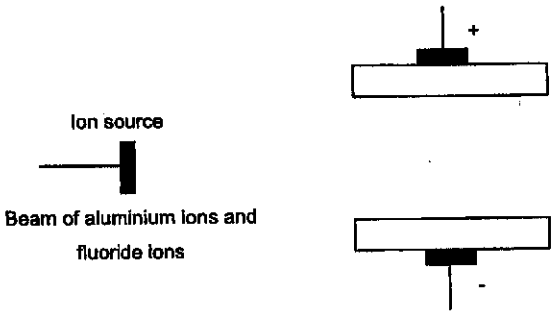
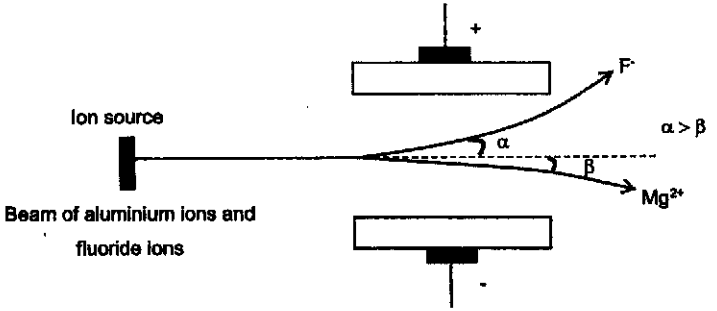


Figure 3

[2]

[Turn over



(c) Magnesium and aluminium react with chlorine to form magnesium chloride and aluminium chloride respectively.

(i) Write equations to show what happens when samples of each of these chlorides are added separately to water. In each case, state the likely pH of the resulting solution. [3]

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$MgCl_2\ (s) + 6\ H_2O\ (l) \rightarrow [Mg(H_2O)_6]^{2+}\ (aq) + 2Cl^-\ (aq)$

$[Mg(H_2O)_6]^{2+}\ (aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^+\ (aq) + H^+\ (aq)$ pH 6.5

$AlCl_3\ (s) + 6\ H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}\ (aq) + 3Cl^-\ (aq)$

$[Al(H_2O)_6]^{3+}\ (aq) \rightarrow [Al(H_2O)_5(OH)]^{2+}\ (aq) + H^+\ (aq)$ pH 3

(ii) Account for the difference in pH of magnesium chloride and aluminium chloride. [2]

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$AlCl_3$ dissolves in water with hydrolysis to give an acidic solution. The acidic nature is due to the relatively small but highly charged (or high charge density) Al^{3+} ion which polarises the surrounding water molecules and weakens the OH bond to a greater

extent and produce H^+ ions. However, $MgCl_2$ undergoes partial hydrolysis due to the weaker polarising power of Mg^{2+} ions to give a weakly acidic solution.

(d) A diagonal relationship exists between certain pairs of diagonally adjacent elements in the second and third periods of the Periodic Table. An example of a pair of such elements is Be and Al.

(i) Based on the position in the Periodic Table, describe the structure and bonding of beryllium chloride. [2]

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Beryllium chloride has simple molecular structure and it is held by weak instantaneous dipole-induced dipole forces of attraction between molecules.

(ii) Predict the pH of beryllium chloride and explain the reason. [2]

.....

.....

pH 3 as Be^{2+} has similar charge density as Al^{3+}

[Total: 14]

4 (a) Photochemical oxidation of arsenic, As(III) ion, to the less toxic As(V) ion, using peroxydisulfate ions, $S_2O_8^{2-}$, as the oxidising agent proved to be a simple and efficient method.

The oxidation takes place according to the following equation.

$$S_2O_8^{2-} + H_3AsO_3 + H_2O \rightarrow 2SO_4^{2-} + H_3AsO_4 + 2H^+$$

20 cm^3 of 0.5 mol dm^{-3} solution of potassium peroxydisulfate was mixed with 200 cm^3 of a solution of arsenic(III) acid, H_3AsO_3 of the same concentration. At fixed time intervals, small portions of the reaction mixture were analysed to determine the concentration of peroxydisulfate ion.

The results are shown in Table 2.

Time / min	$[S_2O_8^{2-}]$ / mol dm^{-3}
0	0.50
4	0.38
8	0.27
12	0.20
16	0.16
20	0.11

Table 2

(i) Write the ion-electron equations for the reaction in an acidic medium. [2]

Reduction: .....

Oxidation: .....

Reduction: $S_2O_8^{2-} + 2e \rightarrow 2SO_4^{2-}$

Oxidation: $AsO_3^{3-} + H_2O \rightarrow AsO_4^{3-} + 2H^+ + 2e^-$

(ii) On Figure 4, plot the graph of the concentration of peroxydisulfate ion against time.

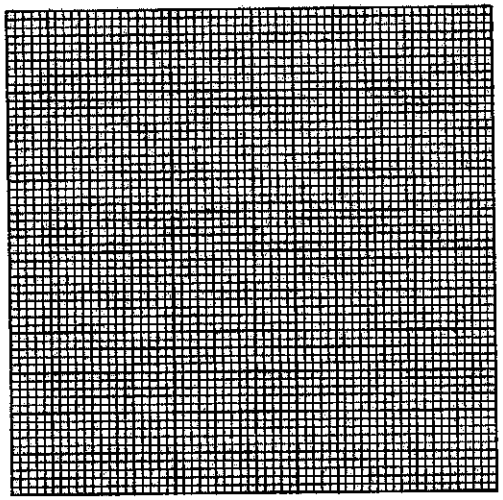
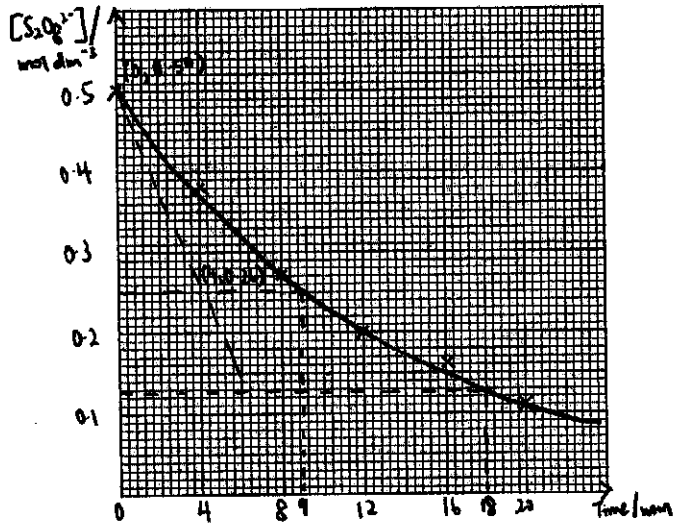


Figure 4

[2]



(iii) Hence, deduce the order of reaction with respect to potassium peroxydisulfate based on (a)(ii). [2]

Since the half-life is constant at 9min, it is a first order reaction with respect to potassium peroxydisulfate

(iv) The experiment was repeated using 20 cm^3 of H_3AsO_3 and 20 cm^3 of $K_2S_2O_8$ at different concentrations.

$[S_2O_8^{2-}]$ / mol dm^{-3}	$[H_3AsO_3]$ / mol dm^{-3}	Initial Rate / mol dm^{-3} min^{-1}
0.5	1.0	0.120
0.5	0.5	0.060

Table 3

Using the information given in Table 3, deduce the order of reaction with respect to H_3AsO_3. [1]

$$\frac{0.120}{0.06} = \frac{k(0.5)(1.0)^x}{k(0.5)(0.5)^x}$$

$2^x = 2$

x=1

order of reaction with respect to H_3AsO_3 = 1

(v) Hence, write the rate equation. [1]

.....

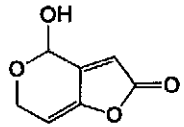
rate = $k[H_3AsO_3][S_2O_8^{2-}]$

(vi) Calculate the value of rate constant, including its units. [1]

$0.120 = k\,(0.5)(1.0)$

$k = 0.240\ mol^{-1}\ dm^3\ min^{-1}$

(b) The Singapore Food Agency (SFA) has recalled Pure Tassie Organic Apple & Raspberry Juice on 30 April 2020 as the samples were found to contain patulin at levels exceeding the maximum limit as stated in the Singapore Food Regulations.



Patulin

The lethal dose of patulin on human is 25 mg kg^{-1} body weight. The maximum limit for patulin in fruit juice as stated in the Singapore Food Regulations is 50 parts per billion (ppb).

[1 ppb = 10^{-6} g per litre]

(i) A sample of 1.5 litre bottle of apple juice from another brand was found to contain 0.047 mg of patulin.

Determine if this sample is within the safety limit suggested by the Singapore Food Regulations. [2]

[patulin] in sample = $\frac{0.047 \times 10^3}{1.5}$ = 31.3 ppb

Yes, it is within the safety limits.

(ii) Determine the maximum number of bottles of apple juice that a 50 kg woman can consume before the lethal dose kicks in. [2]

Maximum mass of patulin that the 50kg woman can consume

= 50 x 25 x 10^{-3} = 1.25 g

Maximum volume = $\frac{1.25}{31.1 \times 10^{-6}}$ = 39894 L

Maximum number of bottles = 39894 / 1.5 = 26595.7 = 26595 bottles

OR

Maximum mass of patulin that the 50kg woman can consume

= 50 x 25 x 10^{-3} = 1.25 g

Maximum number of bottles = 1.25 / (0.047 x 10^{-3}) = 26595 bottles

(iii) The purity of patulin can be determined by reacting patulin with aqueous bromine or phosphorus pentachloride.

Name the type of reaction between patulin and aqueous bromine. [1]

.....

addition

(iv) Draw the structure of the product for the reaction between patulin and aqueous bromine. [1]

(v) $ROH + PCl_5 \rightarrow RCl + POCl_3 + HCl$ where ROH refers to patulin

Calculate the percentage purity of a sample containing patulin if 2.45 g of the sample reacts with 0.015 mol of PCl_5. [M_r of patulin = 154.0] [2]

Amount of pure patulin reacted with PCl_5 = 0.015 mol

Mass of pure patulin = 0.015 x 1.54 = 2.31 g

% purity = 2.31/2.45 x 100% = 94.3%

[Total: 17]

Section B

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

5 **(a)** Chlorous acid, $HClO_2$, is a weak acid which is unstable and will be converted to hypochlorous acid, HClO, and chloric acid, $HClO_3$.

For Examiners' Use

$$2HClO_2 \rightarrow HClO + HClO_3$$

(i) State the oxidation states of chlorine in

$HClO_2$: .....

HClO : .....

$HClO_3$: ..... [2]

+3, +1, +5

(ii) State the type of reaction which chlorous acid undergoes. Explain your reasoning. [2]

.....

.....

.....

Disproportionation. Cl in $HClO_2$ is oxidised and reduced simultaneously. It increases its oxidation state from +3 to +5 in $HClO_3$ and decreases its oxidation state from +3 to +1 in HClO.

(iii) With the aid of an equation, explain what is meant by weak acid, using $HClO_2$ as an example. [1]

[Turn over

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.....

A weak acid dissociates partially in water to produce H^+. $HClO_2 \rightleftharpoons H^+ + ClO_2^-$

(iv) Write an expression for the acid dissociation constant, K_a, for $HClO_2$. [1]

$K_a = \frac{[H^+][ClO_2^-]}{[HClO_2]}$

(v) The pH of a 2.0 mol dm^{-3} solution of $HClO_2$ is 0.83.

Calculate the concentration of H^+ ions. [1]

$[H^+] = 10^{-0.83} = 0.148$ mol dm^{-3}

(vi) Given that $[H^+] = [ClO_2^-]$, calculate the value of K_a for $HClO_2$. [1]

$K_a = \frac{[H^+][ClO_2^-]}{[HClO_2]} = \frac{(0.1479)^2}{2.0} = 0.0109$ mol dm^{-3} or $\frac{(0.1479)^2}{2.0-0.1479} = 0.0118$ mol dm^{-3}

(vii) A mixture of chlorous acid and its salt, sodium chlorite forms a buffer solution.

Explain what is meant by a buffer solution. [1]

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A buffer solution is a solution that can maintain a relatively constant pH when small amounts of acid or base is added to it.

(viii) Write two equations to show how a mixture of chlorous acid and sodium chlorite act as a buffer system. [2]

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.....

$HClO_2 + OH^- \rightarrow ClO_2^- + H_2O$

$ClO_2^- + H^+ \rightarrow HClO_2$

(b) Concentrated sulfuric acid plays an important role in many organic reactions. Other than acting as an acid, concentrated sulfuric acid also catalyses the conversion of alcohol to alkene.

(i) Define the term *catalyst*. [1]

.....

.....

A catalyst speeds up the rate of reaction by lowering activation energy without itself being chemically changed at the end of the reaction.

(ii) Explain how the concentrated sulfuric acid catalyst affects the rate of reaction, with the aid of a labelled Boltzmann distribution curve. [3]

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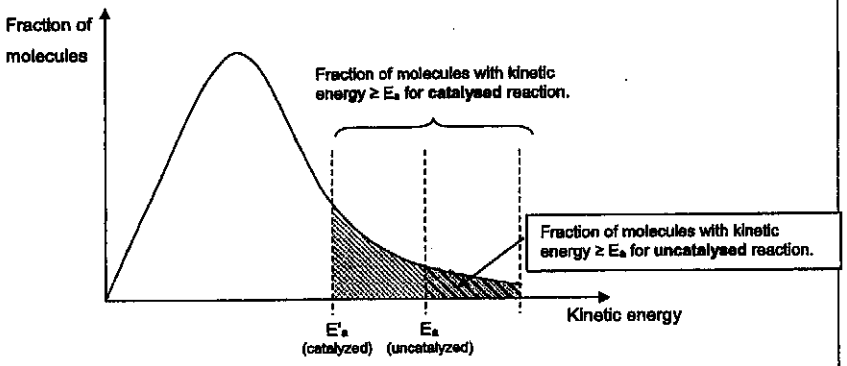


A catalyst provides an **alternative reaction path with lower activation energy (E'_a)** than that for the uncatalysed reaction (E_a). As a result, **fraction of molecules containing energy greater than or equal to the activation energy increases** as shown by the larger shaded area under the curve in the figure above.

Hence, the **frequency of effective collisions is higher when a catalyst is present.** Hence, rate of reaction increases with catalyst.

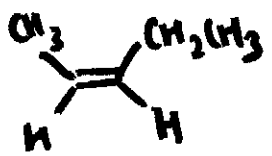
(iii) State the type of reaction that an alcohol undergoes to form an alkene. [1]

.....

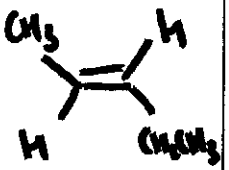
Elimination

(iv) Pentan-2-ol forms alkene with the presence of concentrated sulfuric acid and heat. Name and draw the structures of all the possible products and their isomers, where relevant. [4]

pent-1-ene



cis-pent-2-ene

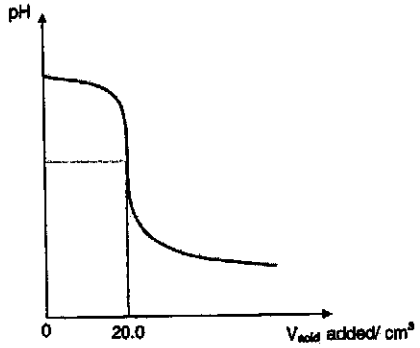


trans-pent-2-ene

[Total: 20]

6 (a) Potassium hydroxide, KOH, is a strong base. When 30.0 cm^3 of 0.125 mol dm^{-3} KOH was titrated against an aqueous solution of ethanoic acid, CH_3COOH, the following graph was obtained.

For Examiners' Use



(i) Calculate the pH of a 0.125 mol dm^{-3} solution of KOH. [2]

$[OH^-] = 0.125$ mol dm^{-3}
$pOH = -\log 0.125 = 0.903$
$pH = 14 - 0.903 = 13.1$

(ii) Calculate the concentration of the ethanoic acid solution. [2]

$KOH + CH_3COOH \rightarrow CH_3COOK + H_2O$
Amount of KOH = $\frac{30}{1000} \times 0.125 = 0.00375$ mol
Amount of $CH_3COOH = 0.00375$
$[CH_3COOH] = 0.00375/0.02 = 0.188$ mol dm^{-3}

(iii) Explain, in terms of structure and bonding, why potassium hydroxide is a solid while ethanoic acid is a liquid at room temperature. [2]

[Turn over

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Potassium hydroxide has a giant ionic structure while ethanoic acid has a simple molecular structure. More energy is needed to overcome the stronger electrostatic forces of attraction between K^+ and OH^- ions than the weaker hydrogen bonding between ethanoic acid molecules.

(iv) Suggest and explain how the boiling point of calcium hydroxide compares with that of potassium hydroxide. [3]

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The boiling point of calcium hydroxide is higher than potassium hydroxide as both have giant ionic structures.

$$|LE| \propto \left|\frac{q^+q^-}{r^+ + r^-}\right|$$

Since the anion is the same, the charge and the size of the cations determine the strength of ionic bond. As K^+ is larger in size and lower in charge than Ca^{2+}, the magnitude of lattice energy for KOH is smaller than that of $Ca(OH)_2$. Less energy is needed to overcome the weaker electrostatic forces of attraction between K^+ and OH^- in KOH. Hence, KOH has a lower boiling point.

(b) (i) Identify the Period 3 element that forms a sparingly soluble amphoteric oxide. [1]

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Aluminium

(ii) Write an ionic equation to illustrate the reaction between the oxide of the element identified in (b)(i) and aqueous sodium hydroxide. [1]

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$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$

(c) (i) Explain why the ionic radius of phosphorus is larger than its atomic radius. [1]

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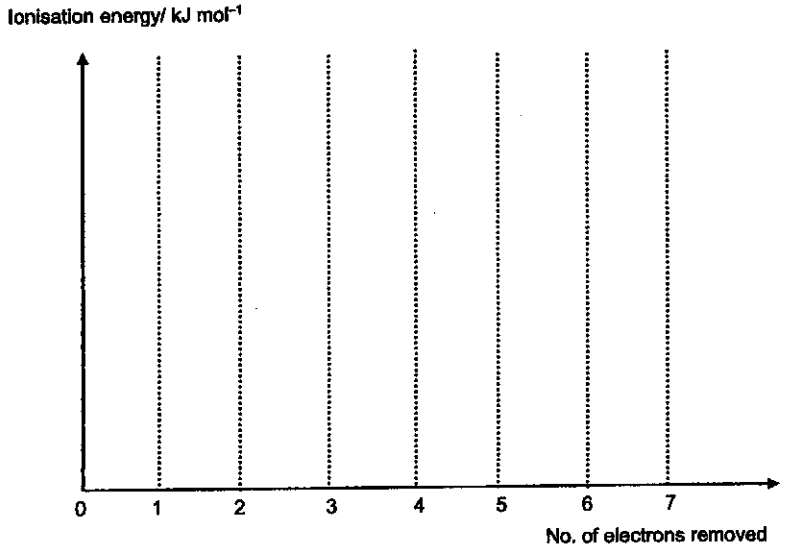
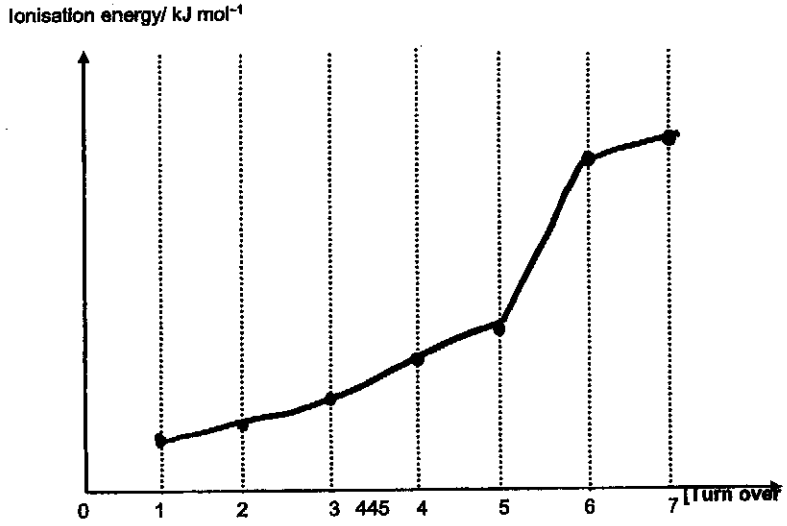
Both P and P^{3-} have the same proton number and the same number of filled inner principal quantum shells. However, the added electrons in P^{3-} experience inter-electronic repulsion, making the electron cloud of the anion more diffused.

(ii) On the axis below, sketch the graph for the first seven ionisation energies of phosphorus against the number of electrons removed. [2]





(iii) Explain why the first ionisation energy of phosphorus is higher than that of silicon. [2]

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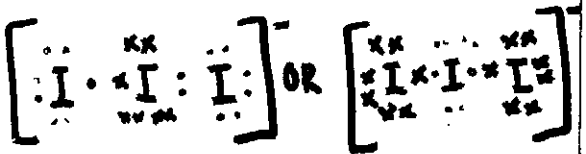
P has a higher nuclear charge than Si (due to an additional proton) while the shielding effect is relatively constant (due to the same number of inner shell electrons) across the period. Hence, the effective nuclear charge increases from Si to P.(;) Attraction between the valence electron and nucleus is stronger and more energy is needed to remove the valence electron from P than Si.(;)

(d) (i) I_2 is not very soluble in water. However when I_2 reacts with KI(aq), it forms highly soluble KI_3.

Draw the dot and cross diagram of the I_3^- ion (including all lone pairs of electrons), and deduce its shape and bond angle. [2]

Shape:..... Bond angle:.....



Shape: linear Bond angle:180°

(ii) Explain why I_3^- ion is more soluble in water than I_2. [2]

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Energy given out from the formation of ion-dipole interaction between I_3^- ion and water is sufficient to overcome the weaker hydrogen bonding between water molecules while energy given out from the formation of instantaneous dipole-induced dipole forces of attraction between I_2 ion and water is insufficient to overcome the stronger hydrogen bonding between water molecules

[Total: 20]

END OF PAPER 2

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