VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE NAME

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CT GROUP

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CHEMISTRY **8873//02**

Paper 2 Structured Questions **15 September 2021**

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		
	1	**/ 8**
	2	**/ 13**
Section A	**3**	**/ 9**
	4	**/ 9**
	5	**/ 13**
	6	**/ 8**
Section B	**7 / 8**	**/ 20**

Total		/
	80	

This document consists of **28** printed pages and **2** blank pages.

Section A

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

1 **(a)** The nth (n = 1, 2, 3, 4 or 5) ionisation energies of consecutive elements **Q** to **Z**, with atomic number below 20, are shown in **Fig. 1.1**.
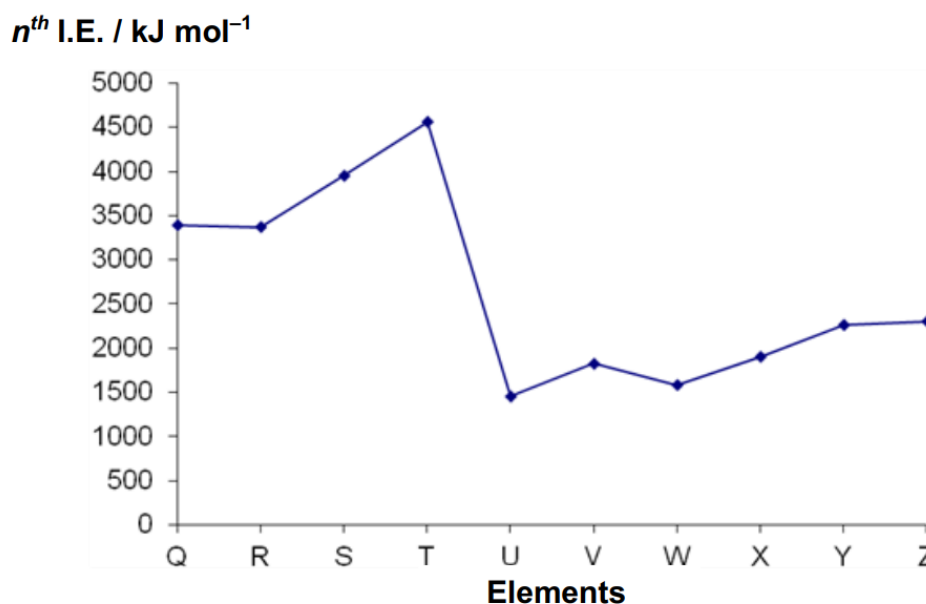
n^{th} **I.E. / kJ mol^{-1}**

Fig. 1.1

(i) Define the nth ionisation energy of element **T**.

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[1]

(ii) Element **U** is identified as A*l*. State the value of **n**.

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[1]

(b) Aluminium chloride has a wide number of uses in the chemical industry. Anhydrous $AlCl_3$ adopts different structures depending on the temperature and the state it is in. In the liquid state, it exists as the dimer Al_2Cl_6 while a mixture of monomer and dimer can be found in the gaseous phase.

(i) State the type of interactions between two molecules of $AlCl_3$.

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(ii) Draw a diagram to show the bonding in an Al_2Cl_6 dimer, and state the bond angle about the Al atom.

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(c) Beryllium chloride, $BeCl_2$, has properties similar to those of $AlCl_3$.

(i) Explain why $BeCl_2$ behaves similarly to $AlCl_3$.

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[1]

(ii) $BeCl_2$ and dimethylamine, $(CH_3)_2NH$ reacts in the molar ratio 1:2. By considering the number of bond pairs and lone pairs around the central atoms of each molecule, explain the molar ratio and draw a diagram to show the bonding in the product.

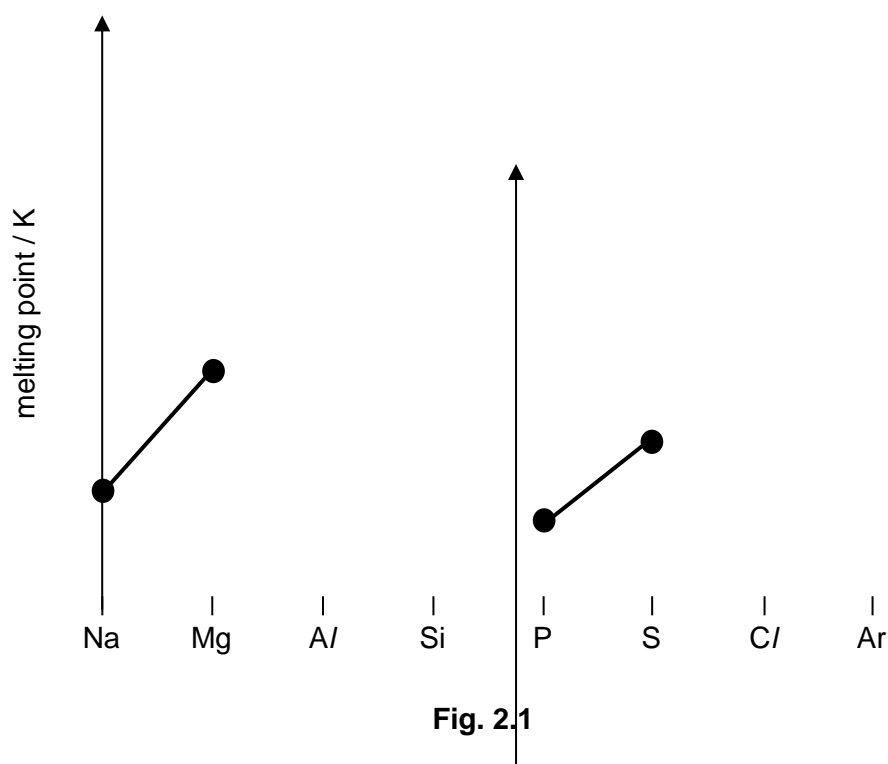..
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[2]

[Total: 8]

2 (a) **Fig. 2.1** shows the trend in melting points of some Period 3 elements:

Fig. 2.1

(i) Complete the trend in melting point of the Period 3 elements for aluminium, silicon, chlorine and argon on **Fig 2.1**.

[1]

(ii) Explain, with reference to structure and bonding, why magnesium has a higher melting point than sodium.

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(iii) Explain, with reference to structure and bonding, why sulfur has a higher melting point than phosphorus.

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[2]

(b) Serpentine has the formula $Mg_3Si_2O_5(OH)_x$.

There is currently a lot of interest in the use of serpentine as a "green" cement as it chemically absorbs carbon dioxide, a major constituent of greenhouse gases.

(i) Deduce the value of x in $Mg_3Si_2O_5(OH)_x$.

[1]

(ii) Serpentine reacts with carbon dioxide to form water, silicon(IV) oxide and one other product. Write a balanced equation for this reaction.

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[1]

(c) Dolomite has the formula $MgY(CO_3)_2$, where **Y** is a metal element.

Dolomite is insoluble in water but dissolves in aqueous acid due to the reaction between the carbonate ions and hydrogen ions.

$$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$$
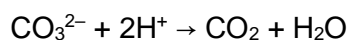
A 4.50 g sample of dolomite is dissolved in 25.0 cm^3 of 5.00 mol dm^{-3} hydrochloric acid, in excess.

The resulting solution is made up to 100 cm^3 in a volumetric flask using distilled water and labelled solution **A**. 10.0 cm^3 of solution **A** is titrated against a 0.100 mol dm^{-3} solution of sodium hydroxide. An average titre of 27.30 cm^3 is obtained.

(i) Calculate the amount of hydrochloric acid in 100 cm^3 of solution **A**.

[2]

**(ii)** Hence, calculate the amount of hydrochloric acid that reacted with the 4.50 g sample of dolomite.

[1]

(iii) Determine the mole ratio of Mg**Y**(CO$_3$)$_2$: CO$_3^{2-}$: H$^+$.

[1]

(iv) Hence, calculate the molar mass of **Y** and suggest its identity.

[2]

[Total: 13]

3 This question involves the study of the kinetics of decomposition of hydrogen peroxide, H$_2$O$_2$ in the presence of iron(III) nitrate, Fe(NO$_3$)$_3$.

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$
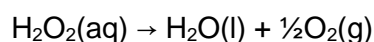
A small amount of Fe(NO$_3$)$_3$ was added to 100 cm^3 of 0.200 mol dm^{-3} H$_2$O$_2$ and the stopwatch was started.

At various time intervals, 10 cm^3 samples of the reaction mixture was extracted into a conical flask. 50 cm^3 of 0.200 mol dm^{-3} H$_2$SO$_4$ was added into a sample and titrated against 0.0200 mol dm^{-3} KMnO$_4$.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$
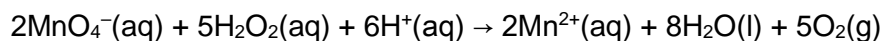
Based on the titration results, the concentration of H_2O_2 in each 10 cm^3 sample was calculated. A graph of concentration of H_2O_2 against time was obtained as show in **Fig. 3.1**.
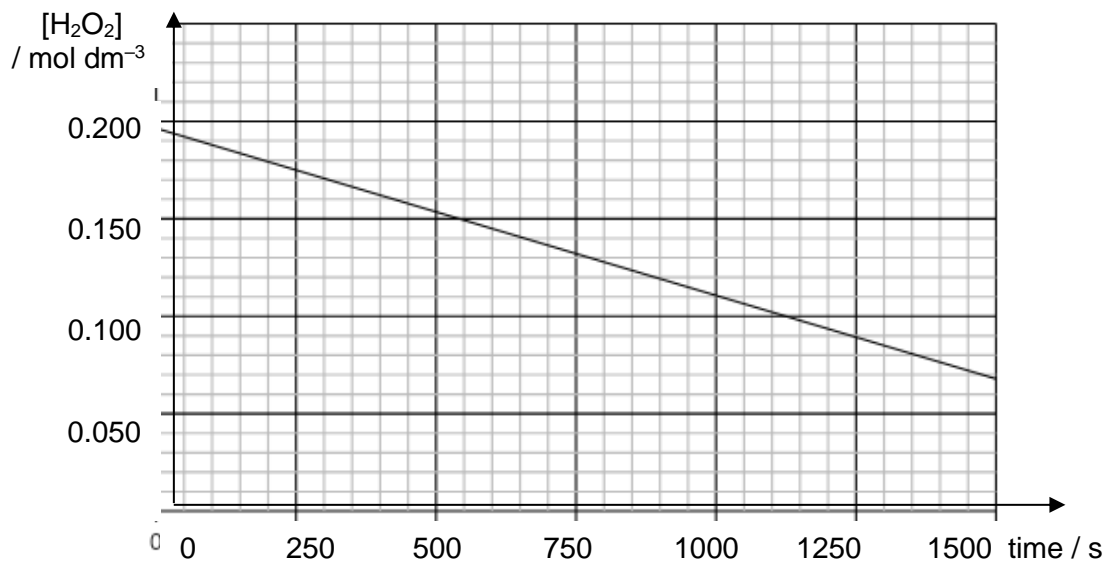

Fig. 3.1

(a) (i) It was observed that the concentration of $Fe(NO_3)_3$ in the reaction mixture remained constant throughout the whole experiment.

Suggest and explain the role of $Fe(NO_3)_3$ in the decomposition of H_2O_2.

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[1]

(ii) Hence, suggest and explain how the shape of the graph in **Fig. 3.1** would change if $Fe(NO_3)_3$ was **not** added to the reaction mixture.

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[2]

(b) **(i)** Calculate the **initial** number of moles of H_2O_2 in a 10.0 cm^3 sample of the reaction mixture.

[1]

(ii) Hence, calculate the volume of $KMnO_4$ that is needed for the titration.

[2]

(c) **(i)** By drawing relevant construction lines on the above graph in **Fig. 3.1**, determine the order of reaction with respect to H_2O_2. Explain your answer.

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[2]

(ii) Given that the initial rate of the reaction is 1.4×10^{-4} mol dm^{-3} s^{-1}. Calculate the rate constant of the reaction, stating its units.
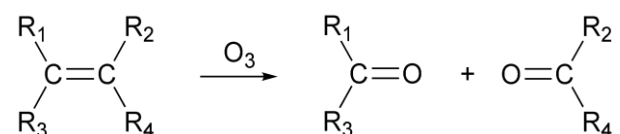
[1]

[Total: 9]

4 **(a)** Two alkenes with the molecular formula C_4H_8 **cannot** show cis-trans isomerism. Draw the **displayed** formulae of these two alkenes.

[2]

(b) Ozonolysis is a reaction where the unsaturated bonds of alkenes are cleaved with ozone, forming carbonyl compounds.

$$\underset{R_3}{\overset{R_1}{}}C=C\underset{R_4}{\overset{R_2}{}} \xrightarrow{O_3} \underset{R_3}{\overset{R_1}{}}C=O \;+\; O=C\underset{R_4}{\overset{R_2}{}}$$

R_1, R_2, R_3 and R_4 can represent either alkyl groups or hydrogen atoms.

(i) Give the structures and names of the products formed from the ozonolysis of 2–methylpent–2–ene.

Structure:

Name: ………………………….. …………………………..

[2]

(ii) Describe a test to distinguish between the two products formed in **(b)(i)**. State the reagents and conditions required, as well as the observation for each compound.

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(c) Consider the following synthesis pathway starting from an alkene:
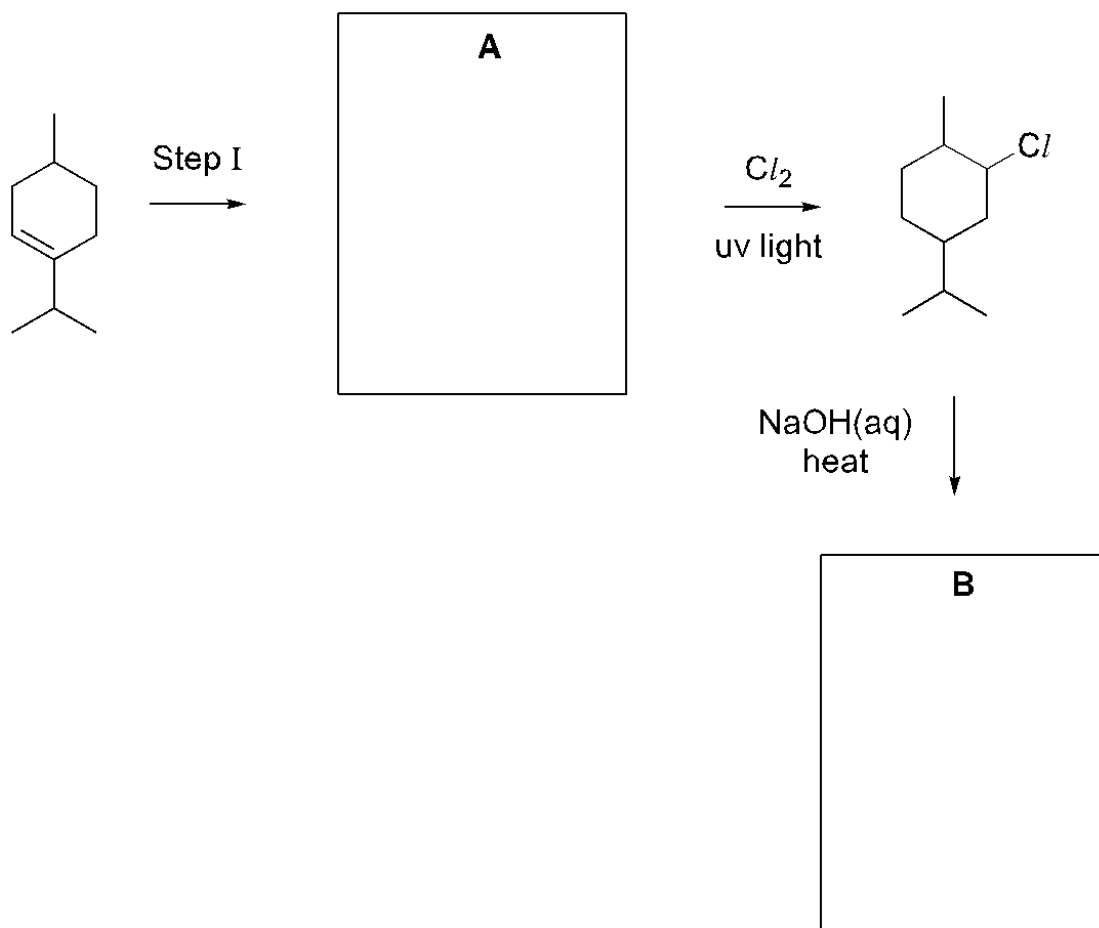

Fig. 4.1

(i) Draw the structures of **A** and **B** in the boxes in **Fig. 4.1**.

[2]

(ii) State the reagents and conditions required for Step **I**.

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[1]

[Total: 9]

S 5 The usage of the wood materials has improved considerably with the development of the industry and consequently the demand for wood adhesives has also increased accordingly. Today, there are several types of adhesives commonly used in woodworks. The use of each of these varies based on the properties such as curing time, strength, viscosity and water resistance.

(a) Poly(vinyl acetate) (PVAc) glue is the common type of glue with advantages that include high initial bonding strength and ease of use. The disadvantage includes rapid deterioration of bonding strength when exposed to moisture and higher temperature and not waterproof.

It is made from the monomer shown.

vinyl acetate
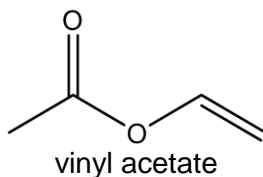
(i) State the type of polymerisation that produces PVAc.

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[1]

(ii) Draw the structure of PVAc, showing **two** repeat units.

[1]

(iii) Dried PVAc glue on any surface can be easily removed using vinegar or soap.

Explain why this is so.

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[1]

(b) Another adhesive, Polyurethane (PU) glue can be used to bond almost any material to wood as it provides very good adhesion and is waterproof. However, dealing with dried polyurethane glue can be problematic for finishes.

Polyurethanes are polymers made up of organic units joined by urethane links.

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

diisocyanate   +   HO—R^2—OH

diol
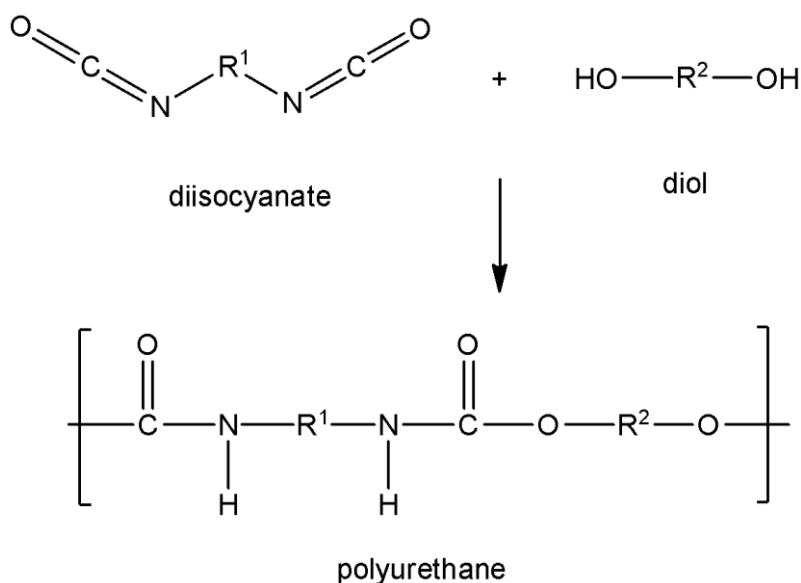
polyurethane

(i) State the functional group(s) present in polyurethane.

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[1]

(ii) Suggest and explain the type of R^1 and R^2 groups that polyurethane can have for the polymer to exhibit possible electrical conducting behaviour.

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[1]

(iii) A derivative of polyurethane can be formed by replacing the diol with glycerol, $CH_2OHCH(OH)CH_2OH$. The new polymer is found to be harder and stronger.

Suggest whether the new polymer formed is a thermosetting or thermoplastic polymer. Explain your answer using your knowledge of the structure and bonding in polymers.

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[2]

(c) A compound of molecular formula, $C_4H_8O_2$, has several possible **functional group isomers**, compound **A** to **C**.

The observations of the three tests carried out on compound **A** to **C** are given in the **Table 5.1**.

Table 5.1

test	chemical reagent and conditions	compound **A**	compound **B**	compound **C**
1	Br_2 in CCl_4 at room temperature	no observable change	no observable change	decolourisation of yellow solution

2	heat with acidified $K_2Cr_2O_7$(aq)	no observable change	solution turns from orange to green with only one organic product formed	solution turns from orange to green with only one organic product formed
3	NaOH(aq) at room temperature	compound **A** dissolves to form a colourless solution	no observable change	no observable change

Complete **Table 5.2** with the structures of compound **A** to **C**.

Give evidence from the observations in **Table 5.1** by stating the **type of reaction** that occurred to support your conclusions.

Further information that may help with the identification of the compounds are as shown:
1. None of the compounds have the same functional group.
2. Compound **A** can exist as two constitutional (structural) isomers.
3. Compound **B** is a sweet-smelling compound.
4. There is no net-dipole moment for compound **C**.

Table 5.2

	structure	evidence
compound A		
compound B		
compound C		

[6]

[Total: 13]

6 Phosgene, $COCl_2$, is very poisonous and was used as a chemical weapon during World War I, It can decompose to gaseous chlorine and carbon monoxide under suitable conditions as shown in the equation below.

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

At the start of the reaction, 3 mol of phosgene were introduced into a 10.0 dm³ vessel at 300 ºC. When equilibrium was established, it was found that 30% of the phosgene was left.

(i) Define the term *dynamic equilibrium*.

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[1]

(ii) Calculate the equilibrium concentrations of the three gases.

[2]

(iii) Determine the equilibrium constant, K_c, for this reaction at 300 ºC, stating its units.

[2]

(iv) When the temperature was increased to 400 ºC, it was found that only 20% of phosgene was left. Hence, deduce whether the reaction is endothermic or exothermic.

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[1]

(v) It is known that 340 parts per million (ppm) of phosgene in a gas mixture is enough to kill a rat within 30 min. (1 ppm of phosgene = 1 molecule of phosgene in 10^6 molecules of gas mixture)

Calculate the concentration, in ppm, of 0.150 g of phosgene in 64.0 dm^3 vessel at room temperature and pressure. Hence, determine if this concentration is enough to kill a rat, placed in the same vessel, in 30 min.

You may assume that phosgene does not undergo decomposition at room temperature and pressure and that the vessel is filled with gaseous air particles.

[2]

[Total: 8]

Section B

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

7 Lactic acid, $CH_3CH(OH)COOH$, is a *weak acid* commonly found in sour milk products such as yogurt and cottage cheese.

$$H_3C \overset{O}{\underset{OH}{\diagup\!\!\diagdown}} OH \rightleftharpoons H_3C \overset{O}{\underset{OH}{\diagup\!\!\diagdown}} O^- + H^+$$
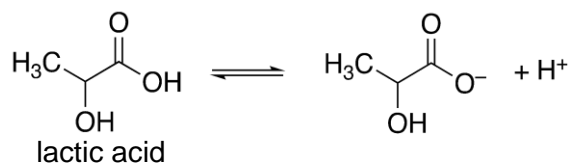
lactic acid

The graph below shows the pH changes during the titration of 20.0 cm³ of 0.100 mol dm⁻³ lactic acid with barium hydroxide. During this titration, barium hydroxide is added gradually, from a burette, until a total volume of 20.00 cm³ has been added to the acid.
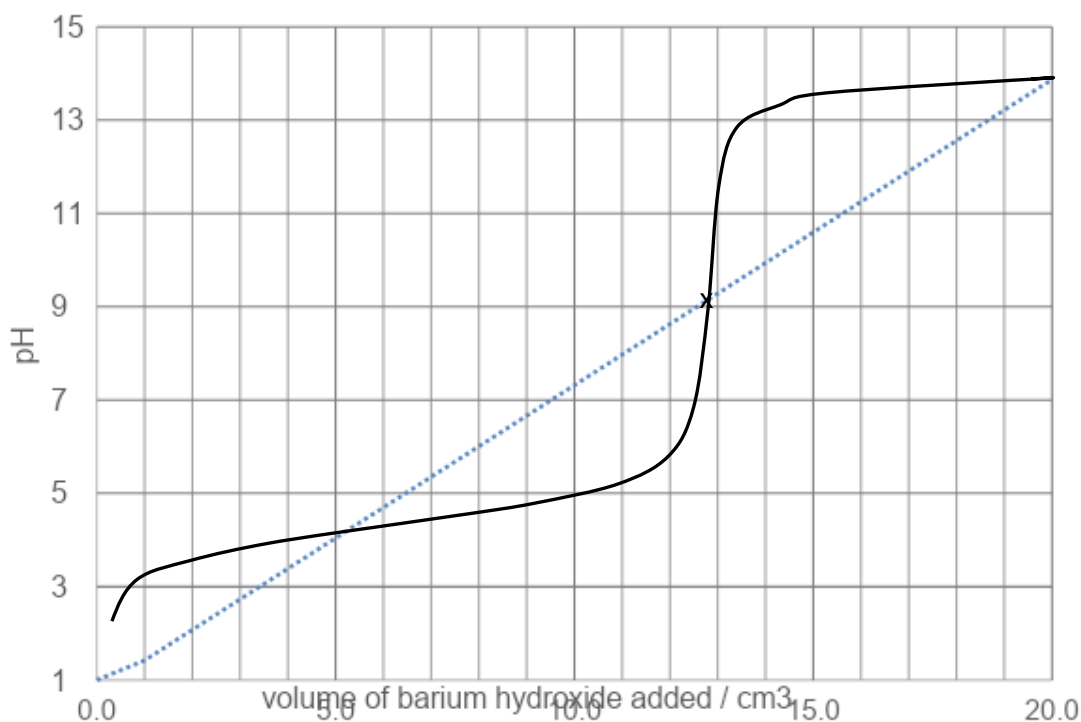
Fig. 7.1

(a) **(i)** Using the Bronsted-Lowry theory of acid, explain the meaning of the term *weak acid* with respect to lactic acid. Use information from **Fig. 7.1** to support your explanation.

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[2]

(ii) Lactic acid has an acid dissociation constant, K_a of 8.3×10^{-4} mol dm^{-3}.

Write the expression for the acid dissociation constant of lactic acid and state its units. You may represent lactic acid with RCO_2H.

[1]

(b) (i) Write a balanced equation for the reaction between lactic acid and barium hydroxide.

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[1]

(ii) Given that '**x**' in **Fig. 7.1** is the end point of the titration, calculate the concentration of barium hydroxide.

[1]

(iii) Using the information from **Fig. 7.1**, suggest which of the following indicators in **Table 7.1** should be used for the titration.

Table 7.1

indicator	colour in acid	colour in alkali	pH range over which colour change occurs
chlorophenol red	yellow	violet	4.8–6.7
phenolphthalein	colourless	pink	8.2–10.0
alizarin yellow	yellow	orange	10.1–13.0

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[1]

(c) **(i)** Using the pH from **Fig. 7.1**, calculate the concentration of hydrogen ions, in mol dm^{-3}, in the solution when 8.00 cm^3 of barium hydroxide is added.

[1]

(ii) The solution formed when 8.00 cm^3 of barium hydroxide is added acts as a buffer.

Explain, with the aid of relevant equations, how the solution can act as a buffer.

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[3]

(d) The *enthalpy change of neutralisation* for the reaction between 1.00 mol dm^{-3} lactic acid and 1.00 mol dm^{-3} barium hydroxide can be determined experimentally by measuring the change in temperature when the two solutions are mixed together.

The following data was obtained:

Table 7.2

volume of lactic acid used / cm^3	30.0
volume of barium hydroxide used / cm^3	20.0
initial temperature of lactic acid solution / $^{\circ}$C	32.1
initial temperature of barium hydroxide solution / $^{\circ}$C	30.0
highest temperature after mixing / $^{\circ}$C	39.2

(i) Define the term *standard enthalpy change of neutralisation*.

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[1]

(ii) When the initial temperatures of two solutions are different, the weighted average initial temperature is calculated as follows:

$$\text{weighted average initial temperature} = \left(\frac{V_1}{V_1 + V_2} \times T_1\right) + \left(\frac{V_2}{V_1 + V_2} \times T_2\right)$$

where V_1 and V_2 are the volumes of solutions 1 and 2 respectively,
T_1 and T_2 are the initial temperatures of solutions 1 and 2 respectively.

Calculate the weighted average initial temperature of the reaction.

[1]

(iii) Using your answer in **(d)(ii)** and the information provided, calculate the enthalpy change of neutralisation of lactic acid with barium hydroxide.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and the density of each solution is 1.00 g cm^{-3}.

[2]

(iv) The K_a of ethanoic acid is 1.8×10^{-5} mol dm^{-3}.

With reference to the data given in **(a)(ii)**, suggest how the magnitude of the enthalpy change of neutralization of ethanoic acid with barium hydroxide would differ from that of lactic acid with barium hydroxide.

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[2]

(e) Anaerobic metabolism and lactic acid accumulation often lead to metabolic acidosis.

Metabolic acidosis is associated with the loss of the bicarbonate ions, HCO_3^-.

(i) The HCO_3^- ion consists of two central atoms, C and O. Draw a dot and cross diagram of HCO_3^-.

[2]

(ii) State the shapes and bond angles about both central atoms.

shape and bond angle about C: …………………………………………..……………..

shape and bond angle about O: …………………………………………..……………..

[2]

[Total: 20]

8 This question is about the chemistry of some Group 17 elements.

(a) Period 3 elements react with chlorine to form chlorides having different chemical structures.

(i) Sketch a graph to show the trend in pH of the resultant solutions when chlorides of Period 3 elements, Na to P, are dissolved in water.

[1]

(ii) With the aid of two equations, explain the two reactions occurring when a zinc metal strip is added to the resultant solution obtained from the reaction of $SiCl_4$ with water.

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[3]

(iii) Explain, why there is no reaction observed when zinc metal strip is added to the resultant solution obtained from the reaction of CCl_4 with water.

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[2]

(b) *Use of the Data Booklet is relevant to this question.*

X_2, Y_2 and Z_2 are Cl_2, Br_2 and I_2 but are not necessarily in the given order.

The table below recorded observations when these halogens are separately added to aqueous solutions containing the halide ions followed by the addition of an organic solvent, CCl_4.

experiment	reactants	observation after shaking with CCl_4
1	X_2 (aq) + Y^- (aq)	violet organic layer seen
2	Z_2 (aq) + X^- (aq)	orange-red organic layer seen

(i) Deduce with reasoning, the oxidising strength of X_2, Y_2 and Z_2 in decreasing order. Hence, identify X_2, Y_2 and Z_2.

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[3]

(ii) By quoting relevant values from the *Data Booklet*, explain with reasons, the relative magnitude of the K_a values of H**Y** and H**Z**.

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[2]

(c) E300, $C_6H_8O_6$, is an oxidant used in white wines. The maximum concentration of E300 allowed in drinks is 8.52×10^{-4} mol dm^{-3}.

To find out if a 250.0 cm^3 sample of a drink containing E300 was within this limit, the following redox titration procedure is carried out.

An I_2 solution was first prepared by reacting 25.0 cm^3 of 0.00500 mol dm^{-3} KIO$_3$(aq) with excess KI(aq) under acidified conditions.

reaction 1 $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$
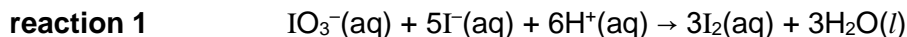
The resultant I_2 solution was then reacted with the E300 in the 250.0 cm^3 sample of the drink as follow.

reaction 2 $C_6H_8O_6 + I_2 \rightarrow C_6H_6O_6 + 2H^+ + 2I^-$

The amount of unreacted I_2 reacted with 20.40 cm^3 of 0.00500 mol dm^{-3} Na$_2$S$_2$O$_3$(aq) in the titration as follow.

reaction 3 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$
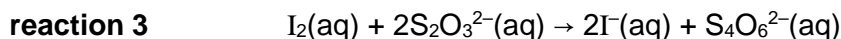
(i) Calculate the amount of I_2 formed in **reaction 1**.

[1]

(ii) Calculate the amount of I_2 remaining after the E300 had reacted.

[1]

(iii) Determine the concentration of the E300 in the 250.0 cm^3 sample of the drink.

Hence, deduce whether the drink is within the limit allowed.

[2]

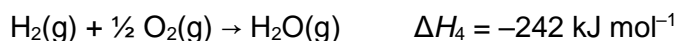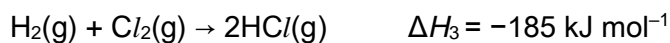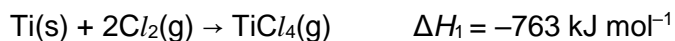**(d)** **(i)** Define *the standard enthalpy change of formation*.

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[1]

         [Turn over

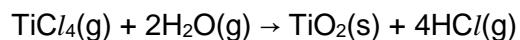**(ii)** Titanium tetrachloride, $TiCl_4$ is an important intermediate in the production of titanium metal and the pigment titanium dioxide.

Use the data given below, calculate the enthalpy change of the following reaction involving $TiCl_4$.

$$TiCl_4(g) + 2H_2O(g) \rightarrow TiO_2(s) + 4HCl(g)$$

$Ti(s) + 2Cl_2(g) \rightarrow TiCl_4(g)$ $\Delta H_1 = -763 \text{ kJ mol}^{-1}$

$Ti(s) + O_2(g) \rightarrow TiO_2(s)$ $\Delta H_2 = -945 \text{ kJ mol}^{-1}$

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ $\Delta H_3 = -185 \text{ kJ mol}^{-1}$

$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g)$ $\Delta H_4 = -242 \text{ kJ mol}^{-1}$

[2]

(iii) The standard enthalpy of formation of $F_2O(g)$ is $+24.5 \text{ kJ mol}^{-1}$.

Given that F_2O is made up of two F–O bonds, use data from the *Data Booklet* to calculate the bond energy of F–O bond.

[2]

[Total: 20]

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