



VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS
Higher 1

CANDIDATE
NAME

CT GROUP

CHEMISTRY

8872/02

Paper 2

13 September 2016

Candidates answer Section A on the Question Paper.

2 hours

Additional Materials: Answer Paper
 Graph Paper
 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 on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A

Answer **all** the questions.

Section B

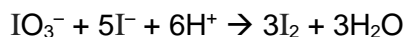
Answer **two** questions on separate answer paper.

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

FOR EXAMINER'S USE			
Section A		Section B	
A1		B4	
A2		B5	
A3		B6	
		Total	/ 80

This document consists of **14** printed pages and **0** blank page.

- 1 A 2.00 g salt contains a mixture of potassium iodate, KIO_3 , and potassium iodide, KI . Dissolving this mixture in the presence of acid will lead to formation of iodine in a redox reaction as shown:



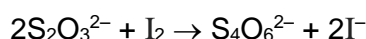
- (a) (i) Identify the oxidising and reducing agent in this reaction and state its change in oxidation number.

Oxidising agent: IO_3^-	Change in oxidation number: +5 to 0
Reducing agent: I^-	Change in oxidation number: -1 to 0

Identifying correct oxidising agent and reducing agent
Correct change in the oxidation number for OA and RA.

[2]

- (ii) 2.00 g of this mixture was dissolved in a 250 cm^3 solution containing excess acidified potassium iodide solution. The iodine produced in this reaction reacts with sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$ as shown below.



10.0 cm^3 of the resultant solution requires 22.35 cm^3 of $2.50 \times 10^{-2} \text{ mol dm}^{-3}$ thiosulfate to completely react with the iodine formed. Determine the percentage composition by mass of potassium iodide and potassium iodate in the mixture.

$$\begin{aligned} \text{No of moles of } \text{I}_2 \text{ in } 10.0 \text{ cm}^3 \text{ solution} &= 2.50 \times 10^{-2} \times \frac{22.35}{1000} \times \frac{1}{2} \\ &= 2.79 \times 10^{-4} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{No of moles of } \text{I}_2 \text{ in } 250 \text{ cm}^3 \text{ solution} &= 2.79 \times 10^{-4} \times \frac{250}{10.0} \\ &= 6.98 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{No of moles of } \text{IO}_3^- \text{ in } 2.00 \text{ g} &= \frac{1}{3} \times 6.98 \times 10^{-3} \\ &= 2.33 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{Mass of potassium iodate in } 2.00 \text{ g} &= 2.33 \times 10^{-3} \times (39.1 + 127 + 48.0) \\ &= 0.500 \text{ g} \end{aligned}$$

$$\begin{aligned} \text{Percentage of potassium iodate by mass} &= (0.500 / 2.00) \times 100\% \\ &= 25\% \end{aligned}$$

$$\begin{aligned} \text{Percentage of potassium iodide by mass} &= 100 - 25 \\ &= 75\% \end{aligned}$$

[3]

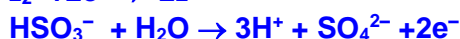
When a colourless solution containing KIO_3 and starch is mixed with acidified sodium hydrogensulfite, NaHSO_3 , the resultant mixture is initially colourless but turned to blue-black after some time. The blue-black colouration is only formed when the concentration of iodine in the solution is sufficiently high.

- (b) (i) When iodate ions are first mixed with hydrogensulfite ions, iodide and sulfate(VI) ions are formed. Write two half-equations and hence a balanced equation for this redox reaction.



- (ii) The iodate in excess will oxidise the iodide generated above to form iodine. However, the iodine is reduced immediately back to iodide by hydrogensulfite.

Write two half-equations and hence a balanced equation for the reaction between iodine and hydrogensulfite.



- (iii) With reference to the reaction between iodide and iodate as well as your answers to (b)(i) and (b)(ii), explain why a blue-black colouration is formed after some time when a colourless solution containing KIO_3 and starch is mixed with acidified sodium hydrogensulfite, NaHSO_3 .

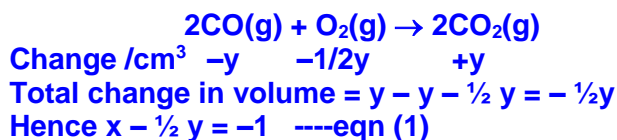
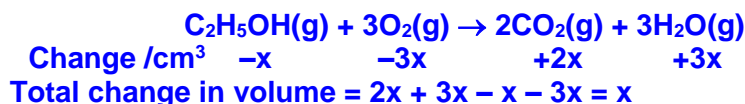
The iodine formed from iodide and iodate reacts with hydrogensulfite. Thus its concentration remains low and no blue-black colouration is observed.

After some time, when all the hydrogensulfite ions have been consumed, iodine concentration increases significantly and thus a blue-black colouration is observed. [2]

- (c) 20 cm³ of a gaseous mixture containing gaseous ethanol, carbon monoxide and excess oxygen was burned completely. There was a contraction of 1 cm³. When the product mixture was passed through sodium hydroxide, there was a further contraction of 6 cm³. All gas volumes are measured at 400 K and 1 atm.

Determine the molar composition of the ethanol and carbon monoxide in this gaseous mixture.

Let the volume of $\text{C}_2\text{H}_5\text{OH}$ and CO be x cm³ and y cm³ measured at 400 K and 1 atm respectively.



The further contraction is due to the removal of CO_2 by NaOH . Hence, $2x + y = 6$ ----eqn(2)

Solving the two simultaneous equations gives $x = 1$ and $y = 4$

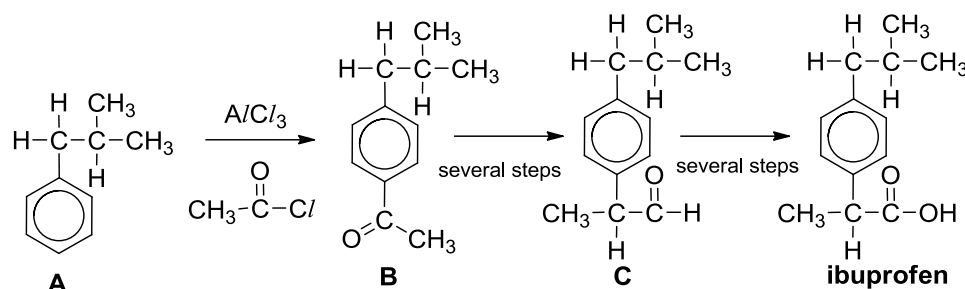
Molar composition of ethanol = $(1/20) \times 100\% = 5\%$

Molar composition of CO = $(4/20) \times 100\% = 20\%$

[3]

[Total: 14]

- 2 Ibuprofen is one of the most commonly used nonsteroidal anti-inflammatory drugs and can be made from the following process:



- (a) State the type of reaction for the conversion of **A** to **B**.

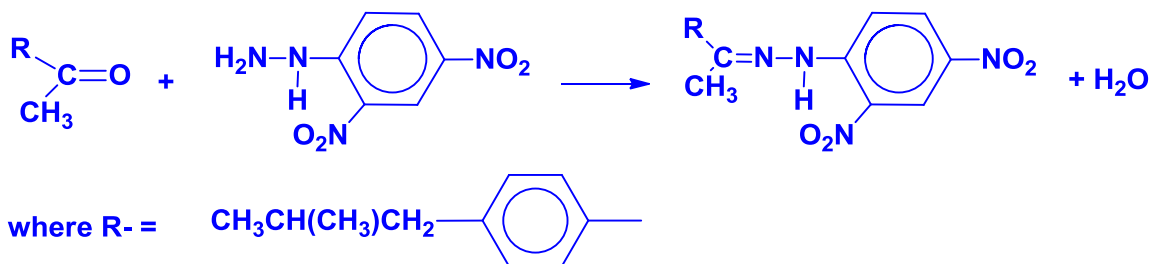
Substitution

[1]

- (b) Describe a simple chemical test to distinguish between **A** and **B**, giving the reagents and conditions, observations, and balanced equation for the positive test.

2,4-dinitrophenylhydrazine, room temperature

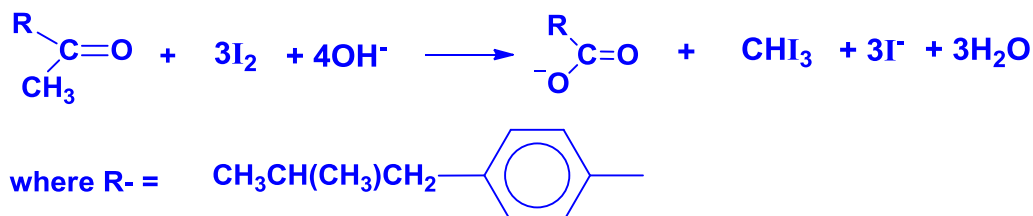
Orange ppt observed for B. No orange ppt for A.



Alternative answer:

$\text{I}_2(\text{aq})$, NaOH, warm

Yellow ppt observed for B. No yellow ppt for A.



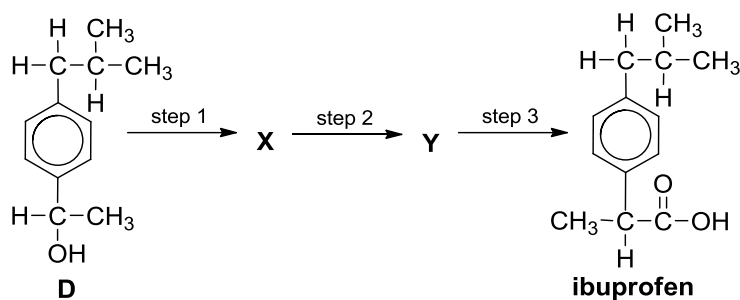
[2]

- (c) Suggest reagents and conditions that can be used to convert compound **C** to ibuprofen in one step in the laboratory.

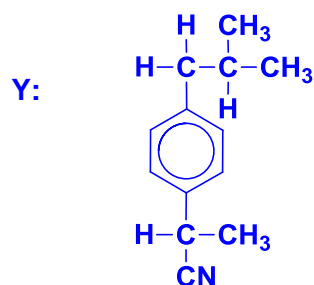
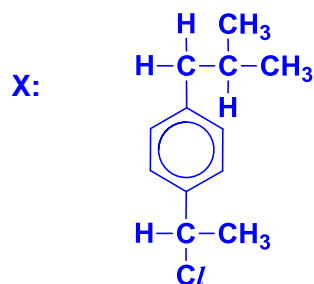
$\text{K}_2\text{Cr}_2\text{O}_7$, $\text{H}_2\text{SO}_4(\text{aq})$, heat. (KMnO_4 not accepted – may oxidise side chain)

[1]

- (d) A student commented that ibuprofen can be produced via a 3-step synthesis in the laboratory starting from compound **D**, as shown below.



State the reagents and conditions for steps 1, 2 and 3. Give the structures of the intermediates **X** and **Y**.



Step 1:

Reagent: PCl_5 ,

Condition: Room temperature

Step 2:

Reagent: Alcoholic KCN

Condition: Reflux

Step 3:

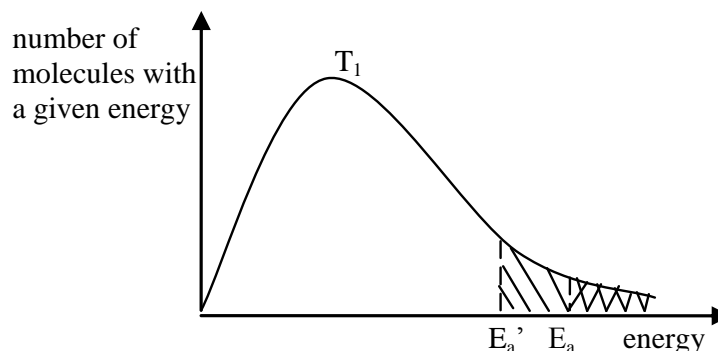
Reagent: $\text{H}_2\text{SO}_4(\text{aq})$

Condition: Heat

[4]

- (e) Ibuprofen can be also synthesised when compound **D** reacts with carbon monoxide over palladium catalyst.

Use the concept of activation energy, together with an appropriate sketch of the Boltzmann distribution, to explain why the addition of a suitable catalyst speeds up a chemical reaction.



where

E_a = activation energy for uncatalysed reaction

E_a' = activation energy for catalysed reaction

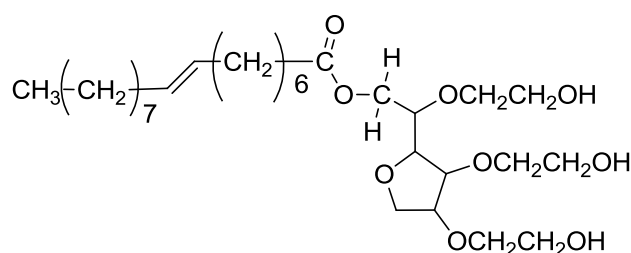
A catalyst works by providing an alternative pathway with lower activation energy, E_a' ,

so that there are more molecules with energy $\geq E_a'$.

Hence frequency of effective collisions increases leading to a higher rate. [3]

- (f) Young children can find it difficult to swallow tablets or pills. As a result, ibuprofen is supplied as an “infant formula” emulsion, which is a homogeneous mixture of two or more liquids (e.g. oil and water) that are immiscible.

To prevent the liquids from separating, an emulsifier is used and one such emulsifier is polysorbate 80. Its structure is given below.



polysorbate 80

Explain why this molecule acts as an emulsifier.

Presence of OH groups that render the molecule to be soluble in water.

Presence of non-polar hydrocarbon groups that render the molecule to be soluble in oil / non-polar liquids.

[1]

- (g) The decomposition of ibuprofen follows a first order kinetics with a half-life of 1.5 hours. Calculate the mass of the drug that remains in the blood for a dosage of 400 mg after 6 hours.

For a first order reaction, half-life is constant.

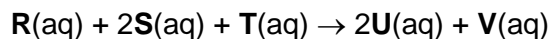
6 hours \Rightarrow 4 half-lives

Final mass of ibuprofen = $(1/2)^4 \times 400$
= 25 mg

[1]

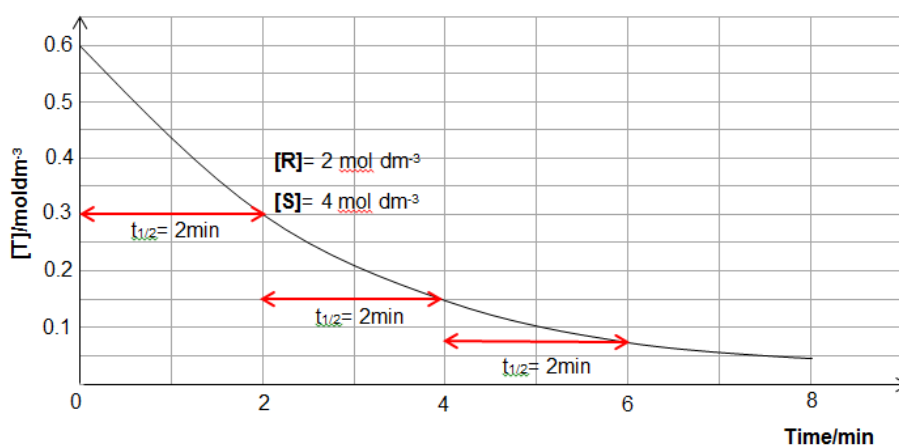
[Total: 13]

- 3 (a) Substances **R**, **S** and **T** react according to the following equation:



To find the rate equation for the above reaction, separate experiments were performed. The results are shown below.

- (i) By showing your working clearly on the graph above, prove that the order of reaction with respect to **T** is first order.

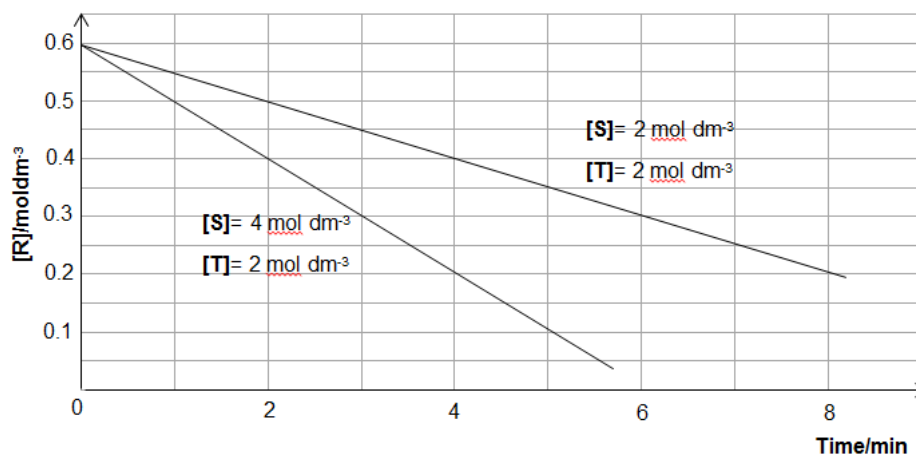


Shows 3 constant $t_{1/2}$ on graph of $[T]$ against time.

Graph shows constant $t_{1/2} = 2 \text{ min}$

Reaction is first order with respect to T.

[1]



- (ii) Deduce the order of reaction with respect to **R** and **S**.

Graph of [R] against time is a straight line with constant gradient.

Rate of reaction is constant at different concentrations of R.

Reaction is zero order with respect to R.

When concentration of S increases by 2 times, the gradient increases by 2 times.

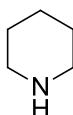
Reaction is first order with respect to S. [2]

- (iii) Write the rate equation for the reaction. Hence, calculate a value for the rate constant, giving its units.

$$\begin{aligned}\text{Rate} &= k[S][T] \text{ (ecf)} \\ k &= (0.100)/(4)(2) \\ &= 0.0125 \text{ mol}^{-1} \text{ dm}^3 \text{ min}^{-1}\end{aligned}$$

[2]

- (b) Piperidine is a monoacidic base and is widely used building block and chemical reagent in the synthesis of organic compounds.



piperidine

- (i) The pH of an aqueous solution of piperidine is 10.1. Calculate the concentration of hydroxide ions in the solution.

$$\begin{aligned}\text{pOH} &= 14 - 10.1 \\ &= 3.9 \\ [\text{OH}^-] &= 10^{-3.9} \\ &= 1.26 \times 10^{-4} \text{ mol dm}^{-3}\end{aligned}$$

[1]

- (ii) In a titration, 25 cm³ of the aqueous solution of piperidine in (b)(i) was found to react completely with 30 cm³ of 0.15 mol dm⁻³ of HCl (aq). Calculate the concentration of piperidine solution.

$$\begin{aligned}C_{\text{piperidine}} V_{\text{piperidine}} &= C_{\text{HCl}} V_{\text{HCl}} \\ C_{\text{piperidine}} (25/1000) &= (30/1000) (0.15) \\ C_{\text{piperidine}} &= 0.180 \text{ mol dm}^{-3}\end{aligned}$$

[1]

- (iii) With reference to your answers to (b)(i) and (b)(ii), explain why piperidine is a weak base.

[OH⁻] is much lower than piperidine concentration

Piperidine did not undergo complete dissociation to give OH⁻. Thus it is a weak base. [1]

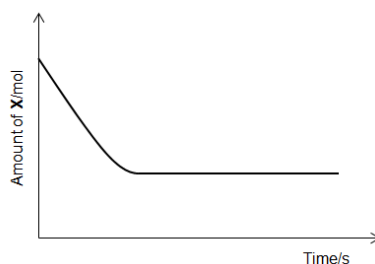
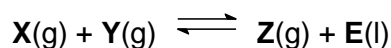
- (iv) Which of the indicators from the table below could you use for this titration in (b)(ii)? Explain your answer.

Indicator	Working range	Low pH color	High pH color
Tetrabromophenol blue	3.0 – 4.6	yellow	blue
Thymolphthalein	9.3 – 10.5	colorless	blue

Tetrabromophenol blue.
It is a strong acid-weak base titration.

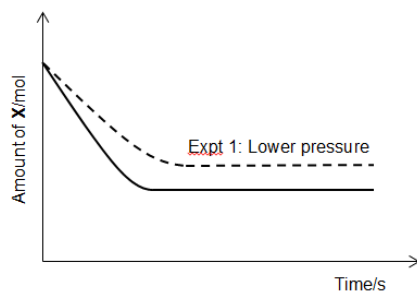
Alternative reason (not too important vs type of acid-base titration):
The working range of the indicator should fall within the range of rapid pH change of the titration curve. [1]

- (c) When 1 mole of **X** is mixed with 1 mole of **Y**, the results were as shown:



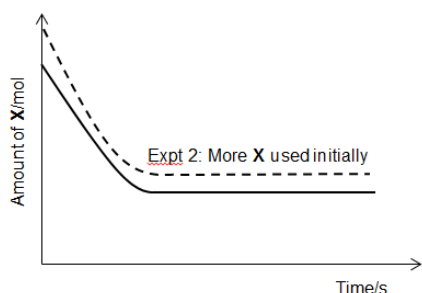
- (i) Experiments were carried out on the above equilibrium with changes in the conditions. Plot and indicate on the graph (using dotted lines) the variation of **X** with time for each experiment.

- (I) Experiment 1: Lower pressure



[1]

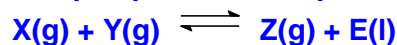
- (II) Experiment 2: More **X** used initially



[1]

- (ii) Explain the shape of the graph obtained for experiment 1 in (c)(i).

When there is lower pressure, molecules are less crowded together.
By Le Chatelier's principle, position of equilibrium shifts left for



to increase the number of moles of gas.

Hence, more X is present at equilibrium.

When there is lower pressure, rate decreases hence a gentler gradient is observed. [2]

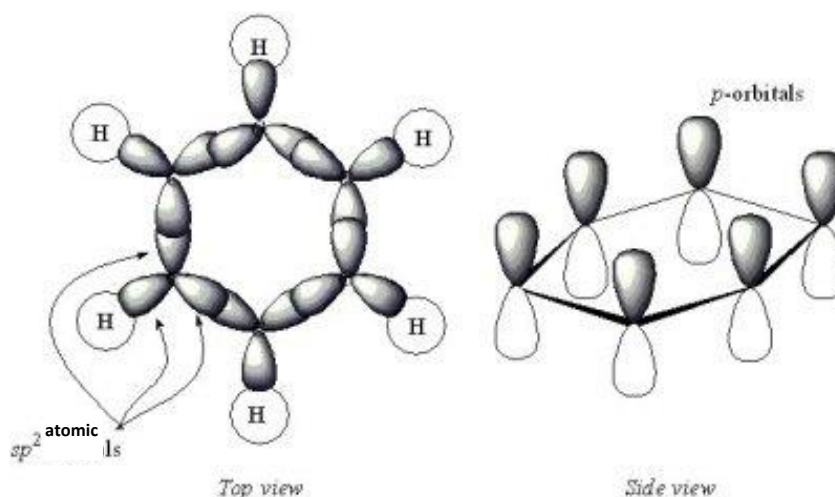
[Total: 13]

Section B

Answer **two** questions from this section on separate answer paper.

4

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



The sigma bond formed between carbon-carbon is formed by the head-on overlap of the orbital of carbon atoms.

The sigma bond formed between carbon-hydrogen is formed by the head-on overlap of the atomic orbital of carbon and the s orbital of hydrogen atom.

The pi bond formed between carbon atoms is formed by the sideways overlap of the p orbital of carbon atoms.

These pi bonds are formed above and below the ring of carbon atoms. [3]

- (b) The successive ionisation energies in kJ mol^{-1} of the elements, X and Y, are given below.

	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th
X	580	1817	2745	11577	14842	19379	23326	27465
Y	1000	2252	3357	4556	7004	8496	27107	31719

- (i) Deduce the group that element **X** and **Y** belongs to.

There is a big jump between the 3rd and 4th ionisation energy of X, hence there are 3 valence electrons.

X: Group III

There is a big jump between the 6th and 7th ionisation energy of Y, hence there are 6 valence electrons.

Y: Group VI

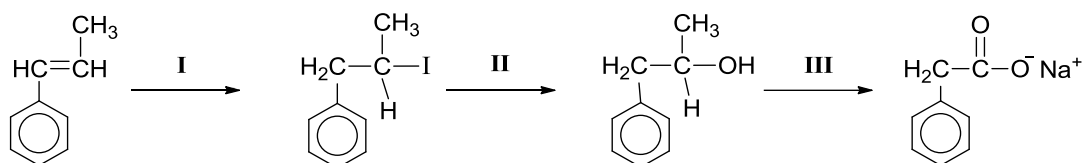
[2]

- (ii) Hence, give the formula of the compound formed between **X** and **Y**.

X₂Y₃

[1]

- (c) Beta-methylstyrene undergoes the reactions shown below:



Beta-methylstyrene

- (i) State the reagents and conditions required for reactions **I** to **III**.

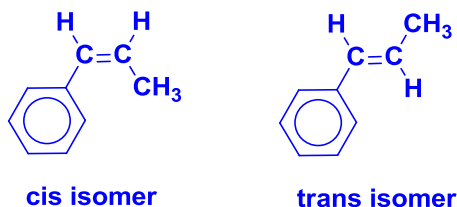
I: HI(g), room temperature

II: NaOH(aq), heat

III: I₂, NaOH(aq), warm

[3]

- (ii) Beta-methylstyrene exists naturally as a pair of geometric isomers. Draw the structures of the isomers, clearly labelling each isomer.



[2]

- (d) I₂ is not very soluble in water. However when I₂ reacts with KI(aq), it forms highly soluble KI₃.

Draw the dot and cross diagram of the I₃⁻ ion (including all lone pairs of electrons), and deduce its shape and bond angle.



Shape: Linear

Bond angle: 180°

[2]

- (e) The standard enthalpy change of vapourisation ($\Delta H^\circ_{\text{vap}}$), is defined as the energy required to convert 1 mol of a compound into the gaseous state.

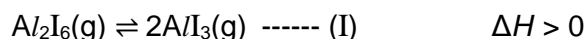
The table below shows the $\Delta H^\circ_{\text{vap}}$ of NH_3 and NI_3 .

Compound	Standard enthalpy change of vapourisation, $\Delta H^\circ_{\text{vap}} / \text{kJ mol}^{-1}$
NH_3	+23.35
NI_3	+ 28.29

- (i) Explain why the $\Delta H^\circ_{\text{vap}}$ of NI_3 is more endothermic than NH_3 . [2]

Although NH_3 molecules are held by hydrogen bonding, NI_3 has a much greater number of electrons than NH_3 . Hence more energy is needed to overcome the stronger dispersion forces in NI_3 . [2]

AlI_3 has a simple molecular structure. In the gas phase, it dimerises readily to form the dimer Al_2I_6 . The two species are related by equilibrium (I) shown below:



- (ii) A 10.0 g sample of Al_2I_6 was allowed to vapourise in a 2 dm^3 vessel at 400°C . Given that the degree of dissociation (α) of Al_2I_6 was 0.35, find the K_c value for equilibrium (I) at 400°C .

$$\begin{aligned}
 \text{Concentration of } \text{Al}_2\text{I}_6 &= 10.0 / 2 \\
 &= 5.00 \text{ g dm}^{-3} \\
 [\text{Al}_2\text{I}_6] &= 5.00 / 816 \\
 &= 0.00613 \text{ mol dm}^{-3} \\
 [\text{Al}_2\text{I}_6] \text{ (after dissociation)} &= 0.65 \times 0.00613 \\
 &= 0.00398 \text{ mol dm}^{-3} \\
 [\text{AlI}_3] &= 2 \times 0.35 \times 0.00613 \\
 &= 0.00429 \text{ mol dm}^{-3} \\
 K_c &= \frac{[\text{AlI}_3]^2}{[\text{Al}_2\text{I}_6]} \\
 &= \frac{0.00429^2}{0.00398} \\
 &= 0.00462 \text{ mol dm}^{-3}
 \end{aligned}$$

[3]

- (iii) Explain what happens to the position of equilibrium (I) for each of the changes below.
- (I) The reaction was carried out at 500°C .
- (II) A sample of $\text{Ar}(\text{g})$ was introduced into a 1 dm^3 vessel containing $\text{AlI}_3(\text{g})$ and $\text{Al}_2\text{I}_6(\text{g})$ at a 400°C .

For (A), when the temperature is increased, the endothermic reaction is favoured or to remove the excess heat.

Hence, the position of equilibrium (I) will shift to the right.

For (B), the concentration of $Al_3(g)$ and $Al_2I_6(g)$ remains the same and there is no shift in the position of equilibrium (I).

[2]

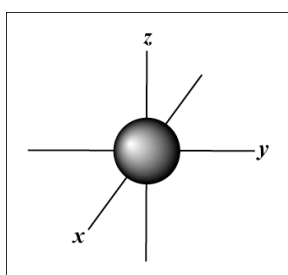
[Total: 20]

- 5 (a) Describe the carbon atom, ^{12}C , as fully as you can, including the nature and location of the sub-atomic particles, and sketch the shapes of the filled valence orbitals.

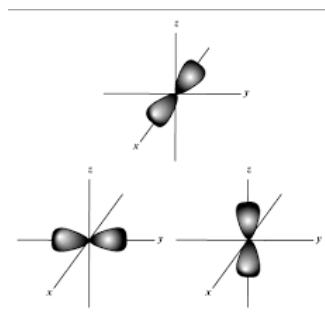
^{12}C has 6 neutral neutrons and 6 positively charged protons located at the centre of the atom.

It has 6 negatively charged electrons moving around the nucleus of the atom.

Correct sketch of 2s and any two 2p orbitals



2s orbital



2p orbitals

[3]

- (b) Predict, with reasons, how the radius of carbon atom would compare with

- (i) C^- ion;

C^- ion has (slightly) larger radius than C atom as it has the same nuclear charge but there is extra electrostatic repulsion produced by the incoming electron(s) in the valence shell. So C^- ion experiences a smaller effective nuclear charge leading to weaker pull of electrons by nucleus.

[1]

- (ii) C^+ ion

C^+ ion has (slightly) smaller radius than C atom as it has the same nuclear charge but an electron is lost from the valence shell. So C^+ ion experiences a greater effective nuclear charge leading to stronger pull of electrons by nucleus.

[1]

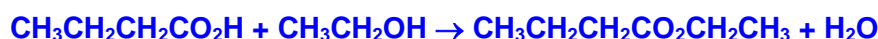
- (c) Esters of carboxylic acids are often used as components of synthetic fruit flavours. Ethyl butanoate, **P**, $CH_3CH_2CH_2CO_2CH_2CH_3$, is a major component of strawberry flavourings.

- (i) Name the reagents and state conditions needed to synthesise **P** from butanoic acid.

Ethanol and concentrated sulfuric acid, heat

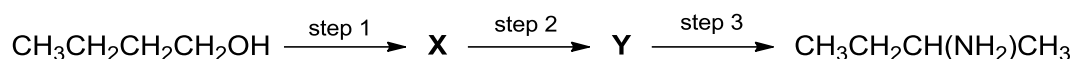
[1]

- (ii) Write an equation for the formation of **P** from butanoic acid.



[1]

- (d) $\text{CH}_3\text{CH}_2\text{CH}(\text{NH}_2)\text{CH}_3$ can be synthesized from $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ through a 3-step reaction route.



Suggest reagents and conditions for each step, showing the structural formulae of the intermediates, **X** and **Y** produced.

X: $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$

Y: $\text{CH}_3\text{CH}_2\text{CH}(\text{Cl})\text{CH}_3$

Step 1:

Reagent: Excess conc H_2SO_4

Condition: 170°C

Step 2:

Reagent: $\text{HCl}(\text{g})$

Condition: room temperature

Step 3:

Reagent: Excess conc $\text{NH}_3(\text{alcoholic})$

Condition: Heat in sealed tube

[4]

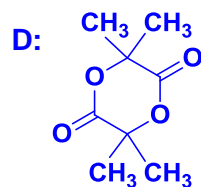
- (e) Compound **A**, $\text{C}_4\text{H}_{10}\text{O}_2$, reacts with sodium metal but is insoluble in aqueous sodium hydroxide, and does not form pale yellow precipitate with alkaline aqueous iodine. On treatment with hot acidified sodium manganate(VII), **A** gives **B**, $\text{C}_4\text{H}_8\text{O}_3$, which is soluble in aqueous sodium hydroxide. On treatment of **B** with phosphorus pentachloride, a compound **C**, $\text{C}_4\text{H}_6\text{OCl}_2$ is obtained. On warming **B** with concentrated sulfuric acid, **D**, $\text{C}_8\text{H}_{12}\text{O}_4$ is obtained.

- (i) From the observations provided above, suggest the identity of the compounds, **A** to **D**, giving your reasons and explain the reactions.

A: $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{OH}$

B: $(\text{CH}_3)_2\text{C}(\text{OH})\text{CO}_2\text{H}$

C: $(\text{CH}_3)_2\text{CClCOCl}$



A has $-\text{OH}$ / $-\text{CO}_2\text{H}$ groups as it can react with Na metal via redox / acid-metal reaction.

A does not have CO_2H group as it cannot dissolve in NaOH & does not have $\text{CH}_3\text{CH}(\text{OH})-$ group (no oxidative cleavage) as it does not give pale yellow precipitate (CHI_3) with alkaline $\text{I}_2(\text{aq})$.

A is a primary or secondary alcohol which can be oxidised by NaMnO_4 .

B has $-\text{CO}_2\text{H}$ group as it can undergo neutralisation with NaOH to give an ionic salt, which is soluble in water.

B undergoes substitution with PCl_5 to give C \Rightarrow B has $-\text{OH}$ / $-\text{CO}_2\text{H}$ groups. In the presence of H_2SO_4 which acts as a catalyst, B undergoes condensation on its own to form ester. [8]

- (ii) Compound E, an isomer of compound A, can also react with sodium metal but forms a pale yellow precipitate with alkaline aqueous iodine. Suggest a structure for compound E.

$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{OH}$ or $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{OH})\text{CH}_3$ [1]

[Total: 20]

- 6 (a) Magnesium, silicon and phosphorus are elements in the third period of the Periodic Table. Arrange the elements in order of increasing melting point. Explain your answer in terms of structure and bonding.

Phosphorus, magnesium, silicon

Si has the highest melting point as it has a giant covalent structure, and strong covalent bonds between atoms.

Mg has a giant metallic lattice with metallic bonds / electrostatic attraction between the delocalised electrons and cations.

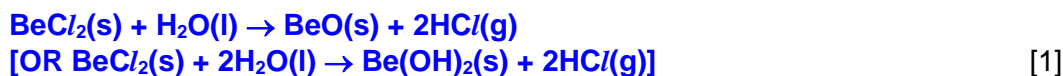
P exists as simple covalent molecules with weak dispersion forces between the molecules.

More energy is required to overcome the covalent bonds between Si atoms than the metallic bonds of Mg, while least energy is required for the dispersion forces between P molecules. [4]

- (b) There is said to be a 'diagonal relationship' between beryllium and aluminium as they show similar chemical behaviour due to their similarities in electronegativity and charge density.

- (i) When a few drops of water are added to solid beryllium chloride, steamy white fumes are evolved and a white solid remains, which is insoluble in water.

Write a balanced equation for this reaction.



- (ii) When a large amount of water is added to solid beryllium chloride, a clear, weakly acidic solution is obtained. Explain.

Due to the high charge density of Be^{2+} , BeCl_2 undergoes hydration and hydrolysis / $\text{Be}^{2+}(\text{aq})$ pulls electrons away from one of the surrounding water molecules, hence weakening the O–H bond which results in the release of a proton and give rise to an acidic solution. [1]

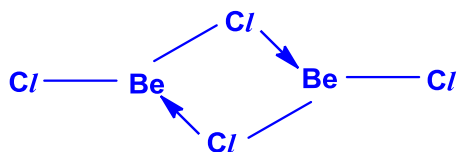
- (iii) At 750°C , the relative molecular mass of gaseous beryllium chloride corresponds to the formula BeCl_2 . At 550°C , gaseous beryllium chloride exists as a mixture of BeCl_2 and Y (relative molecular mass of Y is 160).

Determine the molar composition of gaseous beryllium chloride at 550°C which has a relative molecular mass of 100. Draw a diagram to illustrate the nature of the bonding in Y and indicate the value of the bond angle about Be.

$$100 = 80x + 160(1 - x)$$

$$x = 0.75 \quad \text{and} \quad 1 - x = 0.25$$

Composition is 75% BeCl_2 and 25% Y.



Trigonal planar with respect to Be, hence bond angle is 120° . [2]

- (c) A solid mixture contains two oxides of Period 3 elements. To separate the oxides, water was added to the mixture, followed by filtration. Effervescence was observed when sodium carbonate was added to the filtrate. The residue does not react with dilute acid and dilute alkali.

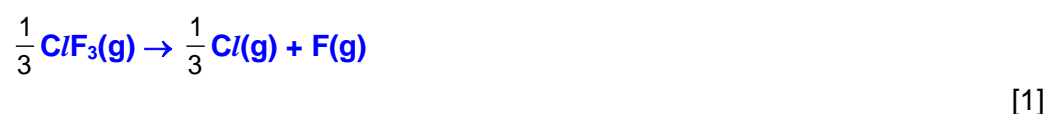
- (i) Identify the two oxides present in the mixture.

P_4O_6 / P_4O_{10} and SiO_2 [1]

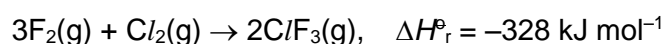
- (ii) Hence, write an equation for the oxide that reacts with water.



- (d) (i) Write an equation, with state symbols, to define the Cl-F bond energy in ClF_3 .



- (ii) The following reaction occurs in the gas phase.



Use these and other data from the *Data Booklet* to calculate the average bond energy of the Cl-F bond in ClF_3 .

$$\Delta H^\circ_r = \Sigma \text{BE}(\text{reactants}) - \Sigma \text{BE}(\text{products})$$

$$-328 = 3\text{BE}(\text{F-F}) + \text{BE}(\text{Cl-Cl}) - 6\text{BE}(\text{Cl-F})$$

$$-328 = 3(158) + 244 - 6\text{BE}(\text{Cl-F})$$

$$\text{BE}(\text{Cl-F}) = 174 \text{ kJ mol}^{-1}$$
 [2]

- (e) An experiment is conducted to determine the enthalpy change of neutralisation between methanoic acid (HCO_2H) and aqueous sodium hydroxide. Some methanoic acid is added to excess sodium hydroxide solution. The changes in temperature and amount of reagents mixed are recorded as follows.

Initial temperature / $^\circ\text{C}$	24.0
Final temperature / $^\circ\text{C}$	34.0
Mass of HCO_2H added / g	1.84
Volume of $1 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ used / cm^3	50.0

- (i) Define standard enthalpy change of neutralisation with respect to methanoic acid and aqueous sodium hydroxide.

The enthalpy change when 1 mole of water is formed when methanoic acid neutralises sodium hydroxide and is carried out in an infinitely dilute aqueous solution under standard conditions of 298K and 1 atm. [1]

- (ii) Use the above data to calculate the enthalpy change of neutralisation, assuming that 4.2 J is required to raise the temperature of 1 cm³ solution by 1°C.

$$\begin{aligned}\text{Heat evolved} \\ &= 50.0 \times 4.2 \times (34.0 - 24.0) \\ &= 2100 \text{ J}\end{aligned}$$

$$\begin{aligned}\text{No. of moles of water formed} \\ &= 1.84 \div 46.0 \\ &= 0.0400 \text{ mol}\end{aligned}$$

$$\begin{aligned}\Delta H_{\text{neut}} \\ &= -2100 \div 0.0400 \\ &= -52500 \text{ J mol}^{-1} \\ &[\text{OR } -52.5 \text{ kJ mol}^{-1}]\end{aligned}$$

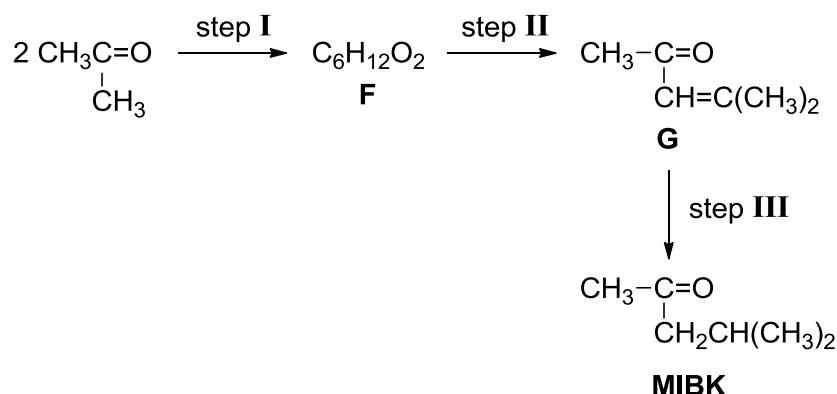
[2]

- (iii) The magnitude of enthalpy change of neutralisation between aqueous nitric acid and aqueous sodium hydroxide is found to be larger than the value calculated in (e)(ii). Explain why this is so.

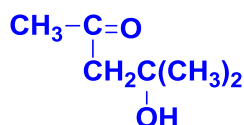
Nitric acid is a strong acid which dissociates completely in solution while methanoic acid is a weak acid which dissociates partially in solution. Some energy released during neutralisation is used to ionise the weak acid.

[1]

- (f) Propanone, CH₃COCH₃, an important industrial solvent, can be converted into another industrially important solvent, MIBK, by the following sequence.



- (i) When **F** is formed in step I, no other compound is produced. Suggest a structural formula for **F**, which contains one –OH group.



[1]

- (ii) Name the types of reaction occurring in steps **I** and **III**.

Step I: addition

Step III: reduction

[1]

- (iii) **G** is formed from **F** in step **II**. Suggest the reagent and condition for step **II**.

Excess concentrated H_2SO_4 , 170 °C

[1]

[Total: 20]