



TEMASEK
JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE
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CHEMISTRY

8872/02

Paper 2

29th August 2016

2 hours

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper

 Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name 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.

Section A

Answer **all** questions.

Section B

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

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.

For Examiner's Use	
A1	/ 8
A2	/ 13
A3	/ 9
A4	/ 10
Section B	/ 40
Paper 1	/ 30
Total	

This document consists of **18** printed pages.

Section A

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

- 1 (a) **A**, **B** and **C** are Period 3 elements, from Na to Ar, inclusive. Some of the physical properties of the three elements are listed below:

- **A** has the highest melting point among Period 3 elements.
- **B** has the highest electrical conductivity in Period 3.
- **C** burns in air with a bright white flame.
- **B** and **C** can show the same oxidation state in their compounds.

Identify **A**, **B** and **C** and explain your answers. Hence give the chemical formulae for their chlorides in the maximum oxidation state.

A: **Si**

Explanation: •**Si has the highest melting point as it has a giant molecular structure and melting involves largest amount of energy to break the numerous strong covalent bonds.**

Chloride in maximum oxidation number: **SiCl₄**

B: **Al**

Explanation: **Al has the highest electrical conductivity as it has 3 valence electrons that can be easily lost to contribute to the sea of delocalised electrons that function as charge carriers under an applied pd.**

Chloride in maximum oxidation number: **AlCl₃**

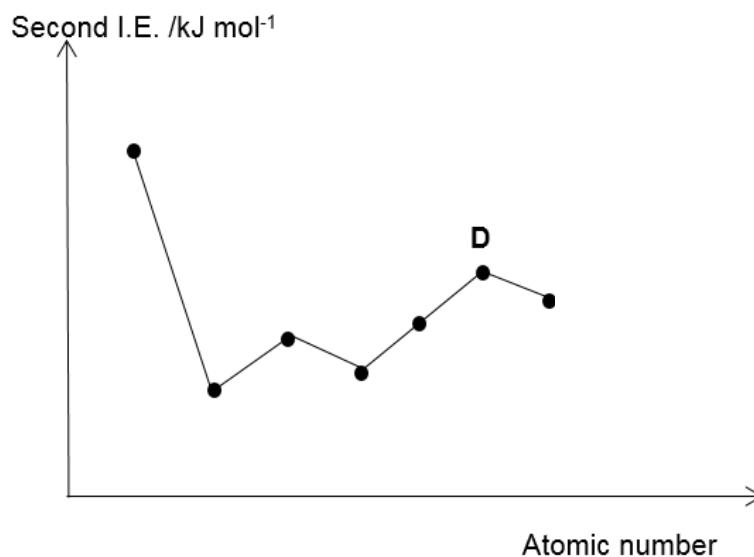
C: **P**

Explanation: **Since B is Al and has +3 oxidation state, the other element with +3 oxidation state is P. P also burns with a bright white flame.**

Chloride in maximum oxidation number: **PCl₅**

[6]

- (b) The graph below shows the variation of the second ionisation energies for seven consecutive elements, which have atomic numbers between 8 to 18 in the Periodic Table.



Suggest and explain the identity of **D**.

D: **S**

Explanation: **The element with the highest 2nd IE is Na as it involves largest amount of energy to remove outermost electron from an inner quantum shell.**

So counting forward, D is Sulfur.

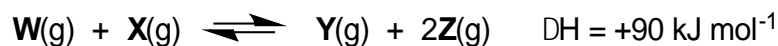
Or

The element with the lowest 2nd IE is Mg as it involves removal of one electron from the 3s subshell of higher energy ($\text{Mg}^+(\text{g}): [\text{Ne}]3s^1$). So counting forward, D is Sulfur.

[2]

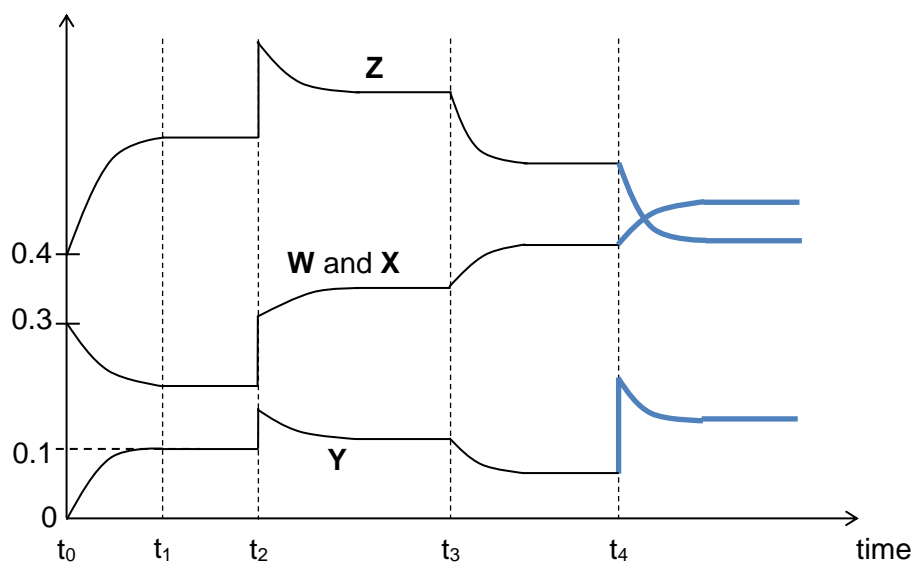
[Total: 8]

2 Gases **W** and **X** react as shown in the equation given.



Gases **W**, **X** and **Z** were injected into a vessel at 25 °C and allowed to reach dynamic equilibrium. The graph below (not drawn to scale) shows how the concentration of the four gases varies with time.

concentration / mol dm⁻³



(a) (i) Explain what is meant by *dynamic equilibrium*.

- When a reversible reaction reaches a state of dynamic equilibrium, reaction continues to occur but the rates of the forward and backward reactions are equal
- such that there is no net change in the concentrations of the reactants and products.

[2]

(ii) Write an expression for K_c for this equilibrium, stating the units.

$$K_c = \frac{[\text{Y}][\text{Z}]^2}{[\text{W}][\text{X}]} \text{ mol dm}^{-3}$$

[2]

(iii) Calculate the value for K_c at time, t_1 .

•	$W(g) + X(g) \rightleftharpoons Y(g) + 2Z(g)$			
Initial conc. / mol dm ⁻³	0.3	0.3	0	0.4
Change in conc. / mol dm ⁻³	- 0.1	- 0.1	+ 0.1	+ 0.2
Equil. conc. / mol dm ⁻³	0.2	0.2	0.1	0.6

• $K_c = 0.1 \times 0.6^2 / 0.2 \times 0.2 = 0.900 \text{ mol dm}^{-3}$

[2]

(b) (i) State *Le Chatelier's principle*.

- If a system at dynamic equilibrium is subjected to a change which disturbs the equilibrium, the system will respond in such a way so as to counteract the effect of the change so as to re-establish the equilibrium.

[1]

At time, t_2 , the volume of the system was reduced which lead to an increase in concentration of the gases. This causes the position of the equilibrium to shift.

(ii) Suggest and explain what happens to the system between time t_3 to t_4 .

- Position of equilibrium shifts to the left as conc. of W and X increases gradually and conc. of Y and Z decreases gradually.
- Since the backward reaction is exothermic, the temperature of the system must have been decreased at time, t_3 .

[2]

(iii) Sketch on the same axes how the concentration of the four gases will change when more gas Y was introduced at time, t_4 .

- Sharp increase in [Y] followed by decrease in [Y], decrease in [Z] and increase in [W]&[X]
- Decrease in [Z] is twice the increase in [W], [X] and [Y]. Equilibrium [Y] should not be lower than the initial [Y] at t_4 .

[2]

(c) State and explain the effect of the presence of a catalyst on the equilibrium position and the value of the equilibrium constant.

- A catalyst has no effect on the equilibrium position and the value of K_c .

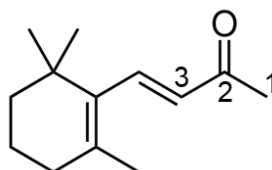
- The presence of catalyst increases the rate of the forward and backward reaction to the same extent. ($K_C = k_f / k_b \Rightarrow K_c$ constant.)

[2]

[Total: 13]

- 3 (a) The ionones, a group of fragrance materials that range from violet sweetness to woody floral tonality, lend a sweet and powdery quality to fragrance.

β -ionone has the following structure:



- (i) Draw the hybrid orbitals and state the type of hybridisation for C2 in β -ionone.



Hybridisation: • sp^2

[2]

β -ionone exists in different isomeric forms.

- (ii) State the type of stereoisomerism exhibited by β -ionone, and identify the number of stereoisomers.

Type of stereoisomerism: • **Geometric isomerism (Accept cis-trans isomerism)**

Number of stereoisomers: • **2**

[2]

- (iii) Although both **C1–C2** and **C2–C3** bonds are single bonds, they have different bond strengths. Suggest which bond is stronger and explain your answer.

• **C2–C3 bond is stronger.**

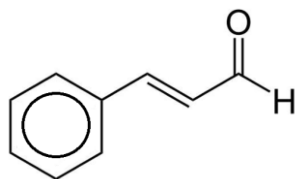
C1–C2 bond: $sp^3 - sp^2$ overlap

C2–C3 bond: $sp^2 - sp^2$ overlap

• **As the sp^2 hybrid orbitals of C2 and C3 contains greater s-character,
there is greater orbital overlap leading to a stronger bond.**

[2]

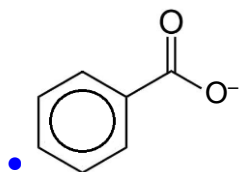
- (b) Cinnamaldehyde is a flavonoid that gives cinnamon its flavour and odour.



cinnamaldehyde

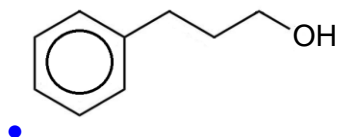
Draw the structures of the organic product(s) formed when cinnamaldehyde reacts with:

- (i) concentrated alkaline KMnO_4 , reflux



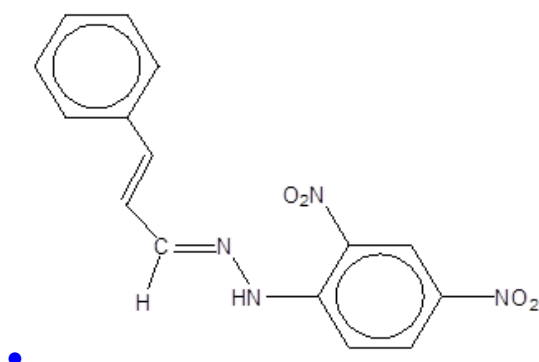
[1]

- (ii) H_2 gas, Pd catalyst at room temperature and pressure



[1]

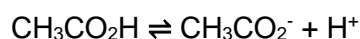
- (iii) 2,4-dinitrophenylhydrazine, room temperature



[1]

[Total: 9]

- 4 (a) Ethanoic acid undergoes dissociation as shown below:



- (i) Write an expression for equilibrium constant, K_c , of the dissociation process.

$$K_c = \frac{[\text{CH}_3\text{CO}_2^-][\text{H}^+]}{[\text{CH}_3\text{CO}_2\text{H}]}$$

[1]

- (ii) Given that the equilibrium constant has a value of 1.74×10^{-5} , calculate the concentration of H^+ present in 0.1 mol dm^{-3} of ethanoic acid. Hence, determine its pH.

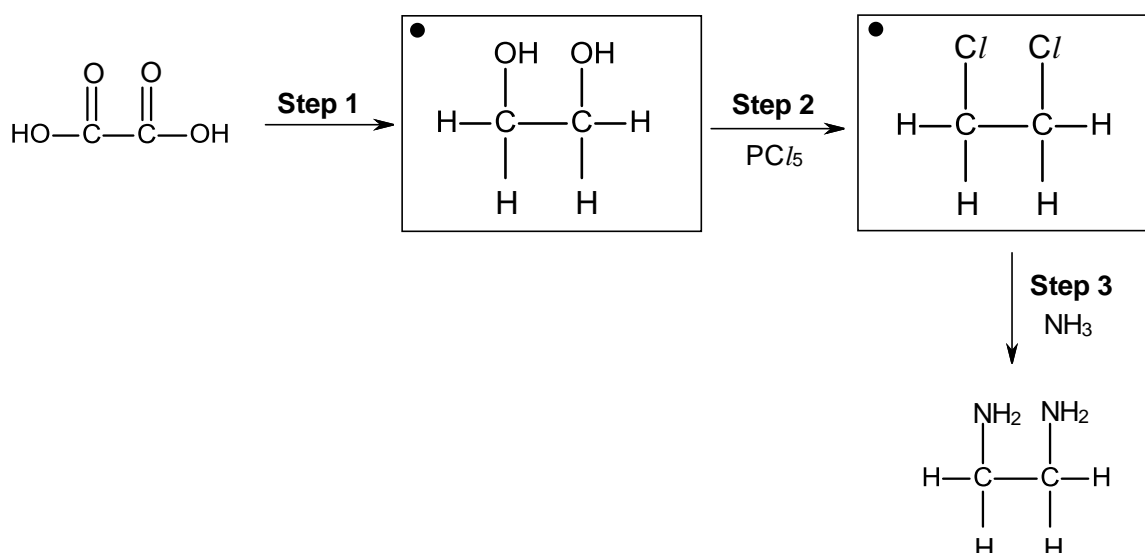
$$1.74 \times 10^{-5} = [\text{H}^+]^2 / 0.1$$

$$[\text{H}^+] = \sqrt{1.74 \times 10^{-5} \times 0.1}$$

- $= 1.32 \times 10^{-3} \text{ mol dm}^{-3}$
- $\text{pH} = -\lg (1.32 \times 10^{-3}) = 2.88$

[2]

- (b) Ethane-1,2-diamine is used in large quantities as a precursor to drugs and various polymers. It can be obtained from ethanedioic acid through a three-step synthesis.



- (i) Draw the structures of the products of steps 1 and 2 in the spaces provided above.

[2]

- (ii) State the reagents and conditions for step 1.

- Anhydrous LiAlH_4 , dry ether as solvent, room temperature pressure

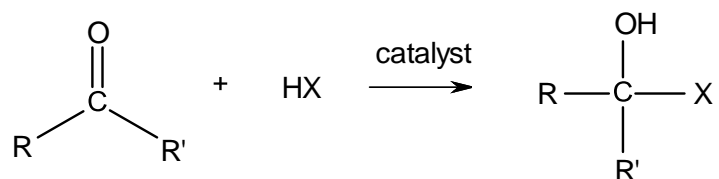
[1]

- (iii) Name the type of reaction that takes place in step 3.

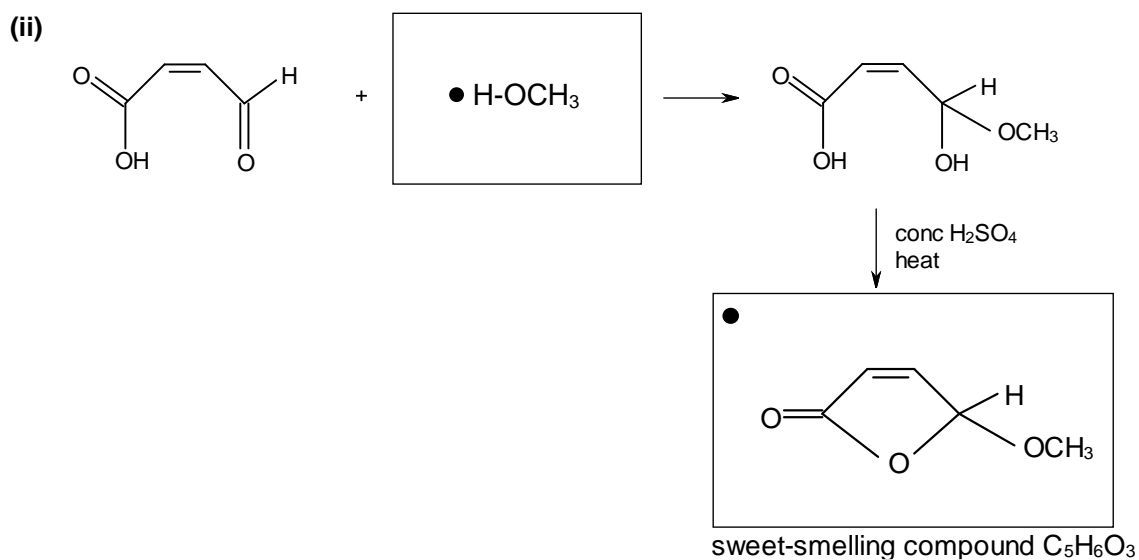
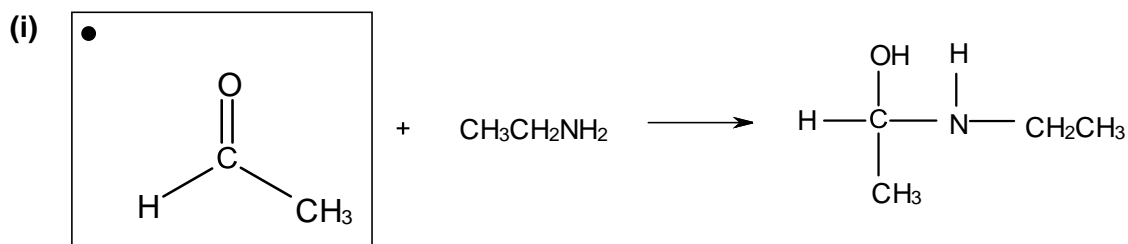
- Nucleophilic substitution

[1]

(c) There is a range of reactions of carbonyl compounds which follows the pattern



One example is the formation of cyanohydrin, where X is CN. Hence, fill in the blanks in the following synthetic routes which involves carbonyl compounds as the reactant.



[3]

[Total: 10]

Section B

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

- 5 Ethanedioic acid is a substance found in many plant foods. Cabbage is among the plant foods with high ethanedioic acid content. However, its anion, $\text{C}_2\text{O}_4^{2-}$ can bind to iron to form iron (II) ethanedioate, which renders much of the iron in cabbage unusable by the body.

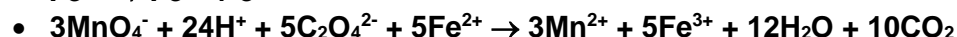
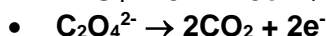
- (a) 50.0 cm³ sample of iron(II) ethanedioate, FeC_2O_4 was extracted from 300 g of cabbage, diluted in water and the solution made up to 250 cm³. A 25.0 cm³ portion of this solution was acidified and required 26.90 cm³ of 0.0100 mol dm⁻³ potassium manganate(VII) for oxidation of iron(II) to iron(III) and ethanedioate ions to carbon dioxide.

- (i) State the change in oxidation number for manganese and carbon in the reaction. [1]

Mn: From +7 to +2 [Or decrease by 5]

C: From +3 to +4 [Or increase by 1]

- (ii) Write down all the relevant ion-electron half equations and hence the overall redox equation for the reaction between potassium manganate(VII) and iron(II) ethanedioate. [2]



- (iii) Calculate the concentration, in mol dm⁻³, of iron(II) ethanedioate in the original sample [2]

$$\begin{aligned} \bullet \text{ Number of moles of FeC}_2\text{O}_4 \text{ in } 25.0 \text{ cm}^3 &= \frac{5}{3} \times 2.69 \times 10^{-4} \\ &= 4.48 \times 10^{-4} \text{ mol} \end{aligned}$$

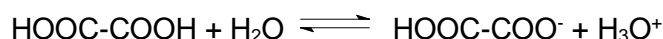
$$\begin{aligned} \text{Number of moles of FeC}_2\text{O}_4 \text{ in } 250 \text{ cm}^3 &= 4.48 \times 10^{-4} \times 250/25.0 \\ &= 4.48 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\begin{aligned} \bullet \text{ Concentration of FeC}_2\text{O}_4 \text{ in the original sample} &= \frac{4.48 \times 10^{-3}}{50 \times 10^{-3}} \\ &= 0.0896 \text{ mol dm}^{-3} \end{aligned}$$

- (iv) Calculate the number of moles of iron in each gram of cabbage. [1]

$$\begin{aligned} \bullet \text{ No. of moles of iron per gram of spinach} &= \frac{4.48 \times 10^{-3}}{300} \\ &= 1.49 \times 10^{-5} \text{ mol/g} \end{aligned}$$

- (b) Ethanedioic acid dissociates in water according to the following equation.



The table below compares the K_a values of three organic acids.

	Formula	K_a
Ethanoic acid	CH_3COOH	1.74×10^{-5}
Ethanedioic acid	$\text{HO}_2\text{CCO}_2\text{H}$	6.46×10^{-2}
Oxoethanoic acid	$(\text{CHO})\text{COOH}$	4.79×10^{-4}

With reference to the K_a values, comment on the order of acidity of the three organic acids. [2]

The bigger the K_a , the stronger the acid. Acid strength is dependent on the stability of the anion formed when the acid ionises. The more stable the anion, the stronger is the acid.

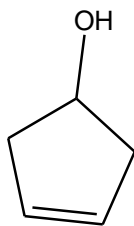
Strength of acid: Ethanedioic acid > Oxoethanoic acid > Ethanoic acid

- **Oxoethanoic acid is a stronger acid than ethanoic acid as -CHO group is electron withdrawing. The negative charge on the anion is dispersed, thereby stabilizing the ion compared to ethanoate ion.**

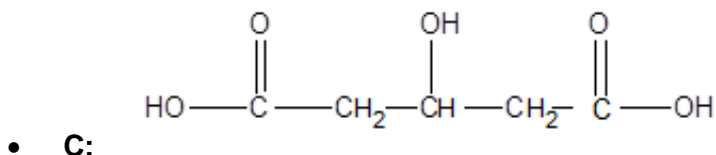
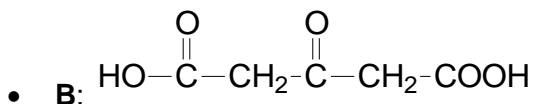
- **Ethanedioic acid is the strongest acid as stabilisation of the monoanion by intramolecular hydrogen bonding with the unionised -COOH group results in the highest K_a value compared with the other two acids.**

- (c) Compound **A**, with molecular formula $\text{C}_5\text{H}_8\text{O}$, decolourises aqueous bromine and reacts with PCl_5 giving off white fumes. Upon refluxing **A** with acidified potassium manganate(VII), a symmetrical product **B**, $\text{C}_5\text{H}_6\text{O}_5$, is formed. **B** does not give a red precipitate with Fehling's solution but an orange precipitate is observed with 2,4-dinitrophenylhydrazine. 1 mole of **B** also reacts with 1 mole of Na_2CO_3 with effervescence observed. **B** reacts with NaBH_4 to form **C**. Deduce the structures of compounds **A**, **B** and **C**, explaining the chemistry of the reactions involved. [8]

- **A decolourises aqueous bromine $\Rightarrow \text{C}=\text{C}$ present**
- **A reacts with PCl_5 giving off white fumes of HCl \Rightarrow -OH present**
- **A undergoes oxidation with KMnO_4 where the -OH group is oxidised and $\text{C}=\text{C}$ in a ring undergoes total bond cleavage to form B.**
OR A undergoes oxidation with KMnO_4 to give a symmetrical product B with no loss in C atoms $\Rightarrow \text{C}=\text{C}$ is in a ring and A is a cyclic compound
- **B does not give a red precipitate with Fehling's solution but form an orange precipitate with 2,4-dinitrophenylhydrazine \Rightarrow B is a ketone and A is a secondary alcohol**
- **1 mole of B also reacts with 1 mole of $\text{Na}_2\text{CO}_3 \Rightarrow$ B has 2 -COOH groups.**
- **B reacts with NaBH_4 to form C \Rightarrow only the carbonyl group in B is reduced but the carboxylic acid groups remain unaffected.**



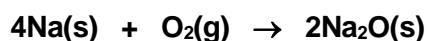
• A:



(9 marking points: Maximum 8)

- (d) (i) Describe what you see when separate samples of sodium and sulfur are burned in excess air. Write equations for the reactions that occur. [2]

Sodium burns readily with a brilliant yellow flame in air or oxygen to form white sodium oxide, Na_2O .

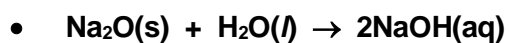


Sulfur burns slowly with a blue flame on heating in air or oxygen to form colourless sulfur dioxide, SO_2 . (Note: SO_3 is not formed)



- Both equations correct
- Both observations correct

- (ii) The products resulting from the reactions in (d)(i) both react with water. Write equations for these two reactions and describe the effect of the resulting solutions on Universal Indicator solution. [2]



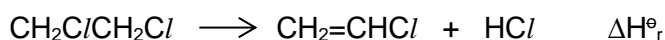
Universal Indicator turns violet.



Universal Indicator turns red.

[Total: 20]

- 6 Chloroethene, $\text{CH}_2=\text{CHCl}$, which is a colourless compound, is an important industrial chemical chiefly used to produce the polymer polyvinyl chloride or PVC.
 $\text{CH}_2=\text{CHCl}$ is made from 1,2-dichloroethane, $\text{CH}_2\text{ClCH}_2\text{Cl}$ as shown in the equation below.



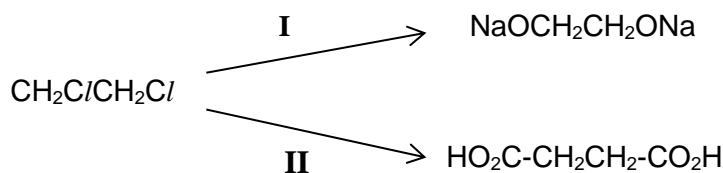
- (a) (i) State the type of reaction occurring and suggest the reagents and conditions for the reaction. [2]

- **Elimination**
- **Alcoholic NaOH, heat with reflux**

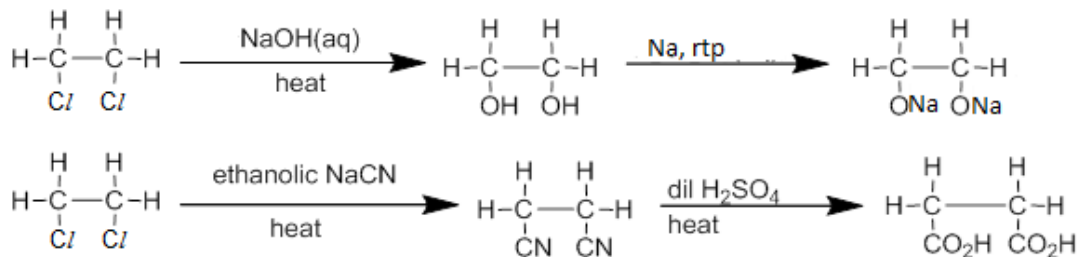
- (ii) Use the bond energy values from the Data Booklet to calculate ΔH°_r . [2]

- $\Delta H^\circ_r = \text{energy to break bonds} - \text{energy to form bonds}$
 $= [\text{BE}(\text{C-H}) + \text{BE}(\text{C-Cl}) + \text{BE}(\text{C-C})] - [\text{BE}(\text{C=C}) + \text{BE}(\text{H-Cl})]$
 $= (410 + 340 + 350) - (610 + 431)$
 $= +59 \text{ kJ mol}^{-1}$

- (b) Suggest synthetic routes for conversions I and II starting from 1,2-dichloroethane.



[6]



1 mark for each reagent and condition and each intermediate

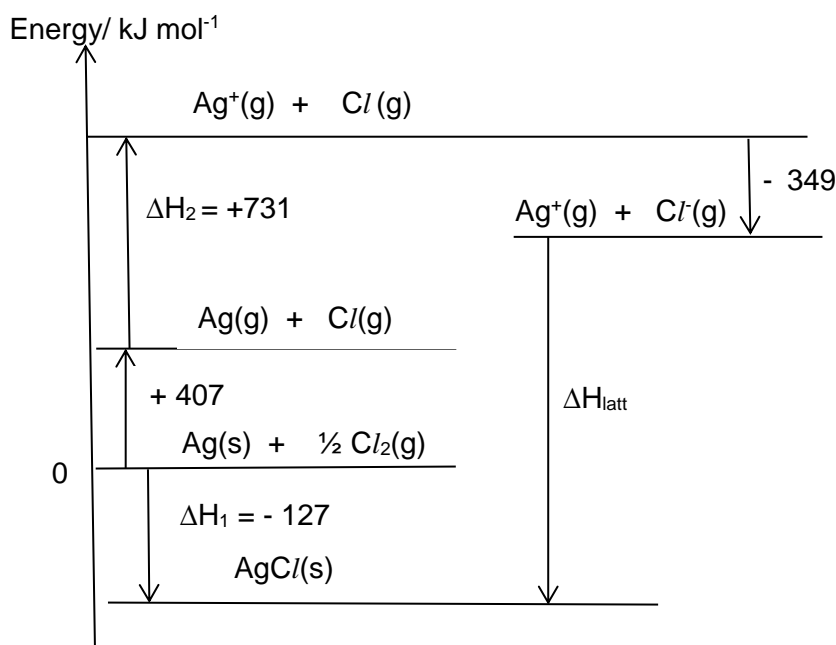
- (c) Chloroethane can be distinguished from iodoethane by heating both compounds separately with aqueous NaOH, then acidified with dilute nitric acid before adding dilute silver nitrate.
- (i) Chloroethane and iodoethane have different rates of hydrolysis with hot aqueous NaOH. Explain the relative rate of hydrolysis of the above two halogen compounds. [2]

- rate of hydrolysis: iodoethane > chloroethane
- Hydrolysis is a nucleophilic substitution reaction that involves breaking of C-X bond. Iodoethane undergoes hydrolysis faster than chloroethane as bond energy of C-I is 240 kJ mol^{-1} while that of C-Cl is 340 kJ mol^{-1} , so C-Br is weaker than C-Cl bond.

(Or I is larger atom than Cl, so extent of orbital overlap is less effective for C-I, so C-I bond is weaker than C-Cl bond)

After hydrolysis with aqueous NaOH, a white ppt of AgCl will be observed for chloroethane, while a yellow ppt of AgI will be seen for iodoethane.

The lattice energy of AgCl can be calculated from figures obtained experimentally using a Born-Haber cycle as shown below.



(ii) Define lattice energy. [1]

- Lattice energy is the heat energy evolved when one mole of solid ionic compound is formed from its constituent gaseous ions under standard conditions.

(iii) In the Born-Haber cycle above, name the enthalpy changes represented as:

- ΔH_1 : enthalpy change of formation of AgCl(s)
- ΔH_2 : first ionisation energy of Ag(g)

[2]

(iv) Using the Born-Haber cycle above, calculate the lattice energy, ΔH_{latt} , of AgCl. [2]

By Hess' Law,

$$\Delta H_1 = 407 + \Delta H_2 + (-349) + \Delta H_{\text{latt}}$$

- $\Delta H_{\text{latt}} = -127 - 407 - 731 + 349 = -916 \text{ kJ mol}^{-1}$

- (d) Besides calculating experimentally using Born-Haber cycles, lattice energies can also be calculated based on the theoretical model of an ionic compound.

The table gives the experimental and theoretical values of lattice energies for the silver halides.

Compound	experimental value / kJ mol^{-1}	theoretical value / kJ mol^{-1}
AgF	967	953
AgCl	916	864
AgBr	904	830
AgI	889	808

- (i) Explain why the value of theoretical lattice energy of AgBr is larger than that of AgI. [1]

$$\text{lattice energy} \propto \left| \frac{q_+ q_-}{r^+ + r^-} \right|$$

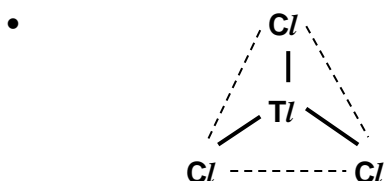
- q^+ , q^- , r^+ are same for both compounds. Br^- and I^- have the same charge but Br^- has a smaller ionic radius than I^- , resulting in AgBr having a larger value of lattice energy.
- (ii) Explain why the difference between the experimental and theoretical values increases from AgF to AgI. [2]
- From F^- to I^- , the anionic radii increases, and thus the extent of anion electron cloud polarised by Ag^+ increases.
 - covalent character of the compound thus increases from AgF to AgI, and the actual structure of compounds deviates greater from the theoretical model of an ionic compound.

[Total: 20]

- 7 Thallium is a Group III element discovered in 1861, and its toxicity was quickly noted. Thallium isotopes and compounds have useful applications, sometimes despite their toxic nature.

(a) Thallium forms compounds similar to aluminium, and thallium(III) chloride and thallium(III) fluoride have very different structures and bonding.

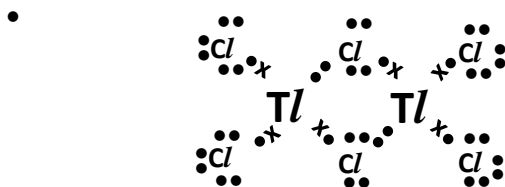
- (i) Draw and state the shape of thallium(III) chloride, $TlCl_3$. [2]



• **Trigonal planar**

- (ii) In gaseous phase, thallium(III) chloride is able to form a compound with a M_r of 621. Draw a dot-and-cross diagram of this compound, and state the $Cl-Tl-Cl$ bond angle. [2]

Based on the M_r , the compound is Tl_2Cl_6 .



• **109.5°**

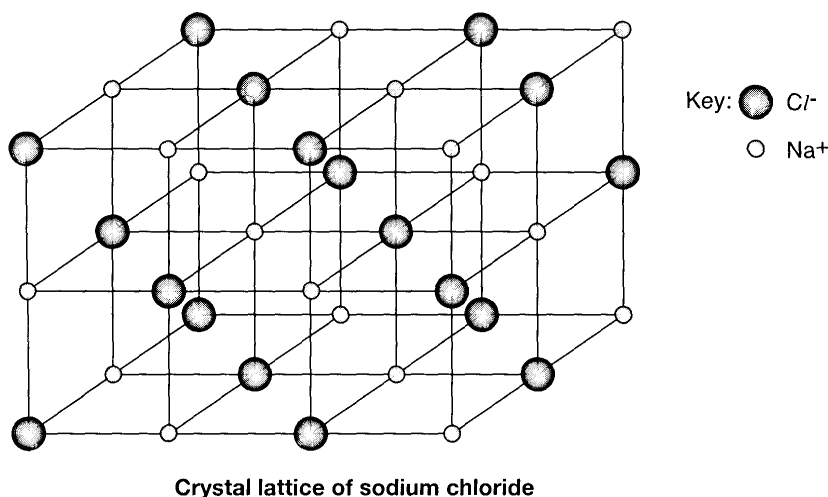
- (iii) Explain, in terms of structure and bonding, why thallium(III) fluoride has a high melting point of 550 °C. [2]

• **Thallium(III) fluoride exists as a giant ionic lattice structure and**

• **a large amount of energy is needed to break strong ionic bonds between oppositely charged ions.**

- (iv) Thallium is also able to form thallium(I) chloride, which is crystalline in nature.

In the crystal lattice of sodium and potassium chlorides, the co-ordination number of each ion is 6. In the crystal lattice of thallium(I) chloride, $TlCl$, the co-ordination number has a different value.

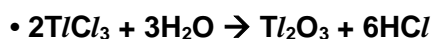


Suggest an explanation for the co-ordination number in the $TlCl$ lattice being different from those in $NaCl$ and KCl . [1]

- The size of the Tl^+ cations is larger than the Group I cations such as Na^+ and K^+ . More chloride ions can be packed around the larger Tl^+ cations.

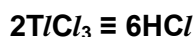
- (b) Thallium(III) chloride, $TlCl_3$, reacts with hot water to produce thallium(III) oxide precipitate and hydrochloric acid.

- (i) Write a balanced equation for the above reaction. [1]



- (ii) In an experiment, a 15 g impure sample of thallium(III) chloride ($M_r = 310.5$) was mixed with hot water, and filtered. Water was then added to the filtrate to make a standard solution in a 250 cm³ volumetric flask. A 25.0 cm³ aliquot was titrated against 0.5 mol dm⁻³ aqueous sodium hydroxide, requiring a titre of 22.00 cm³. Determine the percentage purity of the sample.

You may assume that the impurities are insoluble in water and are inert. [2]



$$\text{No of moles of NaOH} = 0.022 \times 0.5 = 0.0110 \text{ mol}$$

$$\text{No of moles of HCl produced from the sample} = 0.0110 \times 10 = 0.110 \text{ mol}$$

$$\text{No of moles of } TlCl_3 \text{ in sample} = 0.110 / 3 = 0.0367 \text{ mol}$$

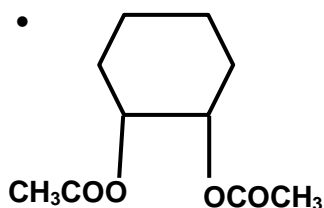
$$\text{Mass of } TlCl_3 \text{ in sample} = 310.5 \times 0.0367 = 11.4 \text{ g}$$

$$\text{Percentage purity of } TlCl_3 \text{ in sample} = 11.4 / 15 \times 100\% = 76.0\%$$

- (c) Thallium(I) sulfate ($M_r = 504.1$) was often employed as a rodenticide and is highly poisonous. The lethal dosage is 16 ppm of the rat's mass. Assuming a typical rat has a mass of 230 g, determine the number of moles of thallium(I) sulfate needed to kill a rat. [2]

- Mass of thallium(I) sulfate needed for lethal dosage = $230 \times 16/10^6 = 0.00368 \text{ g}$
- No of moles of thallium(I) sulfate needed = $0.00368 / 504.1 = 7.30 \times 10^{-6} \text{ mol}$

- (d) Thallium(III) ethanoate, $Tl(CH_3CO_2)_3$, is able to react with an alkene through addition. When cyclohexene reacts with thallium(III) ethanoate, a compound with the molecular formula $C_{10}H_{16}O_4$ is formed. Suggest the structural formula of this compound. [1]



- (e) ^{201}Tl is an isotope of thallium that is often used in medical diagnostics due to its radioactive decay by electron capture with emission of gamma rays. The electronic configuration of the Tl atom is $[Xe]4f^{14}5d^{10}6s^26p^1$.

Electron capture is a process in which a proton-rich nucleus of an atom absorbs one electron from the first or second quantum shell to change one proton into a neutron.

- (i) Suggest the species formed, including the nucleon number, when ^{201}Tl undergoes electron capture. [1]



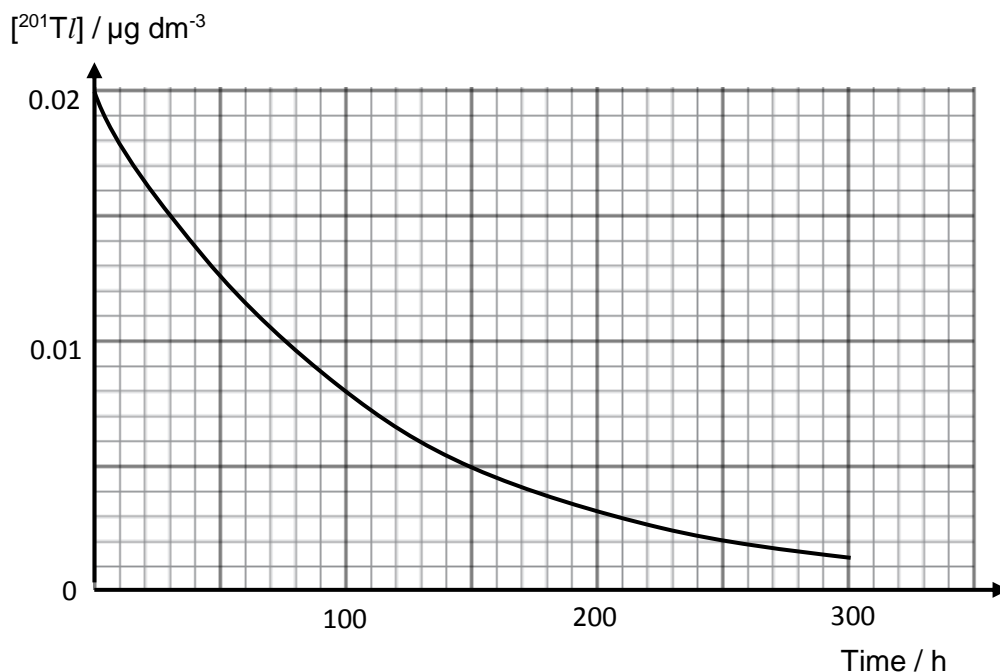
- (ii) The species formed immediately after electron capture is known to be in excited state, before returning to ground state by emitting gamma rays.

Name the orbital where the excited electron is most likely located in, and explain why **high energy** gamma rays are emitted when the species returns to ground state. [2]

- 6p. (*can accept any orbital of higher energy than 6p*)

• When the electron capture occurs, an inner shell (1 or 2) is now short of an electron. The 6p electron is at a high energy level, and needs to release a large amount of energy to replace the absorbed electron in shell 1 or 2 as the atom returns to ground state.

- (iii) A patient is typically injected with $0.02 \mu\text{g}$ of thallium for heart diagnosis. The following graph shows the radioactive decay (through electron capture) of a $0.02 \mu\text{g}$ sample of ^{201}Tl dissolved in 1 dm^3 of inert solvent.



Using the graph, deduce the order of reaction for the radioactive decay of ^{201}Tl .

[2]

- From the graph, $(t_{1/2})_1 = (t_{1/2})_2 = 75 \text{ h}$. Since $t_{1/2}$ is constant,
- order of reaction is 1.

- (iv) Hence, write the rate equation for this reaction and determine the rate constant, stating its units. [2]

- rate = $k[^{201}\text{Tl}]$
- $k = \ln 2 / t_{1/2} = \ln 2 / 75 \text{ h} = 0.00924 \text{ h}^{-1}$

[Total: 20 m]