TEMASEK JUNIOR COLLEGE

2024 JC2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME

MARK SCHEME

CENTRE NUMBER | S | | | | |

INDEX NUMBER | | | | |

Chemistry **8873/02**

Paper 2 Structured Questions **21 August 2024**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name in the spaces provided at the top of this page.
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** the questions.

Section B

Answer **one** question.

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

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

For Examiner's Use		
MCQ		**/ 30**
Section A	**Q1**	**/ 8**
	Q2	**/ 8**
	Q3	**/ 12**
	Q4	**/ 10**
	Q5	**/ 10**
	Q6	**/ 12**
Section B	**Q7**	**/ 20**
	Q8	**/ 20**

This document consists of **23** printed pages and **1** blank page.

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Section A

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

1 This question is about copper-containing species.

(a) Copper can exist as a number of isotopes. Some copper isotopes are unstable but are potentially useful for nuclear medicine.

(i) Complete Table 1.1 for two isotopes of copper. [2]

Table 1.1

isotopes	protons	neutrons	electrons
$^{63}_{29}Cu$	**29**	**34 [✓]**	**29**
$^{67}_{29}Cu$ [✓]	**29**	38	**29**

Cu isotope and neutrons 2✓ = [1]

All protons, electrons (29) [1]

(b) Tumbaga is an alloy of copper and gold. A sample of tumbaga was analysed and the composition of the isotopes present in the sample are shown in Table 1.2.

Table 1.2

Mass number	% abundance
63	56.4
65	x
197	18.5

(i) Determine the percentage abundance, x, of the species of mass number 65. [1]

x = 100 – 56.4 – 18.5 = 25.1 [1]

(ii) Hence, calculate the relative atomic mass, A_r, of the copper present in this sample of tumbaga. [1]

A_r of Cu = $\frac{(56.4 \times 63) + (25.1 \times 65)}{56.4 + 25.1}$ = 63.6 [1]

Common mistake: included gold in the calculation.

(c) Brass is an alloy of copper and zinc. The percentage of mass of copper varies from 50% to 85%, depending on the properties needed in the alloy. A series of reactions is carried out in the laboratory to determine the percentage of copper in a sample of brass.

0.30 g of brass is dissolved in acid to give 100.0 cm^3 of solution in which all copper is present as Cu^{2+} ions. 25.0 cm^3 of the solution is transferred to a conical flask using a pipette and reacted with excess potassium iodide, KI. All the copper is precipitated as CuI solid and iodine is formed. The iodine requires 21.50 cm^3 of 0.0400 mol dm^{-3} $S_2O_3^{2-}$ to reach the end-point of titration.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$
$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$$

(i) Determine the number of moles of iodine reacted with $S_2O_3^{2-}$ in the titration. [1]

$I_2 \equiv 2S_2O_3^{2-}$

Number of moles of $S_2O_3^{2-}$ = $\frac{21.50}{1000} \times 0.0400 = 8.60 \times 10^{-4}$ mol

Number of moles of I_2 = ½ x 8.60 x 10^{-4} = 4.30 x 10^{-4} mol [1]

(ii) Use your result in **(c)(i)** to calculate the number of moles of $Cu^{2+}(aq)$ in 100.0 cm^3 of the solution. [1]

$2Cu^{2+} \equiv I_2$

Number of moles of Cu^{2+} in 25.0 cm^3 solution = 2 x 4.30 x 10^{-4}

= 8.60 x 10^{-4} mol

Number of moles of Cu^{2+} in 100.0 cm^3 solution = (100/25) x 8.60 x 10^{-4}

= 3.44 x 10^{-3} mol [1]

(iii) Hence, determine the percentage by mass of copper in this sample of brass. [2]

Mass of Cu = 3.44 x 10^{-3} x 63.5 = 0.218 g [1]

Percentage by mass of Cu = (0.218/0.30) x 100 = 72.7% [1]

[Total: 8]

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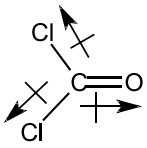
2 Phosgene, $Cl_2C=O$, is a colourless, toxic gas. It is used in the production of pesticides, rubbers and adhesives.

(a) **(i)** State the shape of a phosgene molecule. [1]

[1] trigonal planar

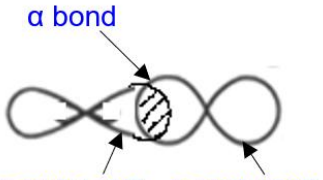
Note: the structure is 

(ii) The molecule of phosgene contains both σ (sigma) and π (pi) bonds.

Draw labelled diagrams to show how orbitals overlap to form

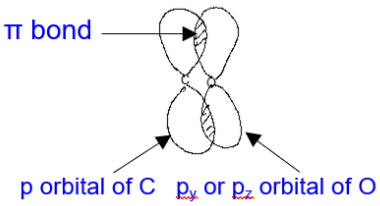
- a σ (sigma) bond
- a π (pi) bond.

[2]



[1]

Head-on overlap between p orbital of C and p_x orbital of O



[1]

Sideway overlap between p orbitals of C and p_y or p_z orbital of O

(b) Table 2.2 shows the electronegativity values of the atoms in phosgene.

Table 2.2

atom	electronegativity / Pauling units
carbon	2.5
chlorine	3.0
oxygen	3.5

(i) Explain what is meant by the term *electronegativity*. [1]

A measure of an atom's **ability to attract shared electrons / electrons in a covalent bond.** [1]

The greater the electronegativity of an atom, the greater the electron-attracting ability

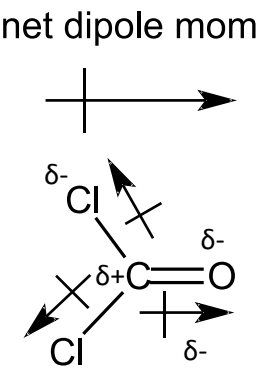
If two atoms of a covalent bond have different electronegativity, the bonding electrons are not equally shared between them and hence a polar covalent bond is formed.

(ii) Using the information in Table 2.2, deduce whether phosgene is a polar molecule.

Explain your answer. [2]

The **dipole moment** [✓] on C=O and C-Cl do not cancel out each other in a trigonal planar arrangement due to different electronegativity difference [✓] between C=O (1 Pauling unit) and C-Cl (0.5 Pauling unit).

So, phosgene is a polar molecule [1] which has a net dipole moment.

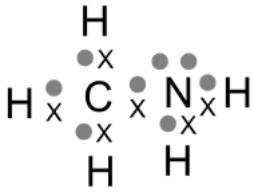


(c) Phosgene reacts with methylamine to form methyl isocyanate.

$$Cl_2C{=}O + CH_3NH_2 \longrightarrow CH_3NCO + 2HCl$$

methylamine methyl isocyanate

(i) Draw a dot-and-cross diagram to show the bonding present within a methylamine molecule. [1]



[1]

Common mistake: missing lone pair electron on N

(ii) In the presence of a catalyst, methyl isocyanate reacts with itself to form compound **A**, which is a non-polar molecule.

$$3CH_3NCO(g) \longrightarrow C_6H_9N_3O_3(s)$$

A

Suggest why, at room temperature, methyl isocyanate is a gas but **A** is a solid.

A has larger electron cloud size, leading to greater extent of distortion of electron cloud. [✓]

More energy is needed to overcome the stronger id-id interactions between molecules of **A**, hence **A** has a higher melting point. [✓]

OR

At r.t.p, the energy provided is insufficient to overcome the stronger id-id between **A** molecules hence **A** exists as a solid.

[1]

[Total: 8]

3 **(a)** Magnesium, aluminium and phosphorus are elements in Period 3 of the periodic table.

(i) State the electronic configuration of aluminium. [1]

$1s^2 2s^2 2p^6 3s^2 3p^1$ [1]

(ii) State and explain the difference in first ionisation energies of aluminium and magnesium. [2]

Ionisation energy of Al is lower.[✓] Less energy is required to remove the 3p electron in Al [✓] as it is further away from the nucleus [✓] compared to the 3s electron in Mg. [✓]

(iii) Write a balanced equation for the reaction of phosphorus(V) oxide with excess water. [1]

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ [1]

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(b) Phosphoric(V) acid, H_3PO_4, is a weak Bronsted-Lowry acid.

In a reaction where it behaves as an acid, phosphoric(V) acid can donate one, two or three protons.

(i) Explain the meaning of the term *weak* Bronsted-Lowry acid. [1]

The acid dissociates partially to give H^+/ donate proton. [1]

(ii) Write the equation showing the equilibrium when phosphoric(V) acid donates one of its protons. [1]

$H_3PO_4 \rightleftharpoons H_2PO_4^- + H^+$ [1]

(c) 50 cm^3 of 0.500 mol dm^{-3} sodium hydroxide is added to 10 cm^3 of 0.500 mol dm^{-3} phosphoric(V) acid.

$$3NaOH\ (aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

(i) Determine the number of moles of NaOH remaining in the solution after reaction. [2]

Number of moles of NaOH added = $\frac{50}{1000} \times 0.500 = 0.0250 mol$

Number of moles of H_3PO_4 = $\frac{10}{1000} \times 0.500 = 0.00500 mol$

for amount of NaOH and H_3PO_4 [1]

Number of moles of NaOH left = 0.0250 – 3(0.005) = 0.0100 mol [1]

(ii) Hence, calculate the pH of the resulting solution. [2]

[NaOH] = $0.0100 \div \frac{60}{1000} = 0.167 \text{moldm}^{-3}$ [1] allow ecf

pOH = –lg(0.167) = 0.78

pH = 14 – 0.78 = 13.2 (or 13.22) [1]

(d) Ethanoic acid is a weak organic acid. A buffer solution is prepared by mixing ethanoic acid with a controlled amount of sodium hydroxide.

The buffer solution contains ethanoic acid and sodium ethanoate.

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

$$CH_3CO_2Na \longrightarrow CH_3CO_2^- + Na^+$$

(i) Write an equation to show what happens when a few drops of H^+ is added to the buffer solution. [1]

$CH_3CO_2^- + H^+ \rightarrow CH_3CO_2H$ [1]

(ii) Ethanoic acid can be titrated with sodium hydroxide. State and explain which of the indicators from Table 3.1 is the most suitable for this titration. [1]

Table 3.1

Indicator	pH range of colour change
Methyl orange	3.2 – 4.4
Bromothymol blue	6.0 – 7.4
Phenolphthalein	8.2 – 10.0

Phenolphthalein [✓]

The working range of indicator falls within the region of rapid change in pH of this titration. [✓]

[Total: 12]

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

0.422 g of but-1-ene, C_4H_8, was used to heat up 500 cm^3 of water from its initial temperature of 30 °C.

(i) Given that the standard enthalpy change of combustion but-1-ene(g) is -2717 kJ mol^{-1}, calculate the expected maximum temperature of the water. [2]

Amt of moles of but-1-ene = $\frac{0.422}{4 \times 12 + 8}$ = 7.54 x 10^{-3} mol

Energy released = 7.54 x 10^{-3} x 2717 x 10^3 = 20474 J [1]

= 500 x 4.18 x (T_{max} – 30)

T_{max} = 39.8°C [1]

(ii) When the experiment was conducted in the laboratory, the maximum temperature of the water was found to be lower than the calculated value in **(a)(i)**.

Suggest an explanation for this. [1]

[1] *Any 1 answer:*

Heat loss to surroundings

Incomplete combustion of but-1-ene

(b) Compound **P**, C_xH_y, also undergoes combustion.

When 15 cm^3 of compound **P** was burned in 100 cm^3 of excess oxygen, the residual gases occupied 70 cm^3. After shaking these residual gases with aqueous potassium hydroxide, the final volume was 25 cm^3. All gaseous volumes were measured under identical conditions.

Deduce the formula of compound **P**, showing your reasoning. [2]

$$C_xH_y + (x + \frac{y}{4})\ O_2 \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

Initial volume /cm^3	15	100	0	-
Change in volume /cm^3	–15	–75	+45	-
Final volume /cm^3	0	25	70–25 = 45	-

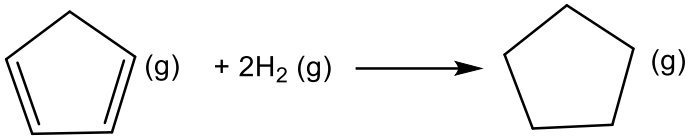
[1] final volume of O_2 and CO_2

Mole ratio = volume ratio

$\frac{x}{1} = \frac{45}{15} \Rightarrow$ x = 3 $\quad\quad$ $\frac{x+\frac{y}{4}}{1} = \frac{75}{15} \Rightarrow$ y = 8

[1] **P** is C_3H_8

(c) Cyclopentadiene undergoes catalytic hydrogenation to form cyclopentane.



(i) Using data from the data booklet, calculate the enthalpy change of hydrogenation of gaseous cyclopentadiene. [2]

Bonds broken: 2 C=C, 2 H–H

Bonds formed: 2 C–C, 4 C–H

$\Delta H_{hydrogenation}$

= energy absorbed to break bonds – energy released to form bonds

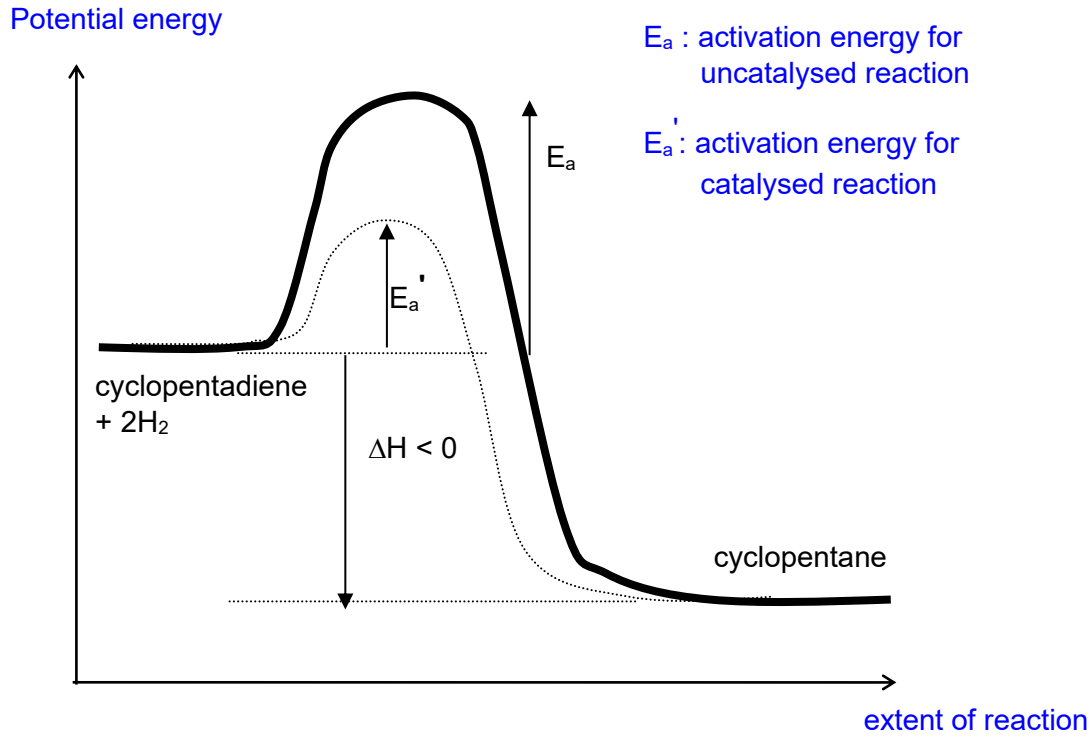
= [2(+610) + 2(+436)] + [2(–350) + 4(–410)] [1]

= –248 kJ mol^{-1} [1]

The hydrogenation reaction is thermodynamically favourable but it will not proceed without a catalyst.

(ii) On the same axes, draw the energy profile diagram for the hydrogenation of cyclopentadiene with and without a catalyst.

Assume the hydrogenation of cyclopentadiene takes place via a one-step reaction. [1]



Well-labelled diagram: reactants and products, legends for E_a' and E_a, ΔH [1]

(iii) Hence, explain using collision theory why the addition of the catalyst speeds up the hydrogenation of cyclopentadiene. [2]

[✓] catalyst provides an alternative pathway, which involves a lower E_a

[✓] number of molecules having energy greater than or equal to E_a' increases.

[✓] frequency of effective collisions increases

[✓] rate constant increases

2[✓]: [1]

[Total: 10]

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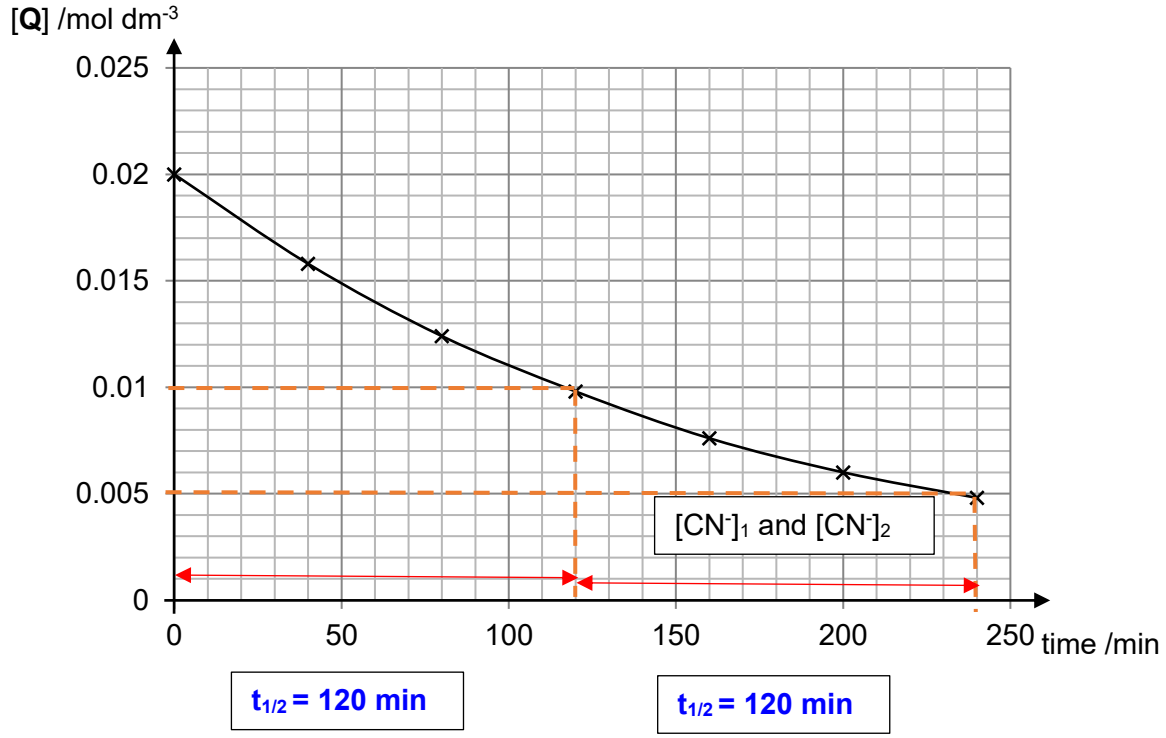
5 **(a)** Compound **Q**, $CH_3CH=CHCHBrCH_3$, reacts with alcoholic KCN according to the following equation:

$$CH_3CH=CHCHBrCH_3 + CN^- \rightarrow CH_3CH=CHCH(CN)CH_3 + Br^-$$

To investigate the above reaction, two separate experiments were performed using different initial concentrations of CN^-. In each experiment, the concentration of **Q** in the reaction mixture was determined at different times as the reaction progresses. The same graph was obtained in both experiments, as shown below:

The following results were obtained:



(i) Deduce the order of reaction with respect to CN^- and **Q**. [3]

The graph shows two constant half-lives of 120 min. Hence, reaction is first order w.r.t. Q. [1]

[1] show construction lines and half-life on graph (accept 115 – 120 min)

Since the same graph is obtained using different concentration of CN^-, the rate is independent of $[CN^-]$. Hence, reaction is zero order w.r.t. CN^-. [1]

(ii) Hence, write the rate equation of the reaction. [1]

rate = k[Q] [1] allow ecf

(iii) The experiment is repeated using 0.0500 mol dm^{-3} of **Q**.

Suggest the total time that has passed when the [**Q**] is 6.25 x 10^{-3} mol dm^{-3}. [1]

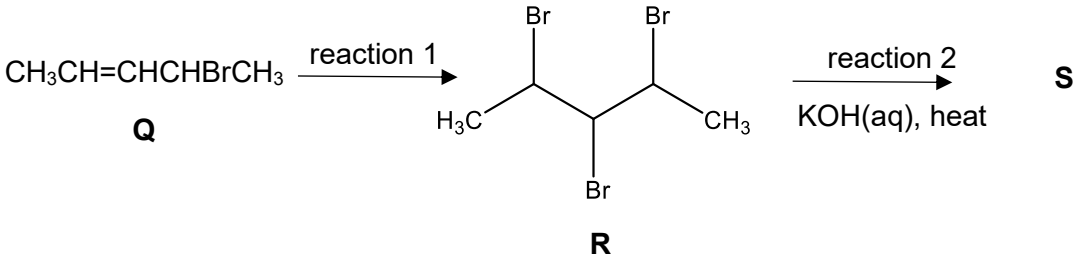
Half-life is independent of concentration.

$0.05 \rightarrow 0.025 \rightarrow 0.0125 \rightarrow 6.25 \times 10^{-3}$

Time = 3 $t_{1/2}$ = 3 x 120 min

= 360 min [1]

(b) The following shows the conversion of compound **Q** to compound **S**:



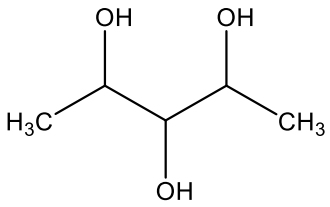
(i) State the type of reaction for reaction 1. [1]

addition [1]

(ii) State the reagent and condition for reaction 1. [1]

Br_2 in CCl_4 or Br_2(l) [1]

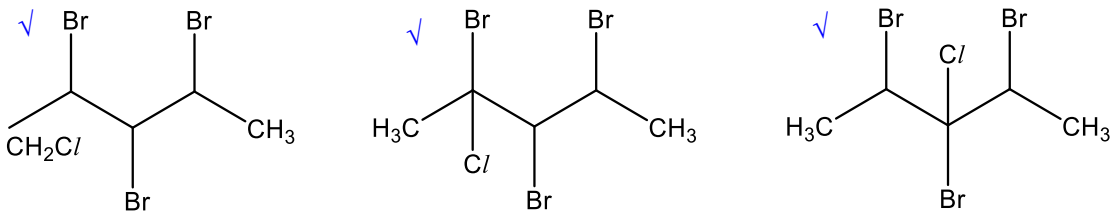
(iii) Draw the structure of compound **S**. [1]



[1]

(iv) Draw the structures of all the monochlorinated isomeric products formed when compound **R** reacts with chlorine in the presence of uv light and state its relative ratio.

[2]



√ 6 : 2 : 1

2√: [1]

[Total: 10]

6 **(a)** Carbon forms many allotropes such as graphite and diamond. Recent scientific research has found that replacing the graphite electrodes with graphene in lithium-ion batteries can extend battery life.

(i) Explain why graphene can conduct electricity along the plane.

The remaining 2p electron on each carbon atom can delocalise along the plane when a potential difference is applied. [1]

[1]

(iii) Explain why the C–C bonds in graphene are stronger compared to that in diamond.

This is due to the presence of both σ and π bonds in graphene, while there are only σ bonds present in diamond. [1]

[1]

(b) Briefly explain how geckos can climb up walls or walk on smooth glass panels.

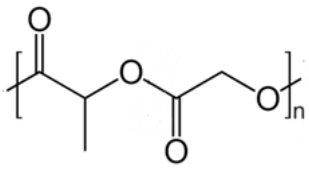
√**nanostructures / spatulae on gecko toes** have **high surface area to volume ratio.**
√**numerous of this nanostructures / spatula** per gecko, creates a **huge collective surface area of contact.**

When the toes of the gecko adhere to smooth glass panels,
√**instantaneous dipole–induced dipole (id-id) interactions formed between the nanostructures / spatulae and the surface of the glass.**

√**The cumulative nanostructures / spatulae-wall id-id interactions are translated into enormous attractive forces capable of supporting the gecko's weight.**

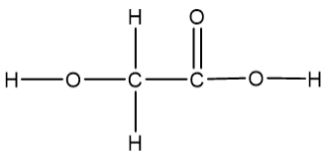
[2]

Poly(lactic-co-glycolic) acid (PLGA) is made from monomers commonly obtained from fermentation from sugars. It is a useful material for making various medical and pharmaceutical applications such as prosthetic devices and surgical sealant films.

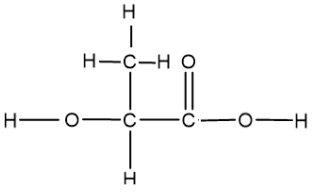


PLGA

(i) Draw the displayed formulae of monomers in PLGA.



and



[2]

(ii) Suggest what type(s) of bonding will occur between the PLGA chains, indicating the groups that are involved.

Instantaneous dipole-induced dipole interactions due to the **methyl** group and **Permanent dipole-permanent dipole interactions** due to the **este**r group

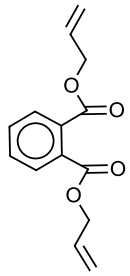
[1]

(iii) Suggest two reasons why PLGA is a suitable material for making medical and pharmaceutical applications such as surgical sealant films.

√able to degradation/biodegradable in body due to the presence of √ ester bonds that can √ hydrolyse in aqueous medium and the products form are √ non-toxic/harmless monomers, i.e: lactic acid and glycolic acid, which can be metabolized by the body.

[2]

(d) Poly(diallyl phthalate), PDAP is another polymer made from diallyl phthalate monomer. It exhibits different properties from PLGA.

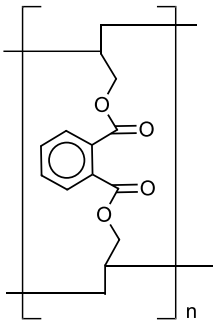


Diallyl phthalate monomer

(i) Draw the polymer of PDAP and state the type of polymerisation.

Type of reaction used to form polymer: **Addition [1]**

Structure of PDAP polymer:



[1]

[2]

(ii) PDAP is used for high-performance military and commercial electrical components. It can retain its insulating properties, even when subjected to high heat over long time periods. Suggest a reason for this.

It is a thermoset plastic with strong covalent bond as cross-link between the polymer chains. The strong covalent bond need a large amount of heat to overcome. Hence it can withstand high heat over long periods of time. [1]

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[1]

[Total:12]

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Section B

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

7 **(a)** The Periodic Table is an arrangement of the elements in increasing order of their atomic numbers, such that elements with similar chemical behaviour are grouped together.

(i) The melting points of the oxides of the Period 3 elements, sodium to sulfur, are given in Table 7.1.

Table 7.1

Compound	Formula	Melting Point / °C
Sodium oxide	Na_2O	1132
Magnesium oxide	MgO	2830
Aluminium oxide	Al_2O_3	2054
Silicon dioxide	SiO_2	1710
Phosphorus pentoxide	P_4O_{10}	422
Sulfur trioxide	SO_3	17

Explain the difference in melting points, in terms of structure and bonding between Na_2O and MgO. [2]

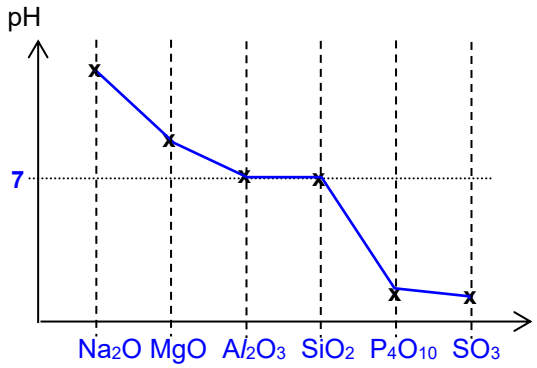
Both Na_2O and MgO have giant ionic structures (√) with strong electrostatic forces of attractions between the oppositely charged ions.

However, due to the higher charge and smaller ionic radius of Mg^{2+} (√) as compared to Na^+, MgO has stronger ionic bonds (√) than Na_2O. More energy (√) is required to break the ionic bonds in MgO than Na_2O. Hence, MgO has a higher melting point than Na_2O. (or explain in terms of lattice energy, using equation)

2√ = 1m

(ii) The oxides of the Period 3 elements, sodium to sulfur, can dissolve in or react with water.

Sketch a graph showing the variation in pH of the solution obtained when each of these oxides is added to water. Specific pH values are not required to be indicated on the graph. [1]



(b) **(i)** Write a balanced chemical equation, including state symbols, of a reaction to illustrate each of the three types of reactions below. Each equation must include one element or compound from either Group 1 or Group 17. [3]

Reaction	Equation from Group 1 or Group 17
Reaction with oxygen	**$2Li(s) + ½\ O_2(g) \rightarrow Li_2O(s)$** **$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$** **$K(s) + O_2(g) \rightarrow KO_2(s)$**
Decomposition	**$2HCl(g) \rightarrow H_2(g) + Cl_2(g)$**
Displacement	**$Cl_2(g) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(aq)$** **OR $Li(s) + H_2O(l) \rightarrow LiOH(aq) + ½\ H_2(g)$**

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(ii) State and explain the relative reactivity of Group 1 elements as reducing agents. [2]

The ease of oxidation of Group 1 metals increases down the Group / reducing power becomes stronger down the Group. (√)

Down the Group, atomic radius increases and I.E. decreases. (√) As the attraction of the nucleus for the valence electrons decreases (√), electrons can be removed more easily (√) through ionisation (i.e. more readily oxidised).

2√ = 1m

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(iii) Cl_2 forms Cl^- and ClO_3^- ions in alkaline medium.

State the type of reaction and write a balanced equation for this reaction. [2]

Type of reaction: **Disproportionation [1]**

Equation: **$3Cl_2 + 6OH^- \rightarrow ClO_3^- + 5Cl^- + 3H_2O$ [1]**

(c) Phosgene can dissociate to form carbon monoxide and chlorine.

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

0.200 mol of phosgene was placed into a rigid reaction vessel of volume 12.5 dm^3 and allowed to dissociate at a temperature of 770 K. The total amount of gas at equilibrium was found to be 0.319 mol.

(i) Calculate the equilibrium concentrations of $COCl_2$, CO and Cl_2 at 770 K. [2]

Let the amount of CO produced be *x* mol

	$COCl_2(g)$	⇌	$CO(g)$	+	$Cl_2(g)$
Initial amount / mol	0.200		0		0
Change in amount / mol	−*x*		+*x*		+*x*
Equilibrium amount / mol	0.200 − *x*		*x*		*x*

Total amount of gas at equilibrium = 0.200 + *x* = 0.319 mol

⇒ *x* = 0.119 mol

At equilibrium, [CO] = [Cl_2] = 0.119 ÷ 12.5 = 0.00952 mol dm^{-3}

[$COCl_2$] = (0.200 − 0.119) ÷ 12.5 = 0.00648 mol dm^{-3}

Relevant working to find *x* or other relevant equilibrium amounts [1]

Concentrations of CO, Cl_2 and $COCl_2$[1]

(ii) Hence, determine the percentage of $COCl_2$ dissociated at 770 K. [1]

Percentage of $COCl_2$ dissociated = (0.119 ÷ 0.200) × 100 % = 59.5 % [1]

allow ecf

(iii) Write the expression for the equilibrium constant, K_c, showing its units clearly. [1]

$K_c = \frac{[CO][Cl_2]}{[COCl_2]}$ **, mol dm^{-3} [1]**

(iv) Calculate the value of K_c at 770 K. [1]

$K_c = \frac{0.00952^2}{0.00648}$ **= 0.013986 = 0.0140 mol dm^{-3} [1]**

(v) The value of K_c for the dissociation of $COCl_2$ at 298 K is smaller than that at 770K.

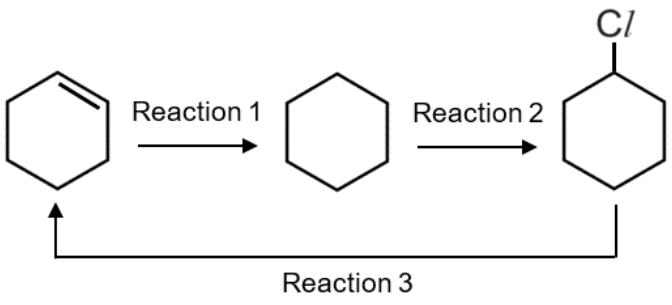
Deduce whether the forward or backward reaction will be favoured when the temperature of the equilibrium mixture is decreased from 770 K to 298 K.

Hence, deduce the sign of the enthalpy change of reaction, ΔH, for the dissociation of phosgene. [2]

As temperature decreases from 770 K to 298 K, K_c decreases, meaning the reactant-product ratio decreases. Therefore, the backward reaction is favoured [1], which is exothermic since temperature has decreased.

Hence, ΔH for the dissociation (forward reaction) is positive [1].

(d)



(i) State the reagents and conditions for Reactions 2 and 3 in the reaction scheme above. [2]

Reaction 2: Cl_2(g), uv light [1]

Reaction 3: Alcoholic KOH, heat [1]

(ii) Identify the type of reactions for Reaction 1. [1]

Reaction 1: Reduction [1]

Common mistake: addition

[Total: 20]

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8 This question is about the physical and chemical properties of chlorides.

Some period 3 chlorides are given in the list below.

$$NaCl \quad MgCl_2 \quad AlCl_3 \quad SiCl_4 \quad PCl_5$$

(a) From the list above, identify all possible chlorides which fulfill the criteria below.

(i) giant ionic structures in the solid state

[1] $NaCl$, $MgCl_2$

(ii) react(s) vigorously with water to form solutions with pH 3 and below

[1] $AlCl_3$, $SiCl_4$, PCl_5

(iii) react(s) with excess water to give a solid

[1] $SiCl_4$

[3]

(b) With reference to structure and bonding, suggest an explanation for the difference in melting point of $NaCl$ and $SiCl_4$. [2]

[1] $NaCl$ has giant ionic structure while $SiCl_4$ has a simple molecular structure. [1] Large amount of energy is required to overcome the strong ionic bonds in $NaCl$ compared to the weaker instantaneous dipole – induced dipole interactions between molecules of $SiCl_4$.

(c) When chlorine is bubbled through a solution of iodine in hot aqueous sodium hydroxide, the two halogens react in the $Cl_2 : I_2$ ratio of 7 : 1, forming a white solid **A** and a solution of sodium chloride.

A has the following percentage composition by mass:

Na	16.9 %
H	1.1%
I	46.7%
O	35.3%

(i) Show that the empirical formula of **A** is $Na_2H_3IO_6$. [1]

	Na	H	I	O
%mass	16.9	1.1	46.7	35.3
Ar	23	1	126.9	16
[1] %mass / Ar	0.732	1.1	0.368	2.2
Simplest ratio	2	3	1	6

empirical formula of **A** is $Na_2H_3IO_6$ (sodium *ortho*periodate)

(ii) **A** is a useful reagent in organic synthesis.

With reference to the oxidation state of iodine in **A**, suggest the role of **A** in organic synthesis. [2]

[1] Oxidation state of I in **A** is +7.

Since iodine (group 17) has a [1] maximum oxidation state of +7, A can only be reduced, hence **A** functions as an oxidising agent.

(d) Sulfur reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2.

(i) SCl_2 is a cherry-red liquid that reacts vigorously with water to form an acidic solution and yellow solid. The acidic solution comprises of sulfurous acid, H_2SO_3, as one of products.

Use this information to deduce the structure and bonding shown by SCl_2. Explain your answer. [2]

[1] "Liquid" implies that SCl_2 has a simple molecular structure due to a low melting point.

[1] "reacts vigorously with water" implies that SCl_2 is a covalent chloride as it hydrolyses in water to give an acidic solution/ SCl_2 has covalent bonds between its atoms.

(ii) Construct a balanced equation for the reaction of SCl_2 and water. [1]

[1] $2SCl_2 + 3H_2O \rightarrow H_2SO_3 + S + 4HCl$

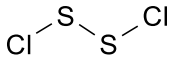
(iii) S_2Cl_2 can exist in 2 isomeric forms, **C** and **D**.

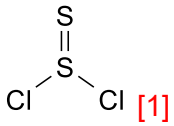
Sulfur is the central atom in both isomers.

Isomer **C** has only single bonds in the structure.

The sulfur – sulfur bond in isomer **D** is stronger than that in isomer **C**.

Using the information above, deduce possible structure of isomer **C** and **D**. [2]

C is  [1] (ignore shape)

D is  [1]

(e) SCl_2 is formed in an equilibrium reaction between S_2Cl_2 and Cl_2.

$$S_2Cl_2\,(l) + Cl_2\,(g) \rightleftharpoons 2SCl_2\,(l) \qquad \Delta H = -40\ kJ\ mol^{-1}$$

The equilibrium constant of the reaction is K_c.

Once equilibrium has reached at time t_1, a student altered the condition of the reaction and monitored the concentration of each species until new equilibrium is reached at time t_2.

Fig. 8.1 shows the graph of concentration change with time.

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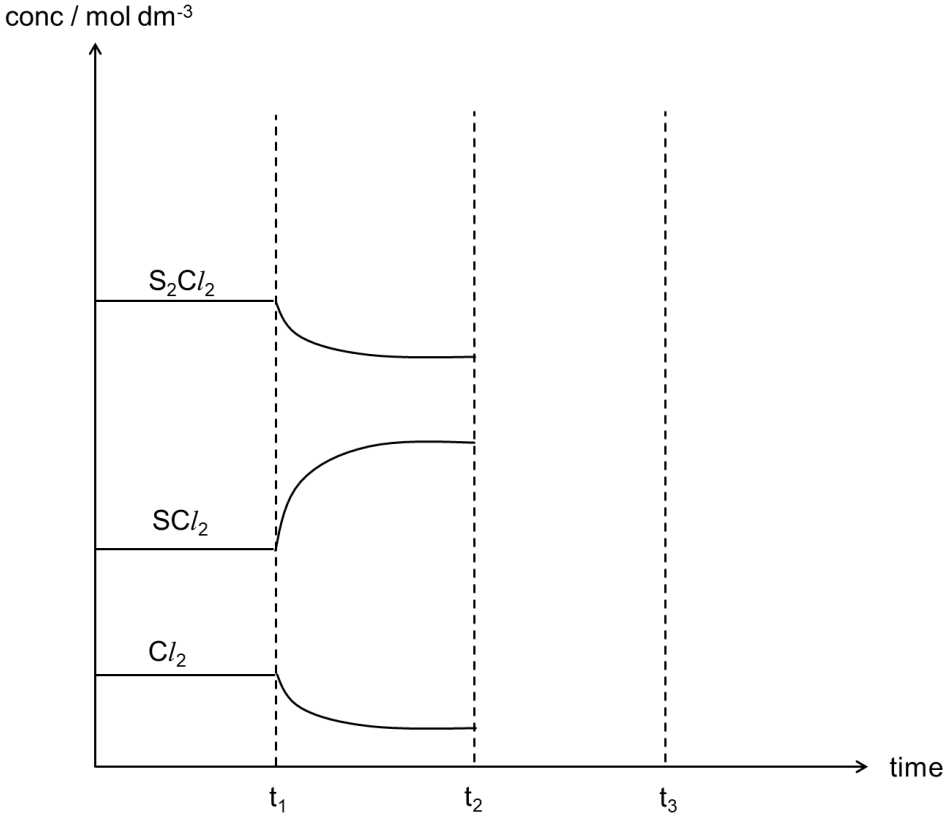


Fig. 8.1

(i) State Le Chatelier's Principle. [1]

[1] When a system at dynamic equilibrium is subjected to a change which disturbs the equilibrium, the system will react in a way to counteract the effect of the change to re-establish equilibrium.

(ii) Write an expression for the equilibrium constant, K_c, of this reaction. [1]

[1] $K_c = \frac{[SCl_2]^2}{[S_2Cl_2][Cl_2]}$

(iii) Using Fig. 8.1, deduce the condition which was altered at time t_1 and explain your answer. [2]

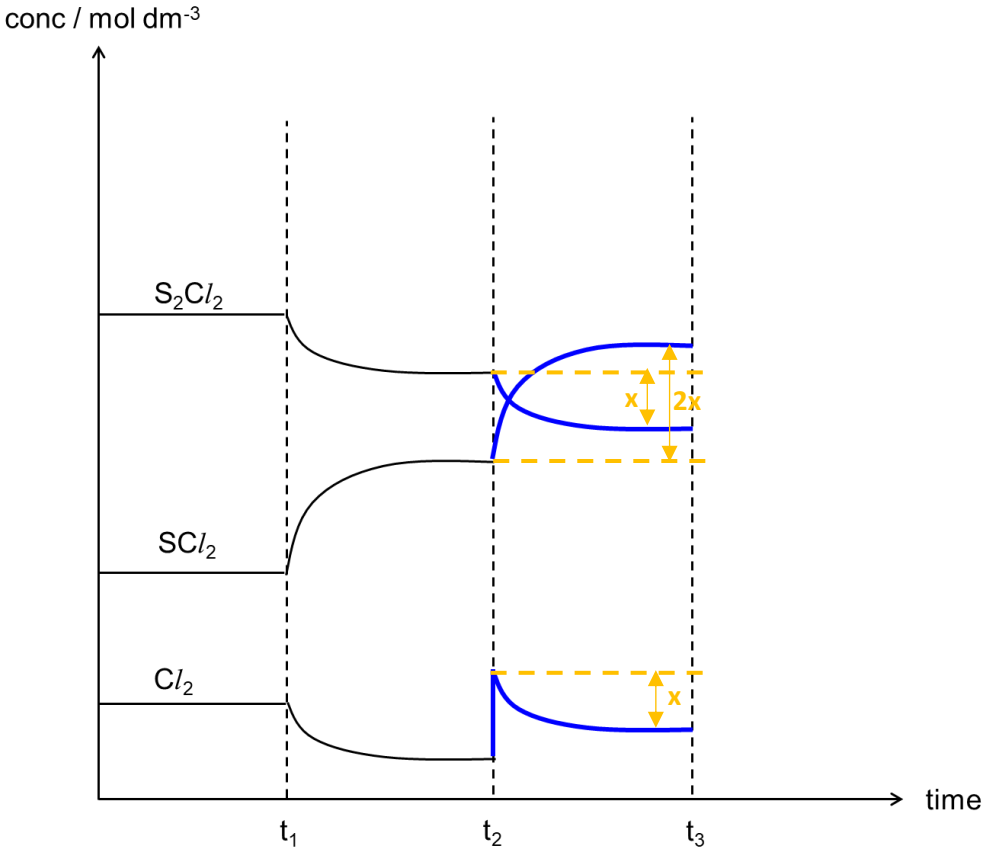
[✓] Temperature is decreased.

When temperature is decreased, [✓] by Le Chatelier's Principle, equilibrium position will shift to the right, [✓] favouring the exothermic reaction which releases heat. At new equilibrium, there is [✓] more [SCl_2] and less [S_2Cl_2] and [Cl_2].

2[✓] = [1]

(iv) At time t_2, the student added more Cl_2 at constant volume. A new equilibrium is reached at time t_3.

On Fig. 8.1, sketch the graphs to show how the concentration of all species change from t_2 to t_3. [2]



[1] sharp increase for Cl_2 + gradual decrease to a value higher than at t_2.

[1] gradual increase for SCl_2 (twice that of Cl_2) and decrease for S_2Cl_2 (similar to Cl_2).

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(iv) Sketch on Fig. 8.2 to show how the equilibrium constant change from t_1 to t_3. [1]

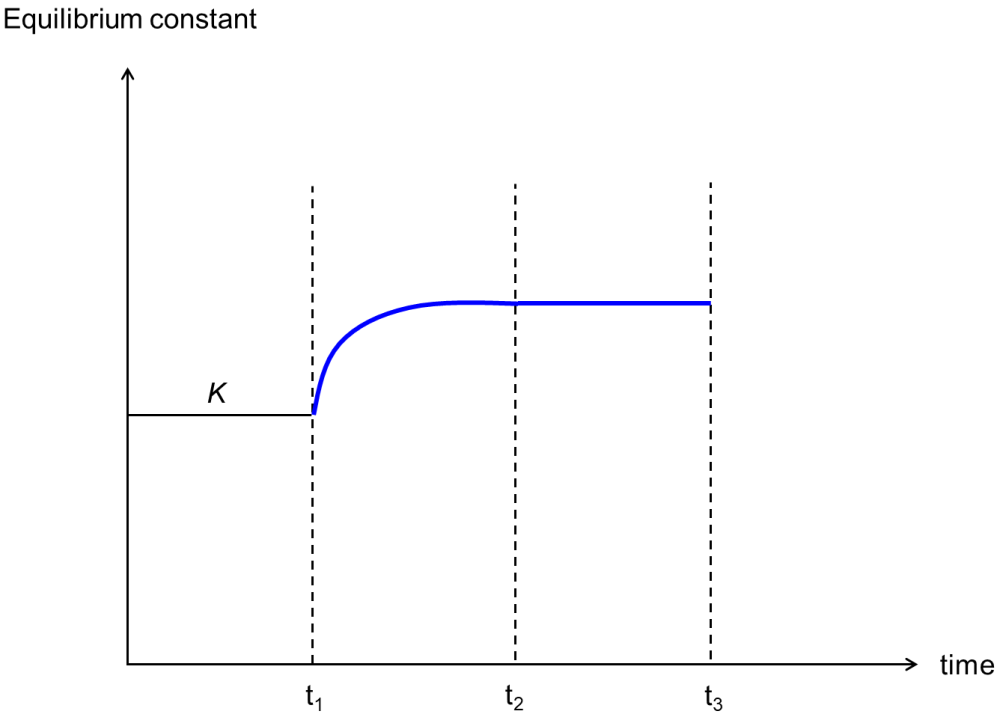

Fig. 8.2

[1] gradual increase from t_1 to t_2 to a higher value than *K* then constant value to t_3

[Total: 20]

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