TEMASEK JUNIOR COLLEGE

2024 JC2 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME		CLASS	
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, name and class 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 **26** printed pages and **2** blank pages.

[Turn over

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.

Complete Table 1.1 for two isotopes of copper.

Table 1.1

isotopes	protons	neutrons	electrons
$^{63}_{29}Cu$			
		38	

[2]

(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]

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

[1]

(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]

(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]

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

[2]

[Total: 8]

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]

(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]

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(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]

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

.....

.....

.....

.....[2]

(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]

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

$$3CH_3NCO(g) \longrightarrow \underset{\textbf{A}}{C_6H_9N_3O_3(s)}$$

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

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

.....

.....

.....[2]

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

.....[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]

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

.....[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]

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

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[2]

(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]

(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.

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

.....

.....[1]

[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]

(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]

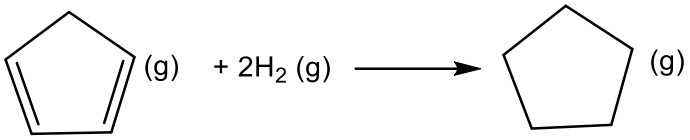
(b) Compound **P**, C_xH_y, also undergoes combustion.

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) Cyclopentadiene undergoes catalytic hydrogenation to form cyclopentane.



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

[2]

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]

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

.....

.....

.....

.....

.....[2]

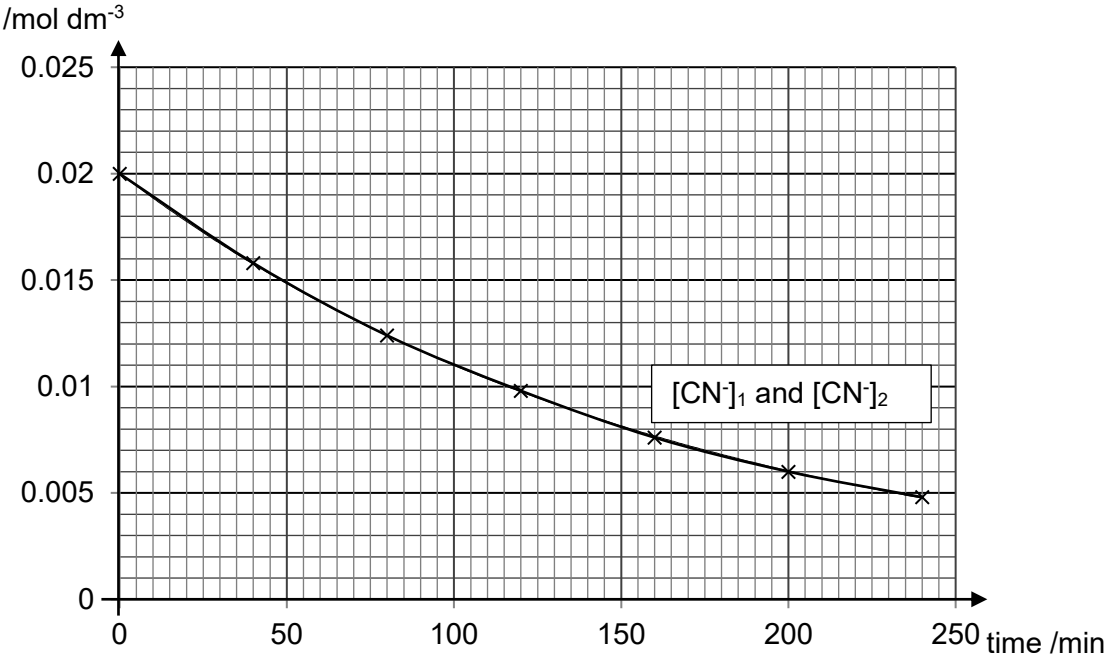
[Total: 10]

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]

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

.....[1]

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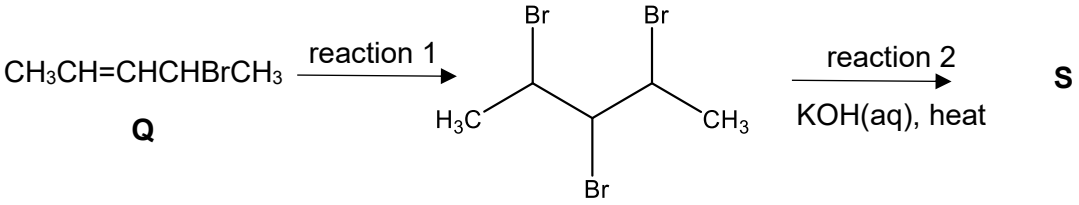
(iii) The experiment is repeated using 0.0500 mol dm^{-3} of **Q**.

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

[1]

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



Q

R

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

.....[1]

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

.....[1]

(iii) Draw the structure of compound **S**.

[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 their relative ratios.

[2]

[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.

.....

.....

.....[1]

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

.....

.....[1]

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

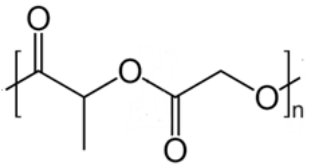
.....

.....

.....

.....[2]

(c) 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.

[2]

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

.....

.....

.....[1]

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

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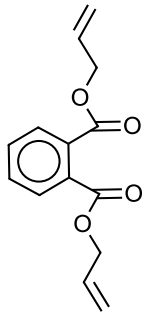
.....[2]

(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: .....

Structure of PDAP polymer:

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[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.

.....

.....[1]

[Total:12]

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.

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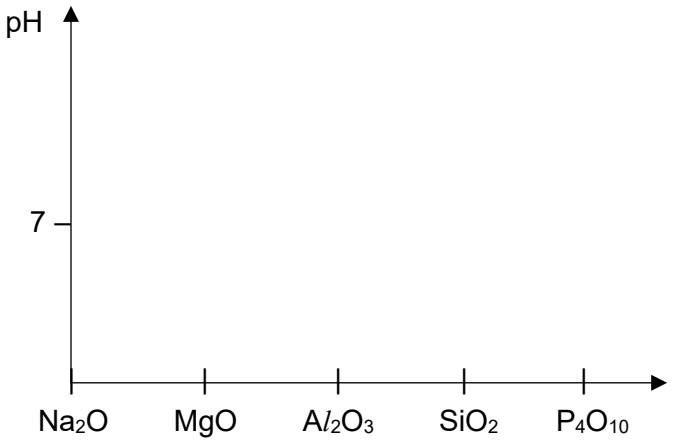
.....[2]

(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.

Reaction	Equation from Group 1 or Group 17
Reaction with oxygen	
Decomposition	
Displacement	

[3]

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

.....

.....

.....[2]

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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.

Type of reaction: .....

Equation: .....[2]

(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]

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

[1]

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

[1]

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

[1]

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

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.

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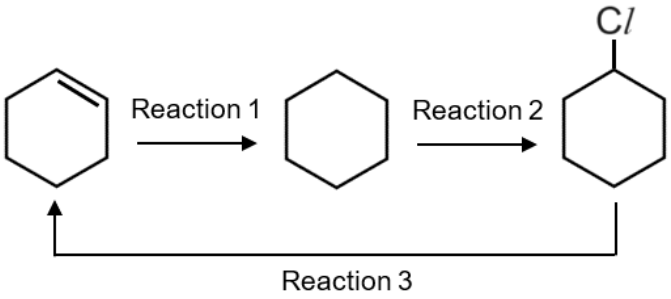
.....[2]

(d)



(i) Identify the type of reaction for Reaction 1.

Reaction 1: ..... [1]

(ii) State the reagents and conditions for Reactions 2 and 3.

Reaction 2: .....

Reaction 3: ..... [2]

[Total: 20]

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

Some period 3 chlorides are given in the list below.

$NaCl$ $MgCl_2$ $AlCl_3$ $SiCl_4$ 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]

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

.....[1]

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

.....[1]

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

.....

.....

.....

.....[2]

(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]

(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]

(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 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]

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

.....[1]

(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**.

C	**D**

[2]

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(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*.

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.

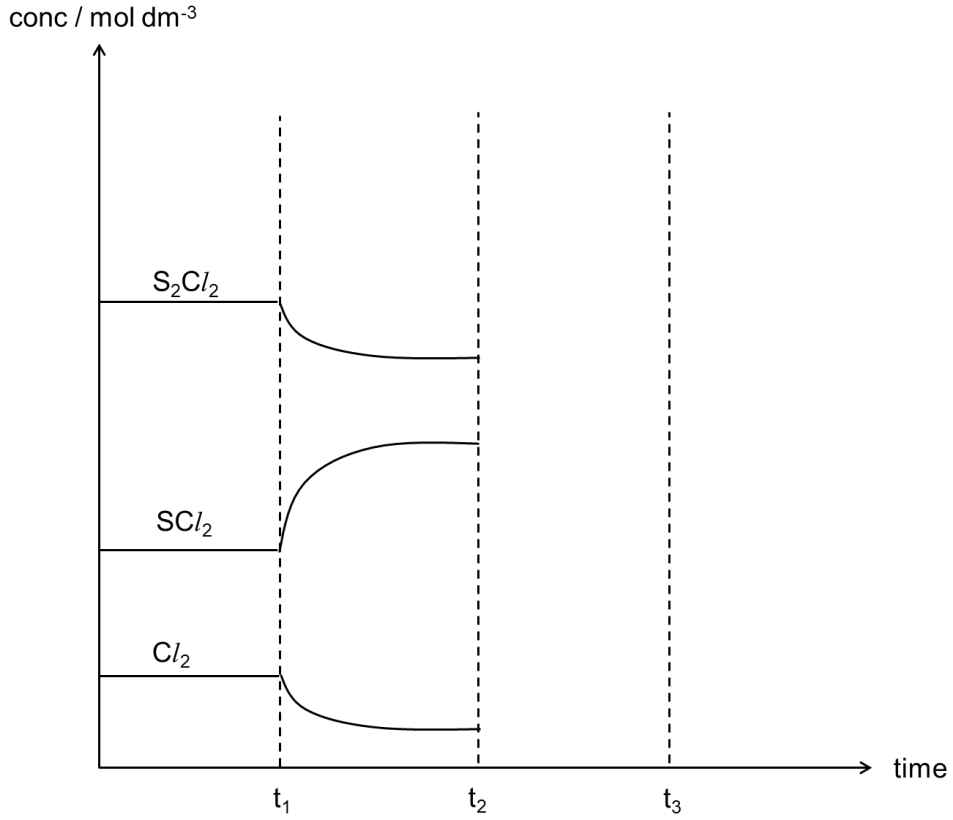

Fig. 8.1

(i) State Le Chatelier's Principle.

.....

.....[1]

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

[1]

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

.....

.....

.....[2]

(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]

Fig. 8.2 shows the graph of equilibrium constant against time of the reaction in **(e)**.

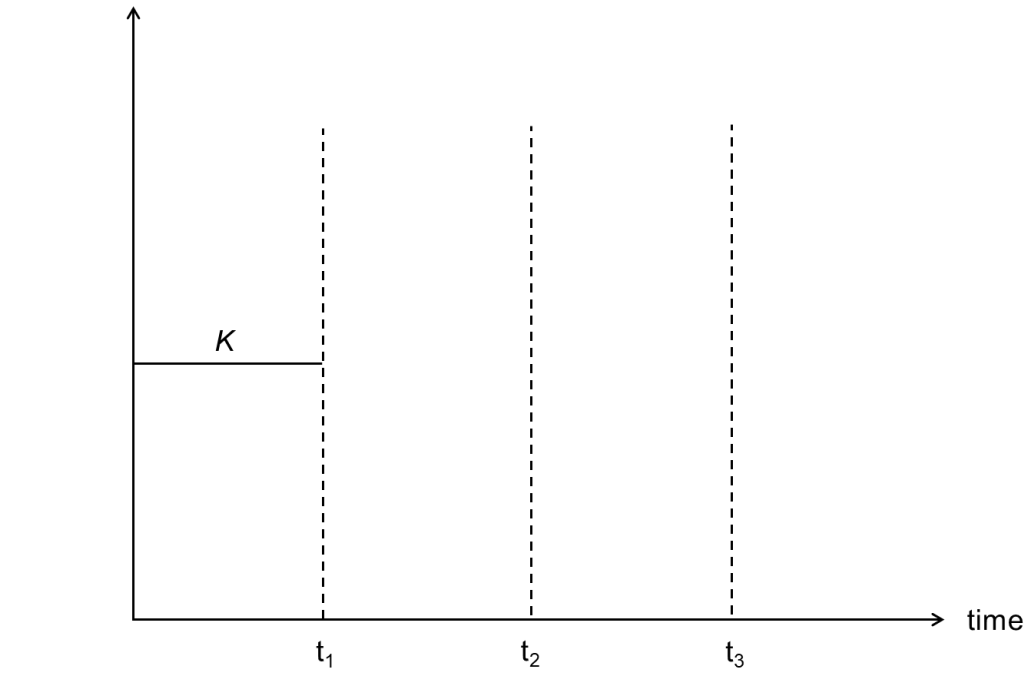

Fig. 8.2

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

[Total: 20]

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