

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 1

CHEMISTRY

8872/02

18 August 2016

Paper 2

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Data Booklet
Writing Papers

READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group.
Write in dark blue or black pen.
You may use pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A: Structured Questions (40m)

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

Section B: Free Response Questions (40m)

Answer **two** questions on writing papers provided.

A *Data Booklet* is provided.

You are advised to show all working in calculations.
You are reminded of the need for good English and clear presentation in your answers.
You are reminded of the need for good handwriting.
Your final answers should be in 3 significant figures.

You may use a calculator.

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

At the end of the examination, fasten all your work securely together.

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



Innova Junior College

[Turn over

Section A

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

- 1 Magnesium exists as three principal isotopes, ^{24}Mg , ^{25}Mg and ^{26}Mg .

Isotope	Relative isotopic mass	Natural abundance (%)
^{24}Mg	23.99	78.99
^{25}Mg	24.99	10.00
^{26}Mg	25.98	11.01

- (a) Use the above data to calculate the relative atomic mass of magnesium to **two** decimal places.
[1]

$$\text{RAM} = \frac{78.99 \times 23.99 + 10 \times 24.99 + 11.01 \times 25.98}{100}$$

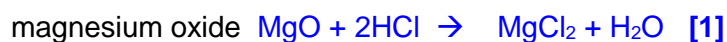
$$= 24.31 \text{ [1] ans to 2dp}$$

- (b) Magnesium and phosphorus are both in period 3.
Describe and explain the difference in the size of their atomic radii.
[2]

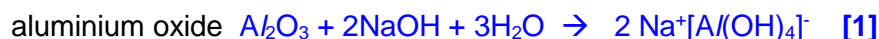
Proton number of P > Mg. Hence, nuclear charge of P > Mg. [✓] Both have the same number of quantum shells hence shielding effect remains relatively constant for Mg and P. [✓] Therefore effective nuclear charge of P > Mg or Valence electrons are more strongly attracted to the nucleus of P than Mg. [✓] Hence atomic size of P is smaller [✓] than Mg.

- (c) Write equations for the reactions of the following oxides with aqueous hydrochloric acid and with aqueous sodium hydroxide.

- (i) with aqueous hydrochloric acid [2]



- (ii) with aqueous sodium hydroxide [2]

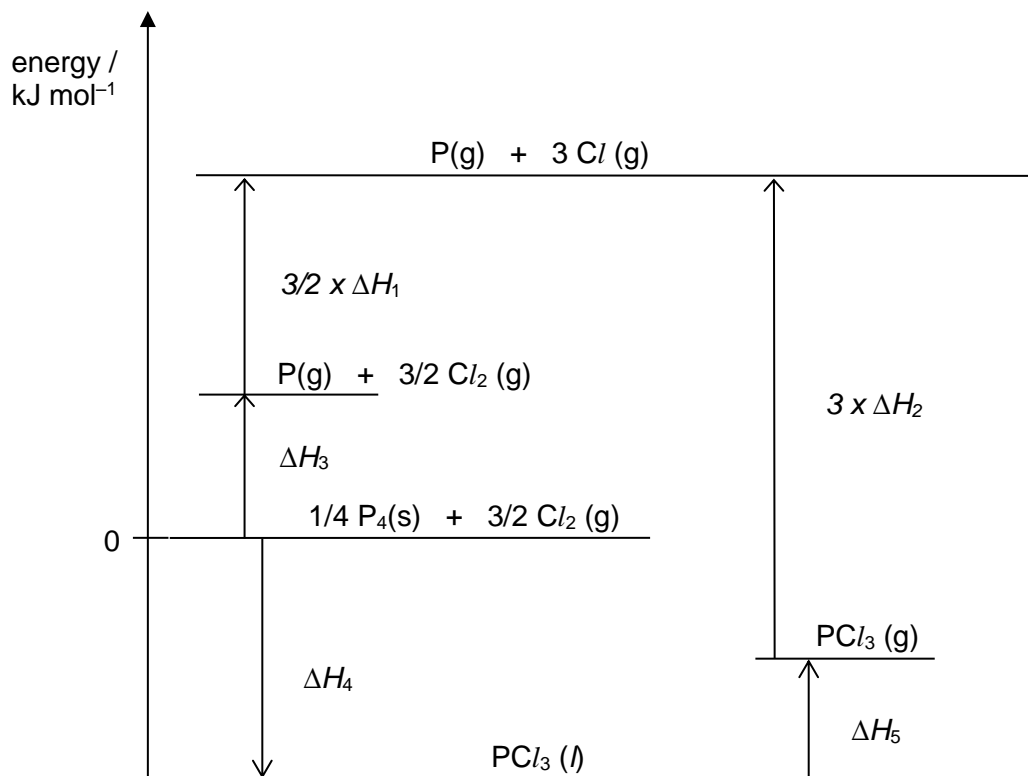


- (d) Explain why aluminum oxide exhibits character of both magnesium oxide and phosphorus (V) oxide. [1]
This is due to the high charge density of Al^{3+} ion polarising the O^{2-} anion hence resulting in partial covalent character of Al-O interaction. [1]

Accept: Aluminium oxide is an ionic compound with covalent character

[Total: 8]

- 2 (a) Liquid phosphorous trichloride can be prepared in the laboratory by the reaction of chlorine with red phosphorus. An energy level diagram which starts from $P_4(s)$ and $Cl_2(g)$ is shown below.



- (i) Define the term *standard enthalpy change of formation*. [1]
 Standard enthalpy change of formation is the enthalpy change when one mole of a substance is formed from its constituent elements in their standard states under standard conditions of 298 K and 1 atm.

- (ii) State the enthalpy changes that are represented by ΔH_1 , ΔH_2 and ΔH_4 . [2]

- ΔH_1 : bond energy (Cl–Cl) [✓]
- ΔH_2 : bond energy (P–Cl) [✓]
- ΔH_4 : ΔH_f° ($PCl_3(l)$) [✓] (**Accept liquid or without**)

3 correct: 2m ; 2 correct: 1m ; 1 or none correct: 0m

- (iii) Hence, use the information given below and relevant data from the *Data Booklet* to calculate the bond energy of P–Cl bond.

ΔH_3	+314.6 kJ mol ⁻¹
ΔH_4	–319.7 kJ mol ⁻¹
ΔH_5	+31.0 kJ mol ⁻¹

[2]

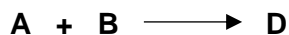
By Hess law,

$$\Delta H_4 = \Delta H_3 + 3/2 \times \Delta H_1 - 3 \times \Delta H_2 - \Delta H_5 \quad [1]$$

$$-319.7 = +314.6 + 3/2 (244) - 3 \times \text{BE (P-Cl)} - 31.0$$

$$\text{BE (P-Cl)} = +323 \text{ kJ mol}^{-1} \quad [1]$$

- (b) The reaction between **A** and **B** is monitored by finding the time taken for **A**, a coloured reactant to decolourise. Water is added to the reaction mixture to keep the volume of the reaction mixture for experiment 1, 2 and 3 constant at 60 cm³.



The following results are obtained:

Experiment	Volume of A added/cm ³	Volume of B added/cm ³	Volume of H ₂ O added/cm ³	Relative rate of reaction
1	10	20	30	1
2	15	40	5	6
3	20	20	20	2

- (i) Explain why is there a need to keep the total volume of the reaction mixture constant. [1]

When the total volume is constant, the initial concentration of each reactant in the reaction mixture is directly proportional to its volume used. [1]

- (ii) Deduce, showing your working, the orders of reaction with respect to **A** and **B**. [2]

Inspection method:

Comparing experiment 1 and 3, where concentration of B is constant, when concentration of A doubles, the relative rate of reaction doubles. Hence order of reaction with respect to X is 1. [1]

Comparing experiment 1 and 2, when concentration of A increased by 1.5 times of original concentration, the relative rate increased from 1 to 1.5. When concentration of B doubles, the relative rate increased by 4 times. Hence order of reaction with respect to Y is 2. [1]

Substitution method:

Comparing Expt 1 and 3,

$$\frac{\text{Rate}_3}{\text{Rate}_1} = \frac{k[A]_3^m[B]_3^n}{k[A]_1^m[B]_1^n}$$

$$\frac{2}{1} = \left(\frac{20}{10}\right)^m$$

$$m = 1$$

Order of reaction wrt [A] = 1 [1]

Comparing Expt 1 and 2,

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \frac{k[A]_2^m[B]_2^n}{k[A]_1^m[B]_1^n}$$

$$\frac{6}{1} = \left(\frac{15}{10}\right)^m \left(\frac{40}{20}\right)^n$$

Since m = 1,

$$4 = 2^n$$

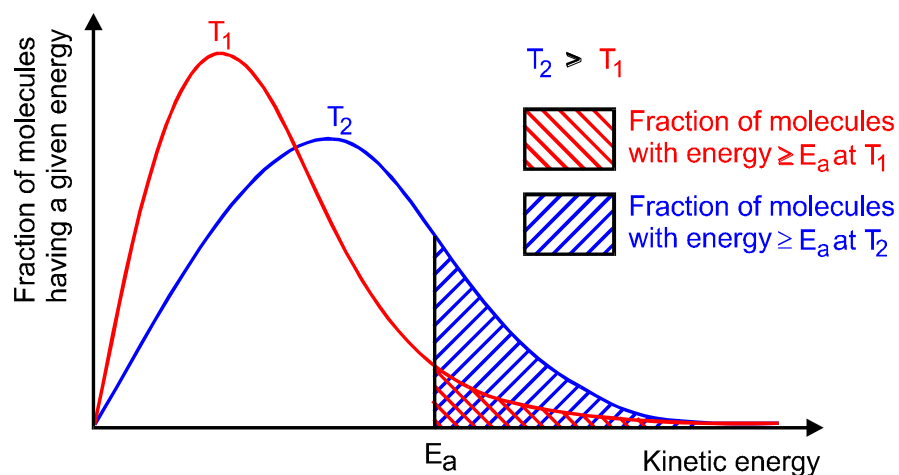
$$n = 2$$

Order of reaction wrt [B] = 2 [1]

- (iii) Hence, state the overall rate equation for this reaction. [1]

$$\text{Rate} = k[A][B]^2 \text{ [1]}$$

- (c) Explain, with an aid of the Maxwell-Boltzmann distribution curve, the effect of increasing temperature on the rate of the reaction. [3]



[✓] for labelling both axis, curve starts at zero

[✓] for labelling correct shading

[✓] for labelling E_a

[✓] for legend with correct shading

4 [✓] – 1

Average kinetic energy of the particles increases [✓].

There is an increase in the fraction of particles with energy equal to or greater than the activation energy, E_a . [✓]

This result in an increase in the frequency of effective collisions [✓], hence the rate of reaction increases. [✓]

[Total: 12]

- 3 Beryllium chloride, BeCl_2 , is an inorganic colourless solid that dissolves well in polar solvents. At solid state, BeCl_2 molecules undergo polymerisation to form a long chain. In vapour phase, BeCl_2 exists as a dimer, and at higher temperature, it exists as individual molecules.

- (a) (i) Draw the dot-and-cross diagram of a molecule of BeCl_2 . State the shape of the molecule. [2]

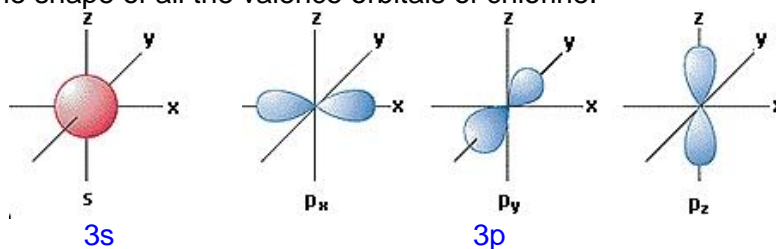


Shape: Linear [1]

- (ii) By considering the lone pairs and valence electrons on the atoms of BeCl_2 molecules, suggest the type of bonding formed during the polymerisation process. [1]

Dative covalent bond / Co-ordinate bond [1]

- (b) Draw the shape of all the valence orbitals of chlorine. [2]



3s orbital – 1m and all three 3p orbitals – 1m

- (c) $\text{Ba}(\text{OH})_2$ is a *strong base*.
(i) Define the term *strong base*. [1]

A strong base **dissociates completely in aqueous solution/ water to form OH^- ions.** [1]

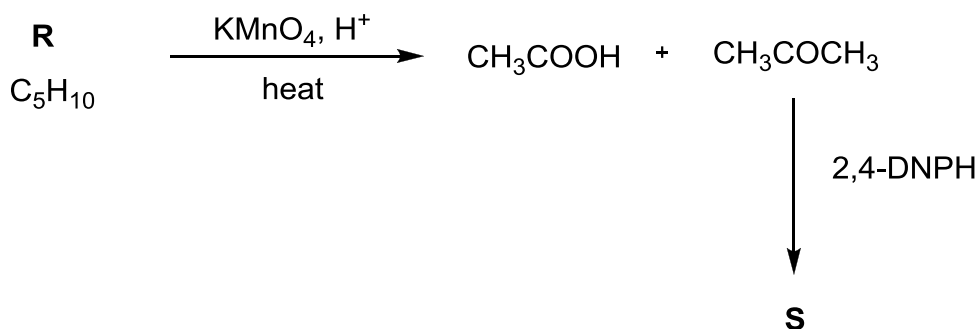
- (ii) Given that $\text{Ba}(\text{OH})_2$ is a strong diacidic (diprotic) base, calculate the pH of a 0.01 mol dm^{-3} solution of $\text{Ba}(\text{OH})_2$ at 25°C . [1]

$$[\text{OH}^-] = 0.02 \text{ mol dm}^{-3}$$

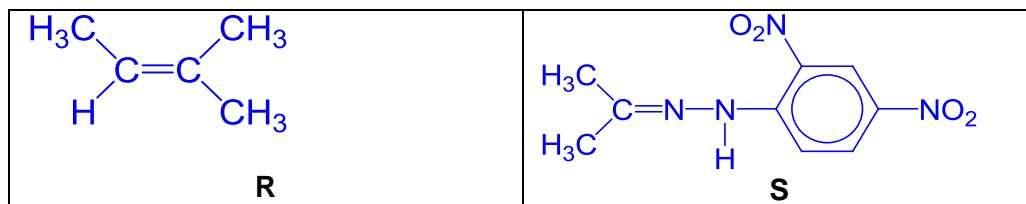
$$\text{pOH} = -\lg(0.02) = 1.6989$$

$$\text{pH} = 14 - 0.6989 = 12.3 \text{ [1]}$$

- (d) The reaction scheme shows the reactions for alkene **R** and its product.



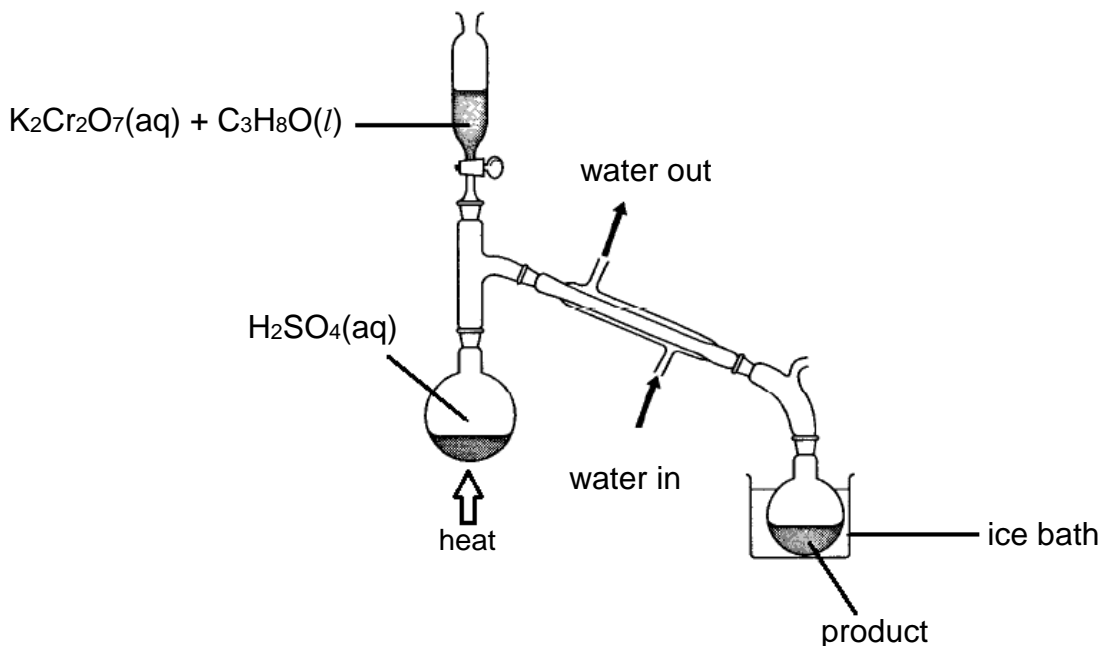
- (i) Suggest the structures for **R** and **S**. [2]



- (ii) State the type of reaction for the formation of **S** from CH_3COCH_3 . [1]
 condensation

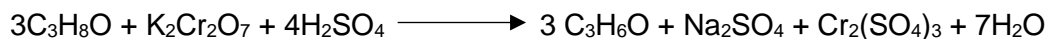
[Total: 10]

- 4 A student was given the following instructions for the oxidation of an alcohol, $\text{C}_3\text{H}_8\text{O}$. However, the structure of the alcohol was unknown.
1. To 20 cm^3 of water in a round bottom flask, carefully add 5 cm^3 of concentrated sulfuric acid and set up the distillation apparatus as shown below.



2. Make up a solution containing 47.2 g of potassium dichromate(VI), $\text{K}_2\text{Cr}_2\text{O}_7$, in a 15 cm^3 of water, add 18.0 g of the alcohol, $\text{C}_3\text{H}_8\text{O}$, and pour this mixture into the dropping funnel.
3. Boil the acid in the flask. Add the mixture from the dropping funnel at such a rate that the product is slowly collected.
4. Re-distil the product and collect the fraction that boils between 48°C and 50°C .

The balanced equation of the reaction is



- (i) State the colour change that the student would observe during the reaction. [1]

from..... to

Orange to green [1]

- (ii) Calculate the amount of $K_2Cr_2O_7$ and C_3H_8O used. Hence, determine the limiting reagent. [2]

$$\text{No. of moles of } K_2Cr_2O_7 = \frac{47.2}{39.1 \times 2 + 52 \times 2 + 16 \times 7} = 0.160 \text{ [✓]}$$

$$\text{No. of moles of } C_3H_8O = \frac{18}{60} = 0.3 \text{ [✓]}$$

If all the $K_2Cr_2O_7$ reacted, no. of moles of C_3H_8O required = 0.480 mol

Since the no. of moles of C_3H_8O present is less than the no. of moles of C_3H_8O required, C_3H_8O is the limiting reagent. [1] (or words to the same effect)

- (iii) The student obtained 5.22 g of the carbonyl compound, C_3H_6O . Calculate the percentage yield of the product obtained by the student assuming that the reaction goes to completion. [2]

$$\begin{aligned} \text{Theoretical mass of } C_3H_6O \text{ produced} &= 0.3 \times (36 + 6 + 16) \\ &= 17.4 \text{g [1]} \end{aligned}$$

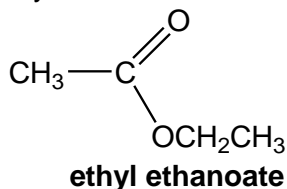
$$\begin{aligned} \% \text{ yield} &= \frac{5.22}{17.4} \times 100\% \\ &= 30\% \text{ [1]} \end{aligned}$$

- (iv) Identify the possible isomers of the alcohol, C_3H_8O . [2]



- (v) Use the table of characteristic values for Typical proton chemical shift value (δ) in the Data Booklet to answer this question.

Nuclear magnetic resonance can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows a chemical shift at 2.0ppm.



An impure sample of C_3H_6O obtained by a student was analysed using nuclear magnetic resonance. The nuclear magnetic resonance recorded a chemical shift at 9.0-13.0 ppm.

Identify the functional group present in the impurity. Explain your answer. [2]

Impurity

Reason.....

.....

.....

Impurity : carboxylic acid [1]

Reason : Chemical shift of 9.0-13.0ppm represents the presence of R-COOH group. [1]

(vi) Based on your answer in (iv) and (v), suggest a structure for the alcohol used.

[1]

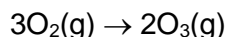
$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ [1]

[Total: 10]

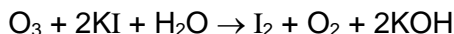
Section B

Answer **two** of the three questions in this section on separate answer paper.

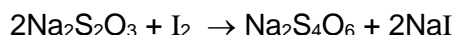
- 5 (a) Ozone is usually made by passing oxygen gas through a tube between two highly charged electrical plates.



The reaction does not go to completion, so a mixture of the two gases results. The concentration of O_3 in the mixture can be determined by its reaction with aqueous KI.



The iodine formed can be estimated by its reaction with sodium thiosulfate.



When 500 cm^3 of an oxygen/ozone gaseous mixture at s.t.p. was passed into an excess of aqueous KI, and the iodine titrated, 15.0 cm^3 of $0.100 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3$ was required to discharge the iodine colour.

- (i) Calculate the amount in moles of iodine produced. [1]
 $\text{I}_2 : \text{S}_2\text{O}_3^{2-} = 1:2$

$$\text{amount of } \text{S}_2\text{O}_3^{2-} = \frac{15}{1000} \times 0.1 = 1.5 \times 10^{-3} \text{ mol } [\checkmark]$$

$$\text{amount of } \text{I}_2 = \frac{1}{2} \times 1.5 \times 10^{-3} = 7.5 \times 10^{-4} \text{ mol } [\checkmark]$$

- (ii) Hence calculate the percentage of O_3 in the gaseous mixture. [2]
 $\text{I}_2 : \text{O}_3 = 1:1$

$$\text{amount of } \text{O}_3 = 7.5 \times 10^{-4} \text{ mol } [\checkmark] \text{ (ecf)}$$

$$\text{Volume of } \text{O}_3 = 7.5 \times 10^{-4} \times 22400 = 16.8 \text{ cm}^3 [\checkmark]$$

$$\% \text{ of } \text{O}_3 = 16.8/500 \times 100\% = 3.36\% [1]$$

- (b) Carbon exists in two allotropic forms, diamond and graphite.

- (i) Explain, in terms of structure and bonding, why diamond and graphite have very high melting points. [1]

Both diamond and graphite have giant covalent structures. $[\checkmark]$

A large amount of energy is required to break the strong covalent bonds between carbon atoms $[\checkmark]$ in diamond and graphite during melting.

Hence, they have very high melting points.

2 $[\checkmark]$ awards 1 mark

- (ii) State and explain how diamond and graphite differ in their electrical conductivity. [2]

Graphite conducts electricity but not for diamond. $[1]$

In graphite, the 4th valence electron of each C atom is delocalised over the layer and act as charge carriers. In diamond, there is no free mobile ions or delocalised electrons to act as charge carriers. $[1]$

- (c) Like carbon, phosphorus has different allotropes, exhibiting different colours and properties. Phosphorus reacts with chlorine to produce two chlorides, PCl_3 and PCl_5 , depending on the amount of chlorine present during the reaction.

However, nitrogen reacts with chlorine to form only one chloride, NCl_3 , although nitrogen is in the same group as phosphorus.

- (i) Suggest a reason why PCl_5 exists but NCl_5 cannot be formed. [2]
 PCl_5 exists because phosphorous is in Period 3 [✓] and it can expand its octet structure by using the energetically accessible 3d orbitals [1] for bonding.

NCl_5 cannot be formed because nitrogen is in Period 2 [✓] and there are no energetically accessible 3d orbitals to accommodate more than eight electrons.

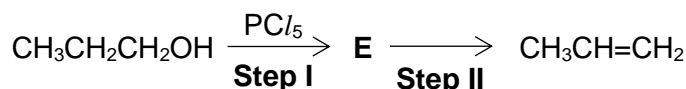
- (ii) At 298 K, PCl_5 is a solid, while PCl_3 is a liquid.

Account for the difference in physical states of the two phosphorus chlorides at room temperature. [2]

Both PCl_5 and PCl_3 have simple molecular structures. [✓]

PCl_5 has a larger electron cloud size than PCl_3 . The larger electron cloud in PCl_5 is more easily polarised. [✓] The van der Waals' forces between PCl_5 molecules are stronger. [✓] More energy is needed [✓] to overcome the van der Waals' forces between PCl_5 than that of PCl_3 .

- (d) PCl_5 is used as a reagent in organic reactions with alcohols. It was used in the first step of the following reaction.



- (i) Draw the structure of **E** and state the type of reaction taking place in **Step I**. [2]

Structure of **E**:



Type of reaction in **Step I**: substitution [1]

- (ii) Suggest the reagents and conditions for **Step II**. [1]
 Reagents and conditions: ethanolic KOH, heat [1]

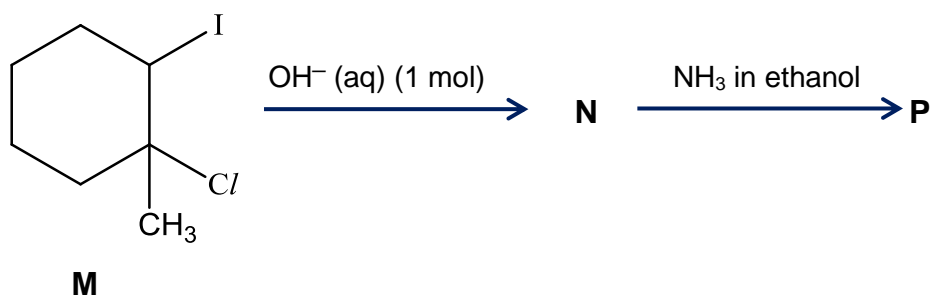
- (e) Halogenoalkanes (R-X , $\text{X} = \text{Cl}, \text{Br}, \text{I}$) are used widely in the industry to produce organic compounds commercially. Halogenoalkanes can undergo hydrolysis by heating under reflux with aqueous sodium hydroxide.

- (i) Write a balanced equation to show the reaction between 1-bromopropane and sodium hydroxide. [1]
 $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{NaOH} \longrightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{NaBr}$ [1]

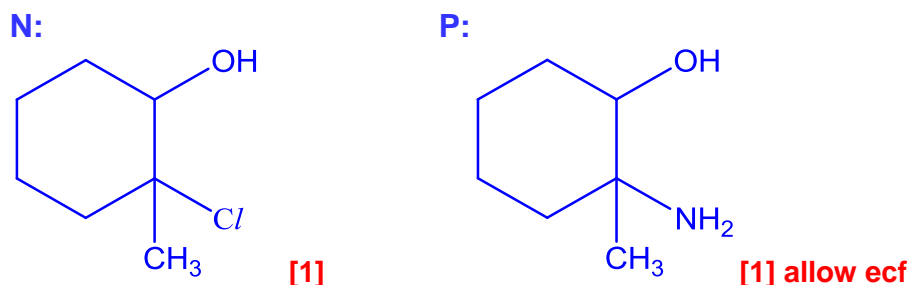
- (ii) Describe and explain the relative reactivity of chloro and iodo-compounds with respect to hydrolysis. [2]

The reactivity of iodo-compounds with respect to hydrolysis will be faster than that of chloro-compounds. [✓] The bond length of C-I bond is longer than C-Cl bond [✓] and hence the C-I bond is weaker than C-Cl bond [✓]. Less energy is required to break the C-I bond than C-Cl bond [✓].

- (iii) Hence, predict the outcome of the following transformation on **M**, a dihalogeno compound, by drawing the structures of the intermediate **N** and product **P**.

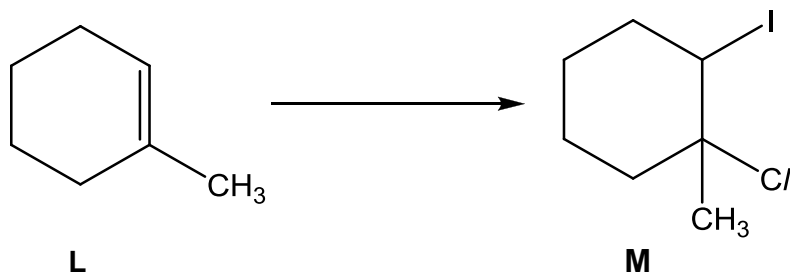


[2]



- (iv) Compound **M** can be synthesized from compound **L**.

Suggest suitable reagents and conditions needed to perform this conversion. [1]



Reagents and conditions: gaseous ICl (or in CCl_4), r.t.p in the dark [1]

- (v) Halogenoalkanes can also be synthesised from alkanes. Suggest with reasoning why this method of synthesis is not reliable. [1]
The substitution is random [1] as all the C-H in alkanes can be substituted and many different products can be formed.
 Accept mixture of products

[Total: 20]

- 6 (a) **W**, **X** and **Y** are three consecutive period 3 elements in the periodic table. **Z** is an isotope of one of the elements.

The table below provides information on the number of protons, neutrons and electrons in species of **W**, **X**, **Y** and **Z**.

	protons	neutrons	electrons
W	15	16	15
X²⁻	16	17	q
Y	17	18	17
Z⁻	17	17	18

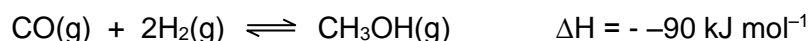
- (i) State the value of **q**. [1]
18
- (ii) Identify the element, **W**, **X** or **Y**, that is isotopic to **Z**. Explain your answer. [2]
Y. They have the same number of protons but different number of neutrons.

The first nine successive ionisation energies, in kJ mol⁻¹, of an unknown Period 3 element are given in the following table.

1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th
1251	2298	3822	5159	6542	9362	11018	33604	38600

- (iii) Use the information given above to deduce the identity of this element, and explain your answer. [2]
Chlorine. [1, conditional]
The first drastic increase occurs between the 7th and 8th IE [✓], suggesting that there are 7 valence electrons [✓]. Since the element is in period 3, it is Cl.
- (b) Methanol is an important alcohol used in fuel mixtures, making methyl esters and oxidation to methanol (formaldehyde) to make urea–formaldehyde resin glues.

Methanol is manufactured industrially from carbon monoxide and hydrogen gas in an enclosed system according to the following reaction.



The reaction is typically subjected to the following industrial conditions.

pressure	50 MPa
temperature	250 °C
catalyst	copper-zinc oxide mixture

- (i) Define the term dynamic equilibrium. [1]
Dynamic equilibrium refers to a reversible reaction in which the forward and the backward reactions are taking place at the same rate [✓] and hence, the concentrations of reactants and products remain constant (no net change in concentrations of reactants and products) [✓]

- (ii) Suggest the effect of the high pressure under industrial conditions and catalyst has on
- the position of equilibrium
 - the rate of reaction

[3]

Pressure

By Le Chatelier's Principle, with a high pressure of 50 MPa, the **equilibrium position will shift to the right [1]** so as to favour the production of **less gaseous molecules** to reduce the pressure.

At higher pressure, the reaction proceeds at a **faster rate. [1]**

Catalyst:

There is **no change** to the equilibrium position [\checkmark], as the catalyst **speeds up the rate of both forward and backward reaction** to the **same extent**.

Hence, the **rate of the reaction increases** [\checkmark], compared to that under room conditions, without catalyst.

- (iii) The reaction is performed at a moderately high temperature of 250 °C. Suggest why a low temperature is not used industrially instead. [1]
The reaction will be **very slow** if performed at low temperature.

- (c) (i) Explain in terms of its structure why ethanoic acid is acidic. [2]
- The **negative charge on the carboxylate anion can be delocalised** [\checkmark]
over two electronegative oxygen atoms [\checkmark].
 - This **disperses the negative charge on the oxygen atom** [\checkmark] and leads to a **stabilisation of the anion** [\checkmark].
 - The stability of the anion is far greater than the acid. The **equilibrium for dissociation of ethanoic acid lies more to the right** and thus, it is acidic.

- (ii) Esters can be synthesise from alcohol and carboxylic acids.
Describe, with named reagents and suitable conditions, how you would carry out the reaction to synthesise methyl ethanoate. [2]
Add **methanol** [\checkmark] and **ethanoic acid** [\checkmark] in the presence of **trace amount of concentrated sulfuric acid** [\checkmark] and **heat** [\checkmark] the mixture **with reflux**

- (iii) Explain why benzene undergoes substitution, instead of addition, with chlorine, in the presence of the halogen carrier $AlCl_3$. [2]
Benzene does not undergo addition reaction as it undergoes substitution instead to **retain aromatic stability** [1]. As result, $AlCl_3$ is required as a **catalyst** [1] for the reaction.

- (d) Describe **two** tests that could distinguish between propanoic acid and propanone.

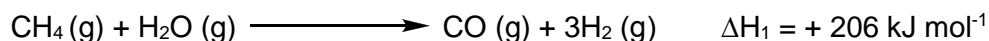
In each case you should state what reagent and conditions you would use and what observations you would make. [4]

Test	propanoic acid	propanone
$\text{Na}_2\text{CO}_3(\text{s}) + \text{rt}$	Effervescence will be observed. Gas forms white precipitate with $\text{Ca}(\text{OH})_2(\text{aq})$.	No effervescence observed.
$\text{Na}(\text{s}) + \text{rt}$	Effervescence will be observed. Gas extinguished lighted splint with a pop sound.	No effervescence observed.
$\text{I}_2(\text{aq}), \text{NaOH}(\text{aq}) + \text{warm (or heat)}$	No pale yellow precipitate will be observed	Pale yellow precipitate will be observed
2,4-DNPH + rt	No orange precipitate will be observed.	Orange precipitate will be observed.

Any 2 tests [1 – correct test, 1m – correct observation]

[Total: 20]

- 7 (a) Hydrogen is used in large quantities in industry to convert nitrogen into ammonia, for use in fertilizers. One method of manufacturing hydrogen is to pass methane and steam over a heated nickel catalyst.



- (i) Use the value of ΔH_1 above, and bond energy values from the Data Booklet, to calculate the total bond energy in the carbon monoxide molecule. [2]

Let the bond energy in the carbon monoxide be $y \text{ kJ mol}^{-1}$.

<i>Bonds broken</i>	<i>No. of moles</i>	<i>Energy absorbed</i>	<i>Bonds formed</i>	<i>No. of moles</i>	<i>Energy released</i>
<i>C–H</i>	<i>4</i>	<i>4 X 410</i>	<i>C≡O</i>	<i>1</i>	<i>1 X y</i>
<i>O–H</i>	<i>2</i>	<i>2 X 460</i>	<i>H–H</i>	<i>3</i>	<i>3 X 436</i>

Enthalpy change of reaction = + 206

$\Sigma \text{ B.E. (bonds broken)} - \Sigma \text{ B.E. (bonds formed)} = + 206$

$$4(410) + 2(460) - [y + 3(436)] = 206 \quad [1]$$

$$y = +1046 \text{ kJ mol}^{-1}$$

Bond energy for $\text{C} \equiv \text{O} = +1.05 \times 10^3 \text{ kJ mol}^{-1}$ [1]

- (ii) Use the following data to calculate the enthalpy change of combustion of hydrogen gas.

$$\Delta H_c[\text{CO}(\text{g})] = -283 \text{ kJ mol}^{-1}$$

$$\Delta H_c[\text{CH}_4(\text{g})] = -891 \text{ kJ mol}^{-1}$$

[2]

$$\Delta H_r = \sum n\Delta H_c^\theta (\text{reactants}) - \sum m\Delta H_c^\theta (\text{products})$$

$$206 = -891 - [(-283) + 3 \Delta H_c(\text{H}_2)] \quad [1]$$

$$\Delta H_c(\text{H}_2) = -271 \text{ kJ mol}^{-1} \quad [1]$$

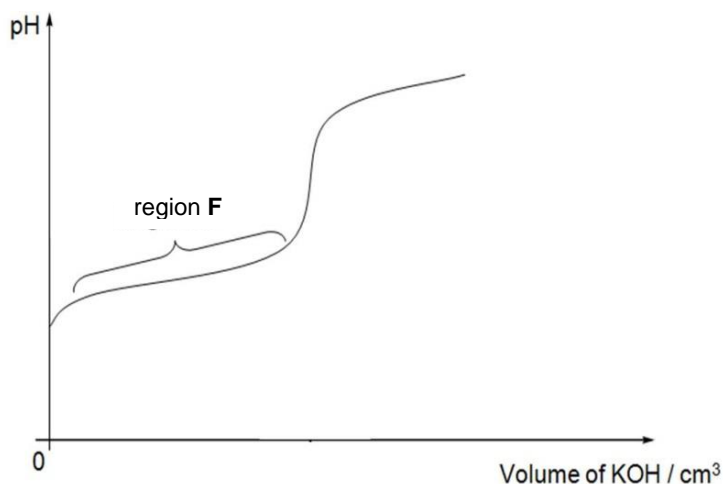
- (b) Explain how and why the lattice energies of magnesium oxide and magnesium chloride have different numerical values. [2]

Magnitude of the lattice energy of MgO is greater. [✓]

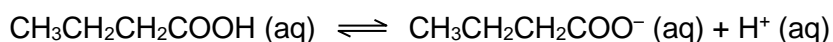
This is because **O²⁻ has a smaller ionic radius** [✓] and **has higher charge** [✓] than Cl⁻.

$$\text{Lattice Energy} \propto \frac{q_+ \times q_-}{(r_+ + r_-)} \quad [✓]$$

- (c) 25.0 cm³ of butanoic acid, CH₃CH₂CH₂COOH, was titrated against 0.20 mol dm⁻³ of KOH and the following titration curve was obtained.



- (i) The following equilibrium exists within a sample of butanoic acid.



Write a K_c expression for the above equilibrium.

[1]

$$K_c = \frac{[\text{H}^+][\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2^-]}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}]} \quad [1]$$

- (ii) Given that the initial pH of butanoic acid is 2.76, calculate the concentration of H⁺ ions present.

[1]

$$\begin{aligned} [\text{H}^+] &= 10^{-2.76} \text{ mol dm}^{-3} \\ &= 1.74 \times 10^{-3} \text{ mol dm}^{-3} \quad [1] \end{aligned}$$

- (iii) The butanoic acid used in this titration has a concentration of 0.196 mol dm⁻³.

Use your answer in (c)(i) and (c)(ii) to calculate the value of K_c .

[2]

	$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH (aq)} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^- \text{ (aq)} + \text{H}^+ \text{ (aq)}$		
I	0.196	–	–
C	$+1.7378 \times 10^{-3}$	-1.7378×10^{-3}	-1.7378×10^{-3}
E	<i>0.1943 (or ≈ 0.196 since weak acid dissociates partially)</i>	1.7378×10^{-3}	1.7378×10^{-3}

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

$$K_c = \frac{[\text{H}^+]^2}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}]}$$

$$K_c = \frac{[1.7378 \times 10^{-3}]^2}{0.196} \quad [1]$$

$$= 1.54 \times 10^{-5} \text{ mol dm}^{-3} \quad [1]$$

OR

$$K_c = \frac{[1.7378 \times 10^{-3}]^2}{0.1943} \quad [1]$$

$$= 1.55 \times 10^{-5} \text{ mol dm}^{-3} \quad [1]$$

- (iv) Region F contains a buffer solution made up of $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ and $\text{CH}_3\text{CH}_2\text{CH}_2\text{COO}^-$.

Explain what is meant by a buffer solution. [1]

A buffer solution is a solution in which its **pH does not change significantly** [✓] on **addition of a small amount of acid or base**[✓].

- (d) Reactions with nitrile ions are useful ways of increasing carbon chain of organic compounds.

Halogenoalkane and carbonyl compounds undergo two different reactions with nitrile ions. Using chlorobutane and butanal as example, write an equation for **each** one of the reaction, give the reagents and conditions and identify the type of reaction that occur. [6]

Chlorobutane



Reagents and conditions: ethanolic KCN, heat [1]

TOR: Substitution [1]

Butanal



Reagents and conditions: HCN, trace NaCN/NaOH [1] 10-20 °C

TOR: Addition [1]

- (e) Using the chlorides of aluminium and silicon, describe their reactions with water. Write equations where appropriate to support your answers. [3]

aluminium chloride

- Hydration [✓] occurs in large quantity of water.

$$\text{AlCl}_3(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow [\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{Cl}^-(\text{aq}) \quad [✓]$$
- Hydrated aluminium ion undergoes hydrolysis. [✓]

$$[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) \rightarrow [\text{Al}(\text{H}_2\text{O})_5\text{OH}]^{2+}(\text{aq}) + \text{H}^+(\text{aq}) \quad [✓]$$

silicon chloride

- Hydrolysis takes place. [✓]

$$\text{SiCl}_4(\text{l}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{SiO}_2(\text{s}) + 4\text{HCl}(\text{aq}) \quad [✓]$$

(State symbols are not required)

[Total: 20]