

# Anglo-Chinese Junior College

JC2 Preliminary Examinations  
Higher 2



A Methodist Institution  
(Founded 1856)

CANDIDATE  
NAME

**SUGGESTED SOLUTIONS**

FORM  
CLASS

TUTORIAL  
CLASS

INDEX  
NUMBER

## CHEMISTRY

Paper 2 Structured Questions

**9729/02**

27 August 2025  
2 hours

Candidates answer on the Question Paper.  
Additional Materials: Data Booklet

### READ THESE INSTRUCTIONS FIRST

Write your index number and name in the spaces at the top of this page.  
Write in dark blue or black pen.  
You may use an HB pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.  
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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

For Examiners' use only	
1	/ 7
2	/ 12
3	/ 10
4	/ 11
5	/ 11
6	/ 16
7	/ 8
<b>Total</b>	<b>/ 75</b>

This document consists of **19** printed pages.

- 1 When ammonium dichromate(VI) is added gradually to molten ammonium thiocyanate, Reinecke's salt is formed. It has the formula  $\text{NH}_4[\text{Cr}(\text{SCN})_x(\text{NH}_3)_y]$  and the following composition by mass: Cr 15.5 %; S 38.15 %; N 29.2 %.

(a) Calculate the values of x and y in the above formula.

Given Cr is 15.5% of total

Therefore  $M_r = 100 \times 52.0 / 15.5 = 335.5$

For S,  $38.15 / 100 \times 335.5 = 128$

$n\text{S} = 128 / 32.1 = 4$

$x = 4$

Therefore  $\text{NH}_4[\text{Cr}(\text{SCN})_4(\text{NH}_3)_y] = 335.5$

Therefore  $18 + 52 + 4 \times 58.1 + 17y = 335.5$

Therefore  $17y = 33.5$

$y = 2$

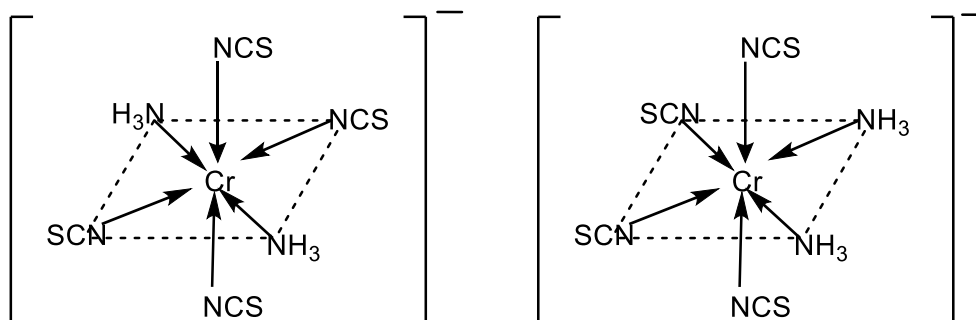
[2]

(b) Suggest a shape for the complex anion.

octahedral

[1]

(c) Draw two possible structures for the anion and state the type of isomerism it exhibits.



cis-trans isomerism

[2]

(d) Linkage isomerism is a form of constitutional isomerism in which certain coordination compounds have the same composition but differ in which atom of the ligand is bonded to the metal.

Examples of linkage isomers are violet-colored  $[(\text{NH}_3)_5\text{Co-SCN}]^{2+}$  (S being the donor atom) and the orange  $[(\text{NH}_3)_5\text{Co-NCS}]^{2+}$  (N being the donor atom).

Draw the dot-and-cross diagrams of  $\text{NCS}^-$  and  $\text{SCN}^-$ . In each diagram, underline the donor atom.



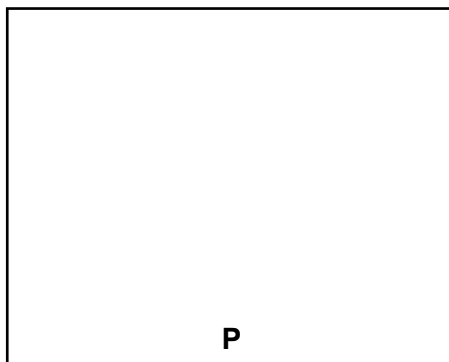
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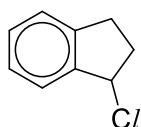
2 (a) **X** can be converted to **Y** via three steps as shown in the reaction scheme below.



- (i) There are two isomers possible for **P**. Draw the structure of **P** that will eventually lead on to **Y**.



[1]



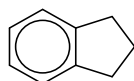
- (ii) Explain if your answer in (a)(i) is the major product.

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..... [2]

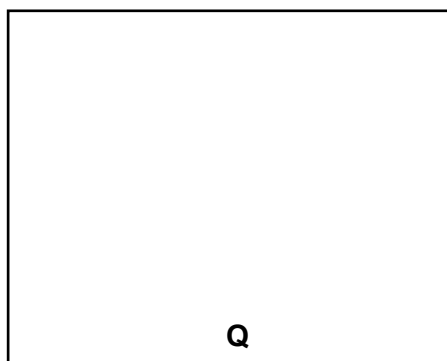
Yes



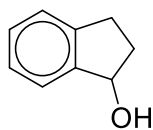
The above radical that leads to **P** is much more stable as it is benzylic in nature, where the unpaired electron can be delocalised into the benzene ring.

Can answer in terms of stability or probability

- (iii) Draw the structure of **Q**. State the reagents and conditions to synthesise **Q** from **P**.



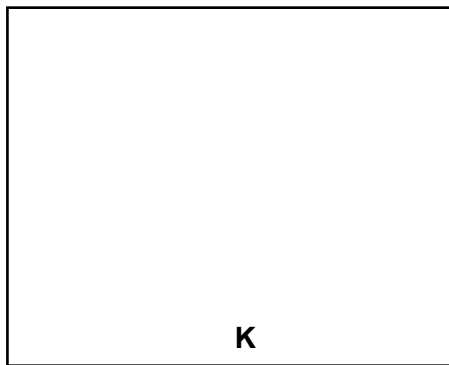
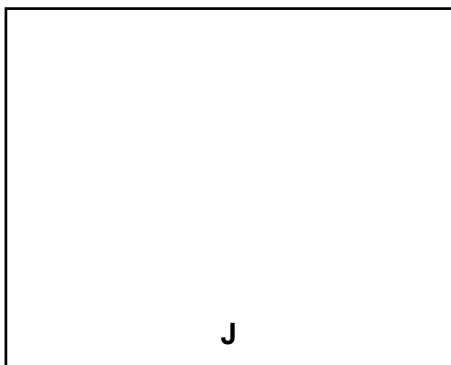
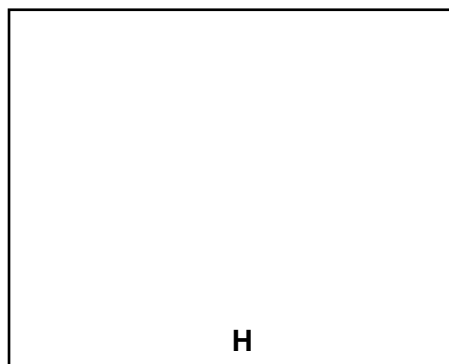
reagents & conditions .....[2]



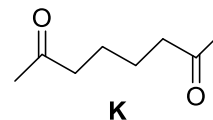
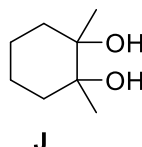
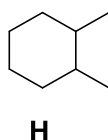
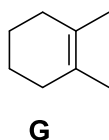
NaOH(aq) and heat

- (b) (i) **G** has the molecular formula,  $C_8H_{14}$ . Treating **G** with hydrogen in the presence of Ni, yields **H**, with the molecular formula,  $C_8H_{16}$ . Upon mild oxidation, **G** gives a tertiary diol, **J**. Upon vigorous oxidation **G** gives a diketone, **K**, which reacts with aqueous alkaline iodine to produce hexanedioic acid upon acidification.

Draw the structures of **G**, **H**, **J** and **K**.

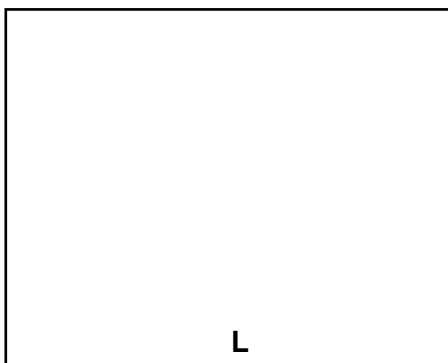


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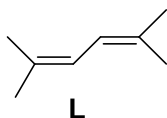


- (ii) **L** is an isomer of **G**. Treating **L** with hydrogen in the presence of Ni, yields **W**, with the molecular formula,  $C_8H_{18}$ . It undergoes vigorous oxidation to give propanone as the only organic product in addition to  $CO_2$ .


Deduce the structure of **L** with reasoning.

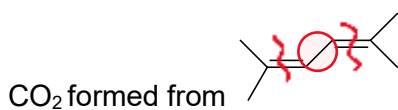


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 ..... [3]



**L**,  $C_8H_{14}$  with hydrogen in the presence of Ni  $\rightarrow$  reduction. Hence,  $2C=C$  present in **L**.

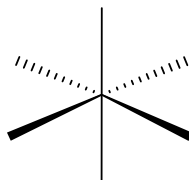
**L** undergoes vigorous oxidation to give propanone and  $CO_2 \rightarrow$  **L** has 2  structures.



[Total: 12]

- 3 (a)** At the time of its discovery by Scottish chemist Sir William Ramsay, the noble gas xenon was considered to be inert. It has since been discovered that xenon will react with strong oxidants. For example, xenon reacts with fluorine gas, forming a series of fluorides,  $XeF_2$ ,  $XeF_4$  and  $XeF_6$ .

- (i) The structure of xenon tetrafluoride has six electron pairs on xenon and therefore the structure is based on an octahedral configuration as shown below.



On Fig. 3.1, draw the two possible three-dimensional arrangements of the electron pairs on xenon in xenon tetrafluoride and tick the one observed, that gives the molecule its shape, explaining your choice with appropriate reasoning based on the principles of the VSEPR theory.

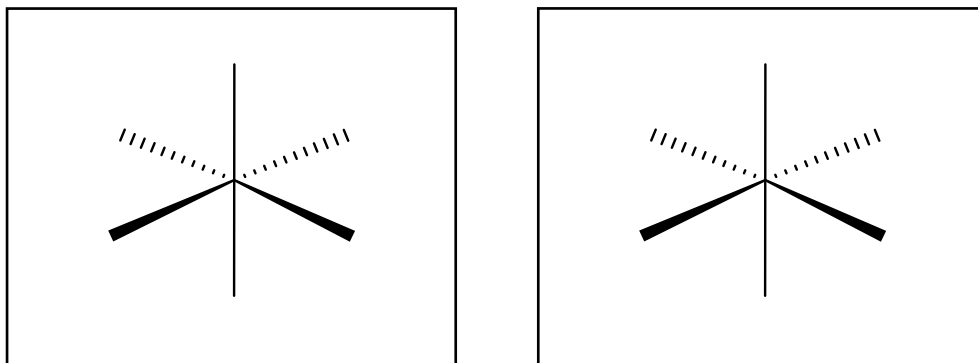
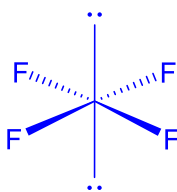
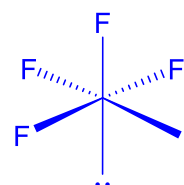


Fig. 3.1

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 .....[2]

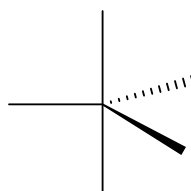


Adopted Arrangement



The **square planar arrangement** is adopted to maximise the separation between the **two lone pairs** by placing them on opposite sides of **plane with the maximum angular separation of 180°** so as to minimise the repulsion due to them resulting in a more stable arrangement.

- (ii) The structure of xenon difluoride has five electron pairs on xenon and therefore the structure is based on a trigonal bipyramidal configuration as shown below.



On Fig. 3.2, draw the three possible three-dimensional arrangements of the five electron pairs on xenon in xenon difluoride and tick the one observed, that gives the molecule its shape, explaining your choice with appropriate reasoning based on the principles of the VSEPR theory.

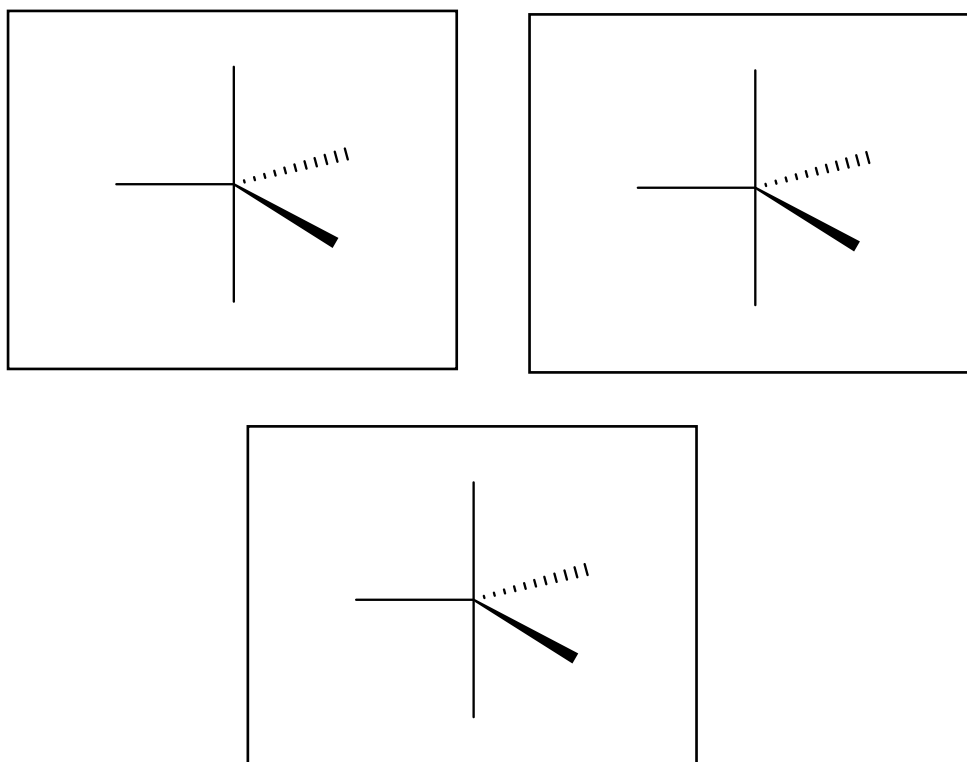


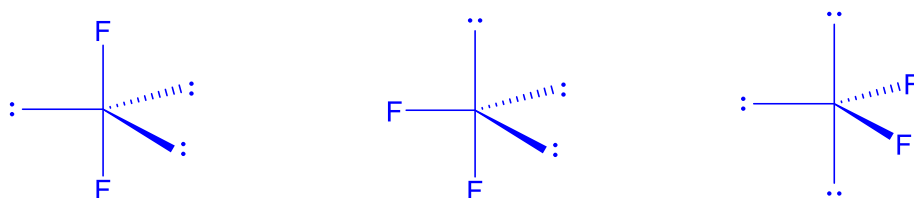
Fig. 3.2

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.....

.....

..... [3]



Adopted Arrangement

The **linear arrangement** is adopted to maximise the separation between the three lone pairs by placing them in the **equatorial plane with the maximum angular separation of  $120^\circ$**  so as to minimise the repulsion due to them resulting in a more stable arrangement.

- (b) The kinetics of the formation of xenon difluoride from xenon and fluorine has been studied under various conditions. At 120 °C, the rate equation for the formation of XeF<sub>2</sub> is found to be first order with respect to Xe and zero order with respect to F<sub>2</sub>.

- (i) Write the rate equation for the formation of XeF<sub>2</sub> and suggest the units for the rate constant.

$$\text{Rate} = k [\text{Xe}] \text{ or Rate} = k P(\text{Xe})$$

$$k = \text{s}^{-1} \text{ or min}^{-1}$$

[2]

- (ii) The Arrhenius equation describes the relationship between the rate constant and temperature.

$$k = Ae^{-\frac{E_a}{RT}}$$

The uncatalysed reaction between xenon and fluorine to form XeF<sub>2</sub> at a temperature  $T$  has a rate constant  $k$ , with collision frequency factor  $A$  and activation energy,  $E_a$ .

When a nickel difluoride catalyst is added to the reaction mixture, the rate constant changes to  $k_{\text{cat}}$ , with a different collision frequency  $A_{\text{cat}}$  and a different activation energy,  $E_{\text{cat}}$ . It is found that the catalysed reaction is 13 times faster at 120 °C and 23 times faster at 100 °C. The change in activation energy,  $\Delta E = E_a - E_{\text{cat}}$ .

Assuming that the collision frequency factors do not depend on temperature, write an expression for the ratio  $k_{\text{cat}}/k$  in terms of  $T$ ,  $\Delta E$  and any constants.

$$\frac{k_{\text{cat}}}{k} = \frac{A_{\text{cat}} e^{-\frac{E_{\text{cat}}}{RT}}}{A e^{-\frac{E_a}{RT}}}$$

$$\frac{k_{\text{cat}}}{k} = \frac{A_{\text{cat}}}{A} e^{\frac{\Delta E}{RT}}$$

[1]

- (iii) Hence, using the ratio in (b)(ii) and the information given below, calculate the change in activation energy,  $\Delta E$ , in kJ mol<sup>-1</sup>, when the temperature increased from 373 K to 393 K. Given that  $\frac{k_{\text{cat}}(393 \text{ K})}{k(393 \text{ K})} = 13$  and  $\frac{k_{\text{cat}}(373 \text{ K})}{k(373 \text{ K})} = 23$ .

$$\ln \frac{k_{\text{cat}}}{k} = \frac{\Delta E}{RT} + \ln \frac{A_{\text{cat}}}{A}$$

$$\ln 13 = \frac{\Delta E}{393R} + \ln \frac{A_{\text{cat}}}{A} \dots (1)$$

$$\ln 23 = \frac{\Delta E}{373R} + \ln \frac{A_{\text{cat}}}{A} \dots (2)$$

$$(1) - (2)$$

$$\ln 13 - \ln 23 = \frac{\Delta E}{393R} - \frac{\Delta E}{373R}$$

$$\ln \frac{13}{23} = \frac{\Delta E}{R} \left( \frac{1}{393} - \frac{1}{373} \right)$$

$$\Delta E = + 34.7 \text{ kJ mol}^{-1}$$

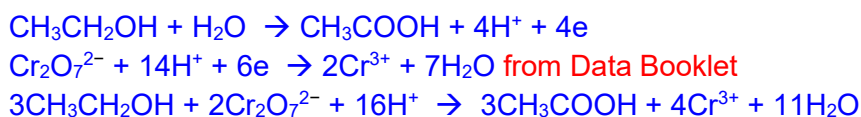
[2]

[Total: 10]

- 4 (a) Ethanol is dissolved in blood and distributed to organs in the body. As a volatile compound, ethanol can be vaporised quite easily. In the lungs, ethanol can change its phase from liquid to gaseous and it can be exhaled with air. Since the concentration of alcohol vapor in lungs is directly related to its concentration in blood, blood alcohol concentration can be measured using a device called a breathalyser.

In one of the older versions of breathalyser, a suspect breathes into the device and exhaled air is allowed to pass through a solution of potassium dichromate which oxidises ethanol to acetic acid. This oxidation is accompanied by a colour change from orange to green and a detector records the change in colour intensity, which is used to calculate the percentage of alcohol in breath. When the oxidation of alcohol by potassium dichromate is carried out in an electrochemical cell, either the electrical current generated by this reaction or the change in the electromotive force can be measured and used for the estimation of alcohol content of blood.

- (i) Write a balanced ionic equation for the oxidation of ethanol by the dichromate ion in acidic solution.



[2]

- (ii) If the standard potential for the reduction of  $\text{Cr}_2\text{O}_7^{2-}$  to  $\text{Cr}^{3+}$  is 1.330 V and that for the reduction of ethanoic acid to ethanol is 0.058 V, calculate the standard electromotive force,  $E^\ominus$ , for the overall reaction.

$$\text{EMF} = 1.330 - 0.058 = +1.272 \text{ V or } +1.27 \text{ V}$$

[1]

- (iii) When a suspect breathes into a breathalyser which is designed as an electrochemical cell, the oxidation of the ethanol generates a current of 0.10 A for 60 s. Calculate the mass of alcohol in the exhaled breath.

$$\begin{aligned}Q &= It = 0.1 \times 60 = 6.0 \text{ C} \\ n(\text{e}^-) \text{ transferred from 3 moles of ethanol to 2 moles of } \text{Cr}_2\text{O}_7^{2-} &= 12 \\ \text{Hence, } 3\text{CH}_3\text{CH}_2\text{OH} &\equiv 12\text{F}; \text{CH}_3\text{CH}_2\text{OH} \equiv 4\text{F} \\ n(\text{CH}_3\text{CH}_2\text{OH}) &= 6 / [4(96500)] = 1.55 \times 10^{-5} \text{ mol} \\ m(\text{CH}_3\text{CH}_2\text{OH}) &= 1.55 \times 10^{-5} \times 46 = 7.15 \times 10^{-4} \text{ g}\end{aligned}$$

[3]

- (iv) In calculating the alcohol content in blood from the mass of alcohol in a breath, the "2100:1 partition ratio" needs to be considered. The ratio states that each milliliter of blood has 2100 times the mass of ethanol as each milliliter of expired air.

If the volume of expired air described in (a)(iii) is  $60.0 \text{ cm}^3$ , calculate the mass of alcohol per  $\text{cm}^3$  of blood.

Hence,  $7.15 \times 10^{-4} \text{ g}$  of ethanol from  $60 \text{ cm}^3$  of expired air means  $1.19 \times 10^{-5} \text{ g}$  per  $\text{cm}^3$  of expired air.

Thus, mass of alcohol per  $\text{cm}^3$  of blood =  $2100 \times 1.19 \times 10^{-5} = 0.0250 \text{ g}$

[1]

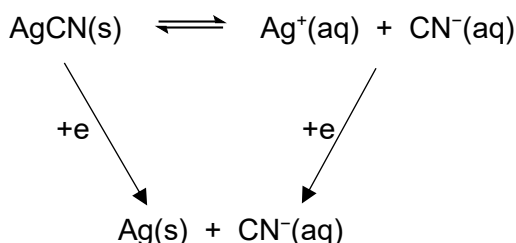
- (b) The value of the solubility product is related to the Gibbs free energy change,  $\Delta G^\circ$ , in  $\text{J mol}^{-1}$ , by the mathematical expression given below.

$$K_{\text{sp}} = 10^{-\left(\frac{\Delta G^\circ}{2.3RT}\right)}$$

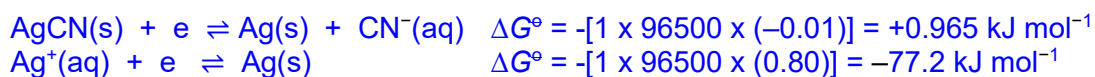
Using the expression above and the cycle in Fig. 4.1 that involves the standard reduction potentials in Table 4.1, calculate the numerical value of the solubility product,  $K_{\text{sp}}$ , of AgCN at 25 °C.

**Table 4.1**

	$E^\circ / \text{V}$
$\text{AgCN(s)} + \text{e} \rightleftharpoons \text{Ag(s)} + \text{CN}^-(\text{aq})$	-0.01
$\text{Ag}^+(\text{aq}) + \text{e} \rightleftharpoons \text{Ag(s)}$	+0.80



**Fig. 4.1**



Hence,



Thus,

$$\begin{aligned} K_{\text{sp}} &= 10^{-\frac{78200}{2.3 \times 8.31 \times 298}} \\ &= 1.86 \times 10^{-14} \end{aligned}$$

[4]

[Total: 11]

- 5 The Haber process is used to make ammonia, the main use of which is in fertilisers that are often sprayed on crops. Around 1% of the entire global energy supply is used in the Haber process and so research groups are looking to find more sustainable methods of producing ammonia.

One recently published approach to making ammonia uses the following three-step method.

Step 1 Electrolysis of molten lithium hydroxide at 750 K to form lithium metal.



Step 2 Reaction of lithium metal with nitrogen to form lithium nitride.

Step 3 Reaction of lithium nitride with water to re-form lithium hydroxide and ammonia.

Thus, the lithium hydroxide formed in Step 3 can be re-used in Step 1 and the process can be repeated.

The relevant thermochemical data are provided in Table 5.1.

**Table 5.1**

At 750 K	LiOH	Li	H <sub>2</sub> O	O <sub>2</sub>
$\Delta H_f / \text{kJ mol}^{-1}$	-446.0	+15.0	-268.0	+15.8
$\Delta S_r$ for step 1 at 750 K is $+427 \text{ J K}^{-1} \text{ mol}^{-1}$				

- (a) Explain why the enthalpy changes of formation of the elements Li and O<sub>2</sub> are not zero at 750 K.

The enthalpy of formation of an element in its standard state is zero because no energy is required to form it from itself.

OR

Enthalpy is a thermodynamic property that depends on temperature. As the temperature increases, because the element's energy content has changed due to the temperature change and hence the enthalpy of a substance (including elements) also increases.

.....  
 .....  
 .....[1]

- (b) Calculate  $\Delta H_r$  and hence  $\Delta G_r$  for Step 1 at 750 K.

$$\Delta H_r = [4(+15) + 2(-268) + (+15.8)] - 4(-446) = +1320 \text{ kJ mol}^{-1}$$

$$\Delta G_r = 1320 - 750(427 \times 10^{-3}) = +1004 \text{ kJ mol}^{-1} \approx +1000 \text{ kJ mol}^{-1}$$

[2]

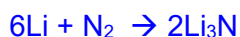
- (c) Given that the electrolysis will only proceed at an appreciable rate when the applied potential exceeds the electrochemical cell potential by 0.60 V, calculate the minimum potential that should be applied in Step 1.

$$E_{\text{cell}} = -\Delta G_r / nF = -[1004 \times 10^3 / (4 \times 96500)] = -2.60 \text{ V}$$

$$\text{Hence, } E_{\text{applied}} = |E_{\text{cell}}| + 0.60 = 2.60 + 0.60 = +3.20 \text{ V}$$

[1]

- (d) Write the chemical equations for Step 2 and Step 3. Hence calculate the stoichiometric ratio between the lithium produced in Step 1 and the ammonia produced in Step 3.



Hence, Li : NH<sub>3</sub> is 3 : 1

[2]

- (e) In a small-scale experiment, the researchers applied a current of 0.200 A for 1000 seconds. The yield of lithium production in this process was 88.5% in Step 1. The yield of Steps 2 and 3 can be assumed to be 100%.

Calculate the mass of lithium generated in Step 1.

$$Q = 0.2 \times 1000 = 200 \text{ C}$$

$$\text{Amount of e} = 200 / 9.65 \times 10^4 = 0.00207 \text{ mol}$$

$$\text{Amount of Li} = 88.5\% \times 0.00207 = 0.00183 \text{ mol}$$

$$\text{Mass of Li} = 0.00183 \times 6.9 = 0.0126 \text{ g}$$

[2]

- (f) Calculate the volume of ammonia produced, in  $\text{cm}^3$ , at room temperature and pressure.

$$\text{Amount of NH}_3 = \text{amount of Li} \times 1/3 = 0.00183 \times 1/3 = 6.11 \times 10^{-4} \text{ mol}$$

$$\text{Volume of NH}_3 = 6.11 \times 10^{-4} \times 24000 = 14.7 \text{ cm}^3$$

[1]

- (g) A potential application of this approach is to use renewable energy sources as the source of electricity for the electrolysis and to produce ammonia at a farm where it can be used straight away. The average size of a UK farm is 130 acres, and a farm requires 0.0770 tonnes of ammonia per acre annually.

If the lithium hydroxide was not recycled at the end of the process, calculate the total mass of lithium, in tonnes, that would have to be produced to generate the required mass of ammonia for a year. [1 tonne = 1000kg]

$$\text{Mass of NH}_3 \text{ required} = 130 \times 0.077 = 10.01 \text{ tonnes}$$

$$\text{Amount of NH}_3 = 10.01 \times 10^6 / 17.0 = 5.888 \times 10^5 \text{ mol}$$

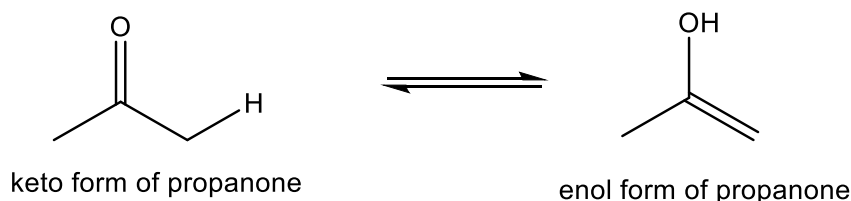
$$\text{Amount of Li} = 5.888 \times 10^5 \times 3 = 1.766 \times 10^6 \text{ mol}$$

$$\text{Mass of Li} = 1.766 \times 10^6 \times 6.9 = 1.22 \times 10^7 \text{ g} = 12.2 \text{ tonnes}$$

[2]

[Total: 11]

- 6 (a) Propanone can exist in **keto** and **enol** forms.



The enol form is derived from the keto form by transferring a hydrogen atom to the oxygen atom.

At room temperature and pressure, the keto form is the predominant form at equilibrium suggesting that the keto form is the more stable form.

Using bond energy data from the *Data Booklet*, calculate the enthalpy change for the above interconversion, and hence explain why the equilibrium lies heavily towards the keto form.

$$\text{Bonds broken} = 740 + 410 + 350 = +1500 \text{ kJ mol}^{-1}$$

$$\text{Bonds formed} = 460 + 610 + 360 = +1430 \text{ kJ mol}^{-1}$$

$$\Delta H_r = 1500 - 1430 = +70 \text{ kJ mol}^{-1}$$

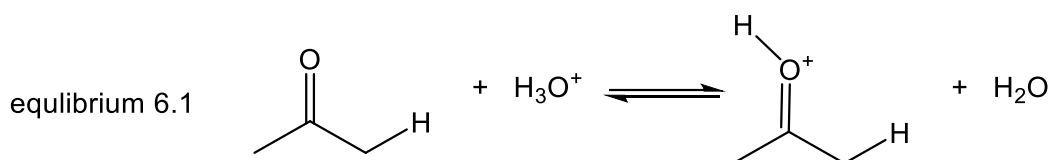
Assuming  $\Delta S \approx 0$ , hence  $\Delta G \approx \Delta H$

Since  $\Delta G$  is positive,  $K < 1$ , hence equilibrium lies to the left.

[2]

- (b) The conversion of keto form to the enol form of propanone can be catalysed by an acid.

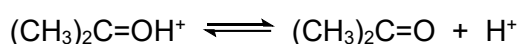
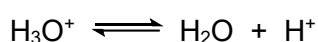
The first equilibrium step of the mechanism involves protonation of oxygen atom of the C=O bond as given below.



The  $K_c$  expression for equilibrium 6.1 is given as follows.

$$K_c = \frac{\left[ \text{CH}_3\text{C}(\text{OH}^+)\text{CH}_2\text{CH}_3 \right] \left[ \text{H}_2\text{O} \right]}{\left[ \text{CH}_3\text{C}(=\text{O})\text{CH}_2\text{CH}_3 \right] \left[ \text{H}_3\text{O}^+ \right]}$$

- (i) Write the  $K_a$  expressions for the acid dissociation of  $\text{H}_3\text{O}^+$  and  $(\text{CH}_3)_2\text{C}=\text{OH}^+$  using their respective equilibrium equations given below.



$$K_a(\text{H}_3\text{O}^+) = [\text{H}^+] [\text{H}_2\text{O}] / [\text{H}_3\text{O}^+]$$

$$K_a((\text{CH}_3)_2\text{C}=\text{OH}^+) = [\text{H}^+] [(\text{CH}_3)_2\text{C}=\text{O}] / [(\text{CH}_3)_2\text{C}=\text{OH}^+]$$

[2]

- (ii) Hence, express  $K_c$  for equilibrium 6.1 in terms of the two  $K_a$  expressions in (b)(i).

$$K_c = K_a(\text{H}_3\text{O}^+) / K_a(\text{CH}_3)_2\text{C}=\text{OH}^+$$

[1]

- (iii) Given that the  $\text{p}K_a$  of  $\text{H}_3\text{O}^+$  is  $-1.7$  and the  $\text{p}K_a$  of  $(\text{CH}_3)_2\text{C}=\text{OH}^+$  is  $-7.2$ , calculate a value of  $K_c$  for equilibrium 6.1.

$$K_c = (10^{1.7} / 10^{7.2}) = 10^{-5.5} = 3.16 \times 10^{-6}$$

[1]

- (iv) Given that  $\Delta G^\circ = -RT \ln K$ , calculate the Gibbs Free energy change, in  $\text{kJ mol}^{-1}$ , for equilibrium 6.1.

$$\Delta G^\circ = -8.31 \times 298 \times \ln(10^{-5.5}) = +31361 \text{ J mol}^{-1} = +31.4 \text{ kJ mol}^{-1}$$

[2]

- (v) Based on your answers to the values of  $K_c$  and  $\Delta G^\circ$ , comment on the relative stability of the keto form versus the enol form.

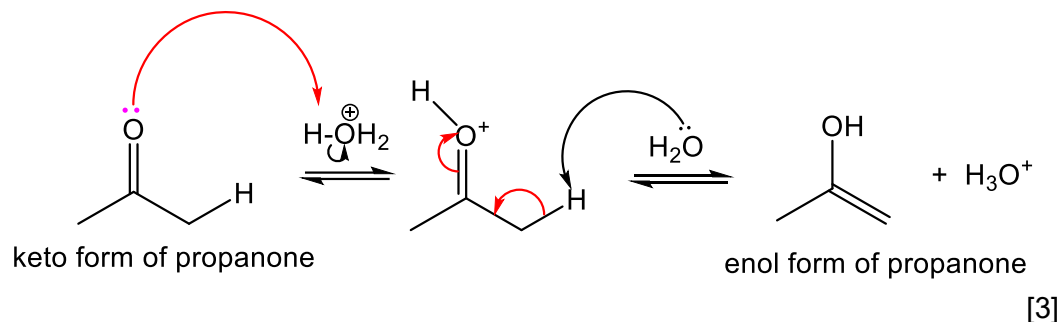
.....  
 .....  
 .....  
 .....[2]

$K_c$  value is very small indicating that the keto form is predominant in the overall equilibrium.

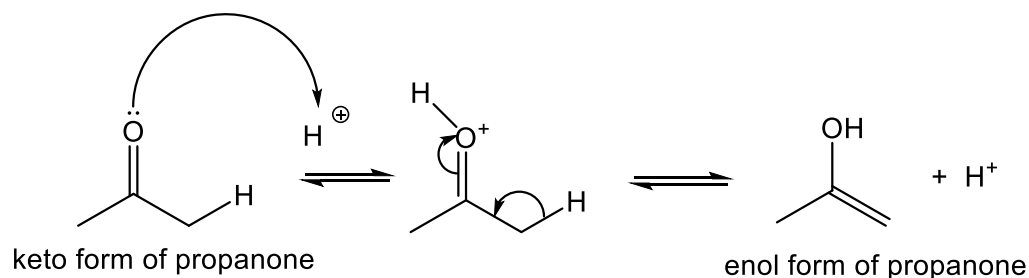
Also  $\Delta G^\circ$  is very positive indicating that the enol form is not energetically favourable.

- (vi) Tautomerisation is a type of isomerisation where two molecules with the same molecular formula but different connectivity (constitutional isomers) rapidly interconvert in a solution or equilibrium. The most well-known example is the interconversion between a keto (containing a carbonyl group) and an enol (containing an alcohol and a double bond) form of a molecule.

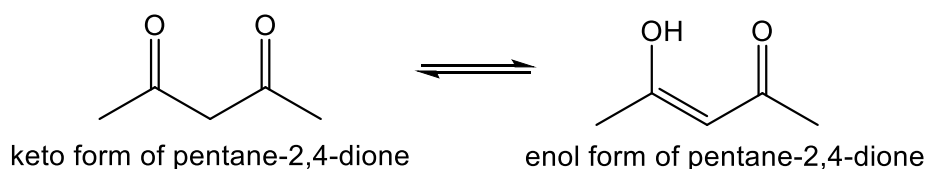
Outline the mechanism for the tautomerisation of propanone to its enol form catalysed by acid, showing all curly arrows, lone pairs and charges.



OR



- (c) The enol form of pentane-2,4-dione is unusually stable and hence the equilibrium lies more towards the enol form.



It is also observed that the percentage of the enol form increases as the solvent used is changed from a polar solvent to a non-polar solvent.

- (i) By comparing the structures of the enol form with the keto form, suggest a reason for the increased stability of the enol form in pentane-2,4-dione.

.....[1]

Enol form is stabilised by intra-molecular hydrogen bonding OR

Conjugation of the  $\text{C=O}$  bond with the  $\text{C=C}$  bond also contributes to the stability.

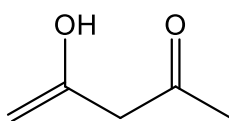
- (ii) Explain why the keto form is favoured with polar solvents.

.....  
 .....  
 .....  
 .....[1]

Keto form participates in dipole-dipole interaction or hydrogen bond formation with polar solvents which suppresses intra-molecular hydrogen bonding.

In a non-polar solvent, the enol form becomes more stable through intramolecular hydrogen bonding.

- (iii) Another enol form of pentane-2,4-dione, as shown below can also be drawn.



another enol form of pentane-2,4-dione

Explain if this enol form is likely to be formed as well.

.....  
 .....[1]

No / less likely

No conjugation between the C=O bond with the C=C bond.

[Total: 16]

- 7 (a) Solid magnesium hydroxide decomposes when heated to form two products. One of the products formed is steam.

- (i) Construct a balanced equation, with state symbols, for the above reaction.

.....[1]



- (ii) The variation in thermal stability of Group 2 hydroxides is similar to that of Group 2 carbonates.

Explain whether magnesium hydroxide is more or less thermally stable than barium hydroxide.

.....  
 .....  
 .....  
 .....  
 .....  
 .....  
 .....[3]

Magnesium hydroxide is less thermally stable than barium hydroxide.

- ionic radius:  $\text{Mg}^{2+} < \text{Ba}^{2+}$
  - charge density:  $\text{Mg}^{2+} > \text{Ba}^{2+}$
  - polarising power:  $\text{Mg}^{2+} > \text{Ba}^{2+}$
  - extent of polarisation/distortion of  $\text{OH}^-$  electron cloud:  $\text{Mg(OH)}_2 > \text{Ba(OH)}_2$
  - extent of weakening of covalent bond (O-H) within the  $\text{OH}^-$  anion:  
 $\text{Mg(OH)}_2 > \text{Ba(OH)}_2$
- $\therefore$  thermal stability:  $\text{Mg(OH)}_2 < \text{Ba(OH)}_2$

- (b) (i) Using relevant data from the *Data Booklet*, comment on the thermal stability of hydrogen bromide and hydrogen iodide.

.....  
 .....  
 .....[1]

Bond energy of H-Br ( $366 \text{ kJ mol}^{-1}$ ) is more than bond energy of H-I ( $299 \text{ kJ mol}^{-1}$ ).

HI has a lower thermal stability as less energy is required to overcome the weaker covalent bond in H-I.

- (ii) Identify a transition metal cation that can be used to differentiate the oxidising strengths of  $\text{Br}_2$  and  $\text{I}_2$ . Explain your answer with appropriate workings.

The transition metal cation is  $\text{Fe}^{2+}$ .

From Data Booklet	$E^\ominus / \text{V}$
$\text{Br}_2 + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	+1.07
$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$	+0.54
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77



$\text{Br}_2$  can oxidise  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  since the reaction is spontaneous.



$\text{I}_2$  cannot oxidise  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  since the reaction is non-spontaneous.

[3]

[Total: 8]