

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

CANDIDATE  
NAME

CLASS

INDEX NUMBER

## CHEMISTRY

**8872/02**

Paper 2 Structured and Free Response Questions

**2 Sept 2015**

**2 hours**

### Section A: Structured

Candidates answer Section A on the Question Paper

### Section B: Free Response

Additional Materials: Writing Paper  
*Data Booklet*

### READ THESE INSTRUCTIONS FIRST

Write your index number, name and civics group on all the work you hand in.

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 space provided.

#### **Section B: Free Response Questions (40m)**

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

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.

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

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

For Examiner's Use	
Section A	
1	12
2	8
3	10
4	10
Section B	
	20
	20
Significant figures	
Handwriting	
Total	80

This document consists of **13** printed pages and **1** blank page.



## Section A

Answer **ALL** questions on the spaces provided.

- 1 Chromium is a transition metal. Chromium compounds are highly valued as pigments for their vivid green, yellow, red and orange colours.

(a) The element chromium has four main naturally occurring isotopes.

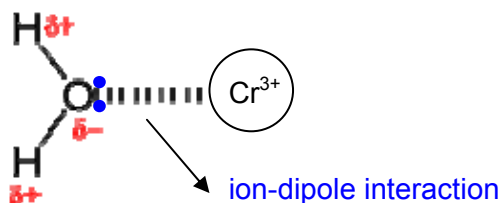
isotope	relative abundance / %
$^{50}\text{Cr}$	4.33
$^{52}\text{Cr}$	83.8
$^{53}\text{Cr}$	9.50
$^{54}\text{Cr}$	2.37

Use the relative abundance data to calculate the relative atomic mass of Cr, showing your working clearly.

$$A_r = \frac{50(4.35) + 52(83.7) + 53(9.5) + 54(2.38)}{4.35 + 83.7 + 9.50 + 2.38} = 52.0$$

[1]

- (b) Chromium(III) chloride dissolves in water to form a green solution. Draw a labelled diagram to illustrate the interaction between a  $\text{Cr}^{3+}$  ion and a water molecule.



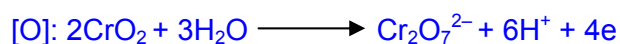
[2]

- (c) Chromium(IV) oxide,  $\text{CrO}_2$  is a black solid that disproportionates into a mixture of  $\text{Cr}^{3+}$  and  $\text{Cr}_2\text{O}_7^{2-}$  in acidic solutions.

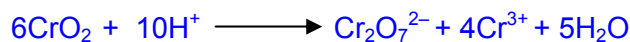
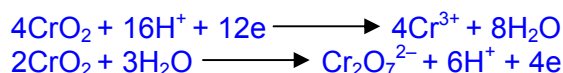
The half equation for the reduction of  $\text{CrO}_2$  to  $\text{Cr}^{3+}$  is as follows:  
 $\text{CrO}_2 + 4\text{H}^+ + \text{e} \longrightarrow \text{Cr}^{3+} + 2\text{H}_2\text{O}$

To determine the percentage purity of a sample of chromium(IV) oxide, a student dissolves 1.5 g of impure sample in  $20\text{ cm}^3$  of sulfuric acid and make up the total volume to  $100\text{ cm}^3$  with distilled water. He then found that  $25\text{ cm}^3$  of the resulting solution, containing  $\text{Cr}_2\text{O}_7^{2-}$  ions, required  $16.00\text{ cm}^3$  of  $0.200\text{ mol dm}^{-3}$  of iron(II) sulfate solution for complete reaction.

- (i) Construct the half equation for the oxidation of  $\text{CrO}_2$  to  $\text{Cr}_2\text{O}_7^{2-}$ .



- (ii) Hence, construct the overall equation for the disproportionation of  $\text{CrO}_2$  to  $\text{Cr}^{3+}$  and  $\text{Cr}_2\text{O}_7^{2-}$ .



- (iii) Calculate the amount of  $\text{Fe}^{2+}$  used in the reaction.

$$\text{No. of moles of } \text{Fe}^{2+} = \frac{16.00}{1000} \times 0.200 = 0.0032$$

- (iv) Hence, calculate the amount of  $\text{Cr}_2\text{O}_7^{2-}$  present in **100 cm<sup>3</sup>** of the solution.

$$\text{Fe}^{2+} : \text{Cr}_2\text{O}_7^{2-} = 6 : 1$$

$$\text{No. of moles of } \text{Cr}_2\text{O}_7^{2-} \text{ in } 25.0 \text{ cm}^3 = \frac{1}{6} \times 0.0032 = 5.333 \times 10^{-4}$$

$$\text{No. of moles of } \text{Cr}_2\text{O}_7^{2-} \text{ in } 100 \text{ cm}^3 = \frac{100}{25.0} \times 5.333 \times 10^{-4} = 2.13 \times 10^{-3}$$

- (v) Calculate the mass of  $\text{CrO}_2$  present in the sample and hence, the percentage purity of the sample.

[You may assume a mole ratio of  $\text{CrO}_2 : \text{Cr}_2\text{O}_7^{2-}$  of 6:1 if you were unable to derive the overall equation in (ii).]

$$\text{No. of moles of } \text{CrO}_2 = 6 \times 2.133 \times 10^{-3} = 0.0128$$

$$\text{Mass of } \text{CrO}_2 = 0.0128 \times 84.0 = 1.075 \text{ g}$$

$$\text{Percentage purity of sample} = \frac{1.075}{1.5} \times 100\% = 71.7\%$$

[7]

- (d) Beams of charged particles are deflected by an electric field. If the particles are all travelling at the same speed, through an electric field of constant strength, the angle of deflection is proportional to their charge/mass ratio.

In a particular experimental set-up, protons are deflected through an angle of  $+15^\circ$ .

- (i) Assuming an identical set of experimental conditions, by what angle will  $\text{Cr}^{3+}$  be deflected?

$$\frac{c}{m} \text{ of } {}^1\text{H}^+ = 1$$

$$k = 15$$

$$\frac{c}{m} \text{ of } {}^{52}\text{Cr}^{3+} = \frac{3}{52}$$

$$\text{Angle of deflection} = +15\left(\frac{3}{52}\right) = +0.866^\circ$$

- (ii) Under identical conditions, a beam of particles, **A**, each having 12 times the mass of a proton, was deflected by an angle of  $+5^\circ$ .

Suggest the overall charge on a particle of A.

$$5 = 15\left(\frac{\text{charge}}{12}\right)$$

$$\text{charge} = +4$$

[2]

[Total: 12]

- 2 (a) The table below shows the lattice energies for the sodium halides and magnesium oxide.

compound	lattice energy / kJ mol <sup>-1</sup>
NaCl	-781
NaBr	-743
NaI	-699
MgO	-3933

- (i) Define the term *lattice energy*.

Lattice energy is the **enthalpy change** when **1 mole of solid ionic compound** is formed from its **separate gaseous ions at standard conditions of 1 atm and 298 K**.

- (ii) By quoting appropriate data from the *Data Booklet*, explain why the lattice energy of MgO is considerably larger than those of the sodium halides.

Ion	Na <sup>+</sup>	Mg <sup>2+</sup>
ionic radius /nm	0.095	0.065

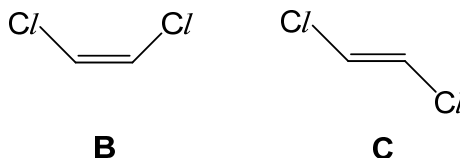
**Both Mg<sup>2+</sup> ions and O<sup>2-</sup> ions have a higher charge than Na<sup>+</sup> ions and halide ions.** In addition, **the ionic radii of Mg<sup>2+</sup> and O<sup>2-</sup> are smaller than**

**that of Na<sup>+</sup> and the halide ions** Since  $L.E. \propto \frac{q^+ q^-}{r^+ + r^-}$ , thus magnitude of lattice energy of MgO is considerably larger than those of sodium halides.

[4]

- (b) The 1,2-dichloroethene molecule can exist in either of the following forms, B or C as shown:

5



By considering the polarity of the molecule, predict which form, **B** or **C**, has a lower boiling point. Explain your answer.

**C has lower boiling point than B.**

This is because **B** is polar covalent simple molecule as the dipole moments do not cancel out each other and has stronger intermolecular permanent dipole - permanent dipole interactions than **C** that has intermolecular temporary dipole - induced dipole interactions.

[2]

(c) Account for the following observation:

At around 30 °C, the relative molecular mass of hydrogen fluoride appears to be 40.0 and above 60 °C, it is about 20.0.

At low temperatures, hydrogen fluoride exists in the form of dimers as there are strong/significant intermolecular hydrogen bonds.

At higher temperature, the intermolecular hydrogen bonds are overcome and thus, hydrogen fluoride appears as single HF molecules.

[2]

[Total: 8]

3 (a) Using blood as an example, explain what is meant by an *acidic buffer solution*.

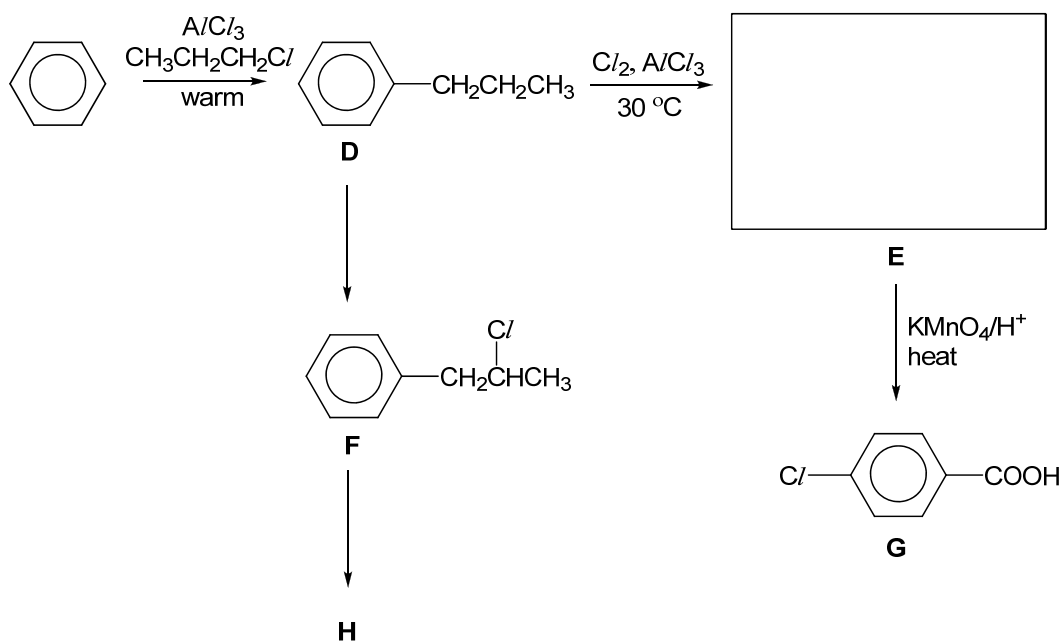
[5]

An *acidic buffer solution* (with pH between 4 and 7) is one that contains a weak acid and the salt of that acid, it is a solution in which the pH does not change significantly on the addition of a small amount of acid or base.

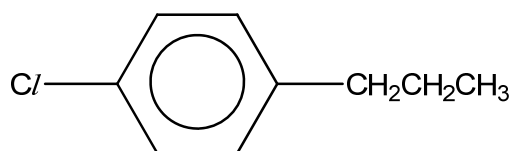
An example is the buffer system  $\text{H}_2\text{CO}_3 / \text{HCO}_3^-$  found in the blood, in this case carbonic acid is the weak acid and hydrogen carbonate is the conjugate salt of the weak acid.

When a small amount of acid is added, it will be removed by the large concentration of  $\text{HCO}_3^-$  and when a small amount of base is added, it is removed by the large concentration of  $\text{H}_2\text{CO}_3$ .

(b) Benzene is used as the starting reagent for the production of many aromatic compounds shown below. Long-term exposure to high levels of benzene in the air can cause leukaemia, cancer of the blood-forming organs.



- (i) Draw the structure of **E** in the space given above.



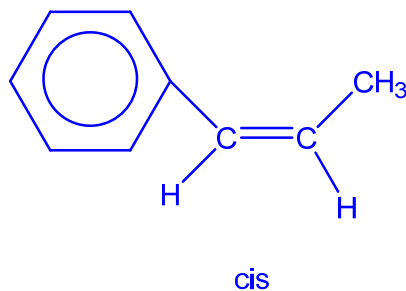
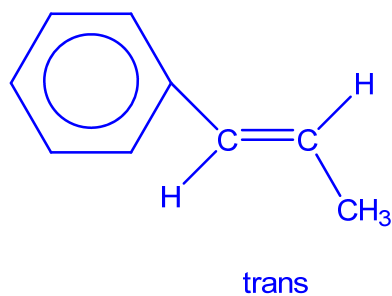
- (ii) State the reagents and conditions needed to convert **D** to **F**.

Limited  $\text{Cl}_2$  (g), UV light

- (iii) **F** can react with a suitable reagent to give **H**,  $\text{C}_9\text{H}_{10}$ , which exists as a pair of geometric isomers. Suggest the reagents and conditions needed to form **H**.

Ethanolic  $\text{NaOH}$ , heat with reflux

- (iv) Draw and label the pair of geometric isomers of **H**.



[5]

[Total: 10]

- 4 1-Bromobutane may be made by reacting together butan-1-ol, sodium bromide and concentrated sulfuric acid in the presence of water.  
Data about these four compounds and 1-bromobutane are given in the table.

compound	melting point / °C	boiling point / °C	density / g cm <sup>-3</sup>	<i>M<sub>r</sub></i>	$\Delta H_f / \text{kJ mol}^{-1}$	$\Delta H_c / \text{kJ mol}^{-1}$	solubility in water
1-bromo butane	-113	102	1.35	137	-143.8	-2676	insoluble
butan-1-ol	-90	118	0.81	74	-327.4	-2716	moderate
sodium bromide	747	1390	3.20	103	-143.9	-	soluble
concentrated sulfuric acid	10	330	1.84	98	-814.0	-	soluble
water	0	100	1.00	18	-241.8	-	-

- (a) A flask containing 1-bromobutane was accidentally mixed with water. The mixture can be separated using a separatory funnel.

In the separation, a chemist poured the mixture into a separatory funnel. He then capped and shook the mixture well, before leaving it to stand for a few minutes. After a while, two layers are formed, and pure 1-bromobutane can be obtained.

The diagram shows the separatory funnel when left to stand.

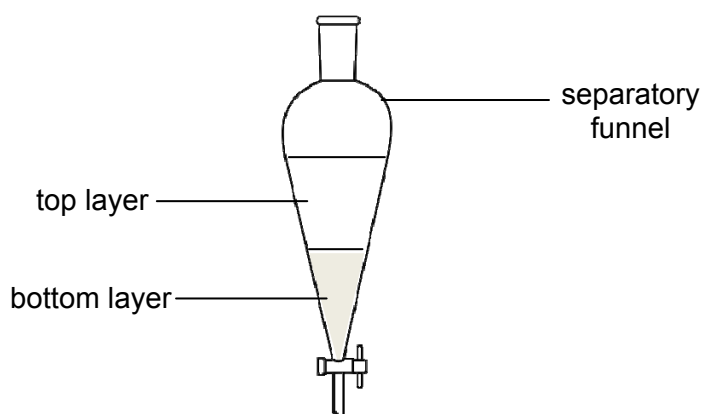


diagram of the separation set-up

- (i) Based on the data given, state the property that resulted in the formation of the two layers.

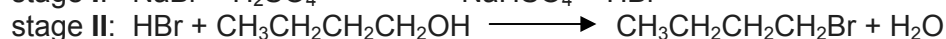
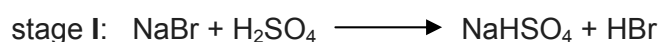
solubility

- (ii) State, with reasoning, which layer 1-bromobutane will be found in.

Bottom layer. 1-bromobutane has a higher density than water.

[3]

- (b) The reaction occurs in 2 stages. Stage I involves the generation of HBr, and stage II is the reaction of HBr with butan-1-ol:



- (i) What is the type of reaction for stage I and II?

Stage I: Acid-base reaction

Stage II: Substitution

- (ii) By using bond energy values from the *Data Booklet*, calculate the enthalpy change of reaction for stage II.

$$\begin{aligned}\Delta H_{\text{rxn}} &= 366 + 360 - (460 + 280) \\ &= \underline{-14 \text{ kJ mol}^{-1}}\end{aligned}$$

- (iii) Given that the enthalpy change of formation of HBr is  $-36.4 \text{ kJ mol}^{-1}$ , use relevant data from the table to calculate another value for the enthalpy change of reaction for stage II.

$$\begin{aligned}\Delta H_{\text{rxn}} &= (-143.8) + (-241.8) - [(-36.4) + (-327.4)] \\ &= \underline{-21.8 \text{ kJ mol}^{-1}}\end{aligned}$$

- (iv) Suggest why the value in (ii) is not an accurate value for the enthalpy change of reaction for stage II.

The values from data booklet are just **average values**.

**OR**

Bond energy values are used for reactions in the **gaseous phase**, however, the reactants and products in stage II are not in the gaseous phase.

[7]

[Total: 10]



## Section B

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

- 5 Oxides of nitrogen and sulfur contribute towards global warming and photochemical smog. Oxides of nitrogen are created by combustion in road transport and oxides of sulfur are produced by the burning of fossil fuels to generate electricity.

- (a) State another environmental consequence caused by oxides of nitrogen and oxides of sulfur.

[1]

Acid rain

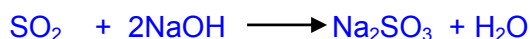
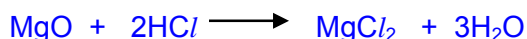
- (b) (i) Draw a dot-and-cross diagram to show the bonding in sulfur dioxide,  $\text{SO}_2$ . State and explain the shape of this molecule and the bond angle it contains.



There are **3 electron regions around S atom** consisting of **2 bond pairs** and **1 lone pair**

Since the **lone pair-bond pair repulsion** is greater than the **bond pair-bond pair repulsion**, sulfur dioxide is **bent** with a bond angle of around  **$115^\circ - 120^\circ$**  (or anything less than  $120^\circ$  but greater than  $100^\circ$ ).

- (ii) How does sulfur dioxide,  $\text{SO}_2$  differ in its acid/base behavior as compared to magnesium oxide,  $\text{MgO}$ ? Explain your answer with the aid of balanced equations.

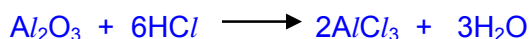


$\text{MgO}$  reacts with acids and  $\text{SO}_2$  reacts with bases.

- (iii) Aluminium oxide is amphoteric.

What is meant by the term *amphoteric*? Write balanced equations to illustrate the fact that aluminum oxide is amphoteric.

Amphoteric means that it can react with **both acids and bases**.



[9]

- (c) Another type of pollutants is known as volatile organic compounds (VOCs) that contribute to the formation of ozone and smog. VOCs are also produced naturally

by vegetation, vehicles and by cleaning and disinfecting chemicals.

Compound **J** is an example of such a VOC. **J** contains C, 62.1% H, 10.3%; O, 27.6% by mass and has a *Mr* of 58.0. **J** is formed by heating **K** with acidified potassium manganate(VII). **K** gives a yellow precipitate upon warming with alkaline aqueous iodine, and reacts with  $\text{PCl}_5$  to form white fumes and compound **L**.

**J** also gives a bright orange precipitate, **M** upon addition of 2,4-dinitrophenylhydrazine.

(i) Determine the molecular formula of **J**.

Elements	C	H	O
Mass in 100g /g	62.1	10.3	27.6
No. of mole	$62.1/12 = 5.2$	$10.3/1 = 10.3$	$27.6/16 = 1.725$
Simplest ratio	$5.2/1.725 = 3$	$10.3/1.725 = 6$	$1.725/1.725 = 1$

Empirical formula =  $\text{C}_3\text{H}_6\text{O}$

*Mr* of Empirical formula = 58.0 = *Mr* of Molecular formula

Molecular formula =  $\text{C}_3\text{H}_6\text{O}$

(ii) Identify and suggest structures for **J**, **K**, **L** and **M**. Show how you deduced these structures and suggest the types of reactions that are occurring.

Write balanced equations for the reactions of

- K** with acidified potassium manganate(VII) to form **J**
- J** with 2,4-dinitrophenylhydrazine to form **M**

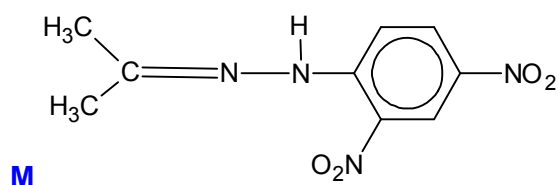
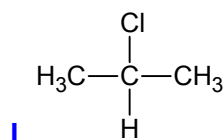
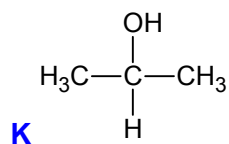
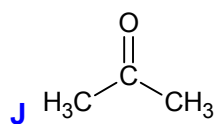
**J** is formed by reacting **K** with acidified potassium manganate(VII) via oxidation, hence it is either a ketone or aldehyde. From the molecular formula, it cannot be a carboxylic acid/ **J** cannot be a primary alcohol.

**K** gives a yellow precipitate in the presence of alkaline aqueous iodine via mild oxidation, hence **K** either has the  $-\text{COCH}_3$  group or the  $-\text{CH}(\text{OH})\text{CH}_3$  group. Since it can be further oxidised, it has the  $-\text{CH}(\text{OH})\text{CH}_3$  group.

**K** reacts with solid  $\text{PCl}_5$  to form white fumes and compound **L** via substitution, **K** has to be an alcohol and **L** is a chloroalkane/halogenoalkane.

**J** reacts with 2,4-dinitrophenylhydrazine via condensation, this means that **J** is a ketone.

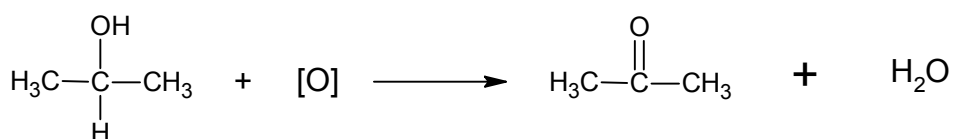
Structures of **J**, **K**, **L** and **M**.



Equations and Types of reactions:

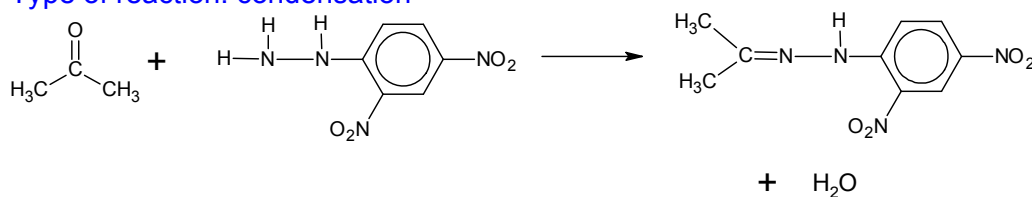
**K → J**

Type of reaction: oxidation



**J → M**

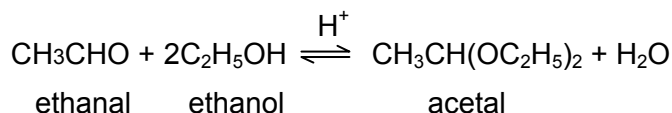
Type of reaction: condensation



[10]

[Total: 20]

- 6 (a) Acetals are compounds formed when aldehydes react with an alcohol and an acid catalyst. The reaction between ethanal and ethanol was studied in the inert solvent dioxane.



When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment	$[\text{CH}_3\text{CHO}]$ / mol dm <sup>-3</sup>	$[\text{C}_2\text{H}_5\text{OH}]$ / mol dm <sup>-3</sup>	$[\text{H}^+]$ / mol dm <sup>-3</sup>	relative rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

- (i) Use these data to deduce the order of reaction with respect to  $\text{CH}_3\text{CHO}$ ,  $\text{C}_2\text{H}_5\text{OH}$  and  $\text{H}^+$ , showing how you arrive at your answers. Hence write a rate equation for the reaction.

Using experiment 1 and 2, when  $[\text{CH}_3\text{CHO}]$  increases by 1.25 times, keeping  $[\text{C}_2\text{H}_5\text{OH}]$  and  $[\text{H}^+]$  constant, the rate increases by 1.25 times. Hence order of reaction wrt  $\text{CH}_3\text{CHO}$  is one.

Using experiment 2 and 3, when  $[\text{C}_2\text{H}_5\text{OH}]$  increases by 1.6 times, keeping  $[\text{CH}_3\text{CHO}]$  and  $[\text{H}^+]$  constant, the rate increases by 1.6 times. Hence order of reaction wrt  $\text{CH}_3\text{OH}$  is one.

Using experiment 1 and 4, when  $[\text{H}^+]$  doubles and  $[\text{C}_2\text{H}_5\text{OH}]$  increases by 1.6 times, keeping  $[\text{CH}_3\text{CHO}]$  constant, the rate increases by 3.2 times. Since order of reaction wrt  $\text{C}_2\text{H}_5\text{OH}$  is one, order of reaction wrt  $\text{H}^+$  is one.

Alternatively, students can use substitution method, comparing ANY 2 expt:

Comparing Experiments 1 and 4,

Let x be order of reaction wrt  $\text{H}^+$ .

$$\frac{\text{Rate}_1}{\text{Rate}_4} = \frac{k [\text{CH}_3\text{CHO}]^1 [\text{C}_2\text{H}_5\text{OH}]^1 [\text{H}^+]^x}{k [\text{CH}_3\text{CHO}]^1 [\text{C}_2\text{H}_5\text{OH}]^1 [\text{H}^+]^x}$$

$$\Rightarrow \frac{1.00}{3.20} = \frac{(0.20)(0.10)(0.05)^x}{(0.20)(0.16)(0.10)^x}$$

$$\Rightarrow 0.3125 = 0.625 \left( \frac{1}{2} \right)^x$$

$$\Rightarrow x = 1$$

$$\text{rate} = k [\text{CH}_3\text{CHO}] [\text{C}_2\text{H}_5\text{OH}] [\text{H}^+]$$

- (ii) Using Experiment 1, calculate a value for the rate constant,  $k$ , giving its units.

From experiment 1,  

$$\text{rate} = k [\text{CH}_3\text{CHO}] [\text{C}_2\text{H}_5\text{OH}] [\text{H}^+]$$

$$1.00 = k (0.20) (0.10) (0.05)$$

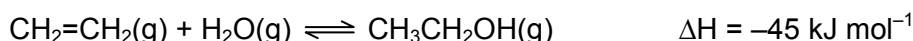
$$k = 1000 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$$

- (iii) State the quantitative effect on the rate of reaction when the volume of dioxane solvent added is doubled.

The rate of reaction decreases by 8 times or is 1/8 of the original rate.

[7]

- (b) In the production of industrial grade ethanol, ethene is reacted with steam in the presence of an acid catalyst. The reaction is reversible and the formation of ethanol is exothermic.



Only 5% of the ethene is converted into ethanol at each pass through the industrial reactor. By removing the ethanol from the equilibrium mixture and recycling the ethene, it is possible to achieve an overall 95% conversion.

By adjusting conditions of temperature and pressure, the yield of ethanol can also be increased.

- (i) Suggest if high or low temperature **and** pressure would favour the production of ethanol.

Low temperature and high pressure.

- (ii) The reaction is carried out at a pressure of 60 atm and a temperature of 300 °C.

Suggest why these particular conditions are chosen.

High pressure will result in the equilibrium position to shift to the right, to favour the side with fewer gaseous particles to obtain a higher yield of ethanol.

However, capital cost and the maintenance cost of equipment increases significantly at high pressure (or words to this effect). Hence the pressure is kept at 60 atm. (moderate pressure).

Low temperature will result in the equilibrium position to shift to the right to favour the exothermic reaction to release heat to obtain a higher yield of ethanol.

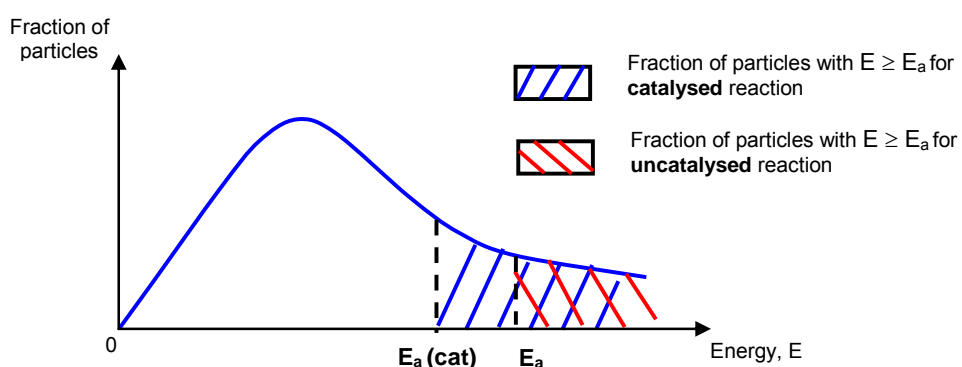
However, with low temperature the rate of the reaction will be too slow. Hence a moderate temperature is used to speed up the reaction.

- (iii) Suggest whether the use of a catalyst has an effect on the yield of ethanol.

The use of catalyst will not increase the yield of ethanol, as catalyst increase the rates of both forward and reverse reactions to the same extent but does not affect the equilibrium position.

- (iv) Sketch a Boltzmann distribution curve for the reactants and use it to explain the effect of a catalyst on the rate of manufacture of ethanol.

- Catalyst works by providing an alternative pathway with a lower activation energy.
- Fraction/proportion of particles with at least the activation energy of the catalysed reaction increases.
- Frequency of effective collisions taking place in the reaction increases.
- Since rate of reaction is proportional to the frequency of effective collisions, rate of reaction increases.



Marking points :

Origin + both axes + graphs start at origin  
Correct legends and shading must tally with graph  
Labelling of  $E_a(\text{cat})$  must be lower than  $E_a$

[8]

- (c) Ethanal can be obtained from ethanol.

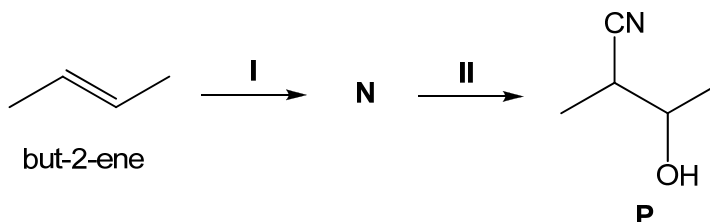
Describe how this can be achieved in a school laboratory, and suggest the identity of an organic impurity that might be found in the product.

Reagents and condition needed are  $\text{K}_2\text{Cr}_2\text{O}_7$ , dilute  $\text{H}_2\text{SO}_4$ , heat with (immediate) distillation.

Organic impurity is ethanoic acid.

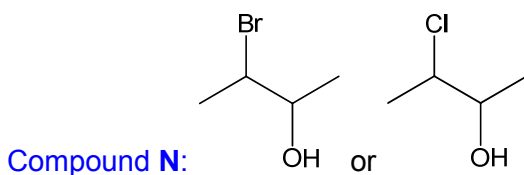
[2]

- (d) In the synthesis of compound **P** from but-2-ene, suggest the reagents and conditions for steps I and II, as well as the intermediate compound **N**.



Step I: aqueous bromine or chlorine, room temperature

Step II: ethanolic KCN, heat with reflux



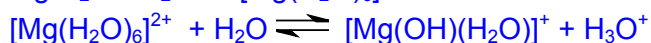
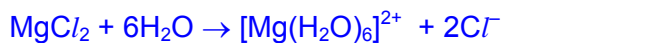
[3]

[Total: 20]

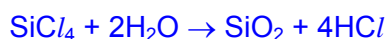
7 This question is about the physical and chemical properties of the chlorides of the elements in the third Period.

- (a) Using the chlorides of magnesium, silicon and phosphorus as examples, describe the reactions of the chlorides of the third period of the Periodic Table with water. Write equations where appropriate.

When  $\text{MgCl}_2$  dissolves in water, the magnesium ion gets hydrated. The hydrated magnesium ion undergoes slight hydrolysis to give  $\text{H}_3\text{O}^+$ .



$\text{SiCl}_4$  and  $\text{PCl}_5$  hydrolyses completely in water to give acidic solution as shown.



[3]

- (b) Phosphorus(V) chloride,  $\text{PCl}_5$ , is a white solid which sublimes at  $160^\circ\text{C}$ .

When gaseous phosphorus(V) chloride is heated in a closed container, the following equilibrium is established.



Initially, 1.00 moles of  $\text{PCl}_5$  is heated in a closed  $5.00\text{ dm}^3$  flask at 500 K. At equilibrium, 0.508 moles of  $\text{PCl}_3$  and  $\text{Cl}_2$  are present.

- (i) Write an expression for  $K_c$  for this equilibrium, stating the units.

$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} \text{ mol dm}^{-3}$$

- (ii) Calculate the value of  $K_c$  at 500 K.

	$\text{PCl}_5$	$\rightleftharpoons$	$\text{PCl}_3$	+	$\text{Cl}_2$
Initial mole/mol	1.00		0		0
Change in mole/mol	-0.508		+0.508		+0.508
Eqm mole/mol	0.492		0.508		0.508

$$K_c = \frac{\left(\frac{0.508}{5}\right)\left(\frac{0.508}{5}\right)}{\left(\frac{0.492}{5}\right)} = 0.105 \text{ mol dm}^{-3}$$

[4]

- (c) **X** is another element of the third period and it forms a chloride,  $\text{XCl}_y$ .  $\text{XCl}_y$  is a liquid which has a boiling point of  $76^\circ\text{C}$  and fumes in moist air. After mixing  $0.010 \text{ mol}$  of  $\text{XCl}_y$  with water, the resulting solution required  $100 \text{ cm}^3$  of  $0.30 \text{ mol dm}^{-3}$  silver nitrate for complete precipitation of the chloride ion.

- (i) Calculate a value of **y**.

Amount of  $\text{Ag}^+$  required for complete precipitation of the chloride  
 $= 0.30 \times 100/1000$   
 $= 0.0300 \text{ mol}$   
 $= \text{amount of } \text{Cl}^- \text{ produced}$   
Mole ratio of  $\text{XCl}_y : \text{Cl}^- = 0.0100 : 0.0300$   
 $= 1 : 3$   
Value of **y** = 3

- (ii) Suggest, with reasons, the identity of element **X**.

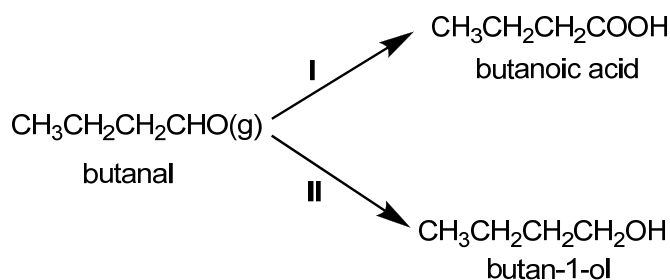
Since 1 mol of  $\text{XCl}_y$  reacts with water to give 3 mol of  $\text{Cl}^-$ , **X** can either be aluminium or phosphorus.

Aluminium chloride is a solid whereas phosphorus trichloride is a liquid which fumes in air or  $\text{AlCl}_3$  from Group III does not have such a low boiling point of  $76^\circ\text{C}$  and exists as a solid at r.t.p.

Thus, **X** is phosphorus

[3]

- (d)



- (i) State the reagents and conditions needed for
- reaction I
  - reaction II

Reaction I:  $\text{KMnO}_4$ ,  $\text{H}_2\text{SO}_4$  (aq), heat with reflux  
Or  $\text{K}_2\text{Cr}_2\text{O}_7$ ,  $\text{H}_2\text{SO}_4$  (aq), heat with reflux

Reaction II:  $\text{LiAlH}_4$  in dry ether, r.t.p.



Or  $\text{NaBH}_4$  in alkaline aqueous methanol, r.t.p.  
 Or  $\text{H}_2$ , Ni catalyst high temp & high pressure.

- (ii) State the reagents and conditions needed in the conversion of butan-1-ol into
- 1-chlorobutane
  - 2-chlorobutane (in two steps)

- For 1-chlorobutane

Reagents & conditions:  $\text{PCl}_5(\text{s})$ , r.t.p. /  $\text{PCl}_3(\text{l})$ , r.t.p. /  $\text{SOCl}_2(\text{l})$ , warm

- For 2-chlorobutane

Reagents & conditions for step 1: excess conc  $\text{H}_2\text{SO}_4$  at  $170^\circ\text{C}$

Reagents & conditions for step 2:  $\text{HCl}$  gas, r.t.p.

[5]

- (e) The compound 2-chlorobutane is a useful intermediate for making other organic compounds.

- (i) 2-chlorobutane forms butan-2-ol by heating with  $\text{NaOH}(\text{aq})$ .

How would you expect the rate of this reaction to compare to that of the reaction of 2-iodobutane with  $\text{NaOH}(\text{aq})$ ? Explain your answer.

The  $\text{C}-\text{Cl}$  bond is stronger than the  $\text{C}-\text{I}$  bond

as the bond length of  $\text{C}-\text{Cl}$  is longer than the  $\text{C}-\text{I}$  bond.

Hence, the  $\text{C}-\text{Cl}$  bond is harder to break than the  $\text{C}-\text{I}$  bond. [or more energy required to break the  $\text{C}-\text{Cl}$  bond]

Thus rate of reaction is slower for 2-chlorobutane than 2-iodobutane.

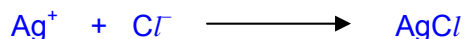
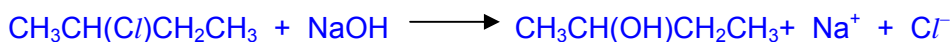
- (ii) Describe, with the help of balanced equations, how 2-chlorobutane could be distinguished from butan-2-ol through a **positive** chemical test for 2-chlorobutane.

1) Add  $\text{NaOH}(\text{aq})$  to both compounds separately and heat

2) Add excess dilute  $\text{HNO}_3$ , followed by  $\text{AgNO}_3(\text{aq})$

For 2-chlorobutane, a white ppt of  $\text{AgCl}$  is formed.

For butan-2-ol, no white ppt is seen.



[5]

[Total: 20]