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.

For Examiner's Use

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}Cr	4.33
^{52}Cr	83.8
^{53}Cr	9.50
^{54}Cr	2.37

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

[1]

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

[2]

(c) Chromium(IV) oxide, CrO_2 is a black solid that disproportionates into a mixture of Cr^{3+} and $Cr_2O_7^{2-}$ in acidic solutions.

The half-equation for the reduction of CrO_2 to Cr^{3+} is as follows:

$$CrO_2 + 4H^+ + e \longrightarrow Cr^{3+} + 2H_2O$$

To determine the percentage purity of a sample of chromium(IV) oxide, a student dissolves 1.5 g of impure sample in 20 cm^3 of sulfuric acid and make up the total volume to 100 cm^3 with distilled water. He then found that 25 cm^3 of the resulting solution, containing $Cr_2O_7^{2-}$ ions, required 16.00 cm^3 of 0.200 mol dm^{-3} of iron(II) sulfate solution for complete reaction.

(i) Construct the half-equation for the oxidation of CrO_2 to $Cr_2O_7^{2-}$.

……

For Examiner's Use

(ii) Hence, construct the overall equation for the disproportionation of CrO_2 to Cr^{3+} and $Cr_2O_7^{2-}$.

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

(iv) Hence, calculate the amount of $Cr_2O_7^{2-}$ present in **100 cm^3** of the solution.

(v) Calculate the mass of CrO_2 present in the sample and hence, the percentage purity of the sample.

[You may assume a mole ratio of CrO_2 : $Cr_2O_7^{2-}$ of 6 : 1 if you were unable to derive the overall equation in **(ii)**.]

[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^o.

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

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

Suggest the overall charge on a particle of **A**.

[2]

[Total: 12]

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

compound	lattice energy / kJ mol^{-1}
NaC*l*	−781
NaBr	−743
NaI	−699
MgO	−3933

(i) Define the term *lattice energy*.

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(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.

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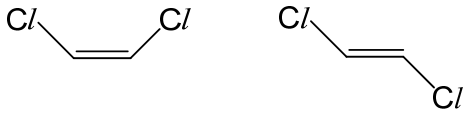
[4]

For Examiner's Use

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



B **C**

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

……..

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[2]

(c) Account for the following observation:

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

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[2]

[Total: 8]

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

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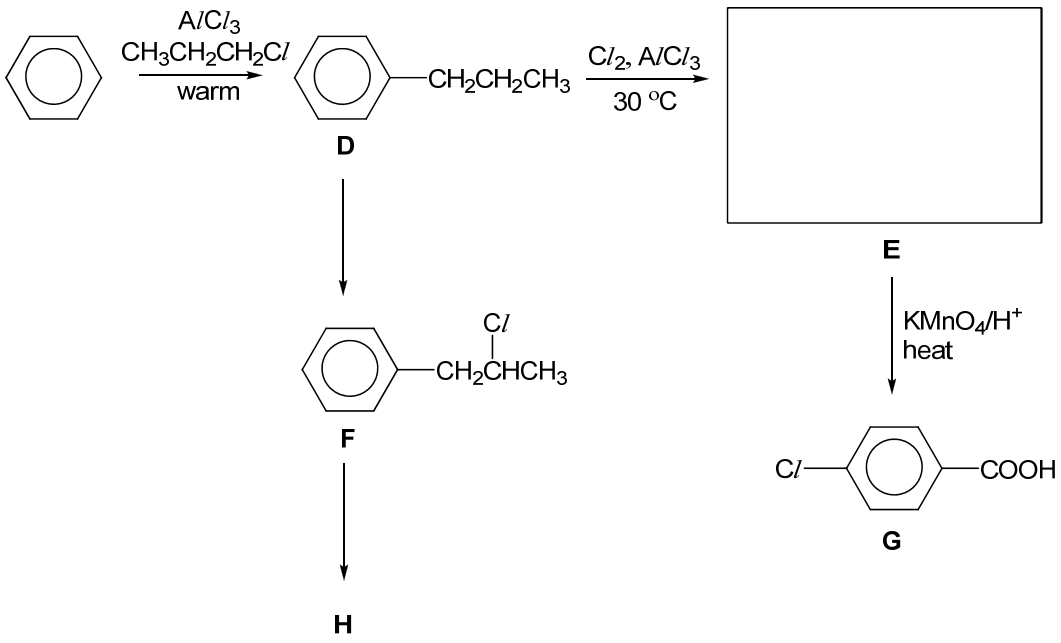
[5]

(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**.

……

(iii) **F** can react with a suitable reagent to give **H**, C_9H_{10}, which exists as a pair of geometric isomers. Suggest the reagents and conditions needed to form **H**.

……

(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^{-3}	M_r	ΔH_f / kJ mol^{-1}	ΔH_c / 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.

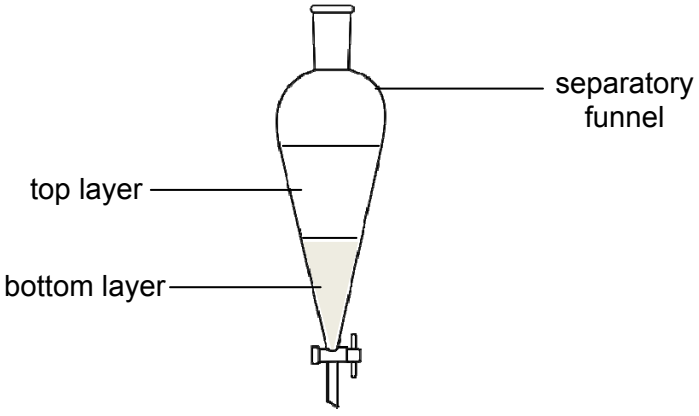


diagram of the separation set-up

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

……..……..……

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

……..……

……..……...

……..……

[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:

stage **I**: $NaBr + H_2SO_4 \longrightarrow NaHSO_4 + HBr$

stage **II**: $HBr + CH_3CH_2CH_2CH_2OH \longrightarrow CH_3CH_2CH_2CH_2Br + H_2O$

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

Stage **I**: ……

Stage **II**: ……..

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

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

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

……..……

[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]

(b) **(i)** Draw a dot-and-cross diagram to show the bonding in sulfur dioxide, SO_2. State and explain the shape of this molecule and the bond angle it contains.

(ii) How does sulfur dioxide, SO_2 differ in its acid/base behavior as compared to magnesium oxide, MgO? Explain your answer with the aid of balanced equations.

(iii) Aluminium oxide is amphoteric.

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

[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 *M*r 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 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**.

(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**

[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.

$$CH_3CHO + 2C_2H_5OH \overset{H^+}{\rightleftharpoons} CH_3CH(OC_2H_5)_2 + H_2O$$

ethanal ethanol acetal

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

experiment	$[CH_3CHO]$ / mol dm^{-3}	$[C_2H_5OH]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	relative rate / mol dm^{-3} s^{-1}
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 CH_3CHO, C_2H_5OH and H^+, showing how you arrive at your answers. Hence write a rate equation for the reaction.

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

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

[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.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

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.

(ii) The reaction is carried out at a pressure of 60 atm and a temperature of 300 ^oC.

Suggest why these particular conditions are chosen.

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

(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.

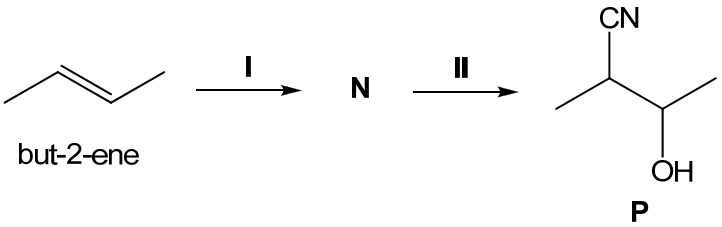
[8]

(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.

[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**.



[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.

[3]

(b) Phosphorus(V) chloride, PCl_5, is a white solid which sublimes at 160 °C.

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

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Initially, 1.00 moles of PCl_5 is heated in a closed 5.00 dm^3 flask at 500 K.
At equilibrium, 0.508 moles of PCl_3 and Cl_2 are present.

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

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

[4]

(c) **X** is another element of the third period and it forms a chloride, $\mathbf{X}Cl_y$.
$\mathbf{X}Cl_y$ is a liquid which has a boiling point of 76 °C and fumes in moist air.

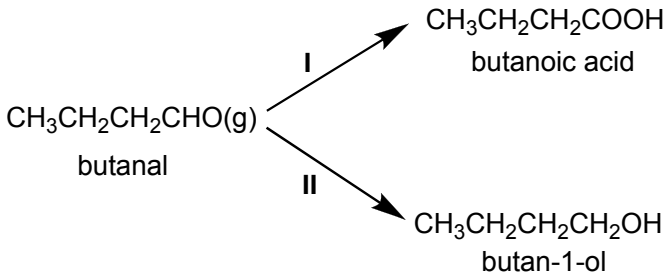
After mixing 0.010 mol of $\mathbf{X}Cl_y$ with water, the resulting solution required 100 cm^3 of 0.30 mol dm^{-3} silver nitrate for complete precipitation of the chloride ion.

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

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

[3]

(d)



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

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

[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 NaOH(aq).

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

(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.

[5]

[Total: 20]

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