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CHEMISTRY
HIGHER LEVEL
PAPER 2

Wednesday 12 May 2010 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

SECTION A

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

1. Brass is a copper containing alloy with many uses. An analysis is carried out to determine the percentage of copper present in three identical samples of brass. The reactions involved in this analysis are shown below.

Step 1: $Cu(s) + 2HNO_3(aq) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$

Step 2: $4I^-(aq) + 2Cu^{2+}(aq) \rightarrow 2CuI(s) + I_2(aq)$

Step 3: $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

(a) (i) Deduce the change in the oxidation numbers of copper and nitrogen in step 1. *[2]*

Copper:

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Nitrogen:

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(ii) Identify the oxidizing agent in step 1. *[1]*

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(b) A student carried out this experiment three times, with three identical small brass nails, and obtained the following results.

Mass of brass $= 0.456\ g \pm 0.001\ g$

Titre	**1**	**2**	**3**
Initial volume of 0.100 mol dm^{-3} $S_2O_3^{2-}$ ($\pm$0.05 cm^3)	0.00	0.00	0.00
Final volume of 0.100 mol dm^{-3} $S_2O_3^{2-}$ ($\pm$0.05 cm^3)	28.50	28.60	28.40
Volume added of 0.100 mol dm^{-3} $S_2O_3^{2-}$ ($\pm$0.10 cm^3)	28.50	28.60	28.40
Average volume added of 0.100 mol dm^{-3} $S_2O_3^{2-}$ ($\pm$0.10 cm^3)	28.50		

(This question continues on the following page)

(Question 1 continued)

(i) Calculate the average amount, in mol, of $S_2O_3^{2-}$ added in step 3. *[2]*

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(ii) Calculate the amount, in mol, of copper present in the brass. *[1]*

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(iii) Calculate the mass of copper in the brass. *[1]*

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(iv) Calculate the percentage by mass of copper in the brass. *[1]*

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(v) The manufacturers claim that the sample of brass contains 44.2 % copper by mass. Determine the percentage error in the result. *[1]*

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(c) In step 1 the copper reacts to form a blue solution.

(i) State the full electronic configuration of Cu^{2+}. *[1]*

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(ii) Explain why the copper solution is coloured. *[2]*

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2. Alex and Hannah were asked to investigate the kinetics involved in the iodination of propanone. They were given the following equation by their teacher.

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI(aq)$$

Alex's hypothesis was that the rate will be affected by changing the concentrations of the propanone and the iodine, as the reaction can happen without a catalyst. Hannah's hypothesis was that as the catalyst is involved in the reaction, the concentrations of the propanone, iodine and the hydrogen ions will all affect the rate.

They carried out several experiments varying the concentration of one of the reactants or the catalyst whilst keeping other concentrations and conditions the same, and obtained the results below.

Experiment	**Composition by volume of mixture / cm^3**				**Initial rate / $mol\ dm^{-3}\ s^{-1}$**
	1.00 $mol\ dm^{-3}$ $CH_3COCH_3(aq)$	**Water**	**1.00 $mol\ dm^{-3}$ $H^+(aq)$**	**5.00×10^{-3} $mol\ dm^{-3}$ I_2 in KI**	
1	10.0	60.0	10.0	20.0	4.96×10^{-6}
2	10.0	50.0	10.0	30.0	5.04×10^{-6}
3	5.0	65.0	10.0	20.0	2.47×10^{-6}
4	10.0	65.0	5.0	20.0	2.51×10^{-6}

(a) Explain why they added water to the mixtures. *[1]*

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(b) (i) Deduce the order of reaction for each substance and the rate expression from the results. *[2]*

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(ii) Comment on whether Alex's or Hannah's hypothesis is correct. *[1]*

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(Question 2 continued)

(c) Using the data from Experiment 1, determine the concentration of the substances used and the rate constant for the reaction including its units. *[3]*

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(d) (i) This reaction uses a catalyst. Sketch and annotate the Maxwell-Boltzmann energy distribution curve for a reaction with and without a catalyst on labelled axes below. *[3]*

(ii) Describe how a catalyst works. *[1]*

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3. Chloroethene, C_2H_3Cl, is an important organic compound used to manufacture the polymer poly(chloroethene).

(a) Draw a section of poly(chloroethene) containing six carbon atoms. *[1]*

(b) Outline why the polymerization of alkenes is of economic importance and why the disposal of plastics is a problem. *[2]*

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(c) (i) Chloroethene can be converted to ethanol in two steps. For each step deduce an overall equation for the reaction taking place. *[2]*

Step 1:

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Step 2:

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(ii) State the reagents and conditions necessary to prepare ethanoic acid from ethanol in the laboratory. *[2]*

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(Question 3 continued)

(d) (i) State an equation for the reaction of ethanoic acid with water. *[1]*

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(ii) Calculate the pH of 0.200 mol dm^{-3} ethanoic acid ($pK_a = 4.76$). *[3]*

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(e) Determine the pH of a solution formed from adding 50.0 cm^3 of 1.00 mol dm^{-3} ethanoic acid, $CH_3COOH(aq)$, to 50.0 cm^3 of 0.600 mol dm^{-3} sodium hydroxide, $NaOH(aq)$. *[4]*

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(f) Explain how the solution formed in part (e) can act as a buffer. Use equations to support your answer. *[2]*

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SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

4. (a) Define the term *relative atomic mass* (A_r). *[1]*

(b) Relative atomic masses are obtained using a mass spectrometer. Draw a simple annotated diagram of the mass spectrometer. *[5]*

(c) The relative atomic mass of naturally occurring copper is 63.55. Calculate the abundances of ^{63}Cu and ^{65}Cu in naturally occurring copper. *[2]*

(d) The isotopes of some elements are radioactive. State a radioisotope used in medicine. *[1]*

(e) Explain why copper is considered a transition metal while scandium is not. *[3]*

(f) State a balanced equation for the reaction of sodium with water. Include state symbols. *[2]*

(g) With reference to electronic arrangements, suggest why the reaction between rubidium and water is more vigorous than that between sodium and water. *[2]*

(h) (i) Compare the structure and bonding in $AlCl_3$ and Al_2O_3. *[2]*

(ii) Describe the acid-base behaviour of $AlCl_3$, Na_2O and P_4O_{10}. Include suitable equations in your answer. *[4]*

(iii) Explain whether $AlCl_3$ and Al_2O_3 will conduct in the solid or molten state. *[3]*

5. (a) The production of ammonia is an important industrial process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Using the average bond enthalpy values in Table 10 of the Data Booklet, determine the standard enthalpy change for this reaction. *[3]*

(ii) The standard entropy values, *S*, at 298 K for $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are 193, 131 and 192 $JK^{-1}\ mol^{-1}$ respectively. Calculate $\Delta S^{\ominus}$ for the reaction and with reference to the equation above, explain the sign of $\Delta S^{\ominus}$. *[4]*

(iii) Calculate $\Delta G^{\ominus}$ for the reaction at 298 K. *[1]*

(iv) Describe and explain the effect of increasing temperature on the spontaneity of the reaction. *[2]*

(b) The reaction used in the production of ammonia is an equilibrium reaction. Outline the characteristics of a system at equilibrium. *[2]*

(c) Deduce the equilibrium constant expression, K_c, for the production of ammonia. *[1]*

(d) (i) 0.20 mol of $N_2(g)$ and 0.20 mol of $H_2(g)$ were allowed to reach equilibrium in a 1 dm^3 closed container. At equilibrium the concentration of $NH_3(g)$ was 0.060 mol dm^{-3}. Determine the equilibrium concentrations of $N_2(g)$ and $H_2(g)$ and calculate the value of K_c. *[3]*

(ii) Predict and explain how increasing the temperature will affect the value of K_c. *[2]*

(e) Describe how increasing the pressure affects the yield of ammonia. *[2]*

(f) In practice, typical conditions used in the Haber process are a temperature of 500 °C and a pressure of 200 atmospheres. Outline why these conditions are used rather than those that give the highest yield. *[2]*

(g) A catalyst of iron is used in the Haber process. State and explain how the catalyst affects K_c and the position of equilibrium. *[3]*

6. (a) (i) Draw an annotated diagram of a voltaic cell composed of a magnesium electrode in 1.0 mol dm^{-3} magnesium nitrate solution and a silver electrode in 1.0 mol dm^{-3} silver nitrate solution. State the direction of electron flow on your diagram. *[4]*

(ii) Deduce half-equations for the oxidation and reduction reactions. *[2]*

(iii) Using Table 14 of the Data Booklet, calculate the cell potential for this cell. *[2]*

(b) The standard electrode potentials for three other electrode systems are given below.

	$E^{\ominus}$ / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	–0.40

(i) Identify which species in the table above is the best reducing agent. *[1]*

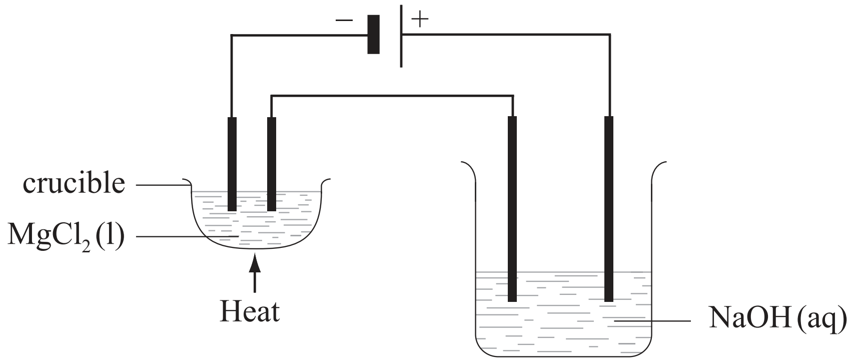
(ii) Deduce the equation for the overall reaction with the greatest cell potential. *[2]*

(c) These values were obtained using a standard hydrogen electrode. Describe the materials and conditions used in the standard hydrogen electrode. (A suitably labelled diagram is acceptable). *[4]*

(d) (i) Solid sodium chloride does not conduct electricity but molten sodium chloride does. Explain this difference. *[2]*

(ii) Outline what happens in an electrolytic cell during the electrolysis of molten sodium chloride using inert electrodes. Deduce equations for the reactions occurring at each electrode. *[4]*

(iii) Two electrolytic cells are connected in series as shown in the diagram below. In one there is molten magnesium chloride and in the other, dilute sodium hydroxide solution. Both cells have inert electrodes. If 12.16 g of magnesium is produced in the first cell, deduce the identity and mass of products produced at the positive and negative electrodes in the second cell. *[4]*



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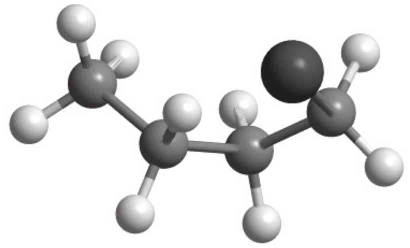
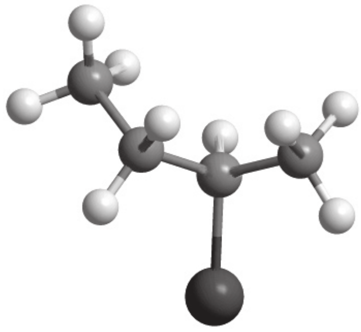
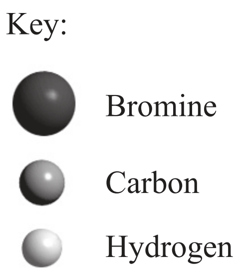
7. (a) Below are **four structural** isomers with molecular formula C_4H_9Br. State the name of each of the isomers **A**, **B**, **C** and **D**. *[4]*

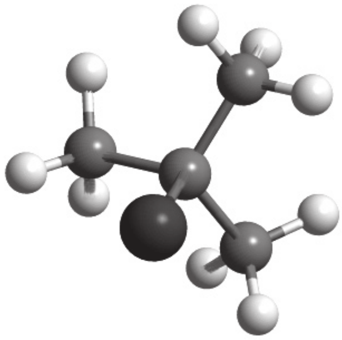


A



B





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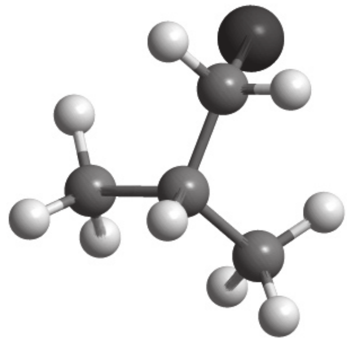

D

(b) (i) Identify the isomer(s) which will react with aqueous sodium hydroxide almost exclusively by an S_N1 mechanism. State the meaning of the symbols in the term S_N1 mechanism. *[2]*

(ii) Using the formula RBr to represent a bromoalkane, state an equation for the rate determining step of this S_N1 reaction. *[1]*

(iii) Identify one isomer that will react with aqueous sodium hydroxide almost exclusively by an S_N2 mechanism. Draw the mechanism for this reaction using curly arrows to represent the movement of electron pairs. Include the structural formulas of the transition state and the organic product. *[4]*

(c) State and explain how the rates of the reactions in parts (b) (i) and (b) (iii) are affected when the concentration of the sodium hydroxide is doubled. *[2]*

(This question continues on the following page)

(Question 7 continued)

(d) State and explain how the rate of reaction of 1-bromobutane with sodium hydroxide compares with that of 1-chlorobutane with sodium hydroxide. *[2]*

(e) Identify the isomer of C_4H_9Br that can exist as stereoisomers. Outline how a polarimeter will distinguish between the isomers, and how their physical and chemical properties compare. *[5]*

(f) (i) State the type of reaction that occurs when isomer **B**, $CH_3CHBrCH_2CH_3$, reacts with a hot alcoholic solution of sodium hydroxide. *[1]*

(ii) Explain how the reaction in part (f) (i) occurs by drawing the mechanism, using curly arrows to represent the movement of electron pairs and identify the two possible organic products. *[4]*