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CHEMISTRY
STANDARD LEVEL
PAPER 2

Tuesday 11 November 2008 (afternoon)

1 hour 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 one question 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.

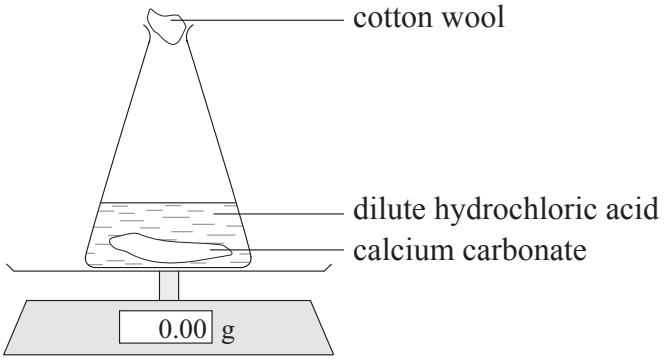
0112

SECTION A

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

1. The diagram shows the apparatus used to study the rate of reaction between calcium carbonate and hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$



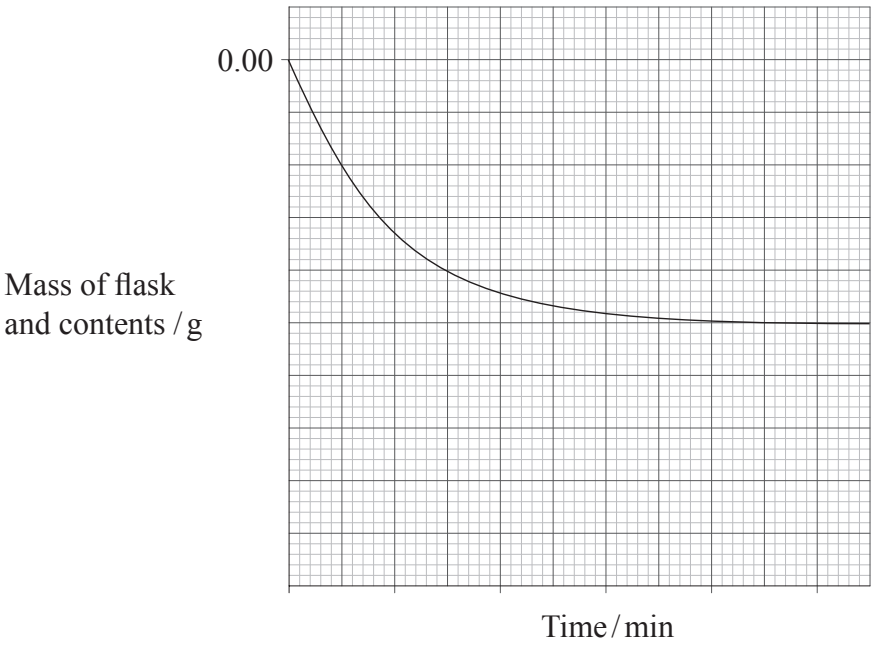
(a) The quantities of reactants added to the flask in one experiment carried out at room temperature were:

mass of single piece of $CaCO_3(s)$ = 5.00 g

volume of 1.00 mol dm^{-3} $HCl(aq)$ = 50.0 cm^3

The balance was set to zero at the start of the experiment.

The graph shows how the mass of the flask and contents changed during Experiment 1.



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(Question 1 continued)

(i) Explain why the mass decreased. *[1]*

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(ii) Calculate the amount, in moles, of each reactant at the start of Experiment 1. *[2]*

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(iii) Use your answers to (a) (ii), and the equation for the reaction, to deduce which reactant was added in excess. *[1]*

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(iv) The experiment was repeated with **small** pieces of calcium carbonate. Draw **two** lines (labelled 2 and 3) on the graph to show how the mass of the flask and contents changes in the following experiments at the same temperature.

Experiment	**Mass of small pieces of $CaCO_3(s)$ / g**	**Volume of 1.00 mol dm^{-3} $HCl(aq)$ / cm^3**
2	2.50	50.0
3	5.00	25.0

[4]

(This question continues on the following page)

(Question 1 continued)

(b) Further experiments were carried out using the reaction in part (a), making only one change to Experiment 1. In Experiment 4, the mass of small pieces of calcium carbonate used was 5.00 g. In Experiment 5, the temperature of the mixture was increased by 30 °C. In both cases, the reaction was faster than in Experiment 1.

(i) Use the collision theory to explain the main reason why Experiment 4 was faster than Experiment 1. *[2]*

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(ii) Use the collision theory to explain the main reason why Experiment 5 was faster than Experiment 1. *[2]*

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2. (a) Define the term *isotopes*. *[2]*

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(b) A sample of krypton contains these isotopes.

Isotope	Percentage abundance
^{82}Kr	15.80
^{84}Kr	65.40
^{86}Kr	18.80

(i) Calculate the relative atomic mass of krypton in this sample. Give your answer to **two** decimal places. *[2]*

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(ii) Deduce the number of each sub-atomic particle in an atom of ^{84}Kr. *[2]*

Protons . . . . . .

Neutrons . . . . . .

Electrons . . . . . .

3. (a) Three types of covalent bond (single, double and triple) are present in the molecules in the following equation.

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$$

(i) Identify **one** bond in these molecules that is correctly described by the following. *[4]*

A polar single bond . . . . . .

A polar double bond . . . . . .

A non-polar double bond . . . . . .

A non-polar triple bond . . . . . .

(ii) Identify the shortest bond in these molecules. *[1]*

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(b) The equation for the reaction that occurs when ammonia gas dissolves in water is shown below.

$$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(i) State how the equation indicates that ammonia is a base. *[1]*

. . . . . .

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(ii) State how the equation indicates that ammonia is a **weak** base. *[1]*

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(iii) Identify which pH value is approximately correct for ammonia solution.

pH 1 3 7 11 13 *[1]*

. . . . . .

(This question continues on the following page)

(Question 3 continued)

(c) Complete the table to show the Lewis structure of each ion and the name of the shape of each ion.

	NH_4^+	H_3O^+
Lewis structure		
Name of shape		

[4]

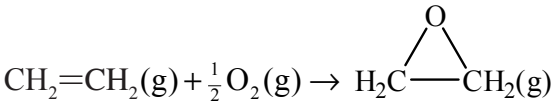
SECTION B

*Answer **one** question. 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) (i) Define the term *average bond enthalpy*. *[2]*

(ii) Explain why the H–H bond cannot be used as an example to illustrate average bond enthalpy. *[1]*

(iii) The equation for an important reaction of ethene is given below.



Use information from Table 10 in the Data Booklet to calculate the enthalpy change for this reaction. *[3]*

(iv) Draw a labelled enthalpy level diagram to represent the reaction in part (a) (iii). *[2]*

(v) Predict the sign of $\Delta S^{\ominus}$ for the reaction in part (a) (iii) and explain your choice. *[2]*

(b) The standard enthalpy changes for the following reactions can be found in Table 13 of the Data Booklet.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$$

$$C_8H_{18}(l) + 12\tfrac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$$

(i) Use this information to determine the standard enthalpy change for the formation of octane from its elements.

$$8C(s) + 9H_2(g) \rightarrow C_8H_{18}(l)$$ *[4]*

(ii) Predict which of the following reactions has the most negative enthalpy change, and explain your choice.

I $H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g)$

II $H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$ *[2]*

(This question continues on the following page)

(Question 4 continued)

(c) (i) State the name of the energy change represented by $\Delta G^{\ominus}$. *[1]*

(ii) The standard enthalpy and standard entropy changes for a reaction are given below.

$$CH_4(g) + 2H_2O(g) \rightarrow 4H_2(g) + CO_2(g) \qquad \Delta H^{\ominus} = +178 \text{ kJ}$$
$$\Delta S^{\ominus} = +174 \text{ J K}^{-1}$$

Explain how the spontaneity of this reaction is affected by changes in temperature. *[3]*

5. (a) The reaction between chlorine and bromide ions is a redox reaction.

$$Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$$

Define the term *oxidation* in terms of electron transfer and identify the species that is oxidized in this reaction. *[2]*

(b) The oxidation number of oxygen is –2 in most compounds containing oxygen. Identify the oxidation numbers of all the other elements in both reactants and products in the following equation.

$$TiO_2(s) + 2Cl_2(g) + C(s) \rightarrow TiCl_4(l) + CO_2(g)$$ *[3]*

(c) By referring to oxidation numbers, deduce what happens, if anything, in terms of oxidation and reduction, to the named element in each of these reactions.

(i) Chromium in
$2K_2CrO_4(aq) + 2HCl(aq) \rightarrow K_2Cr_2O_7(aq) + 2KCl(aq) + H_2O(l)$ *[2]*

(ii) Chlorine in
$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$ *[2]*

(d) The table shows some reactions involving the metals **W**, **X**, **Y** and **Z**.

Reaction	Reactants	Products
1	$W + Z(NO_3)_2$	$Z + W(NO_3)_2$
2	$X + YCl_2$	no reaction
3	$Y + ZSO_4$	no reaction
4	$Z + XO$	$X + ZO$

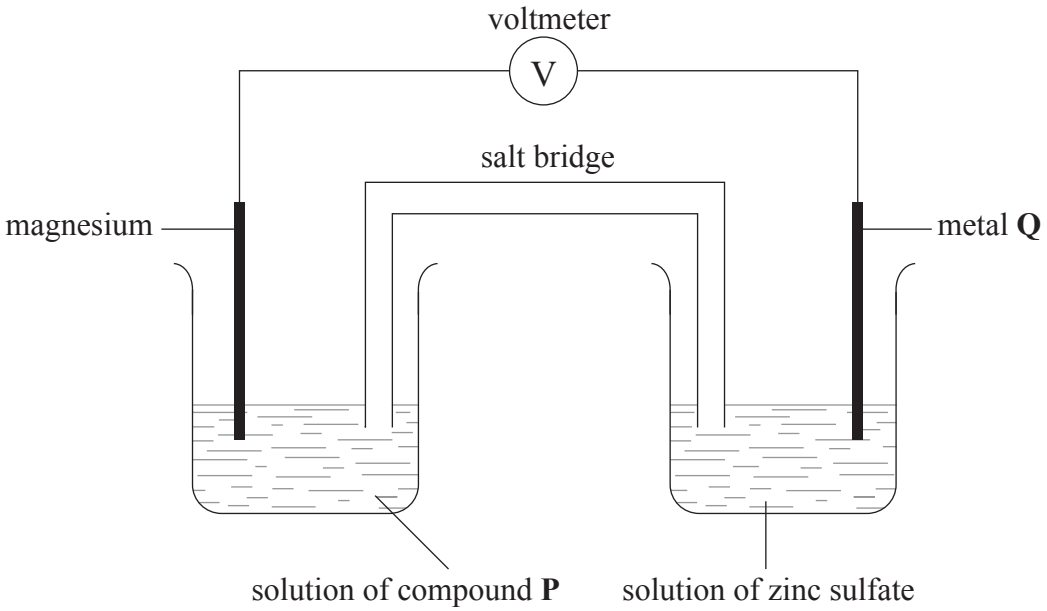
(i) Use the information to arrange the four metals in a reactivity series, starting with the most reactive. Explain with reference to each of the metals how you decided which metal was the least reactive. *[4]*

(ii) Metal **V** forms compounds in which it has an oxidation number of +3. It is more reactive than any of the metals in the table. Predict the equation for the reaction between metal **V** and the oxide of metal **X**. *[1]*

(This question continues on the following page)

(Question 5 continued)

(e) The diagram shows two half-cells connected together by a salt bridge. The metal in the left-hand cell is more reactive than the metal in the right-hand cell. The reading on the voltmeter is 1.6 V.



(i) Describe the purpose of the salt bridge and identify **one** substance that might be used in it. *[2]*

(ii) Identify compound **P** and metal **Q**. *[2]*

(iii) Deduce the half-equation for the reaction in the left-hand cell. *[1]*

(iv) The voltmeter is replaced by a battery with a voltage of 2.0 V so that the reaction in part (e) (iii) is reversed. Deduce the half-equation for the reaction in the right-hand cell when the battery is connected. *[1]*

6. Several **straight-chain** organic compounds have the molecular formula $C_4H_8O_2$. Compound **A** is acidic but compounds **B**, **C** and **D** are neutral liquids with characteristic smells. None of the compounds contain C=C bonds.

(a) (i) Deduce the empirical formula for these compounds. *[1]*

(ii) Deduce the structural formula and name of compound **A**. *[2]*

(iii) State the name of the functional group present in compounds **B**, **C** and **D**. *[1]*

(b) (i) Compound **A** can be prepared by the oxidation of butan-1-ol. Identify the reagents used for the oxidation. Predict the name of the organic compound that can be formed when butan-1-ol is partially oxidized. Suggest how the reaction can be controlled to give a low yield of this compound formed by partial oxidation and a high yield of compound **A**. *[4]*

(ii) Compound **B** is formed when ethanol and ethanoic acid are warmed together. Give the equation for this reaction and name compound **B**. *[2]*

(iii) Draw the structural formulas of compounds **C** and **D**. *[2]*

(iv) Predict, with reference to the intermolecular forces in each case, which of the compounds **A** and **B** has the higher boiling point. *[2]*

(c) The compound butan-2-ol exists as optical isomers. Describe the molecular feature responsible for this and draw 3-dimensional structures for each optical isomer, showing the relationship between them. State how separate samples of each isomer could be distinguished using plane polarized light. *[4]*

(d) A reaction similar to that in part (b) (ii) occurs when the compounds $HOOCC_6H_4COOH$ and $HOCH_2CH_2OH$ react together. Deduce the structure of the repeating unit of the polymer formed. *[2]*