Covalent Bonding & Shapes of Molecules

Question Paper 5

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Bonding
Sub-Topic	Covalent Bonding & Shapes of Molecules
Paper Type	Theory
Booklet	Question Paper 5

Time Allowed: **76 minutes**

Score: **/63**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** Hydrogen fluoride, HF, behaves as a weak acid in water, with $K_a = 5.6 \times 10^{-4}\,\text{mol dm}^{-3}$.

Calculate the pH of a $0.050\,\text{mol dm}^{-3}$ solution of HF.

pH = ...[2]

(b) Gaseous ammonia and hydrogen fluoride react together to give solid ionic ammonium fluoride.

$$NH_3(g) + HF(g) \rightleftharpoons NH_4F(s) \qquad \Delta H = -147\,\text{kJ mol}^{-1}$$

(i) What *type of reaction* is this?

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(ii) Draw dot-and-cross diagrams (outer shells only) describing the bonding in the three compounds involved in this reaction.

NH_3	HF	NH_4F

(iii) There are **three** types of bonding in NH_4F.
Give the names of each of the three types, and state where in the compound each type occurs.

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(iv) The reaction between NH_3 and HF is reversible. What conditions of temperature and pressure would favour the **reverse** reaction, i.e. the dissociation of NH_4F? Explain your answer.

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[9]

(c) Many commercial copper and brass polishes contain ammonia. The tarnish that forms on the surface of copper is often copper sulfide, CuS. In the presence of O_2 from the air, NH_3 can combine with this copper sulfide to produce the soluble cuprammonium sulfate, $[Cu(NH_3)_4]SO_4$.

(i) Construct an equation for this reaction.

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(ii) State the colour of cuprammonium sulfate solution.

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(iii) Describe what you would see if a solution of cuprammonium sulfate was diluted with water. Explain your answer.

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[3]

(d) When sulfuric acid is added to $Cu^{2+}(aq)$, no colour change occurs, but when concentrated hydrochloric acid is added to $Cu^{2+}(aq)$, the solution turns yellow-green. The solution reverts to its original colour when it is diluted with water.

Suggest the type of reaction occurring with HC*l*(aq), suggest what is formed during the reaction, and write an equation for the change.

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.....[3]

[Total: 17]

2 Hydrazine, N_2H_4, can be used as a rocket fuel and is stored as a liquid. It reacts exothermically with oxygen to give only gaseous products.

The enthalpy change of a reaction such as that between hydrazine and oxygen may be calculated by using standard enthalpy changes of formation.

(a) Define the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$.

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..... [3]

(b) Hydrazine reacts with oxygen according to the following equation.

$$N_2H_4(l) + O_2(g) \longrightarrow N_2(g) + 2H_2O(g)$$

(i) Use the data in the table to calculate the standard enthalpy change of this reaction.

compound	$\Delta H_f^{\ominus}$/kJ mol^{-1}
$N_2H_4(l)$	50.6
$H_2O(g)$	–241.8

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(ii) Although the above reaction is highly exothermic, hydrazine does not burn spontaneously in oxygen.
Suggest a reason for this.

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(iii) Suggest why using hydrazine as a rocket fuel could be regarded as being 'environmentally friendly'.

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[4]

(c) The bonding in hydrazine is similar to that in ammonia.

(i) Showing outer-shell electrons only, draw a 'dot-and-cross' diagram of an ammonia molecule.

(ii) Draw a diagram to show the three-dimensional shape of an ammonia molecule.

(iii) Draw a diagram to show the shape of a hydrazine molecule.
Show clearly which atom is joined to which and show clearly the value of **one** bond angle.

[4]

(d) Deduce the oxidation state of nitrogen in hydrazine.

..... [1]

[Total: 12]

3 The elements of the third period of the Periodic Table form chlorides of general formula ECl_x where *E* represents the element. These chlorides show a variation in oxidation number from sodium to sulfur.

(a) (i) Use the information given to complete the table below.

formula of chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
oxidation number of element in the chloride						

(ii) By considering the electron configurations of the elements, explain the variation in oxidation number in the chlorides from Na to Al and from Si to S.

Na to Al .....

.....

Si to S .....

.....

[5]

Sodium hydride, NaH, is a colourless crystalline solid which melts at 800 °C and has the same crystal structure as sodium chloride which has a melting point of 808 °C. When molten sodium chloride is electrolysed using graphite electrodes, a shiny deposit, **D**, forms on the cathode and a greenish-yellow gas is evolved from the anode. When molten sodium hydride is electrolysed, under suitable conditions using graphite electrodes, the same shiny deposit **D** is formed on the cathode and a colourless gas, **G**, is evolved from the anode.

(b) (i) Describe with the aid of a diagram the bonding in a sodium chloride crystal.

(ii) Suggest the type of bonding that is present in sodium hydride.

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(iii) What is the oxidation number of hydrogen in sodium hydride?

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(iv) Draw a 'dot-and-cross' diagram for sodium hydride. Show outer electrons only.

(v) The metals magnesium and aluminium form hydrides with formulae MgH_2 and AlH_3. The non-metals phosphorus and sulfur form hydrides with formulae PH_3 and H_2S.
By considering their positions in the Periodic Table, suggest oxidation numbers for these four elements in their hydrides.

compound	MgH_2	AlH_3	PH_3	H_2S
oxidation number of element in the hydride				

[8]

At room temperature, the chlorides of sodium, magnesium and aluminium are all solids which dissolve in water.
The hydrides of sodium, magnesium and aluminium are also solids which react with water with the rapid evolution of the **same** colourless gas **G** in each case.

(c) (i) What is the pH of the solutions formed when separate samples of sodium chloride, magnesium chloride, and aluminium chloride are dissolved in water?

chloride	sodium	magnesium	aluminium
pH			

(ii) Suggest an equation for the reaction between sodium hydride and water.

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(iii) Suggest a value for the pH of the solution formed in **(ii)**.

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[4]

At room temperature, the chlorides of silicon, phosphorus and sulfur are all low melting point solids or low boiling point liquids that can be seen to react with water.

(d) (i) Suggest what type of bonding is present in sulfur dichloride, SCl_2.

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(ii) Write a balanced equation for the reaction between the chloride of silicon, $SiCl_4$, and water.

..... [2]

[Total: 19]

4 This question is about the properties and reactions of the oxides of some elements in their +4 oxidation state.

(a) Chlorine dioxide, ClO_2, is an important industrial chemical, used to bleach wood pulp for making paper, and to kill bacteria in water supplies.

However, it is unstable and decomposes into its elements as follows.

$$2ClO_2(g) \rightarrow Cl_2(g) + 2O_2(g)$$

(i) The chlorine atom is in the middle of the ClO_2 molecule. Using the chlorine-oxygen bond energy as 278 kJ mol^{-1}, and other values from the *Data Booklet*, calculate ΔH for the above reaction.

ΔH = ... kJ mol^{-1}

(ii) Assuming the Cl-O bonds in chlorine dioxide are double bonds, predict the shape of the ClO_2 molecule. Explain your answer.

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(iii) ClO_2 can be made in the laboratory by reacting $KClO_3$ with concentrated H_2SO_4. Other products are K_2SO_4, $KClO_4$ and H_2O.

Construct a balanced equation for this reaction. You may find the use of oxidation numbers helpful.

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[5]

(b) Sulphur dioxide is an atmospheric pollutant.

(i) State **two** sources of atmospheric SO_2 that arise from human activity.

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(ii) Explain why SO_2 is a pollutant, and state an environmental consequence of this pollution.

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[3]

(c) All the oxides of the elements in Group IV in their +4 oxidation state are high melting point solids except CO_2.

(i) Explain this observation by describing the bonding in CO_2, SiO_2 and SnO_2.

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(ii) State the difference in the thermal stabilities of SnO_2 and PbO_2. Illustrate your answer with an equation.

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CO_2 dissolves in water to form a weakly acidic solution containing the hydrogencarbonate ion.

(iii) Write an equation for the reaction of CO_2 with water, and write an expression for the equilibrium constant, K_c.

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(iv) Explain the role of the hydrogencarbonate ion in controlling the pH of blood, illustrating your answer with relevant equations.

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[7]

[Total: 15]