Covalent Bonding & Shapes of Molecules

Question Paper 3

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 3

Time Allowed: **70 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

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

1 The Contact process for the manufacture of sulfuric acid was originally patented in the 19th century and is still in use today.

The key step in the overall process is the reversible conversion of sulfur dioxide to sulfur trioxide in the presence of a vanadium(V) oxide catalyst.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) One way in which the sulfur dioxide for this reaction is produced is by heating the sulfide ore iron pyrites, FeS_2, in air. Iron(III) oxide is also produced. Write an equation for this reaction.

..... [2]

(b) The sulfur trioxide produced in the Contact process is reacted with 98% sulfuric acid. The resulting compound is **then** reacted with water to produce sulfuric acid.

(i) Explain why the sulfur trioxide is not first mixed directly with water.

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..... [1]

(ii) Write equations for the two steps involved in the conversion of sulfur trioxide into sulfuric acid.

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..... [2]

(c) Sulfur dioxide and sulfur trioxide both contain only S=O double bonds.

Draw labelled diagrams to show the shapes of these two molecules.

SO_2 SO_3

[2]

(ii) For your diagrams in **(i)**, name the shapes and suggest the bond angles.

SO_2 shape ..... SO_3 shape .....

SO_2 bond angle ..... SO_3 bond angle .....

[2]

(d) The conversion of sulfur dioxide into sulfur trioxide is carried out at a temperature of 400 °C.

(i) With reference to Le Chatelier's Principle and reaction kinetics, state and explain one advantage and one disadvantage of using a higher temperature.

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..... [4]

(ii) State the expression for the equilibrium constant, K_p, for the formation of sulfur trioxide from sulfur dioxide.

K_p =

[1]

(iii) 2.00 moles of sulfur dioxide and 2.00 moles of oxygen were put in a flask and left to reach equilibrium.
At equilibrium, the pressure in the flask was 2.00×10^5 Pa and the mixture contained 1.80 moles of sulfur trioxide.

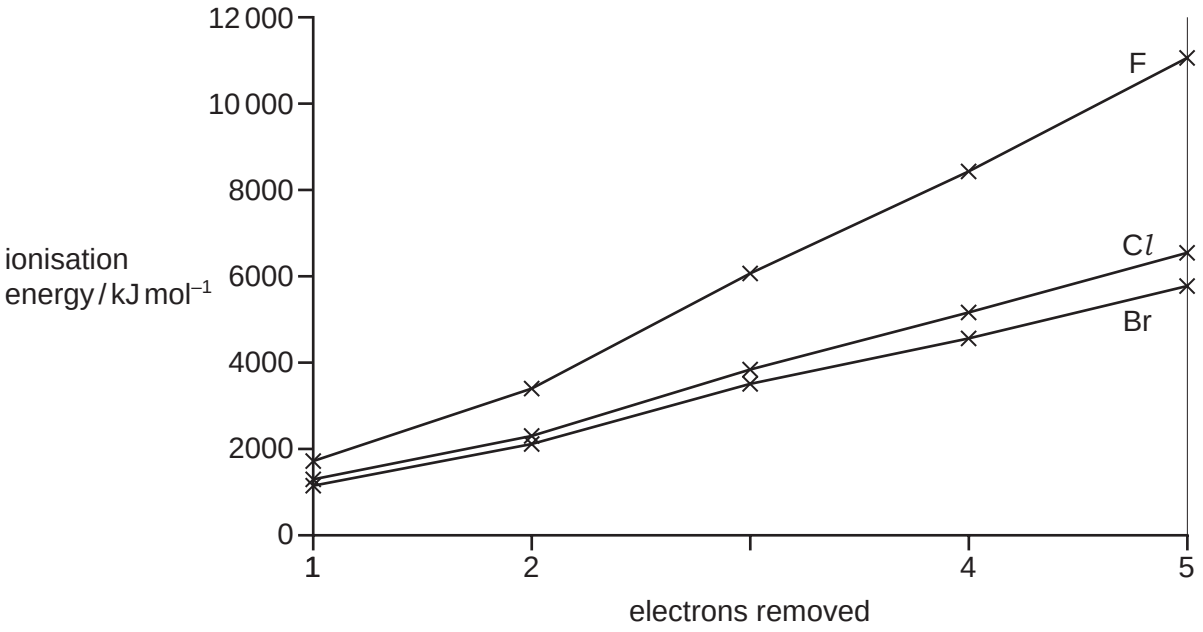
Calculate K_p. Include the units.

K_p = ...

units = ...
[5]

[Total: 19]

2 (a) Successive ionisation energies for the elements fluorine, F, to bromine, Br, are shown on the graph.



(i) Explain why the first ionisation energies decrease down the group.

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..... [3]

(ii) Explain why there is an increase in the successive ionisation energies of fluorine.

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..... [2]

(b) Group VII is the only group in the Periodic Table containing elements in all three states of matter at room conditions.

State and explain, in terms of intermolecular forces, the trend in the boiling points of the elements down Group VII.

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..... [4]

(c) Compounds containing different halogen atoms covalently bonded together are called interhalogen compounds.

(i) One interhalogen compound can be prepared by the reaction between iodine and fluorine. This compound has M_r = 222 and the percentage composition by mass: F, 42.8; I, 57.2.

Calculate the molecular formula of this interhalogen compound.

molecular formula ..... [3]

(ii) Another interhalogen compound has the formula IC*l*.

Draw a 'dot-and-cross' diagram of a molecule of this compound, showing outer shell electrons only. Explain whether or not you would expect this molecule to be polar.

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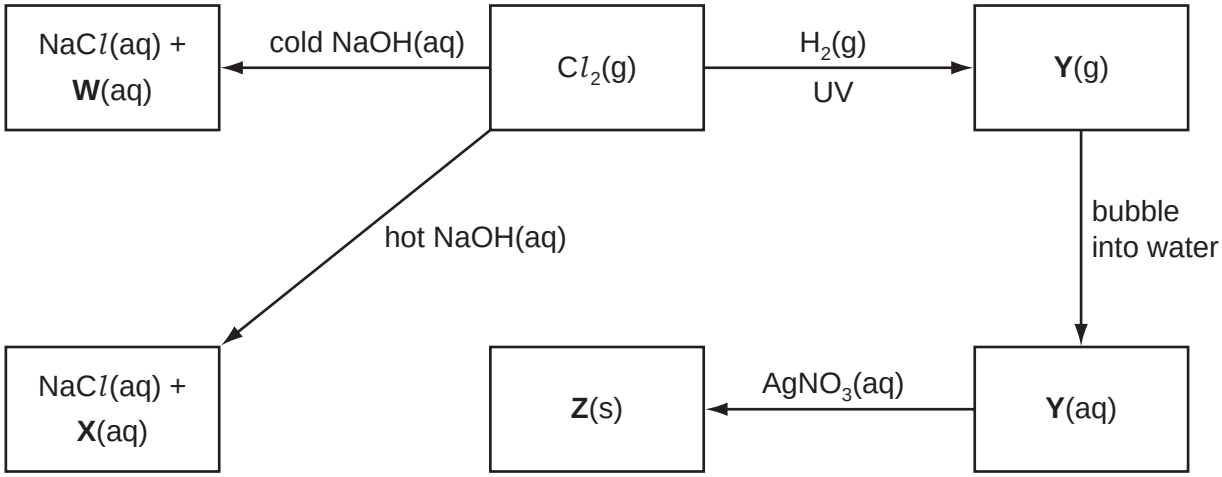
..... [2]

(d) Some reactions involving chlorine and its compounds are shown in the reaction scheme below.



(i) Give the **formulae** of **W**, **X**, **Y** and **Z**.

W .....

X .....

Y .....

Z .....

[4]

(ii) Write an equation for the reaction of chlorine with **hot** NaOH(aq).

..... [2]

(iii) State the oxidation numbers of chlorine at the start and at the end of the reaction in **(ii)**.

..... [2]

(iv) Write an **ionic** equation for the reaction of **Y** with $AgNO_3(aq)$. Include state symbols.

..... [1]

[Total: 23]

3 **(a)** Natural phosphorus consists of one isotope, ^{31}P. Chlorine exists naturally as two isotopes, ^{35}Cl and ^{37}Cl, in the relative abundance ratio of 3 : 1.

(i) The mass spectrum of PCl_3 contains several peaks corresponding to a number of molecular fragments.

Suggest the isotopic composition of the fragments with the following mass numbers.

mass number	isotopic composition
101	
103	
105	

(ii) Predict the relative ratios of the peak heights of the three peaks corresponding to these fragments.

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[4]

(b) Phosphorus reacts with chlorine to form a variety of chlorides.
PCl_5 is an example of a compound that exists as two structures depending on the conditions.

$$2PCl_5(g) \rightleftharpoons [PCl_4]^+[PCl_6]^-(s)$$

(i) Draw a 'dot-and-cross' diagram to show the bonding in PCl_5. Show the outer electrons only.

(ii) Draw diagrams to suggest the shapes of $[PCl_4]^+$ and $[PCl_6]^-$.

$[PCl_4]^+$ $[PCl_6]^-$

[3]

(c) Phosphorus(III) oxide, P_4O_6, contains no P–P or O–O bonds.
In the P_4O_6 molecule, all oxygen atoms are divalent and all phosphorus atoms are trivalent.

Sketch a structure for P_4O_6.

(ii) P_4O_6 can act as a ligand.

What is meant by the term *ligand*?

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.....

[2]

(d) Phosphate ions in water can be removed by adding a solution containing $Ca^{2+}(aq)$ ions, which form a precipitate of calcium phosphate, $Ca_3(PO_4)_2$.

(i) Write an expression for the K_{sp} of $Ca_3(PO_4)_2$.

K_{sp} =

(ii) The solubility of $Ca_3(PO_4)_2$ is 2.50×10^{-6} mol dm^{-3} at 298 K.

Calculate the solubility product, K_{sp}, of $Ca_3(PO_4)_2$ at this temperature. Include the units.

K_{sp} = ... units .....

[4]

(e) What is meant by the term *lattice energy*?

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(ii) Explain why the lattice energy of calcium phosphate is **less** exothermic than that of magnesium phosphate.

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[3]

[Total: 16]