Covalent Bonding & Shapes of Molecules

Question Paper 6

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 6

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

Grade Boundaries:

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

1 The elements of Group IV all form tetrachlorides with the general formula MCl_4.

(a) Draw a diagram of a molecule of $SiCl_4$ stating bond angles.

[2]

(b) Describe and explain how the volatilities of the Group IV chlorides vary down the group.

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..... [2]

(c) The relative stabilities of the $M^{2+}(aq)$ and $M^{4+}(aq)$ ions also vary down Group IV.

(i) Use the *Data Booklet* to illustrate this observation when *M* = Sn and *M* = Pb.

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(ii) Use the *Data Booklet* to predict the products formed, and write equations for the reactions occurring, when

- an equimolar mixture of $Sn^{2+}(aq)$ and $Sn^{4+}(aq)$ is added to $I_2(aq)$,

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- an equimolar mixture of $Pb^{2+}(aq)$ and $Pb^{4+}(aq)$ is added to $SO_2(aq)$.

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[4]

(d) **(i)** The Sn–C*l* bond energy is +315 kJ mol^{-1}. Use this and other values from the *Data Booklet* to calculate $\Delta H^{\ominus}$ for the reaction

$$MCl_2(g) + Cl_2(g) \rightarrow MCl_4(g)$$

for the following cases.

- *M* = Si

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

- *M* = Sn

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

(ii) Do your results agree with the trend in relative stabilities of the +2 and +4 oxidation states in **(c)**? Explain your answer.

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[3]

[Total: 11]

2 Ketene, C_2H_2O, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds.

$CH_2=C=O$

ketene

(a) (i) Suggest values for the H-C-H and C=C=O bond angles in ketene.

H-C-H …… C=C=O ……

(ii) By considering the structure of the molecule, suggest why the name *ketene* is used.

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..... [3]

(b) Ketene burns completely in air to form carbon dioxide and water.

(i) Write a balanced equation for this reaction.

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(ii) Use your equation to calculate the volume of CO_2, in dm^3, measured at room temperature and pressure, which will be formed when 3.5 g of ketene are burned in an excess of air.

Give your answer to **two** significant figures.

volume of CO_2 = ... dm^3 [4]

(c) **(i)** Define the term *standard enthalpy change of formation.*

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(ii) Use the data below to calculate the standard enthalpy change of formation of ketene.

	$\Delta H^{\ominus}$/kJ mol^{-1}
standard enthalpy change of formation of CO_2	–395
standard enthalpy change of combustion of H_2	–286
standard enthalpy change of combustion of $CH_2{=}C{=}O$	–1028

[6]

(d) Ketene can be converted directly into ethanoic acid, CH_3CO_2H, by reaction with a compound **A**.

Suggest the identity of **A**.

.....

[1]

[Total: 14]

3 Ethene, C_2H_4, and hydrazine, N_2H_4, are hydrides of elements which are adjacent in the Periodic Table. Data about ethene and hydrazine are given in the table below.

	C_2H_4	N_2H_4
melting point/°C	–169	+2
boiling point/°C	–104	+114
solubility in water	insoluble	high
solubility in ethanol	high	high

(a) Ethene and hydrazine have a similar arrangement of atoms but differently shaped molecules.

(i) What is the H-C-H bond angle in ethene?

.....

(ii) Draw a 'dot-and-cross' diagram for hydrazine.

(iii) What is the H-N-H bond angle in hydrazine?

.....

[4]

(b) The melting and boiling points of hydrazine are much higher than those of ethene. Suggest reasons for these differences in terms of the intermolecular forces **each** compound possesses.

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.....[3]

(c) Explain, with the aid of a diagram showing lone pairs of electrons and dipoles, why hydrazine is very soluble in ethanol.

[3]

Ethene and hydrazine each react with HC*l*.

(d) When ethene is reacted with HC*l*, C_2H_5Cl is the only product.

(i) Using structural formulae, give an equation for the reaction between ethene and HC*l*.

(ii) What type of reaction occurs between HC*l* and ethene?

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(iii) Explain why there is no further reaction between C_2H_5Cl and HC*l*.

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[3]

(e) When aqueous hydrazine is reacted with HC*l*, a solid compound of formula N_2H_5Cl may be isolated. When an excess of HC*l* is used, a second solid, $N_2H_6Cl_2$, is formed.

(i) Suggest what type of reaction occurs between hydrazine and HC*l*.

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(ii) What feature of the hydrazine molecule enables this reaction to occur?

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(iii) Suggest why one molecule of hydrazine is able to react with one or two molecules of HC*l*.

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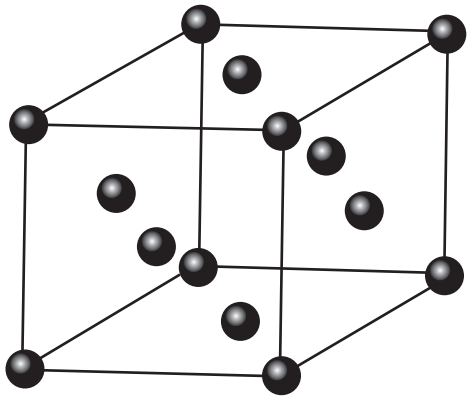
[3]

[Total: 16]

4 Copper and iodine are both solids which have different physical and chemical properties. Each element has the same face-centred crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, anions or cations. In the diagram above, the particles present are represented by ● .

(a) Which type of particles are present in the iodine crystal? Give their formula.

particle .....

formula ..... [2]

(b) When separate samples of copper or iodine are heated to 50 °C, the copper remains as a solid while the iodine turns into a vapour.

(i) Explain, in terms of the forces present in the solid structure, why copper remains a solid at 50 °C.

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(ii) Explain, in terms of the forces present in the solid structure, why iodine turns into a vapour when heated to 50°C.

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[4]

(c) **(i)** Although copper is a relatively unreactive metal, when it is heated to a high temperature in an excess of chlorine, copper(II) chloride is formed.

How does chlorine behave in this reaction?

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(ii) When a mixture of copper and iodine is heated to a high temperature, no reaction occurs.

Suggest a reason for this difference.

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[2]

[Total: 8]

5 Carbon disulphide, CS_2, is a volatile, stinking liquid which is used to manufacture viscose rayon and cellophane.

(a) The carbon atom is in the centre of the CS_2 molecule.

Draw a 'dot-and-cross' diagram of the carbon disulphide molecule.

Show outer electrons only.

[2]

(b) Suggest the shape of the molecule and give its bond angle.

shape .....

bond angle ..... [2]

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

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..... [3]

(d) Calculate the standard enthalpy change of formation of CS_2 from the following data.

standard enthalpy change of formation of SO_2 = $-298\ kJ\ mol^{-1}$

standard enthalpy change of formation of CO_2 = $-395\ kJ\ mol^{-1}$

standard enthalpy change of combustion of CS_2 = $-1110\ kJ\ mol^{-1}$

[3]

(e) Carbon disulphide reacts with nitrogen monoxide, NO, to form a yellow solid and two colourless gases which are produced in a 1:1 molar ratio.

Deduce the identity of **each** gas and write a balanced equation for the reaction.

gases ..... and .....

equation ..... [3]

[Total: 13]