The Periodic Table: Chemical Periodicity

Question Paper 4

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	The Periodic Table: Chemical Periodici
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 4

Time Allowed: **77 minutes**

Score: **/64**

Percentage: **/100**

Grade Boundaries:

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

1 **(a)** Phosphorus and sulfur are two non-metallic elements on the right hand side of the Periodic Table.
For each of these elements describe the observations you would make when it burns in air, and write a balanced equation for the reaction.

phosphorus

observation .....

equation .....

sulfur

observation .....

equation .....

[4]

(b) White phosphorus, P_4, is produced commercially by heating calcium phosphate(V) rock with a mixture of silica, SiO_2, and coke in an electric furnace at 1400 °C. Calcium silicate, $CaSiO_3$, and carbon monoxide are the other products.

(i) Balance the following equation which represents the overall process.

___ $Ca_3(PO_4)_2$ + ___ SiO_2 + ___ C → ___ P_4 + ___ $CaSiO_3$ + ___ CO

When heated to 400 °C in the absence of air, white phosphorus is changed into the red form of the element. The following table lists some of the properties of the two forms, which are known as allotropes.

allotrope	electrical conductivity	melting point / °C	solubility in water	solubility in benzene
white	none	44	insoluble	soluble
red	none	500	insoluble	insoluble

(ii) Suggest the type of structure and bonding in each allotrope.

allotrope	type of structure	type of bonding
white		
red		

(iii) In both allotropes, phosphorus has a valency of 3. Suggest by means of diagrams how the phosphorus atoms might be joined together in each allotrope.

white phosphorus	red phosphorus

[7]

[Total: 11]

2 **(a)** Fluorine is much more electronegative than both silicon and sulfur, but whereas the molecule of SF_4 has an overall dipole, that of SiF_4 has none.

Suggest a reason for this difference.

.....

..... [1]

(b) Predict whether or not the following molecules will have an overall dipole. Place a tick in the appropriate column.

compound	molecule has an overall dipole	molecule does not have an overall dipole
BCl_3		
PCl_3		
CCl_4		
SF_6		

[2]

(c) Boron and silicon are two elements adjacent to carbon in the periodic table. CCl_4 does not react with water, whereas BCl_3 and $SiCl_4$ do react.

(i) Suggest a reason for this difference in reactivity.

.....

.....

(ii) Construct equations showing the reaction of these two chlorides with an excess of water.

BCl_3 .....

$SiCl_4$ .....

[3]

(d) When reacted with a small quantity of water, $SiCl_4$ produces an oxychloride **X**, $Si_xCl_yO_z$. The mass spectrum of **X** shows peaks at mass numbers of 133, 149, 247, 263 and 396. (You should assume that the species responsible for all these peaks contain the ^{16}O, the ^{35}Cl and the ^{28}Si isotopes only.)

(i) Use these data to deduce the molecular formula of **X**.

molecular formula .....

(ii) Suggest the structures of the fragments responsible for the peaks at the following mass numbers.

mass number	structure
133	
247	
263	

(iii) Hence suggest the displayed formula of **X**.

[5]

[Total: 11]

3 The most typical oxides of tin and lead are SnO, SnO_2, PbO and PbO_2.

The following two generalisations can be made about the oxides of the elements in Group IV.

- As the metallic character of the elements increases down the Group, the oxides become more basic.
- The oxides of the elements in their higher oxidation states are more acidic than the oxides of the elements in their lower oxidation states.

(a) Use these generalisations to suggest which of the above oxides of tin or lead is **most likely** to react with each of the following reagents. In each case write a balanced equation for the reaction.

(i) with NaOH(aq)

formula of oxide .....

equation .....

(ii) with HC*l*(aq)

formula of oxide .....

equation .....

[4]

(b) 'Red lead' is used as a pigment, and as a metal primer paint to prevent the corrosion of steel. It is an oxide of lead that contains 9.30% oxygen by mass.

Calculate to **3 significant figures** the number of moles of oxygen and lead contained in a 100.0 g sample of red lead. Hence calculate its empirical formula.

empirical formula: ..... [2]

(c) Lead(II) chloride is slightly soluble in water.

$$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^-(aq) \qquad K_{sp} = 2.0 \times 10^{-5}$$

(i) Write an expression for the solubility product, K_{sp} for lead(II) chloride and state its units.

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

(ii) Calculate $[Pb^{2+}(aq)]$ in a saturated solution of $PbCl_2$.

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An excess of $PbCl_2(s)$ is stirred with $0.50\,mol\,dm^{-3}$ $NaCl$ until equilibrium has been established. The excess $PbCl_2(s)$ is then filtered off.

(iii) Assuming $[Cl^-]$ remains at $0.50\,mol\,dm^{-3}$ throughout, calculate the $[Pb^{2+}(aq)]$ in the remaining solution.

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(iv) Suggest an explanation for the difference between this value and the value that you calculated in **(ii)**.

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[4]

[Total: 10]

4 The elements carbon and silicon are both in Group IV of the Periodic Table.
Carbon is the second most abundant element by mass in the human body and silicon is the second most common element in the Earth's crust.

Carbon and silicon each form an oxide of general formula XO_2.
At room temperature, CO_2 is a gas while SiO_2 is a solid with a high melting point.

(a) Briefly explain, in terms of the chemical bonds and intermolecular forces present in **each** compound, why CO_2 is a gas and SiO_2 is a solid at room temperature.

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..... [3]

(b) Draw a simple diagram to show the structure of SiO_2. Your diagram should contain at least **two** silicon atoms **and** show clearly how many bonds each atom forms.

[2]

CO_2 does not behave as an ideal gas.

(c) **(i)** State the basic assumptions of the kinetic theory as applied to an ideal gas.

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(ii) Suggest **one** reason why CO_2 does not behave as an ideal gas.

.....

[5]

Carbon exists in a number of forms, one of which is a conductor of electricity and one of which is a non-conductor of electricity. Silicon is the main component of most semi-conductors.

(d) Graphite is the form of carbon that is a conductor of electricity. Give a simple explanation for this property.

.....

..... [1]

When carbon and silicon(IV) oxide are heated together at about 2000 °C, silicon carbide, SiC, is formed. Silicon carbide is a hard material which is widely used as an abrasive and in ceramics.

(e) **(i)** Construct an equation for the reaction of carbon and silicon(IV) oxide.

.....

(ii) SiC has a similar structure to one of the common forms of carbon.
Which form is this? Give a reason for your answer.

form .....

reason .....

[2]

[Total: 13]

5 **(a)** The Group IV oxides CO_2 and SiO_2 differ widely in their physical properties. Describe these differences and explain them in terms of their structure and bonding.

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..... [3]

(b) What are the properties of a *ceramic* material? Why is silicon(IV) oxide very suitable as a component of ceramics?

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..... [2]

(c) Lead(II) oxide reacts with both acids and bases.

(i) What is the name given to oxides that have this property?

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(ii) Write a balanced equation for the reaction between PbO and NaOH.

.....
[2]

(d) Tin forms an oxide, **A**, that contains the metal in both oxidation states II and IV. The formula of **A** can be found by the following method.

- A sample of **A** was dissolved in H_2SO_4(aq), producing solution **B**, which was a mixture of tin(II) sulfate and tin(IV) sulfate.
- A 25.0 cm^3 sample of solution **B** was titrated with 0.0200 mol dm^{-3} $KMnO_4$. 13.5 cm^3 of $KMnO_4$ was required to reach the end-point.
- Another 25.0 cm^3 sample of solution **B** was stirred with an excess of powdered zinc. This converted all the tin into tin(II). The excess of zinc powder was filtered off and the filtrate was titrated with 0.0200 mol dm^{-3} $KMnO_4$, as before. This time 20.3 cm^3 of $KMnO_4$ was required to reach the end-point.

The equation for the reaction occurring during the titration is as follows.

$$2MnO_4^- + 16H^+ + 5Sn^{2+} \longrightarrow 2Mn^{2+} + 8H_2O + 5Sn^{4+}$$

(i) Write a balanced equation for the reaction between Zn and Sn^{4+}.

.....

(ii) Use the *Data Booklet* to calculate the $E^{\ominus}$ values for the reactions between

- Zn and Sn^{4+}, ...
- MnO_4^- and Sn^{2+}.. .....

(iii) Use the results of the two titrations to calculate

- the number of moles of Sn^{2+} in the first titration sample,

.....

.....

- the number of moles of Sn^{2+} in the second titration sample.

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(iv) Use the results of your calculation in **(iii)** to deduce the Sn^{2+}/ Sn^{4+} ratio in the oxide **A**, and hence suggest the formula of **A**.

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[8]

(e) A major use of tin is to make 'tin plate', which is composed of thin sheets of mild steel electroplated with tin, for use in the manufacture of food and drinks cans. A tin coating of 1.0×10^{-5} m thickness is often used.

(i) Calculate the volume of tin needed to coat a sheet of steel 1.0 m × 1.0 m to this thickness, on one side only.

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(ii) Calculate the number of moles of tin that this volume represents.
[The density of tin is 7.3 g cm^{-3}.]

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(iii) The solution used for electroplating contains Sn^{2+} ions. Calculate the quantity of electricity in coulombs needed to deposit the amount of tin you calculated in **(ii)**.

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[4]

[Total: 19]