

# 9. The Periodic Table: Chemical Periodicity

## 9.2 Periodicity of chemical properties

### Paper 2

#### Question Paper

1 (e) Two Period 3 elements react with an excess of oxygen at room pressure.

(i) Complete Table 1.2.

Table 1.2

1	2	3
Period 3 element	state of oxide at room temperature and pressure	approximate pH of solution made when oxide is added to water
Na		
S		

[2]

(ii) The solutions made in column 3 of Table 1.2 are mixed together. Name the type of reaction that occurs.

..... [1]

(iii) Write an equation to describe the reaction between  $P_4O_{10}$  and an excess of water.

..... [1]

(f) Aluminium hydroxide is amphoteric.

(i) Explain what is meant by amphoteric.

.....  
 ..... [1]

(ii) Write an equation to describe the reaction that occurs when aluminium hydroxide,  $Al(OH)_3$ , reacts with  $NaOH(aq)$ .

..... [1]

2 (a) Sulfur chloride,  $SCl_2$ , is a liquid at room temperature. When  $SCl_2$  is added to water, misty fumes are seen and a solution is made that turns universal indicator red.

(i) Identify the type of reaction that occurs when  $SCl_2$  is added to water.

..... [1]

(ii) Name a chloride of a different Period 3 element that is also a liquid at room temperature and produces misty fumes when added to water.

..... [1]

**3** The Group 14 elements show a change from non-metallic to metallic character down the group.

**(e)** Silicon readily reacts with elements of high electronegativity.

**(i)** Write an equation for the formation of  $\text{SiCl}_4$  from its constituent elements.

..... [1]

**(ii)** Describe what is observed when a small sample of  $\text{SiCl}_4$  is added to water.

.....  
..... [1]

**(iii)**  $\text{SiO}_2$  is a white solid that melts above  $1700^\circ\text{C}$ .

$\text{SiCl}_4$  is a colourless liquid at room temperature.

Explain the difference in the melting points of these two compounds with reference to their structure and bonding.

.....  
.....  
.....  
.....  
..... [2]

**(f)** Tin forms an amphoteric oxide,  $\text{SnO}_2$ .

Suggest the formula of the tin compound that forms when  $\text{SnO}_2$  reacts with  $\text{H}_2\text{SO}_4$  in an acid–base reaction.

..... [1]

**4** Oxygen is a Group 16 element.

**(a) (i)** Write equations for the following reactions.

- sodium and oxygen

.....

- sulfur and oxygen

.....

[2]

**(ii)** Draw a dot-and-cross diagram to show the species present in  $Al_2O_3$ .

Draw outer electrons only.

[1]

**(iii)** The maximum oxidation state of the Period 3 elements in their oxides varies across the period.

State and explain the variation.

.....

.....

.....

[2]

(b)  $\text{H}_2\text{O}$  reacts with both inorganic and organic compounds.

(i) Complete Table 2.1 to give details of the reactions of some Period 3 oxides with  $\text{H}_2\text{O}$ .

**Table 2.1**

Period 3 oxide	product of reaction with $\text{H}_2\text{O}$	pH of solution formed
	$\text{Mg}(\text{OH})_2$	
$\text{P}_4\text{O}_{10}$		

[2]

**5** Tellurium is an element in Group 16. The most common isotope of tellurium is  $^{130}\text{Te}$ . Its electronic configuration is  $[\text{Kr}] 4d^{10} 5s^2 5p^4$ .

(f)  $\text{TeF}_x$  reacts with water to form tellurium hydroxide and HF. The oxidation number of tellurium does **not** change during this reaction.

(i) Construct an equation for the reaction of  $\text{TeF}_x$  with water.

..... [1]

(ii) Name the type of reaction that occurs when  $\text{TeF}_x$  reacts with water.

..... [1]

**6** Chlorine is a very reactive element.

- (a) Chlorine reacts with silicon to form silicon(IV) chloride.  
Describe the appearance of silicon(IV) chloride at room temperature and pressure. State its structure and bonding.

appearance .....

structure and bonding .....

[2]

- (b) Samples of magnesium chloride and phosphorus(V) chloride are added to separate beakers of cold water.

Complete Table 3.1. Ignore temperature changes when considering observations for these reactions.

**Table 3.1**

	magnesium chloride	phosphorus(V) chloride
appearance at room temperature		
one similarity in observation on addition to cold water		
one difference in observation on addition to cold water		
pH of final solution		

[4]

**7** Chlorine is a reactive element. It forms many compounds.

- (a) (i) Complete Table 2.1 to show the maximum oxidation number of the elements Na to P in their chlorides.

**Table 2.1**

element	Na	Mg	Al	Si	P
maximum oxidation number					

[1]

- (ii) State what determines the maximum oxidation number of elements in Period 3.

.....

..... [1]

- (b) An excess of cold water is added to the chloride of silicon.

- (i) Write an equation for the reaction between an excess of cold water and the chloride of silicon.

..... [1]

- (ii) Suggest the pH of the solution produced in (b)(i).

..... [1]

- (c) An excess of cold water is added to the chloride of phosphorus.

- (i) Write an equation for the reaction between an excess of cold water and the chloride of phosphorus.

..... [1]

- (ii) Suggest the pH of the solution produced in (c)(i).

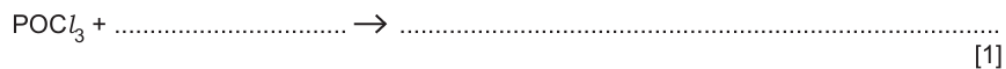
..... [1]

- 8 (d)  $\text{POCl}_3$  shows similar chemical properties to  $\text{PCl}_5$ .

$\text{POCl}_3$  has a melting point of  $1^\circ\text{C}$  and a boiling point of  $106^\circ\text{C}$ .

$\text{POCl}_3$  reacts vigorously with water, forming misty fumes and an acidic solution.

- (ii) Construct an equation for the reaction of  $\text{POCl}_3$  with water.



- 9 Some of the common chlorides of Period 3 elements are shown in the list.



- (a) From this list, identify:

- (i) all the chlorides that have giant ionic structures in the solid state

..... [1]

- (ii) all the chlorides that react vigorously with water to form strongly acidic solutions

..... [1]

- (iii) the chloride that dissolves in water to form a neutral solution

..... [1]

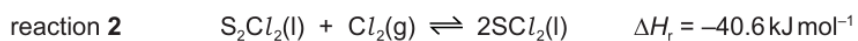
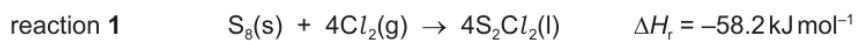
- (iv) the chloride formed from the **element** with the highest melting point.

..... [1]

**10** Some of the common chlorides of Period 3 elements are shown in the list.



(d) Sulfur,  $\text{S}_8$ , reacts with chlorine to form several different chlorides. The most common are  $\text{S}_2\text{Cl}_2$  and  $\text{SCl}_2$ .  $\text{SCl}_2$  forms when sulfur reacts with an excess of chlorine.



(i)  $\text{SCl}_2$  is a cherry-red liquid that reacts vigorously with water to form an acidic solution.

Use this information to deduce the bonding and structure shown by  $\text{SCl}_2$ .  
Explain your answer.

.....

.....

..... [2]

- 11** The chlorides of some of the Period 3 elements are shown in Table 2.1.

**Table 2.1**

Period 3 chloride	NaCl	AlCl <sub>3</sub>	SiCl <sub>4</sub>	PCl <sub>5</sub>	PCl <sub>3</sub>	SCl <sub>2</sub>
bonding					C	C
structure					S	S
oxidation state of Period 3 element						

- (a) Complete Table 2.1.

- Identify the bonding shown by each chloride under standard conditions. Use C = covalent, I = ionic, M = metallic.
- Identify the structure shown by each chloride under standard conditions. Use G = giant, S = simple.
- Deduce the oxidation state of the Period 3 element in each chloride.

[4]

- (b) Write equations for the reactions of NaCl and PCl<sub>5</sub> with water. Include state symbols in both equations.

NaCl .....

PCl<sub>5</sub> .....

[3]

- 12** Phosphorus, sulfur and chlorine can all react with oxygen to form oxides.

- (a) Phosphorus reacts with an excess of oxygen to form phosphorus(V) oxide.

- (i) Write an equation to show the reaction of phosphorus with excess oxygen.

..... [1]

- (ii) Describe the reaction of phosphorus(V) oxide with water.

.....

.....

..... [2]

**13** The Period 3 elements, Na to S, all react with oxygen to form oxides.

(a) State the trend in acid/base behaviour of the oxides of the Period 3 elements, from Na to S.

.....  
 ..... [1]

(b) State and explain the trend, from Na to S, in the maximum oxidation number of the Period 3 elements in their oxides.

.....  
 .....  
 ..... [2]

(c) Sodium oxide and phosphorus(V) oxide both react with water.

**Name** the product of each reaction.

reaction	product
sodium oxide with water	
phosphorus(V) oxide with water	

[2]

(e) Aluminium oxide,  $Al_2O_3$ , reacts separately with both acids and alkalis.

(i) Write an equation for the reaction of aluminium oxide with excess aqueous hydrochloric acid.

..... [1]

(ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

..... [1]

- (g) Sodium oxide and silicon(IV) oxide react to form sodium silicate(IV),  $\text{Na}_2\text{SiO}_3$ .

Sodium oxide is obtained from the thermal decomposition of sodium carbonate.

Write equations for the following reactions:

- (i) sodium oxide with silicon(IV) oxide

..... [1]

- (ii) the thermal decomposition of sodium carbonate, forming sodium oxide and carbon dioxide.

..... [1]

- 14**  $\text{PCl}_5$ ,  $\text{PCl}_3$  and  $\text{NCl}_3$  are halides of Group 15 elements.

- (a)  $\text{PCl}_5$  can be formed from the reaction of phosphorus with chlorine.  $\text{PCl}_5$  has a melting point of  $161^\circ\text{C}$ .

- (i) Write an equation for the formation of  $\text{PCl}_5$  from the reaction of phosphorus and chlorine.

..... [1]

- (ii) State the type of structure and bonding shown by liquid  $\text{PCl}_5$ .

..... [1]

- (b) A small amount of  $\text{PCl}_5$  is added to excess water. The  $\text{PCl}_5$  reacts vigorously to form a colourless solution.

- (i) Give **one** other observation you would make when  $\text{PCl}_5$  reacts with excess water.

..... [1]

- (ii) Write the equation for the reaction of  $\text{PCl}_5$  with excess water.

..... [1]

- (iii) Estimate the pH of the resulting solution.

..... [1]

**15** Magnesium silicide,  $Mg_2Si$ , is a compound made by heating magnesium with sand.

(f) Silicon dioxide reacts with hot, concentrated sodium hydroxide.

(i) Identify the **two** products formed during this reaction.

.....  
 ..... [2]

(ii) Describe the behaviour of the silicon dioxide during this reaction.

..... [1]

**16** Period 3 elements react with chlorine gas,  $Cl_2(g)$ , to form chlorides.

(a) The table shows the differences in observations which occur when two Period 3 chlorides are added to water.

Period 3 chloride	observations when added to water	pH of solution formed with water
$NaCl$	White solid disappears. Colourless solution made.	7
$SiCl_4$	Pale yellow solution forms. Bubbles form and the test-tube feels hot. White precipitate forms.	1–2

(i) Write an equation for the reaction occurring when  $SiCl_4$  is added to cold water. Include state symbols.

..... [1]

(ii) Name the type of reaction occurring when  $SiCl_4$  is added to water. Ignore the exothermic/endothermic nature of the reaction.

..... [1]

- 17 (a)** Complete the table to give details of the type of bonding and structure shown by some of the oxides of Period 3 elements.

	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	SO <sub>3</sub>
boiling point/°C	1275	3670	2977	2950	45
nature of oxide	basic	basic	amphoteric	acidic	acidic
bonding					
structure					

[2]