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 $SiCl_4$ from its constituent elements.

..... [1]

(ii) Describe what is observed when a small sample of $SiCl_4$ is added to water.

.....

..... [1]

(iii) SiO_2 is a white solid that melts above 1700 °C.

$SiCl_4$ 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, SnO_2.

Suggest the formula of the tin compound that forms when SnO_2 reacts with H_2SO_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) H_2O reacts with both inorganic and organic compounds.

(i) Complete Table 2.1 to give details of the reactions of some Period 3 oxides with H_2O.

Table 2.1

Period 3 oxide	product of reaction with H_2O	pH of solution formed
	$Mg(OH)_2$	
P_4O_{10}		

[2]

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

(f) 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 TeF_x with water.

..... [1]

(ii) Name the type of reaction that occurs when 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)** $POCl_3$ shows similar chemical properties to PCl_5.

$POCl_3$ has a melting point of 1°C and a boiling point of 106 °C.

$POCl_3$ reacts vigorously with water, forming misty fumes and an acidic solution.

(ii) Construct an equation for the reaction of $POCl_3$ with water.

$POCl_3$ + ... → .....
[1]

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

$NaCl$ $MgCl_2$ $AlCl_3$ $SiCl_4$ PCl_5

(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.

$$NaCl \quad MgCl_2 \quad AlCl_3 \quad SiCl_4 \quad PCl_5$$

(d) Sulfur, S_8, reacts with chlorine to form several different chlorides. The most common are S_2Cl_2 and SCl_2. SCl_2 forms when sulfur reacts with an excess of chlorine.

reaction **1** $S_8(s) + 4Cl_2(g) \rightarrow 4S_2Cl_2(l)$ $\Delta H_r = -58.2\,kJ\,mol^{-1}$

reaction **2** $S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$ $\Delta H_r = -40.6\,kJ\,mol^{-1}$

(i) 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 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	$NaCl$	$AlCl_3$	$SiCl_4$	PCl_5	PCl_3	SCl_2
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_5 with water.
Include state symbols in both equations.

$NaCl$ .....

PCl_5 .....

[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), Na_2SiO_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 PCl_5, PCl_3 and NCl_3 are halides of Group 15 elements.

(a) PCl_5 can be formed from the reaction of phosphorus with chlorine. PCl_5 has a melting point of 161 °C.

(i) Write an equation for the formation of PCl_5 from the reaction of phosphorus and chlorine.

..... [1]

(ii) State the type of structure and bonding shown by liquid PCl_5.

..... [1]

(b) A small amount of PCl_5 is added to excess water. The PCl_5 reacts vigorously to form a colourless solution.

(i) Give **one** other observation you would make when PCl_5 reacts with excess water.

..... [1]

(ii) Write the equation for the reaction of 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_2O	MgO	Al_2O_3	SiO_2	SO_3
boiling point / °C	1275	3670	2977	2950	45
nature of oxide	basic	basic	amphoteric	acidic	acidic
bonding					
structure					

[2]