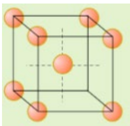
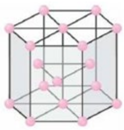
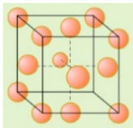
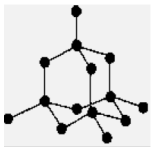
9 The Periodic Table: chemical periodicity

9.2 Periodicity of **chemical properties** of the elements in Period 3

1 Bonding and structures

Group	**1**	**2**	**3**	**4**
Element	sodium	magnesium	aluminium	silicon
Character	Metal			Metalloid
Structure	Giant metallic lattice			Macromolecular
Bonding	Metallic bonds between cations and delocalised electrons			Covalent bonds between atoms
Diagram				

2 Reaction of elements with oxygen

Element	**Product and state**	**Reaction observation**	**Structure**	**Oxidation number**	**Nature**
Na	$Na_2O(s)$	Burns yellow flame	Giant ionic lattice	+1	Basic
Mg	$MgO(s)$	Burns blinding white flame		+2	Basic
Al	$Al_2O_3(s)$	Coating		+3	Amphoteric
Si	$SiO_2(s)$	Coating	Giant covalent	+4	Weakly acidic
P	$P_4O_{10}(s)$	Burns yellow flame	Simple molecular	+5	Strongly acidic
S	$SO_2(g)$ $SO_3(g)$	Burns blue flame		+4 +6	Strongly acidic

From Na to P, state the relationship between the group number and the highest oxidation number:
The highest oxidation number of the element is the same as the group number.
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3 Reaction of Na and Mg with water and/or steam

Element	Reaction equation	Observation
Na	$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$	Very fast, forms ball and floats, dissolves, fizzing
Mg	$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2(g)$	Very slow
Mg	$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$	Very slow

Note: $Mg(OH)_2$ is only slightly soluble

4 Reaction of oxides with water

Oxide	Reaction equation	Oxidation no.	Nature	pH
$Na_2O(s)$	$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$	+1	Strongly alkaline	13
$MgO(s)$	$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$	+2	Weakly alkaline	9-11
$Al_2O_3(s)$	$Al_2O_3(s) + H_2O(l) \rightarrow$ insoluble, no reaction	+3	Amphoteric	-
$SiO_2(s)$	$SiO_2(s) + H_2O(l) \rightarrow$ insoluble, no reaction	+4	Acidic	-
$P_4O_{10}(s)$	$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$	+5	Strongly acidic	2
$SO_2(g)$ $SO_3(g)$	$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$	+4 +6	Strongly acidic	2

5 Acid/base behaviour

Oxide	Acid-base reaction equation
$Na_2O(s)$	$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l)$
$MgO(s)$	$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$
$Al_2O_3(s)$	$Al_2O_3(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2O(l)$
	$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$ Note: use hot conc. NaOH(aq)
$SiO_2(s)$	$SiO_2(aq) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$ Note: use hot conc. NaOH(aq)
$P_4O_{10}(s)$	$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$
$SO_2(g)$ $SO_3(g)$	No excess NaOH: $SO_2(g) +$ $NaOH(aq) \rightarrow NaHSO_3(aq)$ $SO_3(g) +$ $NaOH(aq) \rightarrow NaHSO_4(aq)$
	With excess NaOH: $SO_2(g) +$ $NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$ $SO_3(g) +$ $NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$

What does the dual nature of Al_2O_3 tells us about its bonding?

It is amphoteric, so it must have ionic bonding with covalent character

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6 Reactions of elements with chlorine

Element	Product and state	Structure	Oxidation number	Nature
Na	$NaCl(s)$ bright orange flame	Giant ionic	+1	Neutral
Mg	$MgCl_2(s)$ bright white flame		+2	Neutral
Al	$AlCl_3(s)$ pale yellow	(s): simple molecular (g): ionic	+3	Acidic
Si	$SiCl_4(l)$ colourless liquid	Simple molecular	+4	Strongly acidic
P	$PCl_3(l)$ $PCl_5(l)$ white phosphorus burns spontaneously, off-white solid		+3 +5	Strongly acidic
S*	$S_2Cl_2(l)$ $SCl_2(l)$		+1 +2	Strongly acidic

*not in syllabus

From Na to P, state the relationship between the group number and the highest oxidation number:
The highest oxidation number of the element is the same as the group number.
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7 Reactions of chloride with water

Chloride	Reaction equation	Observation	Nature	pH
$NaCl(s)$	$NaCl(s) + H_2O(l) \rightarrow NaCl(aq)$	Dissolves to give colourless solution	Neutral	7
$MgCl_2(s)$	$MgCl_2(s) + H_2O(l) \rightarrow MgCl_2(aq)$		Near neutral	6.5
$Al_2Cl_6(s)$	$AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$	White fumes	Acidic	3
$SiCl_4(l)$	$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$ Observation: off-white ppt forms		Acidic	2
$PCl_3(l)$* $PCl_5(s)$	*$PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$ $PCl_5(l) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$		Acidic	2 2

*not in syllabus

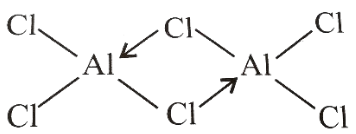
NaCl is purely ionic, so it simply dissolves in water. Water is polar ∴ positive Na^+ is attracted to OH^- while Cl^- is attracted to H^+.

$MgCl_2$ is slightly acidic because Mg ion has smaller radius and higher charge attraction to water is so strong that H_2O loses a proton and solution becomes slightly acidic.

$[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^{+}(aq) + H^+(aq)$

$AlCl_3$:

As anhydrous crystal, it exists as dimer Al_2Cl_6; covalent.



As hydrated crystal or gaseous phase, it exists as ions Al^{3+} and Cl^-; ionic.

When water is added, the dimer Al_2Cl_6 is broken down and Al^{3+} and Cl^- enter the solution. Each Al^{3+} ion is hydrated and causes a water molecule bonded to it to lose an H^+ ion, thus turning the solution acidic.

$[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$

$SiCl_4$ and **PCl_5** are hydrolysed in water, releasing white fumes of hydrogen chloride gas in a rapid reaction:

$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(g)$

The SiO_2 is seen as an off-white precipitate. Some of the HCl gas dissolves to form $HCl(aq)$.

$PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(g)$