

PROSPERITY ACADEMY

**AS CHEMISTRY 9701**

**Crash Course**

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**PERIODICITY**

**COMPLETE NOTES**



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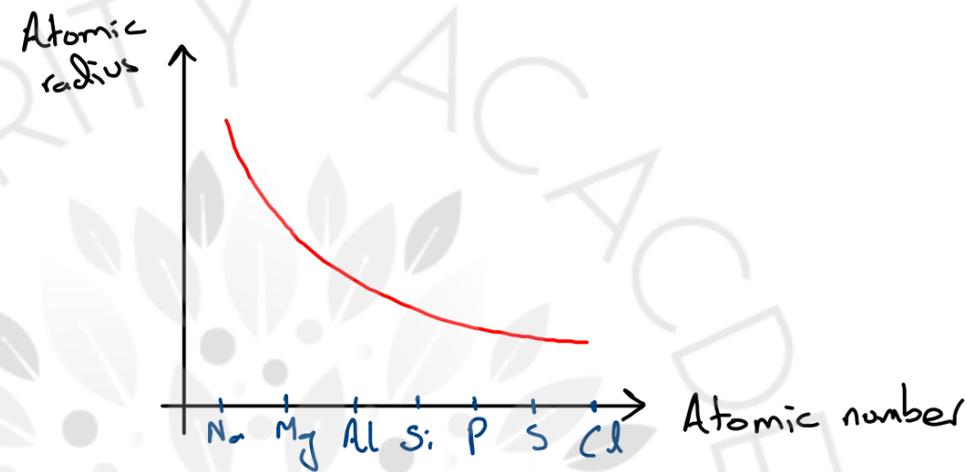


# Periodicity: Period 3

Trend in atomic radius:-

- Atomic radius decreases down the group

- 1) Nuclear charge increases
- 2) Shielding remains constant
- 3) The valence electrons experience a stronger pull



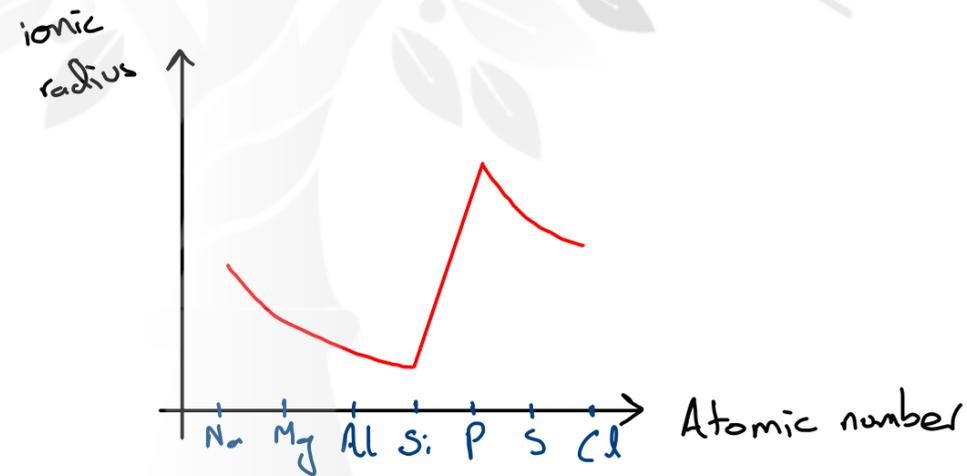
2) Trend in ionic radius:-

-  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Si}^{4+}$ ,  $\text{P}^{3-}$ ,  $\text{S}^{2-}$ ,  $\text{Cl}^{-}$   
- Na  $\rightarrow$  Si decreases and P  $\rightarrow$  Cl decreases

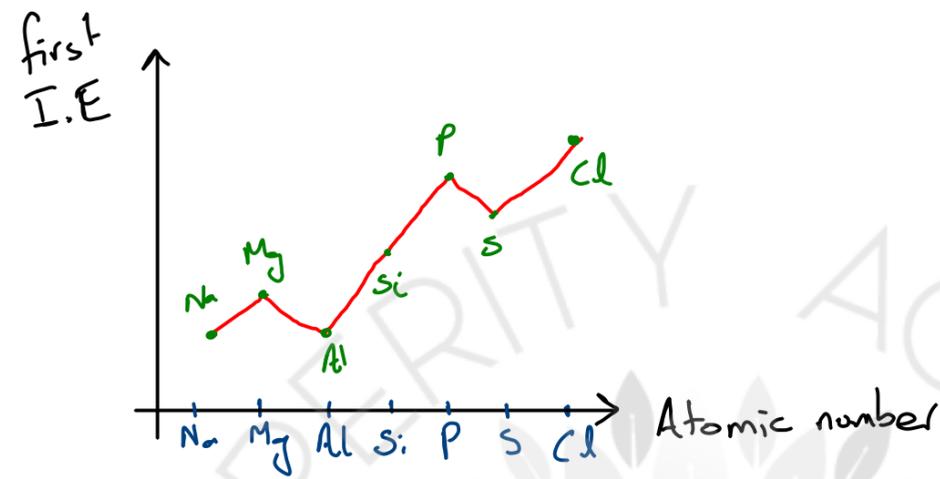
- 1) nuclear charge increases
- 2) Shielding remains constant
- 3) The valence electrons experience a stronger pull

- Increases between Si and P as

The cations have 2 shells, the anions have 3 shells



Trend in ionisation energy:-  
Visit chapter atomic structure.



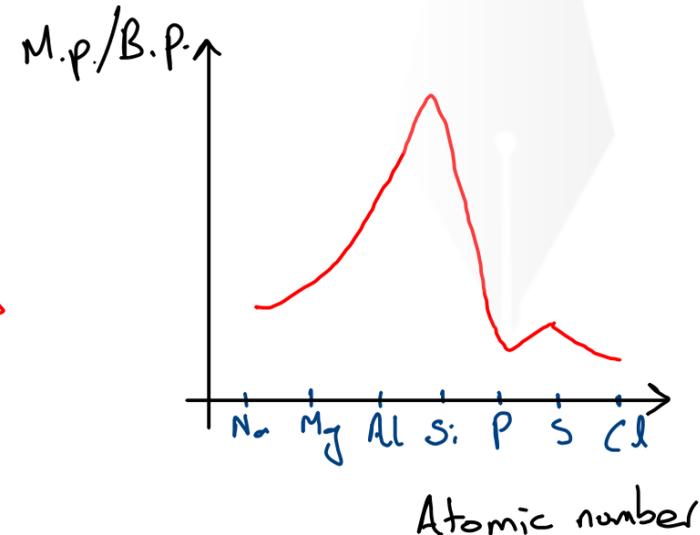
Structures and bonding:-

Na	] Metallic bonding → Giant metallic structures
Mg	
Al	
Si	→ Giant Covalent → high melting and boiling point, semiconductor
P <sub>4</sub>	] Simple molecular
S <sub>8</sub>	
Cl <sub>2</sub>	

- high melting and boiling points  
 - good conductivity  
 - low melting and boiling points  
 - poor conductivity

Trend in melting/boiling point:-

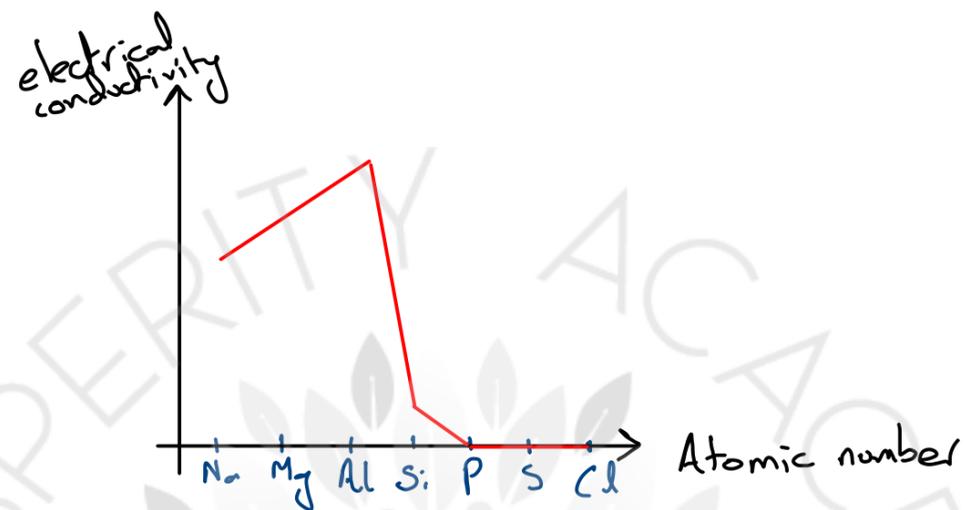
- Na → Mg increases
  - 1) Cationic charge increases
  - 2) No. of delocalized electrons per atom increases
- Si has highest
  - 1) Si has giant covalent structure



- Decreases between P and Si
- P<sub>4</sub>, S<sub>8</sub>, Cl<sub>2</sub> are simple molecular; only have temporary dipoles
- S<sub>8</sub> > P<sub>4</sub> > Cl<sub>2</sub>
  - S<sub>8</sub> has highest as it has most no. of e<sup>-</sup>
  - Cl<sub>2</sub> has lowest as it has least no. of e<sup>-</sup>

## Trend in electrical conductivity:-

- Na  $\rightarrow$  Al increases  
No. of delocalized electrons per atom increases
- Si is a semiconductor
- P  $\rightarrow$  Cl zero  
No free moving electrons



## Reactions of elements with oxygen:-

- Na and Mg react vigorously with  $O_2$ :
  - 1)  $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$  (yellow flame)
  - 2)  $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$  (white flame)
- Aluminium does not react vigorously with  $O_2$  as it develops a protective oxide coat on it. If powdered, then it reacts vigorously  
 $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
- Silicon reacts slowly with oxygen:  $Si(s) + O_2(g) \rightarrow SiO_2(s)$
- Phosphorus reacts vigorously with oxygen:  $P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$
- Sulfur, once ignited, gently burns in oxygen:  $S_8(s) + 8O_2(g) \rightarrow 8SO_2(g)$  (blue flame)
- $SO_2$  can further be oxidised by using  $V_2O_5$  as catalyst:  $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
- Cl does not react with oxygen.

# Properties of Oxides:-

Period 3 element	Na	Mg	Al	Si	P	S
Formula	$\text{Na}_2\text{O}$	$\text{MgO}$	$\text{Al}_2\text{O}_3$	$\text{SiO}_2$	$\text{P}_4\text{O}_6$ $\text{P}_4\text{O}_{10}$	$\text{SO}_2$ $\text{SO}_3$
Oxidation no. of element	+1	+2	+3	+4	+3 +5	+4 +6
Solubility in water	soluble	insoluble	insoluble	insoluble	soluble	soluble
Acid/Base nature	basic	basic	amphoteric	acidic	acidic	acidic
Relative m.p./b.p.	high	high	high	high	low	low
Electrical conductivity	good (molten or aqueous)	good (molten or aqueous)	good (molten or aqueous)	poor	poor	poor
Chemical bonding	ionic	ionic	ionic	covalent	covalent	covalent
Structure	giant	giant	giant	giant	simple	simple
Used in Ceramics?	No	Yes	Yes	Yes	No	No

Ceramics:- Inorganic and non metallic products subject to high temperature under use or manufacture.

- Have high m.p & b.p.
- Have high rigidity
- Good insulators at room temperature

Trend in oxidation number of oxides:-

- Always positive

Oxygen is more electronegative than any Period 3 element

- Oxidation numbers increase

Across the period, the valence electrons increases hence more electrons are available for bonding

Trend in bonding of oxides:-

- Across the period, the bonding transitions from ionic to covalent.

Difference in electronegativity of oxygen and Period 3 element gets less

Acid / Base Natures:-

- Sodium oxide dissolves in water to give a strongly alkaline solution

$$\text{Na}_2\text{O}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow 2\text{NaOH}_{(aq)} \quad (\text{pH } 13)$$
$$\text{NaOH}_{(aq)} + \text{HCl}_{(aq)} \longrightarrow \text{NaCl}_{(aq)} + \text{H}_2\text{O}_{(l)}$$

- Magnesium oxide is not very soluble and only gives weakly alkaline solution

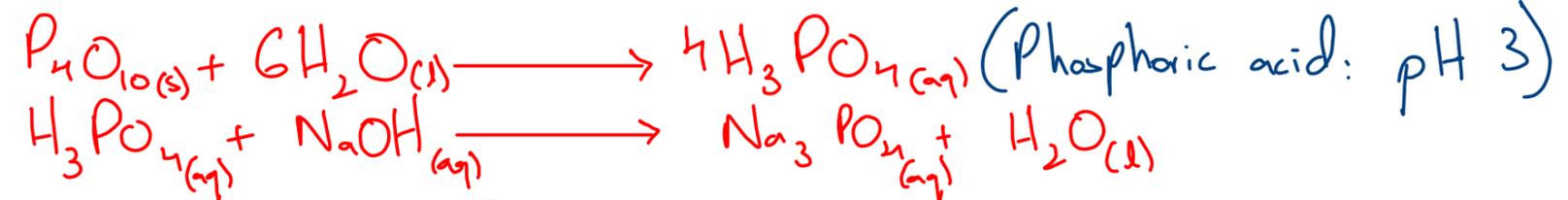
$$\text{MgO}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow \text{Mg}(\text{OH})_{2(aq)} \quad (\text{pH } 9)$$
$$\text{MgO}_{(s)} + 2\text{HCl}_{(aq)} \longrightarrow \text{MgCl}_{2(aq)} + \text{H}_2\text{O}_{(l)}$$
$$\text{Mg}(\text{OH})_{2(aq)} + 2\text{HNO}_3_{(aq)} \longrightarrow \text{Mg}(\text{NO}_3)_{2(aq)} + 2\text{H}_2\text{O}_{(l)}$$

- Aluminium oxide is amphoteric:  $\text{Al}_2\text{O}_3_{(s)} + 3\text{H}_2\text{SO}_4_{(aq)} \longrightarrow \text{Al}_2(\text{SO}_4)_3_{(aq)} + 3\text{H}_2\text{O}_{(l)}$

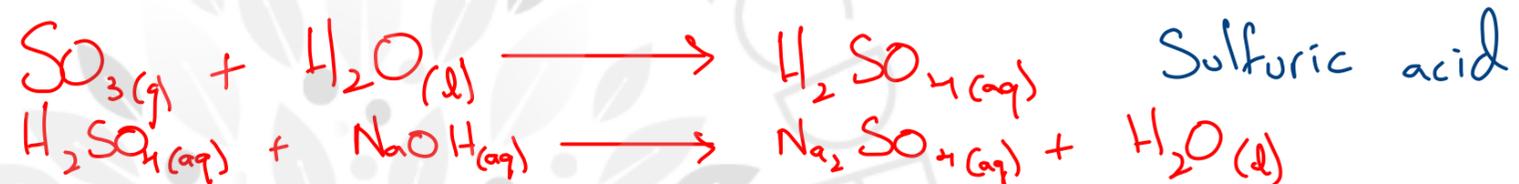


- Silicon dioxide reacts with hot concentrated NaOH:  $\text{SiO}_2_{(s)} + \text{NaOH}_{(aq)} \longrightarrow \text{Na}_2\text{SiO}_3_{(aq)} + \text{H}_2\text{O}_{(l)}$

- Phosphorus (V) oxide dissolves in water



- Both oxides of sulfur react and dissolve in water to give strongly acidic solutions. (pH 1)



Reactions with Chlorine:-

- Na, Mg, Al react vigorously with chlorine:



- Si and P react slowly with chlorine:



# Properties of Chlorides:-

Period 3 element	Na	Mg	Al	Si	P	S
Formula	NaCl	MgCl <sub>2</sub>	Al <sub>2</sub> Cl <sub>6</sub>	SiCl <sub>4</sub>	PCl <sub>3</sub> PCl <sub>5</sub>	S <sub>2</sub> Cl <sub>2</sub>
Oxidation number of period 3 element	+1	+2	+3	+4	+3 +5	+1
Chemical bonding	ionic	ionic	covalent & dative	covalent	covalent	covalent
Structure	giant	giant	simple	simple	simple	simple
Observations when added to water	solid dissolves; colourless solution		solution dissolves to give colourless acidic solution (+ steamy fumes of HCl(g) with SiCl <sub>4</sub> & PCl <sub>5</sub> )			
pH of solution	7	6.5	3	1	1	1

## Reactions of Chlorides with water:-

- NaCl and  $MgCl_2$  do not react but dissolve completely ( $MgCl_2$  gives pH of 6.5 as 2+ charge density of  $Mg^{2+}$  can polarise some water molecules and release  $H^+$ )

-  $Al_2Cl_6$  breaks down in water and dissolves in it. Al has a charge density of +3 so it can polarise water molecules even more and release more  $H^+$

-  $SiCl_4$  goes under rapid hydrolysis. An off white precipitate of  $SiO_2$  is formed and steamy fumes of HCl are given off.



-  $PCl_5$  also undergoes rapid hydrolysis when added to water



1 Which of the following oxides is **unlikely** to dissolve in aqueous sodium hydroxide?

- A  $Al_2O_3$    **B** MgO   C  $SO_2$    D  $SiO_2$

3 Which statement explains the observation that magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride?

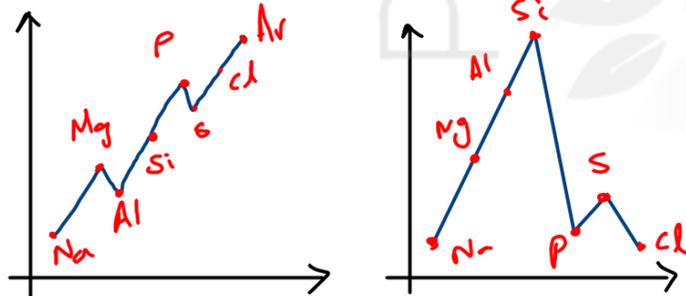
- A The ionic radius of the  $NH_4^+$  ion is similar to that of  $Mg^{2+}$  but not that of  $Na^+$ .  
 B  $NH_4Cl$  dissociates less fully than  $NaCl$ .  
 C The ions  $Na^+$  and  $Mg^{2+}$  are isoelectronic (have the same number of electrons).  
**D** The ion  $NH_4^+$  acts as an acid.



9 Consecutive elements X, Y, Z are in the third period of the Periodic Table. Element Y has the highest first ionisation energy and the lowest melting point.

What could be the identities of X, Y and Z?

- A aluminium, silicon, phosphorus  
 B magnesium, aluminium, silicon  
**C** silicon, phosphorus, sulfur  
 D sodium, magnesium, aluminium



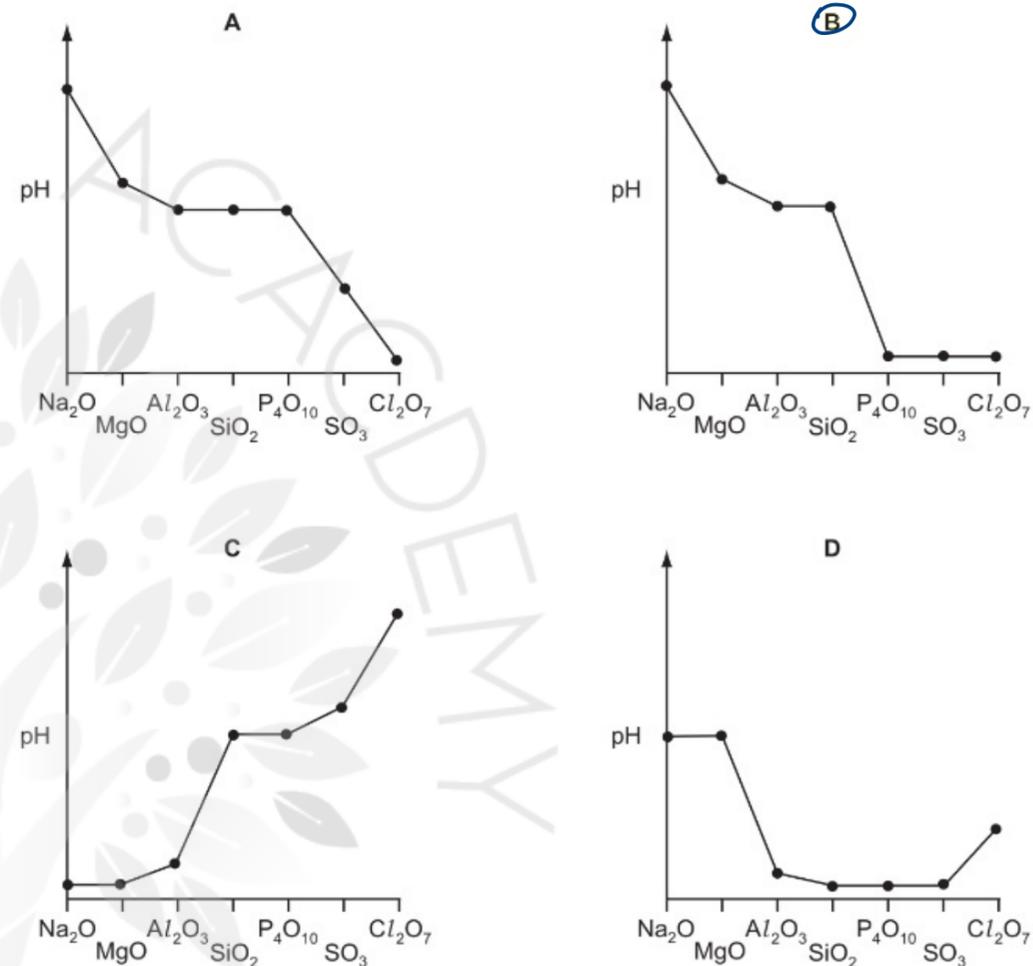
10 The oxide and chloride of an element X are separately mixed with water. The two resulting solutions have the same effect on litmus.

What is element X?

- A sodium  
 B magnesium  
 C aluminium  
**D** phosphorus

31 The highest oxides of the elements sodium to chlorine are separately added to water.

Which diagram best represents the pH of the resulting mixtures?



55 X and Y are oxides of different Period 3 elements.

If one mole of Y is added to water, the solution formed is neutralised by exactly one mole of X.

What could be the identities of X and Y?

	X	Y
<b>A</b>	$Al_2O_3$	$P_4O_{10}$
<b>B</b>	$Al_2O_3$	$SO_3$
<b>C</b>	$Na_2O$	$P_4O_{10}$
<b>D</b>	$Na_2O$	$SO_3$



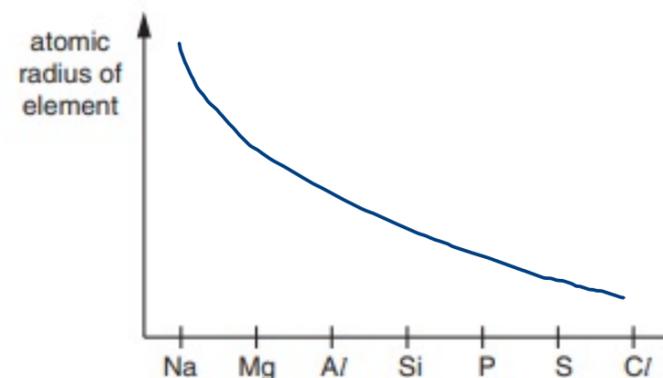
3 Elements in the same period of the Periodic Table show trends in physical and chemical properties. The grids on this page and on the opposite page refer to the elements of the third period, Na to Cl.

On **each** of these grids, draw a clear sketch to show the variation of the stated property.

Below **each** grid, briefly explain the variation you have described in your sketch.

For each explanation you should refer to the important factors that cause the differences in the property you are describing.

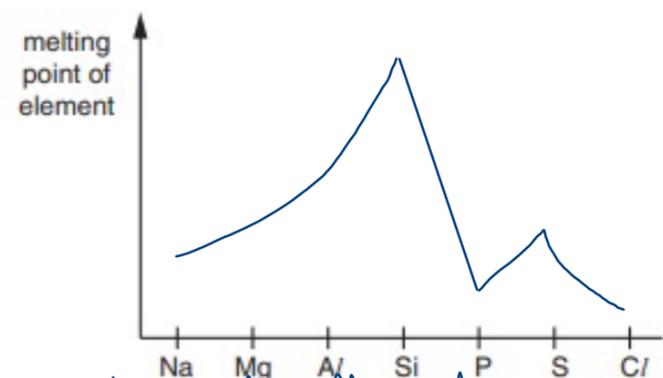
(a)



explanation The nuclear charge increases across the period while shielding remains constant. The valence electrons experience a stronger pull and the atomic radius decreases

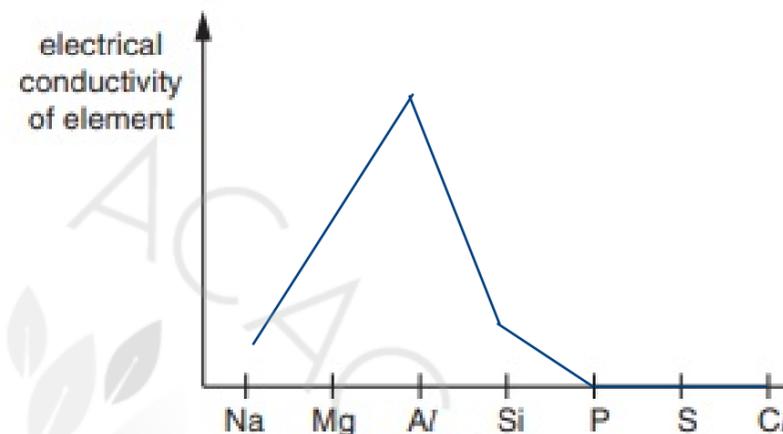
[3]

(b)



explanation Na → Mg, have giant metallic structures the melting point increases as the cationic charge increases and number of delocalised electrons per atom increases. Si is a giant covalent structure so lots of heat is required to break the covalent bonds. P → Cl are simple molecules, S has most while Cl has least as the number of electrons decrease from S<sub>8</sub> to P<sub>4</sub> to Cl<sub>2</sub>

(c)



explanation Na → Al have free moving electrons and conductivity increases as number of delocalised electrons per atom increases. Si is a semiconductor and P to Cl do not conduct as they don't have free moving electrons

[4]

(d) The melting points of some of the oxides of the elements sodium to sulfur are given in the table below.

compound	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>4</sub> O <sub>6</sub>	SO <sub>2</sub>
mp/K	1193	3173	2313	1883	297	198

(i) What type of bond is broken when **each** of the following compounds is melted?

Na<sub>2</sub>O ionic

SiO<sub>2</sub> covalent

P<sub>4</sub>O<sub>6</sub> Vander Waals

(ii) Identify **one** of these six oxides that has no reaction at all with water.

SiO<sub>2</sub>

[4]

[Total: 15]

3 The table below gives data for some of the oxides of Period 3 elements.

oxide	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>4</sub> O <sub>6</sub>	SO <sub>2</sub>
melting point/°C	1275	2827	2017	1607	24	-75
bonding	ionic	ionic	ionic	covalent	covalent	covalent
structure	giant	giant	giant	giant	simple	simple

(a) Complete the table by filling in

(i) the 'bonding' row by using **only** the words 'ionic' or 'covalent',

(ii) the 'structure' row by using **only** the words 'simple' or 'giant'.

[2]

(b) From the table of oxides above, suggest the formula of **one** oxide that is **completely** insoluble in water.

SiO<sub>2</sub>

[1]

(c) Separate samples of Na<sub>2</sub>O and SO<sub>2</sub> were added to water.

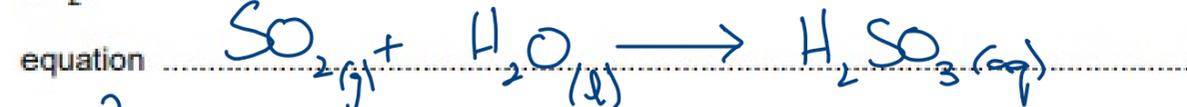
(i) For **each** oxide, write a balanced equation for its reaction with water and suggest a numerical value for the pH of the resulting solution.

Na<sub>2</sub>O



pH 13

SO<sub>2</sub>



pH 2

(ii) Construct a balanced equation for the reaction that occurs when a solution of Na<sub>2</sub>O in water reacts with a solution of SO<sub>2</sub> in water.



(d) Separate samples of the oxides MgO and SiO<sub>2</sub> are melted. Each molten sample is then tested to see whether or not it conducts electricity.

Suggest what would be the results in **each** case. Explain your answers.

MgO conducts as it has free moving ions

SiO<sub>2</sub> does not conduct because it has neither free moving electrons or ions.

[4]

[Total: 12]

3 This question refers to the elements shown in the section of the Periodic Table below.

		H															He
Li	Be										B	C	N	O	F	Ne	
Na	Mg										Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr

(a) From this list of elements, identify in **each** case **one** element that has the property described. Give the symbol of the element.

(i) an element that sinks in cold water and reacts readily with it

Ca

(ii) an element that forms an oxide that is a reducing agent

S

(iii) the element that has the largest first ionisation energy

He

(iv) the metal in Period 3 (Na to Ar) that has the smallest cation

Al

(v) the element which has a giant molecular structure **and** forms an oxide which also has a giant molecular structure

Si

(vi) the element in Period 3 (Na to Ar) with the greatest electrical conductivity

Al

[6]

(b) From the section of the Periodic Table above, identify **two** elements whose hydrides form hydrogen bonds between their molecules.

Cl and O

[1]

(c) Use the elements in Period 3 (Na to Ar) in the section of the Periodic Table opposite to identify the oxide(s) referred to below.

In **each** case, give the formula of the oxide(s).

(i) an oxide which has no reaction with water

SiO<sub>2</sub>

(ii) **two** acidic oxides formed by the same element

SO<sub>2</sub> and SO<sub>3</sub>

(iii) an oxide which dissolves readily in water to give a strongly alkaline solution

Na<sub>2</sub>O

(iv) an oxide which is amphoteric

Al<sub>2</sub>O<sub>3</sub>

[5]