- Assumptions (need confirmation)
- Raj bhaia imp notes
- Stuff I added (confirmed)

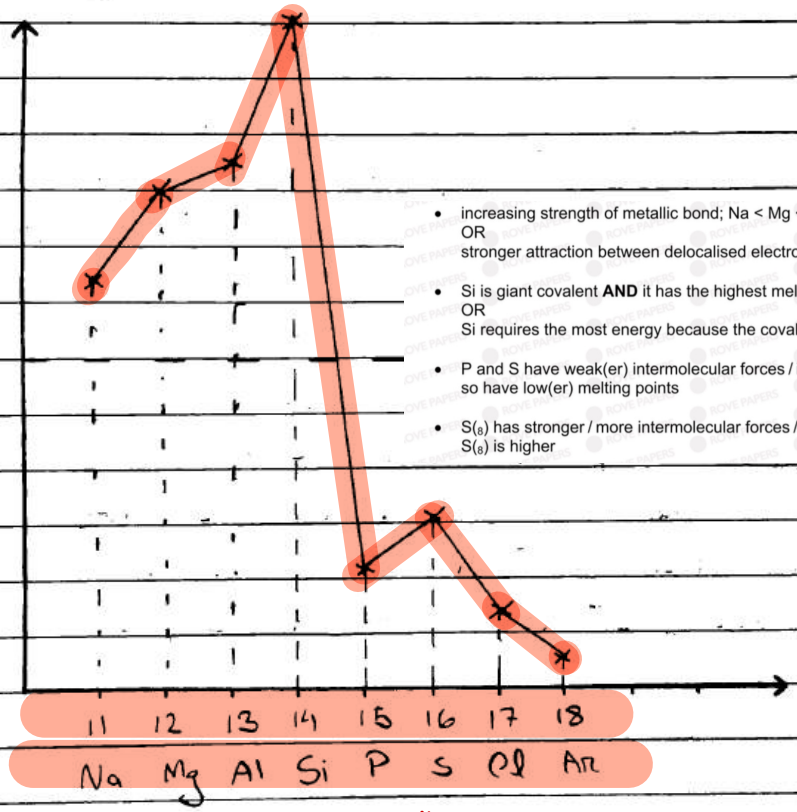
Periodicity

We will only work with period 3 (mostly) and 2:

↳ Trend in the m.p of the Period 3 elements across the Period

Na - Mg - Al - Si - P - S - Cl - Ar

Do not draw the dotted lines



- increasing strength of metallic bond; Na < Mg < Al
  OR
  stronger attraction between delocalised electrons and (positive) ion so melting point of Na < Mg < Al
- Si is giant covalent **AND** it has the highest melting point due to breaking / presence of strong (covalent) bonds
  OR
  Si requires the most energy because the covalent bonds in Si are stronger than metallic bonds (in Na / Mg / Al)
- P and S have weak(er) intermolecular forces / induced dipoles / van der Waals forces (than covalent / metallic bonds) so have low(er) melting points
- $S_{(8)}$ has stronger / more intermolecular forces / van der Waals forces / induced dipoles than $P_{(4)}$ so melting point of $S_{(8)}$ is higher

// and have a giant metallic lattice structure *

Na, Mg and Al are metals * with strong metallic bonds (in their giant metallic lattice structure) causing them to have higher melting point than P, S, Cl and Ar as they are ~~non-metallic~~ non-polar simple covalent molecules or atom. They have simple molecular structure with weak intermolecular forces.

Si has the highest m.p as it has a giant covalent structure with many strong covalent bonds.

Na has 1 e^- in its outer shell, thus it can only donate 1 e^- in its metallic bonding whereas Mg can donate 2 e^- in its metallic bond and Al can donate 3 e^-. This causes the metallic bond in Al to be strongest due to very strong electrostatic forces of attraction between highly positively charged Al^{3+} ions and a large number of sea of delocalized e^-. compared to Na and Mg

positive

Al^{3+} has a very high charge density, thus it reabsorbs some of the delocalised e^- ^ Hence the difference in m.p. between Mg and Al is very little compared to difference jump in m.p. between Na and Mg

(P_4) (Cl_2)

From P to Cl they exist as simple covalent non-polar molecules. Their m.p. depends on the strength of TDDF. The S_8 molecule has the heighest no. of e^- causing it to have the strongest TDDF. Whereas Ar being monoatomic, has the lowest no. of e^-, causing it to have the weakest T.D.D.F.

Trend in atomic radius across the period

↳ Across the period, atomic radius decreases. As across the period nuclear charge increases and shell no. remaining constant. This causes effective nuclear attractive force acting on the e^- to increase. Thus the atom shrinks in size.

Trend in ionic radius across the period

↳ $_{11}Na^+$ $_{12}Mg^{2+}$ $_{13}Al^{3+}$ $_{14}Si^{4+}$ | $_{15}P^{3-}$ $_{16}S^{2-}$ $_{17}Cl^-$

no. of e^-: 10 10 10 | 18 18 18

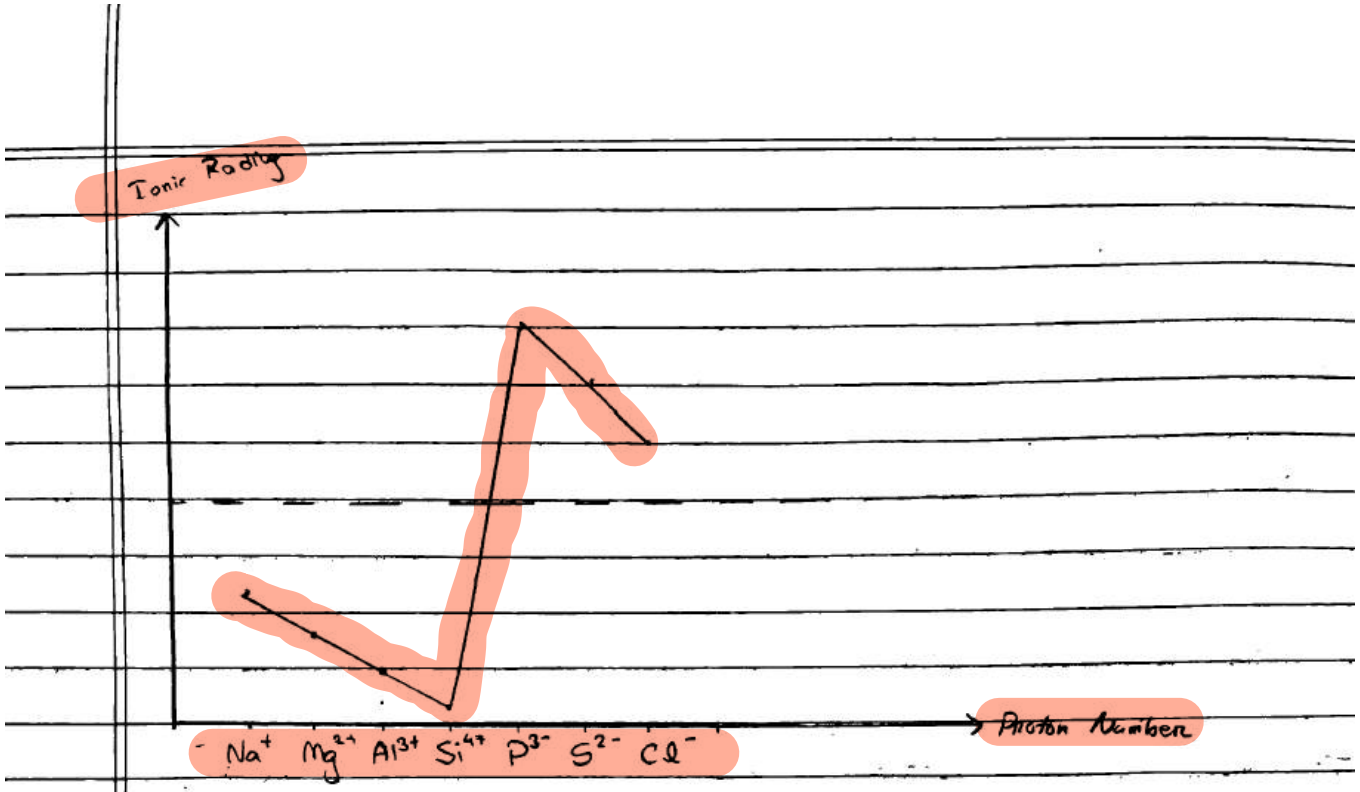
↳ Across the period

↳ Compared to any anion, the size of a cation is always smaller as anions always have one more electronic shell than the cation. when comparing ions of elements from the same Period

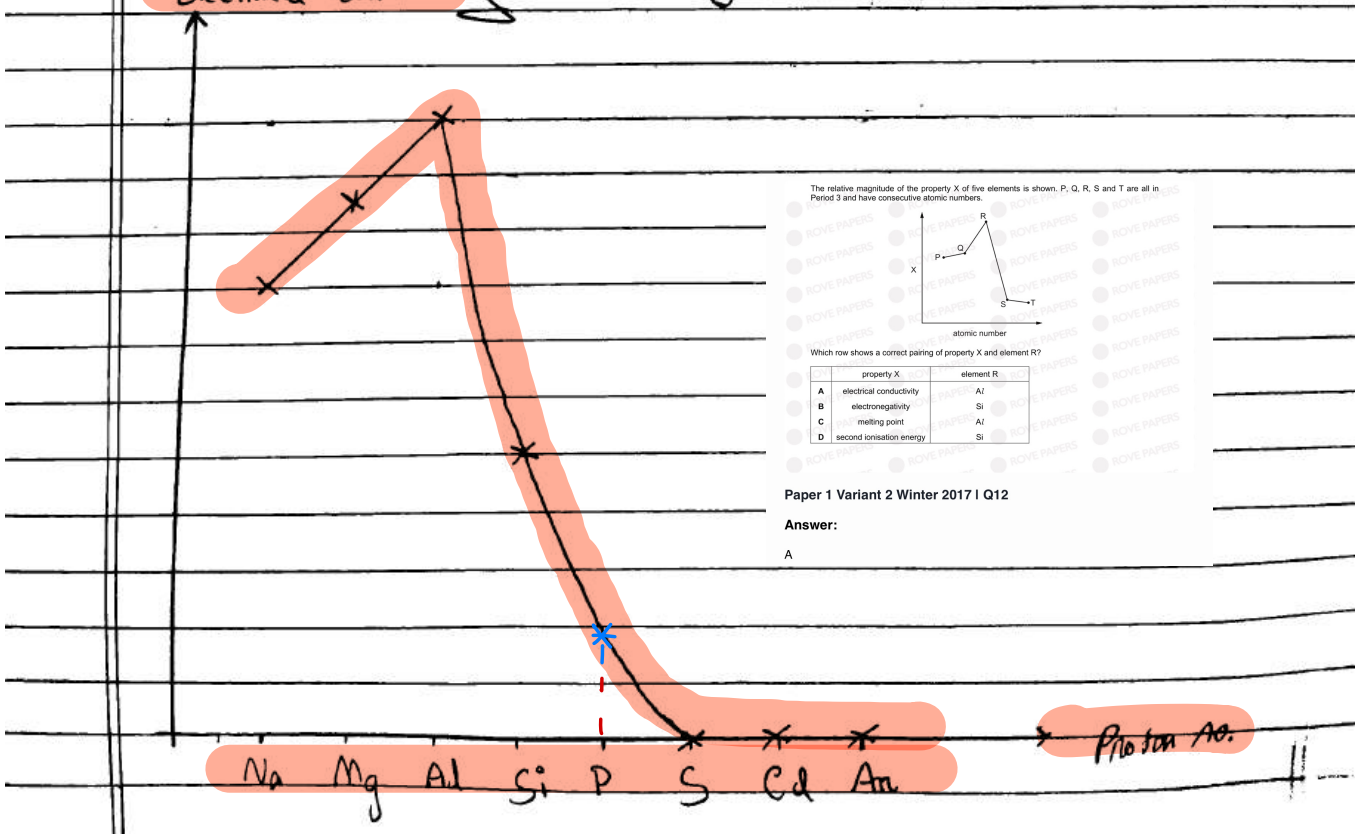
P^{3-} // Cl^- //

↳ From Na^+ ion to Si^{4+} ion, nuclear charge increases due to increase in the no. of protons however no. of e^- remaining and shell no. constant causing effective nuclear attractive force acting on the e^- to increase. Thus the ionic radius decreases.

Same as above for anions



↳ Trend in Electrical Conductivity across the period



The relative magnitude of the property X of five elements is shown. P, Q, R, S and T are all in Period 3 and have consecutive atomic numbers.

Which row shows a correct pairing of property X and element R?

	property X	element R
A	electrical conductivity	Al
B	electronegativity	Si
C	melting point	Al
D	second ionisation energy	Si

Paper 1 Variant 2 Winter 2017 I Q12

Answer:

A

→ ✗ REACTS with O_2 NOT ✗ BURNS in O_2

Reaction of Period 3 elements with O_2

↳ Na reacts vigorously with O_2. It Observation: It catches fire and burns with a yellow flame
: A white solid is produced

$4Na + O_2 \rightarrow 2Na_2O$

↳ Mg also reacts vigorously with O_2 when heated. Observation: It catches fire and burns with an intense/bright white flame
: A white solid is produced

$2Mg + O_2 \rightarrow 2MgO$

↳ Al does not react with O_2 or due to its protective oxide coating. However a freshly prepared powdered same sample of Al reacts readily with O_2. Observation: Burns with a white flame
: White solid is produced

(4) $4Al + 3O_2 \rightarrow 2Al_2O_3$

↳ Si reacts slowly with O_2 (does not burn in O_2) to produce SiO_2 (silicon (IV) oxide). Observation: White solid

$Si + O_2 \rightarrow SiO_2$

↳

↳ P_4 (red solid) reacts vigorously with O_2 to form P_4O_{10} (white powder) (Phosphorous (V) oxide) it catches fire. Observation: Burns with a white / yellow (preferred) flame

$P_4 + 5O_2 \rightarrow P_4O_{10}$: White powder

↳ S_8 (yellow solid) (S_8 has to be ignited for reaction to occur) also reacts readily with O_2 to produce SO_2 gas (colourless)

Observation: It burns with a blue flame

$S + O_2 \rightarrow SO_2$ (use S_8 if question asks for it // mentioning it) (... mentioning that S exists as S_8)

↳ Cl_2 and Ar do not react with O_2 (Cl_2 does react with O_2 but it is not included in our syllabus)

Reacting with O_2

Na - vigorously - yellow flame - white solid

Mg - vigorously when heated - Intense Bright White flame
- White Solid

Al - no reaction

Freshly prepared powdered sample of Al - readily
- white flame
- white solid
- readily

Si - slowly (no burning) - white solid

P_4 (red solid) - vigorously - white/yellow (↳ books, ms) flame
- white powder (P_4O_{10})

S_8 (yellow solid) - readily - blue flame
- SO_2 (colourless gas)

↳ has to be ignited for the reaction to occur

No flames in Reactions with Cl_2 because burning means reacting with O_2

Reactions of Period 3 elements with Cl_2

Burns in Cl_2 with a YELLOW flame

↳ Na reacts vigorously with Cl_2 to produce ~~NaCl~~ white solid of NaCl

$2Na + Cl_2 \rightarrow 2NaCl$

$+Cl \rightarrow Al_2Cl_3(g) \rightarrow$ GAS

↳ Mg and ~~Al_2~~ Al both also react vigorously with Cl_2 to produce $MgCl_2$ (white solid) and Al_2Cl_6 (colourless gas)

$Mg + Cl_2 \rightarrow MgCl_2$

~~2~~ $2Al + 3Cl_2 \rightarrow Al_2Cl_6$ → white fumes

↳ Si reacts slowly with Cl_2 to form $SiCl_4$ (silicon tetrachloride) (LIQUID (colourless)) *

$Si + 2Cl_2 \rightarrow SiCl_4(l)$

↳ P_4 reacts slowly with Cl_2 to produce PCl_5 (phosphorous pentachloride) (colourless LIQUID) *

$P_4 + 10Cl_2 \rightarrow 4PCl_5$

PCl_3 liquid
PCl_5 solid

Burns in Cl_2 with coloured (probably blue) flame

↳ S_8 and Ar reacting with Cl_2 not included in our syllabus

* When reacting with steam [$H_2O_{(g)}$] MO is produced NOT M(OH)

Reactions of Period 3 elements with H_2O *

↳ * Na reacts violently with regular water to produce a strongly alkaline [pH 13-14] sol^n of $NaOH_{(aq)}$ and H_2 gas. * Due to rapid production of H_2 gas Na catches fire and burns with a yellow flame. * Na fizzes around on the surface of the water. * Na melts to form a fiery ball.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

↳ pH (13-14)

↳ Mg reacts ~~very~~ slowly with cold water but reacts vigorously with steam, ~~to f~~

$$Mg + H_{2}O_{(l)} \longrightarrow Mg(OH)_{2\,(aq)} + H_2$$

↳ weakly alkaline sol^n (pH 10-11)

also white powder of MgO.

↳ During reaction with steam, Mg catches fire and burns with an Intense White flame

$$Mg + H_2O_{(g)} \longrightarrow MgO_{(s)} + H_{2\,(g)}$$

↳ white solid

↳ Al to Ar do not react with H_2O (except Cl_2)

↳ When Cl_2 gas is bubbled through water, it reacts with water to form an acidic sol^n ↳ weakly

↗ Rate not mentioned

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

↳ hypochlorous acid (ClO^- strong oxidising agent)

Observation: Greenish yellow gas disappears

Reactions of Period 3 Oxides

	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2 / SO_3
Bonding and Structure	Ionic Giant ionic lattice structure	→ Same → Same	→ Same → Same	Covalent Giant Covalent	Covalent Simple molecular	→ same → same
Acidity or Basicity	Basic	Basic	Amphoteric	Acidic (insoluble)	Acidic	Acidic

Reacting with Water → All ADDITION Reactions

↳ $Na_2O + H_2O \rightarrow 2NaOH_{(aq)}$ pH (13-14)

↳ $MgO + H_2O \rightleftharpoons Mg(OH)_{2(aq)}$ pH (10-11)

↳ $Al_2O_3 + H_2O \rightarrow$ no reaction

↳ $SiO_2 + H_2O \rightarrow$ no reaction

↳ $P_4O_{10} + H_2O \rightarrow H_3PO_{4(aq)}$ pH (3-4) → ms + book → vigorous reaction

↳ $SO_2 + H_2O \rightarrow H_2SO_{3(aq)}$ pH (4-5)

↳ $SO_3 + H_2O \rightarrow H_2SO_{4(aq)}$ pH (1-2)

non-reversible

$Na_2O + HCl \longrightarrow NaCl + H_2O$

$MgO + HCl \longrightarrow MgO + H_2O$

$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$ *

NOT Al_2Cl_6 NOT GAS

$Al_2O_3 + NaOH \longrightarrow 2NaAlO_2 + H_2O$ * (Sodium Aluminate)

$SiO_2 + 2NaOH \xrightarrow{\text{hot conc}^n\ (\text{conc.})} Na_2SiO_3 + H_2O$ (Sodium Silicate (IV))

$P_4O_{10} + 2NaOH \longrightarrow 4Na_3PO_4 + 6H_2O$

$SO_2 + 2NaOH \longrightarrow Na_2SO_3 + H_2O$

$SO_3 + 2NaOH \longrightarrow Na_2SO_4 + H_2O$

(as they are)

Ionic compounds dissolve in water, whereas covalent (non-polar // non-hydrogen bonded) compounds react with water to mix with // dissolve in it.

When such covalent compounds react with water, the products of the reactions are acidic, lowering the pH of the water

Since dissolving Ionic compounds do not react with water, pH remaining neutral (7)

	$NaCl$	$MgCl_2$	Al_2Cl_6 // $AlCl_3$	$SiCl_4$	PCl_5
Oxidation state	+1	+2	+3	+4	+5
Structure	Giant ionic	Giant ionic	simple molecular	simple molecular	simple molecular
		pH = 6.5	pH = 3		

However most ionic compounds are not purely ionic

When ionic compounds with covalent characteristics react with water, they form an acidic sol^n.

Degree of acidity depends on how covalent the compound is.

Reactions of Period 3 Chlorides with H_2O + H_2O is Hydrolysis reac^n

→ $NaCl_{(s)} + aq \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$ [pH 7]

☆ → $PCl_{5(s)} + 4H_2O_{(l)} \rightarrow H_3PO_{4(aq)} + 5HCl_{(g/aq)}$ [pH 3] ↓ pH 1-2 : ms

↳ observation: steamy fumes

→ $SiCl_{4(l)} + H_2O_{(l)} \rightarrow SiO_{2(s)} + HCl_{(g/aq)}$ [pH ~~3~~) can be 2 in some qs

↳ observation: white ppt. AND steamy fumes

→ $MgCl_{2(s)} + aq \rightarrow Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}$

↳ No steamy fumes

H_2O forms Dative covalent bonds with Mg ion in the complex ~~$MgCl_2$~~ $[Mg(H_2O)_6]^{2+}$ pH: 6.5

$[Mg(H_2O)_6]^{2+} \rightleftharpoons [Mg(H_2O)_5OH]^+ + H^+$

either one of these reactions for $AlCl_3$ reactions

→ $AlCl_3 + aq \longrightarrow Al^{3+}_{(aq)} + 3Cl^-_{(aq)}$

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

$[Al(H_2O)_5OH]^{2+} \rightleftharpoons [Al(H_2O)_4(OH)_2]^+ + H^+$

$[Al(H_2O)_4(OH)_2]^+ \rightleftharpoons Al(H_2O)_3(OH)_3 + H^+$

$[Al(H_2O)_6]^{3+} + 3Cl^- \rightleftharpoons Al(H_2O)_3(OH)_3 + 3HCl_{(g)}$ then aq

~~pH 3~~ (can also be 2 pH 1-2 in some qs)

HCl gas dissolves to make $HCl_{(aq)}$ acid

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0		Key: atomic number / atomic symbol / name / relative atomic mass									5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

Misc. Notes

Reaction of Mg with $H_2O_{(l)}$ is not reversible

↳ $Mg + 2H_2O_{(l)} \longrightarrow Mg(OH)_2 + H_2$

However, the reaction of MgO with H_2O is reversible

↳ $MgO + H_2O \rightleftharpoons Mg(OH)_2$

pH 10-11

pH of soln containing HCl as product is usually 3

Exception : $Cl_2 + H_2O \longrightarrow HCl + HOCl$ [weakly acidic]

: $Mg(H_2O)_6^{2+} \rightleftharpoons Mg(H_2O)_5(OH)^+ + H^+$ [pH 6.5]

pH of soln containing ___ as product is usually ___ :

→ H_2SO_4 : 1 - 2

→ H_3PO_4 : 3 - 4 # use 3 as H_3PO_4 is usually formed with HCl

→ H_2SO_3 : 4 - 5

Due to $\rightleftharpoons$ sign. Although, $Al(H_2O)_6^{3+} + 3Cl^- \rightleftharpoons Al(H_2O)_3(OH)_3 + 3HCl$ is reversible, the first step is not $\rightleftharpoons$,

↳ $Al(H_2O)_6^{3+} \longrightarrow Al(H_2O)_5(OH)^{2+} + H^+$

pH of $NaOH_{(aq)}$ is 13 - 14

(d) The acid/base behaviour of the oxides in the third period varies across the period.

(i) Describe this behaviour and explain it with reference to the structure and bonding of sodium oxide, Na_2O, aluminium oxide, Al_2O_3, and sulfur trioxide, SO_3.

.....

.....

..... [2]

(ii) Write equations for reactions of these three oxides with hydrochloric acid and/or sodium hydroxide as appropriate.

.....

.....

.....

..... [4]

[Total: 18]

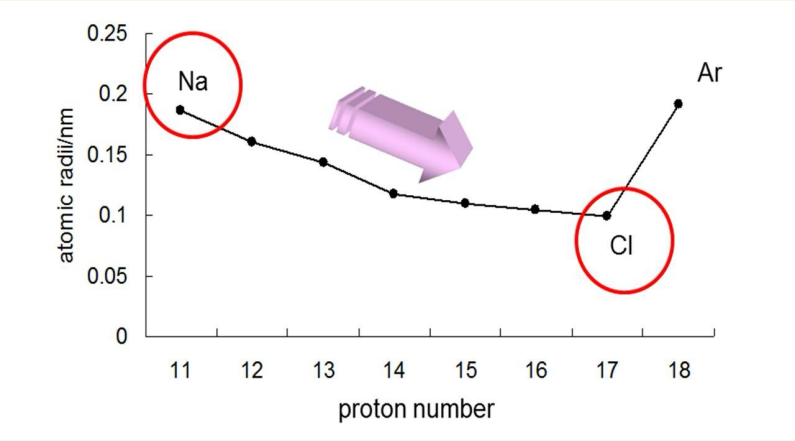
Paper 2 Variant 2 Summer 2015 I Q1

(d) (i)	Na_2O basic/alkaline; Al_2O_3 amphoteric/acidic and basic; SO_3 acidic Na_2O (giant) ionic **AND** SO_3 (simple/molecular) covalent	[1] [1]	[2]
(ii)	$Na_2O + 2HCl \rightarrow 2NaCl + H_2O$	[1]	
	$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$	[1]	
	$Al_2O_3 + 2NaOH + 7H_2O \rightarrow 2NaAl(OH)_4(H_2O)_2$ **OR** $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ **OR** $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ **OR** $Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(OH)_4(H_2O)_2]^-$ **OR** $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ **OR** $Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$	[1]	
	$SO_3 + NaOH \rightarrow NaHSO_4$ **OR** $SO_3 + 2NaOH \rightarrow Na_2SO_4 + H_2O$	[1]	[4]

Recent Ms prefers :

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

Argon is an inert gas that has a complete valence shell.
Since it has a maximum number of electrons in the valence shell thus, the electronic repulsion will be maximum.
Therefore, argon will be bigger than the chlorine atom.



The Periodic Table Chemical Periodicity 3

Elements D and E are both in Period 3. Element D has the smallest atomic radius in Period 3. There are only two elements in Period 3 which have a lower melting point than element E. Elements D and E react together to form compound L.

Which compound could be L?

A $MgCl_2$ **B** MgS **C** Na_2S **D** PCl_3

Paper 1 Variant 2 Summer 2019 I Q14

Answer:

D

An Ar atom is larger than a Cl atom

Reaction between $SiCl_4$ and H_2O is a Hydrolysis reac^n

$SiCl_{4(l)} + 2H_2O_{(l)} \rightarrow SiO_{2(s)} + 4HCl_{(aq)}$

Explain, in terms of electronegativity, why the bonding in NaCl is different from the bonding in $SiCl_4$

↳ Si is more electronegative than Na
↳ NaCl transfer of e^-
↳ $SiCl_4$ shared (pair of) e^-

Reaction of $AlCl_3$ with H_2O is a Hydrolysis reac^n

P to Cl ions have a larger radius than P to Cl atoms because:
↳ (P to Cl atoms) gain e^- to the same outer shell / p-subshell
↳ increased repulsion between e^- in the same shell / p-subshell
- ing

$Ga_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaGa(OH)_4$

$SiCl_4$ and PCl_5 react with H_2O to give BOTH HCl gas (steamy fumes) AND HCl aqueous (pH: 3)

Environmental effects of SO2 being released:

M1 acid rain [1]

M2 any of the following [1]
- lowers pH / increases acidity of rivers / lakes / oceans / water supplies / seas / soil / ground water
- kills / harms / damages fish / coral / aquatic life / plants / crops / trees or deforestation
- leaches (toxic) aluminium (ions / salts) from soil (into rivers/lakes)
- leaches away soil nutrients / soil unfit for agriculture
- damages / weathers / erodes / destroys buildings / statues
- causes breathing difficulties

13 Which gas is present in the exhaust fumes of a car engine in a much greater amount than any other gas?

A carbon dioxide
B carbon monoxide
C nitrogen
D water vapour

ALWAYS use S in equations and NOT S_8 unless the question specifically asks you to use S_8.

When distinguishing between ionic and covalent compounds respective to their different interactions with water, we might say:
- (Purely) ionic compounds dissolve in water without reacting with water
- (Purely) covalent compounds are (almost always) hydrolysed by water (simply writing react with water will not be awarded any marks)

Lack of Reactivity of N_2 is because of: High E_a
: Strong triple bond
: Non-Polar molecule - MS

(b) $LiAlH_4$ cannot be used in aqueous solution because it reacts with water to produce LiOH(aq), $H_2(g)$ and a white precipitate which is soluble in excess sodium hydroxide.

Identify the white precipitate.

~~Al_2O_3~~ $Al(OH)_3$ [1] -1

Only Group 1 metals catch fire (ish) in water

Na burns in Cl_2 with a YELLOW flame
P_4 (heated sample) burns in Cl_2 with a White or YELLOW flame
S burns in Cl_2 with coloured (probably blue) flame

Observations: Al_2Cl_6 - White fumes
$AlCl_3$ - White solid

P_4O_{10} reacts VIGOROUSLY with H_2O

$AlCl_3$, $SiCl_4$ and PCl_5 react vigorously with $H_2O_{(l)}$
↳ MS

MgO, Al_2O_3 and SiO_2 are Ceramic materials