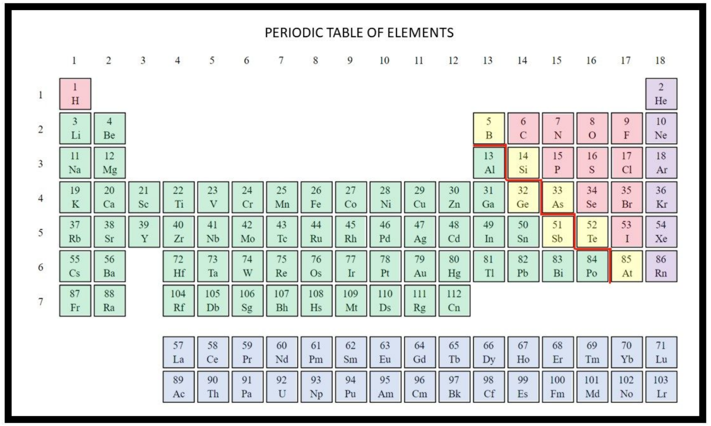
The Periodic Table: chemical periodicity

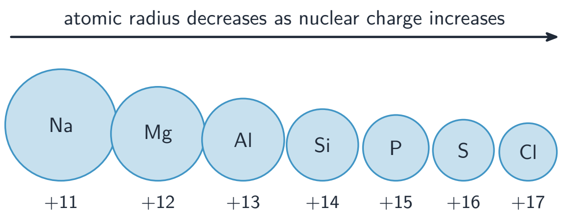
A-Level Chemistry

Physical properties across Period 3



Properties repeat in a regular pattern across each period of the table.

Periodicity 周期性 means that properties repeat in a regular pattern as you go across each **period** 周期 of the Periodic Table. Period 3 (Na to Ar) is the standard example.



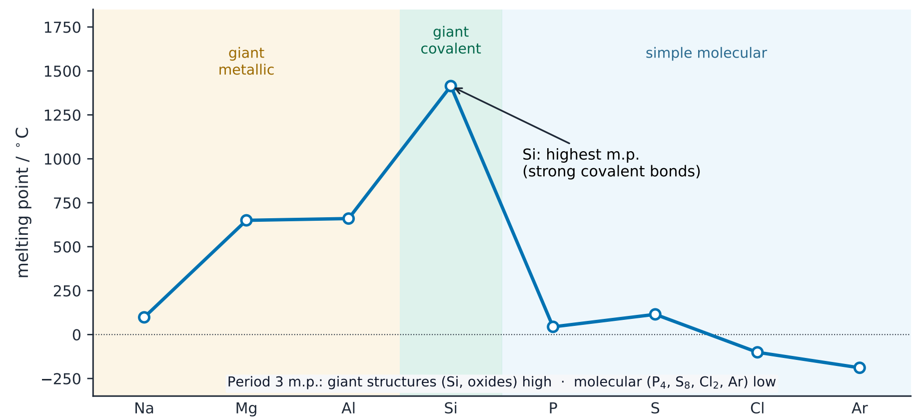
Atomic radius decreases across Period 3: the rising nuclear charge pulls the same outer shell inwards

Property	Trend across Period 3
atomic radius 原子半径	gets smaller (more nuclear charge pulls the same shell in)
ionic radius 离子半径	positive ions are small; from P^{3-} onwards the negative ions are larger
melting point 熔点	rises to a peak at silicon, then falls sharply
electrical conductivity 导电性	high for Na, Mg, Al; almost zero from Si onwards

The melting point and conductivity follow from the structure and bonding:

- **Na, Mg, Al** are **giant metallic** 金属晶体. Melting points rise (Na → Al) because each atom gives more delocalised electrons and the ions get smaller, so the bonding is stronger. They conduct well.
- **Si** is **giant molecular** 原子晶体 (giant covalent). It has the highest melting point, because strong covalent bonds must be broken. It barely conducts.
- **P, S, Cl, Ar** are **simple molecular** 分子晶体 (or single atoms). Their melting points are low, because the only forces that break are the weak **van der Waals' forces** 范德华力 **between** the molecules - the strong covalent bonds **inside** each molecule are never broken at all. They do not conduct.

Name **van der Waals' forces** when you explain that drop: it is the marking point, and "the covalent bonds are weak" is the error that loses it. Melting S_8 pulls whole molecules apart from each other; it does not touch a single S–S bond. Their sizes still follow the molecule: S_8 melts higher than P_4 because it is bigger, with more electrons and so stronger van der Waals' forces, while Ar (a single atom) is lowest of all.



Melting point across Period 3 peaks at silicon (giant covalent); it is high for the metals and low for the simple molecular elements

Chemical properties across Period 3

Reactions with oxygen, chlorine and water

With **oxygen**:

$$4\mathrm{Na} + \mathrm{O_2} \rightarrow 2\mathrm{Na_2O} \qquad 2\mathrm{Mg} + \mathrm{O_2} \rightarrow 2\mathrm{MgO} \qquad 4\mathrm{Al} + 3\mathrm{O_2} \rightarrow 2\mathrm{Al_2O_3}$$

$$\mathrm{P_4} + 5\mathrm{O_2} \rightarrow \mathrm{P_4O_{10}} \qquad \mathrm{S} + \mathrm{O_2} \rightarrow \mathrm{SO_2}$$

With **chlorine**:

$$2\mathrm{Na} + \mathrm{Cl_2} \rightarrow 2\mathrm{NaCl} \qquad \mathrm{Mg} + \mathrm{Cl_2} \rightarrow \mathrm{MgCl_2} \qquad 2\mathrm{Al} + 3\mathrm{Cl_2} \rightarrow 2\mathrm{AlCl_3}$$

$$\mathrm{Si} + 2\mathrm{Cl_2} \rightarrow \mathrm{SiCl_4} \qquad 2\mathrm{P} + 5\mathrm{Cl_2} \rightarrow 2\mathrm{PCl_5}$$

With **water** (only Na and Mg react):

$$2\mathrm{Na} + 2\mathrm{H_2O} \rightarrow 2\mathrm{NaOH} + \mathrm{H_2} \qquad \mathrm{Mg} + 2\mathrm{H_2O} \rightarrow \mathrm{Mg(OH)_2} + \mathrm{H_2}$$

Sodium reacts fast; magnesium reacts only very slowly with cold water.

Oxidation number of the oxides and chlorides

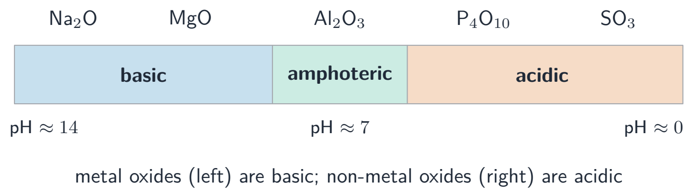
The **oxidation number** 氧化数 of the Period 3 element in its oxide or chloride rises across the period, because it equals the number of outer-shell (**valence shell** 价层) **electrons** 电子 the atom uses in bonding:

Oxides	Na_2O	MgO	Al_2O_3	P_4O_{10}	SO_2 / SO_3
oxidation number	+1	+2	+3	+5	+4 / +6

The chlorides NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$, PCl_5 show oxidation numbers +1 to +5 in the same way.

Oxides with water, and acid–base behaviour

Across the period the **oxides** 氧化物 change from basic to acidic:



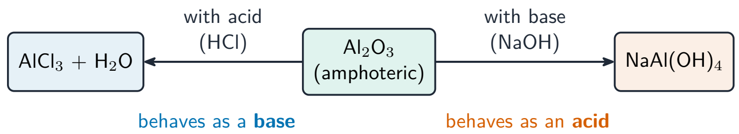
The Period 3 oxides change from basic (the metals) through amphoteric (Al_2O_3) to acidic (the non-metals)

Oxide	With water	Acid–base nature	Approximate pH
Na_2O	$Na_2O + H_2O \rightarrow 2NaOH$	basic	13–14
MgO	$MgO + H_2O \rightarrow Mg(OH)_2$	basic	9–10
Al_2O_3	insoluble	**amphoteric** 两性	7
SiO_2	insoluble	weakly acidic	7
P_4O_{10}	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$	acidic	1–2
SO_3	$SO_3 + H_2O \rightarrow H_2SO_4$	strongly acidic	0–1

Metal oxides (left) are basic; non-metal oxides (right) are acidic. Al_2O_3 and its **hydroxide** 氢氧化物 $Al(OH)_3$ are amphoteric — they react with **both** acids and bases:

$$\mathrm{Al_2O_3} + 6\mathrm{HCl} \rightarrow 2\mathrm{AlCl_3} + 3\mathrm{H_2O}$$

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

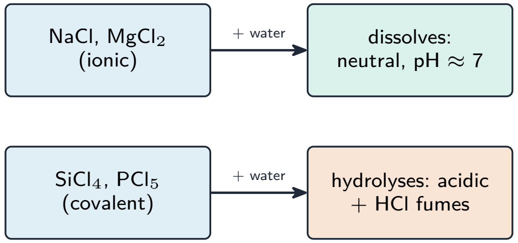


Aluminium oxide is amphoteric — it reacts with acids (behaving as a base) and with bases (behaving as an acid)

Chlorides with water

- NaCl and $MgCl_2$ are ionic. They simply dissolve, giving a near-neutral solution.
- $SiCl_4$ and PCl_5 are covalent. They undergo **hydrolysis** 水解 (react with water) to make acidic solutions and fumes of HCl:

$$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl \qquad PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$$



The ionic chlorides just dissolve (neutral); the covalent chlorides react with water (hydrolyse) to give an acidic solution and HCl fumes

Explaining the trends

These trends follow from the change in bonding and **electronegativity** 电负性. On the left, the elements are metals with low electronegativity, so their oxides and chlorides are ionic and basic (or neutral). On the right, the elements are non-metals with high electronegativity, so their oxides and chlorides are covalent and acidic. You can use a chloride's or oxide's properties (melting point, conductivity, effect on water) to suggest whether its bonding is ionic or covalent.

Worked example. Predict the pH when Na_2O, Al_2O_3 and SO_3 are each added to water. Acid-base character follows the **metal to non-metal** change across Period 3. Na_2O is ionic and basic: it dissolves to give NaOH, so the pH is about **13**. SO_3 is covalent and acidic: it reacts to give H_2SO_4, so the pH is about **1**. Al_2O_3 sits at the changeover - it is **amphoteric** and essentially **insoluble** in water, so the pH stays about **7**. The trap is that last one: amphoteric does **not** mean neutral, it means the oxide reacts with acids **and** with alkalis - it simply does not react with water.

Periodicity of other elements

The same idea works for any group. If you know the pattern down a group and across a period, you can:

- **predict** the properties of an element from its position (for example, a Group 1 element will be a reactive metal forming a +1 ion).
- **deduce** the likely position and identity of an unknown element from its physical and chemical properties.

Exam tips

- Always pair the **trend with its reason**: atomic radius falls across Period 3 (rising nuclear charge, similar shielding).
- Explain the **melting-point pattern** by structure: giant metallic (Na→Al), giant covalent (Si, highest), then simple molecular (P_4, S_8, Cl_2) and monatomic (Ar).
- Oxides go **basic → amphoteric (Al_2O_3) → acidic** across the period; link to ionic-to-covalent bonding.
- For reactions of oxides/chlorides with water, give the **products and the resulting pH**.