

Period 3 trends in radius, energy and melting

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lesson

Quick answer: Periodicity means that properties repeat across the periodic table. Across period 3, from sodium to argon, atomic radius falls and first ionisation energy rises (with dips at aluminium and sulfur) because nuclear charge increases in the same shell. Melting point peaks at giant covalent silicon and drops for simple molecules.

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What does periodicity mean for period 3?

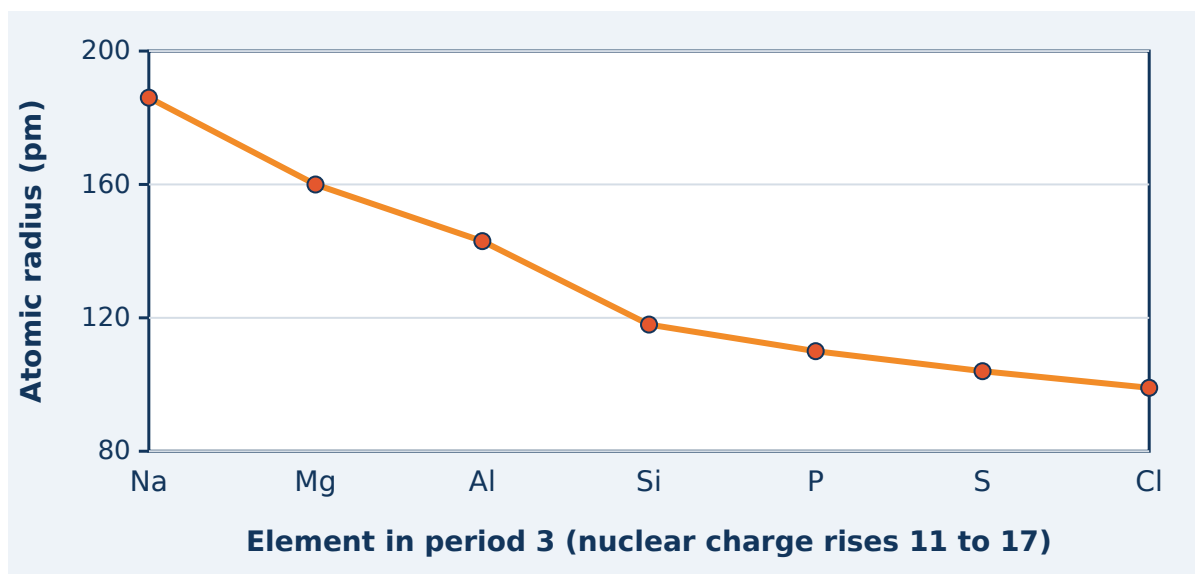
Definition

Periodicity is the repeating pattern in the physical and chemical properties of elements when they are placed in order of atomic number. Period 3 runs from sodium to argon, and each element adds one electron to the third shell (3s then 3p) while the 10 inner electrons stay the same.

That single fact, a rising nuclear charge acting on a shell that stays at about the same distance, explains most of the trends below. Always say which of the two ideas you are using.

Why does atomic radius decrease across period 3?

From sodium to chlorine the nuclear charge grows from +11 to +17. The extra electrons enter the same shell, so shielding by the 10 inner electrons hardly changes. The outer electrons feel a stronger pull and the atom shrinks.



Atomic radius falls steadily from sodium to chlorine (argon omitted: it forms no bonds).

Element	Nuclear charge	Outer electrons	Radius (pm)
Na	+11	3s ¹	186
Mg	+12	3s ²	160
Al	+13	3s ² 3p ¹	143
Si	+14	3s ² 3p ²	118
P	+15	3s ² 3p ³	110
S	+16	3s ² 3p ⁴	104
Cl	+17	3s ² 3p ⁵	99

Worked example

Calculate the percentage fall in radius from sodium (186 pm) to chlorine (99 pm).

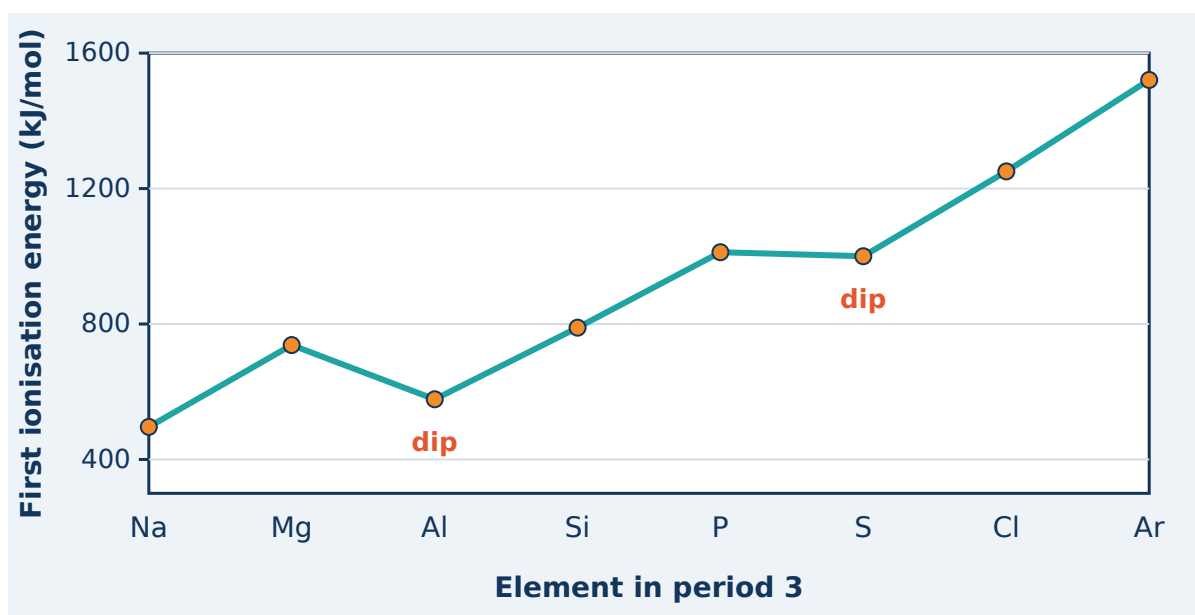
Fall = 186 – 99 = 87 pm. Percentage = 87 / 186 × 100 = **46.8 %**.

How does first ionisation energy change across period 3?

Definition

The first ionisation energy is the energy needed to remove one mole of electrons from one mole of gaseous atoms to form one mole of gaseous 1+ ions: $X(g) \rightarrow X^+(g) + e^-$. Its unit is kJ/mol.

The overall rise comes from the same cause as the shrinking radius: a bigger pull on a closer outer electron. Two dips break the pattern.



First ionisation energy rises across period 3 but dips at aluminium and at sulfur.

Worked example

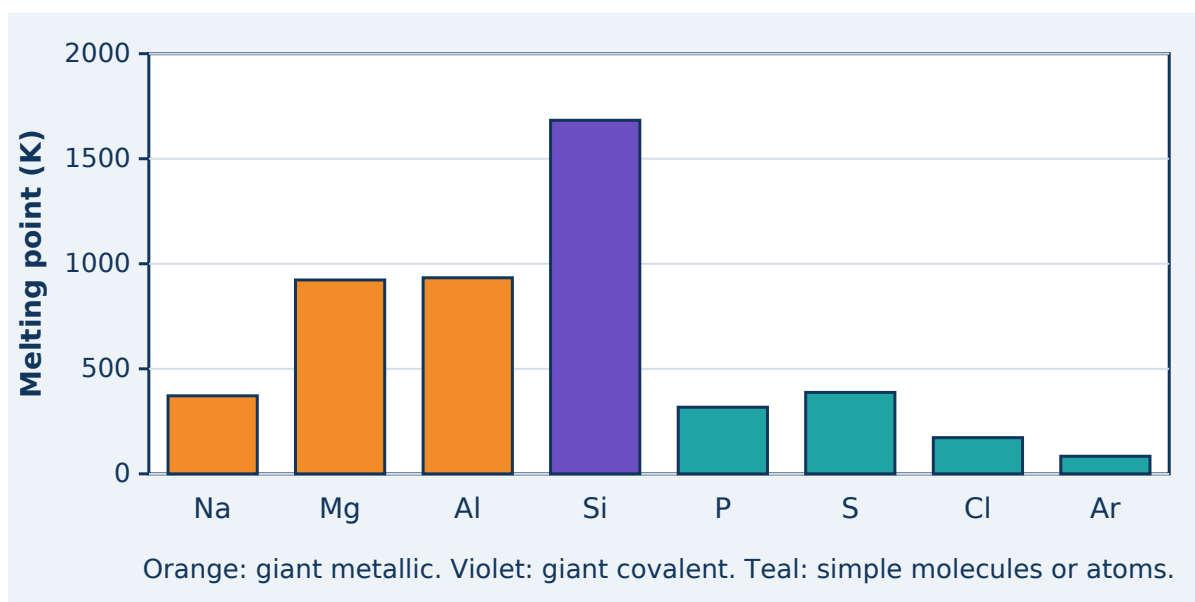
Explain why aluminium (578 kJ/mol) has a lower first ionisation energy than magnesium

(738 kJ/mol), and sulfur (1000 kJ/mol) a lower one than phosphorus (1012 kJ/mol).

Al: the outer electron is in a 3p subshell, which has higher energy than 3s and is partly shielded by the 3s electrons, so it is removed more easily. S: the 3p⁴ configuration pairs two electrons in one 3p orbital, and their repulsion makes one of them easier to remove than the unpaired 3p³ electron of phosphorus. **Both dips come from subshell energy or electron pairing, not from distance.**

Why do melting points change across period 3?

Melting point depends on the strength of the forces that must be overcome, and these change with structure.



Melting points peak at silicon (giant covalent) and are low for the simple molecular elements.

Elements	Structure	What is overcome on melting
Na, Mg, Al	Giant metallic lattice	Attraction between cations and delocalised electrons
Si	Giant covalent lattice	Many strong covalent bonds
P ₄ , S ₈ , Cl ₂	Simple molecules	Weak London forces between molecules
Ar	Single atoms	Very weak London forces between atoms

Key law

Metals: the more delocalised electrons per atom and the smaller the cation, the stronger the metallic bonding and the higher the melting point. Simple molecular substances: the more electrons in the molecule, the stronger the London forces and the higher the melting point.

Worked example

Explain why sulfur (S₈, 388 K) melts at a higher temperature than phosphorus (P₄, 317 K).

Electrons per molecule: P₄ = 4 × 15 = 60; S₈ = 8 × 16 = 128. The larger electron cloud of

S₈ gives stronger London forces, so more energy is needed to separate the molecules. **S₈ has 128 electrons against 60 for P₄, so its melting point is higher.**

Common mistake

Never write that covalent bonds break when sulfur or chlorine melts. Only the weak forces between molecules are overcome. Covalent bonds break only in giant covalent silicon.

Lina's tip

Before explaining any trend, name the structure first (metallic, giant covalent or simple molecular). The structure tells you which force to talk about.

How do conductivity and structure link?

Magnesium and aluminium conduct because their delocalised electrons move. Silicon is a poor conductor (a semiconductor), while phosphorus, sulfur, chlorine and argon have no free charge carriers, so they are insulators.

Key points to remember

- Nuclear charge rises from +11 (Na) to +18 (Ar) while shielding by inner electrons stays about constant.
- Atomic radius falls from 186 pm (Na) to 99 pm (Cl).
- First ionisation energy dips at Al (3p electron) and S (paired 3p electrons).
- Melting points: giant metallic rising Na to Al, highest for giant covalent Si (1683 K), low for simple molecules.
- Simple molecular melting points rise with electron count: S₈ above P₄ above Cl₂ above Ar.

Period 3 trends in radius, energy and melting: frequently asked questions

What is periodicity in chemistry?

Periodicity is the repeating pattern of properties as atomic number increases. Elements in the same group show similar behaviour because they have the same number of outer electrons.

Why does atomic radius decrease across period 3?

The nuclear charge increases but the outer electrons stay in the same shell with similar shielding. The stronger attraction pulls the electrons closer to the nucleus, so the atom gets smaller.

Why is the first ionisation energy of aluminium lower than that of magnesium?

The outer electron of aluminium is in a 3p subshell, which is higher in energy and partly shielded by the 3s electrons. It is therefore easier to remove than the 3s electron of

magnesium.

Why does silicon have such a high melting point?

Silicon has a giant covalent lattice in which every atom is bonded to four others. Melting needs a huge amount of energy to break many strong covalent bonds.

Why does the melting point fall sharply after silicon?

Phosphorus, sulfur and chlorine exist as small separate molecules. Melting only overcomes weak London forces between the molecules, not covalent bonds.