Cambridge (CIE) A Level Chemistry

Your notes

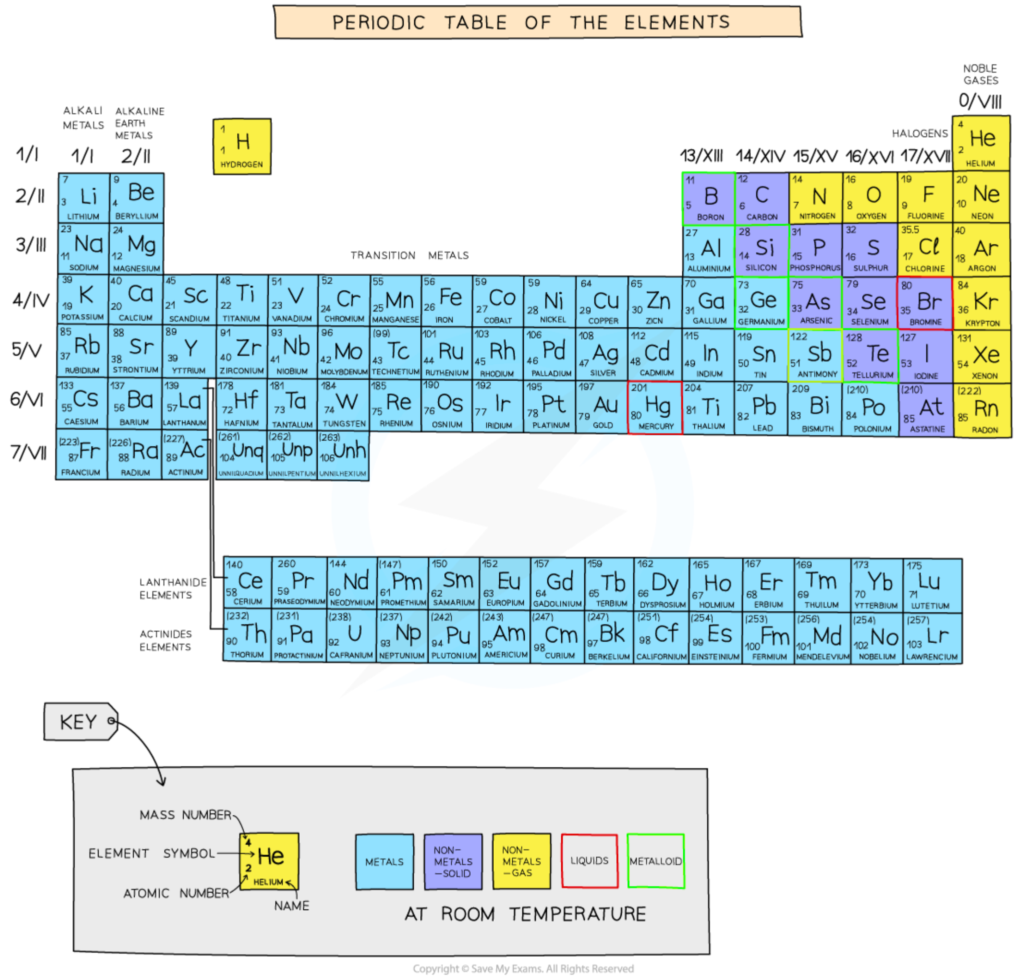
Periodicity of Physical Properties of the Elements in Period 3

Contents

Describing Physical Properties of the Period 3 Elements

- Elements in the periodic table are arranged in order of increasing atomic number and placed in vertical columns (**groups**) and horizontal rows (**periods**)
- The elements across the periods show **repeating patterns** in chemical and physical properties
- This is called **periodicity**

Arrangement of elements in the Periodic Table



Elements are arranged by increasing atomic number from left to right

Atomic radius

- The **atomic radius** is the distance between the nucleus and the outermost electron of an atom

- The atomic radius is measured by taking two atoms of the same element, measuring the distance between their nuclei and then halving this distance
- In **metals,** this is also called the **metallic radius** and in **non-metals**, the **covalent radius**

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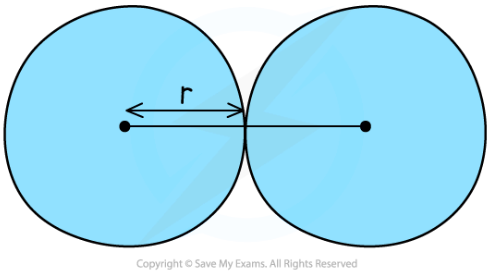
Atomic radius

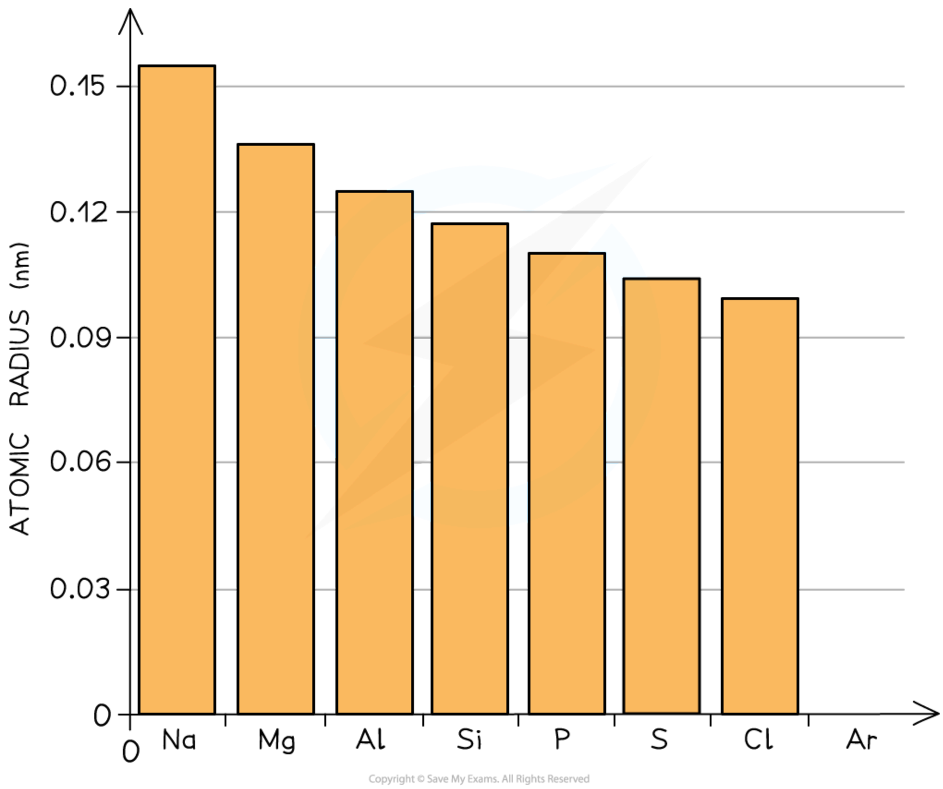


The atomic radius gives a measure of the size of atoms

Atomic radii of Period 3 elements table

Period 3 element	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic radius (nm)	0.157	0.136	0.125	0.117	0.110	0.104	0.099	-

Graph of atomic radii across Period 3



There is a decrease in atomic radii of Period 3 elements across the period

- Across the period, the atomic radii decrease
- This is because the number of protons (**the nuclear charge**) and the number of **electrons** increases by one every time you go an element to the right
- The elements in a period all have the same number of shells (so the **shielding effect** is the same)
- This means that as you go across the period the nucleus attracts the electrons more **strongly pulling them closer** to the nucleus
- Because of this, the atomic radius (and thus the size of the atoms) **decreases** across the period

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Ionic radius

- The **ionic radius** is the distance between the nucleus and the outermost electron of an ion
- Metals produce positively charged ions (**cations**) whereas nonmetals produce negatively charged ions (**anions**)
- The **cations** have lost their valence electrons which causes them to be much **smaller** than their parent atoms
  - This is because there are less electrons, which also means that there is less **shielding** of the outer electrons
- Going across the period from Na^+ to Si^{4+} the ions get **smaller** due to the **increasing nuclear charge** attracting the outer electrons in the **second principal quantum shell** nucleus (which has an increasing atomic number)
- The **anions** are larger than their original parent atoms because each atom has gained one or more electrons in their **third principal quantum shell**
- This increases the repulsion between electrons, while the **nuclear charge** is still the same, causing the electron cloud to spread out
- Going across P^{3-} to Cl^-, the ionic radii **decrease** as the nuclear charge increases across the period and fewer electrons are gained by the atoms (P gains 3 electrons, S 2 electrons and Cl 1 electron)

Ionic radii of ions of Period 3 elements table

Period 3 ion	Na^+	Mg^{2+}	Al^{3+}	Si^{4+}	P^{3-}	S^{2-}	Cl^-	Ar
Ionic radius (nm)	0.095	0.065	0.050	0.041	0.212	0.184	0.181	No data

Graph of ionic radii across Period 3 ions

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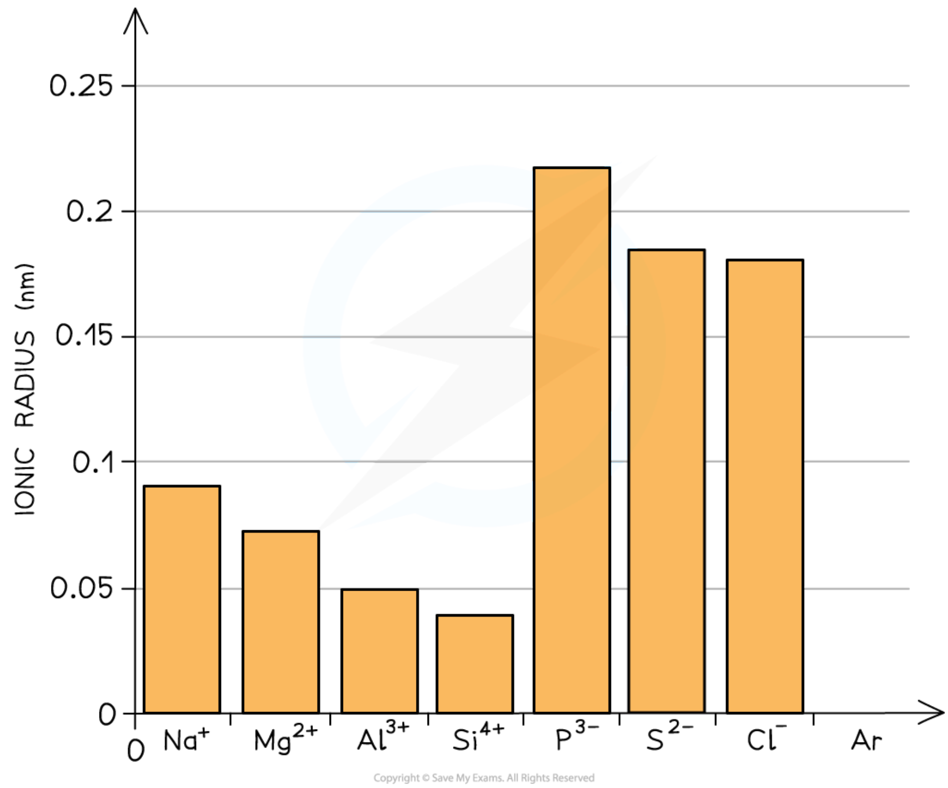

Ions of Period 3 elements with increasing positive charge (metals) and increasing outer electrons across the period

Melting point

Melting points of the elements across Period 3 table

Period 3 element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting point (K)	371	923	932	1683	317	392	172	84

Graph of melting points across Period 3

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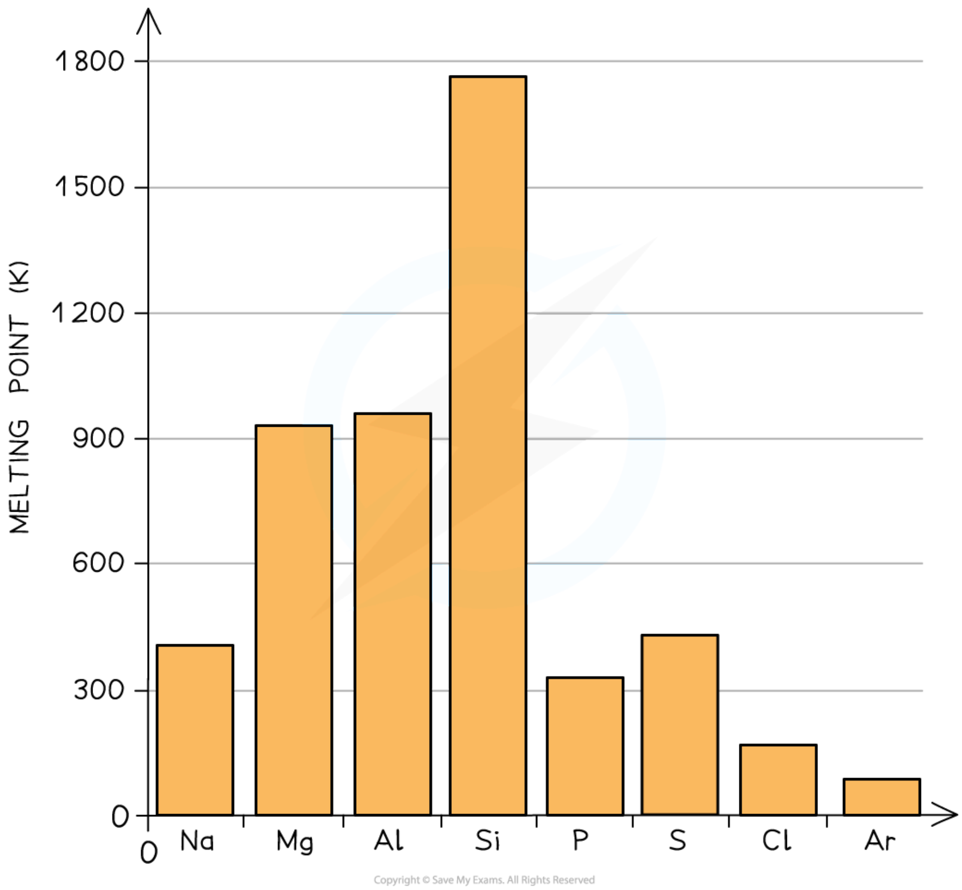

There is a general increase in melting point from Na to Si, followed by a sharp drop to the lower melting points of P to Ar

- A general increase in **melting point** for the Period 3 elements up to silicon is observed
- **Silicon** has the highest **melting point**
- After the Si element, the melting points of the elements **decrease** significantly

Electrical conductivity

- **Electrical conductivity** refers to how well a substance can conduct **electricity**
- Unlike the melting points, the electrical conductivity of the Period 3 elements shows a clear trend
- Going across the period, the electrical conductivity of the elements **decreases** significantly
  - Initially there is an increase in the electrical conductivity from Na to Al and then this decreases across the remaining elements

Trends in electrical conductivity across Period 3 table

Period 3 element	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**Ar**

Electrical conductivity ($S\ m^{-1}$)	0.218	0.224	0.382	2×10^{-10}	10^{-17}	10^{-23}	-	-

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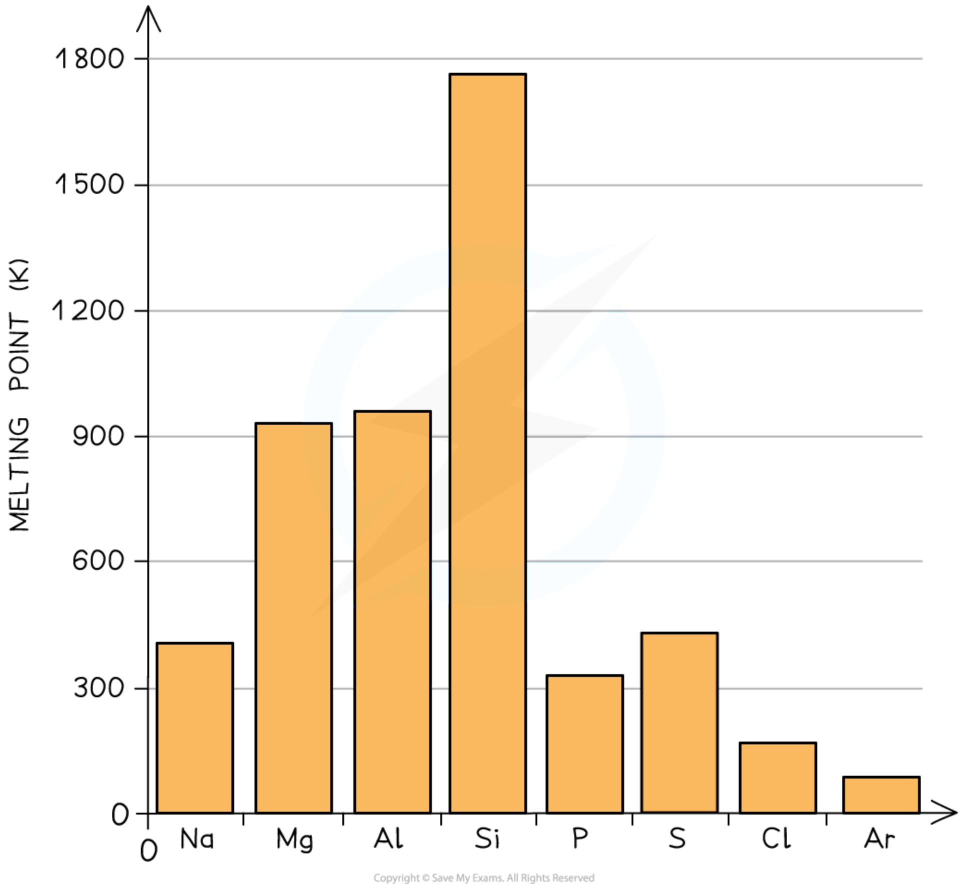
Explaining Physical Properties of the Period 3 Elements

Melting point

Melting points of the elements across Period 3 table

Period 3 element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting point (K)	371	923	932	1638	317	392	172	84

Graph of melting points across Period 3



There is a general increase in melting point from Na to Si, followed by a sharp drop to the lower melting points of P to Ar

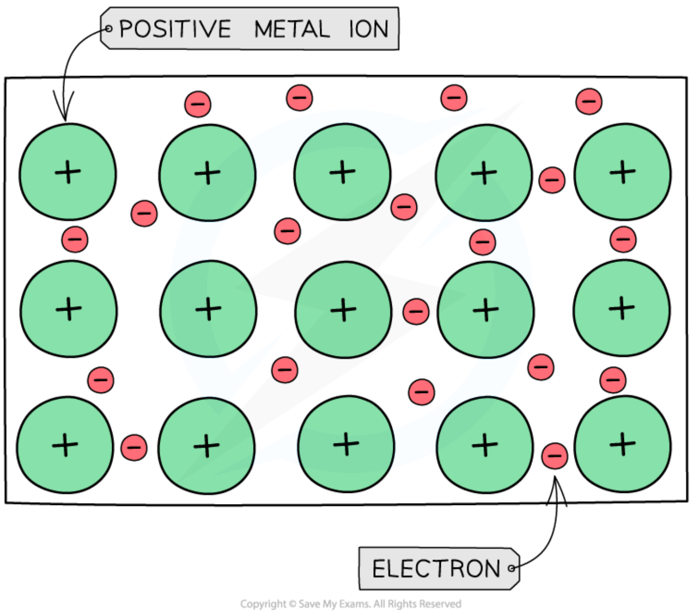
- The above trends can be explained by looking at the bonding and structure of the elements

Bonding and structure of the Period 3 elements table

Period 3 element	Na	Mg	Al	Si	P	S	Cl
Bonding	Metallic	Metallic	Metallic	Covalent	Covalent	Covalent	Covalent
Structure	Giant metallic	Giant metallic	Giant metallic	Giant molecular	Simple molecular	Simple molecular	Simple molecular

- The table shows that **Na**, **Mg** and **Al** are metallic elements which form positive ions arranged in a **giant lattice** in which the ions are held together by a 'sea' of delocalised electrons around them

The structure of metals



Metal cations form a giant lattice held together by electrons that can freely move around

Na, Mg and Al

- The electrons in the 'sea' of delocalised electrons are those from the **valence shell** of the atoms
- **Na** will donate one electron into the 'sea' of delocalised electrons, **Mg** will donate two and **Al** three electrons
- As a result of this, the metallic bonding in **Al** is stronger than in **Na**
- This is because the electrostatic forces between a **3+ ion** and the larger number of negatively charged delocalised electrons is much larger compared to a **1+ ion** and the smaller number of delocalised electrons in Na

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- Due to this, the **melting points increase** going from **Na** to **Al**

Si

- **Si** has the highest melting point due to its giant molecular structure in which each Si atom is held to its neighbouring Si atoms by **strong covalent bonds**

P, S, Cl and Ar

- **P**, **S**, **Cl** and **Ar** are non-metallic elements and exist as **simple molecules** (P_4, S_8, Cl_2 and Ar as a single atom)
- The **covalent bonds within** the molecules are strong, however, **between** the molecules, there are only weak **instantaneous dipole-induced dipole forces**
- It doesn't take much energy to break these **intermolecular** forces
- Therefore, the melting points decrease going from **P** to **Ar** (note that the melting point of S is higher than that of P as sulphur exists as larger S_8 molecules compared to the smaller P_4 molecule)

Electrical conductivity

- The **electrical conductivity decreases** going across the Period 3 elements

Trends in electrical conductivity across Period 3 table

Period 3 element	Na	Mg	Al	Si	P	S	Cl	Ar
Electrical conductivity (S^{m-1})	0.218	0.224	0.382	2×10^{-10}	10^{-17}	10^{-23}	-	-

- Going from **Na** to **Al**, there is an increase in the number of valence electrons that are donated to the 'sea' of delocalised electrons
- Because of this, in **Al** there are more electrons available to move around through the structure when it conducts electricity, making **Al** a better electrical conductor than **Na**
- Due to the **giant molecular structure** of **Si**, there are no delocalised electrons that can freely move around within the structure
- **Si** is therefore not a good electrical conductor and is classified as a **semimetal** (**metalloid**)
- The lack of delocalised electrons is also why **P** and **S** cannot conduct electricity

Examiner Tips and Tricks

- **Intermolecular forces** are forces **between** molecules
- **Intramolecular forces** are forces **within** a molecule

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