CAIE Chemistry A-level

Topic 9 - The Periodic Table: Chemical Periodicity

Flashcards

Describe and explain the trend in atomic radius across Period 3

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As you go across the period:

- Number of protons in the nucleus (nuclear charge) increases;
- Number of electrons in the outer shell increases;
- Shielding remains the same.

Therefore, nuclear attraction between the electrons and the nucleus increases so electron shells are drawn closer to the nucleus, decreasing the atomic radius.

Describe and explain the trend in ionic radius across Period 3

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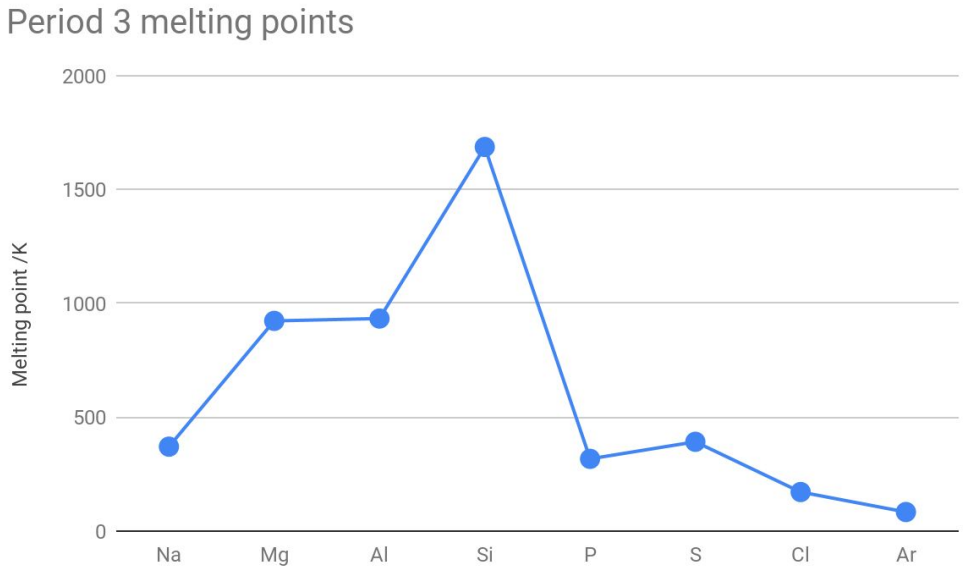
- From Na^{+} to Mg^{2+} to Al^{3+}:
  Ionic radius decreases because the number of electrons decreases and the ionic charge increases. There is greater attraction between outer shell electrons and the nucleus meaning the electrons are drawn inwards.

- From P^{3-} to S^{2-} to Cl^{-}:
  Ionic radius increases because the number of electrons increases which weakens the nuclear attraction meaning the electrons are not drawn inwards as strongly.

Use a diagram to describe the trend in melting points across Period 3

Use a diagram to describe the trend in melting points across Period 3



Describe the trend in melting point across Period 3

Describe the trend in melting point across Period 3

- Melting point increases from sodium to silicon.
- There is a sharp decrease in melting point between silicon and phosphorus.
- There is a slight increase in melting point between phosphorus and sulfur.
- Melting point then decreases from sulfur to argon.

Why does melting point increase from sodium to silicon?

Why does melting point increase from sodium to silicon? Na → Mg → Al → Si

Na, Mg and Al are all giant metallic structures. As you go from Na to Mg to Al, number of protons and electrons increases whilst atomic radius decreases. This leads to greater electrostatic attraction between nuclei and electrons which requires more energy to overcome.

Silicon has a giant covalent lattice structure. It has strong covalent bonds between atoms which require a lot of energy to break.

Why is there is a sharp decrease in melting point between silicon and phosphorus?

Why is there is a sharp decrease in melting point between silicon and phosphorus?

Silicon has a giant covalent lattice structure whereas phosphorus has a simple covalent structure.

The strong covalent bonds between the silicon atoms require a lot of energy to overcome whereas the weak London forces between P_4 molecules require little energy to overcome.

Why is there is a slight increase in melting point between phosphorus and sulfur?

Why is there is a slight increase in melting point between phosphorus and sulfur?

Sulfur has more atoms per molecule than phosphorus so sulfur molecules contain more protons and electrons. As a result, the London forces between molecules are stronger so more energy is required to overcome these forces.

The increase is only small because sulfur is still a simple molecular compound.

Why does melting point decrease from sulfur to argon?

Why does melting point decrease from sulfur to argon?

S_8, Cl_2 and Ar are all simple covalent substances.

From S_8 to Cl_2 to Ar, the molecules are getting smaller. This means that there are weaker intermolecular London forces between molecules.

As a result, less energy is required to overcome these forces and melt the substance.

Describe and explain how electrical conductivity varies across Period 3

Describe and explain how electrical conductivity varies across Period 3

Conductivity increases from sodium to magnesium to aluminium because metallic bonding means that they contain delocalised electrons that are free to move. Conductivity increases as the charge of the cation increases as it means there are more delocalised electrons.

Silicon is a semiconductor.

Elements from phosphorus to argon are non-conductors because they are simple molecular substances so they have no mobile charged particles.

How does ionisation energy vary across Period 3?

How does ionisation energy vary across Period 3?

In general, across a period:

- Nuclear charge and atomic radius increases;
- Shielding remains the same;
- Nuclear attraction increases.

As a result, more energy is required to remove an electron, so ionisation energy increases.

Describe how sodium reacts with oxygen (include an equation)

Describe how sodium reacts with oxygen (include an equation)

$$2Na + ½O_2 \rightarrow Na_2O$$

Sodium burns in oxygen with an orange flame to produce sodium oxide, a white solid.

Describe how magnesium reacts with oxygen (include an equation)

Describe how magnesium reacts with oxygen (include an equation)

$$Mg + \frac{1}{2}O_2 \rightarrow MgO$$

Magnesium burns in oxygen with an intense white flame to form magnesium oxide, a white solid.

Describe how aluminium reacts with oxygen (include an equation)

Describe how aluminium reacts with oxygen (include an equation)

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

Powdered aluminium will burn in oxygen. Sprinkling this powder into a bunsen gives white sparkles and forms aluminium oxide, a white solid.

Describe how phosphorus reacts with oxygen (include an equation)

Describe how phosphorus reacts with oxygen (include an equation)

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$

White phosphorus catches fire spontaneously in air and burns with a white flame. In excess oxygen, phosphorus(V) oxide forms.

Describe how sulfur reacts with oxygen (include an equation)

Describe how sulfur reacts with oxygen (include an equation)

$$S + O_2 \rightarrow SO_2$$

Sulfur burns in air on gentle heating with a pale blue flame. This produces colourless SO_2 gas. To convert SO_2 to SO_3:

- $2SO_2 + O_2 \rightleftharpoons 2SO_3$
- 400-450℃, 1-2 atm, V_2O_5 catalyst.

Describe how sodium reacts with chlorine (include an equation)

Describe sodium reacts with chlorine (include an equation)

$$Na + \frac{1}{2}Cl_2 \rightarrow NaCl$$

Sodium burns in chlorine with a bright orange flame to produce sodium chloride, a white solid.

Describe how magnesium reacts with chlorine (include an equation)

Describe how magnesium reacts with chlorine (include an equation)

$$Mg + Cl_2 \rightarrow MgCl_2$$

Magnesium burns in chlorine with an intense white flame to form magnesium chloride, a white solid.

Describe how aluminium reacts with chlorine (include an equation)

Describe how aluminium reacts with chlorine (include an equation)

$$2Al + 3Cl_2 \rightarrow 2AlCl_3$$

Dry chlorine is passed over aluminium foil to form aluminium chloride, a very pale yellow solid.

$$2AlCl_3 \rightleftharpoons Al_2Cl_6$$

At around 180 - 190℃ (dependent upon pressure), $AlCl_3$ is converted to Al_2Cl_6 which then vaporises.

Describe how silicon reacts with chlorine (include an equation)

Describe how silicon reacts with chlorine (include an equation)

$$Si + 2Cl_2 \rightarrow SiCl_4$$

If chlorine is passed over powdered silicon and heated, it reacts to form silicon tetrachloride, a colourless liquid, which then evaporates.

Describe how phosphorus reacts with chlorine (include an equation)

Describe how phosphorus reacts with chlorine (include an equation)

$$P_4 + 10Cl_2 \rightarrow 4PCl_5$$

White phosphorus burns spontaneously in excess chlorine to form PCl_5, an off-white, almost yellow, solid.

Describe how sodium reacts with cold water (include an equation)

Describe how sodium reacts with water (include an equation)

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

A very exothermic reaction forms hydrogen gas and a colourless solution of sodium hydroxide.

Describe how magnesium reacts with cold water (include an equation)

Describe how magnesium reacts with cold water (include an equation)

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

Magnesium hydroxide forms on the outside of the metal strip. A few bubbles of hydrogen float to the surface of container. The reaction generally stops after this.

Describe how magnesium reacts with steam (include an equation)

Describe how magnesium reacts with steam (include an equation)

$$Mg + H_2O \rightarrow MgO + H_2$$

Magnesium burns in steam with its typical white flame.

How do Period 3 oxides (from sodium to sulfur) vary in oxidation number?

How do Period 3 oxides (from sodium to sulfur) vary in oxidation number?

Na_2O, MgO, Al_2O_3, P_4O_{10}, SO_2, SO_3

+1 +2 +3 +5 +4 +6

The general trend is that oxidation numbers increase (apart from SO_2) across Period 3 oxides.

How do Period 3 chlorides (from sodium to phosphorus) vary in oxidation number?

How do Period 3 chlorides (from sodium to phosphorus) vary in oxidation number?

$\underset{+1}{NaCl}$, $\underset{+2}{MgCl_2}$, $\underset{+3}{Al_2Cl_6}$, $\underset{+4}{SiCl_4}$, $\underset{+5}{PCl_5}$

From sodium to phosphorus, the oxidation number increases.

Why does the oxidation number of Period 3 oxides and chlorides vary?

Why does the oxidation number of Period 3 oxides and chlorides vary?

Each element in Period 3 has a different number of electrons in its outer shell. Therefore, each element needs to gain/lose/share a different number of electrons to have a full outer shell and form the oxide/chloride. This leads to each element having a different oxidation state.

Describe how sodium oxide reacts with water (include an equation)

Describe how sodium oxide reacts with water (include an equation)

$$Na_2O + H_2O \rightarrow 2NaOH$$

The reaction is exothermic and forms a highly alkaline solution.

Describe how magnesium oxide reacts with water (include an equation)

Describe how magnesium oxide reacts with water (include an equation)

$$MgO + H_2O \rightarrow Mg(OH)_2$$

- Forms a slightly alkaline solution.
- Most of the $Mg(OH)_2$ product is insoluble and so doesn't further increase the pH.

Describe how phosphorus(V) oxide reacts with water (include an equation)

Describe how phosphorus(V) oxide reacts with water (include an equation)

$$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$$

- Forms an acidic solution.
- Violent reaction.

Describe how sulfur dioxide reacts with water (include an equation)

Describe how sulfur dioxide reacts with water (include an equation)

$$SO_2 + H_2O \rightarrow H_2SO_3$$

- Forms an acidic solution.

Describe how sulfur trioxide reacts with water (include an equation)

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$$SO_3 + H_2O \rightarrow H_2SO_4$$

- Forms an acidic solution.
- Violent reaction.

How does sodium oxide react with hydrochloric acid?

How does sodium oxide react with hydrochloric acid?

Na_2O is a strong base. It reacts with an acid to form a salt and water:

$$Na_2O + 2HCl \rightarrow 2NaCl + H_2O$$

How does magnesium oxide react with hydrochloric acid?

How does magnesium oxide react with hydrochloric acid?

MgO is a weaker base than Na_2O. It reacts with warm dilute HCl to form a salt and water:

$$MgO + 2HCl \rightarrow MgCl_2 + H_2O$$

What does *amphoteric* mean?

What does *amphoteric* mean?

An amphoteric compound is able to act as both an acid and a base.

How is aluminium oxide amphoteric?

How is aluminium oxide amphoteric?

Aluminium oxide (Al_2O_3) is amphoteric as it reacts with both acids and bases.

How does phosphorus(V) oxide react with NaOH?

How does phosphorus (V) oxide react with NaOH?

There are many different reactions that can occur between phosphorus(V) oxide and NaOH, an example is:

$$P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$$

How does sulfur dioxide react with NaOH?

How does sulfur dioxide react with NaOH?

Sulfur dioxide is bubbled through sodium hydroxide solution:

$$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$$

If the sulfur dioxide is in excess:

$$Na_2SO_3 + H_2O + SO_2 \rightarrow 2NaHSO_3$$

Which oxides do not react with water?

Which oxides do not react with water?

Aluminium oxide - insoluble in water.

Silicon dioxide - breaking up its giant covalent lattice structure is too difficult.

Does silicon dioxide react with acids or bases?

Does silicon dioxide react with acids or bases?

Bases (e.g. sodium hydroxide)

Describe how NaCl reacts with water (include an equation)

Describe how NaCl reacts with water (include an equation)

NaCl dissolves in water to form a neutral solution (pH 7).

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Describe how $MgCl_2$ reacts with water (include an equation)

Describe how $MgCl_2$ reacts with water (include an equation)

$MgCl_2$ dissolves in water to form a slightly acidic solution:

$$MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$$

A small proportion of hydrogen ions are removed from the hydrated magnesium ion, as it a weak acid:

$$[Mg(H_2O)_6]^{2+} + H_2O \rightleftharpoons [Mg(H_2O)_5(OH)]^+ + H_3O^+$$

Describe how $AlCl_3$ reacts with water (include an equation)

Describe how $AlCl_3$ reacts with water (include an equation)

$$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$$

Hydrated aluminium ions are a stronger acid than hydrated magnesium ions so the position of equilibrium lies further to the right:

$$[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H_3O^+$$

Describe how $SiCl_4$ reacts with water (include an equation)

Describe how $SiCl_4$ reacts with water (include an equation)

$$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$$

Violent reaction, produces silicon dioxide and misty fumes of hydrogen chloride gas.

Write an equation for the reaction between PCl_5 and cold water

Write an equation for the reaction between PCl_5 and cold water

$$PCl_5 + H_2O \rightarrow POCl_3 + 2HCl$$

How does PCl_5 react with boiling water?

How does PCl_5 react with boiling water?

With water: $PCl_5 + H_2O \rightarrow POCl_3 + 2HCl$

If the water is boiling the $POCl_3$ will continue to react:

$$POCl_3 + 3H_2O \rightarrow H_3PO_4 + 3HCl$$

Overall boiling water equation:

$$\mathbf{PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl}$$

Describe how the bonding in Period 3 oxides and chlorides varies across the period

Describe how the bonding in Period 3 oxides and chlorides varies across the period

Sodium and magnesium form ionic bonds with oxygen and chlorine. Aluminium forms covalent bonds with oxygen and either covalent or ionic bonds with chlorine. Other period 3 elements form simple covalent compounds.

Why does the bonding in Period 3 oxides and chlorides vary across the period?

Why does the bonding in Period 3 oxides and chlorides vary across the period?

The difference in electronegativity between chlorine/oxygen and the period 3 element decreases across the period. There is sufficient difference in the electronegativity of chlorine/oxygen and sodium or magnesium to form ions. After aluminium, the difference in electronegativity is too small for ions to form.

How can physical properties be used to predict the type of chemical bonding in Period 3 oxides and chlorides?

How can physical properties be used to predict the type of chemical bonding in Period 3 oxides and chlorides?

A high melting point indicates a giant molecular structure. This could either be ionic (like NaCl and MgO) or covalent (like SiO_2).

How can chemical properties be used to predict the type of chemical bonding in Period 3 oxides and chlorides?

How can chemical properties be used to predict the type of chemical bonding in Period 3 oxides and chlorides?

- Chlorides and water: Ionic chlorides form a solution with a pH close to 7. Covalent chlorides react to form an acidic solution and HCl gas.
- Oxides and water: Covalent oxides form an acidic solution. Ionic oxides may react to form an alkaline solution or they may not react at all.
- Acids and bases: Ionic oxides are generally basic (react with acids). Covalent oxides tend to be acidic (react with bases). Amphoteric oxides such as aluminium oxide are usually ionic with some covalent character.
- Electrolysis: Only molten ionic chlorides/oxides undergo electrolysis.

What is meant by periodicity?

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The recurring variations or trends in the properties of elements in the periodic table.

Which group normally forms stable -1 ions?

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Group 7:

F^-, Cl^-, Br^- and I^-

Which group normally forms stable +1 ions?

Which group normally forms stable +1 ions?

Group 1:

Li^+, Na^+, K^+ and Rb^+

Which group normally forms stable +2 ions?

Which group normally forms stable +2 ions?

Group 2:

Be^{2+}, Mg^{2+}, Ca^{2+} and Sr^{2+}

What structure do group 4 elements normally have?

What structure do group 4 elements normally have?

Giant covalent structure