Week 17

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

9. The Periodic Table: chemical periodicity

Starter Quiz · 课前小测

A-Level Chemistry Name: _____ Score: _____

1. Periodicity means that properties:

   ☐ repeat in a regular pattern across each period

   ☐ are random

   ☐ only change down a group

   ☐ never change

2. Which Period 3 elements react with water?

   ☐ sodium (fast) and magnesium (very slowly)

   ☐ all of them

   ☐ silicon and phosphorus

   ☐ none of them

3. Across Period 3, the oxides change from:

   ☐ basic (metals) through amphoteric to acidic (non-metals)

   ☐ acidic to basic

   ☐ all basic

   ☐ all neutral

4. From its position, what can you predict about a Group 1 element?

   ☐ it is a reactive metal that forms a $+1$ ion

   ☐ it is an unreactive gas

   ☐ it forms a -1 ion

   ☐ it is a non-metal

5. Across Period 3, the atomic radius:

   ☐ decreases, as the rising nuclear charge pulls the same shell inwards

   ☐ increases

   ☐ stays constant

   ☐ doubles

6. The same periodic patterns apply to any group or period, not just Period 3.

   ☐ True ☐ False

7. Across a period, elements change from metallic to _____.

   _____

8. Across Period 3, atomic radius decreases.

   ☐ True ☐ False

9. Sodium reacts vigorously with water to form sodium hydroxide and _____.

   _____

10. Sodium oxide dissolves in water to form an alkaline solution.

    ☐ True ☐ False

9. The Periodic Table: chemical periodicity

Answers · 答案

A-Level Chemistry

1. **repeat in a regular pattern across each period**

   Periodicity is the repeating pattern of properties across the periods of the table.

2. **sodium (fast) and magnesium (very slowly)**

   Only Na and Mg react with water; sodium reacts fast, magnesium only very slowly with cold water.

3. **basic (metals) through amphoteric to acidic (non-metals)**

   Metal oxides on the left are basic; non-metal oxides on the right are acidic; Al_2O_3 is amphoteric in between.

4. **it is a reactive metal that forms a +1 ion**

   Group 1 elements are reactive metals with one outer electron, forming +1 ions.

5. **decreases, as the rising nuclear charge pulls the same shell inwards**

   More protons pull the outer shell in more strongly, while shielding stays about the same.

6. **True**

   Periodicity is general — once you know the trends, they apply across the whole table.

7. **non-metallic**

   Metallic character decreases across a period.

8. **True**

   Increasing nuclear charge pulls electrons closer.

9. **hydrogen**

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

10. **True**

    Metal oxides are basic; non-metal oxides acidic.

A-LEVEL CHEMISTRY • EXERCISE SHEET

9.1 Periodicity of physical properties of Period 3

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS atomic radius 原子半径 • ionic radius 离子半径 • melting point 熔点 • electrical conductivity 导电性 • period 周期

Objective

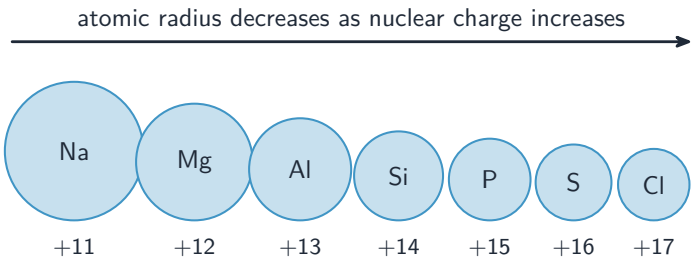
Build the skills to answer exam questions on the **physical properties of Period 3** — the trends in **atomic radius** 原子半径, **melting point** 熔点 and **electrical conductivity** 导电性, explained by structure and bonding.

You must be able to:

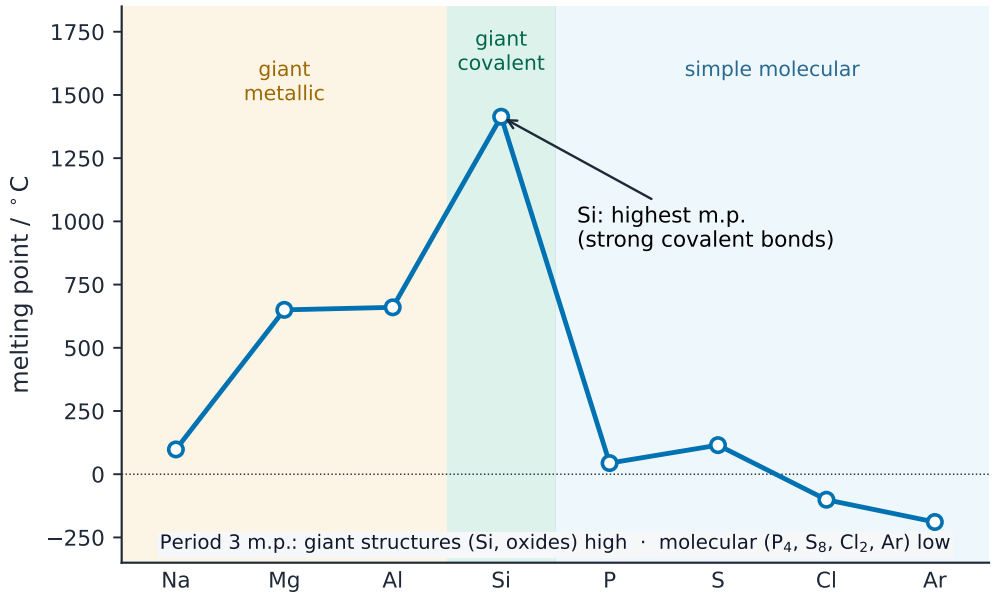
- describe the trends in atomic/ionic radius, melting point and conductivity across Period 3
- explain the melting point and conductivity trends in terms of structure and bonding

1 Worked examples

■ Trends across Period 3



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



Melting point peaks at silicon (giant covalent); high for the metals, low for the simple molecular elements

- **Na, Mg, Al — giant metallic**: m.p. rises (more delocalised electrons, smaller ions); conduct well.
- **Si — giant covalent**: highest m.p. (strong covalent bonds); barely conducts.
- **P, S, Cl, Ar — simple molecular**: low m.p. (weak forces); do not conduct.

2 Practice

2.1 Describe the trend in atomic radius across Period 3. [1]

2.2 State which Period 3 element has the highest melting point and what type of structure it has. [2]

3 Exam-style questions

3.1 Why do Na, Mg and Al conduct electricity well? [1]

- **A** they are simple molecular
- **B** they have delocalised electrons (giant metallic)
- **C** they have covalent networks
- **D** they have low melting points

3.2 Why does silicon have the highest melting point in Period 3? [1]

- **A** it is a metal
- **B** strong covalent bonds throughout a giant structure must be broken
- **C** it has the most delocalised electrons
- **D** only weak forces hold it together

3.3 Explain why the melting point increases from sodium to aluminium. [3]

3.4 Explain why the melting point of sulfur (S_8) is higher than that of phosphorus (P_4). [2]

Solutions

2.1 it decreases across the period.

2.2 silicon; giant covalent / giant molecular.

3.1 B. Giant metallic structures have delocalised electrons that conduct.

3.2 B. Silicon is a giant covalent structure with strong bonds throughout.

3.3 from Na to Al each atom releases more delocalised electrons ($1 \rightarrow 3$); and the metal ions get smaller with higher charge; so the metallic bonding is stronger, needing more energy to melt.

3.4 sulfur exists as larger S_8 molecules with more electrons than P_4; so it has stronger London (van der Waals) forces, giving a higher melting point.

16 The atomic radii and ionic radii for three elements in Period 3 are shown.

	atomic radius / nm	ionic radius / nm
element X	0.118	0.053
element Y	0.099	0.180
element Z	0.160	0.072

Using this data, which statement is correct?

A Element X has lower electrical conductivity than element Y.

B Element Y has a higher melting point than element X.

C Element Y and element Z react to form an ionic compound.

D Element Z forms ionic compounds by gaining electrons.

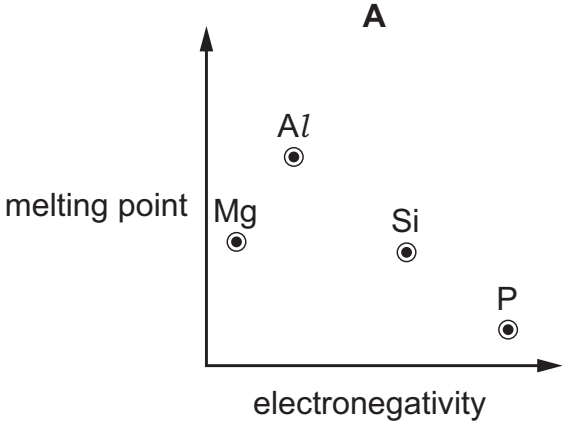
17 Sodium and sulfur react together to form sodium sulfide, Na_2S.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

	atomic radius	ionic radius
A	sulfur is greater	sodium is greater
B	sulfur is greater	sulfur is greater
C	sodium is greater	sodium is greater
D	sodium is greater	sulfur is greater

17 Which graph shows the relative melting points of the elements Mg, A*l*, Si and P plotted against their relative electronegativities?

A



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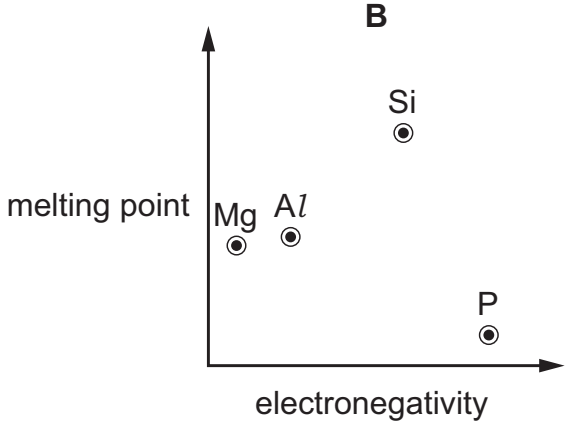

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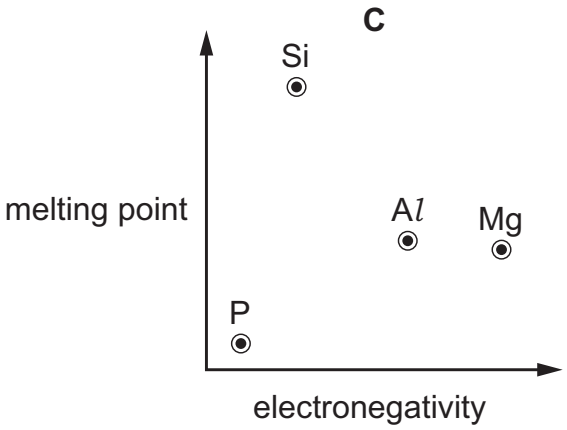

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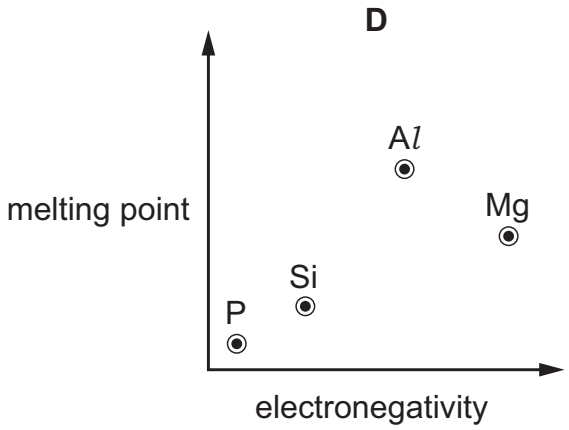


2 The Period 3 elements show trends in physical and chemical properties across the period.

(a) Fig. 2.1 shows the variation in atomic and ionic radii of the Period 3 elements Na to C*l*.

The ionic radius of Si is **not** shown.

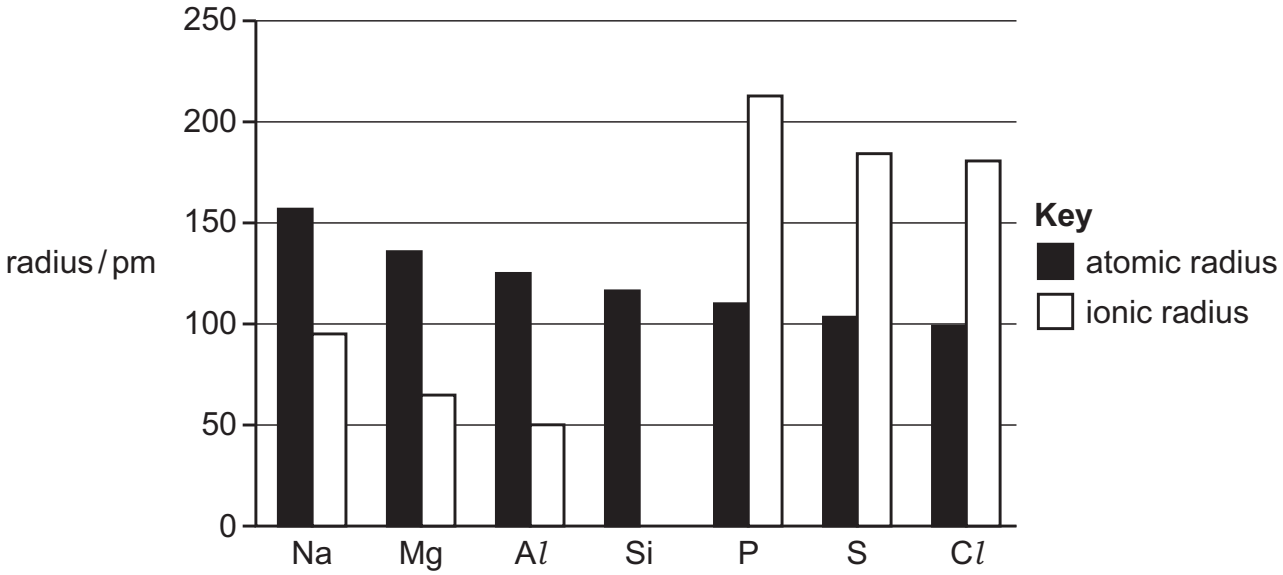


Fig. 2.1

(i) Explain the trend shown in the atomic radii of the Period 3 elements Na to C*l*.

.....

.....

.....

..... [2]

(ii) Explain why there is a large difference in the ionic radii of A*l* and P.

.....

.....

.....

..... [2]

(b) Table 2.1 gives some information about some of the Period 3 oxides.

Row B gives the pH of the solution that forms when the Period 3 oxide is added to water.

Table 2.1

	formula of Period 3 oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_3
A	oxidation number of Period 3 element			+3			
B	pH of solution			—	—		

(i) Complete Table 2.1. [2]

(ii) State why there is no data given in row B for Al_2O_3 and SiO_2.

..... [1]

(c) **(i)** Write an equation for the reaction of Na_2O with dilute hydrochloric acid.

..... [1]

(ii) Construct an equation for the reaction of Al_2O_3 with a base to form $NaAlO_2$.

..... [1]

(d) Group 2 nitrates decompose on heating to form oxides.

(i) State the trend in thermal stability of the Group 2 nitrates down the group.

..... [1]

(ii) Identify the other products of the thermal decomposition of Group 2 nitrates.

..... [1]

[Total: 11]

2 The Period 3 elements show trends in physical and chemical properties across the period.

(a) **(i)** Explain why the elements Na to A*l* are good electrical conductors.

.....

..... [1]

(ii) Explain why the elements P, S and C*l* do not conduct electricity.

.....

..... [1]

(b) Fig. 2.1 shows the variation in melting point of the Period 3 elements Si to C*l*.

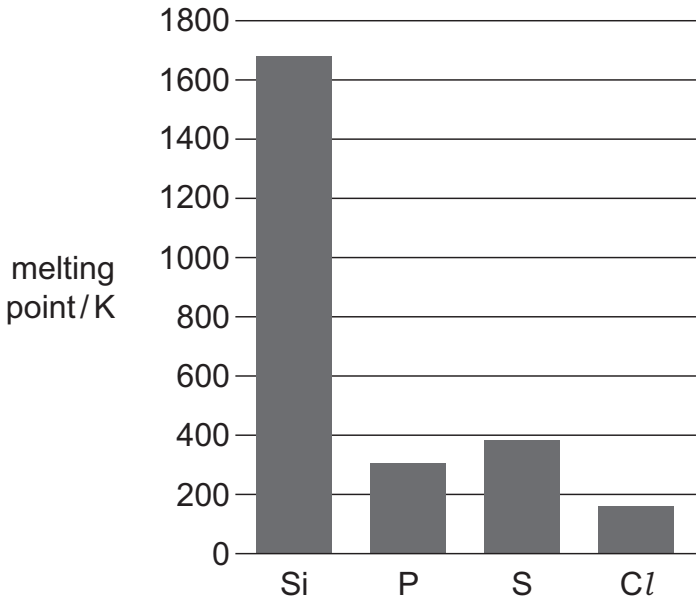


Fig. 2.1

The Period 3 elements Si to C*l* are all non-metals.

Explain why there is a large difference between the melting point of Si and the melting points of P, S and C*l*.

.....

.....

.....

..... [2]

(c) Table 2.1 gives some information about some Period 3 chlorides.

Row B refers to the pH of the solution that forms when the Period 3 chloride is added to water.

Table 2.1

	formula of Period 3 chloride	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_5
A	oxidation number of element bonded to Cl					
B	pH of solution		6.5			
C	bonding			ionic		
D	structure			giant		

Complete Table 2.1.

You may use the following abbreviations.

I = ionic, C = covalent, M = metallic
G = giant, S = simple

[4]

(d) **(i)** Write an equation for the formation of $AlCl_3$ from its elements.

.....

..... [1]

(ii) Write an equation for the formation of H_3PO_4 from PCl_5.

..... [1]

(e) $S_2Cl_2(l)$ reacts with $Cl_2(g)$ in a reversible reaction to form $SCl_2(l)$. Under certain conditions, a dynamic equilibrium is established.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

(i) State what is meant by dynamic equilibrium.

.....

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii) $S_2Cl_2(l)$ is yellow and $SCl_2(l)$ is red.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

State what is observed when the following changes are made to an equilibrium mixture of $S_2Cl_2(l)$ and $SCl_2(l)$.

Explain your answers.

- The equilibrium mixture is warmed gently.

  observation .....

  explanation .....

  .....

  .....

- The overall pressure of the equilibrium mixture is increased.

  observation .....

  explanation .....

  .....

  .....

[4]

(f) Aqueous $MgCl_2$ reacts with aqueous Na_2CO_3 to form a white precipitate. Upon heating, the white precipitate undergoes thermal decomposition.

(i) Construct an equation to show the reaction of aqueous $MgCl_2$ with aqueous Na_2CO_3. Use state symbols in your equation.

..... [2]

(ii) Identify the products of the thermal decomposition of the white precipitate.

..... [1]

(iii) State the trend in thermal stability of the Group 2 carbonates down the group.

..... [1]

[Total: 20]

A-LEVEL CHEMISTRY • EXERCISE SHEET

9.2 Periodicity of chemical properties of Period 3

Name: _____ Class: _____ Date: _____ **Total: 13 marks**

KEY WORDS oxidation number 氧化数 • oxide 氧化物 • chlorides 氯化物 • amphoteric 两性 • hydrolysis 水解

Objective

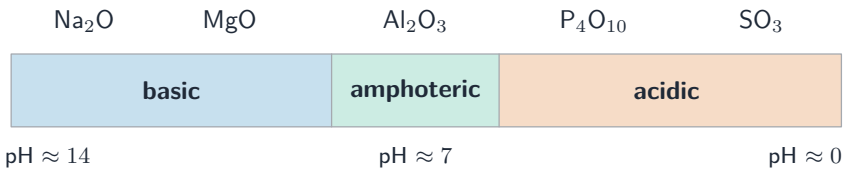
Build the skills to answer exam questions on the **chemical properties of Period 3** — reactions with oxygen, chlorine and water, the **oxides** 氧化物 and **chlorides** 氯化物, **amphoteric** 两性 behaviour, and **hydrolysis** 水解.

You must be able to:

- write equations for the reactions with oxygen, chlorine and water
- explain the acid–base behaviour of the oxides (including amphoteric Al_2O_3)
- explain the reactions of the chlorides with water and the pH obtained

1 Worked examples

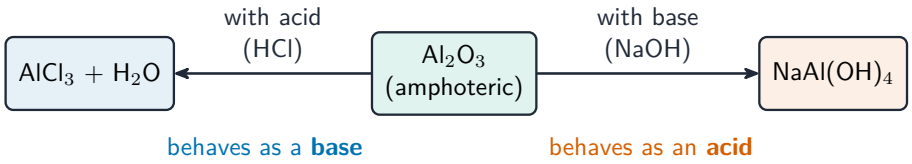
■ Oxides: acid–base trend



metal oxides (left) are basic; non-metal oxides (right) are acidic

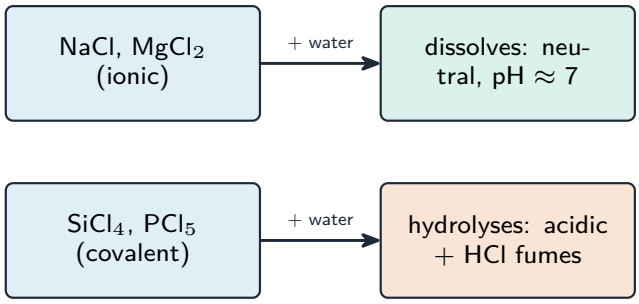
Oxides change from basic (metals) → amphoteric (Al_2O_3) → acidic (non-metals)

Na_2O, MgO are **basic** ($Na_2O + H_2O \rightarrow 2NaOH$, pH 13–14). P_4O_{10}, SO_3 are **acidic** ($SO_3 + H_2O \rightarrow H_2SO_4$, pH 0–1). The oxidation number rises across (Na_2O +1 … SO_3 +6) = the outer-shell electrons used.



Al_2O_3 is amphoteric — it reacts with both acids and bases

■ Chlorides with water



Ionic $NaCl/MgCl_2$ just dissolve (neutral); covalent $SiCl_4/PCl_5$ hydrolyse to an acidic solution + HCl

E.g. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$.

2 Practice

2.1 Write the equation for the reaction of sodium with water. [1]

2.2 State the acid–base nature of (a) MgO and (b) SO_3. [2]

3 Exam-style questions

3.1 Which Period 3 oxide is amphoteric? [1]

- **A** Na_2O
- **B** MgO
- **C** Al_2O_3
- **D** SO_3

3.2 When PCl_5 is added to water, the solution formed is: [1]

- **A** strongly alkaline
- **B** neutral
- **C** acidic, with HCl fumes
- **D** unchanged (no reaction)

3.3 (a) Write an equation for the reaction of sulfur trioxide, SO_3, with water, and state the approximate pH. [2]

(b) Explain what is meant by Al_2O_3 being **amphoteric**, and write an equation for its reaction with hydrochloric acid. [3]

3.4 Explain why sodium chloride dissolves to give a neutral solution but silicon(IV) chloride gives an acidic solution. [3]

Solutions

2.1 $2Na + 2H_2O \rightarrow 2NaOH + H_2$.

2.2 (a) basic; (b) (strongly) acidic.

3.1 C. Al_2O_3 is amphoteric.

3.2 C. PCl_5 hydrolyses to an acidic solution and HCl fumes.

3.3 (a) $SO_3 + H_2O \rightarrow H_2SO_4$; pH 0–1.
(b) amphoteric = reacts with both acids and bases; $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$.

3.4 NaCl is ionic, so it just dissolves to give ions and a neutral solution; $SiCl_4$ is covalent and is hydrolysed by water, releasing HCl which makes the solution acidic.

18 Which oxide has a simple structure rather than a giant structure?

A MgO **B** Al_2O_3 **C** SiO_2 **D** P_4O_{10}

18 Compound X is an oxide of a Period 3 element.

Compound X is a white solid at 25 °C. It reacts with water to form an acidic solution.

What is compound X?

A aluminium oxide

B silicon dioxide

C sulfur dioxide

D phosphorus(V) oxide

23 Element E is in Period 3. It forms a chloride which reacts with a small amount of water to produce a white precipitate and steamy fumes. This precipitate is soluble in NaOH(aq) and in HCl(aq).

What is element E?

A magnesium

B aluminium

C silicon

D phosphorus

16 A student investigated the chloride of a Period 3 element. This is what the student wrote down as their observations.

> The compound was a white crystalline solid. It dissolved easily in water to give a solution of pH 12. When placed in a test-tube and heated in a roaring Bunsen flame, the compound melted after several minutes' heating.

What can be deduced from these observations?

A At least one of the recorded observations is **not** correct.

B The compound was magnesium chloride, $MgCl_2$.

C The compound was phosphorus pentachloride, PCl_5.

D The compound was sodium chloride, NaCl.

2 The Period 3 elements show trends in physical and chemical properties across the period.

(a) Fig. 2.1 shows the variation in atomic and ionic radii of the Period 3 elements Na to C*l*.

The ionic radius of Si is **not** shown.

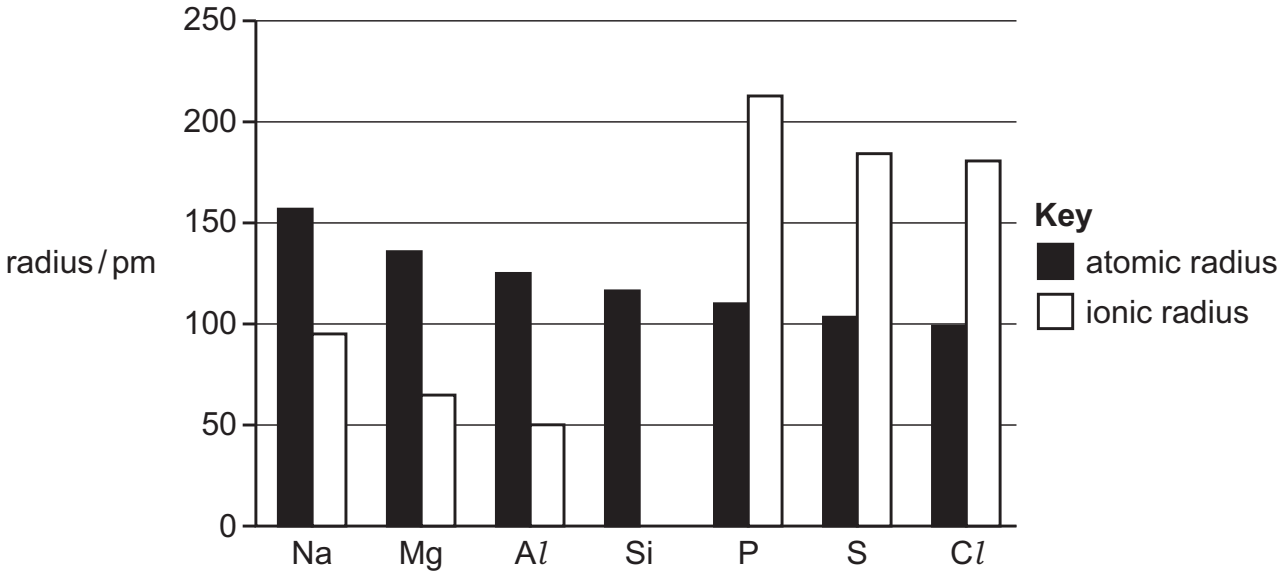


Fig. 2.1

(i) Explain the trend shown in the atomic radii of the Period 3 elements Na to C*l*.

.....

.....

.....

..... [2]

(ii) Explain why there is a large difference in the ionic radii of A*l* and P.

.....

.....

.....

..... [2]

(b) Table 2.1 gives some information about some of the Period 3 oxides.

Row B gives the pH of the solution that forms when the Period 3 oxide is added to water.

Table 2.1

	formula of Period 3 oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_3
A	oxidation number of Period 3 element			+3			
B	pH of solution			—	—		

(i) Complete Table 2.1. [2]

(ii) State why there is no data given in row B for Al_2O_3 and SiO_2.

..... [1]

(c) **(i)** Write an equation for the reaction of Na_2O with dilute hydrochloric acid.

..... [1]

(ii) Construct an equation for the reaction of Al_2O_3 with a base to form $NaAlO_2$.

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(d) Group 2 nitrates decompose on heating to form oxides.

(i) State the trend in thermal stability of the Group 2 nitrates down the group.

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(ii) Identify the other products of the thermal decomposition of Group 2 nitrates.

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[Total: 11]

2 The Period 3 elements show trends in physical and chemical properties across the period.

(a) **(i)** Explain why the elements Na to A*l* are good electrical conductors.

.....

..... [1]

(ii) Explain why the elements P, S and C*l* do not conduct electricity.

.....

..... [1]

(b) Fig. 2.1 shows the variation in melting point of the Period 3 elements Si to C*l*.

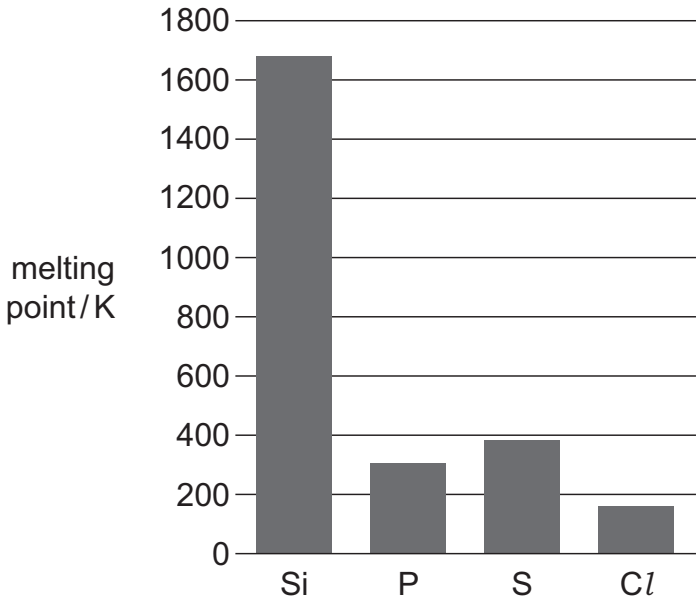


Fig. 2.1

The Period 3 elements Si to C*l* are all non-metals.

Explain why there is a large difference between the melting point of Si and the melting points of P, S and C*l*.

.....

.....

.....

..... [2]

(c) Table 2.1 gives some information about some Period 3 chlorides.

Row B refers to the pH of the solution that forms when the Period 3 chloride is added to water.

Table 2.1

	formula of Period 3 chloride	NaCl	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_5
A	oxidation number of element bonded to Cl					
B	pH of solution		6.5			
C	bonding			ionic		
D	structure			giant		

Complete Table 2.1.

You may use the following abbreviations.

I = ionic, C = covalent, M = metallic
G = giant, S = simple

[4]

(d) **(i)** Write an equation for the formation of $AlCl_3$ from its elements.

.....

..... [1]

(ii) Write an equation for the formation of H_3PO_4 from PCl_5.

..... [1]

(e) S_2Cl_2(l) reacts with Cl_2(g) in a reversible reaction to form SCl_2(l). Under certain conditions, a dynamic equilibrium is established.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

(i) State what is meant by dynamic equilibrium.

.....

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii) $S_2Cl_2(l)$ is yellow and $SCl_2(l)$ is red.

$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -41\,kJ\,mol^{-1}$$

State what is observed when the following changes are made to an equilibrium mixture of $S_2Cl_2(l)$ and $SCl_2(l)$.

Explain your answers.

- The equilibrium mixture is warmed gently.

  observation .....

  explanation .....

  .....

  .....

- The overall pressure of the equilibrium mixture is increased.

  observation .....

  explanation .....

  .....

  .....

[4]

(f) Aqueous $MgCl_2$ reacts with aqueous Na_2CO_3 to form a white precipitate. Upon heating, the white precipitate undergoes thermal decomposition.

(i) Construct an equation to show the reaction of aqueous $MgCl_2$ with aqueous Na_2CO_3. Use state symbols in your equation.

..... [2]

(ii) Identify the products of the thermal decomposition of the white precipitate.

..... [1]

(iii) State the trend in thermal stability of the Group 2 carbonates down the group.

..... [1]

[Total: 20]

2 Aluminium oxide, Al_2O_3, and phosphorus(V) oxide, P_4O_{10}, are both used as reagents and catalysts.

(a) The melting point of Al_2O_3 is 2072 °C. The melting point of P_4O_{10} is 340 °C.

Explain the difference in the melting points of these two compounds.

.....

.....

.....

..... [3]

(b) A 5.00 dm^3 sealed flask contains 0.400 mol of CO(g) and 0.800 mol of H_2(g) and an Al_2O_3 catalyst. The flask is heated to a temperature of 290 °C and allowed to reach equilibrium. Equation 1 shows the reaction.

equation 1 $\quad CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

The equilibrium constant, K_c, of equation 1 is given.

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$

(i) State the units of K_c.

..... [1]

(ii) The equilibrium mixture contains 0.280 mol of CH_3OH(g).

Calculate the value of K_c.

Give your answer to **three** significant figures.

value of K_c = ... [3]

(iii) State and explain the effect, if any, on the value of K_c when the overall pressure in the sealed flask is increased.

.....

..... [1]

(c) P_4O_{10} catalyses the reversible reaction of CO with H_2 to form CH_3OH.

equation 1 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

P_4O_{10} then acts as a dehydrating agent, causing CH_3OH to form CH_3OCH_3.

(i) Explain how the presence of a catalyst affects a chemical reaction.

.....

.....

..... [1]

(ii) Construct an equation for the dehydration reaction of CH_3OH to form CH_3OCH_3.

..... [1]

(iii) Write an equation to show the reaction of P_4O_{10} with an excess of water.

..... [1]

[Total: 11]

A-LEVEL CHEMISTRY • EXERCISE SHEET

9.3 Chemical periodicity of other elements

Name: _____ Class: _____ Date: _____ **Total: 9 marks**

KEY WORDS periodicity 周期性 • oxide 氧化物 • period 周期 • giant metallic 金属晶体 • melting point 熔点

Objective

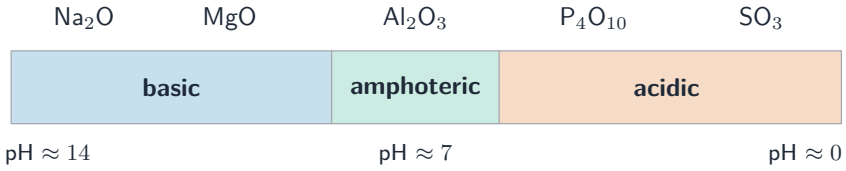
Build the skills to answer exam questions on the **chemical periodicity of other elements** — using periodic trends to **predict** properties from position and **deduce** an unknown element's identity.

You must be able to:

- predict the characteristic properties of an element from its group
- deduce the likely position and identity of an unknown element from its properties

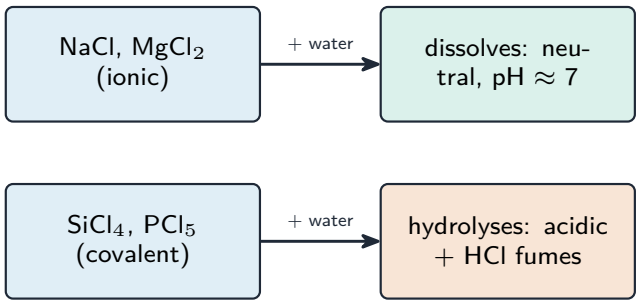
1 Worked examples

Predicting from position



metal oxides (left) are basic; non-metal oxides (right) are acidic

Knowing how properties vary across a period and down a group lets you predict or deduce an element



Period 3 chlorides react differently with water

Use the patterns you know:

- **down a group** — properties change steadily (e.g. Group 1: more reactive, larger atoms going down).
- **across a period** — metal → non-metal; oxides basic → acidic; bonding ionic → covalent.

Predict: a Group 1 element forms a +1 ion, is a reactive metal, and has a basic oxide. **Deduce:** an element with a basic oxide, high conductivity and a +2 ion is a Group 2 metal.

2 Practice

2.1 Predict the charge of the ion formed by an element in Group 2. [1]

2.2 State whether the oxide of a Group 1 element is acidic or basic. [1]

3 Exam-style questions

3.1 An element X has a giant metallic structure, conducts electricity, and forms a basic oxide of formula XO. X is most likely in: [1]

- **A** Group 1
- **B** Group 2
- **C** Group 16
- **D** Group 17

3.2 Going **down** Group 17 (the halogens), the elements become: [1]

- **A** less reactive
- **B** more reactive
- **C** more metallic in their oxides
- **D** smaller atoms

3.3 An unknown element Y forms a chloride that fumes in moist air and gives an acidic solution with water; Y's oxide is acidic.

(a) Deduce whether Y is a metal or a non-metal, and explain. [2]

(b) Suggest the region of the Periodic Table where Y is found. [1]

3.4 Using periodic trends, predict **two** properties of caesium (Cs), in Group 1 below sodium. [2]

Solutions

2.1 2+.

2.2 basic.

3.1 B. A basic oxide XO (+2) and metallic conductivity point to Group 2.

3.2 A. Reactivity decreases down Group 17.

3.3 (a) a non-metal; its oxide and chloride are acidic/covalent and the chloride hydrolyses — typical of non-metals.
(b) the right-hand side (non-metal region) of the Periodic Table.

3.4 any two: it is a (very) reactive metal; forms a +1 ion; has a basic oxide; reacts vigorously with water; larger atom / lower melting point than sodium.

1 Chromium, Cr, and its compounds are widely used in many chemical reactions.

(a) Cr exists as four stable isotopes.

(i) The most common isotope of Cr is chromium-52.

Determine the number of protons, neutrons and electrons in an atom of chromium-52.

number of protons ..... neutrons ..... electrons .....
[1]

(ii) Describe how an atom of chromium-54 differs from an atom of chromium-52. Refer to numbers of particles in your answer.

.....

..... [1]

(iii) The relative isotopic masses of the isotopes of Cr can be determined using mass spectrometry.

State what other information is needed to calculate the relative atomic mass, A_r, of Cr.

..... [1]

(iv) Atoms of ^{52}Cr, ^{53}Cr and ^{54}Cr make up more than 95% of naturally occurring chromium atoms. The A_r of naturally occurring Cr is 51.996.

Suggest what these statements imply about the relative isotopic mass of the fourth stable isotope of chromium.

..... [1]

(b) The shorthand electronic configuration of chromium is [Ar] $3d^5 4s^1$.

(i) Complete the full electronic configuration of chromium.

..... $3d^5 4s^1$ [1]

(ii) Deduce the total number of unpaired electrons in an atom of chromium.

..... [1]

(c) Acidified dichromate(VI) ions will convert methanal, CH_2O, to carbon dioxide. The movement of electrons to or from relevant species is shown in the following half-equations.

half-equation 1 $CH_2O + H_2O \rightarrow CO_2 + 4H^+ + 4e^-$

half-equation 2 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

(i) Identify the species that is reduced in half-equation 2. Explain your answer.

..... [1]

(ii) The oxidation state of the carbon atom in methanal is 0.

Calculate the oxidation state of carbon in carbon dioxide.

..... [1]

(iii) Construct the ionic equation for the reaction of dichromate(VI) ions with methanal in acidic conditions.

..... [2]

(iv) Methanal is a liquid at –30 °C but carbon dioxide is a gas at this temperature. Explain why.

.....

.....

.....

..... [2]

(d) In acidic conditions, a dynamic equilibrium is established between $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l) \qquad \Delta H > 0$$

(i) State what is meant by dynamic equilibrium.

.....

..... [1]

(ii) Identify the condition necessary to establish dynamic equilibrium.

..... [1]

(iii) $CrO_4^{2-}(aq)$ ions are yellow and $Cr_2O_7^{2-}(aq)$ ions are orange.

State what is observed when the following changes are made to an equilibrium mixture of acidified $CrO_4^{2-}(aq)$ and $Cr_2O_7^{2-}(aq)$ ions.

Explain your answers.

- The equilibrium mixture is warmed gently.

  observation .....

  explanation .....

  .....

  .....

- Dilute HC*l*(aq) is added to the equilibrium mixture.

  observation .....

  explanation .....

  .....

  .....

[4]

(e) Chromium(IV) fluoride, CrF_4, is a covalent molecule that shows similar chemical properties to $SiCl_4$.

Suggest the type of reaction that occurs when CrF_4 is placed in water.

Construct a relevant equation for this reaction.

type of reaction .....

equation ....

[2]

[Total: 20]