Past-paper walk-through

Periodicity of chemical properties of the elements in Period 3 ▪ 9.2

eXercise

Questions in this set

- 9701/11 N25 Q18 ▪ 1 mark
- 9701/12 N25 Q18 ▪ 1 mark
- 9701/12 N25 Q23 ▪ 1 mark
- 9701/14 N25 Q16 ▪ 1 mark
- 9701/21 N25 Q2 ▪ 11 marks
- 9701/22 N25 Q2 ▪ 20 marks
- 9701/24 N25 Q2 ▪ 11 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 18

9701/11 N25 ▪ Q18 ▪ 1 mark

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}

Solution 18

Answer: **D**

Why

- MgO and Al_2O_3 are giant ionic, and SiO_2 is giant covalent.
- P_4O_{10} exists as discrete molecules held together by weak van der Waals forces.
- That is why it is the only one of the four with a low melting point.

Question 18

9701/12 N25 ▪ Q18 ▪ 1 mark

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

Solution 18

Answer: **D**

Why

- It must be a solid at $25\,^{\circ}\text{C}$, which rules out sulfur dioxide, a gas.
- It must react with water, which rules out silicon dioxide – insoluble and unreactive.
- Aluminium oxide is amphoteric and insoluble; phosphorus(V) oxide is a white solid giving phosphoric acid.

Question 23

9701/12 N25 ▪ Q23 ▪ 1 mark

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

Solution 23

Answer: **B**

Why

- Steamy fumes are HCl, so the chloride hydrolyses – that rules out sodium and magnesium chlorides.
- A precipitate soluble in *both* acid and alkali is amphoteric.
- $Al(OH)_3$ is the amphoteric hydroxide, so E is aluminium.

Question 16

9701/14 N25 ▪ Q16 ▪ 1 mark

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.

Question 16

D The compound was sodium chloride, $NaCl$.

Solution 16

Answer: **A**

Why

- A white crystalline solid with a very high melting point must be ionic.
- The only ionic Period 3 chlorides are NaCl and $MgCl_2$ – and NaCl is neutral in water while $MgCl_2$ is slightly acidic.
- Neither can give pH 12, so the observations contradict each other: at least one must be wrong.

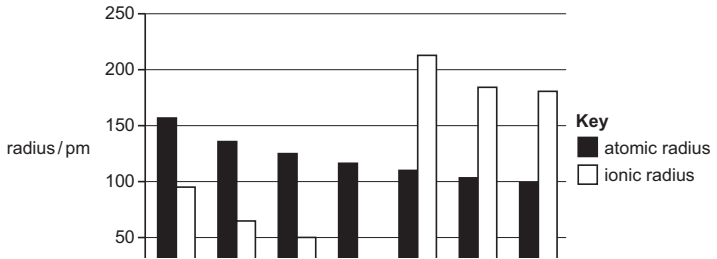
Question 2

9701/21 N25 ▪ Q2 ▪ 11 marks

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.



Question 2

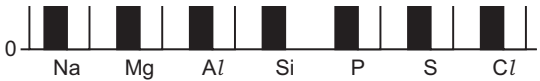


Fig. 2.1

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

Question 2

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

Question 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.

Question 2

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

Question 2

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

Question 2

(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.

Question 2

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

Question 2

[Total: 11]

Solution 2

(a)(i)

Mark scheme

- M1 nuclear charge increases (across period) AND similar shielding M2
- greater / stronger attraction to nucleus
- 2

Solution 2

(a)(ii)

Mark scheme

- M1 Al loses (3) electrons / Al is 3+, and P gains (3) electrons / P is 3– M2
- Al (3+) has (one) fewer shell (than P(3–))
- 2

Solution 2

(b)(i) Mark scheme

- (+)1
- (+)2
- (+)3
- (+)4
- (+)5
- (+)6
- 12-14
- 8-10

Solution 2

- —
- —
- 0-4
- 0-4
- 2

Solution 2

(b)(ii)

Mark scheme

- they are insoluble
- 1

Solution 2

(c)(i)

Mark scheme

- $Na2O + 2HCl \rightarrow 2NaCl + H2O$
- 1

(c)(ii)

Mark scheme

- $Al2O3 + 2NaOH \rightarrow 2NaAlO2 + H2O$
- 1

Solution 2

(d)(i)

Mark scheme

- (thermal stability) increases (down the group)
- 1

Solution 2

(d)(ii)

Mark scheme

- NO2 AND O2
- 1
- 9701/21
- October/November 2025

Question 2

9701/22 N25 ▪ Q2 ▪ 20 marks

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

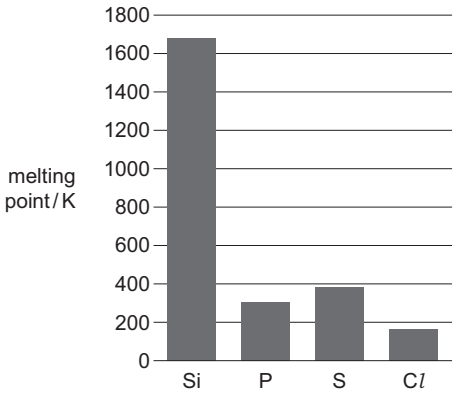
(a) (i) Explain why the elements Na to A*l* are good electrical conductors.

Question 2

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

Question 2

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



Question 2

Fig. 2.1

The Period 3 elements Si to Cl 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 Cl.

Question 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		

Question 2

D	structure			giant			

Question 2

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.

Question 2

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

Question 2

(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.

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

(i) State what is meant by dynamic equilibrium.

Question 2

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

Question 2

(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.

Question 2

Question 2

- The overall pressure of the equilibrium mixture is increased.

Question 2

Question 2

[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.

Question 2

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

Question 2

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

Question 2

[Total: 20]

Solution 2

(a)(i)

Mark scheme

- delocalised electrons move (through the structure / between layers)
- 1

Solution 2

(a)(ii)

Mark scheme

- P / S / Cl have no charge carriers
- OR (no ions and) no delocalised electrons
- OR no mobile / moving ions
- 1

Solution 2

(b)

Mark scheme

- M1 Si has (lots of) strong covalent bonds broken M2
- P / S / Cl (only) has weak Van der Waals' (forces) broken
- 2
- 9701/22
- October/November 2025

Solution 2

(c) Mark scheme

- +1
- +2
- +3
- +4
- +5
- 7
- 6.5
- 0–4

Solution 2

- 0–4
- 0–4
- I
- I
- I
- C
- C
- G
- G
- G

Solution 2

- S
- S
- 4

Solution 2

(d)(i)

Mark scheme

- $2Al + 3Cl2 \rightarrow 2AlCl3$
- 1

(d)(ii)

Mark scheme

- $PCl5 + 4H2O \rightarrow H3PO4 + 5HCl$
- 1

Solution 2

(e)(i)

Mark scheme

- rate of forward and backward (reaction) are the same / equal
- OR (ratio of) concentrations of reactants and products are constant
- 1

Solution 2

(e)(ii)

Mark scheme

- closed system
- 1

Solution 2

(e)(iii) Mark scheme

- M1 (mixture / solution becomes more) yellow M2
- (forward) reaction is exothermic (equilibrium shifts left)
- OR equilibrium / reaction shifts (left) to absorb (additional) heat / energy M3
- (mixture / solution becomes more) red M4
- fewer moles of gas on right-hand side
- OR (gas on left and) no gas on the right
- 4

Solution 2

(f)(i)

Mark scheme

- $MgCl_2(aq) + Na_2CO_3(aq) \rightarrow MgCO_3(s) + 2NaCl(aq)$ M1
- formulae in balanced equation M2
- state symbols
- 2

Solution 2

(f)(ii)

Mark scheme

- MgO / magnesium oxide AND CO2 / carbon dioxide
- 1

Solution 2

(f)(iii)

Mark scheme

- (thermal stability) increases (down the group)
- 1
- 9701/22
- October/November 2025

Question 2

9701/24 N25 ▪ Q2 ▪ 11 marks

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.

Question 2

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

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.

Question 2

(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.

Question 2

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

Question 2

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

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

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.

Question 2

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

Question 2

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

Question 2

[Total: 11]

Solution 2

(a)

Mark scheme

- M1 Al2O3 is ionic **M2**
- P4O10 is a (simple) molecule **M3**
- ionic bonds are stronger than intermolecular forces
- 3

Solution 2

(b)(i)

Mark scheme

- mol–2 dm6
- 1

Solution 2

(b)(ii)

Mark scheme

- M1 at equilibrium: moles of CO $= 0.120$ AND moles of H2 $= 0.240$ **M2**

$CH_3OH = 0.056$ AND $[CO] = 0.024$ AND $[H_2] = 0.048$ **M3**

- use of Kc with correct evaluation $= 1.01 \times 103$
- 3

Solution 2

(b)(iii)

Mark scheme

- no effect AND Kc is not affected by pressure
- 1

Solution 2

(c)(i)

Mark scheme

- increases rate by providing a different mechanism with a lower activation energy
- 1

(c)(ii)

Mark scheme

- $2CH3OH \rightarrow CH3OCH3 + H2O$
- 1

Solution 2

(c)(iii)

Mark scheme

- P4O10 + 6H2O → 4H3PO4
- 1