# 05 The Periodic Table

**Set B** **Answer key**

## A Multiple choice

3 MARKS

**1**

**C** Y, X, W, Z [1]

The chloride of W dissolves in water and turns blue litmus red: W is not Na (NaCl is neutral).

X is a good conductor of electricity but insoluble in water: X can be Mg or Al. Since Y is Mg, X must be Al.

The oxide of Y has the highest melting point: MgO, so Y is Mg. Z has the highest first ionisation energy and largest ionic radius: Z is P.

Since the four elements in Period 3 must be consecutive, W must be Si. Hence the order is Y, X, W, Z (Mg, Al, Si, P).

**2**

**C** G, F, E, H [1]

$MgCl_2$, $AlCl_3$, $SiCl_4$ and $PCl_5$ dissolve in water to give acidic solutions and hence turn blue litmus red, so E could be Mg, Al, Si or P.

Only $Al_2O_3$ is amphoteric, so F is Al. Across a period, the electronegativity increases, so G is the first element among E, F, G and H. Chlorine has the smallest atomic radius, so H is chlorine.

**3**

**D** The acidity of Period 3 chlorides in water decreases from NaCl to $PCl_5$. [1]

Statement D is wrong. The acidity of Period 3 chlorides in water increases from NaCl to $PCl_5$, and the pH of the resultant solution decreases from pH 7 to pH 1.

**A** Correct. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

**B** Correct. $Al_2O_3$ is an amphoteric oxide that can react with both acid and base to give soluble products.

**C** Correct. $Na_2O + H_2O \rightarrow 2NaOH$, $SO_3 + H_2O \rightarrow H_2SO_4$, $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

## B Structured questions

30 MARKS

**4**

**NaCl** dissolves readily in water to form hydrated ions in a neutral solution. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$, pH = 7 [1]

**$AlCl_3$** dissolves in water with partial hydrolysis to give an acidic solution. $AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$, $[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$, pH = 3 [1]

**$PCl_5$** undergoes complete hydrolysis in water to form a strongly acidic solution. $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$, pH = 2 [1]

**5** **(a)(i)**

As E has a low melting point, E has a simple covalent structure, hence E could be sulfur or phosphorus. Sulfur is a yellow solid, and the two oxides that sulfur forms ($SO_2$ and $SO_3$) do not have an empirical formula of $E_2O_5$, so E is not sulfur.

E is **phosphorus**, as one of its oxides is $P_4O_{10}$, with an empirical formula of $E_2O_5$. [1]

**(ii)**

$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ [1]

$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$ [1]

**(iii)**

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ [1]

Resulting pH: 2 [1]

**(b)**

MgO is an ionic oxide and is basic, so it can react with acids. $P_4O_{10}$ is a covalent oxide and is acidic, so it can react with bases. The oxide of F is $Al_2O_3$, which is an amphoteric oxide, so it can react with both acids and bases. [1]

As $Al^{3+}$ has a high charge and small ionic radius, it has a high charge density. $Al^{3+}$ polarises the $O^{2-}$ electron cloud to a large extent, resulting in significant covalent character. [1]

As $Al_2O_3$ is an ionic compound with significant covalent character, it possesses the properties of both a metallic and a non-metallic oxide, making it amphoteric.

$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$ [1]

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq)$ [1]

**6**

From the Data Booklet: $F_2 + 2e^- \rightleftharpoons 2F^-$, $E^{\ominus} = +2.87$ V; $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$, $E^{\ominus} = +1.36$ V; $I_2 + 2e^- \rightleftharpoons 2I^-$, $E^{\ominus} = +0.54$ V

As $E^{\ominus}(X_2/X^-)$ is less positive down the group, oxidising power: $F_2 > Cl_2 > I_2$. [1]

$F_2$ is the strongest oxidising agent and oxidises Cr to $CrF_4$, where the oxidation state of Cr increases from 0 to +4. $Cl_2$ is less oxidising than $F_2$ and oxidises Cr to $CrCl_3$, where the oxidation state of Cr increases from 0 to +3. [1]

$I_2$ is the weakest oxidising agent and oxidises Cr to $CrI_2$, where the oxidation state of Cr increases from 0 to +2. [1]

**7** **(a)**

$2HI(g) \rightarrow H_2(g) + I_2(g)$ [1]

**(b)**

Black fumes would evolve very vigorously for HAt, as it is the least thermally stable of the four HX. [1]

Decomposition of H–X depends on the energy supplied by the red hot wire to break the H–X bond. From Cl to At, the size of the X atom increases, the effectiveness of overlap between H and X atoms decreases, and the bond strength decreases: HAt < HI < HBr < HCl. So thermal stability: HAt < HI < HBr < HCl, and the vigour of formation of $X_2$ fumes: HAt > HI > HBr > HCl. [1]

**8** The nuclear charge of calcium is higher than that of potassium, while the shielding effect by the inner shells of electrons remains relatively constant. Hence, the effective nuclear charge is higher for calcium than for potassium. [1]

The attraction between the valence electrons and the nucleus is stronger in calcium, so its valence electrons are closer to the nucleus, resulting in a smaller atomic radius for calcium. [1]

**9** **(a)** Compared with Si, P has a smaller atomic radius and a greater nuclear charge, while the shielding effect by the same number of inner electrons is similar. Therefore, the nuclear attraction in P is larger, and hence the first ionisation energy of P is higher than that of Si. [1]

P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$ and S: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$ [1]

In S, the two electrons occupying the same 3p orbital ($3p_x$) give rise to inter-electronic repulsion. Thus, less energy is required to remove a paired 3p electron from S than to remove an unpaired 3p electron from P. [1]

**(b)** Si has a giant molecular structure, with the Si atoms held together by an extensive network of strong covalent bonds. However, $P_4$ and $S_8$ have simple molecular structures, with weak instantaneous dipole–induced dipole interactions between the molecules, which require less energy to overcome. Thus $P_4$ (and $S_8$) have lower melting points than Si. [1]

$P_4$ has fewer electrons than $S_8$, hence its instantaneous dipole–induced dipole interactions are weaker and require less energy to overcome. Thus $P_4$ has a lower melting point than $S_8$. [1]

**10** **(a)** $2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$ [1]

**(b)** $Mg(NO_3)_2$ decomposes at a lower temperature. [1]

$Mg^{2+}$ has a much smaller ionic radius than $Ba^{2+}$ but the same charge, so $Mg^{2+}$ has a higher charge density and hence greater polarising power than $Ba^{2+}$. [1]

$Mg^{2+}$ distorts the electron cloud of the $NO_3^-$ anion to a greater extent than $Ba^{2+}$. [1]

Hence, the N–O bond in $Mg(NO_3)_2$ is more easily broken, resulting in $Mg(NO_3)_2$ decomposing at a lower temperature. [1]