05 The Periodic Table

Set A **Answer key**

A From the lesson

10 MARKS

1. **$Mg^{2+} < Na^{+} < F^{-} < O^{2-}$**. All have 10 electrons (isoelectronic). [1]
   Nuclear charge decreases from Mg (12) to O (8), so the electrons are less strongly attracted and the radius increases. [1]

2. More vigorously: Ba is a stronger reducing agent, so it loses its valence electrons more readily. [1]
   $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$ [1]

3. Na loses its valence electron, so Na^{+} has one less principal quantum shell. [1]

4. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ [1]
   pH 2 [1]

5. Ba^{2+} is larger, with lower charge density [1]
   so it polarises the CO_3^{2-} anion less: C–O bonds are weakened less. [1]

6. No: Br_2 is a weaker oxidising agent than Cl_2. [1]

B Practice

22 MARKS

7. **B** aluminium [1]
   Based on the information provided, the only possible Period 3 element for J is Al.
   $AlCl_3 + 3NaOH \rightarrow Al(OH)_3 + 3NaCl$, then $Al(OH)_3 + NaOH \rightarrow Na[Al(OH)_4]$
   Al is a solid at room temperature. The oxide of Al, Al_2O_3, is amphoteric and is soluble in hydrochloric acid: $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

8. **A** SO_3, SiO_2, MgO, Na_2O [1]
   Ionic oxides tend to be basic in nature, hence higher pH. Covalent oxides tend to be acidic oxides, hence lower pH. SiO_2 is insoluble in water, hence neutral pH.

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W has a giant ionic lattice structure. A large amount of energy is needed to overcome the strong electrostatic forces of attraction between oppositely charged ions in the lattice, hence the very high melting point. Mobile ions in molten W allow good electrical conductivity. W has very little reaction with water to form a basic solution, hence W is MgO: $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$ **[1]**

X has a giant covalent structure. A large amount of energy is needed to overcome the strong covalent bonds in the covalent lattice, hence the high melting point. The absence of mobile charge carriers in molten X results in poor electrical conductivity. X does not react with water, so it is SiO_2.

Similar to W, Y has a giant ionic lattice structure. Y reacts with water exothermically to form a strongly basic solution, hence Y is Na_2O: $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ **[1]** **[1]**

Z has a simple covalent structure. A small amount of energy is needed to overcome the weak intermolecular instantaneous dipole–induced dipole attraction, hence the relatively low melting point. The absence of mobile charge carriers in molten Z results in poor electrical conductivity. Z reacts with water exothermically to form a highly acidic solution, hence Z is P_4O_{10}: $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ **[1]**

10 **(a)**

From the Data Booklet, charge density of $Na^+ = \frac{1}{0.095} = 10.5$, of $Mg^{2+} = \frac{2}{0.065} = 30.8$, of $Al^{3+} = \frac{3}{0.050} = 60.0$

NaCl undergoes only hydration, as Na^+ has the lowest charge density. Hence, the resulting solution is pH 7. $NaCl(s) + aq \rightarrow Na^+(aq) + Cl^-(aq)$ **[1]**

$MgCl_2$ undergoes hydration and slight hydrolysis due to the relatively high charge density of the Mg^{2+} ion, which polarises the electron cloud of its surrounding water molecules, weakening the O–H bond, which results in the release of H^+. Hence, the resulting solution is slightly acidic, pH 6.5. $MgCl_2(s) + 6H_2O(l) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + 2Cl^-(aq)$, $[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^+(aq) + H^+(aq)$ **[1]**

$AlCl_3$ undergoes hydration and extensive hydrolysis due to the very high charge density of the Al^{3+} ion, which polarises the electron cloud of its surrounding water molecules, weakening the O–H bond, which results in the release of H^+. Hence, the resulting solution is acidic, pH 3. $AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$, $[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$ **[1]**

(b)

$SiCl_4$ reacts vigorously with water to form a white solid and white fumes of HCl, and the pH of the resulting solution is 2. $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ **[1]**

PCl_5 reacts vigorously with water to form white fumes of HCl, and the pH of the resulting solution is 2. $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ **[1]**

11 **(a)**

$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$ **[1]**

(b)

X is $Ca(OH)_2(aq)$. (Do not accept "limewater".) [1]

Mg^{2+} has a smaller cationic radius, hence a greater charge density (and polarising power) than Ba^{2+}. The electron cloud of CO_3^{2-} in $MgCO_3$ is polarised to a greater extent, and hence the C–O bond is weakened more. [1]

Less energy is required to break the C–O bond in $MgCO_3$, and hence a shorter time (3 minutes) is required for CO_2 to be produced. [1]

NOTE The $CO_2(g)$ produced forms a white precipitate of $CaCO_3(s)$ in $Ca(OH)_2(aq)$.

12 **(a)**

$BeCl_2$ is covalent and exists as simple molecules, with weak instantaneous dipole–induced dipole interactions between its molecules. [1]

$MgCl_2$ is ionic, with strong ionic bonds between its ions. [1]

More energy is needed to overcome the strong ionic bonds between Mg^{2+} and Cl^- ions than the weak interactions between $BeCl_2$ molecules, so the boiling point of $MgCl_2$ is much higher. [1]

$BeCl_2$ is covalent because too much energy is required to remove two electrons from its valence 2s subshell. Hence $BeCl_2$ is much more volatile than $MgCl_2$. [1]

(b)

Covalent oxides are generally acidic (e.g. SO_2) while ionic oxides are basic (e.g. Na_2O). [1]

BeO has ionic bonding with substantial covalent character, so its oxide is amphoteric and it can react with both alkalis and acids. [1]

The oxides of the other alkaline earth metals are predominantly ionic, so they are basic, reacting with acids but not bases. $O^{2-} + H_2O \rightarrow 2OH^-$ [1]