Chapter 10 – Answers to end of chapter questions

1  
   a and b  
   i Atomic radius increases as electrons are occupying an additional shell.  
   ii Ionisation energy decreases. The distance of the outermost electrons from the  
      nucleus and the shielding of these electrons increases. These factors make it easier to  
      remove the outermost electrons despite the increasing nuclear charge.  
   iii Strength as reducing agents increases; $E^*$ for the process.  
      $\text{M(s)} \rightarrow \text{M}^{2+}(\text{aq}) + 2\text{e}^-$ is more positive with increasing proton number.  
      The process $\text{M(s)} \rightarrow \text{M}^{2+}(\text{aq})$ involves atomisation, ionisations and then hydration of  
      ions. Overall this is more likely to happen (i.e. the elements react more readily as  
      reducing agents) as proton number increases.  
   iv The vigour of the reaction increases with proton number. The reaction involved is  
      $\text{M(s)} + \text{Cl}_2(\text{g}) \rightarrow \text{M}^{2+}(\text{Cl}^-)(\text{s})$ and the metal is acting as a reducing agent (see part iii).  
   v Electropositivity is a measure of the tendency of the metal to lose electrons and form  
      positive ions, (i.e. to act as a reducing agent). This increases with proton number.  

2  
   a Be, Mg, Ca, Sr, Ba, Ra  
   b Mg is $1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^0$, Ca is $1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^6 \, 4s^2$  
   c  
   d Their most stable ions are those of the form $\text{M}^{2+}$.  
   e The process $\text{M(s)} \rightarrow \text{M}^{2+}(\text{aq}) + 2\text{e}^-$ or $\text{M(s)} \rightarrow \text{M}^{2+}(\text{s}) + 2\text{e}^-$ is more exothermic than  
      the corresponding processes for $\text{M}^+$ or $\text{M}^{3+}$.  

3  
   a i $\text{Ba(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Ba(OH)}_2 (\text{aq or s}) + \text{H}_2(\text{g})$  
      ii On adding barium to water, there is vigorous bubbling. On adding magnesium to  
         water, tiny bubbles form slowly on the surface of the metal. The reaction with barium is  
         more vigorous.  
   b i $\text{Mg(s)} + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$  
      ii Barium would bubble very vigorously on being added to water. The products are  
         barium chloride and hydrogen.  
   c i Carbon dioxide  
      ii $\text{MgCO}_3(\text{s}) + 2\text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O(l)}$  

4  
   a i $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO(s)} + \text{CO}_2(\text{g})$  
      ii $\text{Sr(NO}_3)_2 (\text{s}) \rightarrow \text{SrO(s)} + 2\text{NO}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})$
b i No reaction

ii Going down the group, the size of the metal ion increases. Near the top of the group, the relatively small Mg$^{2+}$ ion polarises the much larger CO$_3^{2-}$ ion, distorting it and making it less stable. On heating, the CO$_3^{2-}$ decomposes relatively easily, producing CO$_2$ and the O$_2^-$ ion.

Ba$^{2+}$ is much larger than Mg$^{2+}$, so its polarising effect on CO$_3^{2-}$ is smaller. Since the CO$_3^{2-}$ ion is less distorted in BaCO$_3$ than in MgCO$_3$, BaCO$_3$ decomposes less readily than MgCO$_3$.

5 a i Any 2 of the following:

- The m.pt. and b.pt. of Be are much higher than expected.
- Be does not burn brightly in oxygen on heating.
- BeO is amphoteric, the oxides of other Group II metals are basic.
- BeCl$_2$ is simple molecular, other Group II chlorides are ionic.

ii Any 2 of the following:

- Be forms white compounds.
- BeO is ionic.
- Be forms ions with a charge of 2$^+$. 
- BeO reacts with dilute acids to form Be$^{2+}$ salts.
- Be(NO$_3$)$_2$ decomposes on heating to form BeO, NO$_2$ and O$_2$, etc..

b i is correct.

6 a Going down group 2, the solubility of the metal hydroxides increases.

b i Going down group 2, the hydration enthalpy values of the M$^{2+}$ ions become less exothermic. This is because, from top to bottom of the group, the radius of M$^{2+}$ increases, but there is no change in ionic charge. This results in decreasing charge density for M$^{2+}$ down the group, and therefore decreased attractiveness to polar water molecules.

ii If enthalpy of hydration were the only factor to affect solubility, the solubility of the Group 2 hydroxides would be expected to decrease going down the group since the enthalpy of hydration becomes less exothermic.

iii Lattice energy also affects solubility. For the Group 2 hydroxides, the energy required to separate gaseous ions from the lattice decreases from top to bottom of the group. This factor alone would result in an increase in solubility from top to bottom of the group. For the Group 2 hydroxides, the change in lattice energies is more significant than the change in hydrations enthalpies, so the hydroxides get more soluble going down the group.

7 a Metals – they form positive ions and are good conductors of electricity.

b Reactivity for Group II involves the process $\text{M(s)} \rightarrow \text{M}^{2+}(s) + 2\text{e}^{-}$ or $\text{M(s)} \rightarrow \text{M}^{2+}(aq) + 2\text{e}^{-}$. 
Part of each of these processes involves ionisation energies,

\[ \text{M}(g) \rightarrow \text{M}^+(g) + e^- \quad \text{and} \quad \text{M}^+(g) \rightarrow \text{M}^{2+}(g) + e^- \]

whilst the redox (electrode) potential of a Group II metal involves the process

\[ \text{M}^{2+} (aq) + 2e^- \rightleftharpoons \text{M}(s). \]

c The process \( \text{Mg}(s) \rightarrow \text{Mg}^+(g) + e^- \) is easier (less endothermic) than the process \( \text{Mg}(s) \rightarrow \text{Mg}^{2+}(g) + 2e^- \), but the energy evolved when \( \text{Mg}^{2+}(g) \) ions are hydrated in water or surrounded by negative ions in a crystal is much greater than the corresponding processes for \( \text{Mg}(g) \). So, magnesium compounds contain \( \text{Mg}^{2+} \) ions and not \( \text{Mg}^+ \) ions.

d Group II compounds contain \( \text{M}^{2+} \) ions whereas Group I compounds contain \( \text{M}^+ \) ions. \( \text{M}^{2+} \) ions will have a greater charge density and therefore have a greater attraction for polar water molecules.

8 \ a \ 1 \, \text{mole} \ \text{SO}_2 = 1 \, \text{mole} \ I_2

\[
\therefore \text{number of moles of SO}_2 = \frac{12}{1000} \times 0.025 = 3 \times 10^{-4}
\]

\ b \ 1 \, \text{mole} \ \text{Na}_2\text{SO}_3 \rightarrow 1 \, \text{mole} \ \text{SO}_2

\[
\therefore \text{Mass of Na}_2\text{SO}_3 \text{ present} = 3 \times 10^{-4} \times 126 = 3.78 \times 10^{-2} \, \text{g}
\]

\ c \ 0.038 \, \text{g per 100 g meat} \Rightarrow 0.0378 \times 10^4 \, \text{g per 10 g meat} = 378 \, \text{p.p.m.}

\ d \ \text{Ba}^{2+} (aq) + \text{SO}_4^{2-} (aq) \rightarrow \text{BaSO}_4 (s)

\[
\therefore 3 \times 10^{-4} \, \text{moles} \ \text{SO}_{4}^{2-} \text{ are formed.}
\]

Mass of \( \text{BaSO}_4 (s) \) precipitate = \( 3 \times 10^{-4} \times 233 \, \text{g} = 0.0699 \, \text{g} \)

9 \ a \ i \ Without \text{ water} \quad \text{ii} \ Containing \text{ water of crystallisation}

\ iii \ The \text{ water present in hydrated crystals}

\ b \ i \ \text{CaSO}_4 (s) + \text{C}(s) \rightarrow \text{CaO}(s) + \text{SO}_2(g) + \text{CO}(g)

\ ii \ (\text{CaSO}_4 \cdot \text{H}_2\text{O}(s) + 3\text{H}_2\text{O}(l) \rightarrow 2\text{CaSO}_4 \cdot 2\text{H}_2\text{O}(s)

\ iii \ \text{CaSO}_4 \cdot 2\text{H}_2\text{O}(s) \rightarrow \text{CaSO}_4 (s) + 2\text{H}_2\text{O}(g)

\ c \ i \ When \text{ mixed with water it hardens and sets quickly to form a firm solid. Broken limbs can therefore be set quickly.}

\ ii \ When \text{ mixed with water it expands and sets firmly. This means that the mould is filled and an accurate model is produced.}

\ d \ Anhydrite \text{ sets only very slowly when mixed with water.}