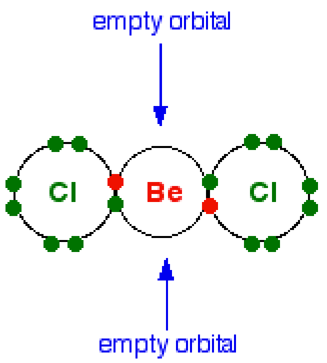
Chemguide – answers

GROUP 2: THE ATYPICAL PROPERTIES OF BERYLLIUM COMPOUNDS

1. a) Beryllium has quite a high electronegativity compared with the rest of the group. The electronegativity is high enough that the bonding pair of electrons is held between the beryllium and the chlorine as a covalent bond.

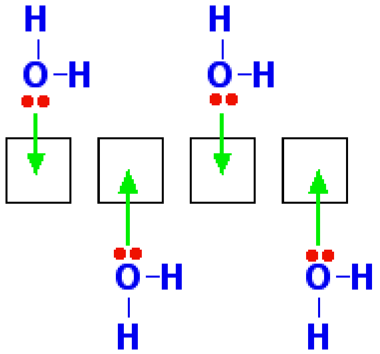
   b) It is electron deficient because there are empty spaces in the beryllium outer energy level.



   c) The blue arrows show lone pairs from the chlorines being used to make dative covalent (coordinate) bonds using the empty orbitals on the berylliums. The black lines show the simple covalent bonds between beryllium and chlorine as in the diagram in part (b). The 2-level orbitals in each beryllium atom are now full.

   d) The $[Be(H_2O)_4]^{2+}$ ion is acidic. The small beryllium ion at the centre attracts the electrons in the dative covalent bonds towards itself, and that makes the hydrogen atoms in the water even more positive than they usually are. Chloride ions can remove these to make hydrogen chloride. If there is only a small amount of water present, and the mixture gets hot because of the heat evolved during the reaction, you will get fumes of hydrogen chloride.

2. The bonding between the water and the beryllium is dative covalent (coordinate). Each water molecule donates a lone pair to form a bond with an empty orbital on a beryllium ion. There are only 4 orbitals at the 2-level (2s and three 2p), and these hybridise to give 4 equal hybrid orbitals.



   Magnesium behaves similarly, except that that at the 3-level (and higher levels) there are also d orbitals which are available for bonding. Magnesium hybridises the 3s, three 3p and two of the 3d orbitals which allows 6 water molecules to bond to it. That is as many as you can physically fit around the magnesium (or the other elements in the group)

3. a) Amphoteric means that it can react with both acids and bases. (The same as saying it has both basic and acidic properties.)

b) The $[Be(H_2O)_4]^{2+}$ ion is acidic because of the strong polarising effect of the beryllium ion on the water molecules. Hydrogen ions (one from each water molecule), can easily be removed by a strong base like hydroxide ions. When this has happened to two of the water molecules, you get the neutral complex formed which we normally just call beryllium hydroxide.

$$[Be(H_2O)_4]^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Be(H_2O)_2(OH)_{2(s)} + 2H_2O_{(l)}$$

c) (i) $Be(H_2O)_2(OH)_{2(s)} + 2H^+_{(aq)} \longrightarrow [Be(H_2O)_4]^{2+}_{(aq)}$

(ii) $Be(H_2O)_2(OH)_{2(s)} + 2OH^-_{(aq)} \longrightarrow [Be(OH)_4]^{2-}_{(aq)} + 2H_2O_{(l)}$