COMPLEX IONS: REACTIONS OF HEXAAQUA IONS WITH OH^-

1. a) $[Cu(H_2O)_6]^{2+}$ and $[Cu(H_2O)_4(OH)_2]$

   b) The hydroxide ions from the sodium hydroxide solution have removed a hydrogen ion from each of two of the attached water molecules to form free water molecules, leaving behind OH groups still attached to the copper ion.

   (You can also explain this in terms of the hydroxide ions reacting with hydroxonium ions (or hydrogen ions) from the ionisation of the hexaaqua ion, followed by equilibrium shifts, but it is much easier to consider the hydroxide ions reacting directly with the hexaaqua ion.)

   c) You would simply need to replace the removed hydrogens. You can do this easily by adding a source of hydrogen ions such as dilute sulphuric acid or hydrochloric acid.

2. a) $[Cr(H_2O)_6]^{3+}$ and $[Cr(H_2O)_3(OH)_3]$ and $[Cr(OH)_6]^{3-}$

   b) In the first stage, hydroxide ions from the sodium hydroxide solution have removed a hydrogen ion from each of three of the attached water molecules to form free water molecules, leaving behind OH groups still attached to the chromium ion.

   In the second stage, the remaining three attached water molecules are converted into OH groups by hydroxide ions removing a hydrogen ion from each one.

   c) An amphoteric compound can act as both an acid and a base. That means that it can react *with* a base or an acid. In this case, we have already seen it acting as an acid by reacting with hydroxide ions (a base) to form the ion $[Cr(OH)_6]^{3-}$.

   You could show that it can act as a base by reacting it with, say, dilute sulphuric acid, replacing the hydrogen ions previously lost and reforming the $[Cr(H_2O)_6]^{3+}$ ion. The precipitate would dissolve again.

3. a) Nickel(II) ions: $[Ni(H_2O)_6]^{2+}$ and $[Ni(H_2O)_4(OH)_2]$

   b) Iron(III) ions: $[Fe(H_2O)_6]^{3+}$ and $[Fe(H_2O)_3(OH)_3]$

   c) Manganese(II) ions: $[Mn(H_2O)_6]^{2+}$ and $[Mn(H_2O)_4(OH)_2]$

   d) Iron(II) ions: $[Fe(H_2O)_6]^{2+}$ and $[Fe(H_2O)_4(OH)_2]$

   e) Cobalt(II) ions: $[Co(H_2O)_6]^{2+}$ and $[Co(H_2O)_4(OH)_2]$