COMPLEX IONS: STABILITY CONSTANTS

1. a) $[Fe(H_2O)_6]^{3+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{3-} + 6H_2O$

b) $$K_{stab} = \frac{[Fe(CN)_6^{3-}]}{[Fe(H_2O)_6^{3+}][CN^-]^6}$$

(The square brackets now show concentration in mol dm^{-3} rather than just keeping the complex ions tidy. That's why they aren't in exactly the same position as in the equation.)

c) 1×10^{31}. (If you don't understand about logs, put 31 on to your calculator and "unlog" it. Probably shift-log or inv-log or something similar. Look for the 10^x function.)

The value for the stability constant is very high indeed, which means that the position of equilibrium is very strongly to the right, and so the hexacyanoferrate(III) ion is very stable.

2. a) K_1: $[Cu(H_2O)_6]^{2+} + NH_3 \rightleftharpoons [Cu(NH_3)(H_2O)_5]^{2+} + H_2O$

$$K_1 = \frac{[Cu(NH_3)(H_2O)_5^{2+}]}{[Cu(H_2O)_6^{2+}][NH_3]}$$

K_2: $[Cu(NH_3)(H_2O)_5]^{2+} + NH_3 \rightleftharpoons [Cu(NH_3)_2(H_2O)_4]^{2+} + H_2O$

$$K_2 = \frac{[Cu(NH_3)_2(H_2O)_4^{2+}]}{[Cu(NH_3)(H_2O)_5^{2+}][NH_3]}$$

K_3: $[Cu(NH_3)_2(H_2O)_4]^{2+} + NH_3 \rightleftharpoons [Cu(NH_3)_3(H_2O)_3]^{2+} + H_2O$

$$K_3 = \frac{[Cu(NH_3)_3(H_2O)_3^{2+}]}{[Cu(NH_3)_2(H_2O)_4^{2+}][NH_3]}$$

K_4: $[Cu(NH_3)_3(H_2O)_3]^{2+} + NH_3 \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+} + H_2O$

$$K_4 = \frac{[Cu(NH_3)_4(H_2O)_2^{2+}]}{[Cu(NH_3)_3(H_2O)_3^{2+}][NH_3]}$$

b) $$K_{stab} = \frac{[Cu(NH_3)_4(H_2O)_2^{2+}]}{[Cu(H_2O)_6^{2+}][NH_3]^4}$$

c) If you multiply K_1 x K_2 x K_3 x K_4 all the terms in the expressions will cancel out leaving only those in the K_{stab} expression.

$K_{stab} = 1.78 \times 10^4 \times 4.07 \times 10^3 \times 9.55 \times 10^2 \times 1.74 \times 10^2 = 1.20 \times 10^{13}$

Don't forget the units! On the top of the K_{stab} expression you have units of mol dm^{-3}. At the bottom you have $(\text{mol dm}^{-3})^5$. Overall this is therefore $(\text{mol dm}^{-3})^{-4} = \text{mol}^{-4}\ \text{dm}^{12}$.

If your answer is out by several factors of 10, then you are probably misusing the EXP button on your calculator. Read the instruction book! To enter 1.78×10^4, you almost certainly enter 1.78, press the EXP button and then enter 4. You never enter a 10 or use the multiply button when you are entering a number in scientific notation.

3. a) $[Ni(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+} + 6H_2O$

$[Ni(H_2O)_6]^{2+} + EDTA^{4-} \rightleftharpoons [Ni(EDTA)]^{2-} + 6H_2O$

b) The K_{stab} values show that the position of the EDTA equilibrium lies much further to the right than the ammonia one. There are two factors which affect the position of equilibrium – the enthalpy change during the reaction and the entropy change. The dominant factor here is the entropy change.

Reactions are more likely if the amount of disorder in the system increases – an increase in entropy. In the ammonia case, you start with 1 complex ion and 6 small molecules, and end up with the same combination. There is nothing to increase the disorder especially.

In the EDTA case, you start with 1 complex ion and a moderately complicated ion, but end up with a complex ion and 6 small molecules – a combination which can be potentially much more disordered than you started with. The greater value for the stability constant in the EDTA case is largely driven by the increase in entropy.