Chemguide – answers

TRANSITION METALS: CHROMIUM

1. a) about 2 - 3

b) either: $[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$

or: $[Cr(H_2O)_6]^{3+}_{(aq)} \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+}_{(aq)} + H^+_{(aq)}$

(If you have used the second version, it must include state symbols.)

c) A ligand exchange reaction occurs with one of the water molecules being replaced by a sulphate ion to give the green complex $[Cr(H_2O)_5(SO_4)]^+$.

d) (i) first tube: $[Cr(H_2O)_6]^{3+}$
second tube: $[Cr(H_2O)_3(OH)_3]$
third tube: $[Cr(OH)_6]^{3-}$

(ii) first tube: $[Cr(H_2O)_6]^{3+}$
second tube: $[Cr(H_2O)_3(OH)_3]$
third tube: $[Cr(NH_3)_6]^{3+}$ and $[Cr(H_2O)_3(OH)_3]$

(You could actually argue that the second tube still has some coloured solution and so also contains $[Cr(H_2O)_6]^{3+}$.)

(iii) first tube: $[Cr(H_2O)_6]^{3+}$
second tube: $[Cr(H_2O)_3(OH)_3]$

e) Add an excess of sodium hydroxide solution to give the dark green solution containing $[Cr(OH)_6]^{3-}$. Then warm with hydrogen peroxide.

f) (i) Dichromate ions react with hydrogen peroxide solution in the presence of acid, and so it is necessary to destroy any excess hydrogen peroxide before adding the acid. Heating decomposes hydrogen peroxide into water and oxygen.

(ii) $2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$

(iii) Adding excess hydrogen ions shifts the position of equilibrium to the right, according to Le Chatelier's Principle.

2. a) $Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$

b) The orange solution will turn green.

c) $Zn \longrightarrow Zn^{2+} + 2e^-$

d) $$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$
$$3 \times (Zn \longrightarrow Zn^{2+} + 2e^-)$$

$$Cr_2O_7^{2-} + 14H^+ + 3Zn \longrightarrow 2Cr^{3+} + 7H_2O + 3Zn^{2+}$$

e) The solution turns blue and contains $[Cr(H_2O)_6]^{2+}$

3. a) With ethanol in excess, and if you distil off the product as soon as it is formed, you get an aldehyde, ethanal.

   If the oxidising agent is in excess, and you keep the ethanol in contact with it by heating under reflux, you get ethanoic acid.

   b) $$CH_3CH_2OH + [O] \longrightarrow CH_3CHO + H_2O$$
   $$CH_3CH_2OH + 2[O] \longrightarrow CH_3COOH + H_2O$$

4. a) A double salt is a mixture of two salts which behave independently in solution in water, but crystallise to form a single crystal.

   b) If a solution containing chromium(III) sulphate is heated, you get a ligand exchange reaction in which a water molecule attached to the chromium is replaced by a sulphate ion. If that happens, you don't get crystals of the double salt.

5. a) A primary standard is a substance that you can make up a solution of with an accurately known concentration. The solution is also stable, and doesn't change in any way on standing.

   b) Manganate(VII) ions oxidise chloride ions as well as iron(II) ions, and therefore you can't get an accurate result if you are using it to estimate iron(II) ions. Dichromate(VI) ions aren't a strong enough oxidising agent to oxidise chloride ions so that problem doesn't occur.

   c) A manganate(VII) titration is self-indicating. The purple solution turns colourless as you run it into the titration flask until you have added just one drop too much, when it stays pink. The dichromate(VI) titration has an orange solution turning green, and nothing dramatic happens when you get to the end point. You therefore have to use an external indicator.

   d) Start from what you know most about.

$$\text{Number of moles of } Cr_2O_7^{2-} = \frac{23.1}{1000} \times 0.0170$$

The equation shows that you have 6 x as many moles of Fe^{2+} ions.

$$\text{Number of moles of } Fe^{2+} = 6 \times \frac{23.1}{1000} \times 0.0170 \text{ in } 25 \text{ cm}^3$$

$$\text{Concentration of } Fe^{2+} = \frac{1000}{25} \times 6 \times \frac{23.1}{1000} \times 0.0170$$
$$= 0.0942 \text{ mol dm}^{-3}$$

(You could, of course, work out intermediate answers if you are more comfortable with doing that, but if you do, don't over-round them. Your final answer has to be to 3 significant figures, because that's the accuracy of the numbers you are working with. So any intermediate answers should be written down to at least 4 significant figures.

6. Barium chloride solution: pale yellow precipitate formed.

$$Ba^{2+}_{(aq)} + CrO_4{}^{2-}{}_{(aq)} \longrightarrow BaCrO_{4(s)}$$

Lead(II) nitrate solution: bright yellow precipitate formed.

$$Pb^{2+}_{(aq)} + CrO_4{}^{2-}{}_{(aq)} \longrightarrow PbCrO_{4(s)}$$