Topic 15 – Transition Metals and Complex Ions

* I can explain that the transition metal characteristics of elements Ti–Cu arise from an incomplete d sub-level in atoms or ions, and that the characteristic properties include complex formation, formation of coloured ions, variable oxidation states and catalytic activity
* I can describe a ligand as a molecule or ion that forms a co-ordinate bond with a transition metal by donating a pair of electrons, a complex as a central metal atom or ion surrounded by ligands, co-ordination number as the number of co-ordinate bonds to the central metal atom or ion, and I can explain that H2O, NH3 and Cl− act as monodentate ligands, but that ligands can also be bidentate (eg H2NCH2CH2NH2 and C2O42–) or multidentate (eg EDTA4–)
* I can explain that transition metal ions commonly form octahedral complexes with small ligands (eg H2O and NH3), that octahedral complexes can display cis–trans isomerism (a special case of E–Z isomerism) with monodentate ligands and optical isomerism with bidentate ligands, that transition metal ions commonly form tetrahedral complexes with larger ligands (eg Cl–), that square planar complexes are also formed and can display cis–trans isomerism and that cisplatin is a cis isomer
* I can explain how in aqueous solution the following metal-aqua ions are formed: [M(H2O)6]2+, limited to M = Fe and Cu, and [M(H2O)6]3+, limited to M = Al and Fe
* I can explain that transition metal ions can be identified by their colour, that this colour arises when some of the wavelengths of visible light are absorbed and the remaining wavelengths of light are transmitted or reflected, that d electrons move from the ground state to an excited state when light is absorbed, that the energy difference between the ground state and the excited state of the d electrons is given by ∆E = hν = hc/λ, that changes in oxidation state, co-ordination number and ligand alter ∆E and this leads to a change in colour, and I can explain that the absorption of visible light is used in spectroscopy and that a simple colorimeter can be used to determine the concentration of coloured ions in solution
* I can explain why the acidity of [M(H2O)6]3+ is greater than that of [M(H2O)6]2+ and explain this in terms of the charge/size ratio of the metal ion, I can state that some metal hydroxides show amphoteric character by dissolving in both acids and bases (eg hydroxides of Al3+), and I can describe and explain the simple test-tube reactions of: M2+(aq) ions, limited to M = Fe and Cu, and of M3+(aq) ions, limited to M = Al and Fe, with the bases OH–, NH3 and CO32–
* I can explain that the ligands NH3 and H2O are similar in size and uncharged, that exchange of the ligands NH3 and H2O occurs without change of co-ordination number (eg Co2+ and Cu2+), that substitution may be incomplete (eg the formation of [Cu(NH3)4(H2O)2]2+), that the Cl− ligand is larger than the uncharged ligands NH3 and H2O and that exchange of the ligand H2O by Cl– can involve a change of co-ordination number (eg Co2+, Cu2+ and Fe3+)
* I can carry out simple test-tube reactions to identify transition metal ions in aqueous solution (Required Practical 11)
* I can explain that bidentate and multidentate ligands replace monodentate ligands from complexes and that this is called the chelate effect, and I can explain the chelate effect in terms of the balance between the entropy and enthalpy change in these reactions
* I can explain that haem is an iron(II) complex with a multidentate ligand, that oxygen forms a co-ordinate bond to Fe(II) in haemoglobin, enabling oxygen to be transported in the blood and that carbon monoxide is toxic because it replaces oxygen co-ordinately bonded to Fe(II) in haemoglobin
* I can explain that transition elements show variable oxidation states, that vanadium species in oxidation states IV, III and II are formed by the reduction of vanadate(V) ions by zinc in acidic solution, that the redox potential for a transition metal ion changing from a higher to a lower oxidation state is influenced by pH and by the ligand
* I can explain that the reduction of the linear complex [Ag(NH3)2]+ (Tollens’ reagent) to metallic silver is used to distinguish between aldehydes and ketones
* I can describe the redox titrations of Fe2+ and C2O42– with MnO4–, and I perform calculations for these titrations and similar redox reactions
* I can explain that transition metals and their compounds can act as heterogeneous and homogeneous catalysts and that variable oxidation states are important in catalysis
* I can explain that a heterogeneous catalyst is in a different phase from the reactants and the reaction occurs at active sites on the surface, the use of a support medium to maximise the surface area of a heterogeneous catalyst and minimise the cost, that V2O5 acts as a heterogeneous catalyst in the Contact process and explain this with the aid of equations, that Fe is used as a heterogeneous catalyst in the Haber process, that heterogeneous catalysts can become poisoned by impurities that block the active sites and consequently have reduced efficiency and that this has a cost implication
* I can explain that a homogeneous catalyst is in the same phase as the reactants, that when catalysts and reactants are in the same phase the reaction proceeds through an intermediate species, write equations to show how Fe2+ ions catalyse the reaction between I− and S2O82– and explain, with the aid of equations, how Mn2+ ions autocatalyse the reaction between C2O42– and MnO4–