Review of Unit III

In which we consider acid-base reactions, precipitation–solubility reactions, oxidation–reduction reactions, and the formation of metal-ligand complexes and coordination compounds.

1. What is oxidation state of the metals in these ions: $Re_2Cl_8^{2-}$, $Cr_2Cl_9^{3-}$, and $Mo_2Cl_8^{4-}$? In each ion, chlorine has an oxidation state of –1, which means they provide a total charge of –8, –9, and –10 for the compounds $Re_2Cl_8^{2-}$, $Cr_2Cl_9^{3-}$, and $Mo_2Cl_8^{4-}$, respectively. For $Re_2Cl_8^{2-}$, the two rheniums have a net charge of +6 to yield a net anionic charge of –3; thus, each rhenium has an oxidation state of +3. For $Cr_2Cl_9^{3-}$, the two chromiums have a net charge of +6 to yield a net anionic charge of –2; thus, each chromium has an oxidation state of +3. Finally, for $Mo_2Cl_8^{4-}$, the two molybdenums have a net charge of +4 to yield a net anionic charge of –4; thus, each molybdenum has an oxidation state of +2.

2. The reaction below includes an oxidation–reduction reaction and an acid–base reaction. What is being oxidized and what is being reduced? What is the acid in this reaction, and what is the base in this reaction?

   $$4NaCl(aq) + 2H_2SO_4(aq) + MnO_2(s) \rightarrow Na_2SO_4(aq) + MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

   Manganese is reduced from an oxidation state of +4 in MnO_2 to an oxidation state of +2 in $MnCl_2$. Chlorine is oxidized from an oxidation state of –1 in NaCl to an oxidation state of 0 in Cl_2. Sulfuric acid, H_2SO_4, serves as an acid, donating a proton to the oxide anions, O^{2-}, in MnO_2, making it the base.

3. For the following sets of reactants, predict the products, if any, of a reaction (use tables of acid–base reactivity and oxidation–reduction activity distributed in class or available in your textbook):

   $HOCl(aq) + CH_3COO^-(aq) \rightarrow CH_3COOH(aq) + OCl^-(aq)$

   $H_2CO_3(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$ [assume OH^- present in excess]

   $Cl_2(aq) + H_2O_2(aq) \rightarrow O_2(g) + 2Cl^-(aq)$ [unbalanced]

   $O_2(g) + NO(g) \rightarrow HNO_3(aq) + H_2O(l)$ [unbalanced]

   To deduce these reactions we note that a favorable reaction always goes from stronger acids/bases to weaker acids/bases, or from stronger oxidizing/reducing agents to weaker oxidizing/reducing agents. As we are predicting the identify of products only, the reactions above are not balanced.

4. Write molecular formulas for hexaammineiron(III) nitrate and for sodium monochloropentacyanoferrate(III). Give the names for the compounds $[CoBr(NH_3)_5]SO_4$ and $[Fe(NH_3)_6][Cr(CN)_6]$.

   (a) hexaammineiron(III) nitrate is $[Fe(NH_3)_6](NO_3)_3$

   (b) sodium monochloropentacyanoferrate(III) is $Na_3[Fe(Cl)(CN)_5]$

   (c) $[CoBr(NH_3)_5]SO_4$ is pentaamminebromocobalt(III) sulfate

   (d) $[Fe(NH_3)_6][Cr(CN)_6]$ is hexammineiron(III) hexacyanochormate(III)

   For (a), the +3 oxidation state on iron requires three nitrate anions to balance the metal-ligand complex's charge. For (b), the metal-ligand complex has a net charge of –3 from the +3 iron, the single chloride ion, and the five cyanide ions; thus, there are three sodium ions to balance the charge. For (c), cobalt has an oxidation state of +3, yielding a metal-ligand complex with a charge of +2 that balances the charge of –2 for sulfate. Finally, for (d) we know that iron and chromium have common oxidation states of +2 and +3. If we choose the +2 oxidation state for chromium, then the net charge on $[Cr(CN)_6]$ is –4, which requires iron to have the unlikely oxidation state of +4; thus, chromium (and iron) have oxidation states of +3.

5. Draw all possible geometric isomers of the compound $[Cr(NH_3)_3(H_2O)_3]Cl_3$. Are any of these geometric isomers optically active? As we are interested in the metal-ligand complex only, we can ignore the three chloride ions. The metal-ligand complex is of the general form MX_3Y_3. There are two possible geometric isomers, one in which X and Y adopt facial arrangements and one in which X and Y adopt meridional arrangements. Neither one of these geometric isomers has an optical isomer.