CM 1111 Tutorial 7

Question 1

Give the oxidation state of each element in the following compounds and ions:

a) HF +I, –I
b) $FeCl_2$ +II, –I
c) XeF_6 +VI, –I
d) Na_2SO_4 +I, +VI, –II
e) PO_4^{3-} +V, –II
f) $[Cr(OH_2)_6]^{3+}$ +III, –II, +I
g) Co_3O_4 +II (1 Co) , +III (2 Co), –II

Question 2

Which of the following reactions are redox-reactions? In those that are, identify the oxidation and reduction processes.

a) $N_2 + 3\,Mg \rightarrow Mg_3N_2$ yes; Red: N^0/N^{-III}; Ox: Mg^0/Mg^{II}
b) $N_2 + O_2 \rightarrow 2\,NO$ yes; Red: O^0/O^{-II}; Ox: N^0/N^{II}
c) $2\,NO_2 \rightarrow N_2O_4$ no; simple dimerization: N^{IV} and O^{-II} on both sides
d) $SbF_3 + F_2 \rightarrow SbF_5$ yes; Red: F^0/F^{-I}; Ox: Sb^{III}/Sb^{V}
e) $6\,HCl + As_2O_3 \rightarrow 2\,AsCl_3 + 3\,H_2O$ no; Oxidation states remain the same
f) $2\,CO + O_2 \rightarrow 2\,CO_2$ yes; Red: O^0/O^{-II}; Ox: C^{II}/C^{IV}

Question 3

Perchloric acid $HClO_4$ is not only a strong acid, but also a strong oxidizer.

a) What are the oxidation states of H, Cl and O in this compound? (+I, +VII, –II)
b) Explain why perchlorates are explosion hazards and strong oxidizers.
   Cl atom is in an unusually high oxidation state of +VII. The most favorable oxidation state for Cl is –I, which is in line with its relatively high electronegativity and also fulfills the octet rule. In order to achieve this electron configuration, the Cl atom in perchlorate needs 8 electrons, which explains the strong oxidizing power.

Question 4

A few drops of an almost colorless solution of $MnSO_4$ was added to an orange suspension of PbO_2 in 5 mL half-concentrated HNO_3. Heating the mixture for a few minutes leads to a color change to dark-violet indicative of MnO_4^-. Briefly explain what has happened and give the complete equation.

Mn^{2+} (colorless) has been oxidized to Mn^{7+} (dark-violet) by losing 5 electrons. Thus Pb^{4+} must be the oxidizer that accepts 2 electrons to form Pb^{2+} (refer to listed redox-potentials in books or other references). Since this reaction takes place in half-concentrated nitric acid, there must be protons available for balancing the charges in the equation.

Oxidation: $Mn^{II}SO_4 + 4\,H_2O \rightarrow Mn^{VI}O_4^- + 5\,e^- + SO_4^{2-} + 8\,H^+$

Reduction: $PbO_2 + 2\,e^- + 4\,H^+ \rightarrow Pb^{2+} + 2\,H_2O$

Overall: $2\ Mn^{II}SO_4 + 5\ PbO_2 + 10\ e^- + 20\ H^+ + 8\ H_2O \rightarrow$
$2\ Mn^{VI}O_4^{-} + 10\ e^- + 2\ SO_4^{2-} + 5\ Pb^{2+} + 10\ H_2O + 16\ H^+$

After "eliminating" e^-, H_2O and H^+ on both sides:

$$2\ Mn^{II}SO_4 + 5\ PbO_2 + 4\ H^+ \rightarrow 2\ Mn^{VI}O_4^{-} + 2\ SO_4^{2-} + 5\ Pb^{2+} + 2\ H_2O$$

With inclusion of nitrate anion:

$$2\ MnSO_4 + 5\ PbO_2 + 4\ HNO_3 \rightarrow 2\ MnO_4^{-} + Pb^{2+} + 2\ PbSO_4 + 2\ Pb(NO_3)_2 + 2\ H_2O$$