CH 302H Spring 2016 HW 3 key

1) $2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$

$\Delta H_f^\circ(NaHCO_3) = -950.8$ kJ/mol

$\Delta H_f^\circ(Na_2CO_3) = -1130.7$ kJ/mol

$\Delta H_f^\circ(H_2O) = -241.8$ kJ/mol

$\Delta H_f^\circ(CO_2) = -393.5$ kJ/mol

$S_m^\circ(NaHCO_3) = 101.7$ J/Kmol

$S_m^\circ(Na_2CO_3) = 135.0$ J/Kmol

$S_m^\circ(H_2O) = 188.7$ J/Kmol

$S_m^\circ(CO_2) = 213.6$ J/Kmol

→

a) $\Delta H^\circ_{rxn} = \Delta H^\circ_f(Na_2CO_3) + \Delta H^\circ_f(H_2O) + \Delta H^\circ_f(CO_2) - 2\Delta H^\circ_f(NaHCO_3)$

$= -1130.7\ kJ/mol + -241.8\ kJ/mol + -393.5\ kJ/mol - 2(-950.8\ kJ/mol)$

$\boxed{\Delta H^\circ_{rxn} = 135.6\ kJ/mol}$ * does this # make sense based on the info you have been given in the problem? Be sure to justify this to yourself. (+ assume constant)

$\Delta S^\circ_{rxn} = S^\circ_m(Na_2CO_3) + S^\circ_m(H_2O) + S^\circ_m(CO_2) - 2(S^\circ_m(NaHCO_3))$

$= 135.0\ J/K\,mol + 188.7\ J/K\,mol + 213.6\ J/K\,mol - 2(101.7\ J/K\,mol)$

$\boxed{\Delta S^\circ_{rxn} = 333.9\ J/K\,mol}$ * again, make sure the magnitude of this # makes sense to you. (+ assume constant)

$\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn} = 135.6 \times 10^3\ J/mol - (298\ K)(333.9\ J/K\,mol)$

$\boxed{\Delta G^\circ_{rxn} = 36.1\ kJ/mol}$ @ 298 K!

But, since $\Delta S^\circ_{rxn} \gg 0$, we expect that as T increases, ΔG°_{rxn} becomes a smaller number and will eventually cross 0.

@ T = 150 °C = 423 K: $\Delta G_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn} = (135.6 \times 10^3\ J/mol) - (423\ K)(333.9$

$\Delta G_{rxn}(423\ K) = -5.64\ kJ/mol$

$K_p = \exp\left[\frac{-\Delta G_{rxn}}{RT}\right] = \left[-\frac{(-5.64 \times 10^3\ J/mol)}{(8.314\ J/K\,mol)(423\ K)}\right] = \boxed{1.60 = K_p}$

b) $K_p = P(H_2O)P(CO_2)$

$P(CO_2) = 0.8\text{ atm}$

$K_p = 1.60$

$$P(H_2O) = \frac{K_p}{P(CO_2)} = \frac{1.60}{0.8\text{ atm}}$$

$$\boxed{P(H_2O) = 2.0\text{ atm}}$$

(remember there is a P° in the denominator of both partial pressure terms to make units work out).

2) Reaction 1: $CS_{2(g)} + 3O_{2(g)} \rightleftharpoons CO_{2(g)} + 2SO_{2(g)}$

$$K_{p1} = \frac{P_{CO_2} P_{SO_2}^2}{P_{CS_2} P_{O_2}^3}$$

Reaction 2: $\frac{1}{3} CS_{2(g)} + O_2 \rightleftharpoons \frac{1}{3} CO_{2(g)} + \frac{2}{3} SO_{2(g)}$

$$k_{p2} = \frac{P_{CO_2}^{1/3} P_{SO_2}^{2/3}}{P_{CS_2}^{1/3} P_{O_2}}$$

$$\boxed{K_{p1} = k_{p2}^3}$$

3) need $K_{p3} = \dfrac{P(XeO_3F_2)\,P(H_2O)}{P(XeO_4)\,P^2(HF)}$

know: $K_{p1} = \dfrac{P(XeOF_4)\,P^2(HF)}{P(XeF_6)\,P(H_2O)}$ $\quad$ $K_{p2} = \dfrac{P(XeOF_4)\,P(XeO_3F_2)}{P(XeO_4)\,P(XeF_6)}$

By inspection, I can see that I want the numerator of K_{p2} and the denomentator of the numerator of k_{p1}:

$$\frac{K_{p2}}{K_{p1}} = \frac{\dfrac{\cancel{P(XeOF_4)}\,P(XeO_3F_2)}{P(XeO_4)\,P\cancel{(XeF_6)}}}{\dfrac{\cancel{P(XeOF_4)}\,P^2(HF)}{\cancel{P(XeF_6)}\,P(H_2O)}} = \frac{P(XeO_3F_2)\,P(H_2O)}{P(XeO_4)\,P^2(HF)} = K_3$$

So $\boxed{K_{p3} = \dfrac{K_{p2}}{K_{p1}}}$

4) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

$FW(PCl_5) = 217.5\ g/mol$

$m = 1.5\ g$

$$n(PCl_5) = \frac{1.5\ g}{217.5\ g/mol} = 0.0069\ mols$$

$V = 0.010\ L$

$T = 250°C = 523\ K$

$$\Rightarrow P(PCl_5) = \frac{nRT}{V} = (0.0069\ mols)(0.082\ \frac{L\,atm}{mol\,K})(523\ K)$$

$P(PCl_5) = 0.30\ atm$

	PCl_5	PCl_3	Cl_2
I:	0.30	0	0
Δ:	$-x$	$+x$	$+x$
E:	$0.30-x$	x	x

$\Delta G_f^\circ(PCl_5) = -305.0\ kJ/mol$

$\Delta G_f^\circ(PCl_3) = -267.8\ kJ/mol$

$\Delta G_f^\circ(Cl_2) = 0$

$\Delta G_{rxn}^\circ = \Delta G_f^\circ(Cl_2) + \Delta G_f^\circ(PCl_3) - \Delta G_f^\circ(PCl_5)$

$\Delta G_{rxn}^\circ = 0 + -267.8\ kJ/mol - -305.0\ kJ/mol$

$\Delta G_{rxn}^\circ = 37.2\ kJ/mol$

$$K_p = \exp\left[\frac{-\Delta G_{rxn}^\circ}{RT}\right] = \exp\left[\frac{-(37.2\times10^3\ J/mol)}{(8.314\ J/K\,mol)(523\ K)}\right]$$

$K_p = 1.9\times10^{-4}$ $\ll 1$, so assume $0.30 - x \approx 0.30$

$$K_p = \frac{P(Cl_2)P(PCl_3)}{P(PCl_5)} = \frac{(x)(x)}{0.30} = \frac{x^2}{0.30} = K_p$$

$$x = (0.30 K_p)^{1/2} = [(0.30)(1.9\times10^{-4})]^{1/2} = 0.0076$$

$P(PCl_5) = 0.30\ atm$

$P(Cl_2) = P(PCl_3) = 0.0076\ atm$