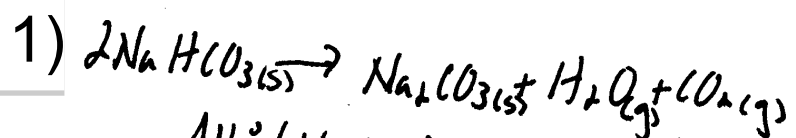


CH 302H Spring 2016 HW 3 key



$$\Delta H_f^\circ(\text{NaHCO}_3) = -950.8 \text{ kJ/mol}$$

$$\Delta H_f^\circ(\text{Na}_2\text{CO}_3) = -1130.7 \text{ kJ/mol}$$

$$\Delta H_f^\circ(\text{H}_2\text{O}) = -241.8 \text{ kJ/mol}$$

$$\Delta H_f^\circ(\text{CO}_2) = -393.5 \text{ kJ/mol}$$

$$S_m^\circ(\text{NaHCO}_3) = 101.7 \text{ J/kmol}$$

$$S_m^\circ(\text{Na}_2\text{CO}_3) = 135.0 \text{ J/kmol}$$

$$S_m^\circ(\text{H}_2\text{O}) = 188.7 \text{ J/kmol}$$

$$S_m^\circ(\text{CO}_2) = 213.6 \text{ J/kmol}$$

→

$$a) \Delta H_{rxn}^{\circ} = \Delta H_f^{\circ}(\text{Na}_2\text{CO}_3) + \Delta H_f^{\circ}(\text{H}_2\text{O}) + \Delta H_f^{\circ}(\text{CO}_2) - 2\Delta H_f^{\circ}(\text{NaHCO}_3)$$

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

$$\Delta H_{rxn}^{\circ} = 135.6 \text{ kJ/mol}$$

* does this # make sense based on the info you have been given in the problem?

Be sure to justify this to yourself.
(assume constant)

$$\Delta S_{rxn}^{\circ} = S_m^{\circ}(\text{Na}_2\text{CO}_3) + S_m^{\circ}(\text{H}_2\text{O}) + S_m^{\circ}(\text{CO}_2) - 2(S_m^{\circ}(\text{NaHCO}_3))$$

$$= 135.0 \text{ J/kmol} + 188.7 \text{ J/kmol} + 213.6 \text{ J/kmol} - 2(101.7 \text{ J/kmol})$$

$$\Delta S_{rxn}^{\circ} = 333.9 \text{ J/kmol}$$

* again, make sure the magnitude of this # makes sense to you.
(assume constant)

$$\Delta G_{rxn}^{\circ} = \Delta H_{rxn}^{\circ} - T\Delta S_{rxn}^{\circ} = 135.6 \times 10^3 \text{ J/mol} - (298 \text{ K})(333.9 \text{ J/kmol})$$

$$\Delta G_{rxn}^{\circ} = 36.1 \text{ kJ/mol}$$

@ 298 K!

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

$$@ T = 150^{\circ}\text{C} = 423 \text{ K}: \Delta G_{rxn} = \Delta H_{rxn}^{\circ} - T\Delta S_{rxn}^{\circ} = (135.6 \times 10^3 \text{ J/mol}) - (423 \text{ K})(333.9 \text{ J/kmol})$$

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

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

$$b) K_p = P(\text{H}_2\text{O})P(\text{CO}_2)$$

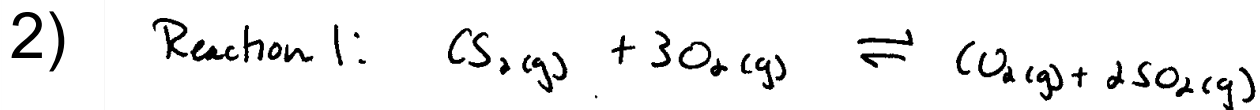
$$P(\text{CO}_2) = 0.8 \text{ atm}$$

$$K_p = 1.60$$

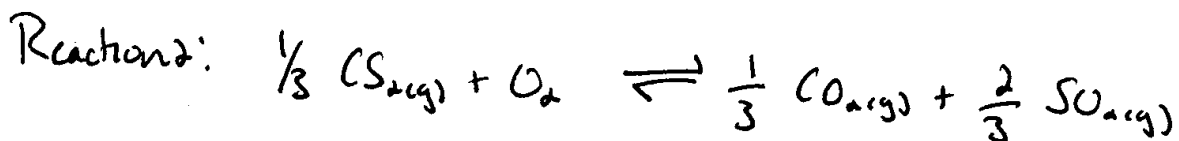
$$P(\text{H}_2\text{O}) = \frac{K_p}{P(\text{CO}_2)} = \frac{1.60}{0.8 \text{ atm}}$$

$$P(\text{H}_2\text{O}) = 2.0 \text{ atm}$$

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

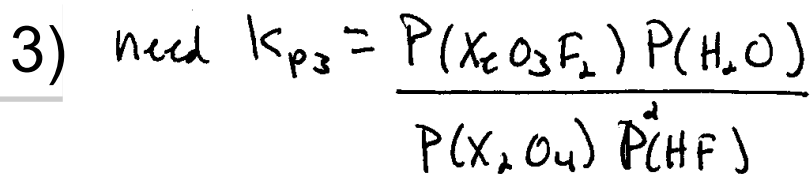


$$K_{p1} = \frac{P_{\text{CO}_2} P_{\text{SO}_2}^2}{P_{\text{CS}_2} P_{\text{O}_2}^3}$$



$$K_{p2} = \frac{P_{\text{CO}_2}^{1/3} P_{\text{SO}_2}^{2/3}}{P_{\text{CS}_2}^{1/3} P_{\text{O}_2}}$$

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



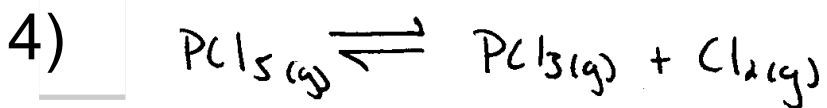
know: $K_{p1} = \frac{P(\text{XeOF}_4) P^2(\text{HF})}{P(\text{XeF}_6) P(\text{H}_2\text{O})}$

$$K_{p2} = \frac{P(\text{XeOF}_4) P(\text{XeO}_3\text{F}_2)}{P(\text{XeO}_4) P(\text{XeF}_6)}$$

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

$$\frac{K_{p2}}{K_{p1}} = \frac{\frac{P(\text{XeOF}_4) P(\text{XeO}_3\text{F}_2)}{P(\text{XeO}_4) P(\text{XeF}_6)}}{\frac{P(\text{XeOF}_4) P^2(\text{HF})}{P(\text{XeF}_6) P(\text{H}_2\text{O})}} = \frac{P(\text{XeO}_3\text{F}_2) P(\text{H}_2\text{O})}{P(\text{XeO}_4) P^2(\text{HF})} = K_{p3}$$

$$\text{So } \boxed{K_{p3} = \frac{K_{p2}}{K_{p1}}}$$



$\text{FW}(\text{PCl}_5) = 217.5 \text{ g/mol}$

$m = 1.5 \text{ g}$

$n(\text{PCl}_5) = \frac{1.5 \text{ g}}{217.5 \text{ g/mol}} = 0.0069 \text{ mols}$

$V = 0.010 \text{ L} \Rightarrow P(\text{PCl}_5) = \frac{nRT}{V} = (0.0069 \text{ mols})(0.082 \frac{\text{Latm}}{\text{molk}})(523 \text{ K})$
 $T = 250^\circ\text{C} = 523 \text{ K}$

$P(\text{PCl}_5) = 0.30 \text{ atm}$

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

$\Delta G_f^\circ(\text{PCl}_5) = -305.0 \text{ kJ/mol}$

$\Delta G_f^\circ(\text{PCl}_3) = -267.8 \text{ kJ/mol}$

$\Delta G_f^\circ(\text{Cl}_2) = 0$

$\Delta G_{rxn}^\circ = \Delta G_f^\circ(\text{Cl}_2) + \Delta G_f^\circ(\text{PCl}_3) - \Delta G_f^\circ(\text{PCl}_5)$

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

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

$k_p = \exp\left[\frac{-\Delta G_{rxn}^\circ}{RT}\right] = \exp\left[\frac{-(37.2 \times 10^3 \text{ J/mol})}{(8.314 \text{ J/kmol})(523 \text{ K})}\right]$

$k_p = 1.9 \times 10^{-4} \ll 1$, so assume $0.30 - x \approx 0.30$

$k_p = \frac{P(\text{Cl}_2)P(\text{PCl}_3)}{P(\text{PCl}_5)} = \frac{(x)(x)}{0.30} = \frac{x^2}{0.30} = k_p$

$x = (0.30 k_p)^{1/2} = [(0.30)(1.9 \times 10^{-4})]^{1/2} = 0.0076$

$P(\text{PCl}_5) = 0.30 \text{ atm}$

$P(\text{Cl}_2) = P(\text{PCl}_3) = 0.0076 \text{ atm}$