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Exam #2

Who did I work with?

- Joel Atoa

$$\Delta G^\circ_r = \sum [\Delta G_f^\circ (\text{products}) \times (\text{mols product})] - \sum [\Delta G_f^\circ (\text{reactants}) \times (\text{mols reactants})]$$

$$= [(1 \text{ } 33 \text{ kJ/mol}) + (-394 \text{ kJ/mol})] - [(-463 \text{ kJ/mol})]$$

$$= -64 \text{ kJ/mol}$$

Spontaneous under standard conditions
because ΔG is negative.

$$\ln k_p (T_f) = \ln k_p (298.15 \text{ K}) - \frac{\Delta H^\circ_r}{R} \left(\frac{1}{T_f} - \frac{1}{298.15} \right)$$

$$\Delta H^\circ_r = 24 \text{ kJ/mol}$$

$$\ln k_p = \frac{-\Delta G^\circ_r}{R \cdot T} \rightarrow \frac{(-64 \text{ kJ/mol})}{(8.314 \text{ J/mol K})(298.15 \text{ K})}$$

$$\ln k_p = 0.0258$$

$$k_p = 1.026$$

$$\ln k_p (80 \text{ K}) = \ln (1.026) - \frac{24 \text{ kJ/mol}}{8.314 \text{ J/mol K}} \left(\frac{1}{80 \text{ K}} - \frac{1}{298.15} \right)$$

$$\ln k_p (80 \text{ K}) = 0.0258 - 0.0264$$

$$k_p (80 \text{ K}) = 0.999$$

Reactants Favored.

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

$$\delta S_m = \frac{\delta S}{n} \text{ molar}$$

$$\beta = \frac{1}{V} \left(\frac{\partial V}{\partial T}\right)_P \quad \beta \quad \kappa = -\frac{1}{V} \left(\frac{\partial V}{\partial P}\right)_T$$

$$\left(\frac{\partial V}{\partial T}\right)_P \cdot \left(\frac{\partial P}{\partial V}\right)_T \cdot \left(\frac{\partial T}{\partial P}\right)_V = -1$$

$$BV \left(\frac{1}{-kV}\right) = -\left(\frac{\partial P}{\partial T}\right)_V$$

$$\Rightarrow \left(\frac{\partial P}{\partial T}\right)_V = \frac{\beta}{\kappa}$$

$$\left(\frac{\partial S_m}{\partial V}\right)_T = \frac{\beta}{n\kappa}$$

With increasing volume entropy also increases

$$\left(\frac{\partial U_i}{\partial P}\right)_{T, n_{j \neq i}} = -\left(\frac{\partial V}{\partial n_i}\right)_{T, P, n_{j \neq i}}$$

$$d(n, G) = (nV) dP - (nS) dT$$

$$\left[\frac{\partial (nG)}{\partial P}\right]_{T, n} = nV \quad \left\{ \quad \left[\frac{\partial (nG)}{\partial T}\right] = -nS \right.$$

$$d(n, G) = \left[\frac{\partial(n, G)}{\partial p} \right]_{T, n_i} dp + \left[\frac{\partial(n, G)}{\partial T} \right]_{p, n_i} dT + \sum_i \left[\frac{\partial(n, G)}{\partial n_i} \right]_{p, T, n_{j \neq i}} dn_i$$

$$d(n, G) = (nV) dp + (-nS) dT + \sum_i dn_i$$

$$V = \left. \frac{\partial(n, G)}{\partial p} \right|_{T, n_i}$$

$$V_i = \left. \frac{\partial(n, G)}{\partial n_i} \right|_{T, p}$$

$$\left. \frac{\partial V}{\partial n_i} \right|_{T, p, n_{j \neq i}} = \frac{\partial^2(n, G)}{\partial n_i \partial p} \quad \text{and} \quad \left. \frac{\partial V_i}{\partial p} \right|_{T, n_i} = \frac{\partial^2(n, G)}{\partial n_i \partial p}$$

$$\boxed{\left. \frac{\partial V}{\partial n_i} \right|_{T, p, n_{j \neq i}} = \left. \frac{\partial V_i}{\partial p} \right|_{T, n_i}}$$

d) $\left(\frac{\partial U_{COCl_2}}{\partial p} \right)_{T, n_{CO}, n_{Cl_2}}$

$$\boxed{\left(\frac{\partial U_{COCl_2}}{\partial p} \right)_{T, n_{CO}, n_{Cl_2}} = \left(\frac{\partial V}{\partial n_{COCl_2}} \right)_{T, p, n_{CO}, n_{Cl_2}}}$$

If pressure increased, the equilibrium will shift in where ^{more} gas is lost



$$\left(\frac{\partial U_{\text{COCl}_2}}{\partial p} \right)_{T, n_{\text{CO}}, n_{\text{Cl}_2}}$$

• Chemical potential increases when the pressure increases.

$$\left. \frac{d\mu_i}{dp} \right|_{T, n_i, z_i} = \left. \frac{\partial U}{\partial n_i} \right|_{T, p, n_j, z_j}$$

$$\rightarrow \int_{\mu_i}^{\mu_i'} d\mu_i = \int_{p_0}^p \left(\frac{\partial U}{\partial n_i} \right) dp$$

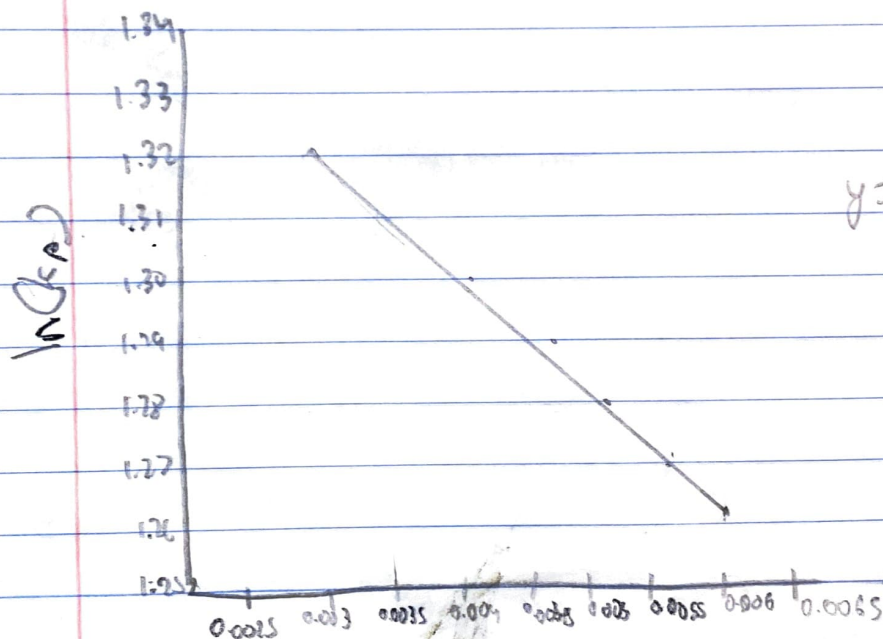
$$(\mu_i' - \mu_i) = \frac{dU}{dn_i} (p - p_0)$$

" μ_i " is chemical potential at p_0 .

③ $k_p = \frac{e^{-u^0}}{RT}$

$$\ln k_p = -\frac{\Delta G}{R} \times \frac{1}{T}$$

$\ln k_p$ vs. $\frac{1}{T}$



b) $-\Delta G = -19,388 \text{ K}$
 $\Delta G = 19,388 \times R$
 $\Delta G = 19,388 \times 8.314 \text{ J/mol K}$

$\Delta G = 161.19 \text{ Jole/mol}$
 non spontaneous

c) Driven from enthalpy

$$\boxed{\frac{d \ln K_p}{dT} = \frac{\Delta H_{rxn}}{RT^2}}$$

$\Delta S_{\text{uni}} \geq 0$, System + Surrounding = Universe
For any irreversible process in an isolated system there is a unique direction of spontaneous change.

$\Delta S > 0$ for spontaneous process, $\Delta S < 0$ for nonspontaneous process & $\Delta S = 0$ for a reversible process.

There is no direction of spontaneous change in a quasi-state reversible process because the system is proceeding along a path, each step corresponds to an equilibrium state.

The entropy of a system approaches a constant value as its temperature reaches absolute zero, in a closed system.

We cannot build one because it violates the first & second law of Thermodynamics. A perpetual machine is supposed to produce work without energy, violating the first law. Stating the total energy of an isolated

System is constant, energy can neither be created nor destroyed.

Also a perpetual machine is spontaneously converting thermal energy into mechanical work. which violates the 2nd law of thermodynamics. This is because there is suppose to be only one heat reservoir being spontaneously cooled without heat transfer to a cooler reservoir. That is why this conversion of heat to work with no side effects is impossible.

⑦ Gibbs free energy is defined under constant pressure which is how we conduct most of the experiments. Helmholtz is defined under constant volume which is better suited for other areas such as engineering.

$$\textcircled{8} \mu_i = \left(\frac{\partial G}{\partial n_i} \right)_{P, T, n_j \neq n_i}$$

↳ chemical potential \rightarrow change in Gibbs free energy per mole of substance i added at constant pressure.

The mixing of different types of molecules in an ideal gas, increases entropy. For instance, when adding a molecule to an ideal gas, the # of moles increases. Thus the entropy increases.

The chemical potential is inversely proportional to the # of molecules. So potential decreases as # of particles increases.

Higher the entropy, more spontaneous reaction is.

So it is ~~the~~ Spontaneous process

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta H - T\Delta S = +$$

$$\Delta H > T\Delta S$$
$$=$$

$\Delta G_{rxn} > 0 \rightarrow$ nonspontaneous in
forward direction.

$$\Delta G_{rxn} = -RT \ln K_{eq}$$

$$RT \ln K_{eq} > 0$$

$$\hookrightarrow K_{eq} < 1$$

$$\frac{[\text{product}]}{[\text{reactants}]} < 1$$

$$[\text{Product}] < [\text{Reactant}]$$

Reactants are favored over products
if $\Delta G_{rxn} > 0$.

Extra Credit

Favorite equation is the ideal gas law

$$PV = nRT$$

This is my favorite equation this semester because it is the basis for all other future ideologies and theories. We use it as a reference and expect other things to happen because life is not ideal.