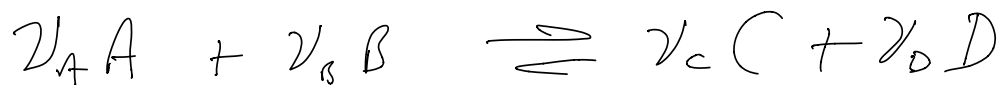


# Chemical Equilibrium:



$$\Delta G^\circ = -RT \ln(K_p) \quad \begin{array}{c} \text{Ideal Gases} \\ T, P \end{array}$$

↑ pressure-based  
Equil. Constant.

$$K_p = e^{-\Delta G^\circ / RT}$$

$$K_p(T)$$

$$\Delta G^\circ = \sum_{i=1}^{\text{species}} \nu_i \mu_i^\circ$$

"nu" Stoichiometric Coefficient  
 "i" chemical potential of "i" in standard (reference state)  
 "mu"

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

What is  $T$  dependence of  $K_p(T)$ ?

$$\ln K_p = \frac{-1}{RT} \Delta G^\circ = \frac{-1}{RT} \Delta G^\circ$$

If I know  $K_p$  at  $T_1$ ,

what is  $K_p$  at  $T_2$ ?

$$\begin{aligned} \left( \frac{d(\ln K_p)}{dT} \right)_p &= \frac{d}{dT} \left( \frac{-1}{RT} \Delta G^\circ \right) \\ &= \frac{-1}{RT} \frac{d(\Delta G^\circ)}{dT} + \Delta G^\circ \frac{d}{dT} \left( \frac{-1}{RT} \right) \\ &= \left( \frac{-1}{RT} \right) (-\Delta S^\circ) + \Delta G^\circ \left( \frac{1}{RT^2} \right) \\ &= \frac{\Delta S^\circ}{RT} + \frac{1}{RT^2} [\Delta H^\circ - T\Delta S^\circ] \\ &= \frac{\Delta S^\circ}{RT} + \frac{\Delta H^\circ}{RT^2} - \frac{\Delta S^\circ}{RT} \end{aligned}$$

$$\boxed{\frac{d(\ln K_p)}{dT} = \frac{\Delta H^\circ}{RT^2}}$$

$$\int_{T_1}^{T_2} d(\ln K_p) = \int_{T_1}^{T_2} \frac{\Delta H^\circ}{RT^2} dT$$

Assume over  $[T_1, T_2]$

$\Delta H^\circ$  is constant

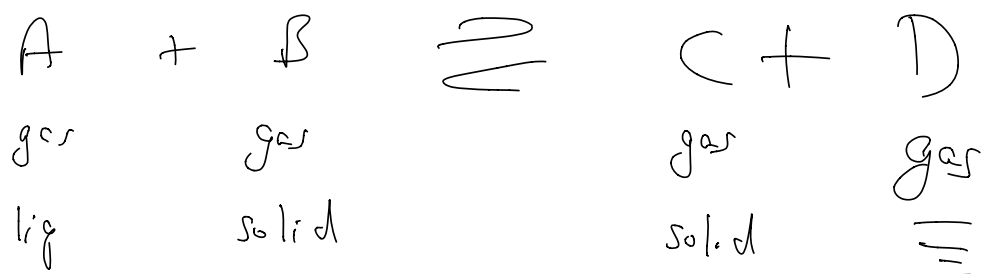
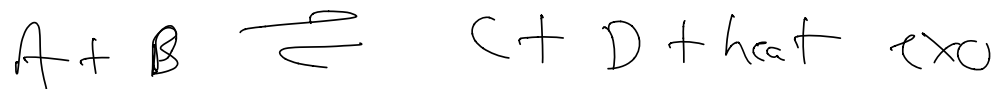
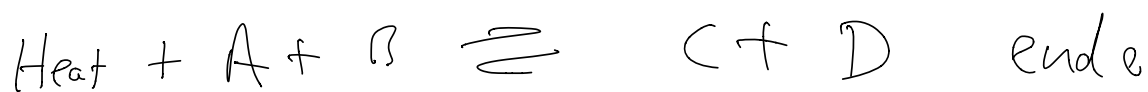
$$\begin{aligned} \ln K_p(T_2) - \ln K_p(T_1) &= \frac{-\Delta H^\circ}{R} \left. \frac{1}{T} \right|_{T_1}^{T_2} \\ &= \frac{\Delta H^\circ}{R} \left. \frac{1}{T} \right|_{T_2}^{T_1} \end{aligned}$$

$$\ln K_p(T_2) - \ln K_p(T_1) = \frac{\Delta H^\circ}{R} \left[ \frac{1}{T_1} - \frac{1}{T_2} \right]$$

$$\ln K_p(T_2) - \ln K_p(T_1) = \frac{\Delta H^\circ}{R} \left[ \frac{T_2 - T_1}{T_1 T_2} \right]$$

endo  $\Delta H^\circ_{\text{rxn}} > 0$

exo  $\Delta H^\circ_{\text{rxn}} < 0$



$$K_p = \frac{P_C^{\nu_C} P_D^{\nu_D}}{P_A^{\nu_A} P_B^{\nu_B}} = P_D^{\nu_D}$$

$$\Delta G^\circ = -RT \ln K_p$$

$$\Delta G^\circ = \sum \nu_i \mu_i^\circ$$

$$= \nu_A \mu_A^\circ + \nu_B \mu_B^\circ + \nu_C \mu_C^\circ + \nu_D \mu_D^\circ$$

