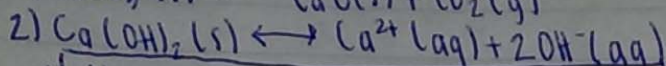
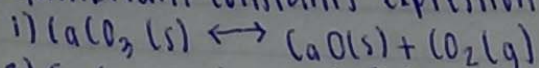


2.11.14

" $\leftrightarrow$ " equilibrium, does not go to completion, rxn occurring @ same rate forward and reverse

Equilibrium constants expression



$K_c = [\text{CO}_2]$ ;  $K_c = [\text{Ca}^{2+}][\text{OH}^{-}]^2$

pure solids + liquids Not included

Calculate  $K_c$  given  $K_p$  for  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \leftrightarrow 2\text{NH}_3(\text{g})$

$PV = nRT$

$P = \frac{n}{V}RT$

$K_p = K_c(RT)^{\Delta n}$

difference in gas moles

$K_c = K_p RT^{-\Delta n}$

$K_c = (RT)^2 K_p$

$\Delta n = n_p - n_r$

$\Delta n = -2$

$-\Delta n = 2$

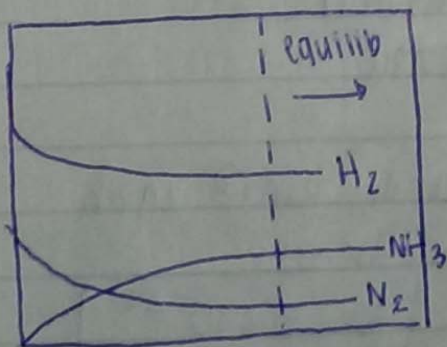
Given  $K = 200$

$[\text{H}_2]_{\text{eq}} = 0.7\text{M}$ ,  $[\text{N}_2]_{\text{eq}} = 0.4\text{M}$ ,  $[\text{NH}_3]_0 = 0.1\text{M}$

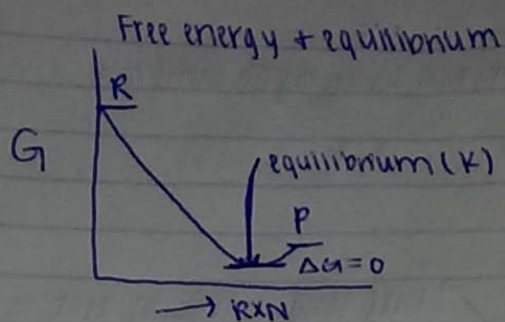
$K =$

Reaction	$3\text{H}_2(\text{g})$	$+ \text{N}_2(\text{g})$	$\leftrightarrow$	$2\text{NH}_3(\text{g})$
initial				0.1
change	$-3x$	$-x$		$+2x$
equilibr.	0.7	0.4		0.8

$x = 0.35$



mixture at end has lowest free energy, because moving towards equilibrium



298K, 1atm, 1molar  
 $\Delta G_{rxn}^{\circ} < 0$  spontaneous

→ Rxn proceeds towards products,  $-\Delta G$ , spontaneous

→ Pure products are lower in free energy

Thermodynamic

$$\Delta G_r = \Delta G_r^{\circ} + RT \ln Q$$

← gas constant

$Q = \frac{\text{activities of products}}{\text{activities of reactants}}$

- spontaneous → product favored ( $-\Delta G$ )
- nonspontaneous → reactant favored ( $\Delta G > 0$ )

\* change in Gibbs free energy (+) the actual min is less than 100% product or 100% reactant

• at this min, the value of  $Q = K$

At equilibrium:

$$\Delta G = \Delta G^{\circ} + RT \ln Q$$

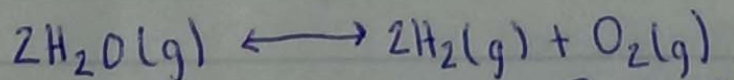
↓  
0

$$= \Delta G^{\circ} = -RT \ln K$$

↓  
K

$K > 1$  (product favored)

$(K < 1)$  reactant favored



What is K for this rxn @ 298K?

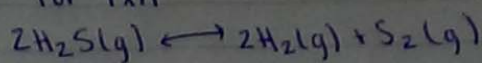
$$K = \frac{P_{\text{H}_2}^2 P_{\text{O}_2}}{P_{\text{H}_2\text{O}}^2}$$

\* extremely small

What is K for this rxn @ 298K given  $\Delta_r G^{\circ} = 113.4 \text{ kJ}$

$$K = 1.3 \times 10^{-20}$$

At 313K,  $\Delta_r G^\circ = 41 \text{ kJ mol}^{-1}$  for rxn



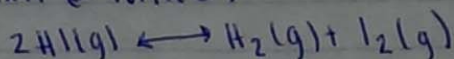
You find the partial pressures @ 313K  $p_{\text{H}_2} = 1 \text{ atm}$ ,  $p_{\text{I}_2} = 1 \text{ atm}$ ,  $p_{\text{H}_2\text{S}} = 2 \text{ atm}$

→ The rxn will proceed towards the reactants

Calculate  $Q = (\frac{1}{4})$   $K < 1$

$$\rightarrow \Delta G^\circ = -RT \ln K \leftarrow K < 1$$

$K = 2.2 \times 10^{-3}$  for this rxn @ some(T)



Start partial press of 1 atm HI

What partial press at constant P of 1 atm + constant T

R	$2\text{HI} \leftrightarrow \text{H}_2 + \text{I}_2$			
I	1 atm	0	0	$2.2 \times 10^{-3} = \frac{x^2}{(1-2x)^2}$
C	-2x	+x	+x	$x = 0.043$
E	1-2x	x	x	
	.914	.043	.043	

Add 0.5 atm of HI(g)

→ Rxn will shift right

$$K = \frac{(0.043)(0.043)}{(0.914)^2}$$

↑  
0.5

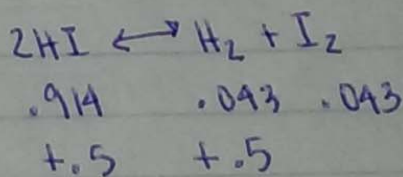
Add 0.5 atm of HI(g) and 0.5 atm of  $\text{H}_2(g)$

→ Rxn will shift left

$$Q = \frac{(0.543)(0.043)}{(1.414)^2}$$

$$Q = 1.11 \times 10^{-2}$$

$$K = 2.2 \times 10^{-3}$$



\* value of K depends on Temperature

↑ Temp = ↓ K