

Poll → What is change for H₂O?

R	$2C_2H_6(g) + 7O_2(g) \rightleftharpoons 4CO_2(g) + 6H_2O(g)$			
I	1.0	1.4	1.8	0
C	-2x	-7x	+4x	+6x
E	1.0-2x	1.4-7x	1.8+4x	0+6x



you have 5 mol N₂, 5 mol H₂ & 10 mol NH₃ in a 5L container?

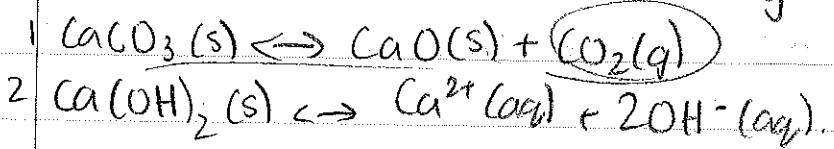
- A. RXN will go to products
- B. RXN will go to reactants
- C. RXN will go to equilibrium.

$$\frac{[NH_3]^2}{[N_2][H_2]^3}$$

$[N_2] = \frac{5 \text{ mol}}{5 \text{ L}} = 1 \text{ M}$ 2.55
 $[H_2] = \frac{5}{5} = 1 \text{ M}$ $Q < K$

$Q > K \rightarrow$ left
 $Q < K \rightarrow$ right

1. Write the equilibrium constant for following.



~~$\frac{[CaO(s)][CO_2]}{[CaCO_3]}$~~ $\frac{[Ca][OH]^2}{[Ca(OH)_2]}$

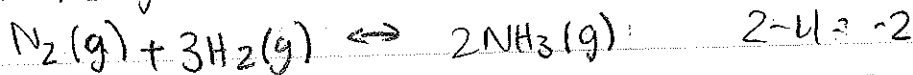
$K = P_{CO_2}$

$K = [Ca^{2+}][OH^-]^2$

Never express aq in pressure.

express in molar concentration.

Calculate K_c given K_p for



A) $K_c = K_p$

B) $K_c = RTK_p$

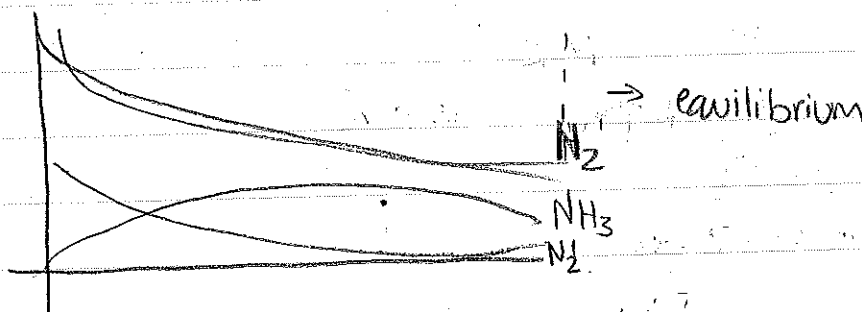
C) $K_c = K_p^{-2}$

D) $K_c = K_p (RT)^{+2}$

$$K_p = \frac{(RT)^{\Delta n} K_c}{(RT)^{-2}} \quad \boxed{K_p (RT)^2 = K_c}$$

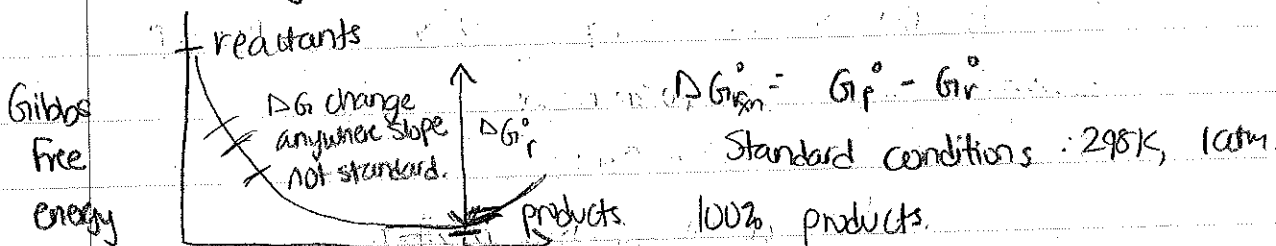
$\Delta n = n_{\text{gas final}} - n_{\text{gas initial}}$

• Which is lower in Free energy?



free energy is lower at end because we achieved equilibrium.
 Concentrations fixed at end. Rxn goes toward lower free energy spontaneously.

Free energy and Equilibrium



reaction path $\Delta G = 0$. Concentration = 1M
 • Minimum free energy = equilibrium condition.

• Pure products are lower in free energy.

$$\Delta G = \overset{\substack{\uparrow \\ \text{standard}}}{\Delta G^\circ} + RT \ln Q$$

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

$T = 298\text{K}$ $R = 8.314\text{ J/mol}\cdot\text{K}$

con 1M $T = \text{absolute T.}$

$P = 1\text{atm.}$

$$\Delta G_{\text{rxn}} = \Delta G_{\text{rxn}}^{\circ} + RT \ln Q$$

@ equilibrium $\Delta G_{\text{rxn}} = 0$

$$Q = K$$

$$0 = \Delta G_{\text{rxn}}^{\circ} + RT \ln K$$

$$\Delta G_{\text{rxn}}^{\circ} = -RT \ln K \quad \text{memorize}$$

K depends on $\Delta_r G^{\circ}$

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

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

Pol.

$$\Delta_r H^{\circ} = 10\text{kJ mol}^{-1} \quad \Delta_r S^{\circ} = 20\text{ J}\cdot\text{K}^{-1}\text{ mol}^{-1}$$

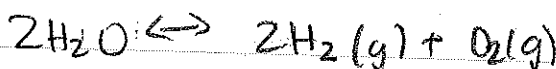
Assuming $\Delta_r H^{\circ}$ & $\Delta_r S^{\circ}$ don't change with temp.
does this reaction favor products or reactants?

$$\Delta_r G^{\circ} = 10 - T(20)$$

$$10000\text{J} - 8000 + 2000\text{J} \quad \Delta_r G^{\circ} > 0$$

reactant favored. \rightarrow nonspontaneous.

Pol.



What is the K for this reaction @ 298K?

$$\frac{[\text{H}_2]^2 [\text{O}_2]}{[\text{H}_2\text{O}]^2}$$

Water is way more stable.

expression for $K = \frac{\text{Products}}{\text{Reactants}}$

(A)

extremely small

Lots more reactants $\Delta_r G^{\circ} > 0$

(B)

extremely big

Lots more products $\Delta_r G^{\circ} < 0$

c. approximately one $K=1$ same amount



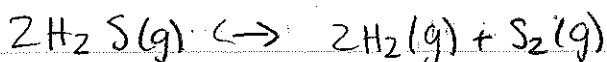
What is K for this reaction @ 298K given that $\Delta_r G^\circ = +113.4 \text{ kJ mol}^{-1}$

$$\Delta_r G^\circ = -RT \ln K \quad T = 298\text{K}$$

$$e^{\left(\frac{+113.4 \text{ kJ}}{-8.314 \cdot 298}\right) - \frac{(8.314)(298\text{K})}{\text{J/mol}\cdot\text{K}} \ln K}$$

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

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



You find the partial pressure @ 313K

$$\text{H}_2 = 1 \text{ atm} \quad \text{S}_2 = 1 \text{ atm} \quad \text{H}_2\text{S} = 2 \text{ atm}$$

How will this reaction proceed?

need to calculate K & Q .

$$+41 \text{ kJ} = -RT \ln K$$

$$-(8.314)(313\text{K}) \ln K = -41000 \quad Q = \frac{[\text{H}_2]^2 [\text{S}_2]}{[\text{H}_2\text{S}]^2}$$

$$\frac{41}{-(8.314)(313)} = \ln K \quad K = 1.437 \times 10^{-7}$$

$$Q = \frac{(1)^2 (1)}{4} = 0.25$$

$$Q > K \text{ has too much products.}$$

Moves towards reactants

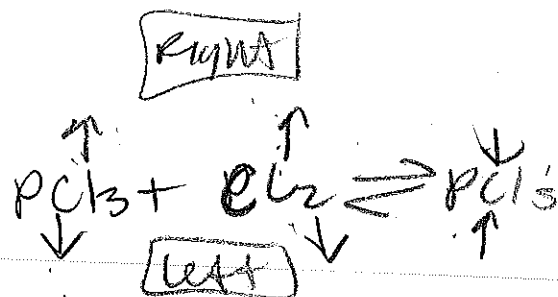
Ex. $K = 2.2 \times 10^{-3}$ for this reaction (at some T).



R	2HI	→	H ₂	+	I ₂		$K = \frac{P_{\text{H}_2} P_{\text{I}_2}}{P_{\text{HI}}^2} = \frac{[x][x]}{(1-2x)^2}$
I	1	→	∅	+	∅		

C	-2x	→	+x	+	+x		$2.2 \times 10^{-3} = \sqrt{\frac{x^2}{(1-2x)^2}}$
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E	1-2x	→	x	+	x		$x = 0.043$
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Consider adding .94 atm of HI (g). (increase reactants)

So @ equilibrium you add more reactants

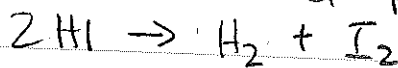
So you shift right.

(C)

Shift right

$$Q = \frac{P_{\text{H}_2} P_{\text{I}_2}}{(P_{\text{HI}})^2} = \frac{(0.043)(0.043)}{(0.914 + 0.5)^2}$$

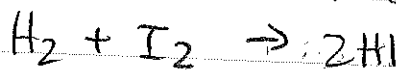
$$Q < K$$



equilibrium

$$0.914 \qquad 0.043 \quad 0.043$$

add 0.5 more HI (g) and 0.5 atm ^{H₂} (g)



↑

↑

$$Q = \frac{P_{\text{H}_2} P_{\text{I}_2}}{(P_{\text{HI}})^2} = \frac{(0.043 + 0.5)(0.043)}{(0.914 + 0.5)^2}$$

$$Q = .01167$$

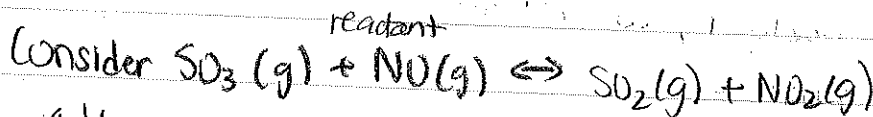
$$Q > 2.2 \times 10^{-3}$$

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

Q > K shift left

Equilibrium response to change:

Le Chatelier's Principle - when a stress is applied to a system in dynamic equilibrium, the equilibrium tends to adjust to minimize the effect of the stress.



add reactant shift right

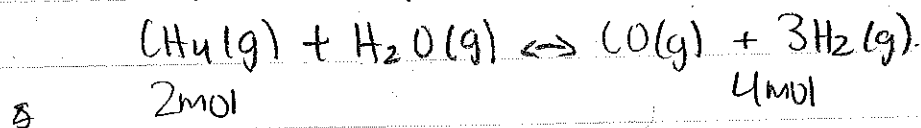
remove product shift right

adding product shift left

If you compress minimize the resulting ↑ in pressure. either left or right.

- Expand a container \rightarrow lower partial pressure to achieve equilibrium
Shift to side that has more gas moles.

\rightarrow Predict the effect of compression of



Shift to side that has less moles. So shift left.

• T & K

500 90 $T \uparrow, K \downarrow$

600 3 K is dependent on T.

700 0.3

800 0.01

What is the relationship here.

$\uparrow T$, goes from product favored to reactant favored
Shift is left.



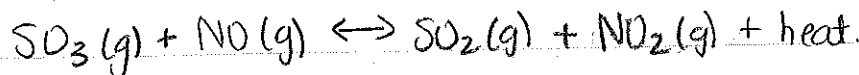
- exothermic \rightarrow heat is given off. as you $\uparrow T$, shift left.

if you add more product reaction shift back left.

- endothermic \rightarrow the value of K gets bigger.

\checkmark heat reactant, so shift right. as you $\uparrow T$, shift right.

- Consider equilibrium



① $\uparrow T$, shift left.

② \downarrow Volume, since # of mol = both sides so no change.

③ addition of $\text{NO}_2 \rightarrow$ shift left.

④ removal of $\text{SO}_2 \rightarrow$ shift right

⑤

addition of NO \rightarrow shift right