

Equilibrium Key

1. Answer the following three questions for the reaction of HF gas decomposing into hydrogen gas and fluorine gas at 78.5 °C.

a. Write out the balanced reaction and the K_c and K_p expressions.



$$K_c = \frac{[\text{H}_2][\text{F}_2]}{[\text{HF}]^2}$$

$$K_p = \frac{P_{\text{H}_2} P_{\text{F}_2}}{P_{\text{HF}}^2}$$

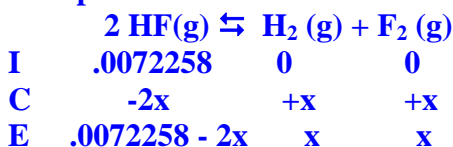
b. Given $K_p = 4.25 \times 10^{-4}$ calculate K_c .

$$(4.25 \times 10^{-4}) = K_c [(0.08206)(351.5\text{K})]^0 \text{ so } 4.25 \times 10^{-4} = K_c \text{ (anything raised to 0 is equal to 1)}$$

c. If I begin the reaction with 0.224 g of pure hydrogen fluoride in a 1550 mL closed flask, calculate all the equilibrium concentrations for each species in the reaction in units of moles/L.

$$0.224 \text{ g HF} \left(\frac{1 \text{ mol}}{20.0 \text{ g}} \right) \left(\frac{1}{1.550 \text{ L}} \right) = 7.2258 \times 10^{-3} \text{ M}$$

Set up ICE table



$$\text{Thus } 4.25 \times 10^{-4} = x^2 / (0.0072258 - 2x)^2$$

take the square root of both sides, no quadratic necessary

$$0.020616 = x / (0.0072258 - 2x)$$

collect terms

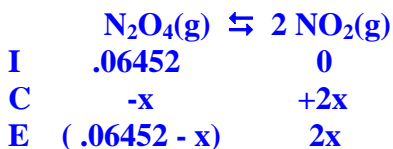
$$1.4896 \times 10^{-4} - 0.041232x = 1x$$

$$1.4896 \times 10^{-4} = 1.041232x$$

$$x = [\text{H}_2] = [\text{F}_2] = 1.43 \times 10^{-4} \text{ M} \text{ and } [\text{HF}] = 6.94 \times 10^{-3} \text{ M}$$

2. A 0.0240 mol sample of $\text{N}_2\text{O}_4(\text{g})$ is allowed to reach equilibrium with $\text{NO}_2(\text{g})$ in a 0.372 L flask at 25.0°C. Calculate the concentration of $\text{N}_2\text{O}_4(\text{g})$ at equilibrium. $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g}) \quad K_c = 4.61 \times 10^{-3}$

$$\text{initial molarity } \text{N}_2\text{O}_4(\text{g}) = \left(\frac{.0240 \text{ mol}}{.372 \text{ L}} \right) = .06452 \text{ M}$$



$$4.61 \times 10^{-3} = (2x)^2 / (0.06452 - x)$$

$$4x^2 = -4.61 \times 10^{-3}x + 2.974 \times 10^{-4}$$

$$4x^2 + 4.61 \times 10^{-3}x - 2.974 \times 10^{-4} = 0$$

quadratic formula with $a = 4$, $b = +4.61 \times 10^{-3}$ and $c = -2.974 \times 10^{-4}$
 $x = 8.065 \times 10^{-3}$ (the other solution is negative and can't have negative concentration)
 thus $[N_2O_4] = 0.0565M$

3. Consider the reaction $N_2O_4(g) \rightleftharpoons 2 NO_2(g)$, where $K_c = 5.7$ at $250^\circ C$. If the initial concentration of N_2O_4 is $0.350 M$ and that of NO_2 is $1.20 M$ in a flask at $250^\circ C$, will the reaction go forwards or backwards to reach equilibrium? (Must show work for credit)

$$Q = \left(\frac{(1.20)^2}{0.350} \right) = 4.11 \text{ which is less than } K \text{ so reaction is going forwards till } \rightleftharpoons \text{ reached}$$

4. A quantity of 2.40 moles of pure SO_2Cl_2 gas was placed in an $8.00 L$ sealed flask. At $500 K$, after equilibrium is established, there are 1.60 moles of the product gas SO_2 present. Calculate K_c for the reaction.



$$2.40 \text{ mol} / 8.00 \text{ L} = .300M \text{ initial } SO_2Cl_2(g)$$

$$1.60 \text{ mol} / 8.00L = .200 M SO_2(g) \text{ at } \rightleftharpoons$$

	$SO_2Cl_2(g)$	\rightleftharpoons	$SO_2(g)$	$+$	$Cl_2(g)$
I	.300		0		0
C	-x		+x		+x
E	(.300-x)		.200		x

$$\text{So } x \text{ must} = .200 \text{ so } K_c = (.200)^2 / .100 = .400$$

5. Consider this endothermic reaction: $CO_2(g) + C(s) \rightleftharpoons 2 CO(g)$. To make the most CO gas:
- You could increase the pressure. (true or false?) **false**
 - You could increase the volume. (true or false?) **true, more space for more moles of gas**
 - You could add more carbon monoxide gas. (true or false?) **false**
 - You could decrease the temperature. (true or false?) **false (heat is a reactant)**
 - You could add more carbon. (true or false?) **false solids don't affect K**
 - You could add a catalyst. (true or false?) **false, catalysts make rxns reach \rightleftharpoons faster**

6. Write the equilibrium constant expressions K_c and K_p and the balanced reaction for the reaction between aqueous potassium sulfate and aqueous calcium nitrate.



$$K_c = [KNO_3]^2 / [K_2SO_4] [Ca(NO_3)_2]$$

$$K_p = \text{none, there are no gases}$$

7. Calculate K_p for the formation of steam reaction if at equilibrium at $150^\circ C$ the gas pressures are 0.145 atm for hydrogen, 0.108 atm for oxygen, and 15.4 atm for steam.



$$K_p = [H_2O]^2 / [H_2]^2 [O_2] = (15.4)^2 / (.145)^2(.108) = 1.04 \times 10^5 \text{ (product favored)}$$