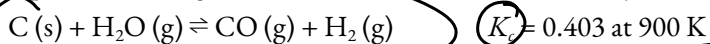


Week 1 Step-Up Session

1. A reaction used in the production of gaseous fuels from coal, which is mainly carbon, is:

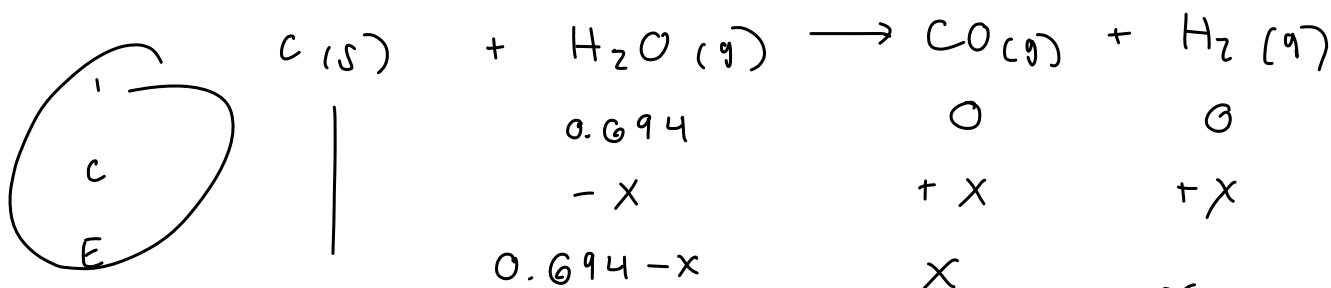


A 5.20-kg sample of graphite and 125 g of water were placed into a 10.0-L container and heated to 900 K. What are the equilibrium concentrations?

$$5.20 \times 10^3 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g}} = 433. \text{ mol C}$$

$$125 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.016 \text{ g}} = 6.94 \text{ mol H}_2\text{O}$$

$$\text{conc: } \frac{n}{V} = \frac{6.94 \text{ mol H}_2\text{O}}{10.0 \text{ L}} = 0.694 \text{ mol} \cdot \text{L}^{-1}$$



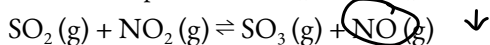
$$K_c = \frac{[\text{CO}][\text{H}_2]}{[\text{H}_2\text{O}]} = \frac{(x)(x)}{0.694 - x} = 0.403$$

$$x^2 = 0.403 (0.694 - x)$$

$$x = 0.364 \text{ M} = [\text{CO}] = [\text{H}_2\text{O}]$$

$$x = +0.364, -0.766 \quad [\text{H}_2\text{O}] = 0.694 - 0.364 = 0.330 \text{ M}$$

2. The two air pollutants SO_2 and NO_2 can react in the atmosphere as follows:



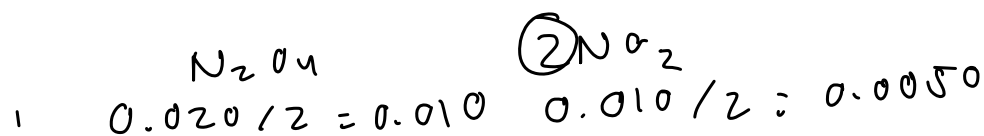
Predict the effect of the following changes to the amount of NO when the reaction above has come to equilibrium in a stainless steel bulb equipped with entrants for chemicals.

- The amount of NO_2 is increased. \uparrow
- The SO_3 is removed by condensation. \uparrow
- The pressure is tripled by pumping in helium. \uparrow

3. At 25°C, $K_c = 1.93$ for the reaction $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$.

- a. If 0.020 mol of N_2O_4 and 0.010 mol of NO_2 are placed in a 2.00-L reaction vessel and the reaction is allowed to reach equilibrium, what are the equilibrium concentrations of N_2O_4 and NO_2 ?

$$Q = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{[0.010/2]^2}{[0.020/2]} = 2.5 \times 10^{-3}$$



$$K_c = 1.93 = \frac{(0.0050 + 2x)^2}{(0.010 - x)}$$

$$x = 9.69 \times 10^{-3} \text{ mol.L}^{-1}$$

$$[\text{N}_2\text{O}_4] = 3.1 \times 10^{-4} \text{ M}$$

$$[\text{NO}_2] = 2.44 \times 10^{-2} \text{ M}$$

- b. If additional NO_2 is added to the flask how will this change affect the concentration of N_2O_4 ?



4. The equilibrium constant $K_c = 0.56$ for the reaction $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$ at $250.^\circ\text{C}$. On analysis, 1.50 mol PCl_5 , 3.00 mol PCl_3 , and 0.500 mol Cl_2 were found to be present in a 0.500 L reaction vessel at $250.^\circ\text{C}$.

Is the reaction at equilibrium? If not, in which direction does it tend to proceed?

$$[\text{PCl}_5] = \frac{1.50 \text{ mol}}{0.500 \text{ L}} = 3.00 \text{ M} \quad [\text{PCl}_3] = \frac{3.00 \text{ mol}}{0.500 \text{ L}} = 6.00 \text{ M}$$

$$[\text{Cl}_2] = \frac{0.500 \text{ mol}}{0.500 \text{ L}} = 1.00 \text{ M}$$

$$Q = \frac{[\text{PCl}_5]}{[\text{PCl}_3][\text{Cl}_2]} = \frac{(3.00)}{(6.00)(1.00)} = 0.500$$

$Q \neq K$ not at equilibrium

$Q < K$ rxn proceeds to form products

5. The following reaction is at equilibrium: $\text{NH}_3(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{N}_2(\text{g})$ 8

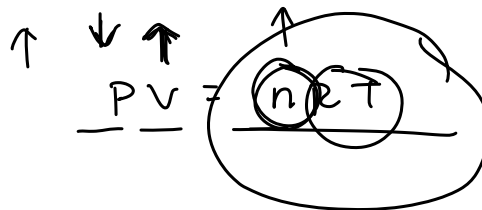


How will the equilibrium shift if:

- a. The volume is increased.

$V \uparrow$ shift right

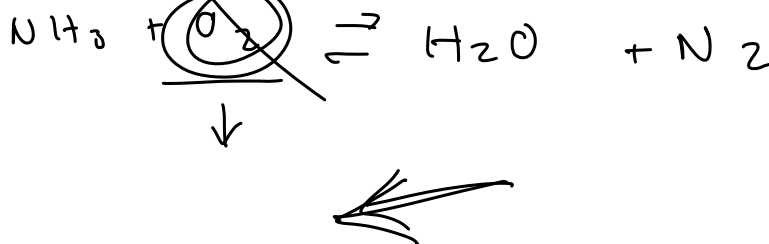
$P \downarrow$ \uparrow moles gas



- b. Four moles of Helium gas is added.

~~Q~~

- c. A lit match is placed inside the container.



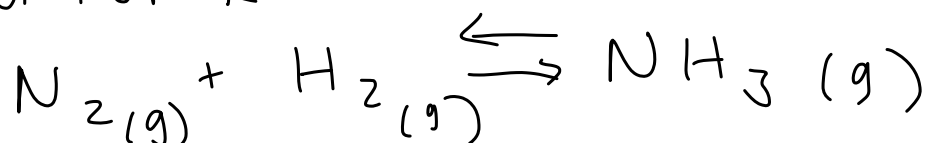
Stuff to Know

equilibrium constant: an expression that describes the relationship between the amount of products and reactants at equilibrium

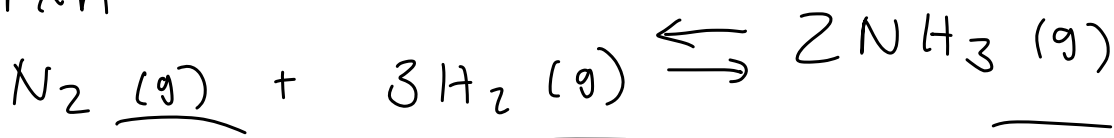
@ equilibrium: FORWARD RATE = REVERSE



SOLVING FOR K



1) Balance rxn



$$K = \frac{[\text{products}]}{[\text{reactants}]}$$

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

$$K_{rev} = \frac{1}{K_{forward}} = \frac{[N_2][H_2]^3}{[NH_3]^2}$$

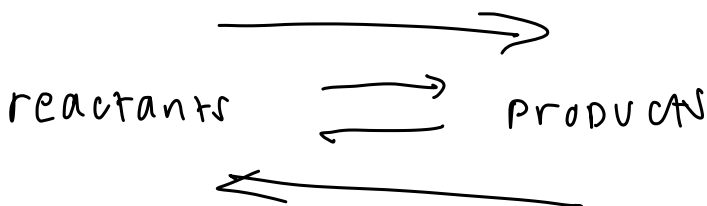
What does K tell you?

Stability

$K > 10^3$
————— products are more stable
forward rxn is favored

$K = 1$ neither forward or reverse is
more stable

$K < 10^{-3}$ reactants are more stable
reverse reaction is favored



K concentrations

$$\frac{[\text{product}]^{\text{coefficient}}}{[\text{reactant}]^{\text{coefficient}}}$$

$$K_p = \frac{(P_{\text{products}})^{\text{coefficients}}}{(P_{\text{reactants}})^{\text{coefficients}}}$$

$$P = \frac{nRT}{V}$$

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

n = moles

T = temperature (K)

V = volume (L)

R = universal gas constant

What doesn't go in the equilibrium constant K ?

1) PURE SOLIDS — NO CONC., NOT POSSIBLE

2) PURE LIQUIDS — so much, any change insignificant

↑
 H_2O

Reaction quotient (Q) = tells the product:reactant ratio at any point in rxn

→ tell you if it's at equilibrium

$Q < K$: forward rxn is favored

$Q > K$: reverse rxn is favored

$Q = K$: equilibrium

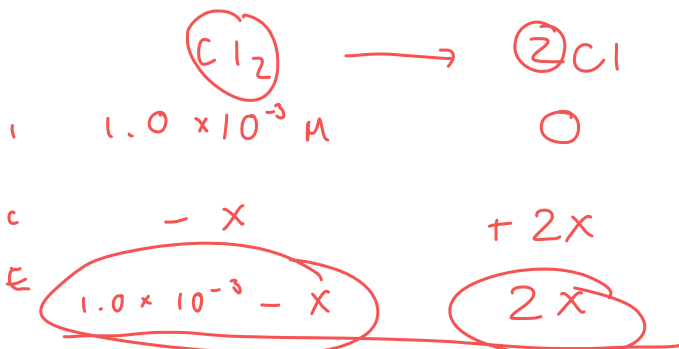
In an experiment, 2.0 mmol Cl_2 (g) was sealed into a rxn vessel of volume 2.0 L and heated to 1000 K. calculate K.



$$K = 1.2 \times 10^{-7} @ 1000 \text{ K}$$

$$K = \frac{[\text{Cl}]^2}{[\text{Cl}_2]}$$

$$2.0 \times 10^{-3} \text{ mol} / 2.0 \text{ L} =$$



$$K = 1.2 \times 10^{-7} = \frac{[\text{Cl}]^2}{[\text{Cl}_2]} = \frac{(2x)^2}{(1.00 \times 10^{-3} - x)}$$

$$1.2 \times 10^{-7} = \frac{(2x)^2}{(1.00 \times 10^{-3} - x)}$$

$$1.2 \times 10^{-7} (1.00 \times 10^{-3} - x) = (2x)^2$$

$$1.2 \times 10^{-10} - (1.2 \times 10^{-7})x = 4x^2$$

$$4x^2 + (1.2 \times 10^{-7})x - (1.2 \times 10^{-10}) = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-1.2 \times 10^{-7} \pm \sqrt{(1.2 \times 10^{-7})^2 - 4(4)(1.2 \times 10^{-10})}}{2(4)}$$

$$= 5.5 \times 10^{-6}$$