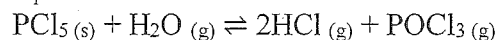


Chemistry 12 – Dynamic Equilibrium  
Learning Goal B5  
Equilibrium Calculations: Problem Set E

Solve each problem and show all of your work.

1. At equilibrium, a 5.0L flask contains:  
0.75 mol of  $\text{PCl}_5$       0.50 mol of  $\text{H}_2\text{O}$       7.50 mol of  $\text{HCl}$       5.00 mol of  $\text{POCl}_3$

Calculate the  $K_{\text{eq}}$  for the reaction:



$$K_{\text{eq}} = \frac{[\text{HCl}]^2 [\text{POCl}_3]}{[\text{H}_2\text{O}]}$$

$$= \frac{\left(\frac{7.50 \text{ mol}}{5.0 \text{ L}}\right)^2 \left(\frac{5.00 \text{ mol}}{5.0 \text{ L}}\right)}{\left(\frac{0.50 \text{ mol}}{5.0 \text{ L}}\right)} = \boxed{23}$$

or 22.      rounding rules

2.  $K_{\text{eq}} = 798$  for the reaction at a particular temperature:  $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$ .

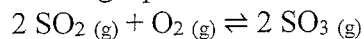
In a particular mixture at equilibrium,  $[\text{SO}_2] = 4.20 \text{ M}$  and  $[\text{SO}_3] = 11.0 \text{ M}$ . Calculate the equilibrium  $[\text{O}_2]$  in this mixture.

$$K_{\text{eq}} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

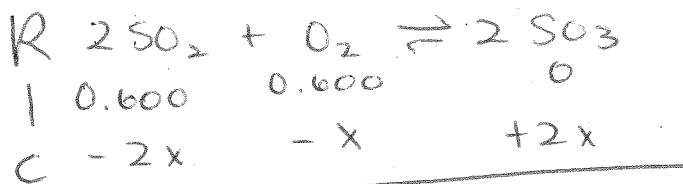
$$\begin{aligned} [\text{O}_2] &= \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 K_{\text{eq}}} \\ &= \frac{(11.0)^2}{(4.20)^2 (798)} \\ &= \boxed{8.60 \times 10^{-3}} \end{aligned}$$

(Round to even)

3. Consider the following equilibrium:



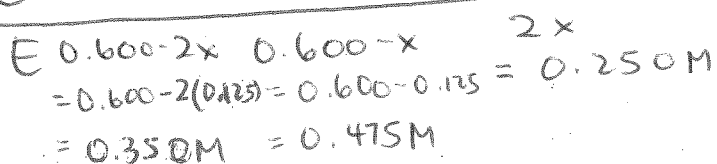
When 0.600 moles of  $\text{SO}_2$  and 0.600 moles of  $\text{O}_2$  are placed into a 1.00 L container and allowed to reach equilibrium, the equilibrium  $[\text{SO}_3]$  is to be 0.250 M. Calculate  $K_{\text{eq}}$ .



$$2x = 0.250 \text{ M}$$

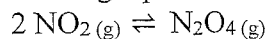
$$x = \frac{0.250 \text{ M}}{2}$$

$$x = 0.125 \text{ M}$$

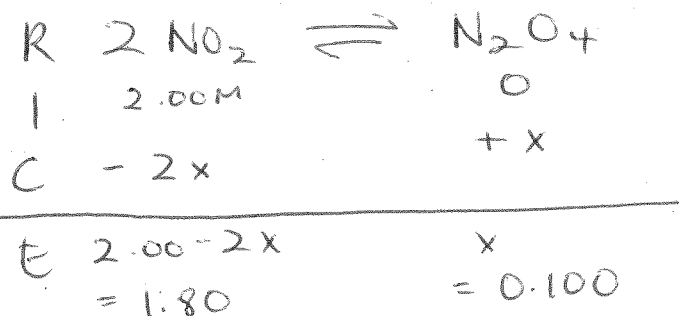


$$K_{\text{eq}} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{(0.250)^2}{(0.350)^2 (0.475)} = \boxed{1.07}$$

4. Consider the following equilibrium:



2.00 moles of  $\text{NO}_2$  are placed in a 1.00 L flask and allowed to react. After equilibrium is established, 1.80 moles of  $\text{NO}_2$  are present. Calculate  $K_{\text{eq}}$ .



$$2.00 - 2x = 1.80$$

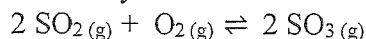
$$x = 0.100$$

$$K_{\text{eq}} = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2}$$

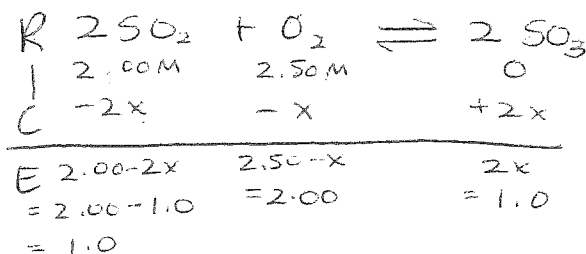
$$= \frac{(0.100)}{(1.80)^2}$$

$$= \boxed{0.0309}$$

5. Consider the chemical system below:



4.00 moles of  $\text{SO}_2$  and 5.00 moles  $\text{O}_2$  are placed in a 2.00 L container at  $200^\circ\text{C}$  and allowed to reach equilibrium. If the equilibrium  $[\text{O}_2]$  is 2.00 M, calculate the value of  $K_{\text{eq}}$ .



$$2.50 - x = 2.00$$

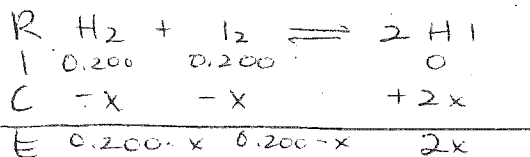
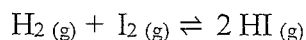
$$x = 0.50$$

$$K_{\text{eq}} = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

$$= \frac{(1.0)^2}{(1.0)^2 (2.00)}$$

$$= \boxed{0.50}$$

6. If the initial  $[\text{H}_2] = 0.200 \text{ M}$ ,  $[\text{I}_2] = 0.200 \text{ M}$  and  $K_{\text{eq}} = 55.6$  (at  $250^\circ\text{C}$ ) calculate the equilibrium concentrations of all molecules in the following chemical system.



$$K_{\text{eq}} = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = 55.6$$

$$\sqrt{\frac{(2x)^2}{(0.200-x)^2}} = \sqrt{55.6}$$

$$2x = \sqrt{55.6} (0.200 - x)$$

$$2x + 7.456x = 1.4913$$

$$x = 0.158$$

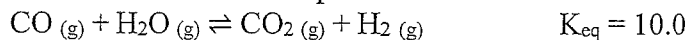
$$[\text{H}_2] = [\text{I}_2] = 0.200 - x$$

$$= 0.200 - 0.158$$

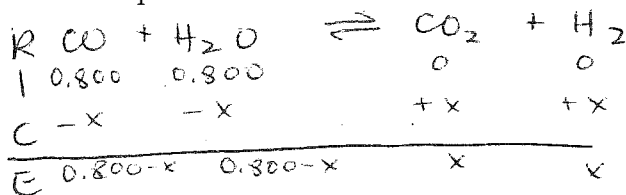
$$= 0.042 \text{ M}$$

$$[\text{HI}] = 2(0.158) = 0.316 \text{ M}$$

7. 1.60 moles  $\text{CO}$  and 1.60 moles  $\text{H}_2\text{O}$  are placed in a 2.00 L container at  $690^\circ\text{C}$ .



Calculate all equilibrium concentrations.



$$K_{\text{eq}} = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]} = 10.0$$

$$K_{\text{eq}} = \frac{(x)(x)}{(0.800-x)(0.800-x)} = 10.0$$

$$\sqrt{\frac{x^2}{(0.800-x)^2}} = \sqrt{10.0}$$

$$x = 25298 - 3.162x$$

$$\frac{4.162x}{4.162} = \frac{25298}{4.162}$$

$$x = 0.607 \text{ M}$$

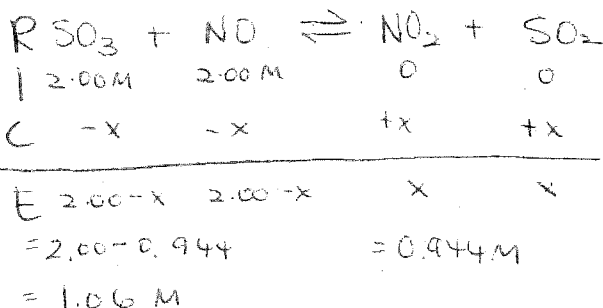
$$[\text{CO}_2] = [\text{H}_2] = 0.607 \text{ M}$$

$$[\text{CO}] = [\text{H}_2\text{O}] = 0.800 - 0.607$$

$$= 0.192 \text{ M}$$



If 4.00 moles of each reactant are placed in a 2.00L container, calculate all equilibrium concentrations at  $100^\circ\text{C}$  for the chemical system shown above.



$$\begin{aligned}
 [\text{SO}_3] &= [\text{NO}] = 1.06\text{M} \\
 [\text{NO}_2] &= [\text{SO}_2] = 0.944\text{M}
 \end{aligned}$$

$$K_{\text{eq}} = \frac{[\text{NO}_2][\text{SO}_2]}{[\text{SO}_3][\text{NO}]} = 0.800$$

$$\frac{(x)(x)}{(2.00-x)(2.00-x)} = 0.800$$

$$\sqrt{\frac{x^2}{(2.00-x)^2}} = \sqrt{0.800}$$

$$x = \sqrt{0.800} (2.00-x)$$

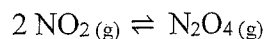
$$x = 1.7889 - 0.8944x$$

$$1.8944x = 1.7889$$

$$\frac{1.8944x}{1.8944} = \frac{1.7889}{1.8944}$$

$$x = 0.944\text{M}$$

\*9. Consider the following equilibrium system:



Two sets of equilibrium data are listed for the same temperature.

Container 1	2.00 L	0.12 moles $\text{NO}_2$	0.16 moles $\text{N}_2\text{O}_4$
Container 2	5.00 L	0.26 moles $\text{NO}_2$	? moles $\text{N}_2\text{O}_4$

Determine the number of moles  $\text{N}_2\text{O}_4$  in the second container.

$$\begin{aligned}
 K_{\text{eq}} &= \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2} = \frac{(0.16\text{mol}/2.00\text{L})}{(0.12\text{mol}/2.00\text{L})^2} \\
 &= 22
 \end{aligned}$$

Data from container 1

Same temperature

$\therefore$  same  $K_{\text{eq}}$  value

$$22 = \frac{(x\text{mol}/5.00\text{L})}{(0.26\text{mol}/5.00\text{L})^2}$$

$$22 = \frac{(x\text{mol}/5.00\text{L})}{2.704 \times 10^{-3}\text{M}}$$

$$0.0595\text{M} = x\text{mol}/5.00\text{L}$$

$$0.30\text{mol} = \text{mol } \text{N}_2\text{O}_4$$