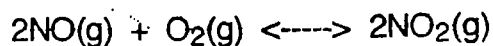


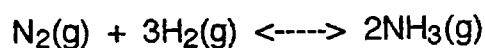
In solving the following problems • write the equilibrium expression  
 • convert moles and litres to concentration  
 • omit the units for  $K_{eq}$  but write them for all other quantities

1. A closed container is found to have 0.45 M NO(g), 0.78 M O<sub>2</sub>(g), and 0.26 M NO<sub>2</sub>(g). Determine the equilibrium constant for the following equilibrium:



$$K_{eq} = \frac{[\text{NO}_2]^2}{[\text{NO}]^2 [\text{O}_2]} \quad K_{eq} = \frac{(0.26)^2}{(0.45)^2 (0.78)} = 0.43$$

2. A 1.00 L bulb holds 1.22 mol NH<sub>3</sub>(g), 2.46 mol H<sub>2</sub>(g), and 1.80 mol N<sub>2</sub>(g). Calculate the  $K_{eq}$  for the following equilibrium:



$$K_{eq} = \frac{[\text{NH}_3]^2}{[\text{N}_2] [\text{H}_2]^3}$$

$$K_{eq} = \frac{(1.22)^2}{(1.80)(2.46)^3} = 0.0555$$

$$[\text{H}_2] = \frac{2.46 \text{ mol}}{1.00 \text{ L}} = 2.46 \text{ M}$$

$$[\text{NH}_3] = \frac{1.22 \text{ mol}}{1.00 \text{ L}} = 1.22 \text{ M}$$

$$[\text{N}_2] = \frac{1.80 \text{ mol}}{1.00 \text{ L}} = 1.80 \text{ M}$$

3. A 2.50 L container holds 1.65 moles PCl<sub>5</sub>(g), 0.575 moles PCl<sub>3</sub>(g), and 1.55 moles Cl<sub>2</sub>(g). Calculate the  $K_{eq}$  for the following equilibrium:



$$K_{eq} = \frac{[\text{PCl}_3] [\text{Cl}_2]}{[\text{PCl}_5]}$$

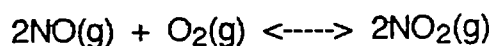
$$K_{eq} = \frac{(0.230)(0.620)}{(0.660)} = 0.216$$

$$[\text{PCl}_5] = \frac{1.65 \text{ mol}}{2.50 \text{ L}} = 0.660 \text{ M}$$

$$[\text{PCl}_3] = \frac{0.575 \text{ mol}}{2.50 \text{ L}} = 0.230 \text{ M}$$

$$[\text{Cl}_2] = \frac{1.55 \text{ mol}}{2.50 \text{ L}} = 0.620 \text{ M}$$

4. A 5.00 L container is found to hold 0.340 moles NO(g), 0.950 moles O<sub>2</sub>(g), and 0.505 moles NO<sub>2</sub>(g). Determine the equilibrium constant for the following equilibrium:



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

$$K_{eq} = \frac{(0.101)^2}{(0.0680)^2 (0.190)} = 11.6$$

$$[\text{NO}_2] = \frac{0.505 \text{ mol}}{5.00 \text{ L}} = 0.101$$

$$[\text{NO}] = \frac{0.340 \text{ mol}}{5.00 \text{ L}} = 0.0680$$

$$[\text{O}_2] = \frac{0.950 \text{ mol}}{5.00 \text{ L}} = 0.190$$

10. A 1.00 L reaction vessel has 0.654 moles of  $\text{NOCl(g)}$  placed in it. After equilibrium is achieved according to the equation  $2\text{NOCl(g)} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2\text{(g)}$ , the concentration of  $\text{Cl}_2\text{(g)}$  is found to be 0.168 M. Determine the  $K_{\text{eq}}$  for this reaction.

	$[\text{NOCl}]$	$[\text{NO}]$	$[\text{Cl}_2]$
I	0.654	0.00	0.00
C	-0.336	+0.336	+0.168
E	0.318	0.336	0.168

2 : 2 : 1

$$K_{\text{eq}} = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2}$$

$$[\text{NOCl}] = \frac{0.654 \text{ mol}}{1.00 \text{ L}} = 0.654 \text{ M}$$

$$K_{\text{eq}} = \frac{(0.336)^2 (0.168)}{(0.318)^2} = 0.128$$

11. When 1.42 mol  $\text{N}_2\text{(g)}$  and 2.86 mol  $\text{H}_2\text{(g)}$  are introduced to a 1.00 L container and allowed to reach equilibrium, 0.98 mol  $\text{N}_2\text{(g)}$  are found. What is the  $K_{\text{eq}}$  for the equilibrium  $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$  ?

	$[\text{N}_2]$	$[\text{H}_2]$	$[\text{NH}_3]$
I	1.42	2.86	0.00
C	-0.44	-1.32	+0.98
E	0.98	1.54	0.98

1 : 3 : 2

$$K_{\text{eq}} = \frac{[\text{NH}_3]^2}{[\text{N}_2] [\text{H}_2]^3}$$

$$K_{\text{eq}} = \frac{(0.98)^2}{(0.98)(1.54)^3} = 0.22$$

12. A bulb has 0.345 M  $\text{CO(g)}$  and 0.500 M  $\text{H}_2\text{O(g)}$  placed in it. After 25 min, equilibrium has been reached according to the equation  $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$ . Analysis shows the  $[\text{CO}_2\text{(g)}]$  is now 0.122 M. Calculate  $K_{\text{eq}}$  for this equilibrium.

	$[\text{CO}]$	$[\text{H}_2\text{O}]$	$[\text{CO}_2]$	$[\text{H}_2]$
I	0.345	0.500	0.00	0.00
C	-0.122	-0.122	+0.122	+0.122
E	0.223	0.378	0.122	0.122

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

$$K_{\text{eq}} = \frac{(0.122)(0.122)}{(0.223)(0.378)} = 0.177$$

13. A 4.00 L container was initially filled with 2.44 moles of  $\text{O}_2\text{(g)}$  and 2.68 moles of  $\text{SO}_2\text{(g)}$ . At equilibrium, 1.32 moles of  $\text{SO}_3\text{(g)}$  are found. Determine the  $K_{\text{eq}}$  for the equilibrium  $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)}$ .

	$[\text{SO}_2]$	$[\text{O}_2]$	$[\text{SO}_3]$
I	0.670	0.610	0.00
C	-0.330	-0.165	+0.330
E	0.340	0.445	0.330

2 : 1 : 2

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

$$K_{\text{eq}} = \frac{(0.330)^2}{(0.340)^2 (0.445)} = 2.12$$

$$[\text{O}_2] = \frac{2.44 \text{ mol}}{4.00 \text{ L}} = 0.610 \text{ M}$$

$$[\text{SO}_2] = \frac{2.68 \text{ mol}}{4.00 \text{ L}} = 0.670 \text{ M}$$

$$[\text{SO}_3] = \frac{1.32 \text{ mol}}{4.00 \text{ L}} = 0.330 \text{ M}$$

18. The  $K_{eq}$  for the equilibrium  $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$  is known to be 12.6 at a certain temperature. If, at this temperature, 2.46 mol  $NO(g)$ , 1.23 mol  $O_2(g)$ , and 9.86 mol  $NO_2(g)$  are introduced into a 1.00 L container, which way will the reaction proceed in order to achieve equilibrium?

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2 [O_2]} \quad \text{Trial } K_{eq} = \frac{(9.86)^2 \text{ products}}{(2.46)^2 (1.23) \text{ reactants}} = 13.1 > K_{eq} (12.6)$$

This equilibrium proceeds left.

19. A 3.00 L container has 0.576 moles  $NH_3(g)$ , 0.843 moles  $H_2(g)$ , and 0.972 moles  $N_2(g)$  added to it. As it approaches equilibrium according to  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ , will the reaction proceed in the forward direction or the reverse direction? The  $K_{eq}$  for the reaction is 7.57.

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

$$\text{Trial } K_{eq} = \frac{(0.192)^2}{(0.324)(0.281)^3} = 5.13 < 7.57 K_{eq}$$

shift to right

forward

$$[NH_3] = \frac{0.576 \text{ mol}}{3.00 \text{ L}} = 0.192 \text{ M}$$

$$[H_2] = \frac{0.843 \text{ mol}}{3.00 \text{ L}} = 0.281 \text{ M}$$

$$[N_2] = \frac{0.972 \text{ mol}}{3.00 \text{ L}} = 0.324 \text{ M}$$

20. The  $K_{eq}$  for the reaction  $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$  is 1.24. If the initial conditions are:  $[CO(g)] = 0.678 \text{ M}$ ,  $[H_2O(g)] = 0.456 \text{ M}$ ,  $[CO_2(g)] = 0.961 \text{ M}$ , and  $[H_2(g)] = 0.543 \text{ M}$ , will the  $[CO(g)]$  increase or decrease as the reaction proceeds toward equilibrium?

$$K_{eq} = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

$$\text{Trial } K_{eq} = \frac{(0.961)(0.543)}{(0.678)(0.456)} = 1.69 > 1.24 K_{eq}$$

shifts left  $\therefore [CO]$  increases

21. A 1.00 L bulb is injected with 0.87 mol  $SO_2(g)$ , 0.12 mol  $O_2(g)$ , and 0.59 mol  $SO_3(g)$ . As the reaction  $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$  proceeds towards equilibrium, will the  $[O_2(g)]$  increase or decrease? The  $K_{eq}$  for the equilibrium is 0.41.

$$K_{eq} = \frac{[SO_2]^2 [O_2]}{[SO_3]^2}$$

$$\text{Trial } K_{eq} = \frac{(0.87)^2 (0.12)}{(0.59)^2} = 0.26 < 0.41 K_{eq}$$

shifts right  $\therefore [O_2]$  will increase

