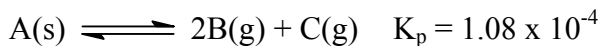


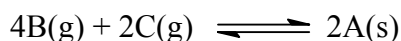
## More Equilibrium Problems

*You should be able to do these problems without a calculator.*

- 1) Solid compound A decomposes according to the endothermic reaction:

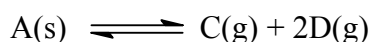


- a) If 50.0 mmol of A(s) is placed in a 6.10-L sealed, evacuated flask at 25°C, calculate the total pressure in the flask at equilibrium. **(9.0 x 10<sup>-2</sup> atm)**
- b) How many millimoles of A(s) will be left at equilibrium in the experiment described in part (a)? **(42.5)**
- c) If some A(s) is placed in a 6.10-L evacuated flask at 25°C and some C(g) added so that the partial pressure of C(g) at equilibrium is 1.00 atm, calculate the equilibrium partial pressure of B(g) in the system. **(about 1 x 10<sup>-2</sup> atm)**
- d) What is the value of K<sub>p</sub> for the equilibrium:



**(about 9 x 10<sup>7</sup>)**

- e) If the equilibrium  $\text{B(g)} \rightleftharpoons \text{D(g)}$  has equilibrium constant  $K_p = 5.0 \times 10^{-3}$ , determine the equilibrium constant for the reaction



**(about 3 x 10<sup>-9</sup>)**

- 2) The fastest growing use of methanol (CH<sub>3</sub>OH) is to make the octane enhancer methyl tert-butyl ether. Today all methanol is produced (as a gas) by the reaction of carbon monoxide and hydrogen. The value of K<sub>p</sub> for this reaction is (about) 2.0 x 10<sup>-4</sup> at 327.°C.
- a) Write the equilibrium reaction for the production of methanol.  
**(2H<sub>2</sub>(g) + CO(g)  $\rightleftharpoons$  CH<sub>3</sub>OH(g))**
- b) What is the value of K<sub>c</sub> at 327.°C? **(about 0.5)**
- c) In which direction will this reaction shift if the temperature is raised, given that the  $\Delta H^\circ_{\text{rxn}} = -90.7 \text{ kJ}$ ? Explain! **(shifts to left because heat is a product when rxn. is exothermic, try to use up "excess" heat to re-establish equilibrium.)**

d) In the industrial process, the stoichiometric ratio of CO to H<sub>2</sub> is used. If the reaction is carried out at an initial total pressure of 300. atm, what are the initial partial pressures of CO and H<sub>2</sub>? **(100. atm CO, 200. atm H<sub>2</sub>)**

3) A flask initially contains only NOBr gas. Once heated to a temperature T, 20.0 % of the original gas decomposes via the following equation to give a total pressure of 0.33 atm at equilibrium:

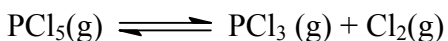


a) Determine the original pressure of NOBr in the flask. **(0.30 atm)**

b) What is the value of K<sub>p</sub> at this temperature T? **(1.9 x 10<sup>-3</sup> or 3/1600)**

c) If the value of K<sub>c</sub> at this temperature T is 3.9 x 10<sup>-5</sup>, determine the temperature T. **(600 K)**

4) For the equilibrium:



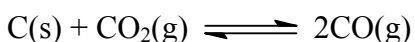
At some temperature T<sub>1</sub>, K<sub>p</sub> = 2.25. An unknown quantity of pure PCl<sub>5</sub>(g) is placed in an evacuated flask and heated to T<sub>1</sub>. When equilibrium was established, the partial pressure of PCl<sub>5</sub>(g) was found to be 0.25 atm.

a) What were the partial pressures of PCl<sub>3</sub> and Cl<sub>2</sub> at equilibrium? **(0.75 atm)**

b) Determine the original pressure of PCl<sub>5</sub> (before any reaction) and the percent dissociation of PCl<sub>5</sub> at equilibrium. **(1.00 atm, 75 %)**

c) What is the value of K<sub>c</sub> for the reaction if T<sub>1</sub> is 327°C? **(about 5 x 10<sup>-2</sup>)**

5) For the following system:



At 700.°C in a 2.00 L flask there are 0.100 moles of CO, 0.200 moles of CO<sub>2</sub>, and 0.400 moles of C at equilibrium. At 600.°C, an additional 0.0400 moles of C forms at equilibrium.

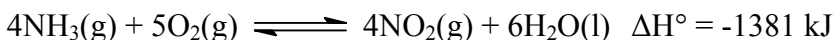
a) The process as written is: exothermic or **endothermic**

b) Determine the value of K<sub>c</sub> at 600.°C and 700.°C. **(K<sub>c</sub> = 0.0250 at 700.°C, 8.3 x 10<sup>-4</sup> at 600.°C)**

c) An additional 0.200 moles of C is added to the flask at 600.°C. What will be the effect on:

- i)  $K_c$     increase    decrease    **no effect**
- ii)  $P_{CO}$     increase    decrease    **no effect**
- iii)  $P_{CO_2}$     increase    decrease    **no effect**

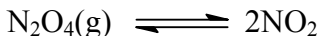
6) Consider the equilibrium:



Predict whether the equilibrium number of moles of  $NH_3$  will increase or decrease and the direction that the reaction will shift in order to establish a new equilibrium if:

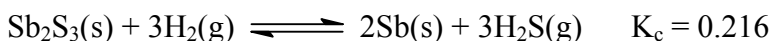
- i) the volume of the system is decreased (**↓, shifts to right**)
- ii) the temperature of the system is increased (**↑, shifts to left**)
- iii) some  $O_2$  is added to the container (**↓, shifts to right**)
- iv) some He is added to the container (**no effect**)
- v) some  $NH_3$  is added to the container (**↑, shifts to right**)
- vi) some  $H_2O$  is removed from the container (**no effect as long as some water remains**)

7) 0.50 moles of  $N_2O_4$  were introduced into a 0.25 L flask. Determine the equilibrium concentrations of  $N_2O_4$  and  $NO_2$  if  $K_c$  for the equilibrium



is  $5.0 \times 10^{-7}$ . ( $N_2O_4 = 2.0 \text{ M}$ ;  $NO_2 = 1.0 \times 10^{-3} \text{ M}$ )

8) Some antimony sulfide and 500 mmol of  $H_2$  were placed in a 500 mL flask and heated. What were the equilibrium concentrations of  $H_2$  and  $H_2S$  once equilibrium had been reached?



( $[H_2] = 0.625 \text{ M}$ ;  $[H_2S] = 0.375 \text{ M}$ )

9) 0.100 mol of  $H_2$  and 0.100 mol of HI were placed in a 1.00 L container and heated. Determine the equilibrium concentrations of all species.



( $[H_2] = [HI] = 0.100 \text{ M}$ ,  $[I_2] = 2.0 \times 10^{-11} \text{ M}$ )