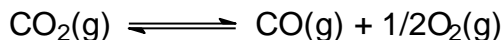


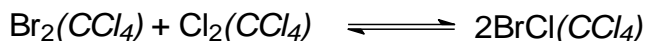
Equilibrium problems (calculator required)

1. For the equilibrium



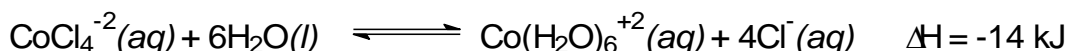
$$K_c = 1.72 \times 10^{-46} \text{ at } 25^\circ\text{C}.$$

- a) Evaluate K_P at 25°C . [**8.56 x 10⁻⁴⁶**]
b) If a flask initially containing only 1.00 bar of CO_2 is allowed to come to equilibrium, what will be the equilibrium pressure of each species?
[**$P_{\text{CO}_2} = 1 \text{ bar}$; $P_{\text{CO}} = 1.1 \times 10^{-30} \text{ bar}$; $P_{\text{O}_2} = 5.7 \times 10^{-31} \text{ bar}$**]
c) Do you expect that this reaction will be exothermic or endothermic? Why? [**endo**]
2. Bromine and chlorine both dissolve in carbon tetrachloride, whereupon they react (slowly) to form BrCl :



Under equilibrium conditions at 25°C , $[\text{Br}_2] = [\text{Cl}_2] = 0.0043 \text{ M}$, and $[\text{BrCl}] = 0.0114 \text{ M}$.

- a) Evaluate the equilibrium constant for this reaction at 25°C . [**7.03**]
b) If 0.078 moles of BrCl were added to the equilibrium mixture above, what would be the new equilibrium concentrations of all species present? Assume 1 L of solution.
[**$[\text{Br}_2] = [\text{Cl}_2] = 0.02107 \text{ M}$; $[\text{BrCl}] = .05586 \text{ M}$**]
3. Predict the effect each of the following would have on the equilibrium reaction:

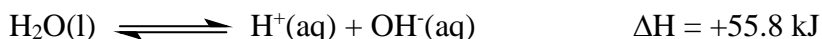


Indicate your choice by writing shift **R**ight, shift **L**eft, or **N**o change:

- a) Adding concentrated HCl _____
b) Heating the reaction _____
c) Adding AgNO_3 (AgCl is insoluble) _____
d) Adding water _____

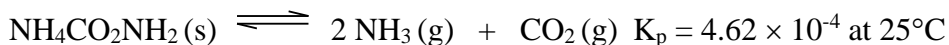
[**L L R R**]

4. The ionization of water is an equilibrium process for which $K_c = 1.0 \times 10^{-14}$ at 25°C :

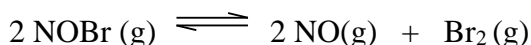


Determine the $[\text{H}^+]$ in water at 50°C . [**2.39 x 10⁻⁷**]

5. The normal boiling point of methanol is 64.65°C and its enthalpy of vaporization is 37.85 kJ/mol . What is its vapour pressure at 21.0°C ? [102.8 mmHg]
6. Ammonium carbamate, $\text{NH}_4\text{CO}_2\text{NH}_2$, dissociates according to the exothermic reaction:



- a) If 1.00 g of ammonium carbamate is placed in a 1.00 L sealed, evacuated flask at 25°C , calculate the total pressure in the flask at equilibrium. (**$P_T = 0.146\text{ bar}$**)
- b) What mass of ammonium carbamate will be left at equilibrium in the experiment described in part a)? (**0.84 g**)
- c) If 1.00 g of ammonium carbamate is placed in the same 1.00 L evacuated flask and some CO_2 is added so that the partial pressure of CO_2 at equilibrium is 1.00 atm, calculate the partial pressure of NH_3 when the system comes to equilibrium at 25°C . (**0.0214 bar**)
7. The fastest growing use of methanol is to make the octane enhancer, methyl *tert*-butyl ether. Today all methanol is produced by the reaction of carbon monoxide and hydrogen. The value of K_p for this reaction is 1.3×10^{-4} at 300°C .
- a) Write the equilibrium reaction for the production of methanol.
 $(2\text{H}_2(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g}))$
- b) What is the value of K_c at 300°C ? (**0.30**)
- 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 eqm.**)
- d) In the industrial process, the stoichiometric ratio of CO to H_2 is used. If the reaction is carried out at an initial total pressure of 300. bar, what are the initial partial pressures of CO and H_2 ? (**100. bar CO , 200. bar H_2**)
8. A flask initially contains only NOBr gas. Once heated to a temperature T , 34.0 % of the original gas decomposes via the following equation to give a total pressure of 0.25 bar at equilibrium:



- a) Determine the original pressure of NOBr in the flask. (**0.21 bar**)
- b) What is the value of K_p at this temperature T ? (**9.6×10^{-3}**)
- c) If the value of K_c at this temperature T is 3.87×10^{-4} , determine the temperature T . (**25°C**)

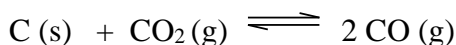
9. For the equilibrium:



At a given temperature T_1 , $K_p = 2.25$. An unknown quantity of pure $\text{PCl}_5(\text{g})$ is placed in an evacuated flask at a temperature T_1 . When equilibrium is established, the partial pressure of $\text{PCl}_5(\text{g})$ is 0.25 bar.

- What are the partial pressures of PCl_3 and Cl_2 at equilibrium? (**0.75 bar**)
- Determine the original pressure of PCl_5 (before any reaction) and the % dissociation of PCl_5 . (**1.00 bar, 75 %**)
- What is the value of K_c for the process if T_1 equals $375\text{ }^\circ\text{C}$? (**0.0418**)

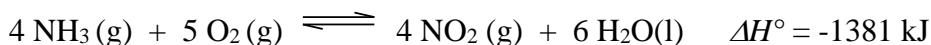
10. For the following system:



At $700\text{ }^\circ\text{C}$ in a 2.00 L flask there are 0.100 moles of CO , 0.200 moles of CO_2 , and 0.400 moles of C at equilibrium. At $600\text{ }^\circ\text{C}$, an additional 0.0400 moles of C forms at equilibrium.

- The process as written is: exothermic or **endothermic**.
- Determine the value of K_c at $600\text{ }^\circ\text{C}$ and $700\text{ }^\circ\text{C}$. (**$K_c = 0.0250$ at $700\text{ }^\circ\text{C}$, 8.3×10^{-4} at $600\text{ }^\circ\text{C}$**)
- An additional 0.200 moles of C is added to the flask at $600\text{ }^\circ\text{C}$. What will be the effect on:
 - K_c increase decrease **no effect**
 - P_{CO} increase decrease **no effect**
 - P_{CO_2} increase decrease **no effect**

11. Consider the equilibrium:



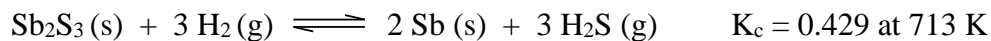
Predict whether the equilibrium amount of NH_3 will increase or decrease and the direction that the reaction will shift in order to establish a new equilibrium if:

- the volume of the system is decreased (**\downarrow , shifts to right**)
- the temperature of the system is increased (**\uparrow , shifts to left**)
- some O_2 is added to the container (**\downarrow , shifts to right**)
- some He is added to the container (**no effect**)
- some NH_3 is added to the container (**\uparrow , shifts to right**)
- some H_2O is removed from the container (**no effect as long as some water remains**)

12. 0.024 mole of N_2O_4 was introduced into a 0.375 L flask at 25°C . Determine the equilibrium concentrations of N_2O_4 and NO_2 at 25.0°C . ($\text{N}_2\text{O}_4 = 0.056 \text{ M}$; $\text{NO}_2 = 0.016 \text{ M}$)



13. 0.150 mol of antimony sulfide and 0.500 mol of H_2 were placed in a 500 mL flask and heated to 713 K. What are the equilibrium concentrations of H_2 and H_2S at 713 K? ($[\text{H}_2] = 0.570 \text{ M}$; $[\text{H}_2\text{S}] = 0.430 \text{ M}$)



14. 0.100 mol of H_2 and 0.100 mol of HI were placed in a 1.00 L container and heated to 445°C . Determine all equilibrium concentrations. ($[\text{H}_2] = 0.102 \text{ M}$; $[\text{I}_2] = 1.81 \times 10^{-3} \text{ M}$, $[\text{HI}] = 0.0964 \text{ M}$)

