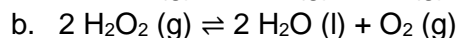
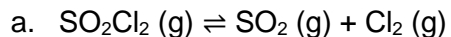


Equilibrium. These problems are from your textbook. More can be found in chapter 19.

1. (19.5) Write the equilibrium-constant expression (K_c) for each of the following reactions.

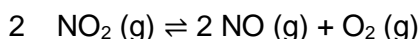


2. (19.11) Phosgene, $\text{COCl}_2(\text{g})$, a toxic gas used in the synthesis of a variety of organic compounds, decomposes according to



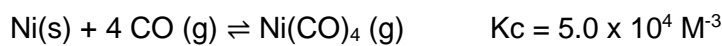
A sample of phosgene gas at an initial concentration of 0.500 M is heated at 527 °C in a reaction vessel. At equilibrium, the concentration of $\text{CO}(\text{g})$ was found to be 0.046 M. Calculate the equilibrium constant for the reaction at 527 °C.

3. (19.14) Nitrogen dioxide decomposes at high temperatures according to the equation:

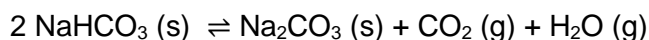


Suppose initially we have pure $\text{NO}_2(\text{g})$ at 1000 K and 0.500 atm. If the total pressure is 0.732 atm when equilibrium is reached, what is the value of K_p (make sure to include the correct units)?

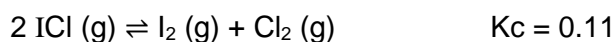
4. (19.17) Given that $[\text{Ni}(\text{CO})_4] = 0.85 \text{ M}$ at equilibrium for the reaction below, calculate the concentration of $\text{CO}(\text{g})$ at equilibrium.



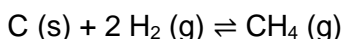
5. (19.24) Sodium bicarbonate decomposes according to the equation below. Given that $K_p = 0.26 \text{ atm}^2$ at 125 °C, calculate the partial pressures of $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{g})$ at equilibrium when $\text{NaHCO}_3(\text{s})$ is heated to 125 °C in a closed vessel.



6. (19.25) For the reaction below, calculate the equilibrium concentrations of $\text{ICl}(\text{g})$, $\text{I}_2(\text{g})$, and $\text{Cl}_2(\text{g})$ when 0.65 moles of $\text{I}_2(\text{g})$ and 0.33 moles of $\text{Cl}_2(\text{g})$ are mixed in a 1.5 liter reaction vessel.



7. (19.37) Consider the chemical equilibrium described below. Predict the way in which the equilibrium will shift in response to each of the following changes.



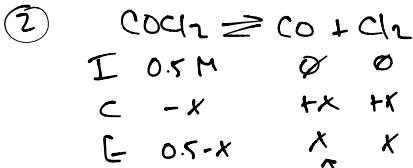
- Decrease in the pressure of H_2
- Increase in the pressure of CH_4
- Adding $\text{C}(\text{s})$ to the flask
- The volume is decreased

8. (19.50) If 0.20 atm H_2 and 3.0 atm $\text{CH}_4(\text{g})$ are mixed in the presence of 4 grams of carbon at 500 °C, determine if the reaction is at equilibrium. If it is not, determine if products or reactants will be formed.



$$\textcircled{1} \quad K_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]}$$

$$K_c = \frac{[\text{CO}_2]}{[\text{H}_2\text{O}_2]^2}$$



$$K_c = \frac{[\text{CO}][\text{Cl}_2]}{[\text{COCl}_2]} = \frac{(0.046 \text{ M})(0.046 \text{ M})}{0.454 \text{ M}}$$

$$K_c = 0.00466 \text{ M}$$

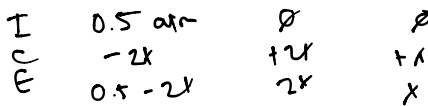
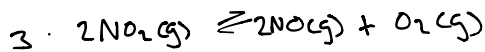
Known: $[\text{CO}]_{\text{equilibrium}} = 0.046 \text{ M}$

$$x = 0.046 \text{ M}$$

$$[\text{CO}] = 0.046$$

$$[\text{Cl}_2] = 0.046 \text{ M}$$

$$[\text{COCl}_2] = 0.5 - 0.046 = 0.454 \text{ M}$$



$$P_{\text{NO}_2} = 0.5 - 2(0.232) = 0.036 \text{ atm}$$

$$P_{\text{NO}} = 2(0.232) = 0.464 \text{ atm}$$

$$P_{\text{O}_2} = 0.232 \text{ atm}$$

$$P_{\text{TOT}} = P_{\text{NO}_2} + P_{\text{NO}} + P_{\text{O}_2}$$

$$0.732 = 0.5 - 2x + 2x + x$$

$$0.732 = 0.5 + x$$

$$x = 0.232$$

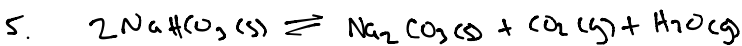
$$K_p = \frac{(0.464 \text{ atm})^2 (0.232 \text{ atm})}{(0.036 \text{ atm})^2} = 38.54 \text{ atm}^2$$

$$4. \quad K_c = \frac{[\text{Ni}(\text{CO})_4]}{[\text{CO}]^4}$$

$$5 \times 10^4 \text{ M}^{-3} = \frac{0.85 \text{ M}}{[\text{CO}]^4}$$

$$[\text{CO}]^4 = 1.75 \times 10^{-5} \text{ M}^4$$

$$[\text{CO}] = 0.0642 \text{ M}$$



$$K_p = 0.26 \text{ atm}^2$$

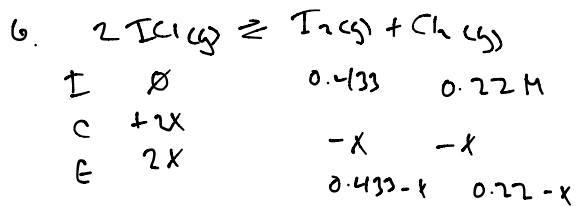


$$0.26 \text{ atm}^2 = x^2$$

$$x = 0.51 \text{ atm}$$

$$P_{\text{CO}_2} = 0.51 \text{ atm}$$

$$P_{\text{H}_2\text{O}} = 0.51 \text{ atm}$$



$$[\text{I}_2] = \frac{0.65 \text{ mol}}{1.5 \text{ L}} = 0.433 \text{ M}$$

$$[\text{Cl}_2] = \frac{0.33 \text{ mol}}{1.5 \text{ L}} = 0.22 \text{ M}$$

$$0.11 = \frac{(0.433-x)(0.22-x)}{(2x)^2} = \frac{0.09526 - 0.653x + x^2}{4x^2}$$

$$0.44x^2 = 0.09526 - 0.653x + x^2$$

$$0 = -0.56x^2 - 0.653x + 0.09563$$

$$a = 0.56$$

$$b = -0.653$$

$$c = 0.09563$$

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

$$x = 0.1717$$

$$x = -0.9943$$

not possible because $[\text{I}_2]$ would be negative!

$$[\text{I}_2] = 0.433 - 0.1717 = 0.2613 \text{ M}$$

$$[\text{Cl}_2] = 0.22 - 0.1717 = 0.0483 \text{ M}$$

$$[\text{ICl}] = 2x = 2(0.1717) = 0.3434 \text{ M}$$

7 a. ↓ amount reactant → more reactants form

b. ↑ product → more reactants form

c. No change! solids are not part of the equilibrium

d. More moles of gas in the reactants. A decrease in volume equals to an increase in pressure of gases (Boyle's Law). Reactants goes up more than Products
So... need to make more products

$$8. Q = \frac{P_{\text{O}_2}}{P_{\text{H}_2}^2} = \frac{3 \text{ atm}}{(0.2 \text{ atm})^2} = 75 \text{ atm}^{-1}$$

$K > Q$ Not at equilibrium
need to make more products