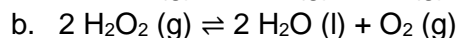
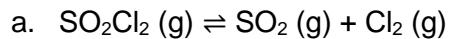


Equilibrium. These problems are from your textbook. More can be found in chapter 19.

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

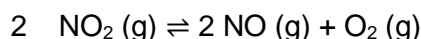


2. (19.11) Phosgene, $\text{COCl}_2(\text{g})$, a toxic gas used in the synthesis of a variety of organic compounds, decomposes according to



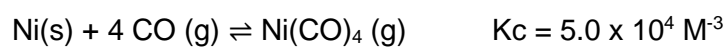
A sample of phosgene gas at an initial concentration of 0.500 M is heated at 527 °C in a reaction vessel. At equilibrium, the concentration of $\text{CO}(\text{g})$ was found to be 0.046 M. Calculate the equilibrium constant for the reaction at 527 °C.

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

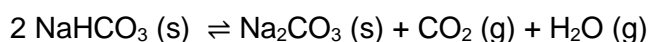


Suppose initially we have pure $\text{NO}_2(\text{g})$ at 1000 K and 0.500 bar. If the total pressure is 0.732 bar when equilibrium is reached, what is the value of K_p (make sure to include the correct units)?

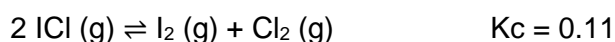
4. (19.17) Given that $[\text{Ni}(\text{CO})_4] = 0.85 \text{ M}$ at equilibrium for the reaction below, calculate the concentration of $\text{CO}(\text{g})$ at equilibrium.



5. (19.24) Sodium bicarbonate decomposes according to the equation below. Given that $K_p = 0.26 \text{ bar}^2$ 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.

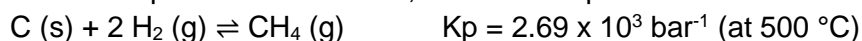


7. (19.37) Consider the chemical equilibrium described below. Predict the way in which the equilibrium will shift in response to each of the following changes.



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

8. (19.50) If 0.20 bar H_2 and 3.0 bar $\text{CH}_4(\text{g})$ 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



$$1a. K_c = \frac{[SO_2][Cl_2]}{[SO_2Cl_2]}$$

$$1b. K_c = \frac{[O_2]}{[H_2O_2]^2}$$

$$2. K_c = \frac{[CO][Cl_2]}{[COCl_2]}$$

$$K_c = \frac{(0.046 M)(0.046 M)}{(0.5 - 0.046 M)}$$

$$K_c = 4.66 \times 10^{-3} M$$



I	0.5 M	0	0
C	-x	+x	+x
E	0.5-x	x	x

$$\hookrightarrow [CO] @ \text{Equilibrium} = 0.046 M$$

$$x = 0.046 M$$



I	0.5 bar	0	0
C	-2x	+2x	+x
E	0.5-2x	2x	x

\downarrow 0.076 bar \downarrow 0.464 bar \downarrow 0.232 bar

$$P_{tot} = 0.732 \text{ bar} = P_{NO_2} + P_{NO} + P_{O_2}$$

$$0.732 \text{ bar} = 0.5 - 2x + 2x + x$$

$$0.732 \text{ bar} = 0.5 + x$$

$$x = 0.232 \text{ bar}$$

$$K_p = \frac{P_{NO}^2 P_{O_2}}{P_{NO_2}^2} = \frac{(0.464 \text{ bar})^2 (0.232 \text{ bar})}{(0.076 \text{ bar})^2} = 38.54 \text{ bar}$$

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

$$5.0 \times 10^4 M^{-3} = \frac{0.85 M}{[CO]^4}$$

$$5.0 \times 10^4 M^{-3} [CO]^4 = 0.85 M$$

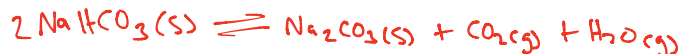
$$[CO]^4 = 1.7 \times 10^{-5} M^4$$

$$[CO] = 0.0642 M$$

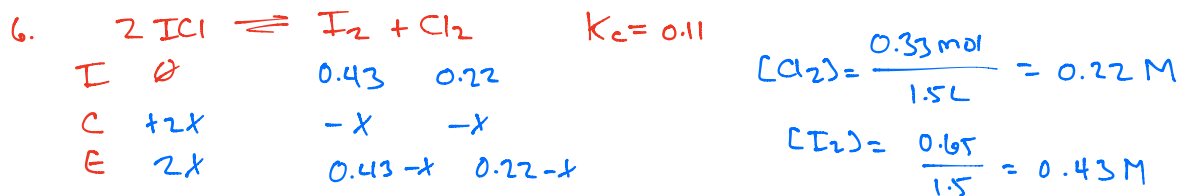
$$5. K_p = P_{CO_2} P_{H_2O}$$

$$0.26 \text{ bar}^2 = (x)(x) = x^2$$

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



I	Y	0	0	0
C	-2x	+x	+x	+x
E	Y-2x	x	x	x



$$K_c = \frac{[\text{I}_2][\text{Cl}_2]}{[\text{ICl}]^2} = \frac{(0.43-x)(0.22-x)}{(2x)^2} = 0.11$$

$$0.0953 - 0.65x + x^2 = 0.11(2x)^2 = 0.44x^2$$

$$0.56x^2 - 0.65x + 0.0953 = 0$$

$$a = 0.56$$

$$b = -0.65$$

$$c = 0.0953$$

$$\frac{0.65 \pm \sqrt{(0.65)^2 - 4(0.56)(0.0953)}}{2(0.56)} = x$$

$$x = \frac{0.65 + 0.457}{1.12} = 0.988$$

Not possible

$$x = \frac{0.65 - 0.457}{1.12} = 0.172$$

$$[\text{ICl}] = 2x = 2(0.172) = 0.345 \text{ M}$$

$$[\text{I}_2] = 0.43 - 0.172 = 0.258 \text{ M}$$

$$[\text{Cl}_2] = 0.22 - 0.172 = 0.048 \text{ M}$$



a. $\downarrow T = \downarrow \text{heat}$ shift to products

b. decreasing the volume will increase the pressure of ALL gases by the same factor ($P \propto \frac{1}{V}$). But, since the P_{H_2} weighs more (because squared), the reaction will shift toward products.

general rule: \downarrow volume favors the side with the fewest moles of gas

\uparrow volume favors the side with the highest moles of gas

c. $\downarrow P_{\text{H}_2} = \text{reactants}$ favored

d. $\uparrow \text{CH}_4 = \text{reactants}$ favored

e. No change (solids don't influence equilibrium)

$$8. \quad Q = \frac{P_{\text{CH}_4}}{P_{\text{H}_2}^2} = \frac{3.0 \text{ bar}}{(0.2 \text{ bar})^2} = 75 \text{ bar}^{-1}$$

$K > Q$
products favored