Now you try!

1. If the K_p for the following reaction is 2.4×10^{-9} and the initial concentration of CO_2 is 2.00 atm, what are the partial pressures of the substances at equilibrium?

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$$

$C_{(s)}$ +	$CO_{2(g)}$	$\rightleftharpoons 2\,CO_{(g)}$
	2.00	Ø
	$-x$	$+2x$
	$2.00-x$	$2x$

$$K_p = \frac{(P_{CO})^2}{P_{CO_2}} = \frac{(2x)^2}{\underbrace{2.00-x}} \approx \frac{4x^2}{2.00} = 2.4E-9$$

x negligible, b/c $2.0 > 1000(2.4E-9)$] $(P_{CO_2})_i$ and K_p differ by factor ↑ 1000!

$$\Rightarrow x = \sqrt{\frac{(2.00)(2.4E-9)}{4}} = \underbrace{3.46}_{2\text{ s.f.}} \times 10^{-5}$$

$$P_{CO} = 2x = 2(3.46E-5) = \boxed{6.9 \times 10^{-5}\text{ atm}}$$

$$P_{CO_2} = 2.00 - x = \boxed{2.00\text{ atm}}$$

Check K:

$$K_p = \frac{(6.9E-5)^2}{2.00} = 2.4E-9 \checkmark$$

Check approximation:

$$\left(\frac{3.46E-5}{2.0}\right) \times 100 = 0.002\% < 5\% \checkmark$$

2. A gas, XY(g), decomposes according to the following reaction: $2\,XY(g) \rightleftharpoons X_2(g) + Y_2(g)$, $K_p = 230$. A sample of each of the gases is places in a previously evacuated container, and the initial partial pressures of the gases are shown in the table below:

Gas	Initial Partial Pressure (atm)
XY	0.010
X_2	0.20
Y_2	2.0

If the temperature of the reaction mixture is held constant, in which direction will the reaction proceed? Explain.

$$Q_p = \frac{P_{X_2} P_{Y_2}}{(P_{XY})^2} = \frac{(0.20)(2.0)}{(0.010)^2} = 4000 > 230$$

$$Q > K$$

K < Q, so the rxn will proceed to the left: decreasing P products + increasing P reactants to achieve equilibrium.

$\Rightarrow [N_2O_4] = \frac{1.0 \text{ mol}}{10.0 \text{ L}} = 0.10\,M$

~~23~~ 32

3. For the reaction $N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$, 1.0 mol of $N_2O_4(g)$ is placed in a 10.0 L reaction vessel at a constant temperature. $K_c = 4.0 \times 10^{-7}$ for this temperature. Find the equilibrium concentrations.

$N_2O_{4(g)}$	$\rightleftharpoons$	$2\,NO_{2(g)}$
0.10		Ø
$-x$		$+2x$
$0.10 - x$		$2x$

$$K_c = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(2x)^2}{\underbrace{0.10 - x}} \approx \frac{4x^2}{0.10} = 4.0 \times 10^{-7}$$

$0.1 > 1000(4E-7)$ so x is negligible! $[N_2O_4]_i$ and K_c differ by a factor ↑ 1000!

$$x = \sqrt{\frac{(0.10)(4.0E-7)}{4}} = 1.0 \times 10^{-4}$$

$[N_2O_4] = 0.10 - x = 0.10 - 1.0E-4 = \boxed{0.10\,M}$

$[NO_2] = 2x = 2(1.0E-4) = \boxed{2.0 \times 10^{-4}\,M}$

Check K:

$$K = \frac{(2.0E-4)^2}{0.10} = 4.0E-7 \checkmark$$

Check approx:

$$\frac{1.0E-4}{0.10} \times 100 = 0.10\% < 5\% \checkmark$$

Multiple Choice Practice!

4. Here is a general reaction with a K value of 16: $A(aq) + B(aq) \rightleftharpoons 2\,C(aq)$.
   Initially, [A] = [B] = 2.0 M. Solve for the equilibrium concentration of each substance.

   a. [A] = [B] = 0.67 M, [C] = 1.3 M
   b. [A] = [B] = 1.6 M, [C] = 0.88 M
   c. [A] = [B] = 0.67 M, [C] = 2.7 M
   d. [A] = [B] = 0.50 M, [C] = 3.0 M

A	+	B	$\rightleftharpoons$	2C
2		2		Ø
$-x$		$-x$		$+2x$
$2-x$		$2-x$		$2x$

$$K = \frac{[C]^2}{[A][B]} = \frac{(2x)^2}{(2-x)^2} = 16$$

$[A] = [B] = 2 - x = 2 - 1.33 = 0.67$

$[C] = 2x = 2(1.33) = 2.67$

$$\Rightarrow 4 = \frac{2x}{2-x} \Rightarrow 8 - 4x = 2x \Rightarrow 8 = 6x \Rightarrow x = 1.33$$

5. Consider the following equilibrium: $Cl_2(g) + 2\,NO(g) \rightleftharpoons 2\,NOCl(g)$. Initially, the reaction was started by adding 10.0 *M* NOCl gas to a reaction vessel. At equilibrium, [NO] = 2.0 *M*. What is the value of K_c?

   a. 0.63 b. 2.3 c. 4.0 $\boxed{\text{d. 16}}$

Cl_2	+	2NO	$\rightleftharpoons$	2NOCl
Ø		Ø		10
$+x$		$+2x$		$-2x$
x		$\underbrace{2x}$		$10-2x$

$2x = 2.0 \Rightarrow x = 1.0$

$[Cl_2] = x = 1.0$

$[NO] = 2.0$

$[NOCl] = 10 - 2x = 10 - 2 = 8$

$$K = \frac{[NOCl]^2}{[Cl_2][NO]^2} = \frac{8^2}{(1)(2)^2} = \frac{8 \cdot 8}{4} = 16$$

~~24~~ 33

6. The reaction below came to equilibrium at a temperature of 100°C. At equilibrium the partial pressure due to NOBr was 4 atm, the partial pressure due to NO was 4 atm, and the partial pressure due to Br_2 was 2 atm. What is the equilibrium constant, K_p, for this reaction at 100°C?

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

a. ¼ b. ½ c. 1 d. 2

$$K_p = \frac{(P_{NO})^2 (P_{Br_2})}{(P_{NOBr})^2} = \frac{(4)^{\cancel{2}}(2)}{(4)^2} = 2$$

7. Consider the following: $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$. Initially, 0.030 mol SO_2 and 0.030 mol O_2 are placed into a 1.0 L container. At equilibrium, there is 0.020 mol O_2 present. What is the $[SO_2]$ at equilibrium?

a. 0.010 mol/L b. 0.020 mol/L c. 0.030 mol/L d. 0.040 mol/L

$2SO_2$	+ O_2	$\rightleftharpoons 2SO_3$
0.030	0.030	Ø
$-2x$	$-x$	$+2x$
$0.030-2x$	$0.030-x$	$2x$

$0.030 - x = 0.020$

$\Rightarrow x = 0.010$

$[SO_2] = 0.030 - 2x$

$= 0.030 - 2(0.010)$

$= 0.010$

Use the information below to answer #8–10.

Reaction 1:	$NOBr(g) \rightleftharpoons NO(g) + ½\ Br_2(g)$	$K_c = 3.4 \times 10^{-2}$	$K < Q$
Reaction 2:	$2\ NOCl(g) \rightleftharpoons 2\ NO(g) + Cl_2(g)$	$K_c = 1.6 \times 10^{-5}$	$K < Q$
Reaction 3:	$2\ NO(g) + 2\ H_2(g) \rightleftharpoons N_2(g) + 2\ H_2O(g)$	$K_c = 4.0 \times 10^{6}$	$K > Q$
Reaction 4:	$N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g)$	$K_c = 4.2 \times 10^{2}$	$K > Q$

8. For a reaction involving nitrogen monoxide inside a sealed flask, the value for the reaction quotient (Q) was found to be 1.1×10^2 at a given point. If, after this point, the amount of NO gas in the flask increased, which reaction is most likely taking place in the flask?

a. reaction 1 b. reaction 2 c. reaction 3 d. reaction 4

9. Which of these reactions proceeds at the slowest rate?

a. reaction 1 b. reaction 2 c. reaction 3 d. cannot be determined

Same! ⇒ n

10. For reaction #3, equimolar amounts of N_2 gas and H_2O gas are allowed to come to equilibrium in a sealed reaction vessel. Which of the following must be true at equilibrium?

I. $[N_2]$ must be less than $[H_2O]$. ✗
II. $[N_2]$ must be greater than $[H_2O]$. ✓
III. $[NO]$ must be greater than $[H_2]$. ✗

$2NO$	+ $2H_2$	$\rightleftharpoons N_2$	+ $2H_2O$
Ø	Ø	n	n
$+2x$	$+2x$	$-x$	$-2x$
$2x$	$2x$	$n-x$	$n-2x$

a. I only b. II only c. I and III d. II and III