

## K<sub>p</sub>, Gas Phase Equilibrium Problems

- Very similar to K<sub>C</sub> problems except you are using partial pressures instead of concentrations.
- Again leave out solids and pure liquids.

For example:  $aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$

$$K_p = \frac{P_A^a \cdot P_B^b}{P_C^c \cdot P_D^d}$$

The relationship between K<sub>C</sub> and K<sub>p</sub> is an easy derivation from the ideal gas law:  $PV = nRT$

for the partial pressure of gas i:  $P_i = n_i \frac{RT}{V}$  and  $\frac{n_i}{V} = [\text{gas } i]$  ← just the molar concentration

so,  $K_p = K_C \cdot (RT)^{\Delta n}$  "Δn" just equals the sum of the stoichiometric coefficients of the products minus the sum of the stoichiometric coefficients of the reactants (like,  $c + d - a - b$ ).

So you can relate K<sub>p</sub> to K<sub>C</sub> as a function of temperature and change in number of moles between products and reactants.

- To do these problems, just algebraically proceed in the same way as K<sub>C</sub>. Set up the table and the expression for K<sub>p</sub>. Then solve for x.

## Le Chatelier's Principle

Le Chat's principle is great chemistry. The people who write the AP do a good job of testing students on their "chemistry intuition." Along with shielding, sublevel stability, and like-dissolves-like, Le Chat's is one of the intuitive rules to know.

Le Chatelier's Principle is just: **A chemical reaction will try to counter, if it can, any change imposed on it. It tries to do the opposite of what is done to it.**

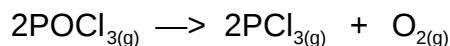
- If you add a product or reactant, the reaction shifts in the direction to use it up.
- If you increase temperature, the reaction will shift in the endothermic direction to try to decrease temperature.
- If you decrease temperature, the reaction will shift in the exothermic direction to try to increase temperature.
- If you increase pressure the rxn will try to decrease pressure by shifting in the direction which makes fewer molecules and vice-versa. (If both sides have the same # of molecules it can't do anything.)  
(Also, remember that volume changes are like pressure changes. Increasing volume decreases the pressure and decreasing the volume increases the pressure.)
- Adding species that don't take part in the reaction does nothing.

**Student Packet: 5.2: Le Chatelier's Principle: AssessMe questions**

- 1) What will be the effect of adding C to the equilibrium mixture  $A + B \rightleftharpoons C + D$  ?
- A) Cause the equilibrium point to shift to the left forming more reactant from existing product.
  - B) Cause the equilibrium point to shift to the right forming more product from existing reactant.
  - C) Have no effect on the reaction equilibrium point.
  - D) Only increase the amount of C present without affecting the values of [A], [B], or [D].
  - E) I'm clueless
- 2) If  $A + B \rightleftharpoons C + D$  and species C and D are gases while A and B are liquids, then increasing the pressure of the reaction vessel will
- A) decrease the amount of products.
  - B) increase the amount of products.
  - C) not affect the ratio of products to reactants.
  - D) shift the heat of reaction.
  - E) I'm clueless
- 3) One possible equilibrium equation based on the following reaction is  
 $aA + bB \rightleftharpoons cC + dD$   
 $K_{eq} = \frac{[D]^d [C]^c}{[A]^a [B]^b}$  The values of [A], [B], [C], and [D] are
- A) the initial concentrations of the reactants and products
  - B) the concentration of the reactants and products at the end of the reaction time
  - C) the equilibrium concentrations of the reactants and products.
  - D) none of the above
  - E) I'm clueless
- 4) If a reaction vessel is observed to heat up, the reaction is said to be:
- A) isothermal    B) endothermic    C) exothermic    D) adiabatic    E) I'm clueless
- 5) Which of these solids is the best conductor of electricity?
- A) tungsten    B) carbon dioxide, "dry ice"  
C) sodium chloride    D) ice    E) I'm clueless
- 6) Which of the following is an example of a substance held together by dispersion forces that melts far below room temperature?
- A) sodium    B) germanium    C) neon    D) calcium chloride    E) I'm clueless

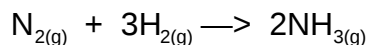
## Student Packet: 5.2: Le Chatelier's Principle: ShowMe questions

1) For the reaction:



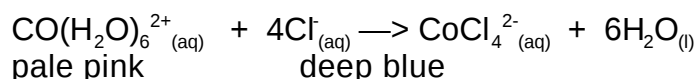
In which direction will the equilibrium shift when  $\text{O}_{2(g)}$  is added? When  $\text{POCl}_{3(g)}$  is added?

2) For the reaction:



In which direction will the equilibrium shift when the volume is reduced?

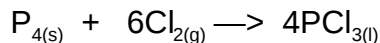
3) The following reaction involves a color change:



What color will the solution shift towards in the following cases?

- $\text{NaCl}_{(s)}$  is added.
- The volume of the solution is doubled by adding water.

4) The following reaction is run:



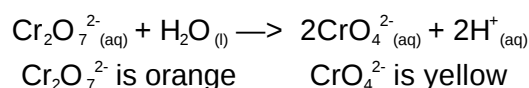
In which direction will the equilibrium shift in response to the following changes:

- $\text{P}_{4(s)}$  is added.
- $\text{Ar}_{(g)}$  is added at constant volume.
- $\text{Cl}_{2(g)}$  is added at constant volume.

## Student Packet: 5.2: Le Chatelier's Principle: TestMe questions

- 1) Which of the following statements is true?
- A) Increasing the amount of a reactant always shifts the equilibrium position to the right.
  - B) Adding  $\text{H}_2\text{O}_{(l)}$  to a reaction in which water is either a reactant or a product will never affect the equilibrium.
  - C) Increasing the temperature of an endothermic reaction will decrease the equilibrium constant.
  - D) Decreasing the temperature of an exothermic reaction will increase the equilibrium constant.
  - E) None of the above
- 2) Which of the following changes to a reaction will change the equilibrium constant,  $K$ ?
- A) decrease in pressure
  - B) change in temperature
  - C) increase in reactant concentration
  - D) decrease in volume (of a gaseous reaction)
  - E) All of the above
- 3) Which of the following effects will shift the following reaction to the right?
- $$\text{H}_{2(g)} + \text{F}_{2(g)} \longrightarrow 2\text{HF}_{(g)}$$
- A) decreasing the pressure of  $\text{HF}_{(g)}$
  - B) decreasing the volume
  - C) adding  $\text{He}_{(g)}$
  - D) decreasing the pressure of  $\text{F}_{2(g)}$
  - E) All of the above

- 4) Consider the reaction:



Which of the following will produce a shift towards a yellow solution?

- A) addition of  $\text{HCl}_{(l)}$
  - B) addition of  $\text{CrO}_4^{2-}$
  - C) addition of  $\text{NaOH}_{(s)}$
  - D) decrease of  $\text{Cr}_2\text{O}_7^{2-}$  concentration
  - E) None of the above
- 5) In which of the following cases will the reaction quotient be greater than the equilibrium constant ( $Q > K$ )?
- A)  $\text{H}_2\text{O}_{(l)}$  is added to:  $\text{Ag}^+{}_{(aq)} + 2\text{NH}_3{}_{(aq)} \longrightarrow \text{Ag}(\text{NH}_3)_2^+{}_{(aq)}$
  - B)  $\text{C}_{(s)}$  is added to:  $\text{C}_{(s)} + \text{CO}_{2(g)} \longrightarrow 2\text{CO}_{(g)}$
  - C)  $\text{Cu}^{2+}$  is added to:  $\text{Zn}_{(s)} + \text{Cu}^{2+}{}_{(aq)} \longrightarrow \text{Zn}^{2+}{}_{(aq)} + \text{Cu}_{(s)}$
  - D)  $\text{KSCN}_{(s)}$  is added to:  $\text{Fe}^{3+}{}_{(aq)} + \text{SCN}^-{}_{(aq)} \longrightarrow \text{FeSCN}^{2+}{}_{(aq)}$
  - E) None of the above