ChemQuest 61

Intro to Equilibrium

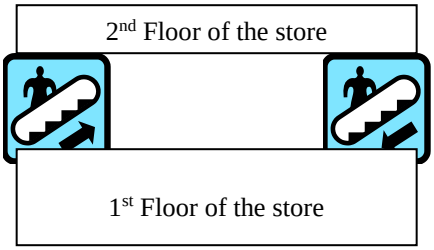
Name: _____

Date: _____

Hour: _____

Information: Equilibrium of a Mall

Consider a store at a large mall. The store has two floors and escalators that connect the two floors. Each escalator moves at the same speed



Before the store opens there are no customers on either floor of the store. The door to the store is on the first floor and there is a crowd of customers waiting to enter.

Critical Thinking Questions

1. Right after the store opens, are there more people on the 1st floor or on the 2nd floor?

2. Sometimes the store owner wants to know if more customers are going to the 2nd or the 1st floor. They will measure the *rate* of people going up or down the escalators. Which of the following would be a good unit for the rate of people using the escalator?
   A) meters per second B) customers per minute C) miles per hour

3. Shortly after the store opens, the rate of people going on the up escalator is _____ than the rate of people going down.
   faster, slower OR the same as

4. Assume the store has now been open for one and a half hours. The rate of people using the downward escalator has _____ since the store opened.
   increased OR decreased

5. There comes a time during the shopping day when the rate of the upward escalator equals the rate of the downward escalator. What does this mean?
   A) Both escalators move at the same speed.
   B) The number of people going up equals the number of people going down.

6. Hopefully you put (B) for the previous question. Equilibrium means that the number of people traveling up equals the number of people traveling down. Let's pretend we have reached equilibrium at the store and also let's pretend that the store doors are closed and locked—no new customers can come in and no one leaves. Answer the true/false questions below:

   _____ a) At equilibrium the number of people shopping on the first floor must be the same as the number of people shopping on the second floor.

_____ b) During equilibrium, the number of people on each floor does not change.

Information: Equilibrium of Salt Water

Salt and water interact with each other. As you know, salt can dissolve in water. When salt dissolves in water, it breaks up into ions and we can write:

$NaCl\ (s) \rightarrow Na^+\ (aq) + Cl^-\ (aq)$ ……. Equation 1

Note that "aq" means "aqueous solution." If you take a bunch of ocean water and evaporate it, what do you have left? Salt! The dissolved ions can sometimes crystallize back into salt. We can write it like this:

$Na^+\ (aq) + Cl^-\ (aq) \rightarrow NaCl\ (s)$ …… Equation 2

Salt's ability to dissolve and then recrystallize is called a reversible change. We can write the equation like this (notice the double arrow):

$NaCl\ (s) \leftrightarrow Na^+\ (aq) + Cl^-\ (aq)$ …… Equation 3

The "forward equation" is what we call the direction toward the right. The "reverse equation" is what we call the direction to the left.

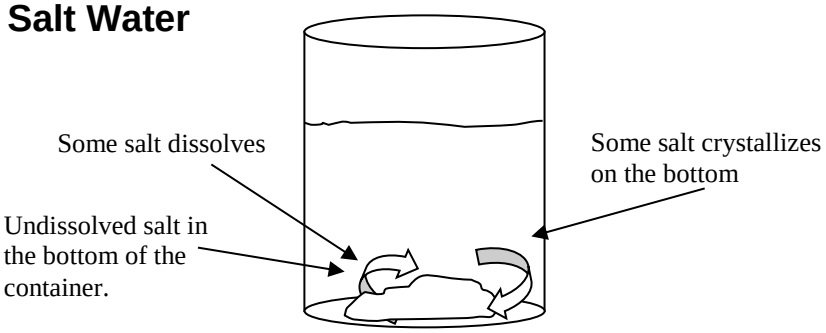
Critical Thinking Questions

7. Which reaction is the "forward equation"?
   A) Salt dissolving into ions.
   B) Ions crystallizing into salt.

8. Let's say you add a huge scoop of salt to some water, which equation will have the fastest rate at the very beginning—the forward or reverse?

Information: Equilibrium of Salt Water

A saturated solution of salt in water:



The above container has had too much salt added to the container. No more salt can dissolve. There is undissolved salt on the bottom of the container. It looks like nothing is happening, BUT if you could magnify it and view the particles you would see that something is indeed going on. Salt is still dissolving! But just as some salt dissolves, other salt crystallizes on the bottom so that there is no net change in the amount of salt setting on the bottom of the container. We could write it like this:

$NaCl \leftrightarrow Na^+ + Cl^-$

The double arrow indicates that some salt is dissolving and some sodium and chloride ions are crystallizing all at the same time and at the same rate. At equilibrium, the forward and reverse reactions take place at the same speed. So, for every gram of salt that dissolves, a gram also recrystallizes.

Critical Thinking Questions

9. Answer the following True/False questions:

_____ a) At equilibrium, the amount of undissolved salt must equal the amount of dissolved salt. (Hint: this question is similar to question 6a.)

_____ b) During equilibrium, the amount of undissolved salt does not change.

_____ c) The concentration of dissolved salt doesn't change after equilibrium has been reached.

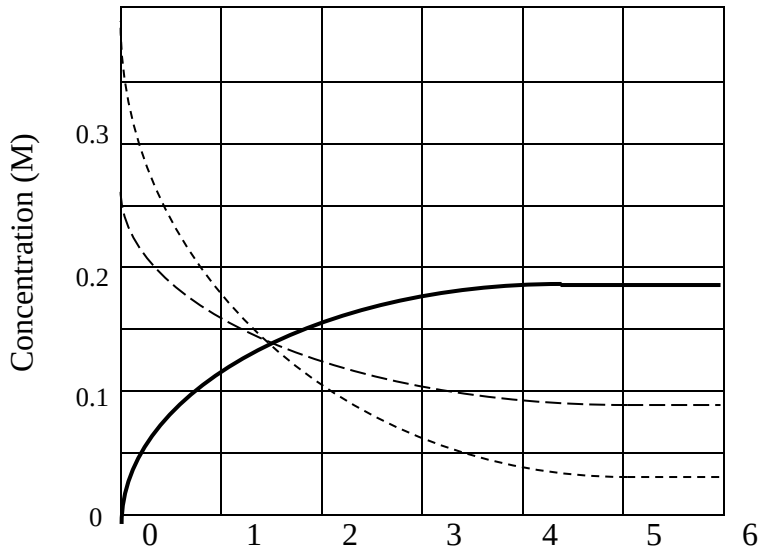
Information: Equilibrium of Reactions

Let's apply this same reasoning to chemical reactions… So far we have studied reactions, but have not considered an important phenomenon called "equilibrium". In equilibrium, there is a forward and a reverse reaction. For example, consider the reaction between carbon and oxygen to form carbon dioxide: $C + O_2 \leftrightarrow CO_2$

Notice the double arrow. The double arrow indicates an equilibrium. What this means is that just as carbon and oxygen react to form carbon dioxide, so also carbon dioxide decomposes to form carbon and oxygen.

If we graphed concentration vs. time for the reactants and products we would get a graph like this:

$C + O_2 \leftrightarrow CO_2$



Time (seconds)

Critical Thinking Questions

10. Which line on the above graph represents CO_2?

11. a) What is the concentration of CO_2 at the beginning of the reaction, according to the graph?

    b) Why does it make sense that this was the concentration?

12. At what time was equilibrium reached, according to the graph?

13. Do all the substances on the graph have equal concentration at equilibrium?

Information: Equilibrium Constants

An equilibrium constant (K) is a ratio of products to reactants. To calculate the equilibrium constant you divide the concentration of the product by the concentration of the reactants. In the above reaction involving carbon dioxide, the equilibrium constant (K) looks like this: $K = \frac{[CO_2]}{[C][O_2]}$

Critical Thinking Questions

14. Consider a container in which carbon and oxygen are reacting according to the equation given earlier. At equilibrium, the concentration of carbon dioxide was 0.80 M, the concentration of carbon and oxygen were each 0.20 M. Calculate the equilibrium constant. (You should get an answer of 20.)

15. Consider the following equilibrium reaction: $N_2 + 3\ H_2 \leftrightarrows 2\ NH_3$.
    The equilibrium constant expression for the reaction is written like this: $K = \frac{[NH_3]^2}{[N_2][H_2]^3}$

    a) What is the relationship between a substance's coefficient in the balanced equation and its exponent in the equilibrium constant expression?

    b) When writing the equilibrium constant expression, are the products always written on the top or on the bottom?

16. Again, consider the equilibrium discussed in the information section above. If at equilibrium the constant was a very large number does that mean that there is a lot of carbon dioxide or a lot of carbon and oxygen?

17. The equilibrium constant can vary at different temperatures and pressures. The equilibrium constant for the reaction of nitrogen and hydrogen to form ammonia was

calculated at three different conditions with the following results: A) K=2.89 B) K=5.21 C) K=1.82

a) Which equilibrium constant indicates the most product present?

b) Which equilibrium constant indicates the most reactant present?

18. Write equilibrium constant expressions for the following reactions:
a) $2H_2 + O_2 \leftrightarrow 2H_2O$ b) $2SO_3 \leftrightarrow 2SO_2 + O_2$ c) $N_2O_4 \leftrightarrow 2\ NO_2$