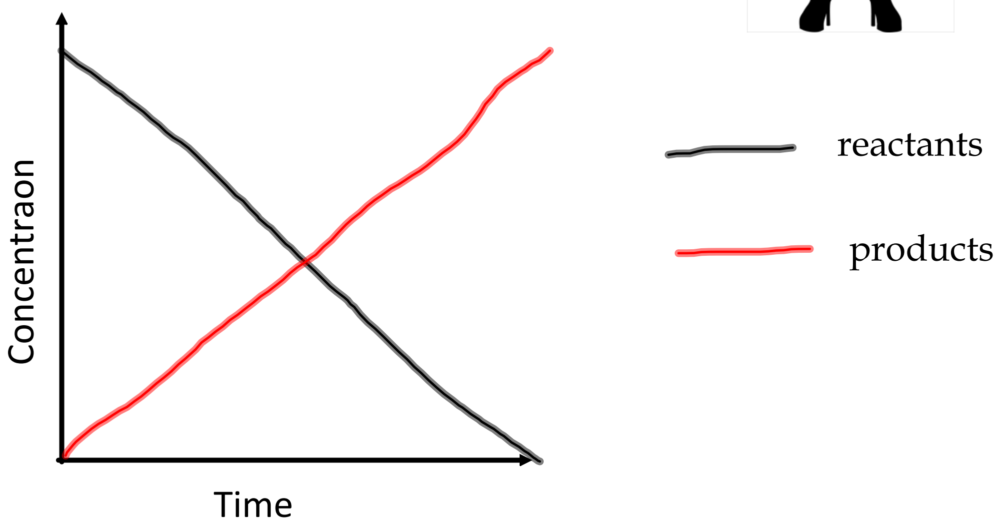
Unit 5 - Equilibrium

5.1 - Reversible Reactions and Equilibrium

pages 558-563 in Matter and Change

pages 514-520 in Health



Reversible Reactions

One misconception about chemical reactions is that they can only happen in one direction.

That is, in previous science courses one way we defined a chemical change is that they cannot be reversed. For example, frying an egg.

In this unit we will learn that reactions can be reversed under the right conditions. (note: almost all physical changes are reversible= **physical equilibria**)

For example, $2NO_2 \rightarrow N_2O_4$ and $N_2O_4 \rightarrow 2NO_2$.

In a situation like this, we can combine the two ideas by writing the equation using a double arrow ($\rightleftarrows$ or $\longleftrightarrow$):

$2NO_2 \rightleftarrows N_2O_4$

In this example, the cycle always continues. Once the $2NO_2$ forms the N_2O_4, the N_2O_4 will decompose back down to $2NO_2$ and the cycle repeats.

Regarding $2NO_2 \rightleftarrows N_2O_4$ we call the reaction where NO_2 is the reactant an N_2O_4 is the product the **forward** reaction.

Likewise, when N_2O_4 is the reactant and NO_2 is the product, we call this the **reverse** reaction.

Note that the forward reaction will always be read from left to right.

Equilibrium

If we add salt to a beaker of water, we will have the reversible reaction:

$NaCl_{(s)} \rightleftarrows NaCl_{(aq)}$

However, if we keep adding salt, we will reach a point where no more salt is able to dissolve and the excess sits at the bottom of the beaker.

One question we must ask is whether or not the dissolving process has stopped.

When a solution becomes saturated, it has reached the point of **equilibrium**. This means that the forward reaction:

$NaCl_{(s)} \rightarrow NaCl_{(aq)}$

and the reverse reaction:

$NaCl_{(aq)} \rightarrow NaCl_{(s)-}$

-happen at the same rate (Rate $_{\text{forward rxn}}$ = Rate $_{\text{reverse rxn}}$)

This is why we think the dissolving process has stopped - we don't see any observable change in the amount of salt at the bottom of the solution. Only microscopic changes occur at equilibrium.

This may also be called **dynamic chemical equilibrium** , but we will just refer to it as equilibrium *(the concentration of products and reactions is not changing).*

Note that we are talking about equal **rates**, not equal concentrations of reactants and products.

Achieving equilibrium takes time-different amount of time for different reactions.

5.1 - Reversible Reactions and Equilibrium

An analogy for equilibrium: subbing players into a sports game or juggling.

In order for equilibrium to be reached with a reversible reaction the system must be **closed**. Imagine if the product was removed as soon as it was formed, how could it be reversed into the reactants?

If you continuously add reactants to a system at the same rate you remove the products you create a **steady state system**.

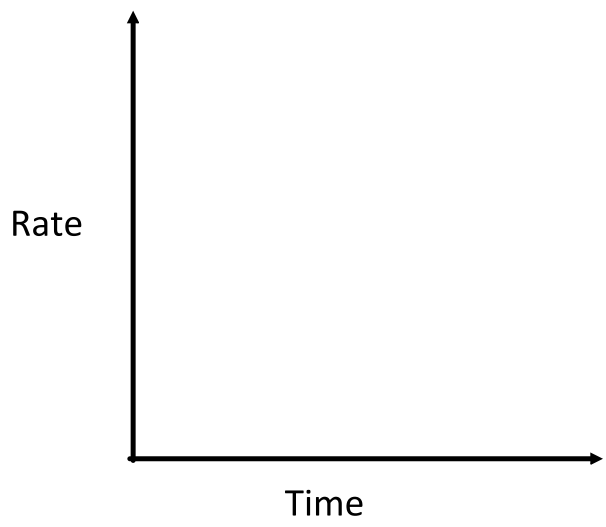
A factory with an assembly line is an example of a steady state system.

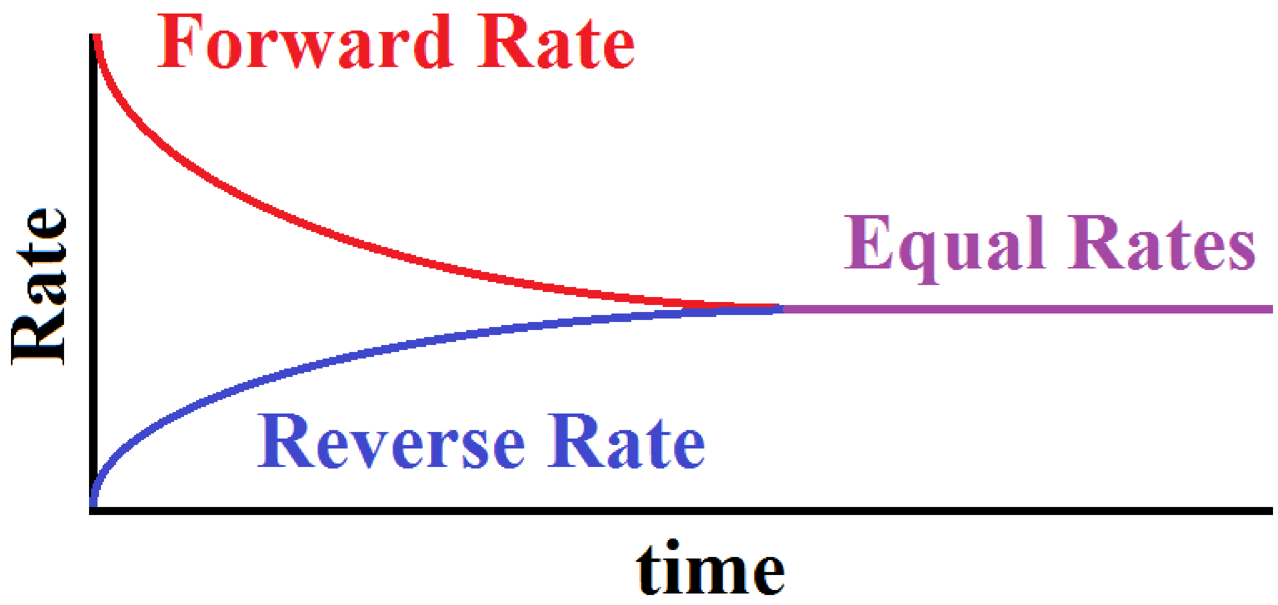
That is, raw materials are constantly being added to make products which are constantly being removed.

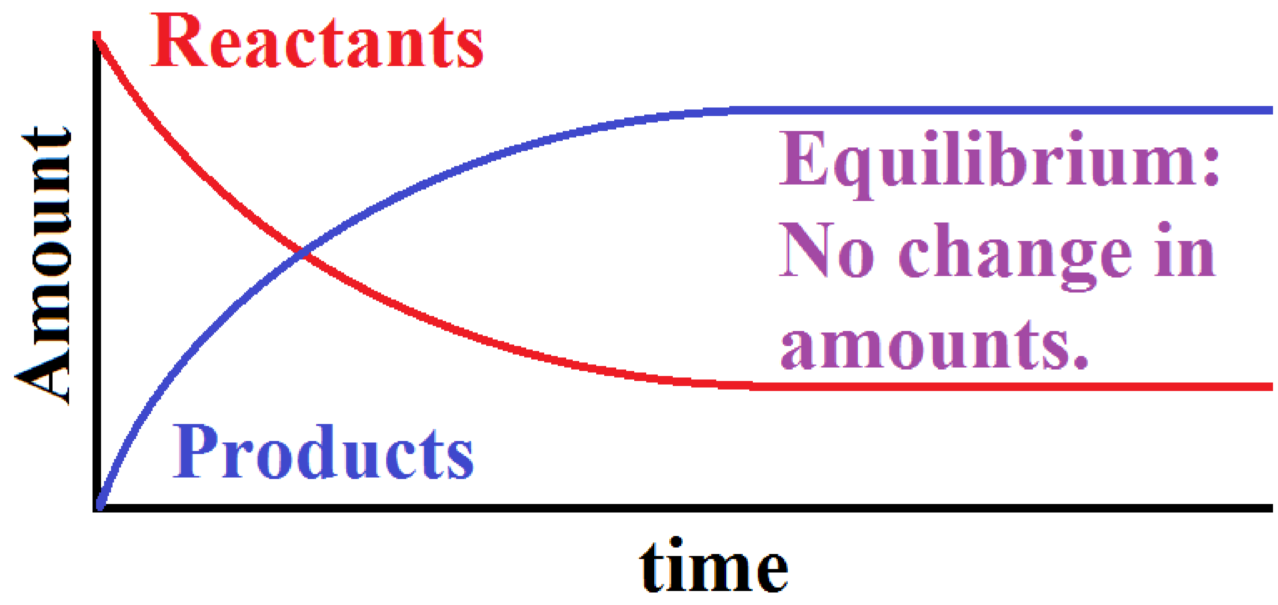
However, a steady state system is not equilibrium because the reverse reaction does not happen.

How does the rate of the forward reaction compare to the rate of the reverse reaction?

For example, $A + B \rightleftharpoons C$







Important Definitions:

-**Steady State:** an open system where some properties are constant, but equilibrium does not exist. There is a constant feeding of reactants to maintain a constant removal of products.

-**Dynamic Equilibrium:** a system in which change is constantly occurring at the microscopic level, but there is no net change

-**Static State:** a system in which no obvious change is occurring at any level

5.1 - Reversible Reactions and Equilibrium

5.1 Assignment

1. Write reversible reactions for each of the following situations (be sure to balance your equations):

a. Hydrogen iodide gas (HI) decomposes into its elements.

b. Hydrogen and nitrogen gases combine to form ammonia gas, NH_3.

2. If the system represented by the following equation is found to be at equilibrium at a specific temperature, which of the following statements is true? Explain your answers.

$H_2O(g) + CO(g) \leftrightarrow H_2\,(g) + CO_2\,(g)$

a. All species must be present in the same concentration.

b. The rate of the forward reaction equals the rate of the reverse reaction.

c. We can measure continual changes in the reactant concentrations.

3. Which of the following are equilibrium systems and which are steady state systems?

a. A playing football team and a bench of reserve players. The number of players o the field is constant and the number of players on the bench is constant

b. A well fed tiger in a cage. The weight of the tiger is constant.

c. The Nipawin Dam and Codette Lake behind the dam. The water level is constant.

d. The liquid alcohol and alcohol vapor in a thermometer. The temperature is constant.

e. A block of wood floating on water

4. Which of the following are chemical equilibria and which are physical equilibria systems?

a. sublimation of dry ice (solid carbon dioxide)

b. a saturated magnesium chloride solution

c. the partial dissociation of 2 moles of HI molecules into 1 mole H_2 and 1 mole of I_2 molecules

5.1 - Reversible Reactions and Equilibrium

5. Which of the following reactions are reversible?

   a. the evaporation of water

   b. the combustion of coal

   c. the magnetization of an iron bar

6. A chemist wished to prepare pure phosgene ($COCl_{2(g)}$) by reacting carbon monoxide and chlorine gas accoridng to the reaction:

$$CO_{(g)} + Cl2_{(g)} \rightleftharpoons COCl_{2(g)}$$

Why will this reaction NOT produce pure phosgene? If the chemist could somehow obtain a sample of pure $COCl_{2(g)}$, would it remain pure? Why?

7. Read the following observations and then answer the questions.

- Two sealed glass tubes containing a mixture of a red–brown gas, $NO_2(g)$, and a colourless gas, $N_2O_4(g)$, are observed. The colour is an identical medium red–brown in each tube and there is no visible change in the colour of the contents as time passes.
- One tube is placed in a beaker of boiling water for a minute. The contents of the tube become much darker red–brown in colour. Upon first placing the tube in the hot water, the colour gets continually darker, but after a few seconds the colour stops changing.
- The second tube is placed in a beaker containing dry ice at –78°C. The colour quickly disappears and the contents of the tube remain colourless.
- The hot and cold tubes are taken out of their beakers, placed side by side and allowed to come to room temperature. The tubes have an identical medium red-brown colour when they both are at room temperature.

a) The gases are involved in the reversible reaction: $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$.
What evidence exists that the forward and reverse rates are equal at room temperature?

b) Can temperature changes affect an equilibrium reaction? How do you know this?

c) What evidence shows that the forward and reverse reaction rates are equal at 100°C? If the temperature were raised above 100°C, what would you expect to happen to the colour?

d) The balanced equation in part (a) should also include "energy". Consider what happened to the colour when a tube was heated. Is the reaction exothermic or endothermic, as written? Explain.

e) What gas was predominantly present at low temperatures? What gas was predominantly present at high temperatures? How would you describe the chemical composition in a tube when it was at room temperature?

f) If one tube were filled with pure $NO_2(g)$ and another tube with pure $N_2O_4(g)$, what might be true of the colours you would expect to see in the tubes after they sit for a minute at the same temperature? What evidence do you have that your prediction should occur?