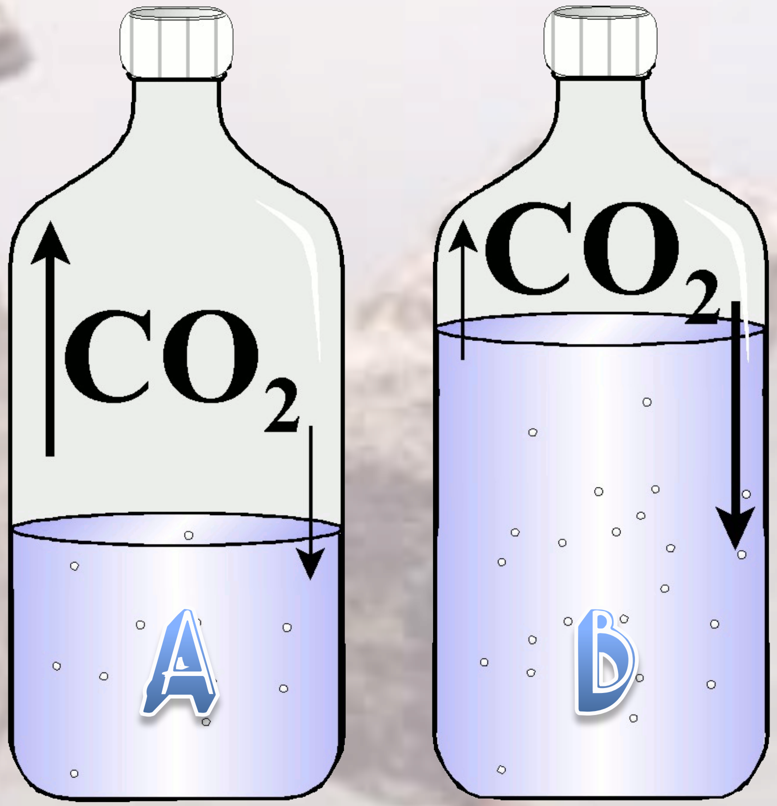
EQUILIBRIUM

Lessons in a Soda Bottle

- Consider the two soda bottles to the right:
  - CO_2 molecules are moving randomly in all directions.
  - Some CO_2 molecules are moving out of the soda into the space above.
  - Other CO_2 molecules are returning to the soda from the space above.



- Which bottle goes flat faster, **A** or **B**?

An Explanation (Part 1)

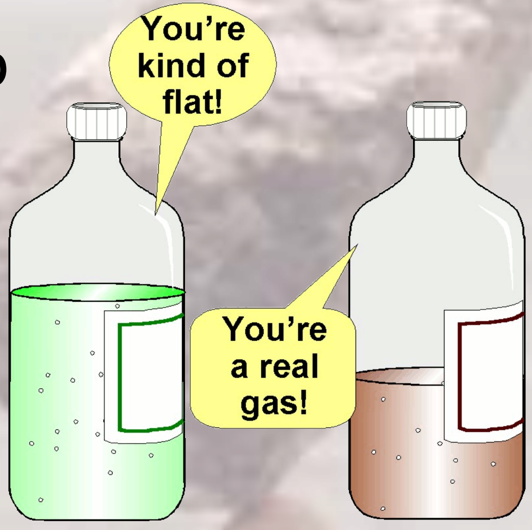
- At first, CO_2 is only moving out of the soda into the air space above the liquid.
  - This is because, initially, all the CO_2 is in the soda. There is no CO_2 in the air space above.
- As the amount of CO_2 in the space above the soda increases, so does the likelihood (probability) that CO_2 molecules will return to the soda.
- This means the speed with which CO_2 returns to the soda increases as the amount of CO_2 in the air space above the soda increases.

An Explanation (Part 2)

- As the amount of CO_2 in the space above the soda increases, the amount of CO_2 dissolved in the soda decreases.
- As the amount of CO_2 dissolved in the soda decreases, so does the likelihood that CO_2 molecules will leave the soda.
- This means the speed with which CO_2 leaves the soda decreases as the amount of CO_2 in dissolved in the soda decreases.

An Explanation (Part 3)

- Eventually, the speed at which the CO_2 leaves the soda becomes equal to the speed at which the CO_2 returns to the soda, and both processes proceed at the same rate.
- When two opposing processes occur at the same rate, the system is said to be in **equilibrium.**
- Since air the space in bottle **B** is smaller, the CO_2 molecules in the space are more crowded (concentrated) and equilibrium is reached sooner.
- As a result, bottle **A** goes flat faster.



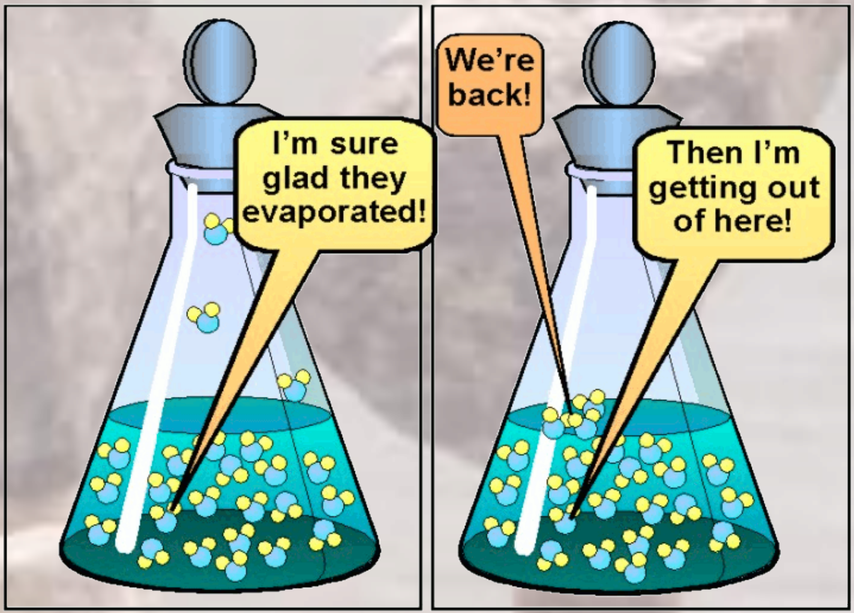
Sodas discuss equilibrium.

A DEFINITION

- **Equilibrium = forward and reverse reaction rates are equal in reversible systems.**
- Dynamic equilibrium = state of balance between two opposing activities.
  - The concentration of the reactants and the products remain constant despite the continuation of both the forward and reverse reactions.
  - The concentrations of reactants and products at equilibrium can be quite different.
- Equilibrium can be attained from either the forward or the reverse reaction.

Types of Equilibrium

- The types of equilibrium are:
  - Phase equilibrium
  - Solution equilibrium; and
  - Chemical equilibrium



The social dynamics of phase equilibrium

PHASE EQUILIBRIUM

- If you leave a closed, partly filled bottle of water in the sunlight, before long you will observe water droplets near the top of the bottle and in the neck. How did they get there?

  Evaporation and condensation. Changing phase is a reversible process.

- Since phase changes are reversible, in closed systems a state of equilibrium between phases can be reached.
  - When solids or liquids are confined in a container, equilibrium will be reached when there are enough particles of gas (vapor) to cause the rate of return to the original phase to be equal to the rate of escape.
  - This causes the characteristic vapor pressure of a substance at a given temperature.

SOLUTION EQUILIBRIUM

GASES IN LIQUIDS

- Dissolving a gas in a liquid means confining it to the space occupied by the liquid. This effects equilibrium. Consider what happens when you shake a warm soda and open it. **No more equilibrium!**
- In gas-liquid solutions, equilibrium is between the gas dissolved in the liquid and the undissolved gas above the liquid.

- Equilibrium of dissolved gases is affected by temperature and pressure:
  - Low temperature and high pressure favor solution of gases;
  - Carbonated beverages stay carbonated best when tightly closed and chilled.

MORE SOLUTION EQUILIBRIUM

SOLIDS IN LIQUIDS

- Solid added to a saturated solution will fall to the bottom instead of dissolving.

- In solid-liquid solutions, equilibrium is reached between undissolved solute and dissolved solute when the rate of dissolving equals the rate of crystallization.

CHEMICAL EQUILIBRIUM

WRITE DOWN

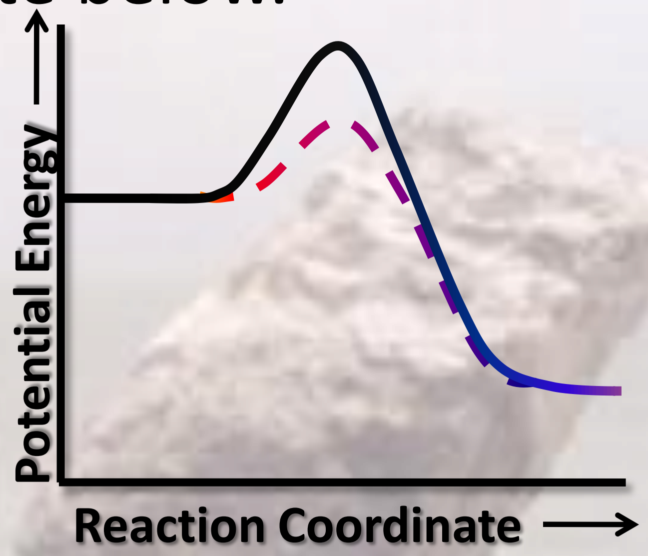
- Equilibrium occurs when forward and reverse reactions occur at equal rates.

$$\mathbf{A + B \rightleftharpoons C + D}$$

- At equilibrium, macroscopic or observable changes no longer occur (color, temperature, pressure, etc.)

Temperature's Effect on Equilibrium

- Examine the reaction coordinate below.
  - The activation energy of the reverse reaction is higher than that of the forward reaction.
  - As a result, temperature changes effect the rates of the forward and reverse reactions differently, changing equilibrium.



  - Increasing the temperature favors endothermic reactions because they need more energy for effective collisions than exothermic reactions do.
  - Decreasing the temperature favors exothermic reactions.

WRITE DOWN

Concentration's Effect on Equilibrium

- Increasing concentration increases reaction rates by increasing collisions.
  - Increasing pressure increases the concentration of gases.

WRITE DOWN

  - When the pressure changes, the relative number of moles of gaseous reactants and products (based on the balanced equation) effects the probability of collisions, effecting equilibrium.
  - Consider an increase in pressure for the reaction $N_2(g) + 3H_2(g) = 2NH_3(g)$
    - ✓ The number of moles of reactant is greater than the number of moles of product.
    - ✓ The number of effective collisions is increased more among reactant molecules than among product molecules at higher pressure, changing the equilibrium.