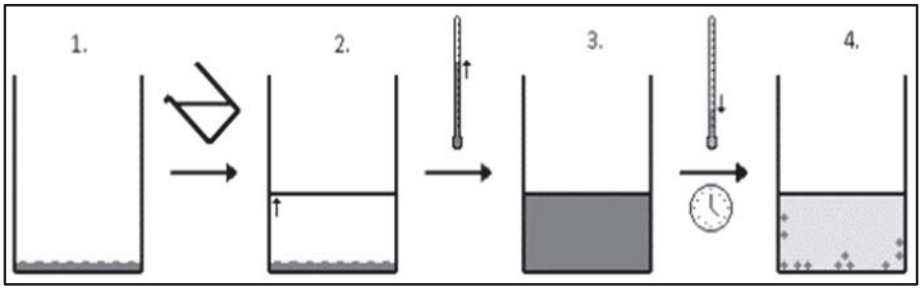
SATURATED SOLUTION

The solubility of a solute is defined as the maximum amount of the solute, measured in grams, that can dissolve in 100 g of a solvent at a specific temperature. A solution formed under these conditions is termed a saturated solution. A saturated solution represents the maximum concentration of a solute that can be held by the solvent at a given temperature. In a saturated solution, any additional solute introduced will not dissolve. The specific amount of solvent required to achieve saturation depends on various factors.



Examples of Saturated Solutions

Saturated solutions are encountered not only in chemistry classrooms but also in everyday life, with water not being the sole solvent.

- **Soda:** Carbon dioxide gas dissolved in water under pressure creates a saturated solution, leading to the formation of bubbles when pressure is released.
- **Chocolate Milk:** Adding chocolate powder to milk creates a saturated solution, causing it to become thick and preventing further dissolving.
- **Salted Butter or Oil:** Introducing salt to melted butter or oil to the point where salt grains no longer dissolve results in a saturated solution.
- **Sweetened Tea or Coffee:** Dissolving sugar in tea or coffee until reaching the saturation point is an example of a saturated solution. Hot beverages allow for more sugar to dissolve than cold ones.
- **Sugar and Vinegar:** Creating a saturated solution by adding sugar to vinegar

Unsaturated and super saturated Solution

Unsaturated Solution

An unsaturated solution permits the dissolution of additional solute at a specific temperature. In this scenario, the inclusion of solute is viable until the solution approaches the saturation threshold.

Example: Dissolving 5g, 10g, or 20g of NaCl in 100g of water illustrates an unsaturated solution.

Saturated Solution

A saturated solution denotes a state where no further solute can dissolve in a given amount of solvent at a designated temperature.

Example: Combining 36g of NaCl with 100g of water at room temperature results in the formation of a saturated solution.

Dynamic Equilibrium

Dynamic equilibrium refers to the state of a system where a reversible reaction has reached a point where the ratio of reactants to products remains constant. Despite this constancy, substances continue to move between reactants and products at an equal rate, resulting in no net change in the overall ratio.

Relevance in Physics and Chemistry

In the realms of Physics and Chemistry, dynamic equilibrium is prevalent in the aftermath of a reversible reaction. This equilibrium arises when the rates of the forward and reverse processes are identical, leading to a system that undergoes no observable changes. Once this equilibrium state is achieved, the concentrations or partial pressures of all species within the system remain stable.

Representation and Equilibrium Constants

Equilibrium constants for such systems are denoted through rate constants for both the forward and backward reactions. Systems in dynamic equilibrium serve as examples of systems in steady states, demonstrating a continuous balance between reactants and products.

Solubility of gas in a liquid

Gas, one of the fundamental states of matter alongside solids, liquids, and plasma, lacks a fixed shape. A pure gas can consist of individual atoms, such as neon (a noble gas), elemental molecules like oxygen, or compound molecules with diverse atoms, like carbon dioxide. Gas mixtures, akin to the composition of air, encompass various pure gases.

Unlike solids and liquids, gases exhibit no defined shape. The molecules within gases are interconnected by weak electrostatic forces or van der Waals forces. The arrangement of gas molecules is notably sparse compared to solids and liquids. This characteristic implies that gas molecules are situated at considerable distances from each other, connected by weak electrostatic forces or van der Waals forces.

Solubility of Gases

The term "solubility" refers to the utmost amount of solute that can be dissolved in a given quantity of solvent or solution, taking into account the specific temperature or pressure conditions (particularly applicable in the case of gaseous solutes). It represents the saturation point at which no more solute can be effectively incorporated into the solvent or solution under the defined environmental parameters.

Factors affecting the solubility of gases in liquids

Nature of gas and the nature of solvent

The Gases that exhibit high liquefaction tendencies tend to possess greater solubility compared to dihydrogen and dioxygen. Gases capable of engaging in chemical reactions with water generally demonstrate higher solubility in water than in other solvents. Examples of polar gases include ammonia (NH_3) and hydrogen sulfide (H_2S), while non-polar gases include diatomic gases such as O_2, H_2, N_2, and CO_2.

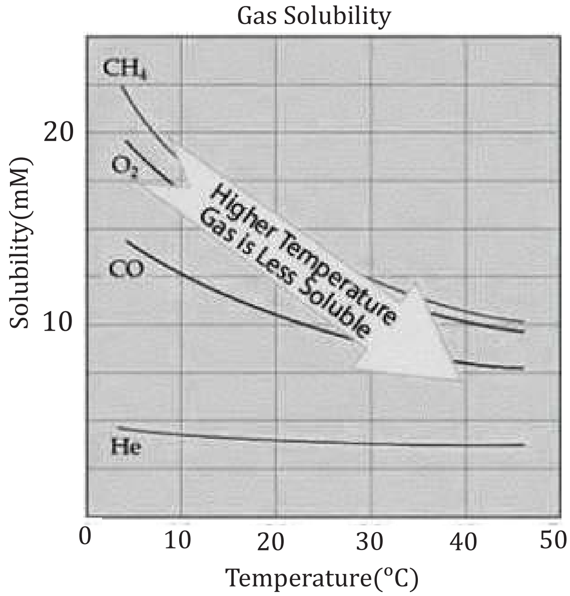
Effect of Nature of Gas on Solubility

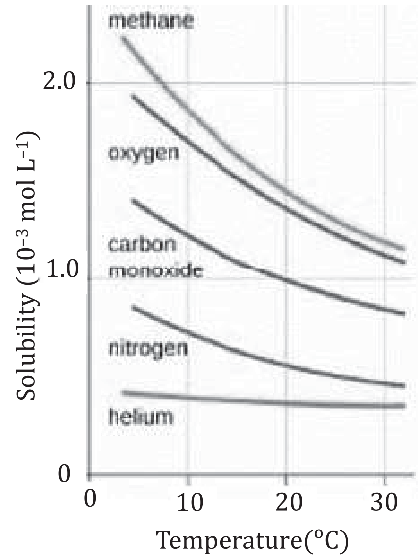
(i) Polar gases are more soluble in polar solvent like water.

(ii) Non-polar gases like O_2, have less solubility in polar solvent.

Effect of Temperature

For gases, solubility diminishes with rising temperatures. This is attributed to the exothermic nature of the dissolution process, where heat is released. Elevated temperatures result in higher kinetic energy, intensifying the motion of gas molecules. This increased motion disrupts intermolecular bonds, facilitating the return of gas molecules to the gas phase. Consequently, an increase in temperature leads to a decrease in the solubility of gases.





Figures showing the effect of temperature on the solubility of gases

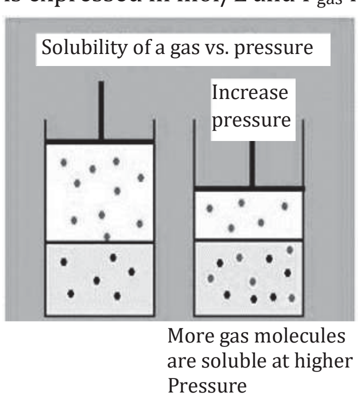
Effect of Pressure

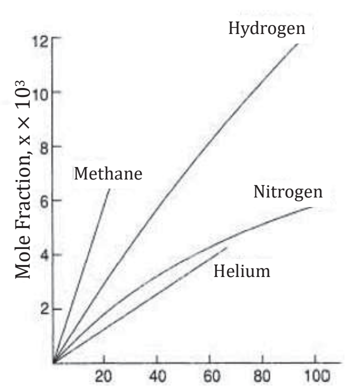
Solubility in liquids and solids remains unaffected by changes in pressure, while gases exhibit a notable increase in solubility under elevated pressure. Consider a scenario with a piston tank containing a gas above a saturated aqueous solution of the gas. In equilibrium, at a specific pressure, an equal number of gas molecules enter and exit the solution per unit time. If the piston is compressed, upsetting this equilibrium, the gas volume above the aqueous solution decreases, but the gas pressure rises. This results in more frequent collisions of gas particles with the surface of the solution, leading to an increased entry of particles into the solution per unit time. The system responds by dissolving more gas to alleviate this disturbance until a new equilibrium is established.

Henry's Law articulates that the solubility (S_{gas}) of a gas in a liquid is directly linked to the partial pressure (P_{gas}) of the gas above the solution's surface. This law establishes a quantitative correlation between gas pressure and solubility.

$$S_{gas} = k_H \text{ X } P_{gas}$$

k_H is Henry's law constant. It is specific for a given gas- solvent combination at a given temperature. S_{gas} is expressed in mol/L and P_{gas} in atm, the units of k_H are mol/L/atm.





Graph showing the relationship between solubility (in mole fraction) and pressure of gases.

Application of Henery's Law

(i) In order to enhance the solubility of CO_2 in soda water and soft drinks, the bottle is tightly sealed at elevated pressure.

(ii) Scuba diver tanks are filled with air that is mixed with helium to prevent the harmful effects of a high concentration of nitrogen in the bloodstream.

Solubility - Effect of Pressure

The dissolvability of gases is contingent on pressure levels; elevated pressure augments solubility, while reduced pressure diminishes solubility. This principle is encapsulated in Henry's Law, affirming that the solubility of a gas within a liquid is directly correlated with the pressure exerted by that gas above the solution's surface.

This can be expressed in the equation:

$$C = K \times P_{gas}$$

Variable represents:

C = the solubility of a gas in solvent

K = the proportionality constant

Pgas = the partial pressure of the gas above the solution