Solvent

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A **solvent** is a liquid that dissolves a solid, liquid, or gaseous solute, resulting in a solution. The most common solvent in everyday life is water. Most other commonly-used solvents are organic (carbon-containing) chemicals. These are called **organic solvents**. Solvents usually have a low boiling point and evaporate easily or can be removed by distillation, leaving the dissolved substance behind. Solvents should therefore not react chemically with the dissolved compounds — they must be inert. Solvents can also be used to extract soluble compounds from a mixture, the most common example is the brewing of coffee or tea with hot water. Solvents are usually clear and colorless liquids and many have a characteristic odor. The concentration of a solution is the amount of compound that is dissolved in a certain volume of solvent. The **solubility** is the maximal amount of compound that is soluble in a certain volume of solvent at a specified temperature.

Common uses for organic solvents are in dry cleaning (e.g. tetrachloroethylene), as paint thinners (e.g. toluene, turpentine), as nail polish removers and glue solvents (acetone, methyl acetate, ethyl acetate), in spot removers (e.g. hexane, petrol ether), in detergents (citrus terpenes), in perfumes (ethanol), and in chemical syntheses. The use of inorganic solvents (other than water) is typically limited to research chemistry and some technological processes.

Contents

Protic and aprotic solvents

Polar solvents can be further subdivided into polar protic solvents and polar aprotic solvents. A polar protic solvent is one that contains an O-H or N-H bond. A polar aprotic solvent is one that does not contain an O-H or N-H bond. Water (H-O-H), ethanol (CH_3-CH_2-OH), or acetic acid (CH_3-C(=O)OH) are representative polar protic solvents. A polar aprotic solvent is acetone (CH_3-C(=O)-CH_3). In chemical reactions the use of polar protic solvents favors the S_N1 reaction mechanism, while polar aprotic solvents favor the S_N2 reaction mechanism.

Polarity, solubility, and miscibility

Solvents and solutes can be broadly classified into *polar* (hydrophilic) and *non-polar* (lipophilic). The polarity can be measured as the dielectric constant or the dipole moment of a compound. The polarity of a solvent determines what type of compounds it is able to dissolve and with what other solvents or liquid compounds it is miscible. As a rule of thumb, polar solvents dissolve polar compounds best and non-polar solvents dissolve non-polar compounds best: "like dissolves like". Strongly polar compounds like inorganic salts (e.g. table salt) or sugars (e.g. sucrose) dissolve only in very polar solvents like water, while strongly non-polar compounds like oils or waxes dissolve only in very non-polar organic solvents like hexane. Similarly, water and hexane (or vinegar and vegetable oil) are not miscible with each other and will quickly separate into two layers even after being shaken well.

Boiling point

Another important property of solvents is boiling point. This also determines the speed of evaporation. Small amounts of low-boiling solvents like diethyl ether, dichloromethane, or acetone will evaporate in seconds at room temperature, while high-boiling solvents like water or dimethyl sulfoxide need higher temperatures, an air flow, or the application of vacuum for fast evaporation.

Density

Most organic solvents have a lower density than water, which means they are lighter and will form a separate layer on top of water. An important exception: many halogenated solvents like dichloromethane or chloroform will sink to the bottom of a container, leaving water as the top layer. This is important to remember when partitioning compounds between solvents and water in a separatory funnel during chemical syntheses.

Chemical interactions

A solvent will create various weak chemical interactions with the solute to solubilize the solute. The most usual of these interactions are the relatively weak van der Waals interactions (induced dipole interactions), the stronger dipole-dipole interactions, and even the strongest interaction, hydrogen bonds (interaction between O-H or N-H hydrogens with adjacent O or N atoms).

Health and Safety

Fire

Most organic solvents are flammable or highly flammable, depending on their volatility. Exceptions are some chlorinated solvents like dichloromethane and chloroform. Mixtures of solvent vapors and air can explode. Solvent vapors are heavier than air, they will sink to the bottom and can travel large distances nearly undiluted. Solvent vapors can also be found in supposedly empty drums and cans, posing a flash fire hazard; hence empty containers of volatile solvents should be stored open and upside down.

Both diethyl ether and carbon disulphide have exceptionally low autoignition temperatures which increase greatly the fire risk associated with these solvents. The autoignition temperature of carbon disulphide is below 100°C (212°F), so as a result objects such as steam pipes, light bulbs, hotplates and recently extinguished bunsen burners are able to ignite its vapours.

Peroxide formation

Ethers like diethyl ether and tetrahydrofuran (THF) can form highly explosive organic peroxides upon exposure to oxygen and light, THF is normally more able to form such peroxides than diethyl ether. One of the most susceptible solvents is diisopropyl ether.

The heteroatom (oxygen) stabilizes the formation of a free radical which is formed by the abstraction of a hydrogen atom by another free radical. The carbon centred free radical thus formed is able to react with an oxygen molecule to form a peroxide compound. A range of tests can be used to detect the presence of a peroxide in an ether, one is to use a combination of iron sulphate and potassium thiocyanate. The peroxide is able to oxidize the ferrous ion to a ferric ion which then form a deep red coordination complex with the thiocyanate. In extreme cases the peroxides can form crystalline solids within the vessel of the ether.

Unless the desiccant used can destroy the peroxides, they will concentrate during distillation due to their higher boiling point. When sufficient peroxides have formed, they can form a crystalline and shock sensitive solid which precipitates. When this solid is formed at the mouth of the bottle, turning the cap may provide sufficient energy for the peroxide to detonate. Peroxide formation is not a significant problem when solvents are used up quickly; they are more of a problem for laboratories which take years to finish a single bottle. Ethers have to be stored in the dark in closed canisters in the presence of stabilizers like butylated hydroxytoluene (BHT) or over sodium hydroxide.

Peroxides may be removed by washing with acidic ferrous sulphate, filtering through alumina, or distilling from sodium/benzophenone. Alumina does not destroy the peroxides; it merely traps them. The advantage of using sodium/benzophenone is that moisture and oxygen is removed as well.

Health effects

Many solvents can lead to a sudden loss of consciousness if inhaled in large amounts. Solvents like diethyl ether and chloroform have been used in medicine as anesthetics, sedatives, and hypnotics for a long time. Ethanol is a widely used and abused psychoactive drug. Diethyl ether, chloroform, and many other solvents (e.g. from gasoline or glues) are used recreationally in glue sniffing, often with harmful long term health effects like neurotoxicity or cancer. Methanol can cause internal damage to the eyes, including permanent blindness.

It is interesting to note that ethanol has a synergistic effect when taken in combination with many solvents. For instance a combination of toluene/benzene and ethanol causes greater nausea/vomiting than either substance alone. Many chemists make a point of not drinking beer/wine/other alcoholic drinks if they know that they have been exposed to an aromatic solvent.

Environmental contamination

A major pathway to induce health effects arises from spills or leaks of solvents that reach the underlying soil. Since solvents readily migrate substantial distances, the creation of widespread soil contamination is not uncommon; there may be about 5000 sites worldwide that have major subsurface solvent contamination; this is particularly a health risk if aquifers are affected.

Chronic health effects

Some solvents including chloroform and benzene (an ingredient of gasoline) are carcinogenic. Many others can damage internal organs like the liver, the kidneys, or the brain.

General precautions

- Avoiding being exposed to solvent vapors by working in a fume hood, or with local exhaust ventilation (LEV), or in a well ventilated area
- Keeping the storage containers tightly closed
- Never using open flames near flammable solvents, use electrical heating instead
- Never flush flammable solvents down the drain, read safety data sheets for proper disposal information
- Avoiding the inhalation of solvent vapors
- Avoiding contact of the solvent with the skin — many solvents are easily absorbed through the skin. They also tend to dry the skin and may cause sores and wounds.

Properties table of common solvents

The solvents are grouped into non-polar, polar aprotic, and polar protic solvents and ordered by increasing polarity. The polarity is given as the dielectric constant. The density of nonpolar solvents that are heavier than water is bolded.

Solvent	Chemical Formula	Boiling point	Dielectric constant	Density
Non-Polar Solvents				
Hexane	CH_3-CH_2-CH_2-CH_2-CH_2-CH_3	69 °C	2.0	0.655 g/ml
Benzene	C_6H_6	80 °C	2.3	0.879 g/ml
Toluene	C_6H_5-CH_3	111 °C	2.4	0.867 g/ml
Diethyl ether	CH_3CH_2-O-CH_2-CH_3	35 °C	4.3	0.713 g/ml
Chloroform	$CHCl_3$	61 °C	4.8	**1.498 g/ml**

Ethyl acetate	$\text{CH}_3\text{-C(=O)-O-CH}_2\text{-CH}_3$	77 °C	6.0	0.894 g/ml
Polar Aprotic Solvents				
1,4-Dioxane	$\text{/-CH}_2\text{-CH}_2\text{-O-CH}_2\text{-CH}_2\text{-O-}\backslash$	101 °C	2.3	**1.033 g/ml**
Tetrahydrofuran (THF)	$\text{/-CH}_2\text{-CH}_2\text{-O-CH}_2\text{-CH}_2\text{-}\backslash$	66 °C	7.5	0.886 g/ml
Dichloromethane (DCM)	CH_2Cl_2	40 °C	9.1	**1.326 g/ml**
Acetone	$\text{CH}_3\text{-C(=O)-CH}_3$	56 °C	21	0.786 g/ml
Acetonitrile (MeCN)	$\text{CH}_3\text{-C}\equiv\text{N}$	82 °C	37	0.786 g/ml
Dimethylformamide (DMF)	$\text{H-C(=O)N(CH}_3)_2$	153 °C	38	0.944 g/ml
Dimethyl sulfoxide (DMSO)	$\text{CH}_3\text{-S(=O)-CH}_3$	189 °C	47	**1.092 g/ml**
Polar Protic Solvents				
Acetic acid	$\text{CH}_3\text{-C(=O)OH}$	118 °C	6.2	**1.049 g/ml**
n-Butanol	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-OH}$	118 °C	18	0.810 g/ml
Isopropanol (IPA)	$\text{CH}_3\text{-CH(-OH)-CH}_3$	82 °C	18	0.785 g/ml
n-Propanol	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-OH}$	97 °C	20	0.803 g/ml
Ethanol	$\text{CH}_3\text{-CH}_2\text{-OH}$	79 °C	24	0.789 g/ml
Methanol	$\text{CH}_3\text{-OH}$	65 °C	33	0.791 g/ml
Formic acid	H-C(=O)OH	100 °C	58	**1.21 g/ml**
Water	H-O-H	100 °C	80	1.000 g/ml

See also

- Partition coefficient (log *P*) is a measure of differential solubility of a compound in two solvents
- Solvent systems exist outside the realm of ordinary organic solvents: Supercritical fluids, ionic liquids and deep eutectic solvents

- Water pollution
- Solvents are often refluxed with an appropriate desiccant prior to distillation to remove water
- Occupational health

External links

- Table (http://www.speckanalytical.co.uk/products/Tips/bps.html) Properties of common organic solvents
- Table and text (http://www.usm.maine.edu/~newton/Chy251_253/Lectures/Solvents/Solvents.html) O-Chem Lecture
- Tables (http://virtual.yosemite.cc.ca.us/smurov/orgsoltab.htm) Properties and toxicities of organic solvents
- Miscibility Table (http://www.phenomenex.com/phen/Doc/z366.pdf) Phenomex Solvent Miscibility Table (includes Polarity Index)
- Miscibility Table (http://www.gls.co.jp/english/pdf/83.PDF) GLS Solvent Miscibility Table (includes Dielectric Constant)

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