Lecture 5

Absorption and stripping of dilute mixtures

In absorption (also called gas absorption, gas scrubbing, and gas washing), a gas mixture is contacted with a liquid (the absorbent or solvent) to selectively dissolve one or more components by mass transfer from the gas to the liquid. The components transferred to the liquid are referred to as solutes or absorbate. Absorption is used to separate gas mixtures; remove impurities, contaminants, pollutants, or catalyst poisons from a gas; or recover valuable chemicals. Thus, the species of interest in the gas mixture may be all components, only the component(s) not transferred, or only the component(s) transferred.

The opposite of absorption is stripping (also called desorption), wherein a liquid mixture is contacted with a gas to selectively remove components by mass transfer from the liquid to the gas phase.

A typical absorption operation is shown in Figure 1. The feed, which contains air (21% 02, 78% N2, and 1% Ar), water vapor, and acetone vapor, is the gas leaving a dryer where solid cellulose acetate fibers, wet with water and acetone, are dried. The purpose of the 30-tray (equivalent to 10 equilibrium stages) absorber is to remove the acetone by contacting the gas with a suitable absorbent, water. By using countercurrent flow of gas and liquid in a multiple-stage device, the material balance, shown in Figure 1, indicates that 99.5% of the acetone is absorbed. The gas leaving the absorber contains only 143 ppm (parts per million) by weight of acetone vapor and can be recycled to the dryer or exhausted to the atmosphere. Although the major component transferred between phases is acetone, the material balance indicates that small amounts of oxygen and nitrogen are also absorbed by the water solvent. Because water is present in both the feed gas and the absorbent, it can be both absorbed and stripped. As seen in Figure 6.1, the net effect is that water is stripped because more water appears in the exit gas than in the feed gas. The exit gas is almost saturated with water vapor and the exit liquid is almost saturated with air. The temperature of the absorbent decreases by 3°C to supply the energy of vaporization needed to strip the water, which in this example is greater than the energy of condensation liberated from the absorption of acetone.

Absorption and stripping are technically mature separation operations. Design procedures are well developed and commercial processes are common. Table 1 lists representative, commercial absorption applications. In most cases, the solutes are contained in gaseous effluents from chemical reactors. Passage of strict environmental standards with respect to pollution by emission of noxious gases has greatly increased the use of gas absorbers in the past decade.

When water and hydrocarbon oils are used as absorbents, no significant chemical reactions occur between the absorbent and the solute, and the process is commonly referred to as physical absorption. When aqueous sodium hydroxide (a strong base) is used as the absorbent to dissolve an acid gas, absorption is accompanied by a rapid and irreversible neutralization reaction in the liquid phase and the process is referred to as chemical absorption or reactive absorption. More complex examples of chemical absorption are processes for absorbing CO2 and H2S with aqueous solutions of monoethanolamine (MEA) and diethanolamine (DEA), where a reversible chemical reaction takes place in the liquid phase. Chemical reactions can increase the rate of absorption, increase the absorption capacity of the solvent, increase selectivity to preferentially dissolve only certain components of the gas, and convert a hazardous chemical to a safe compound.

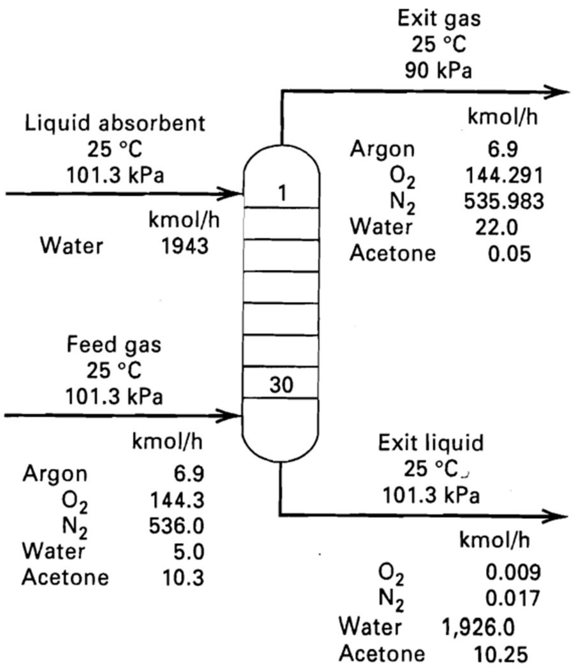

Figure 1 - Typical absorption process

Table 1 - Representative, Commercial Applications of Absorption

Solute	Absorbent	Type of Absorption
Acetone	Water	Physical
Acrylonitrile	Water	Physical
Ammonia	Water	Physical
Ethanol	Water	Physical
Formaldehyde	Water	Physical
Hydrochloric acid	Water	Physical
Hydrofluoric acid	Water	Physical
Sulfur dioxide	Water	Physical
Sulfur trioxide	Water	Physical
Benzene and toluene	Hydrocarbon oil	Physical
Butadiene	Hydrocarbon oil	Physical
Butanes and propane	Hydrocarbon oil	Physical
Naphthalene	Hydrocarbon oil	Physical
Carbon dioxide	Aq. NaOH	Irreversible chemical
Hydrochloric acid	Aq. NaOH	Irreversible chemical
Hydrocyanic acid	Aq. NaOH	Irreversible chemical
Hydrofluoric acid	Aq. NaOH	Irreversible chemical
Hydrogen sulfide	Aq. NaOH	Irreversible chemical
Chlorine	Water	Reversible chemical
Carbon monoxide	Aq. cuprous ammonium salts	Reversible chemical
CO_2 and H_2S	Aq. monoethanolamine (MEA) or diethanolamine (DEA)	Reversible chemical
CO_2 and H_2S	Diethyleneglycol (DEG) or triethyleneglycol (TEG)	Reversible chemical
Nitrogen oxides	Water	Reversible chemical