5 Ultrafiltration

In 1907, Bechold introduced the term ultrafiltration, forcing solutions at pressures up to several atmospheres through membranes prepared by impregnating filter paper with acetic acid collodion. Ultrafiltration (UF) is a variety of membrane filtration in which hydrostatic pressure forces a liquid against a semipermeable membrane. This is an important separation technology used for the production of high purity water in the food and beverage, biochemical and biopharmaceutical industries. Ultrafiltration has the unique ability to purify, separate, and concentrate target macromolecules in continuous systems. In ultrafiltration, suspended solids and solutes of high molecular weight ($10^3 - 10^6$ Da) are retained, while water and low molecular weight solutes pass through the membrane. However, ultrafiltration is not fundamentally different from reverse osmosis, microfiltration or nanofiltration, except in terms of the size of the molecules it retains. In this way, ultrafiltration covers the zone between the other two processes (RO and MF); the particles retained range from small macromolecules (molecular weight 500) upto colloidal particle with a diameter of 0.2 µm.

5.1 BASIC PRINCIPLE OF ULTRAFILTRATION

Ultrafiltration is a pressure driven membrane separation process in which water and low molecular weight substances permeate through a membrane while particles, colloids, and macromolecules are retained. The primary removal mechanism is size exclusion, although the electrical charge and surface chemistry of the particles or membrane may affect the purification efficiency. Ultrafiltration pore ratings range from approximately 1000 to 500,000 Da, thereby making UF more permeable than nanofiltration (200 to 1000 Da). Since only high molecular weight species are removed in UF, the osmotic pressure differential across the membrane surface is negligible. Low applied pressures are, therefore, sufficient to achieve high flux rates from an ultrafiltration membrane. In conventional ultrafiltration configurations, the process solution is pressurized, typically between 10 to 70 psi, while in contact with a supported semipermeable membrane. Solutes smaller than the molecular weight cut off (MWCO) emerge as ultrafiltrate, and retained molecules are concentrated on the pressurized side of the membrane. Pressure sources such as compressed gas (nitrogen) and peristaltic pump systems are commonly used. The process is depicted in Figure 5.1.

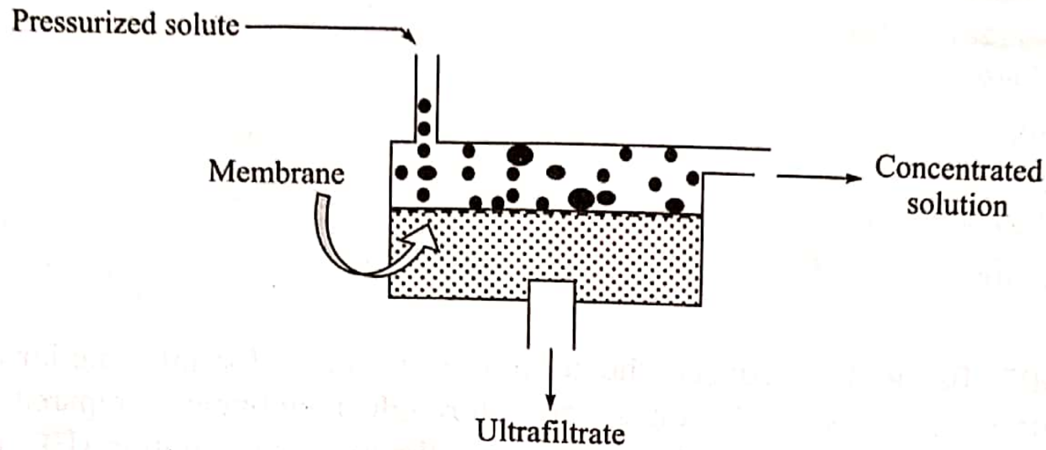

Figure 5.1 Basic system of ultrafiltration.

5.1.1 Advantages of Ultrafiltration

Ultrafiltration offers the following advantages for industrial application:

1. The process can be carried out at ambient temperature, thus avoiding thermal as well as oxidative degradation of the product. However, in such cases solute diffusion coefficient is temperature dependent.
2. Ultrafiltration permits the removal of water upto 90% at ambient temperature.
3. Since there is no phase change, breaking of emulsions, collapse of gels and mechanical damage associated with freeing do not occur.
4. No solvents or other precipitating agents are required for the concentrating process.

A summary of ultrafiltration process is given in Table 5.1.

Table 5.1 Some basic information on ultrafiltration

Driving force	Pressure gradient (1 to 10 bar)
Transport mechanism	Pore flow
Separation principle	Sieving (or size exclusion)
Size of the retained species	10 to 100 Å
Type of membrane	Asymmetric porous, composite
Membrane materials	polysulphone, polyethersulphone, polyvinidilene fluoride, polyacrilonitrile, polyimide, aliphatic polyamides, cellulosic, ceramic.
Pore size	1 – 100 nm (inorganic ions 10 to 100 MW: 0.2 – 0.4 nm)
Flux	50 – 1000 l/m²/h
Energy consumption	10 – 150 W/m³