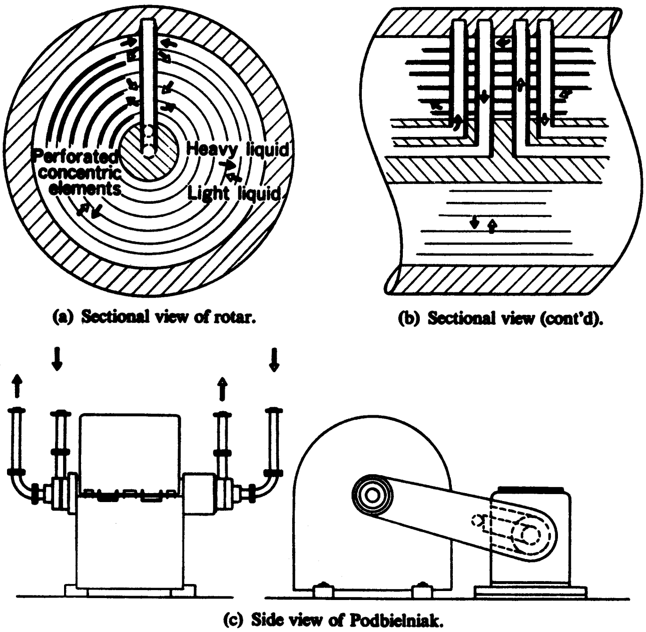


**Figure 11.11.** Liquid-liquid extraction equipment (Podbielniak). Bold arrow indicates heavy liquid flow, while open arrow represents the flow of a mixture or light liquid. (With permission, from S. Aiba, A. E. Humphrey, and N. F. Millis, *Biochemical Engineering*, 2d ed., University of Tokyo Press, Tokyo, 1973.)

where $K_D^{AP}$ is the apparent distribution coefficient, $K_D^0$ is the distribution coefficient for neutral species, and $K_1$ is the dissociation equilibrium constant for weak acids or bases.

A particularly important device for liquid–liquid extraction for fermentation products is the Podbielniak centrifugal extractor (see Fig. 11.11). Many fermentation products are unstable (e.g., penicillin). The use of mixer–settlers can be problematic, because the residence time of the product in the pH-adjusted broth is too long. The rapid rotation of the Podbielniak extractor produces a centrifugal field that rapidly drives the two fluids countercurrent to each other, as depicted in Fig. 11.11. A product can be extracted and returned to another aqueous phase (e.g., a phosphate buffer) within minutes.

**Example 11.2.**

Penicillin is extracted from a fermentation broth using isoamylacetate as the organic solvent in a continuous countercurrent cascade extraction unit. The flow rates of organic ($L$) and aqueous ($H$) phases are $L = 10$ l/min and $H = 100$ l/min, respectively. The distribution coefficient of penicillin between organic and aqueous phases at pH = 3 is $K_D = Y_L/X_H = 50$. If the penicillin concentration in the feed stream is 20 g/l, determine the number of stages required to reduce the penicillin concentration to 0.1 g/l in the effluent of the extraction unit.

**Solution**

$$E = \frac{LK_D}{H} = \frac{(10)(50)}{(100)} = 5$$

$$\frac{X_n}{X_0} = \frac{0.1}{20} = 5 \times 10^{-3}$$

Using Fig. 11.9, we can obtain $n = 4$. If a Podbielniak centrifugal extractor were used, it would have to correspond to four ideal stages.