Freezing-Point Depression

The freezing point of a 1 *m* solution of any nonelectrolyte solute in water is found by experiment to be 1.86°C lower than the freezing point of water. That is, when 1 mol of a nonelectrolyte solute is dissolved in 1 kg of water, the freezing point of the solution is –1.86°C instead of 0.00°C. When 2 mol of a nonelectrolyte solute is dissolved in 1 kg of water, the freezing point of the solution is –3.72°C. This is 2 × (–1.86°C). In fact, for any concentration of a nonelectrolyte solute in water, the decrease in freezing point can be estimated by using the value of –1.86°C/*m*. This value, called the **molal freezing-point constant** (K_f) *is the freezing-point depression of the solvent in a 1-molal solution of a nonvolatile, nonelectrolyte solute.*

Each solvent has its own characteristic molal freezing-point constant. The values of K_f for some common solvents are given in **Table 2.** These values are most accurate for dilute solutions at 1 atmosphere of pressure. Some variations are introduced in the value of K_f at other pressures and with more-concentrated solutions. The table also shows the values of a related quantity called K_b, which you will study next.

As stated earlier, the freezing point of a solution containing 1 mol of a nonelectrolyte solute in 1 kg water is 1.86°C lower than the normal freezing point of water. *The* **freezing-point depression,** Δt_f, *is the difference between the freezing points of the pure solvent and a solution of a nonelectrolyte in that solvent, and it is directly proportional to the molal concentration of the solution.* As shown by the previous example, if the molal concentration is doubled, the freezing-point depression is doubled. Freezing-point depression can be calculated by the following equation.

$$\Delta t_f = K_f m$$

K_f is expressed as °C/*m*, *m* is expressed in mol solute/kg solvent (molality), and Δt_f is expressed in °C. Sample Problems C and D show how this relationship can be used to determine the freezing-point depression and molal concentration of a solution.

TABLE 2 ***Molal Freezing-Point and Boiling-Point Constants***

Solvent	Normal f.p. (°C)	Molal f.p. constant, K_f (°C/*m*)	Normal b.p. (°C)	Molal b.p. constant, K_b (°C/*m*)
Acetic acid	16.6	–3.90	117.9	3.07
Camphor	178.8	–39.7	207.4	5.61
Ether	–116.3	–1.79	34.6	2.02
Naphthalene	80.2	–6.94	217.7	5.80
Phenol	40.9	–7.40	181.8	3.60
Water	0.00	–1.86	100.0	0.51