16

ved solute to crystallize
ɔlve are equal, what two
prevail? (d) The solution
l its temperature rises.
:lier principle and deter-
ssolving or crystallizing,
ıe rise in temperature.
ıbility of a solute with a
ɔlution ordinarily influ-
temperature of its solu-
42n
solution of lithium chlo-
at of solution (Table 13-3)
. (a) Of the two solution
g and *crystallizing*, which
vhich is *exothermic?* (b) As
s and solution concentra-
at change occurs in the
re? (c) When the rates for
crystallize and crystals to
what two solution condi-
he solution is now heated
ıre rises. Apply the Le
e and determine which
crystallizing, is increased
perature. (e) How is the
te with a negative heat of
l by a rise in temperature
A2c, A2g, A2n
CH_3OH, and water are
portions. When 1 mole of
; mixed with 10 moles of
: heat of solution is found
ı) Is the formation of solu-
by an increase or decrease
the argument upon which
sed.) (b) Does the change
ıe separate components or
ls the dissolving process
othermic? Justify your an-
e energy change as indi-
ı of the heat of solution

GROUP A

1. What mass in grams of sucrose, $C_{12}H_{22}O_{11}$, must be dissolved in $200\bar{0}$ g of water to yield a 0.100-*m* solution? *A20, B1*
2. What quantity of ethanol, C_2H_5OH, is required to prepare a 0.225-*m* solution in $25\bar{0}$ g of water? *A20, B1*
3. Determine the molality of a solution containing 42.0 g of glycerol, $C_3H_5(OH)_3$, in $75\bar{0}$ g of water. *A20, B1*
4. A solution of glucose, $C_6H_{12}O_6$, is prepared by dissolving 8.50 g of the glucose in $40\bar{0}$ g of water. What is the molality? *A20, B1*
5. A solution contains 85.0 g of methanol, CH_3OH, in $300\bar{0}$ g of water. Calculate the molality of the solution. *A20, B1*
6. Determine the molality of a solution containing 1.50 g of I_2 (solute) in $45\bar{0}$ g of CCl_4 (solvent). *A20, B1*
7. How many grams of water must be added to 45.0 g of glucose, $C_6H_{12}O_6$, to form a 0.250-*m* solution? *A20, B1*
8. A 0.400-*m* solution of naphthalene, $C_{10}H_8$, in benzene, C_6H_6, is required. If 30.0 g of naphthalene is available, how many grams of benzene must be used? *A20, B1*
9. What is the molality of a solution that contains 25.0 g of ethylene glycol, $C_2H_4(OH)_2$, in $10\bar{0}$ g of water? *A20, B1*
10. What is the freezing point of 250.0 g of water containing 12.5 g of a nonelectrolyte that has a molecular weight of 180? *B2*
11. A solution consists of 15 g sucrose, $C_{12}H_{22}O_{11}$, in $25\bar{0}$ g of water. What is the freezing point of the water? *B2*
12. What is the boiling point of the solution described in Problem 11? *B2*
13. A solution of iodine in benzene is found to have a freezing point of 4.1 °C. What is the molality of the solution? *A20, B1, B2*
14. A sucrose-in-water solution raises the boiling point of the solvent to 100.13 °C at standard pressure. Determine the molality of the solution. *A20, B1, B2*

PROBLEMS

GROUP B

15. A compound contains: carbon, 40.00%; hydrogen, 6.67%; oxygen, 53.33%. Tests show that 18.0 g of the compound dissolved in 1.00 kg of water raises the boiling point of the water 0.051 C°. (a) Determine the empirical formula. (b) Determine its molecular weight. (c) What is the molecular formula? *B2, B3*
16. The analysis of a compound yields: carbon, 32.0%; hydrogen, 4.0%; oxygen, 64.0%. It is found that 12.0 g of the compound added to $80\bar{0}$ g of water lowers the freezing point of the water 0.186 C°. (a) Determine the empirical formula. (b) Determine the molecular weight. (c) What is the molecular formula? *B2, B3*
17. By analysis, a compound consists of: carbon, 30.3%; hydrogen, 1.7%; bromine, 68%. The substance is soluble in benzene and 15.0 g of it lowers the freezing point of 150.0 g of benzene 2.1 C°. (a) What is the empirical formula of the solute? (b) Determine its molecular weight. (c) What is the molecular formula? *B2, B3*
18. Calculate the freezing point of an aqueous solution that boils at 100.46 °C at SP. *B1, B2, B3*

... the addition of a small amount of some molecular solute. The freezing-point depression of the water is 0.36 C°.

$$\Delta T_f = 0.36\ C°$$

The depression of the freezing point of water has been calculated for a 1-molal solution of any molecular solute in water. It has the constant value of 1.86 C°. *This freezing-point depression for a 1-molal water solution is called the **molal freezing-point constant**, K_f, for water.* It is 1.86 C°/molal. Since

$$\text{molality} = \frac{\text{moles solute}}{\text{kg solvent}}$$

K_f has the dimensions $\frac{C°}{\text{mole solute/kg solvent}}$. The molal freezing-point constant for water is

$$K_f = \frac{1.86\ C°}{\text{molal}} = \frac{1.86\ C°}{\text{mole solute/kg } H_2O}$$

According to this value of K_f, a molecular solute added to 1 kg of water should lower the freezing point 1.86 C° per mole of solute dissolved. However, this relation holds experimentally only for dilute solutions. Even a 1-molal solution is concentrated enough so that the freezing-point depression is somewhat less than 1.86 C°. All solvents have their own characteristic molal freezing-point constants. The values of K_f for some common solvents are given in Table 13-5.

The depression of the freezing point of the solvent in a dilute solution of a molecular solute is *directly proportional* to the molal

Table 13-5
MOLAL FREEZING-POINT AND BOILING-POINT CONSTANTS

Solvent	*Normal f.p.* (°C)	*Molal f.p. constant, K_f* (C°/molal)	*Normal b.p.* (°C)	*Molal b.p. constant, K_b* (C°/molal)
acetic acid	16.6	3.90	118.5	3.07
acetone	−94.8	—	56.00	1.71
aniline	−6.1	5.87	184.4	3.22
benzene	5.48	5.12	80.15	2.53
carbon disulfide	−111.5	3.80	46.3	2.34
carbon tetrachloride	−22.96	—	76.50	5.03
ethanol	−114.5	—	78.26	1.22
ether	−116.3	1.79	34.42	2.02
naphthalene	80.2	6.9	218.0	5.65
phenol	40.9	7.27	181.8	3.56
water	0.00	1.86	100.0	0.51