***Chemistry***

**11: Solutions and Colloids**

**11.4: Colligative Properties**

27. What is the microscopic explanation for the macroscopic behavior illustrated in Figure 11.16?

Solution

The strength of the bonds between like molecules is stronger than the strength between unlike molecules. Therefore, some regions will exist in which the water molecules will exclude oil molecules and other regions will exist in which oil molecules will exclude water molecules, forming a heterogeneous region.

29. A solution of potassium nitrate, an electrolyte, and a solution of glycerin (C3H5(OH)3), a nonelectrolyte, both boil at 100.3 °C. What other physical properties of the two solutions are identical?

Solution

Both form homogeneous solutions; their boiling point elevations are the same, as are their lowering of vapor pressures. Osmotic pressure and the lowering of the freezing point are also the same for both solutions.

31. What are the mole fractions of HNO3 and water in a concentrated solution of nitric acid (68.0% HNO3 by mass)?

(a) Outline the steps necessary to answer the question.

(b) Answer the question.

Solution

(a) Find number of moles of HNO3 and H2O in 100 g of the solution. Find the mole fractions for the components.

(b) The number of moles of HNO3 is . The number of moles of water is . The mole fraction of HNO3 is . The mole fraction of H2O is 1 − 0.378 = 0.622.

33. Calculate the mole fraction of each solute and solvent:

(a) 0.710 kg of sodium carbonate (washing soda), Na2CO3, in 10.0 kg of water—a saturated solution at 0 °C

(b) 125 g of NH4NO3 in 275 g of water—a mixture used to make an instant ice pack

(c) 25 g of Cl2 in 125 g of dichloromethane, CH2Cl2

(d) 0.372 g of tetrahydropyridine, C5H9N, in 125 g of chloroform, CHCl3

Solution

(a)



Total number of moles = 555.08 mol + 6.70 mol = 561.78 mol



(b)



Total number of moles = 15.26 mol + 1.56 mol = 16.82 mol



(c)



Total number of moles = 1.47 mol + 0.35 mol = 1.82 mol



(d)



Total number of moles = 1.047 mol + 0.00447 mol = 1.05 mol



35. What is the difference between a 1 *M* solution and a 1 *m* solution?

Solution

In a 1 *M* solution, the mole is contained in exactly 1 L of solution. In a 1 *m* solution, the mole is contained in exactly 1 kg of solvent.

37. What is the molality of nitric acid in a concentrated solution of nitric acid (68.0% HNO3 by mass)?

(a) Outline the steps necessary to answer the question.

(b) Answer the question.

Solution

(a) Determine the molar mass of HNO3. Determine the number of moles of acid in the solution. From the number of moles and the mass of solvent, determine the molality.

(b) Molar mass HNO3 = 63.01288 g mol–1

If we assume 100 g of solution, then 68.0 g is HNO3 and 32.0 g is water.



39. Calculate the molality of each of the following solutions:

(a) 0.710 kg of sodium carbonate (washing soda), Na2CO3, in 10.0 kg of water—a saturated solution at 0 °C

(b) 125 g of NH4NO3 in 275 g of water—a mixture used to make an instant ice pack

(c) 25 g of Cl2 in 125 g of dichloromethane, CH2Cl2

(d) 0.372 g of tetrahydropyridine, C5H9N, in 125 g of chloroform, CHCl3

Solution

(a)



(b)



(c)



(d)



41. A 13.0% solution of K2CO3 by mass has a density of 1.09 g/cm3. Calculate the molality of the solution.

Solution

Find the mass of K2CO3 and the mass of water in solution. Assume 100.0 mL of solution and that the density of water is 1.00 g cm–3. Then find the moles of K2CO3 and the molality.



Mass (H2O) = 109.0 g − 14.2 g = 94.8 g



43. What is the boiling point of a solution of 115.0 g of sucrose, C12H22O11, in 350.0 g of water?

(a) Outline the steps necessary to answer the question

(b) Answer the question

Solution

(a) Determine the molar mass of sucrose; determine the number of moles of sucrose in the solution; convert the mass of solvent to units of kilograms; from the number of moles and the mass of solvent, determine the molality; determine the difference between the boiling point of water and the boiling point of the solution; determine the new boiling point.

(b) 

Δ*T*b = *K*b*m* = (0.512 °C *m*–1)(0.9599 *m*) = 0.491 °C

The boiling point of pure water at 100.0 °C increases 0.491 °C to 100.491 °C, or 100.5 °C.

45. What is the freezing temperature of a solution of 115.0 g of sucrose, C12H22O11, in 350.0 g of water, which freezes at 0.0 °C when pure?

(a) Outline the steps necessary to answer the question.

(b) Answer the question.

Solution

(a) Determine the molar mass of sucrose; determine the number of moles of sucrose in the solution; convert the mass of solvent to units of kilograms; from the number of moles and the mass of solvent, determine the molality; determine the difference between the freezing temperature of water and the freezing temperature of the solution; determine the new freezing temperature.

(b) 

Δ*T*b = *K*b*m* = (1.86 °C *m*–1)(0.960 *m*) = 1.78 °C

The freezing temperature is 0.0 °C − 1.78 °C = –1.8 °C.

47. What is the osmotic pressure of an aqueous solution of 1.64 g of Ca(NO3)2 in water at 25 °C? The volume of the solution is 275 mL.

(a) Outline the steps necessary to answer the question.

(b) Answer the question.

Solution

(a) Determine the molar mass of Ca(NO3)2; determine the number of moles of Ca(NO3)2 in the solution; determine the number of moles of ions in the solution; determine the molarity of ions, then the osmotic pressure.

(b) 

The molarity of the ions is three times the molarity of Ca(NO3)2. Therefore, multiply the molarity of Ca(NO3)2 by 3: *Π* = *MRT* = 3  0.0363 mol L–1 0.08206 L atm mol–1 K–1 298.15 K = 2.67 atm.

49. What is the molar mass of a solution of 5.00 g of a compound in 25.00 g of carbon tetrachloride (bp 76.8 °C; *K*b = 5.02 °C/*m*) that boils at 81.5 °C at 1 atm?

(a) Outline the steps necessary to answer the question.

(b) Solve the problem.

Solution

(a) Determine the molal concentration from the change in boiling point and *K*b; determine the moles of solute in the solution from the molal concentration and mass of solvent; determine the molar mass from the number of moles and the mass of solute. (b) Δ*T*b = 81.5 − 76.8 = 4.7 °C, Δ*T*b = *K*b*m*, so . Moles of solute = molality  kg of solvent = 0.94 *m*  0.02500 kg = 0.024 mol;



Molecular mass = 2.1  102 amu

51. A 1.0 *m* solution of HCl in benzene has a freezing point of 0.4 °C. Is HCl an electrolyte in benzene? Explain.

Solution

No. Pure benzene freezes at 5.5 °C, and so the observed freezing point of this solution is depressed by Δ*T*f = 5.5 – 0.4 = 5.1 °C. The value computed, assuming no ionization of HCl, is Δ*T*f = (1.0 m)(5.14 °C/*m*) = 5.1 °C. Agreement of these values supports the assumption that HCl is not ionized.

53. A 12.0-g sample of a nonelectrolyte is dissolved in 80.0 g of water. The solution freezes at –1.94 °C. Calculate the molar mass of the substance.

Solution

Δ*T*f = 1.94 °C



Moles of solute = 1.04 *m*  0.0800 kg = 0.0834 mol



Molecular mass = 144 amu

55. Calculate the boiling point elevation of 0.100 kg of water containing 0.010 mol of NaCl, 0.020 mol of Na2SO4, and 0.030 mol of MgCl2, assuming complete dissociation of these electrolytes.

Solution

0.010 mol NaCl contains 0.010 mol Na+ + 0.010 mol Cl–

0.020 mol Na2SO4 contains 0.040 mol Na+ + 0.020 mol 

0.030 mol MgCl2 contains 0.030 mol Mg2+ + 0.060 mol Cl–

Total numbers of moles = 0.020 mol + 0.060 mol + 0.090 mol = 0.170 mol



57. A sample of sulfur weighing 0.210 g was dissolved in 17.8 g of carbon disulfide, CS2 (*K*b = 2.43 °C/*m*). If the boiling point elevation was 0.107 °C, what is the formula of a sulfur molecule in carbon disulfide?

Solution

The molality is



mol S = 4.57 *m*  0.0178 kg = 8.13  10–4 mol



The atomic mass of sulfur is 32.066.



The formula for the sulfur molecule is S8.

59. Lysozyme is an enzyme that cleaves cell walls. A 0.100-L sample of a solution of lysozyme that contains 0.0750 g of the enzyme exhibits an osmotic pressure of 1.32  10–3 atm at 25 °C. What is the molar mass of lysozyme?

Solution

The molarity of the solution is:



Number of moles = 5.40  10–5 mol L–1  0.100 L = 5.40  10–6 mol



Molecular mass = 1.39  104 amu.

61. The osmotic pressure of human blood is 7.6 atm at 37 °C. What mass of glucose, C6H12O6, is required to make 1.00 L of aqueous solution for intravenous feeding if the solution must have the same osmotic pressure as blood at body temperature, 37 °C?

Solution

The molarity of the solution is



Number of moles = 0.30 mol/L  1.00 L = 0.30 mol

Mass (glucose) = 180.157 g mol–1  0.30 mol = 54 g

63. What is the boiling point of a solution of NaCl in water if the solution freezes at –0.93 °C?

Solution

Find the molality of the solution from the freezing point depression. Using that value, determine the boiling point elevation and then the boiling point.



Δ*T*b = *K*b*m* = 0.512 °C *m*–1  0.50 *m* = 0.256 °C

The boiling point of pure water is 100.00 °C. Addition gives 100.00 °C + 0.26 °C = 100.26 °C.

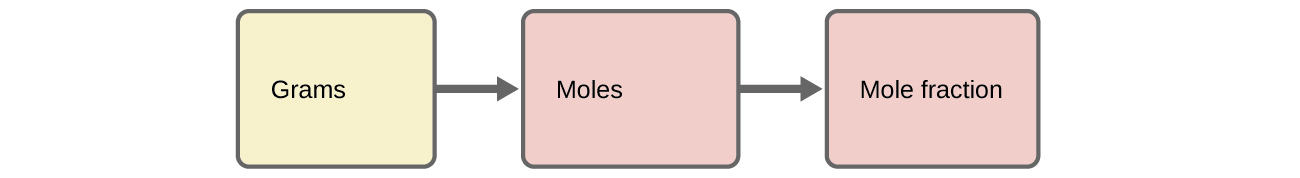
65. The vapor pressure of methanol, CH3OH, is 94 torr at 20 °C. The vapor pressure of ethanol, C2H5OH, is 44 torr at the same temperature.

(a) Calculate the mole fraction of methanol and of ethanol in a solution of 50.0 g of methanol and 50.0 g of ethanol.

(b) Ethanol and methanol form a solution that behaves like an ideal solution. Calculate the vapor pressure of methanol and of ethanol above the solution at 20 °C.

(c) Calculate the mole fraction of methanol and of ethanol in the vapor above the solution.

Solution



(a)



CH3OH = 32.04246 g mol–1

C2H5OH = 46.063 g mol–1



(b) Vapor pressures are:

CH3OH: 0.590  94 torr = 55 torr

C2H5OH: 0.410  44 torr = 18 torr

(c) The number of moles of each substance is proportional to the pressure, so the mole fraction of each component in the vapor can be calculated as follows:





67. Meat can be classified as fresh (not frozen) even though it is stored at –1 °C. Why wouldn’t meat freeze at this temperature?

Solution

The ions and compounds present in the water in the beef lower the freezing point of the beef below –1 °C.

69. A sample of HgCl2 weighing 9.41 g is dissolved in 32.75 g of ethanol, C2H5OH (*K*b = 1.20 °C/*m*). The boiling point elevation of the solution is 1.27 °C. Is HgCl2 an electrolyte in ethanol? Show your calculations.

Solution



The observed change equals the theoretical change; therefore, no dissociation occurs.

This resource file is copyright 2015, Rice University. All Rights Reserved.