Chemistry 2e
11: Solutions and Colloids
11.1: The Dissolution Process

1. How do solutions differ from compounds? From other mixtures?

Solution

A solution can vary in composition, while a compound cannot vary in composition. Solutions are homogeneous at the molecular level, while other mixtures are heterogeneous.

3. When KNO_3 is dissolved in water, the resulting solution is significantly colder than the water was originally.
(a) Is the dissolution of KNO_3 an endothermic or an exothermic process?
(b) What conclusions can you draw about the intermolecular attractions involved in the process?
(c) Is the resulting solution an ideal solution?

Solution

(a) The process is endothermic as the solution is consuming heat. (b) Attraction between the K^+ and NO_3^- ions is stronger than between the ions and water molecules (the ion-ion interactions have a lower, more negative energy). Therefore, the dissolution process increases the energy of the molecular interactions, and it consumes the thermal energy of the solution to make up for the difference. (c) No, an ideal solution is formed with no appreciable heat release or consumption.

5. Indicate the most important types of intermolecular attractions in each of the following solutions:
(a) The solution in Figure 11.2
(b) NO(*g*) in CO(*l*)
(c) Cl_2(*g*) in Br_2(*l*)
(d) HCl(*g*) in benzene C_6H_6(*l*)
(e) Methanol CH_3OH(*l*) in H_2O(*l*)

Solution

(a) ion-dipole forces; (b) dipole-dipole forces; (c) dispersion forces; (d) dispersion forces; (e) hydrogen bonding

7. Heat is released when some solutions form; heat is absorbed when other solutions form. Provide a molecular explanation for the difference between these two types of spontaneous processes.

Solution

Heat is released when the total intermolecular forces (IMFs) between the solute and solvent molecules are stronger than the total IMFs in the pure solute and in the pure solvent: Breaking weaker IMFs and forming stronger IMFs releases heat. Heat is absorbed when the total IMFs in the solution are weaker than the total of those in the pure solute and in the pure solvent: Breaking stronger IMFs and forming weaker IMFs absorbs heat.

Chemistry 2e
11: Solutions and Colloids
11.2: Electrolytes

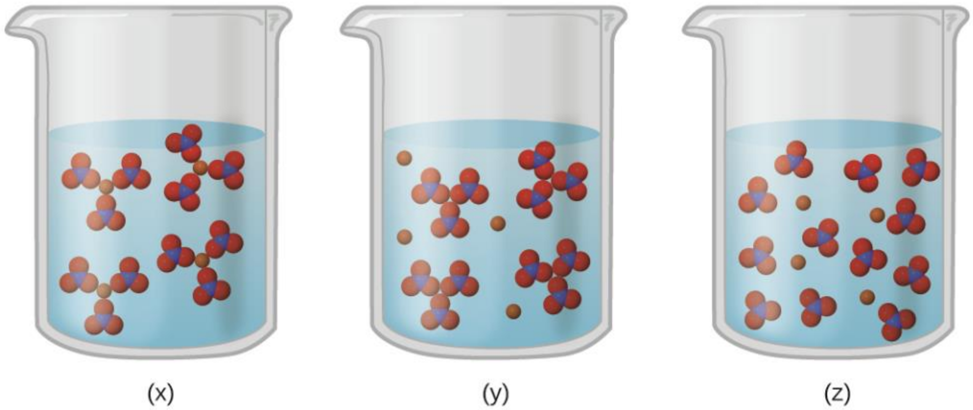
9. Explain why the ions Na^+ and Cl^- are strongly solvated in water but not in hexane, a solvent composed of nonpolar molecules.

Solution

Crystals of NaCl dissolve in water, a polar liquid with a very large dipole moment, and the individual ions become strongly solvated. Hexane is a nonpolar liquid with a dipole moment of zero and, therefore, does not significantly interact with the ions of the NaCl crystals.

11. Consider the solutions presented:

(a) Which of the following sketches best represents the ions in a solution of $Fe(NO_3)_3(aq)$?



(b) Write a balanced chemical equation showing the products of the dissolution of $Fe(NO_3)_3$.

Solution

(a) $Fe(NO_3)_3$ is a strong electrolyte, thus it should completely dissociate into Fe^{3+} and NO_3^- ions. Therefore, (z) best represents the solution. (b)

$$Fe(NO_3)_3(s) \longrightarrow Fe^{3+}(aq) + 3NO_3^-(aq)$$

13. What is the expected electrical conductivity of the following solutions?

(a) $NaOH(aq)$

(b) $HCl(aq)$

(c) $C_6H_{12}O_6(aq)$ (glucose)

(d) $NH_3(aq)$

Solution

(a) high conductivity (solute is an ionic compound that will dissociate when dissolved); (b) high conductivity (solute is a strong acid and will ionize completely when dissolved); (c) nonconductive (solute is a covalent compound, neither acid nor base, unreactive towards water); (d) low conductivity (solute is a weak base and will partially ionize when dissolved)

15. Indicate the most important type of intermolecular attraction responsible for solvation in each of the following solutions:

(a) the solutions in Figure 11.7

(b) methanol, CH_3OH, dissolved in ethanol, C_2H_5OH

(c) methane, CH_4, dissolved in benzene, C_6H_6

(d) the polar halocarbon CF_2Cl_2 dissolved in the polar halocarbon $CF_2ClCFCl_2$

(e) $O_2(l)$ in $N_2(l)$

Solution

(a) ion-dipole; (b) hydrogen bonds; (c) dispersion forces; (d) dipole-dipole attractions; (e) dispersion forces

Chemistry 2e
11: Solutions and Colloids
11.3: Solubility

17. Supersaturated solutions of most solids in water are prepared by cooling saturated solutions. Supersaturated solutions of most gases in water are prepared by heating saturated solutions. Explain the reasons for the difference in the two procedures.

Solution
The solubility of solids usually decreases upon cooling a solution, while the solubility of gases usually decreases upon heating.

19. Calculate the percent by mass of KBr in a saturated solution of KBr in water at 10 °C. See Figure 11.16 for useful data, and report the computed percentage to one significant digit.

Solution
At 10 °C, the solubility of KBr in water is approximately 60 g per 100 g of water.

$$\%\ \text{KBr} = \frac{60\ \text{g KBr}}{(60 + 100)\ \text{g solution}} = 40\%$$

21. At 0 °C and 1.00 atm, as much as 0.70 g of O_2 can dissolve in 1 L of water. At 0 °C and 4.00 atm, how many grams of O_2 dissolve in 1 L of water?

Solution
This problem requires the application of Henry’s law. The governing equation is $C_g = kP_g$.

$$k = \frac{C_g}{P_g} = \frac{0.70\ \text{g}}{1.00\ \text{atm}} = 0.70\ \text{g atm}^{-1}$$

Under the new conditions, $C_g = 0.70\ \text{g atm}^{-1} \times 4.00\ \text{atm} = 2.80\ \text{g}$.

23. The Henry’s law constant for CO_2 is $3.4 \times 10^{-2}\ M$/atm at 25 °C. Assuming ideal solution behavior, what pressure of carbon dioxide is needed to maintain a CO_2 concentration of 0.10 *M* in a can of lemon-lime soda?

Solution

$$P_g = \frac{C_g}{k} = \frac{0.10\ M}{3.4 \times 10^{-2}\ M/\text{atm}} = 2.9\ \text{atm}$$

25. Assuming ideal solution behavior, how many liters of HCl gas, measured at 30.0 °C and 745 torr, are required to prepare 1.25 L of a 3.20-*M* solution of hydrochloric acid?

Solution
First, calculate the moles of HCl needed. Then use the ideal gas law to find the volume required.
$M = \text{mol L}^{-1}$

$$3.20\ M = \frac{x\ \text{mol}}{1.25\ \text{L}}$$

x = 4.00 mol HCl
Before using the ideal gas law, change pressure to atmospheres and convert temperature from °C to kelvins.

$$\frac{1\ \text{atm}}{x} = \frac{760\ \text{torr}}{745\ \text{torr}}$$

x = 0.9803 atm

$$V = \frac{nRT}{P} = \frac{(4.000\ \cancel{\text{mol}}\ \text{HCl})(0.08206\ \text{L}\ \cancel{\text{atm}}\ \cancel{\text{K}^{-1}}\ \cancel{\text{mol}^{-1}})(303.15\ \cancel{\text{K}})}{0.9803\ \cancel{\text{atm}}} = 102\ \text{L HCl}$$

Chemistry 2e
11: Solutions and Colloids
11.4: Colligative Properties

27. What is the microscopic explanation for the macroscopic behavior illustrated in Figure 11.14?

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 ($C_3H_5(OH)3$), 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 HNO_3 and water in a concentrated solution of nitric acid (68.0% HNO_3 by mass)?

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

(b) Answer the question.

Solution

(a) Find number of moles of HNO_3 and H_2O in 100 g of the solution. Find the mole fractions for the components.

(b) The number of moles of HNO_3 is $\frac{68\text{ g}}{63.01\text{ g/mol}} = 1.079\text{ mol}$. The number of moles of water is $\frac{32\text{ g}}{18.015\text{ g/mol}} = 1.776\text{ mol}$. The mole fraction of HNO_3 is $\frac{1.079}{(1.079 + 1.776)} = 0.378$. The mole fraction of H_2O 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), Na_2CO_3, in 10.0 kg of water—a saturated solution at 0 °C

(b) 125 g of NH_4NO_3 in 275 g of water—a mixture used to make an instant ice pack

(c) 25 g of Cl_2 in 125 g of dichloromethane, CH_2Cl_2

(d) 0.372 g of tetrahydropyridine, C_5H_9N, in 125 g of chloroform, $CHCl_3$

Solution

(a)

$$\text{mol Na}_2\text{CO}_3 = 710\ \cancel{\text{g Na}_2\text{CO}_3} \times \frac{1\text{ mol}}{105.9886\ \cancel{\text{g Na}_2\text{CO}_3}} = 6.70\text{ mol}$$

$$\text{mol H}_2\text{O} = \frac{10,000\text{ g}}{18.0153\text{ g/mol}} = 555.08\text{ mol}$$

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

$$X_{Na_2CO_3} = \frac{6.70 \text{ mol}}{561.78 \text{ mol}} = 0.0119$$

$$X_{H_2O} = \frac{555.08 \text{ mol}}{561.78 \text{ mol}} = 0.988$$

(b)

$$\text{mol } NH_4NO_3 = 125 \cancel{\text{ g } NH_4NO_3} \times \frac{1 \text{ mol}}{80.0434 \cancel{\text{ g } NH_4NO_3}} = 1.56 \text{ mol}$$

$$\text{mol } H_2O = \frac{275 \text{ g}}{18.0153 \text{ g/mol}} = 15.26 \text{ mol}$$

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

$$X_{NH_4NO_3} = \frac{1.56 \text{ mol}}{16.82 \text{ mol}} = 0.9927$$

$$X_{H_2O} = \frac{15.26 \text{ mol}}{16.82 \text{ mol}} = 0.907$$

(c)

$$\text{mol } Cl_2 = 25 \cancel{\text{ g } Cl_2} \times \frac{1 \text{ mol}}{70.9054 \cancel{\text{ g } Cl_2}} = 0.35 \text{ mol}$$

$$\text{mol } CH_2Cl_2 = \frac{125 \text{ g}}{84.93 \text{ g/mol}} = 1.47 \text{ mol}$$

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

$$X_{Cl_2} = \frac{0.35 \text{ mol}}{1.82 \text{ mol}} = 0.192$$

$$X_{CH_2Cl_2} = \frac{1.47 \text{ mol}}{1.82 \text{ mol}} = 0.808$$

(d)

$$\text{mol } C_5H_9N = 0.372 \cancel{\text{ g } C_5H_9N} \times \frac{1 \text{ mol}}{83.1332 \cancel{\text{ g } C_5H_9N}} = 4.47 \times 10^{-3} \text{ mol}$$

$$\text{mol } CHCl_3 = \frac{125 \text{ g}}{119.38 \text{ g/mol}} = 1.047 \text{ mol}$$

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

$$X_{C_5H_9N} = \frac{0.00447 \text{ mol}}{1.05 \text{ mol}} = 0.00426$$

$$X_{CHCl_3} = \frac{1.047 \text{ mol}}{1.05 \text{ mol}} = 0.997$$

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% HNO_3 by mass)?

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

(b) Answer the question.

Solution

(a) Determine the molar mass of HNO_3. 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 HNO_3 = 63.01288 g mol^{-1}

If we assume 100 g of solution, then 68.0 g is HNO_3 and 32.0 g is water.

$$\text{mol } HNO_3 = 68.0 \text{ g } HNO_3 \times \frac{1 \text{ mol}}{63.02188 \text{ g } HNO_3} = 1.08 \text{ mol}$$

$$m \text{ } HNO_3 = \frac{1.08 \text{ mol}}{0.0320 \text{ g}} = 33.7 \ m$$

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

(a) 0.710 kg of sodium carbonate (washing soda), Na_2CO_3, in 10.0 kg of water—a saturated solution at 0 °C

(b) 125 g of NH_4NO_3 in 275 g of water—a mixture used to make an instant ice pack

(c) 25 g of Cl_2 in 125 g of dichloromethane, CH_2Cl_2

(d) 0.372 g of tetrahydropyridine, C_5H_9N, in 125 g of chloroform, $CHCl_3$

Solution

(a)

$$\text{mol } Na_2CO_3 = 710 \text{ g } Na_2CO_3 \times \frac{1 \text{ mol}}{105.9886 \text{ g } Na_2CO_3}$$

$$\text{molality of } Na_2CO_3 = \frac{6.70 \text{ mol}}{10.0 \text{ kg}} = 6.70 \times 10^{-1} \ m$$

(b)

$$\text{mol } NH_4NO_3 = 125 \text{ g } NH_4NO_3 \times \frac{1 \text{ mol}}{80.0434 \text{ g } NH_4NO_3} = 1.56 \text{ mol}$$

$$\text{molality of } NH_4NO_3 = \frac{1.56 \text{ mol}}{0.275 \text{ kg}} = 5.67 \ m$$

(c)

$$\text{mol } Cl_2 = 25 \text{ g } Cl_2 \times \frac{1 \text{ mol}}{70.9054 \text{ g } Cl_2} = 0.35 \text{ mol}$$

$$m \text{ } Cl_2 = \frac{0.35 \text{ mol}}{0.125 \text{ kg}} = 2.8 \ m$$

(d)

$$\text{mol } C_5H_9N = 0.372 \text{ g } C_5H_9N \times \frac{1 \text{ mol}}{83.1332 \text{ g } C_5H_9N} = 4.47 \times 10^{-3} \text{ mol}$$

$$\text{molality of } C_5H_9N = \frac{4.47 \times 10^{-3} \text{ mol}}{0.125 \text{ kg}} = 0.0358 \ m$$

41. A 13.0% solution of K_2CO_3 by mass has a density of 1.09 g/cm^3. Calculate the molality of the solution.

Solution

Find the mass of K_2CO_3 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 K_2CO_3 and the molality.

$$\text{Mass (solution)} = 100.0\ \cancel{\text{mL}} \times \frac{1\ \cancel{\text{cm}^3}}{1\ \cancel{\text{mL}}} \times 1.09\ \text{g}\ \cancel{\text{cm}^3} = 109.0\ \text{g}$$

$$\text{Mass (K}_2\text{CO}_3) = \frac{13.0\%}{100\%} \times 109\ \text{g} = 14.2\ \text{g}$$

Mass (H_2O) = 109.0 g − 14.2 g = 94.8 g

$$m\ (\text{K}_2\text{CO}_3) = \frac{0.1027\ \text{mol}}{0.0948\ \text{kg}} = 1.08\ m$$

43. Assuming ideal solution behavior, what is the boiling point of a solution of 115.0 g of nonvolatile sucrose, $C_{12}H_{22}O_{11}$, 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) $$\text{mol sucrose} = \frac{115.0\ \text{g}}{342.300\ \text{g mol}^{-1}} = 0.3360\ \text{mol}$$

$$\text{molality} = \frac{0.3360\ \text{mol C}_{12}\text{H}_{22}\text{O}_{11}}{0.3500\ \text{kg H}_2\text{O}} = 0.9599\ m$$

$\Delta T_b = K_b m = (0.512\ °\text{C}\ m^{-1})(0.9599\ m) = 0.491\ °\text{C}$
The boiling point of pure water at 100.0 °C increases 0.491 °C to 100.491 °C, or 100.5 °C.

45. Assuming ideal solution behavior, what is the freezing temperature of a solution of 115.0 g of sucrose, $C_{12}H_{22}O_{11}$, 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 freezing temperature of water and the freezing temperature of the solution; determine the new freezing temperature.

(b) $$\text{mol sucrose} = \frac{115.0\ \text{g}}{342.300\ \text{g mol}^{-1}} = 0.336\ \text{mol}$$

$$m\ \text{sucrose} = \frac{0.336\ \text{mol}}{0.350\ \text{kg}} = 0.960\ m$$

$\Delta T_b = K_b m = (1.86\ °\text{C}\ m^{-1})(0.960\ m) = 1.78\ °\text{C}$
The freezing temperature is 0.0 °C − 1.78 °C = –1.8 °C.

47. Assuming ideal solution behavior, what is the osmotic pressure of an aqueous solution of 1.64 g of $Ca(NO_3)_2$ 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 $Ca(NO_3)_2$; determine the number of moles of $Ca(NO_3)_2$ in the solution; determine the number of moles of ions in the solution; determine the molarity of ions, then the osmotic pressure.

(b) $M\ \mathrm{Ca(NO_3)_2} = \dfrac{1.64\ \mathrm{g\ Ca(NO_3)_2} \times 1\ \mathrm{mol/164.088\ g\ Ca(NO_3)_2}}{0.275\ \mathrm{L}} = 0.0363\ M$

The molarity of the ions is three times the molarity of $Ca(NO_3)_2$. Therefore, multiply the molarity of $Ca(NO_3)_2$ by 3: $\mathit{\Pi} = MRT = 3 \times 0.0363\ \mathrm{mol\ L^{-1}} \times 0.08206\ \mathrm{L\ atm\ mol^{-1}\ K^{-1}} \times 298.15\ \mathrm{K} = 2.67\ \mathrm{atm}$.

49. Assuming ideal solution behavior, 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) $\Delta T_b = 81.5 - 76.8 = 4.7$ °C, $\Delta T_b = K_b m$, so $m = \dfrac{\Delta T_b}{K_b} = \dfrac{4.7\ ^\circ\mathrm{C}}{5.02\ ^\circ\mathrm{C}/m} = 0.94\ m$. Moles of solute = molality × kg of solvent = 0.94 *m* × 0.02500 kg = 0.024 mol;

$$\text{Molar mass} = \frac{\text{mass}}{\text{moles}} = \frac{5.00\ \mathrm{g}}{0.024\ \mathrm{mol}} = 2.1 \times 10^2\ \mathrm{g\ mol^{-1}}$$

Molecular mass = 2.1×10^2 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 ΔT_f = 5.5 – 0.4 = 5.1 °C. The value computed, assuming no ionization of HCl, is ΔT_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. Assuming ideal solution behavior, calculate the molar mass of the substance.

Solution

ΔT_f = 1.94 °C

$$m = \frac{\Delta T_f}{K_f} = \frac{1.94\ ^\circ\mathrm{C}}{1.86\ ^\circ\mathrm{C}/m} = 1.04\ m$$

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

$$\text{Molar mass} = \frac{12.0\ \mathrm{g}}{0.0834\ \mathrm{mol}} = 144\ \mathrm{g\ mol^{-1}}$$

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 Na_2SO_4, and 0.030 mol of $MgCl_2$, assuming complete dissociation of these electrolytes and ideal solution behavior.

Solution
0.010 mol NaCl contains 0.010 mol Na^+ + 0.010 mol $Cl^–$
0.020 mol Na_2SO_4 contains 0.040 mol Na^+ + 0.020 mol $SO_4^{2–}$
0.030 mol $MgCl_2$ contains 0.030 mol Mg^{2+} + 0.060 mol $Cl^–$
Total numbers of moles = 0.020 mol + 0.060 mol + 0.090 mol = 0.170 mol

$$\Delta T_b = K_b m = 0.512\ °C/m \times \frac{0.170\ \text{mol}}{0.100\ \text{kg}} = 0.870\ °C$$

57. A sample of sulfur weighing 0.210 g was dissolved in 17.8 g of carbon disulfide, CS_2 (K_b = 2.34 °C/*m*). If the boiling point elevation was 0.107 °C, what is the formula of a sulfur molecule in carbon disulfide (assuming ideal solution behavior)?

Solution
The molality is

$$m = \frac{0.107\,°C}{2.34\,°C/m} = 0.0457\,m$$

mol S = 0.0457 *m* × 0.0178 kg = 8.13 × $10^{–4}$ mol

$$\text{Molecular mass} = \frac{0.210\ \text{g}}{8.13 \times 10^{-4}\ \text{mol}} = 258\ \text{g mol}^{-1}$$

The atomic mass of sulfur is 32.066.

$$\frac{258}{32.066} = 8.05$$

The formula for the sulfur molecule is S_8.

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. Assuming ideal solution behavior, what is the molar mass of lysozyme?

Solution
The molarity of the solution is:

$$M = \frac{\Pi}{RT} = \frac{1.32 \times 10^{-3}\ \text{atm}}{\left(0.08206\ \text{L atm mol}^{-1}\ \text{K}^{-1}\right)\left(298\ \text{K}\right)} = 5.40 \times 10^{-5}\ \text{mol L}^{-1}$$

Number of moles = 5.40 × $10^{–5}$ mol $L^{–1}$ × 0.100 L = 5.40 × $10^{–6}$ mol

$$\text{Molar mass} = \frac{0.0750\ \text{g}}{5.40 \times 10^{-6}\ \text{mol}} = 1.39 \times 10^{4}\ \text{g mol}^{-1}$$

Molecular mass = 1.39 × 10^4 amu.

61. The osmotic pressure of human blood is 7.6 atm at 37 °C. What mass of glucose, $C_6H_{12}O_6$, 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 (assuming ideal solution behavior)?

Solution
The molarity of the solution is

$$M = \frac{\Pi}{RT} = \frac{7.6\ \text{atm}}{\left(0.08206\ \text{L atm mol}^{-1}\ \text{K}^{-1}\right)\left(310\ \text{K}\right)} = 0.30\ \text{mol/L}$$

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. Assuming ideal solution behavior, 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.

$$\Delta T_f = |0.0\ °C - 0.93\ °C| = 0.93\ °C = K_f m = 1.86\ °C\ m^{-1} \times m$$

$$m\ \text{NaCl} = \frac{0.93\ °C}{1.86\ °C\ m^{-1}} = 0.50\ m$$

$\Delta T_b = K_b m = 0.512\ °C\ m^{-1} \times 0.50\ m = 0.256\ °C$

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

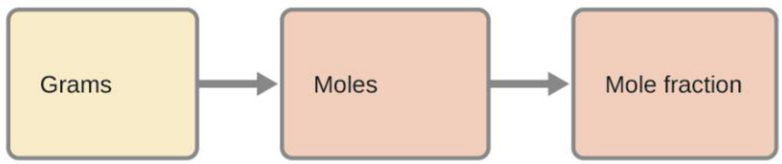
65. The vapor pressure of methanol, CH_3OH, is 94 torr at 20 °C. The vapor pressure of ethanol, C_2H_5OH, is 44 torr at the same temperature.

(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)

$$X_A = \frac{X_A}{X_A + X_B}$$

$CH_3OH = 32.04246\ g\ mol^{-1}$

$C_2H_5OH = 46.063\ g\ mol^{-1}$

$$\text{mol } CH_3OH = \frac{50.0\ \cancel{g}}{32.04216\ \cancel{g}\ mol^{-1}} = 1.5604\ mol$$

$$\text{mol } C_2H_5OH = \frac{50.0\ \cancel{g}}{46.069\ \cancel{g}\ mol^{-1}} = 1.0853\ mol$$

$$X_{CH_3OH} = \frac{1.5604}{1.5604 + 1.0853} = 0.590$$

$$X_{C_2H_5OH} = \frac{1.0853}{1.5604 + 1.0853} = 0.410$$

(b) Vapor pressures are:

CH_3OH: 0.590 × 94 torr = 55 torr

C_2H_5OH: 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:

$$CH_3OH: \frac{55}{(55 + 18)} = 0.75$$

$$C_2H_5OH: \frac{18}{(55 + 18)} = 0.25$$

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 $HgCl_2$ weighing 9.41 g is dissolved in 32.75 g of ethanol, C_2H_5OH (K_b = 1.20 °C/*m*). The boiling point elevation of the solution is 1.27 °C. Is $HgCl_2$ an electrolyte in ethanol? Show your calculations.

Solution

$$\Delta\text{bp} = K_b m = (1.20\ °\text{C}/m)\left(\frac{9.41\ \text{g} \times \dfrac{1\ \text{mol HgCl}_2}{271.496\ \text{g}}}{0.03275\ \text{kg}}\right) = 1.27\ °\text{C}$$

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

Chemistry 2e

11: Solutions and Colloids

11.5: Colloids

71. Identify the dispersed phase and the dispersion medium in each of the following colloidal systems: starch dispersion, smoke, fog, pearl, whipped cream, floating soap, jelly, milk, and ruby.

Solution

Colloidal System	Dispersed Phase	Dispersion Medium
starch dispersion	starch	water
smoke	solid particles	air
fog	water	air
pearl	water	calcium carbonate ($CaCO_3$)
whipped cream	air	cream
floating soap	air	soap
jelly	fruit juice	pectin gel
milk	butterfat	water
ruby	chromium(III) oxide (Cr_2O_3)	aluminum oxide (Al_2O_3)

73. How do colloids differ from solutions with regard to dispersed particle size and homogeneity?

Solution

Colloidal dispersions consist of particles that are much bigger than the solutes of typical solutions. Colloidal particles are either very large molecules or aggregates of smaller species that usually are big enough to scatter light. Colloids are homogeneous on a macroscopic (visual) scale, while solutions are homogeneous on a microscopic (molecular) scale.

75. How can it be demonstrated that colloidal particles are electrically charged?

Solution

If they are placed in an electrolytic cell, dispersed particles will move toward the electrode that carries a charge opposite to their own charge. At this electrode, the charged particles will be neutralized and will coagulate as a precipitate.