# Solutions

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

## Section A — Choose the correct answer — 8 × 1 = 8 marks

**1.** Molality is the number of moles of solute per:

**(a)** litre of solvent **(b)** kilogram of solution

**(c)** litre of solution **(d)** kilogram of solvent

**2.** 60 g of urea (molar mass 60 g/mol) is dissolved in 500 g of water. The molality of the solution is:

**(a)** 2 mol/kg **(b)** 0.002 mol/kg **(c)** 0.12 mol/kg **(d)** 4 mol/kg

**3.** A solution of 46.5 g of ethylene glycol (M = 62 g/mol) in 200 g of water freezes at: (Kf of water = 1.86 K kg/mol, Kb = 0.52 K kg/mol)

**(a)** −1.95 °C **(b)** −13.95 °C **(c)** 6.975 °C **(d)** −6.975 °C

**4.** Liquids A and B form an ideal solution. p°A = 380 mm Hg and p°B = 100 mm Hg. For x_A = 0.8, the total vapour pressure is:

**(a)** 240 mm Hg **(b)** 156 mm Hg **(c)** 324 mm Hg **(d)** 480 mm Hg

**5.** The van't Hoff factor for magnesium sulphate ($MgSO_4$), assuming complete dissociation, is:

**(a)** 2 **(b)** 4 **(c)** 1 **(d)** 3

**6.** The osmotic pressure of a 0.17 M solution of glucose at 273 K, assuming complete dissociation, is: (R = 0.083 L bar $mol^{-1}$ $K^{-1}$)

**(a)** 0 bar **(b)** 1.93 bar **(c)** 7.70 bar **(d)** 3.85 bar

**7.** A solution contains 5 mol of ethanol and 8 mol of water. The mole fraction of ethanol is:

**(a)** 0.38 **(b)** 0.5 **(c)** 0.625 **(d)** 0.62

**8.** Assertion (A): A 0.3 m aqueous solution of sucrose freezes at a lower temperature than a 0.3 m solution of sodium chloride.
Reason (R): The depression of freezing point depends on the number of solute particles: ΔTf = iKf m.

**(a)** Both A and R are true, and R is the correct explanation of A.

**(b)** Both A and R are true, but R is not the correct explanation of A.

**(c)** A is true, but R is false.

**(d)** A is false, but R is true.

## Section B — Short answer — 8 × 2 = 16 marks

**9.** Define molarity and molality. Which of them changes with temperature, and why?

**10.** 13.8 g of glycerol ($C_3H_8O_3$, M = 92 g/mol) is dissolved in water to make 500 mL of solution. Find its molarity.

**11.** 55.8 g of ethylene glycol (M = 62 g/mol) is dissolved in 400 g of water. Find the molality and the mole fraction of ethylene glycol.

**12.** Find the boiling point of a solution of 126 g of glucose (M = 180 g/mol) in 500 g of water. (Kf of water = 1.86 K kg/mol, Kb = 0.52 K kg/mol)

**13.** 24.8 g of a non-volatile non-electrolyte dissolved in 500 g of water lowers its freezing point by 1.488 K. Find the molar mass of the solute. (Kf of water = 1.86 K kg/mol, Kb = 0.52 K kg/mol)

**14.** 4.34 g of a protein-free solute in 500 mL of solution has an osmotic pressure of 3.486 bar at 300 K. Find its molar mass. (R = 0.083 L bar $mol^{-1}$ $K^{-1}$)

**15.** 55.8 g of a non-volatile solute (M = 62 g/mol) is dissolved in 900 g of water. Find the vapour pressure of the solution if that of pure water is 355 mm Hg.

**16.** 37 mg of a pollutant is found in 2,000 g of water. Express its concentration in ppm.

## Section C — Word problems — 4 × 4 = 16 marks

**17.** Explain the four colligative properties and write the expression for each.

**18.** 0.05 mol of calcium chloride ($CaCl_2$) is dissolved in 200 g of water. Assuming complete dissociation, find the van't Hoff factor, the freezing point and the boiling point of the solution. (Kf of water = 1.86 K kg/mol, Kb = 0.52 K kg/mol)

**19.** Liquids A ($p^\circ$ = 550 mm Hg) and B ($p^\circ$ = 490 mm Hg) form an ideal solution with x_A = 0.7. Find the partial pressures, the total vapour pressure and the mole fraction of A in the vapour.

**20.** A solution of 2.76 g of a non-electrolyte in 100 mL of water has an osmotic pressure of 7.47 bar at 300 K. Find the molar mass of the solute, and estimate the freezing point of the solution, taking 100 mL of water as 100 g. (R = 0.083 L bar $mol^{-1}$ $K^{-1}$) (Kf of water = 1.86 K kg/mol, Kb = 0.52 K kg/mol)

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# Answer key

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| Q | Answer | Working |
|---|---|---|
| 1 | **(d) kilogram of solvent** | — |
| 2 | **(a) 2 mol/kg** | m = moles ÷ kg of solvent = 1 ÷ 0.5 |
| 3 | **(d) −6.975 °C** | ΔTf = Kf m = 1.86 × 3.75 |
| 4 | **(c) 324 mm Hg** | p = x_A p°A + x_B p°B |
| 5 | **(a) 2** | $MgSO_4$ gives 2 ions per formula unit |
| 6 | **(d) 3.85 bar** | π = iCRT = 1 × 0.17 × 0.083 × 273 |
| 7 | **(a) 0.38** | 5 ÷ (5 + 8) |
| 8 | **(d) A is false, but R is true.** | A is false: sodium chloride gives 2 particles per formula unit, sucrose gives 1, so its ΔTf is 2 times larger. R is true. |
| 9 | **Molarity is moles of solute per litre of solution; molality is moles of solute per kilogram of solvent. Molarity changes with temperature because the volume of a solution changes; molality does not.** | — |
| 10 | **0.3 M** | M = moles ÷ litres = 0.15 ÷ 0.5 |
| 11 | **2.25 mol/kg; 0.0389** | moles of water = 400/18 |
| 12 | **100.73 °C** | ΔTb = Kb m = 0.52 × 1.4 = 0.728 K |
| 13 | **62 g/mol** | M = Kf × w × 1000 ÷ (ΔTf × W) = 1.86 × 24.8 × 1000 ÷ (1.488 × 500) |
| 14 | **62 g/mol** | M = wRT ÷ (πV) |
| 15 | **348.72 mm Hg** | x(water) = 50 ÷ (50 + 0.9); p = x p° |
| 16 | **18.5 ppm** | ppm = $(37 \times 10^{-3} \div 2000) \times 10^{6}$ |
| 17 | **Relative lowering of vapour pressure: (p° − p)/p° = x(solute). Elevation of boiling point: ΔTb = Kb m. Depression of freezing point: ΔTf = Kf m. Osmotic pressure: π = CRT. All depend only on the number of solute particles; for electrolytes each is multiplied by the van't Hoff factor i.** | — |
| 18 | **i = 3; freezing point −1.395 °C; boiling point 100.39 °C** | m = 0.25 mol/kg; ΔT = iKm |
| 19 | **p_A = 385 mm Hg, p_B = 147 mm Hg; total 532 mm Hg; y_A = 0.72** | Raoult for each; y_A = p_A/p_total |
| 20 | **92 g/mol; −0.558 °C** | M = wRT/(πV); m = moles ÷ 0.1 kg; ΔTf = Kf m |



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