Chemistry 240 Semester 01-2009
Homework for Submission #7

Answer the following questions and submit them for marking on or before 15th April 2009 in the chemistry drop box. If any answers show evidence of copying, the whole exercise will attract zero marks.

1) a) The osmotic pressure of seawater is 27 atm. Calculate (i) the minimum energy requirement in kilojoules and (ii) the electrical energy required in kilowatt-hours assuming 80% efficiency[1], to produce 1000 gallons of pure water from seawater by reverse osmosis. (Consider this as a reversible expansion against a constant external pressure.) You can find appropriate conversions for units at http://www.onlineconversion.com

   a) Electricity in the Bahamas costs about $0.23 per "unit" (kilowatt-hour) to the domestic consumer. What would be the cost of producing 1000 gallons of pure water from seawater on the above basis? How does this compare with Water & Sewerage's $6.00 per thousand gallons?

   b) Why do you think that ground water rather than seawater is generally used as the feedstock for reverse osmosis?

2) Naphthalene ($C_{10}H_8$) steam distils at 98°C and an ambient pressure of 1.01×10^5 Pa. At this temperature, the vapour pressure of water is 9.50×10^4 Pa. Calculate the percentage by mass of naphthalene in the distillate. (Take the RAM of H=1, C=12, O=16.)

3) Define the term *molality.*

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   In terms of the molality, μ, of an undissociated solute, the freezing point depression (ΔT) is given by

$$\Delta T = -k_f \mu$$

   From this, derive the equation

$$\Delta T = -k_f \frac{m}{M} \times \frac{1}{W}$$

   where k_f is the freezing point depression constant, m is the mass of solute in grams, M is the molar mass of the solute in g mol^{-1}, and W is the mass of solvent in kilograms.

4) a) The vapour pressure of one component of an ideal liquid mixture is given by $P_1 = x_1 P_1^0$ (Raoult's law), where P_1 represents the vapour pressure (partial pressure in the mixture of vapours) of component (1), x_1 its mole fraction in the mixture, and P_1^0 the vapour pressure of the component when pure. Show that the composition of the vapour in equilibrium with an ideal mixture of two liquids is always richer in the more volatile component. (That is, prove that $\frac{n_{1vap}}{n_{2vap}} > \frac{n_{1liq}}{n_{2liq}}$ when component (1) is more volatile than component (2)).

   b) Sketch a phase diagram of temperature against composition for a mixture of two volatile liquids which behave ideally, showing the boiling point of the mixture and the composition of the vapour in equilibrium with the mixture.
   What is meant by the term "tie-line"? Draw tie-lines on your graph to illustrate (i) simple distillation and (ii) fractional distillation. Use the tie-lines to describe and explain these processes.

   c) What are meant by positive and negative deviations from Raoult's law? What, in terms of intermolecular forces, leads to such behaviour? What are "high boiling" and "low-boiling" azeotropes?

[1] There are many factors influencing the efficiency of reverse osmosis. The quality of the membrane is just one of them. The amount of liquid pumped is another. In order to keep the osmotic pressure at a minimum the water in contact with the membrane must be changed frequently, which requires a lot of pumping with its attendant energy cost. To minimise pumping costs the water is allowed to spend a longer time in contact with the membrane until it is more concentrated than the original feed-stock water. This reduces the amount of water to be pumped but increases the osmotic pressure, which in turn makes pumping a given amount of water more expensive.