CHEM 361A - Lecture 10 Activity

Colligative Properties

In Class

1. Explain the following phenomena

   (a) A cucumber placed in concentrated brine (saltwater) shrivels into a pickle.

   (b) A carrot placed in fresh water swells in volume.

2. Time release drugs have the advantage of releasing the drug to the body at a constant rate so that the drug concentration at any time is not high enough to have harmful side effects or so low as to be ineffective. A schematic diagram of a pill that work on this basis is shown in Figure 1. Explain how it works.

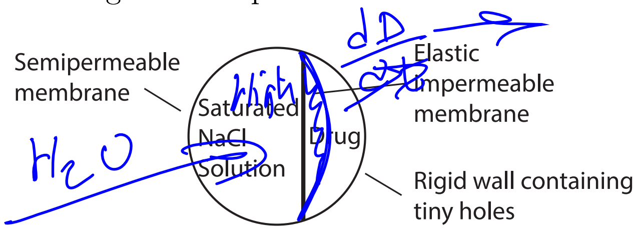

Figure 1: Schematic of a time release drug capsule.

3. Large sections of the description in this question are taken from the Wikipedia entry on Azeotropes. Azeotrope means 'to boil without changing'. A mixture is given this label when it is not possible to separate its components by fractional distillation.

   (a) Systems where both components can be completely separated by fractional distillation are not azeotropes. The phase diagram of a non-ideal two component mixture is shown in Figure 2.

      i. Draw on the figure, starting in the liquid phase at a mole fraction of 0.5, a fractional distillation pathway that purifies the vapour.

      ii. As the vapour becomes purer, what happens to the remaining liquid?

   (b) In general, a positive azeotrope boils at a lower temperature than any other ratio of its constituents. Positive azeotropes are also called minimum boiling mixtures or pressure maximum azeotropes. A well-known example of a positive azeotrope is 95.63% ethanol and 4.37% water (by mass). Ethanol boils at 78.4C, water boils at 100C, but the azeotrope boils at 78.2C, which is lower than either of its constituents. An example of this type of behaviour is seen in Figure 3. Start with a liquid mixture at a 0.2 mole fraction of chloroform and show by using fractional

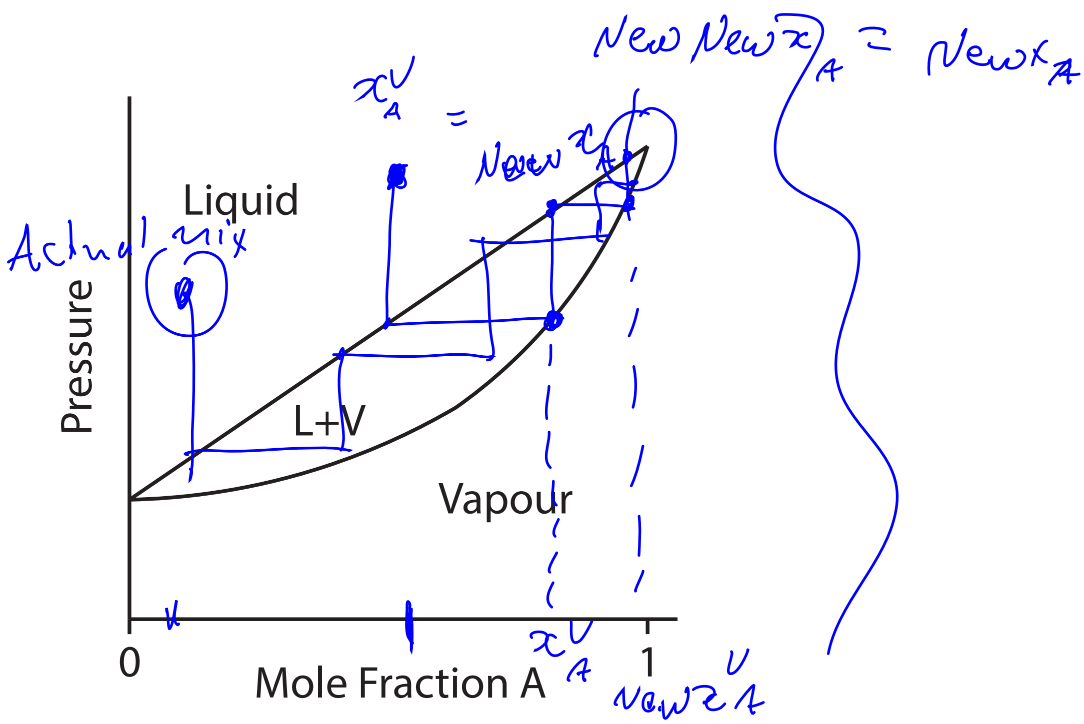

Figure 2: A phase diagram for a non-azeotrope mixture.

distillation that it is not possible to separate completely the mixture since fractional distillation leads to the azeotrope mixture.

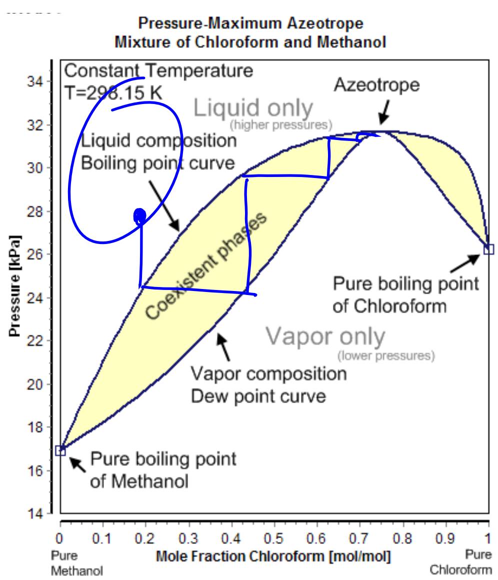

Figure 3: A diagram of a positive azeotrope.

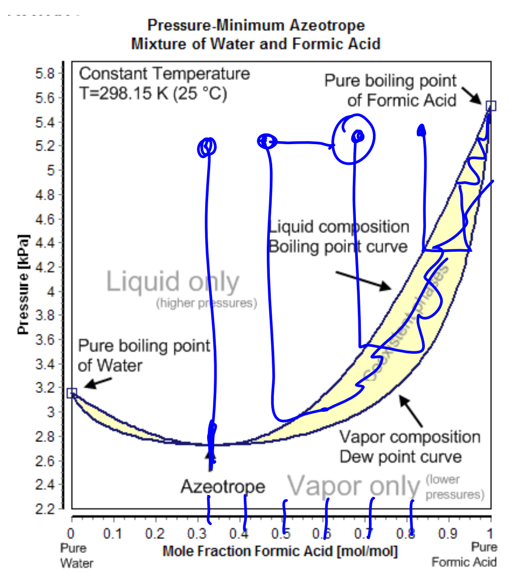

Figure 4: A diagram of a negative azeotrope.

(c) In general, a negative azeotrope boils at a higher temperature than any other ratio of its constituents. Negative azeotropes are also called maximum boiling mixtures or pressure minimum azeotropes. An example of a negative azeotrope is hydrochloric acid at a concentration of 20.2% and 79.8% water (by mass). Hydrogen chloride boils at −84 C and water at 100 C, but the azeotrope boils at 110 C, which is higher than either of its constituents. For these types of mixtures, the liquid that remains gets closer to the azeotrope mixture. Using Figure 4, start at a mole fraction of 0.8 and discuss how a mixture can get to the azeotrope mixture during fractional distillation.

4. Plant cells are surrounded by semipermeable membranes that allow water to pass through, but not the cellular fluids. The redwoods of California can grow to as high as 105 m (350 ft). At the top of the trees, leaves are constantly losing water to the atmosphere. This results in an increased solute concentration in the fluids in the leaves.

   (a) Estimate the osmotic pressure required to draw water up from the roots to the top of a 105 m tree. Hint: the pressure of a column of water of a given height is $p = \rho g h$ where ρ is the density of water, g is the acceleration due to gravity, and h is the height of the column.

   $\Pi = V_m RT$

   (b) What is the concentration of the solute in the leaves in order to cause this osmotic pressure? Assume that $T = 298$ K.

   $P = \rho g h$

   $p = (997)(9.81)(105) = 1025$ kPA

Homework

5. Lysozyme extracted from chicken egg white has a molar mass of $13,930$ g mol^{-1}. Exactly 0.1 g of this protein is dissolved in 50 g of water at 298 K. If the vapour pressure of pure water is 3.17 kPa at 298 K, calculate

   $V_m = 0.414 \frac{M}{L}$

   (a) the vapour pressure lowering (8.19×10^{-6} kPa)

   (b) the depression in freezing point if $k_f = 1.86$ K kg mol^{-1} (2.67×10^{-4} K)

   (c) the elevation of the boiling point if $k_b = 0.51$ K kg mol^{-1} (7.3×10^{-5} K)

   (d) the osmotic pressure (0.356 kPa)