PROBLEMS*

7.1 *Through one's pores*

a. You are making strawberry shortcake. You cut up the strawberries, then sprinkle on some powdered sugar. A few moments later, the strawberries look juicy. What happened? Where did this water come from?

b. One often hears the phrase "learning by osmosis." Explain what's technically wrong with this phrase, and why "learning by permeation" might describe the desired idea better.

7.2 *Pfeffer's experiment*

van 't Hoff based his theory on the experimental results of W. Pfeffer. Here are some of Pfeffer's original 1877 data for the pressure needed to stop osmotic flow between pure water and a sucrose solution, across a copper ferrocyanide membrane at $T = 15°C$:

sugar concentration, g/(100 g of water)	pressure, mm of mercury
1	535
2	1016
2.74	1518
4	2082
6	3075

a. Convert these data to our units, m^{-3} and Pa (the molar mass of sucrose is about 342 g $mole^{-1}$) and graph them. Draw some conclusions.

b. Pfeffer also measured the effect of temperature. At a fixed concentration of (1 g sucrose)/(100 g water) he found:

temperature, °C	pressure, mm of mercury
7	505
14	525
22	548
32	544
36	567

Again convert to SI units, graph, and draw conclusions.

7.3 *Experimental pitfalls*

You are trying to make artificial blood cells. You have managed to get pure lipid bilayers to form spherical bags of radius 10 μm, filled with hemoglobin. The first time you did this, you transferred the "cells" into pure water and they promptly burst, spilling

*Problem 7.4 is adapted with permission from Benedek & Villars, 2000b.

than a certain separation, they'll feel an effective depletion interaction driving them still closer, a force caused by the surrounding suspension of smaller proteins. Draw a picture, assuming that the surfaces are parallel as they approach each other. Estimate the separation at which the force begins.

b. If the contact area is $10\,\mu\mathrm{m}^2$, estimate the total free energy reduction when the surfaces stick. You may neglect any other possible interactions between the surfaces; and as always, assume that we can still use the van 't Hoff (dilute-suspension) relation for osmotic pressure. Is it significant relative to $k_B T_r$?

7.6 *Effect of hydrogen bonds on water*

According to Section 7.5.1, the average number of H-bonds between a molecule of liquid water and its neighbors is about 3.5. Assume that these bonds are the major interaction holding liquid water together and that each H-bond lowers the energy by about $9k_B T_r$. Using these ideas, find a numerical estimate for the heat of vaporization of water (see Problem 1.6), then compare your prediction with the measured value.