

PHYSICS 429: Introduction to Biological Physics

April 28 2008

Problem Set 4 These problems are due on Tuesday May 6.

1. Nelson 7.5

2. This is Hobbie-Roth 5.5. The definition of osmolarity is the number of osmoles per liter of solution. An osmole is the equivalent of a mole of solute particles. Thus the term osmolarity of 0.3 osmole is 0.3 moles of solute per liter.

An understanding of osmotic pressure is important in medicine. Consider the case reported in Steinmuller (1998) in the New England Journal of Medicine 338,1226. A 5% solution of albumin was needed to infuse into a patient with kidney disease (renal insufficiency). No 5% solution was available, so the hospital pharmacy used 25% albumin diluted 1:4 with pure water. Injection of the solution into the patient caused renal failure. The albumin in a 25% albumin solution has an osmolarity of about 36 mosmole. Typically, such a solution also contains about 300 mosmole = .3 osmole of other ions.

(a) Calculate the osmolarity of the solution injected into the patient.

(b) Calculate the osmolarity of the solution if the pharmacy had properly used isotonic saline, which also has a osmolarity of 300 mosmole, instead of pure water to perform the 1:4 dilution. Saline solution has the same osmolarity as blood.

3. This is HR 5.6. Articular cartilage covers the ends of bones in joints and allows the bones to move smoothly against each other. It contains a network of collagen fibers that can exert a mechanical tensile stress to resist tissue swelling, resulting in a pressure P_c within the cartilage. The collagen fibers do not withstand compression. The cartilage also contains proteoglycan molecules that cause tissue swelling because of their osmotic pressure, π_{PG} . One can determine P_c by placing the cartilage in a polyethylene glycol solution with osmotic pressure π_{PEG} , measuring π_{PEG} and π_{PG} , using the relationship $P_c = \pi_{PG} - \pi_{PEG}$. Typical data are

π_{PEG} (atm)	π_{PG}
0.0	4.0
2.5	5.5
5.0	7.0
7.5	8.5
10.0	10.0

(a) Determine the excess pressure P_c exerted by the collagen fibers under normal conditions ($\pi_{PEG} = 0$.)

(b) Determine the value of π_{PEG} for which the collagen fibers exert no tensile stress (become limp).

(c) Find a linear equation for P_c as a function of π_{PEG} .

(d) Osteoarthritis is thought to occur when the collagen fibers are weakened. If the collagen in an arthritic joint can only exert a pressure of 2 atm when $\pi_{PEG} = 0$, by how much will the tissue swell (by what percent will its volume change?)

In (b) (d) assume that only the proteoglycans cause osmotic pressure and that their number does not change, but the tissue volume increases as the tissue swells with water. This problem is based on the work of Bassar et al (1998) Arch. Biochem. Biophys. **351**:207.

3. Nelson problem 7.7

4. Nelson problem 7.8