Homework #5: Due Fri., Nov. 3

1. For a hypothetical molecule in gas phase with molar mass = 70.0 g/mol, and collision diameter \(d = 5.50\ \text{Å}\) at a temperature of 300 K:
   (a) calculate the root mean square molecular speed \((v_{\text{rms}})\).
   (b) calculate the number of molecules per m\(^3\) at 1 bar pressure.
   (c) calculate \(\sigma\), the collision cross section = \(\pi d^2\) in m\(^2\).
   (d) estimate the number of collisions per molecule by multiplying the together the 3 numbers found in a-c. Compare with the “rule of thumb” number of \(10^{10}\) collisions per second per molecule, which comes from N\(_2\) gas, and explain any major difference you find.
   (e) Find the 3-dimensional root mean displacement in cm after 1000 seconds using Eqn. 8.6.
   (f) Using equation 8.12b (page 271), determine the 3D diffusion coefficient, \(D\), in cm\(^2\) s\(^{-1}\) and in m\(^2\) s\(^{-1}\).

2. (a) Calculate the sedimentation coefficient in seconds, and in Svedbergs for a small piece of dust that fell off a ceiling in a quiet room and was observed to fall at a steady speed of 1 millimeter per second.
   (b) Assuming a mass of \(1 \times 10^{-6}\) g, what is the frictional coefficient of the piece of dust in (a)? Assume the altitude is sea level.

3. Suppose a virus particle with a molecular weight of \(3 \times 10^8\) g/mol was moving in an ultra centrifuge at an acceleration of \(2.0 \times 10^3\) times that of earth's gravity (200,000 g/s) at a speed of 0.50 cm/hr, and its partial specific volume is 0.77 cm\(^3\) g\(^{-1}\) at 20 °C.
   (a) what is the diffusion coefficient?
   (b) what is the frictional coefficient?

4. If for a certain protein molecule, \(s_{0,20}^0 = 20.0\ S\) , \(D_{0,20}^{0} = 5.0 \times 10^{-10}\ m^2\) s\(^{-1}\), and the partial specific volume is 0.765 ml/g, calculate the molecular weight in g/mol. (assuming the density of water is, 1.000 g/ml)

5. What are the ratios of sedimentation coefficients, \(s_A/s_B\) , diffusion coefficients, \(D_A/D_B\) , and electrophoretic mobilities, \(\mu_A/\mu_B\) for proteins A and B if: the \(f_A = 3f_B\) , \(q_A = 0.25q_B\) , and \(m_A = 0.5m_B\).
6. (a) Fill in the following table for a peptide with 1 histidine, 1 aspartic acid, 1 glutamic acid, 1 lysine, and one arginine when the pH = 6. Calculate the charges to 2 significant figures.

(b) Toward which electrode will the peptide move at pH 6, positive, negative, or not possible to be sure with 2 significant figures?

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>pKᵢ</th>
<th>Charge when protonated</th>
<th>Charge at pH 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lysine</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amino at N-terminus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Carboxylic acid at C-terminus</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Charge = ____

7. A certain protein consists of 2 chains held together by non-covalent interactions. Chain A contains 100 amino acids whose charged side chains are predominately lysine and arginine. Chain B contains 200 amino acids whose charged side chains are predominately aspartic acid and glutamic acid.

(a) In an SDS PAGE gel electrophoresis, what will be the ratio of forces on the two chains: (force on A)/(force on B) ?

(b) Which chain (A or B) will have the larger frictional coefficient?

(c) Draw a rough picture of the 2D gel electrophoresis pattern expected for this protein, in which the pH gradient in the 1ˢᵗ stage decreases from 11 to 2 going from left to right, with the positive electrode on the right, and in the 2ⁿᵈ stage, the positive electrode is at the bottom of the gel.

Reading Guide for Chapters 5 and 8

Chap. 5 pp 155-56: skip derivations but know Eqn 5.17 and understand Fig. 5.3 qualitatively;
Chap. 8 pp 264-276: Know Eqns. 8.6, 8.8, 8.9, 8.12a,b, 8.21, 8.22
Sedimentation: pp 278-285: Know how to use eqns. 8.31, 8.32, 8.34, 8.42
Electrophoresis: pp 286-295: know Eqn. 8.50