Assignment 1: Dimensions, Units and Order of Magnitude Estimates (bio322)

September 23, 2014

[Total score: 16- individual scores in square brackets]

1. For the following variables provide dimensions and SI units. Please write out (i.e. show) how you arrived at the dimensions [4].

   (a) The permittivity of the space (ϵ_0). Given: The force (f) between like point charges q_1 and q_2 separated by a distance of r is given by Coulomb's law to be

   $$f = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2} \tag{1}$$

   ANS: S.I. units: $\frac{C^2}{m^2 \cdot N}$, $[M^{-1}L^3I^2T^4]$.

   (b) Viscosity of a medium (η). Given: The Stokes frictional drag coefficient ($\zeta = 2m/\Delta t$) for a sphere of mass m and in time (Δt) is

   $$\zeta = 6\pi\eta r \tag{2}$$

   where r is the sphere radius.
   ANS:SI unit: $\frac{kg}{s \cdot m}$, [ML$^{-1}T^{-1}$]

   (c) Concentration (c) of proteins in cells.
   ANS: SI unit $\frac{mg}{mL}$, [ML^{-3}]

   (d) Moles (with reference to molar concentration) of a substance.
   ANS: $\frac{mol}{m^3}$, [molL^{-3}] or $[NL^{-3}]$ or [L^{-3}].

2. Estimate the number of proteins in an *E. coli* cell given the cell consists of 70% water and proteins form half the dry mass. Assume an average protein length. Compare your estimate to that measured and discuss deviations or lack of them from accurate measurements, in the context of your assumptions. [4].
   ANS: $3 \cdot 10^6$ proteins , measured value is $2.4 \cdot 10^6$ molecules.

3. What is the average spacing between two protein molecules of ftsZ (a cytoskeletal protein) in an idealized *E. coli* cell which has an approximate concentration of 1 μM [1]. [4].
a) Assuming uniform distribution of proteins in the cell:
d = $c^{-1/3}$, where d is the mean spacing and c is the concentration (number of molecules per unit volume)
d = $(1\ \mu\text{M} \cdot 6.023 \cdot 10^{23})^{-1/3}$
d = 1.19 μm = 119 nm.
b) Assuming the proteins to be arranged as a ring in the bacterial cell of radius 5 μm, then
total number of protein molecules in the cell $\approx$ 600
circumference of the cell = $2 \cdot 3.14 \cdot 0.5\ \mu$m
assuming end to end arrangement of the proteins in the ring and spacing defined as the distance between the centers of the two monomers (2·d) i.e. radius of one monomer being d
An estimate of the mean spacing (2·d here) can be obtained from: 2·3.14·r = total number of protein molecules · 2·d
$\approx$ 5 nm

References

[1] Rueda,Vicente and Mingorance (2003) Concentration and Assembly of the Division Ring Proteins FtsZ, FtsA, and ZipA during the Escherichia coli Cell Cycle J Bacteriol. 185(11): 3344-3351