EXAM 2017 - Physics of life processes 2

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Tuesday 12.12.2017, 14:00-17:00

Please read the text below.

This exam has **7 questions** plus **1 bonus question**. The end of the exam is marked by the word **'END'**. The total amount of points obtainable is **20 (+ 1 bonus)**. Please note your **name** and **student ID number** on every sheet you hand in. Make sure to give sufficient motivation for your answers. Explain all quantities in the formulas you use. Please write clearly and organize your solutions distinctly, any notes on scrap paper will not be graded. This is an **open book exam** and a **simple, non-graphical calculator** is allowed. Telephones must be turned off and in your bag/coat. If any form of fraud is discovered the student will be excluded from the exam and the exam committee will be notified. Please don't forget to fill out the survey at the end of the exam.

GOOD LUCK!

1. Boltzmann (2 + 1 pts)

Let there be a reversible chemical reaction A + B <--> AB, where B is in abundance.

(a) Calculate from the ratio of the concentrations r=[AB]/[A] at room temperature the energy, ΔE, which is characteristic for this process.

(b) Calculate typical energies for toxin binding ($r=10^{12}$), antibody-antigen binding ($r=10^{9}$) and binding of a drug ($r=10^{3}$).

2. Osmosis (2 pts)

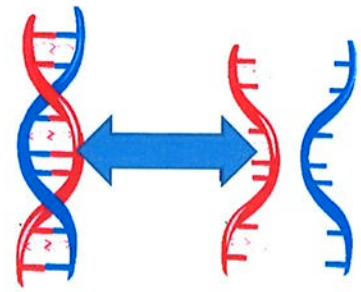
The osmotic pressure of blood plasma proteins is Π = 37 mbar. The density of these proteins is ρ = 60 g/ltr. Find the average molecular mass, m_{mol}, of the proteins.

3. Osmotic pressure and dimerization (3 pts)

Assume that a macromolecule dimerizes according to 2 $M_1 \Leftrightarrow M_2$ characterized by a dissociation constant $k = [M_1]^2 / [M_2]$. Given the total concentration of the monomer-units $[M] = [M_1] + 2[M_2]$, show that the osmotic pressure is given by:

$$\Pi = RT[M] - \frac{RT}{k}[M]^2$$

4. DNA melting (2 + 1 pts)



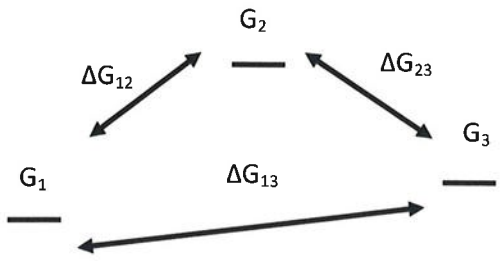
Double stranded Single stranded

(a) The melting temperature (P_D=50% dissociated) of a 20 nucleotide long double-stranded DNA oligomer is T_m=60°C, and has an enthalpy of $\Delta H = 6.54*10^{-20}$J/nucleotide. Express the dissociation probability of this system, p_D, as a function of just the temperature, T, using the information given above.

(b) What is the percentage of dissociated DNA at room temperature (20°C)? To which temperature do you have to heat the sample that 99.9% of the DNA double strand is dissociated?

5. Protein Folding (3 pts)

A particular protein can take on three different conformations, '1', '2' and '3'. Each conformation is characterized by a free energy of G_1, G_2, and G_3, respectively. A very long experiment is performed which can detect the protein's conformation. What is the percentage of time the protein is detected in either of the three conformations?



6. Patch Clamp (2 + 2 pts)

Suppose we have a patch of cell membrane stuck on the end of a pipette (tube). The membrane is permeable to bicarbonate, HCO_3^-. On site A we have a big reservoir of HCO_3^- at a concentration c_A = 1M. On side B there is a similar volume at c_B = 0.1M. Now we connect a power supply and set a constant potential $\Delta V = V_A - V_B$.

(a) What should ΔV be to maintain equilibrium?

(b) Which way will HCO_3^- flow for ΔV=100mV and what will be the equilibrium concentration c_B?

7. Michaelis-Menten Kinetics (2 pts)

By applying the Michealis-Menten rule, find the Michaelis-Menten constant K_M and the maximal velocity v_{max} of the enzymatic reaction, knowing the following experimental data:

substrate concentration	measured initial velocity
c_{s1} = 2 mM,	v_1 = 0.020 mM/s
c_{s2} = 4 mM,	v_2 = 0.030 mM/s

8. Chippendale Mupp (1 pt, Bonus question)

The Chippendale Mupp is a mythical creature that bites its tail before going to sleep.

"Now the news has arrived
From the Valley of Vail
That a Chippendale Mupp has just bitten his tail,
Which he does every night before shutting his eyes.
Such nipping sounds silly. But, really, it's wise.

He has no alarm clock. So this is the way
He makes sure that he'll wake at the right time of day.
His tail is so long, he won't feel any pain
'Till the nip makes the trip and gets up to his brain.
In exactly eight hours, the Chippendale Mupp
Will, at last, feel the bite and yell "Ouch"! and wake up."
--dr. Seuss—

As the poet has sung, his tail is so long that he doesn't feel the pain until it's time to wake up, 8 hours later. Suppose that a single unmyelinated axon connects the Mupp's tail to its spinal cord. Use axon parameters appropriate to squid, given the axon diameter of "real" animals is 1 µm. Estimate how long the Mupp's tail must be.

We wish everyone success in the further study!

'END'