LS2103 (BIOPHYSICS) **MID-SEMESTER EXAMINATION.** **27.09.2024**

Time: 90 MINUTES. **ANSWER ALL QUESTIONS.** **FULL MARKS: 30**

Useful Information:

- Boltzmann constant, k_B = 1.3806 × 10^{-23} m^2 kg s^{-2} K^{-1}
- Gas constant, R = 8.3144 J mol^{-1} K^{-1}
- Planck's constant, h = 6.6261 × 10^{-34} m^2 kg s^{-1}

Q1. Clearly write your selection(s) for each question below. (2 x 3 = 6 marks; wrong selection: -0.5)

i) Assume room temperature to be 27 °C. Select the closest equivalent of **1 k_BT** from the choices below.

a) 4.1 nanoNewton-metre

b) 4.1 picoNewton-nanometre

c) 4.1 x 10^{-9} Newton-metre

d) 41.4 picoNewton-metre

e) 4.1 picoNewton-picometre

ii) A bio-molecular complex has four domains that independently adopt W1, W2, W3 and W4 microscopic states.

a) The overall complex has [W1 + W2 + W3 + W4] microscopic states

b) The overall entropy is proportional to [ln(W1 + W2 + W3 + W4)]

c) The overall entropy is proportional to [W1 x W2 x W3 x W4]

d) The overall entropy is proportional to [ln(W1) + ln(W2) + ln(W3) +ln(W4)]

e) None of the above is correct.

iii) A trainee assumes that the shape of organisms can be approximated as spheres, and that the metabolism rate scales as their volume. He then collects a large (surface to volume) data set and metabolism rates. If his hypothesis is correct, which should hold true?

a) The (surface to volume) ratio of the organisms will have (linear r) dependence

b) The (surface to volume) ratio of the organisms will have (r^{-2}) dependence

c) The metabolism rates will scale as (surface to volume) ratio

d) The metabolism rates will scale independently of (surface to volume) ratio

e) The metabolism rates will scale as the cubical inverse of (surface to volume) ratio

Q2. (2 + 3 + 3 = 8 marks)

A researcher decides to approximate the entropy (S) protein solutions at equilibrium with the ideal gas entropy. Thereby, for 'N' protein molecules, each of mass 'm' in system volume 'V', she uses a constant 'B' and writes,

$$S = k_B ln\left[\left(V\,(2mE)^{3/2}\right)^N\right] + B$$

i) What are the assumptions about the quantity 'E', if any? How does 'E' depend on the temperature?

ii) A protein solution is found to undergo volume expansion at constant temperature, from an initial volume 'V' to a final volume '1.5 V'. Derive an expression for the *entropy change* estimate within the system. Thereby, comment on the spontaneity of the expansion.

iii) The expansion occurred for the solution with 1 mole of protein of molecular weight 1500 g/mol. Find the entropy change in *SI units*.

Q3. (2 + 4 + 2 = 8 marks)

Consider a small peptide molecule in solution with '*M*' number of possible energy states, with the j^{th} state having the probability, P_j.

i) Write down the level of disorder (say *I*) in the system using Shannon's formula. Include additional constants if required.

ii) Assume $M = 4$. Use Shannon's formula to show that the level of disorder is maximum when all P_j are equal. When is the level of disorder a minimum?

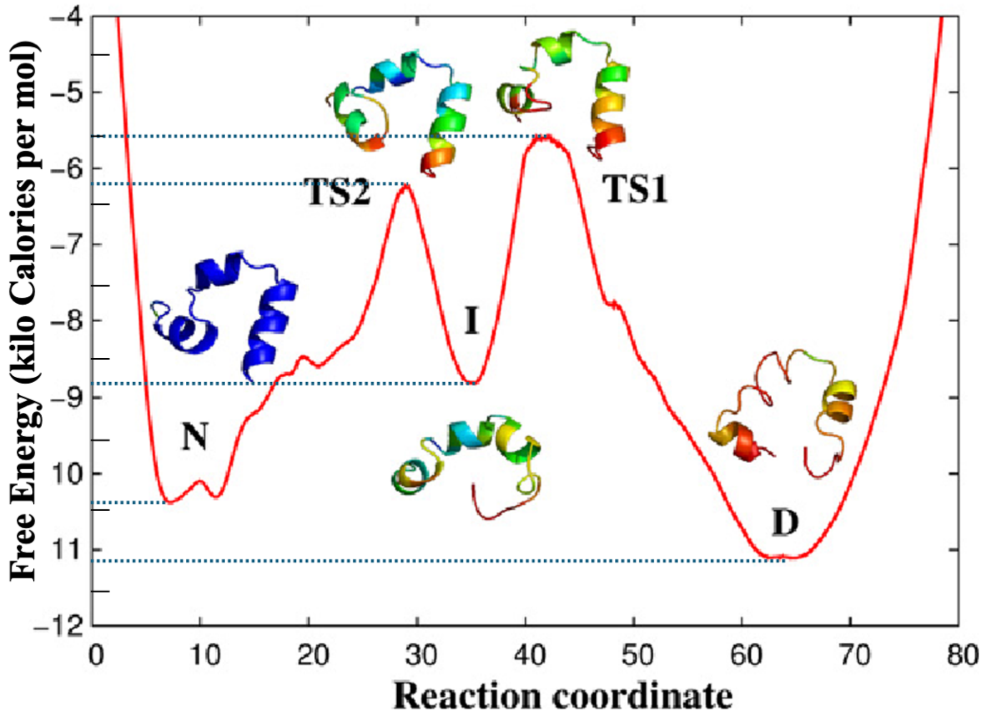
iii) Now assume that the j^{th} state is associated with energy E_j. Write down the probability of occupation of the state, using proportionality constant(s) of your choice. Simplify Shannon's formula with this information.

Q4. Refer to a protein's Free Energy Landscape below.

Free energies of the *observable configurations, Native (N), Intermediate (I) and Disordered (D)*, are provided along with those for the two *transitory configurations (TS2 and TS1)*.

Assume equilibrium at physiological temperature.

Free Energies should be rounded up to the nearest 0.5 value.



(4 + 4 = 8 marks)

i) Designate the most probable configuration as '*MP*'; give reasons. Find the population ratio of *MP* with the other two observable configurations. Show all steps clearly.

ii) Configuration *I* can go to either *N* or *D*. Find the ratio of the rates of the two possible transitions. Show all steps clearly.