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CS/M.Tech (BT)/SEM-1/MBT-102/2011-12

2011
BIOPHYSICAL CHEMISTRY

Time Allotted : 3 Hours *Full Marks :* 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) The probability P_j of observing a particular state J of a system is given by

   a) $P_j = g_j \omega_j / Q$ b) $P_j = g_j \omega_j^2 / Q$

   c) $P_j = g_j / Q$ d) $P_j = g_j \omega_j$.

   ii) Cryoelectron microscopy can resolve structures up to

   a) 1·2 nm b) 0·7 nm

   c) 0·1 nm d) 1·7 nm.

   iii) At any time, the instantaneous kinetic energy, K of an atom is defined by

   a) $K = \frac{7}{6} k_B T$ b) $K = 3 k_B T$

   c) $K = 11 k_B T$ d) $K = 13 k_B T$.

iv) In AFM, the force experienced by the tip on the cantilever is given by

a) $y = ax^2 + bx + c$ b) $f = Z \sin \theta/\lambda$

c) $T = 0 \cdot 9\ \lambda/\beta \cos \theta_B$ d) $F = K.\delta z$.

v) One of the equations representing Von Laue conditions of diffraction is given by

a) $a.S = h$

b) $S = ha^* + kb^* + lc^*$

c) $I\lambda = c(\cos \gamma - \cos \gamma_0)$

d) $2 \sin \theta/\lambda = n/d = |S|$.

vi) In fluorescence sensing, the spectral observable(s) is/are

a) anisotropy b) time

c) phase modulation d) all of these.

vii) Single molecule techniques are ideal for studying which of the following aspects of molecular behaviour ?

a) Specific molecules may exhibit individual static differences in structure, reactivity or function

b) Individual molecules may show dynamic changes in function due to spontaneous structural fluctuations

c) Individual molecules may show ensemble like properties

d) (a) & (b).

viii) The range of wavelength for the *uv* region is

a) 40 - 400 nm b) 200 - 400 nm

c) 20 - 400 nm d) 200 - 300 nm.

ix) Carboxyfluorescein is a typical energy transfer DNA sequencing probe whose excitation and emission are given by

a) 495/525 nm b) 525/555 nm

c) 555/580 nm d) 575/602 nm.

x) The exponential decay of the FID gives the

a) relaxation time with T_2 predominating

b) relaxation time with T_1 predominating

c) full width at half maximum

d) NMR absorption peak.

xi) The turbidity τ to describe "conventional" light scattering is given by

a) $\tau = -ln\, I/I_0$ b) $\tau = I - I_0$

c) $\tau = 4\pi\rho_0/r^3$ d) $\tau = KC/R_0$.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Calculate the intrinsic fluorescence lifetime of Tryptophan, τ_0. If the quantum yield q for tryptophan in a protein is 0·3, what will be the corresponding lifetime, τ ? (Assume A, the Einstein coefficient for spontaneous fluorescence $= 1{\cdot}1 \times 10^8$ molecule sec^{-1}) $2\frac{1}{2} + 2\frac{1}{2}$

3. What is the basis of oxygen sensing by collisional fluorescence quenching ? Highlight your answer with equations and examples. 2 + 3

4. The absorbance of a 10 μM solution of tryptophan in buffer at 280 nm is 0·06. The buffer alone gives an absorbance of 0·04 at 280 nm. Assuming a path length of 1 cm, calculate the extinction coefficient of tryptophan. What are the expected absorbance values for path lengths of 1, 2 and 20 nm ? 2 + 3

5. Zipper models have been used to explain coil-to-helix transitions in polypeptides and melting/annealing of polynucleic acids and DNA. Graphically illustrate (i) the *T*-dependent coil-to-helix transition in poly [γ-benzyl-L-glutamate] (ii) melting and annealing curves of dsDNA. $2\frac{1}{2} + 2\frac{1}{2}$

6. Draw and label appropriate energy level diagrams for ruby and Nd-YAG lasers.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) For a 3 atom nonlinear molecular system, depict the fundamental in-plane and out-of-phase vibrations for three non-linear atoms. 3

   b) Derive the transition dipole expression from the wave function of the dynamics of a particular vibration. 4

   c) Draw a line diagram of an FT-IR spectrometer. 4

   d) Using an appropriate macromolecular example, explain how FT-IR has been used to study hydrogen bonding in solution (use representative IR spectral signatures and intensity plots in your answer). 4

8. a) Use a table to represent the natural abundance, relative sensitivity and approximate range of chemical shifts of ^{1}H, ^{13}C and ^{15}N. Explain why the ^{13}C spectra contain fewer lines than proton spectra and why the number of lines would increase as the abundance of ^{13}C is increased. What kind of NMR spectral changes might accompany dimerization of a protein ? 3 + 2 + 2

b) The dipole moment of a peptide bond is 3·7 debye in water. Assuming that a dipole bond is essentially a dipole-dipole interaction, estimate the energy of a hydrogen bond between two peptides in water and in the interior of a protein (neglect competing interactions with the solvent). 4

c) The optimal distance for the van der Waals interaction between two carbonyl atoms is $r_0 = 0 \cdot 353$ nm. The energy for this interaction is 21·56 kJ/mol.

i) Estimate the repulsive parameter A and dispersion parameter B for the Lennard Jones 6-12 potential.

ii) Calculate the energy at r = 0·44 nm and r = 0·6 nm using parameters in (i) above. 4

9. a) Derive Bragg's law of diffraction. 3

b) Briefly enumerate 3 important limitations of Bragg's law. 3

c) Explain the methods of vapour diffusion and microdialysis developed to facilitate macromolecular crystallization. 3

d) What are the two distinct steps involved in protein single crystal growth ? 3

e) Define reciprocal space. 3

10. AFM is a technique that has become widely used for both the observation and manipulation of biological macromolecules at the single molecule level.

a) Draw a schematic diagram of an atomic force microscope labelling the different parts and essential operational details. 4

b) How is the motion of RNA polymerase on DNA observed by AFM ? How are questions regarding transcription answered on the basis of these results ? 5

c) A theoretical model for measurement of end-to-end distance of a stretched chain (X) in a biopolymer to analyze atomic force microscope data is given by

$$X = L_0 \left[1 - \frac{1}{2} \left(k_B T / F L_p \right)^{1/2} + F / K \right].$$

Define all the terms in the above expression and what the various terms represent in terms of physico-mechanical interactions. 6

11. a) A protein was labelled with a fluorescent dye and the latter has a fluorescence lifetime of 7·0 m sec. How was the lifetime measured ? 4

b) The same protein also has two sites to which fluorescent labels can be attached. R_0 is 2·3 nm for the pair used. Energy transfer efficiency is about 0·015. Estimate the distance between the labels. 4

c) Calculate the decay of ballistic light after penetrating a tissue 40 mfp thick. If the scattering coefficient of the tissue is $100\ cm^{-1}$, calculate the corresponding thickness of the tissue in cm. How does resolution of pure laser imaging vary with tissue thickness ? For good quality medical optical computed tomography (OCT) images, name two techniques employed to overcome challenges presented by scattering phenomena.

$4 + 1\frac{1}{2} + 1\frac{1}{2}$