INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Spring Semester Examination 2024-25

Date of Examination: 18-02-2025 Session: (FN/AN) FN Duration: 2 Hrs

Full Marks: 30 Subject No. : CH40001 Subject : Biochemical Engineering

Department/Center/School: Department of Chemical Engineering

Specific charts, graph paper, log book etc., required: NA

This question paper has 3 pages: Part A (6 questions) and Part B (2 questions)

Part - A

1. Bruce Banner's (a.k.a. The Hulk) rage transformation occurs when Bruce Banner experiences extreme anger or stress, triggering a biochemical reaction in his body that rapidly increases his muscle mass, strength, and size—essentially turning him into an unstoppable green powerhouse fueled by adrenaline and gamma radiation. Bruce Banner is working with Tony Stark to develop an inhibitor that can control his rage-induced transformations. Hulk's rage is linked to an enzyme in his bloodstream, which follows Michaelis-Menten kinetics. Stark Industries uses the Lineweaver-Burk equation to study how a newly developed inhibitor affects this enzyme.

They conduct two experiments on this enzyme-based biochemical reaction:

i. Without the inhibitor (Hulk's normal state):
   - The enzyme has a K_m of 2 mM.
   - The V_{max} (maximum rage reaction rate) is 100 µmol/min. (Rage reaction rate units = µmol/min)

ii. With the inhibitor (using Stark's gamma serum):
   - The new apparent K_m' increases to 4 mM, but V_{max} remains the same.

Tony Stark challenges you to answer the following:

a) What type of inhibition is occurring? Justify your answer using the data.

b) Using the Lineweaver-Burk equation, Calculate Hulk's rage reaction velocity (V) when the substrate concentration is 4 mM, both with and without the inhibitor.

c) Based on your results, how does this inhibitor affect Hulk's rage levels? Would it be useful in controlling his transformations, or should they go back to the lab (Black Widow talking to him still being the best solution so far!)? **[5]**

2. Dr. Molec U. Larity, the world's greatest chemist, has gone missing! The only clue left behind is a set of mysterious chemical samples. To crack the case, you must analyze the intermolecular forces between these substances and uncover their secrets.

Identifying the Forces at Play: Below are two substances found in Dr. Larity's lab. Your mission is to identify the dominant intermolecular force in each one. Choose from the following options:

- Ionic interactions
- Hydrogen bonding
- Van der Waals forces
- Hydrophobic forces

Substances:

1. A vial of table salt (NaCl) in water
2. A flask of methanol (CH_3OH)

For each substance:

(a) Identify the dominant intermolecular force and explain why that force is the most important for each substance based on its molecular structure.

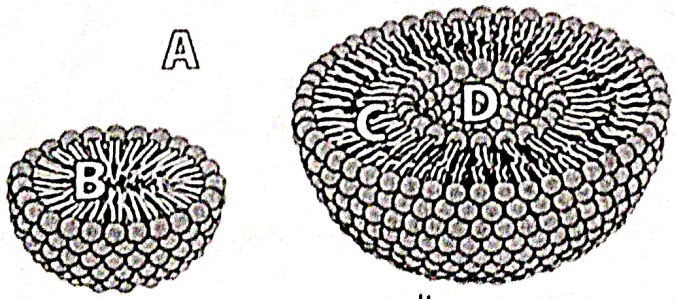
(b) Also, comment on their solubility in water. **[2]**

3. Dr. Helix O'Scope, a world-famous geneticist, has discovered a mysterious biological sample. The only clue? A strange twisted ladder-shaped molecule (DNA) found inside. Your mission is to help Dr. O'Scope decode the structure of DNA and solve the case!

(a) Structure: What is the primary structural shape name of DNA? What is the backbone and what are the base pairs of DNA? What forces hold them together?

(b) Dr. O'Scope finds that the sample contains Adenine (A), Thymine (T), Cytosine (C), and Guanine (G). If Dr. O'Scope finds that 30% of the base pairs in DNA sample is Adenine (A), what percentage of the base pairs of the sample is Guanine (G)? Show your reasoning. **[4]**

4. Phospholipids form micelle and liposome structures in an aqueous environment as represented in the following illustration, in cross-section. The letters A, B, C, and D represent different regions, where region A is an aqueous environment.

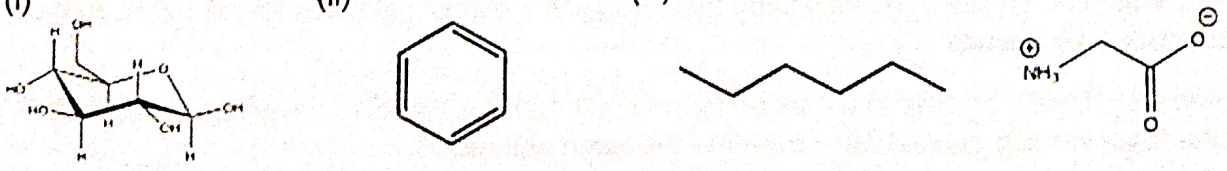


micelle liposome

Indicate, with reasoning, which of the following molecules from (i) to (iv), would be found in

(a) Region A (There can be more than one molecule. No part marking)
(b) Region B (There can be more than one molecule. No part marking)
(c) Region C (There can be more than one molecule. No part marking)
(d) Region D (There can be more than one molecule. No part marking)

(i) (ii) (iii) (iv)



[4]

5. Proteins go through intense **structural workouts** to stay in shape! Match each of the **"gym exercise" (a) to (c)** mentioned below to the correct level of **protein structure (i) to (iii)**.

Protein structures: (i) Primary, (ii) Secondary, and (iii) Tertiary

"Gym exercise":

(a) Amino Acid Line-Up: The protein starts by arranging amino acids in a straight chain.

(b) Protein Yoga: The chain twists into α-helices and folds into β-sheets.

(c) Molecular Bodybuilding: The protein folds into a unique 3D shape.

Explain the reason for each match, using bonds/interactions involved at each level. **[3]**

6. In the G3P to DHAP conversion, the enzyme triose phosphate isomerase (TPI) uses glutamate (Glu) and histidine (His) to facilitate the reaction by transferring hydrogen atoms during the isomerization process.

(a) What is the role of Glu and His in catalyzing this reaction?

(b) If Glu were replaced with negatively charged polar Asp, what would happen to the enzyme's function? **[2]**

Part - B

Q.1 Explain the significance of effectiveness factor, Damköohler number, and Thiele modulus. [6 Marks]

Q.2 The diameter of the agarose beads is 8 mm. It contents 0.018 kg protein per m^3 gel. Ten beads are immersed in a stirred tank reactor containing 3.2×10^{-3} kg/m^3 substrate. The effective diffusivity of substrate in agarose gel is 2.1×10^{-9} m^2/s. The kinetics of the enzymatic reaction is assumed to be first order with specific rate constant 3.11×10^5 s^{-1} kg^{-1} protein. Find out the type of the limiting regime. [4 Marks]

----------Best of luck----------