# CONTENT

## BIOSCIENCE

## SECTION I - BIOLOGY

### BIOCHEMISTRY

### CELL BIOLOGY

### MOLECULAR BIOLOGY

### CELL SIGNALING

### IMMUNOLOGY

### DEVELOPMENTAL BIOLOGY

### PLANT PHYSIOLOGY

## ANIMAL PHYSIOLOGY

## TAXONOMY

## GENETICS

## ECOLOGY

## EVOLUTION

## MICROBIOLOGY

## TECHNIQUES

## SECTION II - CHEMISTRY

## SECTION III - PHYSICS

## SECTION IV - MATHEMATICS

# SECTION – I

# BIOLOGY

## BIOCHEMISTRY: NUMBER OF QUESTIONS ASKED IN IIT JAM EXAM (2005 to 2023)

|  |  | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Structure of Atoms, molecules, bonds and interactions** | - | - | - | - | - | - | - | - | - | 2 | - | 1 | - | - | - | - | - | 2 | - |
| 2 | **Acid, pH, Buffer and Solution** | - | - | - | - | - | - | 1 | 1 | - | 1 | 1 | - | 1 | - | - | - | 2 | - | - |
| 3 | **Thermodynamics** | - | - | 2 | 1 | 1 | 1 | 1 | - | 1 | 2 | - | - | - | - | - | - | 1 | - | - |
| 4 | **Amino acids** | 1 | 3 | 1 | 1 | 2 | - | 1 | 1 | - | - | - | 1 | - | 1 | - | - | - | - | 1 |
| 5 | **Proteins** | 1 | - | - | - | 1 | 1 | - | - | - | 3 | - | 1 | - | 1 | 2 | - | 1 | - | - |
| 6 | **Carbohydrates and Glycobiology** | 1 | 2 | 1 | 2 | 2 | - | 2 | 1 | - | - | - | - | - | - | 1 | 1 | 1 | 1 | - |
| 7 | **Lipids** | 1 | - | 1 | - | - | 1 | 1 | 1 | - | 1 | 1 | - | - | - | - | 1 | - | - | - |
| 8 | **Nucleotides and Nucleic acids** | 1 | - | - | - | 1 | - | - | 1 | - | 3 | - | 1 | - | 1 | - | 1 | 1 | 1 | - |
| 9 | **Enzymes** | 3 | 1 | 2 | 1 | 1 | - | 2 | 2 | 2 | 4 | 3 | 1 | 3 | 2 | 1 | 1 | - | 1 | - |
| 10 | **Metabolism** | 3 | 3 | 5 | 4 | 4 | 2 | 5 | 1 | 2 | 3 | - | 1 | 3 | 2 | 2 | 2 | 2 | 3 | - |
| 11 | **Vitamins** | 1 | 1 | 1 | - | 1 | 1 | - | 1 | - | 1 | - | - | - | 1 | - | 1 | - | - | - |

# CHAPTER-1
# BIOCHEMISTRY

# STRUCTURE OF ATOMS, MOLECULES, BONDS, INTERACTIONS

## IIT JAM BT

### PREVIOUS YEAR EXAM QUESTIONS

**(IIT JAM BT - 2014)**

1. Aqueous environment in a spherical endosome – a closed vesicle of 100 nm diameter, is at a pH 5.0, in order to denature and hydrolyze the material internalized by a cell. Assuming Avogadro's number to be $6\times10^{23}$, the number of free protons in an endosome is closest to
   (1) 24 (2) 3
   (3) 2400 (4) 300

**(IIT JAM BT - 2014)**

2. The number of water molecules present in a 300 residue soluble protein of spherical shape (diameter = 2nm) having 20% (V/V) water is closest to *Assume:* density of water = 1000 kg/m$^3$, Avogadro's number = $6 \times 10^{23}$
   (1) 224 (2) 9
   (3) 140 (4) 28

**(IIT JAM BT - 2016)**

3. Which of the following statements are TRUE for hydrogen bonds? Strength of hydrogen bond is
   (1) low in a solvent of high dielectric constant
   (2) low in a solvent of low dielectric constant
   (3) lower in water as compared to organic solvents
   (4) higher in water as compared to organic

**(IIT JAM BT - 2022)**

4. The correct statement/s for bimolecular nucleophilic substitution reactions is/are
   (1) It goes through a carbocation formation
   (2) There is an inversion of configuration if the reacting center is chiral
   (3) Reaction is enhanced when carried out in polar solvents
   (4) The reaction intermediate is trigonal bipyramidal

**(IIT JAM BT - 2022)**

5. What is the maximum number of hydrogen bonds that a water molecule can make in the liquid state?

**Answer Key**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 2 | 4 | 1,3 | **2,3** | 4 |

### EXPLANATION

**1. Explanation:-**

Given that pH = 5

Hence concentration of H$^+$ ions = $10^{-5}$ mol L$^{-1}$

In order to find out the number of H+ ions, we must calculate the volume of vesicle

Volume of sphere = 4/3 $\pi r^3$ as r = 50 nm = 5 x $10^{-8}$ m

So, volume = 4/3 x 22/7 x 125 x $10^{-24}$ m$^3$ = 5.2381 x $10^{-22}$ m$^3$

Consider the environment as aqueous, (so 1 m$^3$ = 1000 Litre)

Hence, 5.2381 x $10^{-22}$ m$^3$ = 5.2381 x 10 -19 moles

Number of moles of H$^+$ inside a vesicle

= concentration x volume

= $10^{-5}$ x 5.2381 x $10^{-19}$

= 5.2381 x $10^{-24}$ moles

No. of protons = 6 x $10^{23}$ x 5.2 x $10^{-24}$

= 3.19 x $10^0$

= 3 protons

**2. Explanation:-**

To calculate the number of water molecules present in the protein, we need to determine the volume of the protein and the volume of water in it.

Given:

Diameter of the protein = 2 nm

Volume fraction of water = 20% (V/V)

Density of water = 1000 $kg/m^3$

Avogadro's number = $6 \times 10^{23}$

First, let's calculate the volume of the protein.

Radius of the protein = Diameter / 2 = 2 nm / 2 = 1 nm

Volume of the protein

$$= \left(\frac{4}{3}\right) \times \pi \times (radius^3) = (4/3) \times \pi \times (1\,nm)^3$$

Now, let's calculate the volume of water in the protein.

Volume of water = Volume of the protein × Volume fraction of water = $[(4/3) \times \pi \times (1\,nm)^3] \times 0.2$

Next, let's convert the volume of water to cubic meters.

$1\,nm = 1 \times 10^{-9}\,m$

Volume of water (in $m^3$) = Volume of water (in $nm^3$) $\times (1 \times 10^{-9})^3 = [(4/3) \times \pi \times (1\,nm)^3] \times 0.2 \times (1 \times 10^{-9})^3$

Now, let's calculate the mass of the water present in the protein.

Mass of water = Volume of water (in $m^3$) × Density of water $= [(4/3) \times \pi \times (1\,nm)^3] \times 0.2 \times (1 \times 10^{-9})^3 \times 1000\,kg/m^3$

Now, let's convert the mass of water to the number of water molecules.

Mass of water (in grams)

$$= Mass\ of\ water\ (in\ kg) \times 1000 = [(4/3) \times \pi \times (1\,nm)^3] \times 0.2 \times (1 \times 10^{-9})^3 \times 1000 \times 1000\ grams$$

Number of water molecules = Mass of water (in grams) / (Molar mass of water × Avogadro's number) $= [(4/3) \times \pi \times (1\,nm)^3] \times 0.2 \times (1 \times 10^{-9})^3 \times 1000 \times 1000\,grams$ / $(18\,grams/mole \times 6 \times 10^{23})$

Therefore, the number of water molecules present in the protein is closest to (4) 28.

3. **Explanation**- Option 1 is correct because hydrogen bond is an ionic interaction. We know that ionic interactions are weak in polar solvent which has high dielectric constant.

   Option 3 is correct because the strength of hydrogen bond is inversely proportional to the dielectric constant. The strength of hydrogen bond is low in water compared to organic solvents because water has higher dielectric constant than organic solvents.

4. **Explanation-**

1) This option is not correct because in unimolecular nucleophilic substitution reaction carbocation is formed.
2) This option is correct because during replacement of ligand starts in a chiral centre is needed to occur an inversion of configuration.
3) This option is correct because sn2 reaction is favourable in polar aprotic solvents like acetone, DMSO, acetonitrile etc.
4) This option is incorrect because the reaction intermediate in a bimolecular nucleophilic substitution reaction is tetrahedral, not trigonal bipyramidal.

5. **Explanation** - The maximum number of hydrogen bonds is 4 in a water molecule in a liquid state because it has two hydrogen bond donor and two hydrogen bond acceptor.

# CHAPTER-2
BIOCHEMISTRY

# ACID, pH, BUFFER & SOLUTIONS

## IIT JAM BT

### PREVIOUS YEAR EAM QUESTIONS

**(IIT JAM BT - 2011)**

1. An aqueous solution contains 0.01 mol of formic acid ($pK_a = 3.8$) and 0.1 mol of sodium formate. The pH of the solution is

   (1) 3.8 (2) 4.8
   (3) 2.8 (4) 1.8

**(IIT JAM BT - 2012)**

2. $pK_a$ of acetic acid is 4.80. A 10mL of 1M solution of acetic acid is mixed with 5mL of 1M solution of NaOH. The *pH* of the resulting solution is

   (1) 3.2 (2) 7.0
   (3) 4.8 (4) 2.4

**(IIT JAM BT - 2014)**

3. The pH at the equivalence point when 50mL of 0.1M Acetic acid is titrated against 0.1M NaOH is closest to

   (1) 6.0 (2) 7.0
   (3) 8.0 (4) 9.0

**(IIT JAM BT - 2015)**

4. The pH of a 0.1M solution of monosodium succinate ($pKa_1$= 4.19 and $pKa_2$ = 5.57) is ___.

**(IIT JAM BT - 2017)**

5. The $[H^+]$ of 0.1 N acetic acid solution is $1.33 \times 10^{-3}$. The pH of the solution (correct to two decimal places) is_______.

**(IIT JAM BT - 2021)**

6. The molar concentration of water in pure water is __________ M (rounded -off to 1 decimal).

**(IIT JAM BT - 2021)**

7. 1.45 g of sucrose ($C_{12}H_{22}O_{11}$) is dissolved in 30.0 ml of water. Molality (rounded off to 3 decimals) of the resulting solution is _________ m.

| Answer Key | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3 | 3 | 4 | 4.80-4.90 | 2.86-2.89 | 55.7 | 0.141 |

### EXPLANATION

1. **Explanation:**- The formic acid and sodium formate will react to form a buffer solution. The pH of a buffer solution is given by the Henderson-Hasselbalch equation:

$$pH = pKa + log([A-] / [HA])$$

where [A-] is the concentration of the conjugate base, [HA] is the concentration of the acid, and pKa is the acid's pKa.

In this case, the pKa of formic acid is 3.8, the concentration of the conjugate base is 0.1 mol, and the concentration of the acid is 0.01 mol. Plugging these values into the Henderson-Hasselbalch equation,

we get: pH = 3.8 + log(0.1 / 0.01) = 2.8

Therefore, the pH of the solution is 2.8.

2. **Explanation:**- The acetic acid and NaOH will react to form sodium acetate, a salt. The pH of a solution of a salt of a weak acid and a strong base is equal to the pKa of the weak acid.

In this case, the pKa of acetic acid is 4.8, so the pH of the resulting solution will be 4.8.

Calculate the moles of acetic acid and NaOH:

Moles of acetic acid = 10 mL * 1 M = 10 mmol

Moles of NaOH = 5 mL * 1 M = 5 mmol

Calculate the moles of excess acetic acid:

Moles of excess acetic acid = 10 mmol - 5 mmol = 5 mmol

Calculate the pH of the solution:

pH = pKa + log([A-] / [HA])

[A-] = moles of NaOH / total volume = 5 mmol / 15 mL = 0.333 M

[HA] = moles of acetic acid / total volume = 5 mmol / 15 mL = 0.333 M

pH = 4.8 + log(0.333 / 0.333) = 4.8

Therefore, the pH of the resulting solution is 4.8.

3. **Explanation:**- Initial moles of acetic acid = 50mL * 0.1M = 5 mmol

Initial moles of NaOH = 50mL * 0.1M = 5 mmol

Moles of NaOH added = 5 mmol

Moles of acetic acid neutralized = 5 mmol

Moles of acetate formed = 5 mmol
Total volume = 50mL + 50mL = 100mL
[Acetate] = 5 mmol / 100mL = 0.05M
pH = 14 - pKa - log([Acetate])
pH = 14 - 4.8 - log(0.05)
pH = 10.5 which is closest to 9.0

4. **Explanation:**-
pKa1 = 4.19
pKa2 = 5.57
[HA2-] = 0.1M
[HA] = 0.1M - 0.1M = 0
pH = pKa2 + log([A2-] / [HA])
pH = 5.57 + log(0.1 / 0)
pH = 5.57
The pH of the solution is 5.57. However, this is the pH of the solution after the first dissociation of monosodium succinate. The second dissociation of monosodium succinate will also contribute to the pH of the solution, so the pH will be slightly lower than 5.57.
The exact pH of the solution will depend on the relative concentrations of the first and second dissociated forms of monosodium succinate.
pKa2 = 5.57
[A2-] = 0.1M
[HA] = 0.1M - 0.01 = 0.09
pH = pKa2 + log([A2-] / [HA])
pH = 5.57 + log(0.1 / 0.09)
pH = 4.88

5. **Explanation:**-
To determine the pH of the acetic acid solution, we can use the equation relating pH and the concentration of hydrogen ions ([H+]):
pH = -log[H+]
Given that the [H+] of the 0.1 N (normal) acetic acid solution is $1.33 \times 10^{-3}$ M, we can substitute this value into the equation:
pH = -log$(1.33 \times 10^{-3})$
Using a calculator, we find:
pH ≈ 2.88
Therefore, the pH of the 0.1 N acetic acid solution is approximately 2.88.

6. **Explanation:**-
The molar concentration of water in pure water can be calculated using the fact that water has a density of 1 g/cm$^3$, which is equivalent to 1000 kg/m$^3$. The molar mass of water ($H_2O$) is approximately 18.015 g/mol.
The molar concentration (C) can be calculated using the formula:
C = density / molar mass
Substituting the values, we have:
C = 1000 kg/m$^3$ / 18.015 g/mol
Converting the units to match (1 g = 0.001 kg, 1 mol = 6.022 × $10^{23}$ molecules), we get:
C = (1000 kg/m$^3$ / 18.015 g/mol) × (1 mol / 1000 g) × (6.022 × $10^{23}$ molecules / 1 mol)
C ≈ 55.56 mol/m$^3$
Rounding off to one decimal place, the molar concentration of water in pure water is approximately 55.6 M.

7. **Explanation:**-
To calculate the molality of the resulting solution, we need to determine the number of moles of sucrose (C12H22O11) and the mass of water.
The molar mass of sucrose (C12H22O11) can be calculated as follows: 12(12.01 g/mol) + 22(1.008 g/mol) + 11(16.00 g/mol) = 342.34 g/mol
Given that 1.45 g of sucrose is dissolved, we can calculate the number of moles of sucrose: moles of sucrose = mass of sucrose / molar mass of sucrose = 1.45 g / 342.34 g/mol ≈ 0.00424 mol
The mass of water is given as 30.0 mL, which we need to convert to grams using the density of water (1 g/mL): mass of water = volume of water × density of water = 30.0 mL × 1 g/mL = 30.0 g
Now we can calculate the molality (m) of the solution: molality = moles of solute / mass of solvent (in kg) = 0.00424 mol / (30.0 g / 1000) = 0.1413 mol/kg
Rounding off to three decimal places, the molality of the resulting solution is approximately 0.141 m.

# CHAPTER-3
# BIOCHEMISTRY

# THERMODYNAMICS

## IIT JAM BT

### PREVIOUS YEAR EXAM QUESTIONS

**(IIT JAM BT - 2007)**

1. 8M urea solution became cold when it was prepared by dissolving an appropriate amount of urea in water at room temperature. This is because the dissolution of urea is
   (1) Exothermic and exergonic
   (2) Exothermic and endergonic
   (3) Endothermic and exergonic
   (4) Endothermic and endergonic

**(IIT JAM BT - 2007)**

2. A zero order reaction is 50% complete in 30 minutes. The time (in minutes) from the start of the reaction required for 80% completion is
   (1) 42 (2) 48
   (3) 52 (4) 60

**(IIT JAM BT - 2008)**

3. During a cyclic process, which one of the following is NOT always zero?
   (1) Enthalpy change
   (2) Entropy change
   (3) Internal energy change
   (4) Work done by the system

**(IIT JAM BT - 2009)**

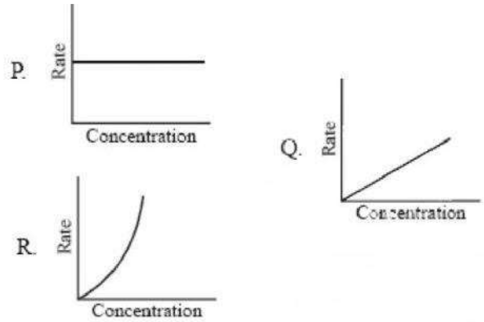
4. The reaction $CaCO_3(s)$ □ $CaO(s) + CO_2(g)$ is not favored at 298K. Given that for this reaction at 298K, $\Delta_t H^0$ =200 kJ $mol^{-1}$ and $\Delta_t S^0$=200 $JK^{-1}$ $mol^{-1}$, the lowest temperature at which this reaction will proceed in the forward direction is
   (1) 801 K (2) 901 K
   (3) 1001 K (4) 1101 K

**(IIT JAM BT - 2010)**

5. Considering the equation $\Delta G^0 = \Delta H^0 - T\Delta S^0$ which one of the following statements is NOT CORRECT?
   (1) When $\Delta G^0$ is negative, the reaction is exergonic
   (2) When $\Delta G^0$ is negative, the reaction can occur spontaneously
   (3) When $\Delta S^0$ is negative, the molecular disorder decreases during the reaction
   (4) When $\Delta H^0$ is negative, the reaction is endothermic

**(IIT JAM BT - 2011)**

6. The *correct* orders of the reactions deduced from the graphs given below, are



   (1) P-First order, Q-Zero order, R-Half order
   (2) P-Zero order, Q-First order, R-Second order
   (3) P-Pseudo-first order, Q-Second order, R-Third order
   (4) P-Second order, Q-First order, R-Zero order

**(IIT JAM BT - 2013)**

7. For the $Na^+$- mediated active transport of a molecule of glutamic acid from a concentration of0.1mM outside the cell to 20 mM inside the cell, calculate the minimum number of $Na^+$ ions required to supply the necessary free energy. Use T = 37ºC, pH = 7,$\Delta\psi$= –70mV and F = 23062 cal/mol.V. $\Delta G$ released for the transport of one $Na^+$ is 3.3 kcal/mol. Glutamic acid carries a net charge of –1 at pH 7.
   (1) 4 (2) 10
   (3) 2 (4) 1

**(IIT JAM BT - 2014)**

8. The zeroth law of thermodynamics
   (1) Gives a fundamental limitation of the efficiency of a heat engine
   (2) Deals with thermal equilibrium leading to the concept of temperature
   (3) Is a direct consequence of the general law of conservation of energy
   (4) Implies that the co-efficient of performance of a refrigerator can never be infinite.

**(IIT JAM BT - 2014)*****

9. If the work done by a human heart is 0.5 J per beat, with the time period "T" of 0.8 seconds for a beat, the approximate energy (in kcal) required by a human heat to beat in a day is *Assume:* 1 calorie = 4.2 Joules
   (1) 13 (2) 26
   (3) 130 (4) 260

**(IIT JAM BT - 2019)**

10. Phosphoglucoisomerase catalyzes the following reaction:

$$Glu - 6 - P \rightleftarrows Fru - 6 - P$$

If 0.05% of the original concentration of Glu-6-P remains at equilibrium, then the equilibrium constant of this reaction is________.

**(IIT JAM BT - 2021)**

11. At 25°C and pH 7.0, the concentrations of glucose 1 phosphate and glucose 6-phosphate are (2)0 mM and 38 mM. respectively at equilibrium. The standard free energy change for the conversion of glucose 1-plosphate to glucose 6-phosphate is _____ J/mol. [R = 8.315 J $mol^{-1}$ $K^{-1}$]

**Answer Key**

| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|
| 3 | 2 | 4 | 3 | 4 | 2 | 3 | 2 |
| **9** | **10** | **11** | | | | | |
| 1 | 1999-1999 | 7295.3 | | | | | |

## EXPLANATION

**1. Explanation:**- When urea dissolves in water, it absorbs heat from the surroundings, making the solution cold. This means that the dissolution of urea is endothermic. However, the dissolution of urea also releases free energy, making it exergonic.

An endothermic reaction is a reaction that absorbs heat from the surroundings. An exergonic reaction is a reaction that releases free energy.

In the case of the dissolution of urea, the energy required to break the bonds in the urea molecules is greater than the energy released when the urea molecules interact with the water molecules. Therefore, the dissolution of urea is endothermic.

However, the free energy released when the urea molecules interact with the water molecules is greater than the energy required to break the bonds in the urea molecules. Therefore, the dissolution of urea is exergonic.

The overall effect of the dissolution of urea is that heat is absorbed from the surroundings, making the solution cold.

**2. Explanation:**- In a zero-order reaction, the rate of reaction is independent of the concentration of the reactant. Given that the reaction is 50% complete in 30 minutes, it means that half of the reactant has been consumed in that time. To determine the time required for 80% completion, we can use the concept that in a zero-order reaction, the time required for a certain percentage of completion is proportional to the initial concentration of the reactant.

The time required for 80% completion is given by: t = (80%/50%) × 30 minutes t = 1.6 × 30 minutes t = 48 minutes

Therefore, the time required for 80% completion is (2) 48 minutes.

**3. Explanation:**- During a cyclic process, the system returns to its initial state. Therefore, the change in internal energy, enthalpy, and entropy are all zero. However, the work done by the system may not be zero. For example, if the system expands during part of the cycle, it will do work on the surroundings. This work will not be undone during the rest of the cycle, so the net work done by the system will not be zero. The other answer choices are incorrect because they are all zero during a cyclic process.

**4. Explanation:**- To determine the lowest temperature at which the reaction CaCO3(s) → CaO(s) + CO2(g) will proceed in the forward direction, we can use the relationship between Gibbs free energy change (ΔG), enthalpy change (ΔH), and entropy change (ΔS):

ΔG = ΔH - TΔS

Given ΔH0 = 200 kJ/mol and ΔS0 = 200 J/(mol·K), we want to find the lowest temperature (T) at which ΔG is negative (ΔG < 0).

Substituting the values into the equation, we have: ΔG = ΔH - TΔS 0 = 200 kJ/mol - T(200 J/(mol·K))

Converting the units to match, we have: 0 = 200 × 10^3 J/mol - T(200 J/(mol·K))

Simplifying the equation, we get:

$$T = (200 \times 10^3 J/mol) / (200 J/(mol \cdot K)) T = 1000 K$$

Therefore, the lowest temperature at which this reaction will proceed in the forward direction is (3) 1001 K.

**5. Explanation:**- In the given equation ΔG0 = ΔH0 - TΔS0:

A negative ΔG0 indicates that the reaction is spontaneous and can occur spontaneously.

When ΔS0 is negative, it means that the molecular disorder decreases during the reaction.

When ΔH0 is negative, it indicates that the reaction releases heat and is exothermic, not endothermic.