Chhatrapati Shahu Ji Maharaj University, Kanpur

Answer Script Details
Barcode 5701221

Roll No. 24063001034
Total Mark 43/75.00

Exam M.SC-III_ODD_EXAM_NOV_2025
Subject B020901T - Bioinorganic Bioorganic Biophysical Chemis

Question wise Mark Summary

Q.No	Mark	Q.No	Mark	Q.No	Mark	Q.No	Mark
1A	3/5	7D	0/3				
1B	3/5	8	10/15				
1C	3/5	9A	0/5				
1D	3/5	9B	0/5				
1E	2/5	9C	0/5				
1F	3/5						
1G	2/5						
1H	2/5						
1I	2/5						
2	10/15						
3	0/15						
4	0/15						
5	0/15						
6	0/15						
7A	0/3						
7B	0/3						
7C	0/3						

Chhatrapati Shahu Ji Maharaj University
Kanpur, Uttar Pradesh

PART-II

Date of Exam: 03/12/25 Shift: 2nd Room No.: 20
Paper Code: B020901T Subject: Chemistry Semester: 3rd
Name of Candidate: Priya Kumari Gupta
Roll No.: 2 4 0 6 3 0 0 1 0 3 4

COE Facsimile

Signature of Invigilator

Signature of Candidate

MARKS OBTAINED

Q.	1	2	3	4	5	6	7	8	9	10
(a)										
(b)										
(c)										
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Total										

Total Marks in Figures — Max. Marks

Total Marks in Words

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Paper Code

Signature of Evaluator

Course: Bioinorganic, Bioorganic, Biophysical Chemistry.
Session: 2024-25 Year/Semester: 3rd
Subject Name: Bioinorganic (Chemistry)
Medium: English ● Hindi ○

Paper Code
B 0 2 0 9 0 1 T

Exam Date
0 3 1 2 2 0 2 5

Name of Candidate
PRIYA KUMARI GUPTA

Father's Name
SHAMBHU NATH PRASAD

College Code
U N 0 1

परीक्षा केंद्र का कोड
Exam Centre Code
U N 0 1

परीक्षा का प्रकार
Type of Exam
संस्थागत Regular ● भूतपूर्व छात्र Ex-Student ○
व्यक्तिगत Private ○ बैक पेपर परीक्षा Back Paper Exam ○

ANSWER BOOKLET NO.
5701221

B 0 2 0 9 0 1 T
Paper Code

नामांकन संख्या
Enrollement Number: C S J M A 2 4 0 0 0 0 6 3 1 7 1

परीक्षार्थी अनुक्रमांक संख्या Candidate's Roll Number
2 4 0 6 3 0 0 1 0 3 4

पेपर कोड Paper Code
B 0 2 0 9 0 1 T

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नोट: 1. परीक्षार्थी को निर्देशित किया जाता है कि आवरण पन्ने के पृष्ठ भाग पर अंकित सभी निर्देशों को सावधानी पूर्वक पढ़ें।
2. गोलों को भरने हेतु काली प्रविष्टियाँ बायीं तरफ से शुरू की जायें। 3. गोलों को काले या नीले बॉलपेन से भरा जायें।

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-I

1. Read the instructions carefully given on the answer script and admit card.
2. Write Date of Exam, Shift, Paper Code & Name of Subject Correctly.
3. Write Name & Roll No. Correctly.
4. Write Semester & Branch Correctly.

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-III

1. Use blue or black ball point pen for writing alphabets & numerals in ☐ boxes.
2. Carefully study the example before you start marking.
3. As shown in the example below, blacken thecircles completely.

4. Make no Stray marks o n this sheet.
5. **DO NOT WRITE OR MARK ON THE BAR CODE.**

IN ORDER TO AVOD UFM (UNFAIR MEANS) :

1. The Roll No. and Answer Book no. found elsewhere or any other symbol found in the answer book will be treated as unfair means.
2. Any tempering of Bar Code and Booklet no shall be treated as Unfair Means.
3. Do Not bring the materials like slip of paper/mobile/digital diaries/ study material/ revision notes in examination hall. Possession of the mobiles/ digital diaries/electronic/digital/ watch and any other electronic gadget except memory less scientific calculator shall be considered as UFM case.
4. Do not keep or paste currency note in answer script it shall be consider as UFM.

अनुचित साधन से बचने हेतु :

1. उत्तर पुस्तिका के निर्देशित स्थान को छोड़कर अनुक्रमांक एवं उत्तरपुस्तिका का क्रमांक कहीं और न लिखे तथा कोई भी चिन्ह न बनायें क्योंकि यह अनुचित साधन प्रयोग की परिधि में आता है।
2. उत्तर पुस्तिका के मास्टरसील अथवा उत्तर पुस्तिका संख्या चिन्ह छेड़ छाड़ करने पर अनुचित साधन प्रयोग माना जायेगा।
3. परीक्षा कक्ष में निम्न वस्तुएं साथ न लायें, जैसे लिखे हुए कागज की पुर्जियां, मोबाईल, डिजिटल डायरी, डिजिटल वॉच, कॉपी, पुस्तक यह सभी वस्तुएं जो अनुचित साधन में आसानी आती है। केवल संवेदित प्रकरण में ही मेमोरी लेस साइंटिफिक कैलकुलेटर ले जाने की अनुमन्यता होगी।
4. उत्तर पुस्तिकाओं में कच्चे न लगे न ही उत्तर पुस्तिका में चिपकायें। ऐसा करना अनुचित साधन प्रयोग की परिधि में आता है।

परीक्षार्थियों के लिए निर्देश

1. प्रवेश पत्र एवं उत्तर पुस्तिका पर दिये गये निर्देशों को ध्यान से पढ़ें।
2. उत्तर पृष्ठ के दूसरी तरफ कुछ न लिखें।
3. उत्तर पुस्तिका के पृष्ठों पर दोनों तरफ लिखें।
4. प्रश्न पत्र पर अपने अनुक्रमांक के अतिरिक्त कुछ न लिखें।
5. प्रश्न पत्र कोड एवं प्रश्न पत्र ID सावधानी पूर्वक लिखें।
6. अपनी स्थिति स्पष्ट लिखें।
7. उत्तर पुस्तिका के पृष्ठों की संख्या देखें। अगर उत्तर पुस्तिका में पृष्ठ (1-24) से कम है या कटे हुए है, तो शुरू होने के पूर्व दूसरी उत्तर पुस्तिका ले लें।
8. प्रश्नपत्र को देख, यदि प्रश्नपत्र के विषय कोड, विषय का नाम तथा प्रश्न में कोई त्रुटि है तो उसके प्रारंभ होने के 30 मिनट के अन्दर कक्ष निरीक्षक को तत्काल सूचित करें, उसके बाद विश्वविद्यालय द्वारा कोई नहीं की जायेगी।
9. प्रश्नों के उत्तर लिखने के लिये पेंसिल का प्रयोग न करें।
10. दी कोपी या अतिरिक्त ग्राफ नहीं दिया जायेगा।

INSTRUCTION TO THE CANDIDATE

1. Read the instructions carefully given on the Question Paper, Admit Card & Answer Script.
2. Do not write anything on back side of the cover page.
3. Write on both sides of pages of answer book.
4. Do not write anything on question paper except Roll Number.
5. Write Paper Code & Question Paper Id carefully.
6. CHECK the number of pages (1-24) or any other kind of damage in your answer script, if found than change the answer script immediately before t commencement of examination.
7. CHECK the Question Paper for any kind of discrepancy e.g. Subject Code, Name, and Question of the Question Paper during first THIRTY MINUTES commencement of the exam, so that it can be corrected in TIME. After that corrections shall be entertained by the university.
8. Do not use pencil for answering the question.
9. Write status correctly e.g. those appearing in carry over papers should fill in as Carry Over. Those appearing as Ex- Students should fill in status as ex
10. No supplementary answer book & graph paper will be provided.

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-IV

1. Use blue or black ball point pen for writing alphabets & numerals in ☐ Boxes.
2. Use blue or black ball point pen for filling the circles.

Note- If your Roll No. is of 10 digits. Please leave first three columns .

Paper Code
B 0 2 0 9 0 1 T

1

Sec-A

UNI- 02.

1 (a) Standard free energy is the change in Gibbs free energy of a reaction when it is carried out under standard conditions:

- Temperature = 298 K (25°C)
- Pressure = 1 atm
- Concentration of all reactants & products = 1M.

It indicates the spontaneity of a reaction under standard conditions:

- $\Delta G_r < 0$ (negative) – Reaction is spontaneous.
- $\Delta G_r > 0$ (positive) – Reaction is non-spontaneous.
- $\Delta G_r = 0$ – Reaction is at equilibrium.

It is related to the equilibrium constant (K) by the equation:

$$\Delta G_r^\circ = -RT \ln K$$

example 1:- Decomposition of hydrogen Peroxide

$$2H_2O_2(l) \longrightarrow 2H_2O(l) + O_2(g)$$

Standard free energy change:

$$\Delta G_r^\circ = -120\ KJ/mol.$$

Example 2:- Formation of water.

$$2H_2 \rightarrow O_2 \longrightarrow 2H_2O$$

(B) Chemical catalyst are non-living substances (usually inorganic or simple organic compounds) that speed up the rate of a chemical reaction without undergoing permanent change.

Characteristics:

- Usually simple inorganic substances (e.g. metal, metal oxides, acids, bases).
- Work under high temperature and pressure.
- Not very specific — can catalyze many reactions

Example:

- Fe catalyzes the Haber process:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Pt/Pd catalyze hydrogenation of alkenes.

Biological Catalyst: are enzymes produced by living organisms (plants, animals, microbes) that speed up biochemical reactions.

Characteristics:

- Mostly proteins — some RNA enzymes

Highly specific – one enzyme usually catalyzes one reaction.
- Work at mild conditions.
- Very efficient.

e.g. Amalyse breaks starch into maltose.

(c) metal ions play essential roles in living organisms by acting as structural components, enzymes cofactors, electron carriers and so on.

- Structural Role – Some enzymes maintain the structure of biomolecules.
  → Mg^{2+} stabilises the structure of DNA & RNA by binding to phosphate group.

- Catalytic Role : many enzymes require metal ions as cofactors to carryout reactions.
  → Fe^{2+} / Fe^{3+} in cytochrome helps in electron transfer during cellular respiration.

- Oxygen Transport & Storage – Important biological metal participate in oxygen binding and movement.
  → Fe^{2+} in hemoglobin and myoglobin binds and transport oxygen in blood and muscles.

- Electron Transfer – Transition metals can easily change oxidation state, making them ideal for redox reaction.

(d)

Water cleavage occurs during the light reaction of photosynthesis in thylakoid membranes of chloroplast. It provides electrons, protons and oxygen.

Role of Photosystem II in Water Cleavage :-

PS II absorbs light → chlorophyll P680 becomes excited → loses electrons.

To replace its lost electrons, PS II pulls electrons from water.

This process is carried out by the oxygen-evolving complex (OEC) or water-splitting complex.

Water Splitting Reactions :-

$$2H_2O \rightarrow 4H^+ + 4e^- + O_2$$

Products of PS II water cleavage :-

- 4e⁻
- 4 protons
- 1 molecule of O_2.

Role of Photosystem I in water cleavage :-

Location - Stroma side

PS I does not split water.

Function:

- Accepts e⁻ that have travelled from PS II through:

PS II → Plastoquinone → Cytochrome B6f → Plastocyanin → PSI.

- Re-excites e⁻ using light energy.
- Reduces $NADP^+$ and NADPH using Fd and $NADP^+$ reductase.

Key Rean :

$NADP^+ + 2e^- + H^+ \longrightarrow NADPH$.

(E) Coenzymes are non-protein organic molecules that bind with enzymes and help them carry out biochemical reactions. They often act as carriers of electrons, atoms or functional groups.

(1) Act as Carriers of Functional Groups :-

Coenzymes transfer chemical groups from one molecule to another. Coenzyme A (CoA) → carries acyl (CH_3CO) group in metabolism.

(2) Participate in Oxidation-Reduction Reaction :-

Many coenzymes accept or donate electrons or H_2 atoms.

- NAD^+ / NADH → electron carriers in respiration.
- FAD / $FADH_2$ → hydrogen carriers in Krebs cycle.

(3) Helps in Energy Transfer :-

Coenzyme stores and transfer energy in metabolic reactions.

ATP acts as an energy transferring coenzyme by donating phosphate group.

(4) Assist in Carbon Transfer Reaction :-

Some coenzymes carry single carbon units in biosynthesis
• Tetrahydrofolate (THF) → transfers one carbon unit.

(E) A cofactor is a non-protein chemical substance required by an enzyme to become active and carry out biochemical reaction.
Without the cofactors, many enzymes cannot function properly.

Cofactors may be :-
- Metal ions (e.g. Mg^{2+}, Zn^{2+})
- Organic molecules (coenzymes) such as NAD^+.
- Prosthetic groups (tightly bound cofactors)

Types of Cofactors :-

(1) Inorganic Cofactors (metal Ions).

These are metal ions that help enzymes in catalysis or stabilization.

examples:-
- Mg^{2+} → stabilizes ATP-using enzymes.
- Zn^{2+} → in carbonic anhydrase

(2) Organic Cofactors (Coenzymes)

These are organic, non-protein molecules that participate in reactions by carrying electrons or groups.
example :-
- NADH / NAD^+
- FAD / $FADH_2$

(3) Prosthetic Group :-

These are cofactors tightly or permanently bound to the enzyme.
example :-
- Heme group in hemoglobin and cytochromes.
- Biotin in carboxylase enzymes.

(4) Affinity labelling is a biochemical technique used to identify and study the active site of enzymes.

It involves using a specifically designed molecule that resembles the enzyme's natural substrate but also contains a reactive group that forms a covalent bond with the enzyme at or near its active site.

Key features :-
→ Uses a substrate analog.
→ The analog carries a reactive group

→ The reactive group forms an irreversible covalent bond.

→ Useful in enzyme mechanism studies, protein mapping and drug design.

Types of Affinity Labelling :-

a) Active-Site Directed Irreversible Inhibition :-
The analog binds to the active site and reacts covalently.
e.g. TPCK labels histidine in chymotrypsin.

(2) Photoaffinity labelling :-

A photoreactive group is attached to the analog. When exposed to UV light, it forms a covalent bond.

(H) In biology, the standard free energy change (ΔG°) represents the amount of free energy released or absorbed during a biochemical reaction under standard biochemical conditions.

- Temperature = 25°C
- Pressure = 1 atm
- Concentration of all reactants and products = 1M
- pH = 7
- Water concentration = Constant.

Paper Code

9

Examples in Biological systems :-

(1) Hydrolysis of ATP

$$ATP + H_2O \longrightarrow ADP + P_i$$

ATP hydrolysis is highly exergonic → releases energy for cellular work.

(2) Glucose → Glucose-6-phosphate

Glucose + P_i → Glucose-6-phosphate.

Biological Importance :-

- Predicts direction of metabolic reactions.
- Helps understand energy flow in pathways.
- Explains coupled reaction.
- Determines whether a reaction can occur spontaneously.

(3) Proteins are essential biological macromolecules that perform a wide variety of functions in living organisms. Their function depend on their structure, sequence of amino acid, and their 3-D shape.

(1) Structural Function :-

Protein provide strength, support and shape to cells and tissues.

example :- • Collagen in tendons.

(2) Enzymatic function :- Most enzymes are proteins. They speed up biochemical reactions.
Example :- • Amylase
• DNA polymerase.

(3) Transport function :- Protein helps transport molecules across the body or across cell membranes.
example :- • Hemoglobin transports oxygen.
• Albumin carries fatty acids.

(4) Hormonal Function :- Some hormones are proteins that regulate physiological activities.
example :- • Insulin
• Growth hormone.

Sec-B.

UN-02.

(2) Hemerythrin is an oxygen-binding metalloprotein found in some marine invertebrates such as sipunculids, brachiopods, annelids, etc. It performs the same function as hemoglobin or hemocyanin but has a different structure and oxygen-binding mechanism.

Structure of Hemerythrin :-

(1) Metal Centre :-

Hemerythrin contains a binuclear iron centre.

(c) Oligomeric Nature :-

- Typically occurs as an octamer, through some species show dimer or tetramer.
- Each subunit is about 110 amino acids and contain a single active site.

(B) Active Site Composition :-

The oxygen-binding site contains a di-iron centre. These two iron atoms are bridged by :-

- μ-oxo or μ-hydroxo bridges
- Carboxylate groups from glutamate residues.
- Imidazole from histidine residues.

(A) Coordination Environment :-

- Each iron atom is typically five or six coordinated.
- No heme or protein.
- The protein matrix precisely arranges the iron atoms for reversible oxygen binding.

Function of Hemerythrin :-

(1) Oxygen Binding (O_2 Uptake).

Hemerythrin binds oxygen by a unique mechanism called oxygenation, not oxidation of the metal.

• In deoxyhemerythrin both Fe atoms are in Fe^{2+} state.

• On oxygen binding:
→ O_2 binds between the two Fe atoms.
→ One Fe^{2+} is oxidized to Fe^{3+}, forming a μ-peroxo bridge.
→ The other Fe remains Fe^{3+}.

(2) No Radical Formation :-
Unlike hemoglobin, hemerythrin does not form superoxide or free radical.
Oxygen is held as a hydroperoxide, not O_2^- or Fe-O_2 species.

(3) Reversibility :-
oxygen binding is reversible so hemerythrin can deliver oxygen to tissues when needed.

(4) Transport and Storage :-
Major role : transport and storage of oxygen in invertebrates living in low-oxygen environments.

(5) Secondary Ro

• Protects organisms from low-oxygen stress.
• Maintains cellular respiration in extreme conditions.

Paper Code

13

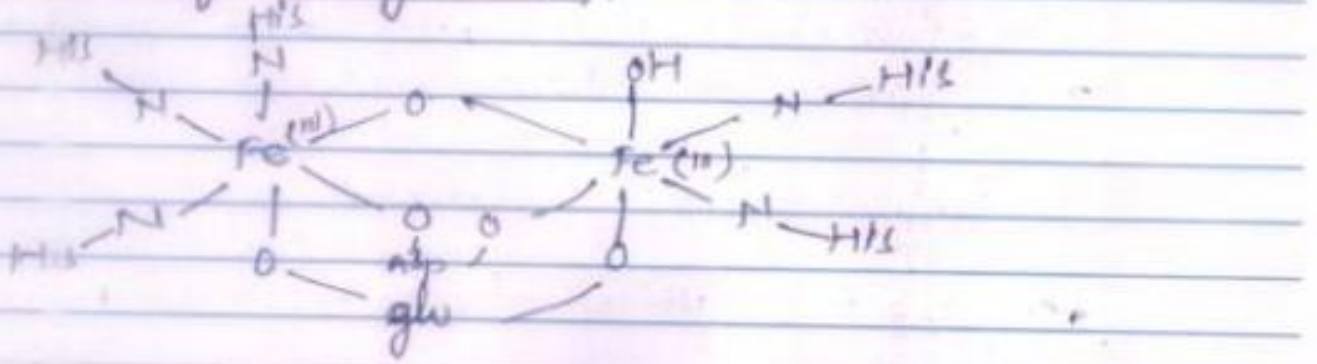
Key Differences from hemoglobin:-

Feature	Hemerythrin	Hemoglobin
• Metal center	Di-Iron (Fe-Fe)	Single Iron.
• Heme group	Absent in hemerythrin	Present in hemoglobin
• Color when oxygenated	Violet / pink	Red.
• O_2 binding	Peroxide bridge	$Fe^{2+} - O_2$ complex
• Occurrence	Marine Invertebrates	Vertebrates.

Hemerythrin is a non-heme di-iron oxygen binding protein found in marine invertebrates.

It contains two Fe atoms bridged by oxo-hydroxo and carboxylate groups. Oxygen binding occurs by formation of a μ-peroxo bridge converting $Fe^{2+} - Fe^{2+}$ to $Fe^{3+} - OOH - Fe^{3+}$.

Structure of hemerythrin:-



Paper Code

Section - C.

9(a) Fisher's lock and key concept :-

According to Fisher's lock and key model, an enzyme active site is rigid and precisely shaped, just like a lock.

The substrate has a specific complementary shape like a key.
Because of this exact fit, only the correct substrate can bind to the enzyme.

Key Features :-

(1) Rigid Active Site :-

- The active site of the enzyme is pre-formed, not flexible.
- It has a specific shape that exactly matches the substrate.

(2) Specificity
- Because the shape match perfectly, enzymes are highly specific.
- One enzyme typically acts on one substrate or a group of very similar substrates.

(3) Enzyme - Substrate Complex :-

- The substrate fits into the active site forming

enzyme-substrate complex.
• This complex undergoes reaction and releases products.

Enzyme + Substrate → Enzyme-Substrate complex
(E) + (S) → (ES)

↓

Products + Enzyme.
(P) + (E).

(A) No major conformational change :-

• The enzyme does not change its shape during binding.

(b) Acid-Base catalysis :-

Acid Base catalysis is a type of catalyst in which a proton (H^+) is donated or accepted by a catalyst to increase the rate of a reaction.
It works by stabilizing intermediates and lowering the activation energy.

Types of Acid-Base Catalysis :-

(a) Specific Acid-Base Catalysis.

• Catalysis occurs only by H^+ or OH^- ions from the solvent.
• Rate depends only on pH, not on the concentration of other

acids / bases.
example - Hydrolysis of esters in strong acid.

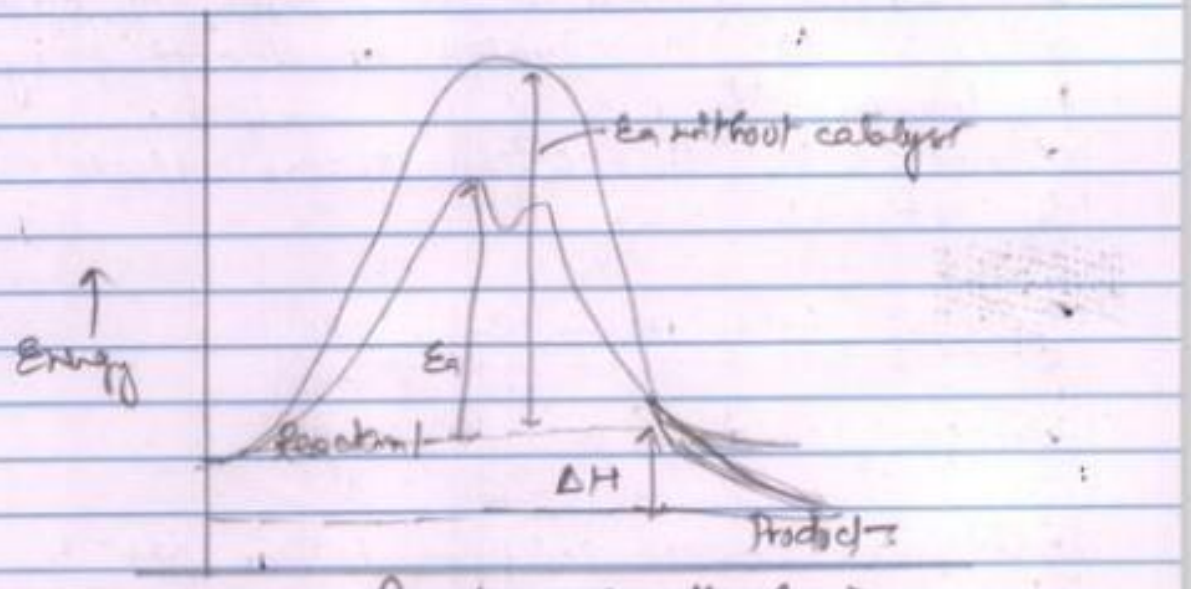
(2) General Acid-Base Catalysis :-

- Catalysis only by any acid or base present, not only H^+ or OH^-
- Reaction rate depends on the concentration of : buffers, weak acids, weak bases, amino acids.

example - Acetate ion acting as a base to remove H^+ form an intermediate.

Mechanism :-

- A proton donor (HA) transfers H^+ to the substrate.
- This increases the electrophilicity of the substrate and stabilizes intermediate.



(c) Synthesis of ATP from ADP:

ATP is made from ADP by phosphorylation transferring a phosphate group onto ADP. The main biological routes are:

- Oxidative phosphorylation – (mitochondria; ATP synthase) major source in aerobic cells.
- Substrate-level phosphorylation – (glycolysis, TCA – linked reactions) – direct transfer from a high-energy phosphorylated substrate to ADP.
- Photophosphorylation (chloroplasts / cyanobacteria; light-driven photon gradient).
- ATP regeneration systems in vitro (PEP / pyruvate kinase, creatine phosphate, acetate kinase).

Energetics:

- Standard Free energy change for ATP hydrolysis:

$ATP \longrightarrow ADP + P_i \qquad \Delta G^\circ = -30.5\ kJ/mol$

Biological mechanisms:

i) Oxidative phosphorylation:

Electrons from $NADP/FADH_2$ → electrons transport chain → pump protons across the inner mitochondrial membrane → generate proton motive force.

- ATP synthase uses the proton flow back through F_0, rotating the central shaft.
- Typically stoichiometry ~ 2.7–3 H^+ per ATP.

2) Substrate - Level phosphorylation:

Direct transfer of a phosphoryl group from a high-energy metabolic intermediate to ADP.

3) Photophosphorylation:

Light excites e⁻ in photosystem → e⁻ transport across thylakoid membrane → H^+ gradient → ATP synthase produces ATP in stroma.

4) Adenylate kinase (AMP recycling):

$2ADP \rightarrow ATP + AMP$.

Paper Code

19

X

Paper Code

20

Do Not Write anything in this Portion

X

Paper Code

21

X

Paper Code

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Do Not Write anything in this Portion

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23

X

Paper Code

24

Do Not Write anything in this Portion