I.12 Bio-inorganic Chemistry

Civil Services 2016–2026: **20** parts, **215** marks · IFoS 2016–2025: **16** parts, **197** marks

Syllabus. Metal ions in biological systems and their role in ion-transport across the membranes (molecular mechanism), oxygen- uptake proteins, cytochromes and ferredoxins.

Marks	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CSE	15	10	25	25	20	20	20	20	20	25	15
IFoS	10	20	10	18	23	30	25	23	23	15	

How to use this chapter. Read every question once and mark the ones that repeat. Pick three, write them by hand against the clock (about 7 minutes for 10 marks), then compare with the model answers on vkcscience.com.

2026

CSE 2026 · Q5(e) Ferredoxins and their classification [5 marks]

What is ferredoxin? How is it classified?

CSE 2026 · Q8(a) T and R forms of haemoglobin [10 marks]

Differentiate between T and R conformation of hemoglobin.

2025

CSE 2025 · Q5(e) Structure of [4Fe–4S] ferredoxin [5 marks]

Draw the structure of Ferredoxin protein containing [4Fe – 4S] and find the average oxidation number of iron.

CSE 2025 · Q7(a) T and R forms of haemoglobin [15 marks]

Distinguish the 'T' (tense) and 'R' (relax) conformations of Hemoglobin on reversible binding of oxygen (O_2).

CSE 2025 · Q7(b) Cytochrome b, cytochrome c and cytochrome c oxidase [5 marks]

What is the basic difference between Cytochrome 'b' and Cytochrome 'c'? Explain the role of Cytochrome 'c' oxidase.

IFoS 2025 · Q7(a) Photosynthesis and magnesium [15 marks]

Explain the major steps involved in photosynthesis. List the significant role of Mg^{2+} in the above process.

2024

CSE 2024 · Q6(c) The sodium pump and its role; Bohr effect; role of cytochrome P450 [20 marks]

(i) What is 'sodium pump'? Explain the role of sodium pump in biological system. *10*

(ii) What is Bohr effect? Explain the role of Cytochrome P450. *10*

IFoS 2024 · Q5(e) Why biological nitrogen fixation needs an enzyme [8 marks]

Write down the chemical equation for nitrogen fixation by nitrogenase enzyme. Discussing the thermodynamic and kinetic aspects of the reduction of N_2, state why nitrogen fixation requires an enzyme.

IFoS 2024 · Q6(b) Haemoglobin oxygenation and carbon dioxide transport [15 marks]

(i) State the changes that occur in Hemoglobin molecule on oxygenation.
(ii) What is 'blue baby syndrome'? Why does it occur?
(iii) What do you understand by 'Haldane effect' in relation to oxygen-uptake proteins? 7+4+4=15

2023

CSE 2023 · Q6(d) Rubredoxin and how it differs from ferredoxins [10 marks]

Explain the structural and other features of rubredoxin. How does it differ from ferredoxins?

CSE 2023 · Q7(a) Haemoglobin and cytochrome c; oxy- and deoxyhaemoglobin [10 marks]

Explain the common structural features of two major iron-containing proteins—haemoglobin and cytochrome c present in the human body. Explain the coordination chemistry involved at the central metal atom in case of oxyhaemoglobin and deoxyhaemoglobin. Give the details of the spin states, magnetic moment and oxidation number of central metal ion in both the cases.

IFoS 2023 · Q5(b) Haem, chlorophyll and fluorescence [8 marks]

State the structural differences between the macrocyclic rings present in chlorophyll and hemoglobin. How does the light-emitting behaviour of the macrocyclic ring present in chlorophyll change without and with metal ion in the cavity? Why does the change occur?

IFoS 2023 · Q7(a) Cytochrome P450 and its active oxidant [15 marks]

What is cytochrome P-450? How do you justify its name? State the oxidation state and spin state of the active metal centre present in the resting enzyme and any two important functions of P-450. During its enzymatic pathway, state the colour and origin of the colour of the radical cation intermediate and the role of the axial thiolate ligand present in its structure. What do you understand by peroxide shunt in the activity of cyt P-450?

2022

CSE 2022 · Q5(c) Allosteric effect and homotropic modulators [10 marks]

What is allosteric effect? Give example of an allosteric protein. Discuss homotropic allosteric modulators with examples.

CSE 2022 · Q8(b) Haemocyanin: active site, colours and functions [10 marks]

Draw the active site structure of Hemocyanin (Hc) in deoxyhemocyanin and oxyhemocyanin forms, and write the colour of Hemocyanin in these two forms. Write the functions of Hemocyanin.

IFoS 2022 · Q6(b) The sodium–potassium pump [15 marks]

Differentiate between active transport and passive transport through the cell membrane. What type of transport occurs in Na^+–K^+ pump? How does this pump function? Explain with mechanism.

IFoS 2022 · Q8(a) Cooperativity and the Bohr effect [10 marks]

What do you understand by 'Cooperativity' (Cooperative interaction) and 'Bohr effect' with respect to the oxygen transport in hemoglobin?

2021

CSE 2021 · Q5(c) Oxidation of haem to hematin, and how the protein prevents it [10 marks]

Give the mechanism of fatal formation of hematin in the binding of dioxygen by heme. How can it be averted by living systems?

CSE 2021 · Q7(a) Iron–sulphur proteins: structures and redox states [10 marks]

Draw the structures of various iron-sulphur proteins and their corresponding redox states.

IFoS 2021 · Q7(b) Z-scheme of photosynthetic electron transport [15 marks]

What is Z-diagram? Explain electron flow mechanism in photo system-I and II through Z-diagram.

IFoS 2021 · Q8(b) Magnesium in glycolysis [15 marks]

How does Mg^{2+} state help in the conversion of glucose into pyruvate? Explain it by proposing a mechanism for conversion.

2020

CSE 2020 · Q7(c) Choice of metal ions in enzymes and proteins [20 marks]

(i) Why are manganese, iron or cobalt used in redox enzymes in preference to zinc, gallium and calcium?
(ii) Explain the emergence of Ca^{2+}, Zn^{2+} and Cu^{2+} in the control of protein folding rather than Al^{3+} or Cr^{3+}.
(iii) State the characteristics of Zn^{2+} that make it suitable as the metal ion in many hydrolytic enzymes.
(iv) What features of manganese suit it to function as a redox centre in PS-II as opposed to metals such as copper or nickel?

IFoS 2020 · Q5(d) Nitrogenase and the nitrogen-fixation pathway [8 marks]

What is a nitrogenase? Show the mechanism of nitrogen fixation pathway catalyzed by nitrogenase.

IFoS 2020 · Q6(b) Ferredoxins: 2Fe–2S and 4Fe–4S active sites [15 marks]

What are ferredoxins? Draw the active site structures of 2Fe–2S and 4Fe–4S ferredoxins. Mention their functions.

2019

CSE 2019 · Q3(b) Active site of oxyhaemerythrin [10 marks]

Describe the active site ligand environment around the coordination sphere of each iron in hemerythrin in the oxygenated form.

CSE 2019 · Q4(a) Active transport; the Na $^{+}$ /K $^{+}$ pump [15 marks]

What is active transport across biological membrane? Propose the mechanism of transport of Na^{+}/K^{+} across the membrane.

IFoS 2019 · Q5(e) Mechanism of cytochrome P-450 [8 marks]

Draw the schematic representation of the mechanism of the function of Cytochrome P– 450 and explain.

IFoS 2019 · Q6(b) K^+ transport by a carboxylic crown-ether ionophore [10 marks]

Draw the schematic representation of the mechanism of transport of K^+ by a crown ether type ionophore bearing a carboxylic acid group in the periphery. Explain various stages involved in the process.

2018

CSE 2018 · Q7(b) Active sites of [2Fe–2S] and [4Fe–4S] ferredoxins [10 marks]

Draw the active site structure of [2Fe-2S] and [4Fe-4S] ferredoxins. Comment on the oxidation state of metal in oxidised and reduced forms of [2Fe-2S].

CSE 2018 · Q8(c) Active sites and functions of cytochrome c and cytochrome P-450 [15 marks]

Draw the active site (coordination sphere only) of cytochrome C and cytochrome P-450. Discuss their biochemical function.

IFoS 2018 · Q8(c) Spin state and geometry of Fe(II) in myoglobin and oxymyoglobin [10 marks]

Explain the spin state and electronic configuration of iron(II) in myoglobin and O_2 bound myoglobin. How does the geometry of iron(II) in these metalloproteins vary subtly?

2017

CSE 2017 · Q7(b) Cytochromes: prosthetic group, haemoglobin, function [10 marks]

Define prosthetic group in cytochromes. How do they differ from haemoglobin? What is their main function?

IFoS 2017 · Q5(b) Deoxymyoglobin and oxidised cytochrome c [20 marks]

Draw the structures of the proteins (i) de-oxy myoglobin, and (ii) oxidised form of cytochrome-c. Comment on the properties of de-oxy myoglobin. 5+5+10=20

2016

CSE 2016 · Q7(b) Ferredoxins: structure and role in photosynthesis [15 marks]

Describe the important structural features of "Ferredoxin molecule". What is its role in photosynthesis?

IFoS 2016 · Q7(b) Ferredoxin: structure and role in photosynthesis [10 marks]

Describe the structural features of 'ferredoxin' molecule. What is its role in photosynthesis?