A) MCQ:

1. Which of the following is true about the dissociative substitution mechanism?

A) The intermediate has a higher coordination number than the starting complex.
B) The rate of substitution depends primarily on the concentration of the entering ligand.
C) The leaving group departs after the incoming ligand forms a bond with the metal center.
D) It involves the formation of a stable intermediate complex.

Answer: B) The rate of substitution depends primarily on the concentration of the entering ligand.

2. Which of the following best describes the associative substitution mechanism?

A) The intermediate complex has a lower coordination number than the starting complex.
B) The entering ligand forms a bond with the metal center before the leaving group departs.
C) It does not involve an intermediate.
D) The rate of substitution is independent of the concentration of the incoming ligand.

Answer: B) The entering ligand forms a bond with the metal center before the leaving group departs.

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3. What distinguishes the interchange mechanism from the associative and dissociative mechanisms?

A) It always involves a stable intermediate complex.
B) It involves no intermediate but may have various transition states.
C) It occurs only in complexes with high-spin metal centers.
D) The rate of substitution is not influenced by the incoming ligand's concentration.

Answer: B) It involves no intermediate but may have various transition states.

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4. Which of the following describes a labile complex?

A) A complex where ligand exchange occurs very slowly.
B) A complex where ligands are exchanged quickly, often with $t_{1/2} \leq 1$ min.
C) A complex that can only undergo inner-sphere electron transfer reactions.
D) A complex that forms stable intermediates in substitution reactions.

Answer: B) A complex where ligands are exchanged quickly, often with $t_{1/2} \leq 1$ min.

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5. Which of the following complexes is considered kinetically inert?

A) $[Cu(NH_3)_4(H_2O)_2]^{2+}$
B) $[Co(NH_3)_6]^{3+}$
C) $[CuCl_4]^{2-}$
D) $[Fe(CO)_5]$

Answer: B) $[Co(NH_3)_6]^{3+}$

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6. In an outer-sphere electron transfer reaction, what occurs between the reductant and oxidant?

A) New bonds are formed between the two species.
B) The coordination spheres of the complexes change during the transfer.
C) The electron transfer occurs without any significant change in the coordination spheres.
D) The electron transfer is coupled with ligand substitution.

Answer: C) The electron transfer occurs without any significant change in the coordination spheres.

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7. In an inner-sphere electron transfer reaction, what is required for the reaction to occur?

A) The complexes must share a common ligand in their coordination spheres.
B) The coordination spheres of both complexes must remain intact.
C) Only one of the complexes needs to undergo substitution.
D) The electron transfer occurs via the solvent, not through any direct bonding interaction.

Answer: A) The complexes must share a common ligand in their coordination spheres.

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8. Which of the following is an example of a biological redox reaction involving a metal center?

A) Conversion of glucose to ethanol in fermentation.
B) Oxidation of NADH to NAD^+ in cellular respiration.
C) Reduction of oxygen to water in the electron transport chain.
D) Conversion of light energy into chemical energy in photosynthesis.

Answer: C) Reduction of oxygen to water in the electron transport chain.

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9. Which of the following factors does NOT affect the reduction potential in biological systems?

A) Ionization energy.
B) Ligand environment.
C) Hydrogen-bonding interactions.
D) The temperature of the system.

Answer: D) The temperature of the system.

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10. Which of the following metal-containing electron transfer centers is most commonly associated with high oxidation potentials?

A) FeS clusters
B) Cytochromes
C) Copper-containing proteins (Cu sites)
D) Zinc-containing proteins

Answer: C) Copper-containing proteins (Cu sites)

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11. Which of the following metal centers in biological redox processes uses the Fe^{3+}/Fe^{2+} redox couple?

A) FeS clusters
B) Cytochromes
C) Cu sites
D) Zinc proteins

Answer: B) Cytochromes

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12. Which of the following redox reactions most likely occurs via the outer-sphere mechanism?

A) A reaction where a ligand from one complex is transferred to another, with no change in coordination number.
B) A reaction where a ligand is substituted by another, with an intermediate complex forming.
C) A reaction where the electron transfer occurs between complexes with shared ligands.
D) A reaction involving a concerted process without a distinct intermediate.

Answer: A) A reaction where a ligand from one complex is transferred to another, with no change in coordination number.

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13. Which of the following best describes the role of ATP in biological energy metabolism?

A) ATP is synthesized from NADH and $FADH_2$ during glycolysis.
B) ATP provides chemical energy for cellular processes by hydrolysis to ADP and inorganic phosphate.
C) ATP is a substrate in photosynthesis to produce glucose.
D) ATP is used to store energy as a secondary messenger in redox reactions.

Answer: B) ATP provides chemical energy for cellular processes by hydrolysis to ADP and inorganic phosphate.

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14. Which of the following is true about the reduction of $NADP^+$ to NADPH in photosynthesis?

A) It is coupled with the oxidation of glucose.
B) It involves the transfer of two electrons and one proton.

C) It occurs during the dark reactions of photosynthesis.
D) It is catalyzed by dehydrogenases.

Answer: B) It involves the transfer of two electrons and one proton.

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15. What is the role of dehydrogenases in biological redox processes?

A) They catalyze the reduction of $NADP^+$ to NADPH.
B) They facilitate the transfer of electrons without forming any bonds.
C) They catalyze oxidation reactions that involve the loss of hydrogen atoms.
D) They are involved in the reduction of oxygen in the electron transport chain.

Answer: C) They catalyze oxidation reactions that involve the loss of hydrogen atoms.

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16. Which of the following processes does NOT occur during light-dependent reactions in photosynthesis?

A) Excitation of electrons by light energy.
B) Formation of ATP from ADP and inorganic phosphate.
C) Reduction of $NADP^+$ to NADPH.
D) Fixation of carbon dioxide into sugars.

Answer: D) Fixation of carbon dioxide into sugars.

B) true and false:

1. The dissociative substitution mechanism involves an intermediate complex with a higher coordination number than the starting complex.

Answer: False
Explanation: The dissociative substitution mechanism involves an intermediate with a lower coordination number than the starting complex.

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2. In the associative substitution mechanism, the incoming ligand forms a bond with the metal center before the leaving group departs.

Answer: True
Explanation: In associative substitution, the incoming ligand forms a bond with the metal before the departure of the leaving group.

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3. The interchange mechanism involves the formation of a stable intermediate complex with a clear coordination number change.

Answer: False
Explanation: The interchange mechanism does not involve a stable intermediate and does not result in a clear coordination number change.

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4. Kinetically inert complexes exchange ligands very quickly, with a substitution rate constant ($t_1/_2$) less than 1 minute.

Answer: False
Explanation: Kinetically inert complexes exchange ligands very slowly, with $t_1/_2$ much longer than 1 minute.

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5. The redox reaction between two complexes involving no bond formation or breaking is an example of an inner-sphere mechanism.

Answer: False
Explanation: The described reaction is an example of an outer-sphere mechanism, where electron transfer occurs without bond formation or breaking.

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6. In an inner-sphere redox mechanism, at least one of the complexes must be labile to allow the formation of a bridging ligand.

Answer: True
Explanation: In an inner-sphere mechanism, one of the complexes must be labile to facilitate the formation of a bridging ligand for electron transfer.

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7. The energy for life on Earth comes directly from the Sun, primarily through photosynthesis in plants, algae, and some bacteria.

Answer: True
Explanation: The primary energy source for life on Earth is sunlight, which is captured by photosynthesis.

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8. $NADP^+$ is reduced to NADPH during the light-independent reactions of photosynthesis.

Answer: False
Explanation: $NADP^+$ is reduced to NADPH during the light-dependent reactions of photosynthesis.

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9. Dehydrogenases are enzymes that catalyze reductions by adding hydrogen to substrates.

Answer: False
Explanation: Dehydrogenases catalyze oxidation reactions, which involve the loss of hydrogen atoms (dehydrogenation).

10. ATP is the primary molecule for storing and transferring chemical energy in cells.

Answer: True
Explanation: ATP (adenosine triphosphate) is the energy currency of the cell, used in many cellular processes that require energy.

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11. In biological redox reactions, strong donor ligands tend to stabilize high oxidation states and lower the reduction potential.

Answer: True
Explanation: Strong donor ligands stabilize higher oxidation states and lower the reduction potential, making electron transfer more favorable.

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12. FeS clusters, cytochromes, and Cu sites are all types of metal-containing electron transfer centers involved in biological redox processes.

Answer: True
Explanation: FeS clusters, cytochromes, and copper-containing sites are all essential components in biological electron transfer chains.

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13. Fe^{3+}/Fe^{2+} couples are primarily found in cytochromes, which are typically six-coordinate and involve low-spin iron in both oxidation states.

Answer: True
Explanation: Cytochromes use the Fe^{3+}/Fe^{2+} redox couple, and iron is typically low-spin in both oxidation states.

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14. Copper-containing proteins, such as those with blue Cu centers, have reduction potentials that are generally more oxidizing than cytochromes.

Answer: True
Explanation: Copper-containing proteins (with blue Cu centers) have higher reduction potentials than cytochromes, making them more oxidizing.

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15. The reduction potential of a metal ion in a biological system is unaffected by the ionization energy of the metal.

Answer: False
Explanation: The reduction potential is influenced by several factors, including ionization energy, which affects the tendency of the metal to gain or lose electrons.

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16. In photosynthesis, the light-dependent reactions capture sunlight and convert it into chemical energy stored in glucose.

Answer: False
Explanation: The light-dependent reactions capture sunlight and store energy in ATP and NADPH, not directly in glucose, which is synthesized in the light-independent reactions (Calvin cycle).

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17. ATP is used by cells in both anabolic (energy-consuming) and catabolic (energy-releasing) processes.

Answer: True
Explanation: ATP is used in both anabolic processes (which require energy) and catabolic processes (which release energy).

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18. The electron transport chain in cellular respiration and photosynthesis always involves a single, continuous flow of electrons from one molecule to the next.

Answer: False
Explanation: The electron transport chain involves multiple steps and the transfer of electrons between various carriers, often involving proton gradients and coupling to other processes like ATP synthesis.

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19. The reduction potential of a redox couple is determined only by the metal ion involved, and not by the surrounding environment or ligands.

Answer: False
Explanation: The reduction potential is influenced by several factors, including the surrounding environment, the ligands, and other neighboring charges, not just the metal ion.

20. In a dissociative substitution reaction, the intermediate complex has a higher coordination number than the starting complex.

Answer: False
Explanation: In a dissociative substitution reaction, the intermediate has a lower coordination number than the starting complex.

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21. The exchange of ligands in a kinetically inert complex occurs rapidly, with a substitution rate constant ($t_1/_2$) much less than 1 minute.

Answer: False
Explanation: Kinetically inert complexes have a slow ligand exchange rate, and their substitution rate constant ($t_1/_2$) is much longer than 1 minute.

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22. In a redox reaction, the outer-sphere mechanism involves electron transfer where the coordination spheres of both the reductant and oxidant stay intact.

Answer: True
Explanation: In the outer-sphere mechanism, electron transfer occurs without any change in the coordination spheres of the reactants.

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23. In an associative substitution mechanism, the intermediate complex has a higher coordination number than the starting complex.

Answer: True
Explanation: In the associative mechanism, the intermediate complex has a higher coordination number because the incoming ligand bonds to the metal before the departing ligand leaves.

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24. The interchange mechanism is a combination of the dissociative and associative mechanisms, but it does not involve the formation of a stable intermediate.

Answer: True
Explanation: The interchange mechanism shares characteristics with both dissociative and associative mechanisms but does not form a stable intermediate.

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25. Copper (Cu) centers in proteins typically have reduction potentials in the range of 0.15–0.8 V, making them more oxidizing than iron-containing cytochromes.

Answer: True
Explanation: Copper (Cu) centers have higher reduction potentials than cytochromes, meaning they are generally more oxidizing.