LECTURES 13 & 14 – ENZYMES

QUESTIONS TO TRY FOR PRACTICE

1) Which of the following is a statement of the first law of thermodynamics?
A) Energy cannot be created or destroyed.
B) The entropy of the universe is decreasing.
C) The entropy of the universe is constant.
D) Kinetic energy is stored energy that results from the specific arrangement of matter.
E) Energy cannot be transferred or transformed.

2) For living organisms, which of the following is an important consequence of the first law of thermodynamics?
A) The energy content of an organism is constant.
B) The organism ultimately must obtain all of the necessary energy for life from its environment.
C) The entropy of an organism decreases with time as the organism grows in complexity.
D) Organisms grow by converting energy into organic matter.
E) Life does not obey the first law of thermodynamics.

3) Living organisms increase in complexity as they grow, resulting in a decrease in the entropy of an organism. How does this relate to the second law of thermodynamics?
A) Living organisms do not obey the second law of thermodynamics, which states that entropy must increase with time.
B) Living organisms are able to transform entropy into energy.
C) Living organisms do not follow the laws of thermodynamics.
D) As a consequence of growing, organisms cause a greater increase in entropy in their environment than the decrease in entropy associated with their growth.
E) Living organisms are able to transform energy into entropy.

4) Whenever energy is transformed, there is always an increase in the
A) free energy of the system.
B) free energy of the universe.
C) entropy of the system.
D) entropy of the universe.
E) enthalpy of the universe.

5) Which of the following statements is a logical consequence of the second law of thermodynamics?
A) If the entropy of a system increases, there must be a corresponding decrease in the entropy of the universe.
B) If there is an increase in the energy of a system, there must be a corresponding decrease in the energy of the rest of the universe.
C) Every energy transfer requires activation energy from the environment.
D) Every chemical reaction must increase the total entropy of the universe.
E) Energy can be transferred or transformed, but it cannot be created or destroyed.

6) Which of the following statements is representative of the second law of thermodynamics?
A) Conversion of energy from one form to another is always accompanied by some gain of free energy.
B) Heat represents a form of energy that can be used by most organisms to do work.
C) Without an input of energy, organisms would tend toward decreasing entropy.
D) Cells require a constant input of energy to maintain their high level of organization.
E) Every energy transformation by a cell decreases the entropy of the universe.

7) Which of the following is an example of potential rather than kinetic energy?
A) the muscle contractions of a person mowing grass
B) water rushing over Niagara Falls
C) light flashes emitted by a firefly
D) a molecule of glucose
E) a crawling beetle foraging for food

8) The mathematical expression for the change in free energy of a system is $\Delta G = \Delta H - T\Delta S$. Which of the following is (are) correct?
A) ΔS is the change in enthalpy, a measure of randomness.
B) ΔH is the change in entropy, the energy available to do work.
C) ΔG is the change in free energy.
D) T is the temperature in degrees Celsius.

9) A system at chemical equilibrium
A) consumes energy at a steady rate.
B) releases energy at a steady rate.
C) consumes or releases energy, depending on whether it is exergonic or endergonic.
D) has zero kinetic energy.
E) can do no work.

10) A chemical reaction that has a positive ΔG is best described as
A) endergonic.
B) entropic.
C) enthalpic.
D) spontaneous.
E) exergonic.

11) Enthalpy (*H*) is the
A) total kinetic energy of a system.
B) total energy in biological systems.
C) system's entropy.
D) cell's energy equilibrium.
E) condition of a cell that is not able to react.

12) Biological evolution of life on Earth, from simple prokaryote-like cells to large, multicellular eukaryotic organisms,
A) has occurred in accordance with the laws of thermodynamics.
B) has caused an increase in the entropy of the planet.
C) has been made possible by expending Earth's energy resources.
D) has occurred in accordance with the laws of thermodynamics, by expending Earth's energy resources and causing an increase in the entropy of the planet.
E) violates the laws of thermodynamics because Earth is a closed system.

13) Which of the following is true for all exergonic reactions?
A) The products have more total energy than the reactants.
B) The reaction proceeds with a net release of free energy.
C) The reaction goes only in a forward direction: All reactants will be converted to products, but no products will be converted to reactants.
D) A net input of energy from the surroundings is required for the reactions to proceed.
E) The reactions are rapid.

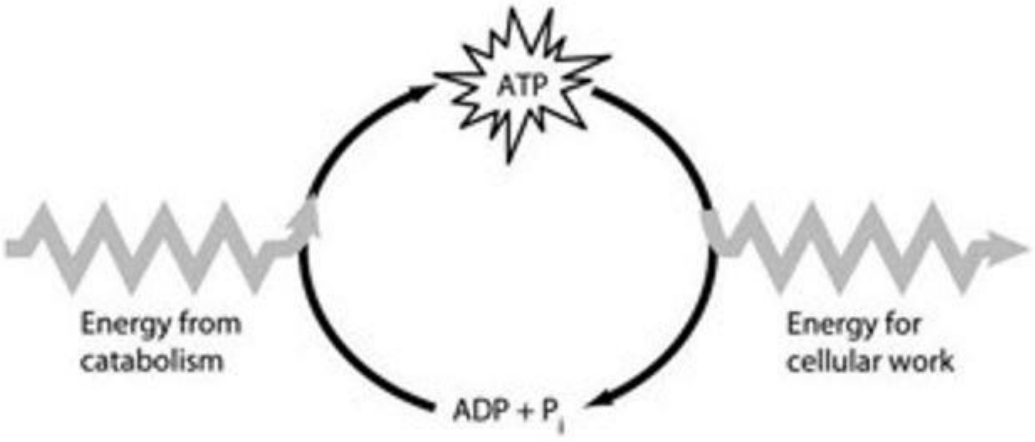
14) Why is ATP an important molecule in metabolism?
A) Its hydrolysis provides an input of free energy for exergonic reactions.
B) It provides energy coupling between exergonic and endergonic reactions.
C) Its terminal phosphate group contains a strong covalent bond that, when hydrolyzed, releases free energy.
D) Its terminal phosphate bond has higher energy than the other two phosphate bonds.
E) It is one of the four building blocks for DNA synthesis.

15) When 10 000 molecules of ATP are hydrolyzed to ADP and $\textcircled{P}_i$ in a test tube, about half as much heat is liberated as when a cell hydrolyzes the same amount of ATP. Which of the following is the best explanation for this observation?
A) Cells are open systems, but a test tube is an isolated system.
B) Cells are less efficient at heat production than nonliving systems.
C) The hydrolysis of ATP in a cell produces different chemical products than does the reaction in a test tube.
D) The reaction in cells must be catalyzed by enzymes, but the reaction in a test tube does not need enzymes.
E) Reactant and product concentrations in the test tube are different from those in the cell.

16) Catabolic pathways
A) combine molecules into more energy-rich molecules.
B) supply energy, primarily in the form of ATP, for the cell's work.
C) are endergonic.
D) are spontaneous and do not need enzyme catalysis.
E) build up complex molecules such as protein from simpler compounds.

17) When chemical, transport, or mechanical work is done by an organism, what happens to the heat generated?
A) It is used to power yet more cellular work.
B) It is used to store energy as more ATP.
C) It is used to generate ADP from nucleotide precursors.
D) It is lost to the environment.
E) It is transported to specific organs such as the brain.

Use the figure below to answer the following question(s).



18) Which of the following is the most correct interpretation of the figure provided?
A) Inorganic phosphate is created from organic phosphate.
B) Energy from catabolism can be used directly for performing cellular work.
C) ADP + P_i are a set of molecules that store energy for catabolism.
D) ATP is a molecule that acts as an intermediary to store energy for cellular work.
E) P_i acts as a shuttle molecule to move energy from ATP to ADP.

19) How do cells use the ATP cycle shown in the figure above?
A) Cells use the cycle to recycle ADP and phosphate.
B) Cells use the cycle to recycle the energy released by ATP hydrolysis.
C) Cells use the cycle to recycle ADP, phosphate, and the energy released by ATP hydrolysis.
D) Cells use the cycle to generate or consume water molecules as needed.
E) Cells use the cycle primarily to generate heat.

20) Which of the following is true when comparing an uncatalyzed reaction to the same reaction with a catalyst?
A) The catalyzed reaction will be slower.
B) The catalyzed reaction will have the same ΔG.
C) The catalyzed reaction will have higher activation energy.
D) The catalyzed reaction will consume all of the catalyst.
E) The catalyzed reaction will only be limited by the amount of substrate.

21) You have discovered an enzyme that can catalyze two different chemical reactions. Which of the following is most likely to be correct?
A) The enzyme contains α-helices and β-pleated sheets.
B) The enzyme is subject to competitive inhibition and allosteric regulation.
C) Two types of allosteric regulation occur: the binding of one molecule activates the enzyme while the binding of a different molecule inhibits it.
D) Either the enzyme has two distinct active sites or the reactants involved in the two reactions are very similar in size and shape.
E) The enzyme must be flexible and composed of two different subunits.

22) Consider the HIV enzyme called protease. The amino acid residues at the active site are highly hydrophobic. In designing a drug that would bind to the active site and jam it, researchers should use a molecule that is
A) hydrophobic.
B) polar.
C) charged.
D) acidic.
E) basic.

23) The lock-and-key analogy for enzymes applies to the specificity of enzymes
A) as they form their tertiary structure.
B) as they form their tertiary and quaternary structure.
C) binding to their substrate.
D) interacting with water.
E) interacting with ions.

24) Which of the following statements is true about enzyme-catalyzed reactions?
A) The reaction is faster than the same reaction in the absence of the enzyme.
B) The free-energy change of the reaction is opposite from the reaction that occurs in the absence of the enzyme.
C) An enzyme catalyzes a reaction by raising the activation energy.
D) Enzyme-catalyzed reactions require energy to activate the enzyme.
E) Enzyme-catalyzed reactions release more free energy than noncatalyzed reactions.

25) Reactants capable of interacting to form products in a chemical reaction must first overcome a thermodynamic barrier known as the reaction's
A) entropy.
B) activation energy.
C) endothermic level.
D) equilibrium point.
E) free-energy content.

26) A solution of starch at room temperature does not readily decompose to form a solution of simple sugars because
A) the starch solution has less free energy than the sugar solution.
B) the hydrolysis of starch to sugar is endergonic.
C) the activation energy barrier for this reaction cannot easily be surmounted at room temperature.
D) starch cannot be hydrolyzed in the presence of so much water.
E) starch hydrolysis is nonspontaneous.

27) Enzymes
A) increase the rate of a reaction by making the reaction more exergonic.
B) increase the rate of a reaction by lowering the activation energy barrier.
C) increase the rate of a reaction by reducing the rate of reverse reactions.
D) change the equilibrium point of the reactions they catalyze.
E) make the rate of a reaction independent of substrate concentrations.

28) During a laboratory experiment, you discover that an enzyme-catalyzed reaction has a ΔG of -20 kcal/mol. If you double the amount of enzyme in the reaction, what will be the ΔG for the new reaction?
A) -40 kcal/mol
B) -20 kcal/mol
C) 0 kcal/mol
D) +20 kcal/mol
E) +40 kcal/mol

29) The active site of an enzyme is the region that
A) binds allosteric regulators of the enzyme.
B) is involved in the catalytic reaction of the enzyme.
C) binds noncompetitive inhibitors of the enzyme.
D) is inhibited by the presence of a coenzyme or a cofactor.
E) aids in increasing the activation energy of the reaction.

30) According to the induced fit hypothesis of enzyme catalysis,
A) the binding of the substrate depends on the shape of the active site.
B) some enzymes change their structure when activators bind to the enzyme.
C) a competitive inhibitor can outcompete the substrate for the active site.
D) the binding of the substrate changes the shape of the enzyme's active site.
E) the active site creates a microenvironment ideal for the reaction.

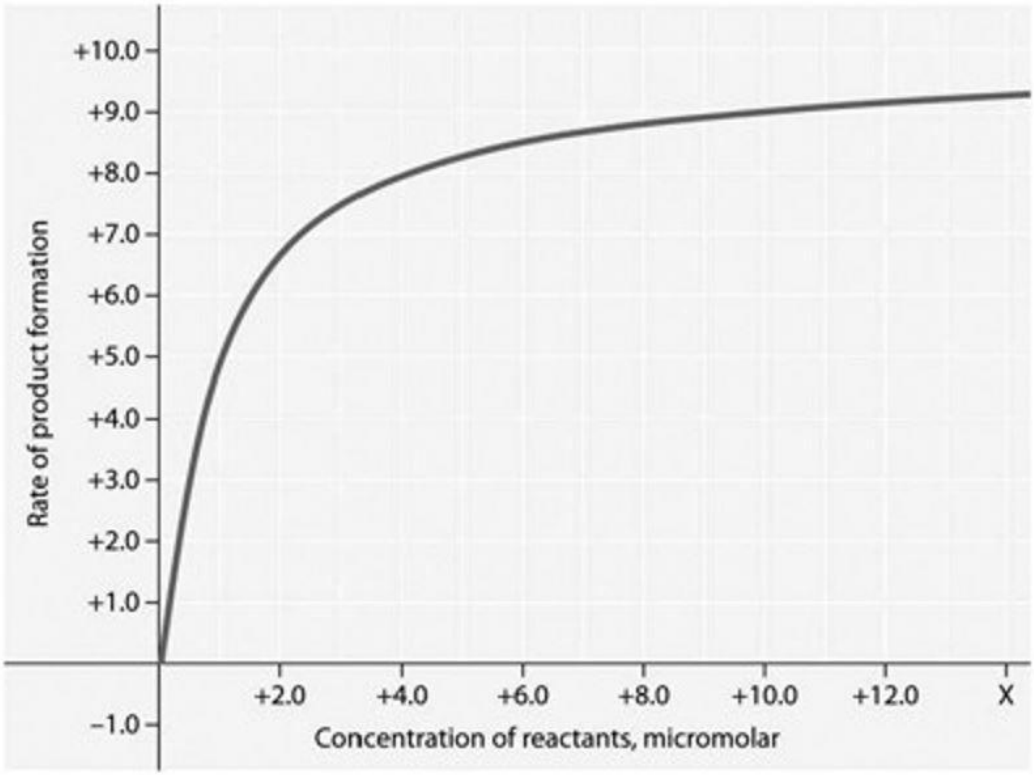
31) Which of the following is true of enzymes?
A) Enzyme function is increased if the three-dimensional structure or conformation of an enzyme is altered.
B) Enzyme function is independent of physical and chemical environmental factors such as pH and temperature.
C) Enzymes increase the rate of chemical reaction by the lowering activation energy required.
D) Enzymes increase the rate of chemical reaction by providing activation energy to the substrate.
E) Enzymes increase the rate of chemical reaction by increasing ΔG.

32) Zinc, an essential trace element for most organisms, is present in the active site of the enzyme carboxypeptidase. The zinc most likely functions as
A) a competitive inhibitor of the enzyme.
B) a noncompetitive inhibitor of the enzyme.
C) an allosteric activator of the enzyme.
D) a cofactor necessary for enzyme activity.
E) a coenzyme derived from a vitamin.

33) To attach a particular amino acid to the tRNA molecule that will transport it, an enzyme, an aminoacyl-tRNA synthetase, is required, along with ATP. Initially, the enzyme has an active site for ATP and another for the amino acid, but it is not able to attach the tRNA. What must occur for the final attachment to occur?
A) The ATP must first have to attach to the tRNA.
B) The binding of the first two molecules must cause a 3-D change that opens another active site on the enzyme.
C) The ATP must be hydrolyzed to allow the amino acid to bind to the synthetase.
D) The tRNA molecule must alter its shape to be able to fit into the active site with the other two molecules.
E) The 3' end of the tRNA must be cleaved before it can have an attached amino acid.

34) Some of the drugs used to treat HIV patients are competitive inhibitors of the HIV reverse transcriptase enzyme. Unfortunately, the high mutation rate of HIV means that the virus rapidly acquires mutations with amino acid changes that make reverse transcriptase resistant to these competitive inhibitors. Where in the reverse transcriptase enzyme would such amino acid changes most likely occur in drug-resistant viruses?
A) in or near the active site
B) at an allosteric site
C) at a cofactor binding site
D) in regions of the protein that determine packaging into the virus capsid
E) Such mutations could occur anywhere with equal probability.
activity.

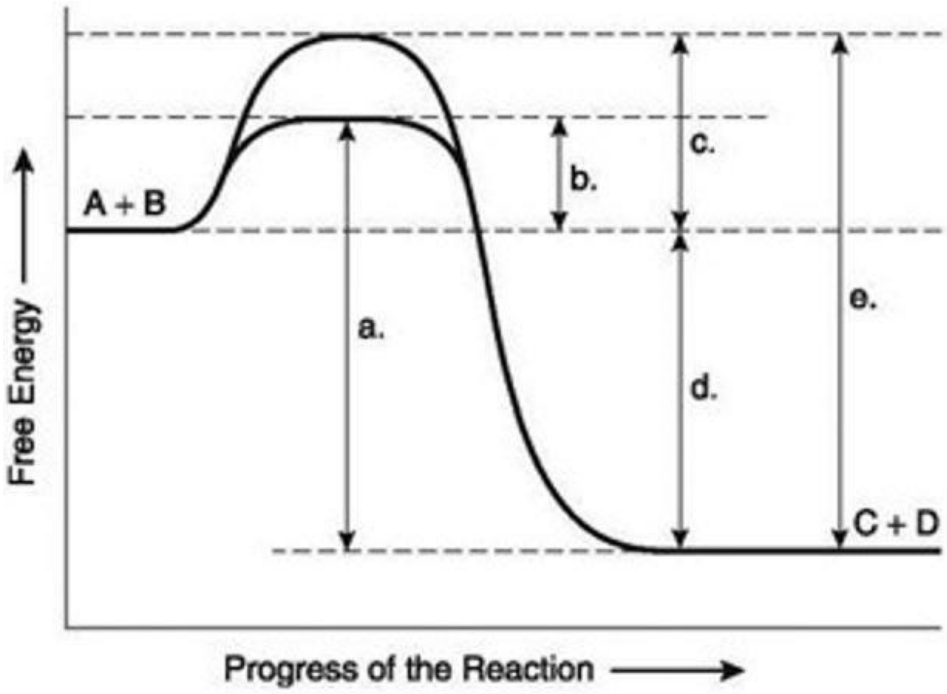
35)



Rate of an enzyme-catalyzed reaction as a function of varying reactant concentration, with the concentration of enzyme constant.

In the graph provided, why does the reaction rate plateau at higher reactant concentrations?
A) Feedback inhibition by product occurs at high reactant concentrations.
B) Most enzyme molecules are occupied by substrate at high reactant concentrations.
C) The reaction nears equilibrium at high reactant concentrations.
D) The activation energy for the reaction increases with reactant concentration.
E) The rate of the reverse reaction increases with reactant concentration.

The following question(s) are based on the reaction $A + B \leftrightarrow C + D$ shown in the figure provided.



36) Which of the following terms best describes the forward reaction in the figure?
A) endergonic, $\Delta G > 0$
B) exergonic, $\Delta G < 0$
C) endergonic, $\Delta G < 0$
D) exergonic, $\Delta G > 0$
E) chemical equilibrium, $\Delta G = 0$

37) Which of the following represents the ΔG of the reaction in the figure?
A) a
B) b
C) c
D) d
E) e

38) Which of the following in the figure would be the same in either an enzyme-catalyzed or a noncatalyzed reaction?
A) a
B) b
C) c
D) d
E) e

39) Which of the following represents the activation energy needed for the enzyme-catalyzed reverse reaction, $C + D \rightarrow A + B$, in the figure?
A) a
B) b
C) c
D) d
E) e

40) Which of the following represents the difference between the free-energy content of the reactants and the free-energy content of the products in the figure?
A) a
B) b
C) c
D) d
E) e

41) Which of the following represents the activation energy required for a noncatalyzed reaction in the figure?
A) a
B) b
C) c
D) d
E) e

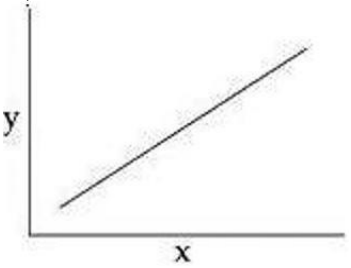
42) Which of the following represents the activation energy needed for the noncatalyzed reverse reaction, $C + D \rightarrow A + B$, in the figure?
A) a
B) b
C) c
D) d
E) e

43) You have isolated a previously unstudied protein, identified its complete structure in detail, and determined that it catalyzes the breakdown of a large substrate. You notice it has two binding sites. One of these is large, apparently the binding site for the large substrate; the other is small, possibly a binding site for a regulatory molecule. What do these findings tell you about the mechanism of this protein?
A) It is probably a structural protein that is involved in cell-to-cell adhesion.
B) It is probably an enzyme that works through allosteric regulation.
C) It is probably an enzyme that works through competitive inhibition.
D) It is probably a cell membrane transport protein–like an ion channel.
E) It is probably a structural protein found in cartilage or skeletal tissue.

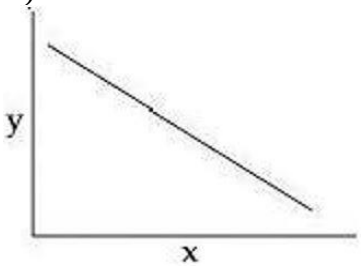
44) HIV is the virus that causes AIDS. In the mid-1990s, researchers discovered an enzyme in HIV called protease. Once the enzyme's structure was known, researchers began looking for drugs that would fit into the active site and block it. If this strategy for stopping HIV infections were successful, it would be an example of what phenomenon?
A) vaccination
B) denaturation
C) allosteric regulation
D) competitive inhibition
E) feedback inhibition

45) You collect data on the effect of pH on the function of the enzyme catalase in human cells. Which of the following graphs would you expect?

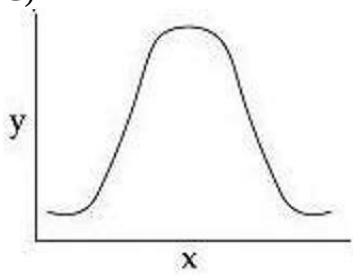
A)



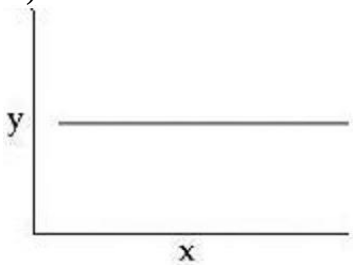
B)



C)



D)



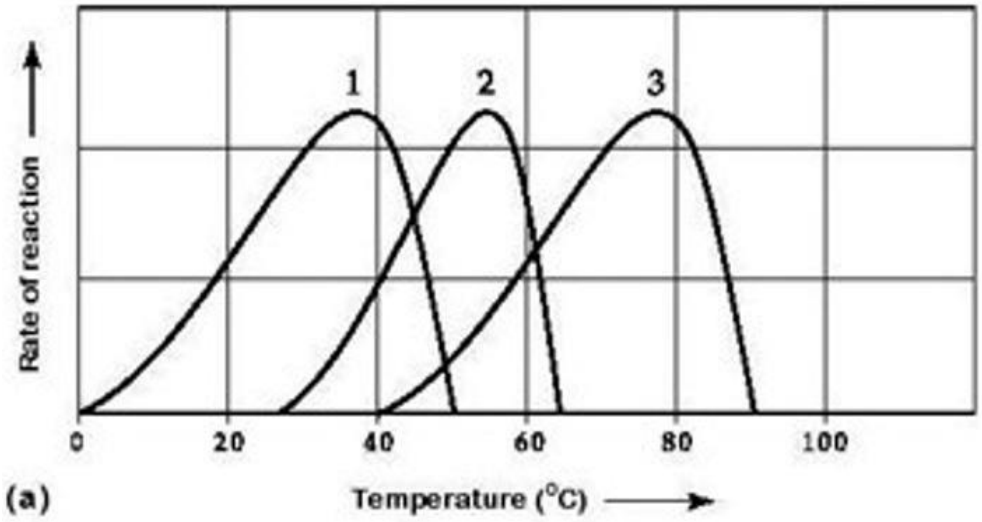
46) Mutations that result in a single amino acid substitution in an enzyme
A) cannot affect the activity or properties of the enzyme.
B) will destroy the activity of the enzyme.
C) will change the substrate specificity of the enzyme.
D) may change the enzyme's optimal temperature or optimal pH.
E) may, in rare cases, cause the enzyme to run reactions in reverse.

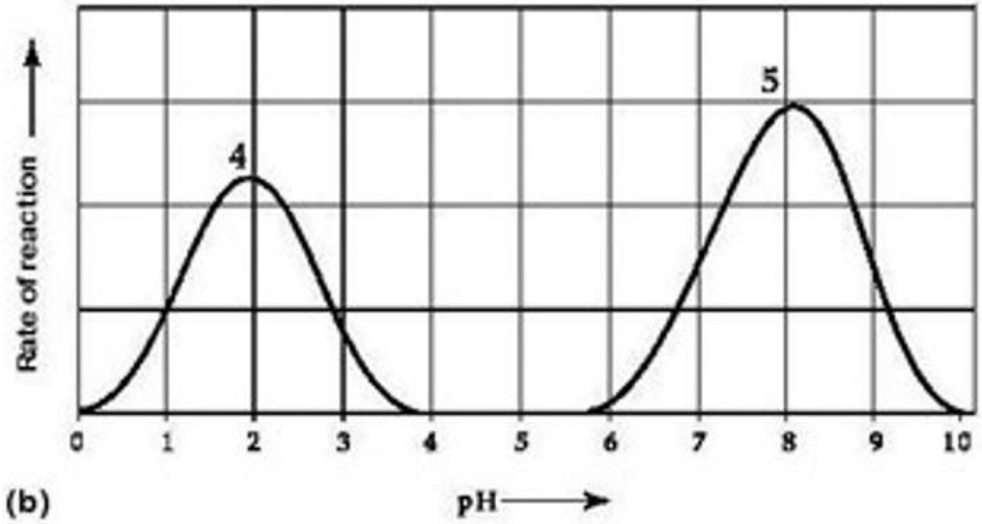
47) Increasing the substrate concentration in an enzymatic reaction could overcome which of the following?
A) the need for a coenzyme
B) allosteric inhibition
C) competitive inhibition
D) insufficient cofactors
E) high activation energy

48) An allosteric regulator decreases the rate of an enzyme reaction by
A) binding at the active site of the enzyme.
B) changing the shape of the enzyme's active site.
C) changing the overall free energy of the reaction.
D) acting as a coenzyme for the reaction.
E) decreasing the activation energy of the reaction.

49) An important group of peripheral membrane proteins are enzymes such as the phospholipases that cleave the head groups of phospholipids. What properties must these enzymes exhibit?
A) resistance to degradation
B) independence from cofactor interaction
C) water solubility
D) lipid solubility
E) membrane-spanning domains

50) How might a change of one amino acid at a site, distant from the active site of an enzyme, alter an enzyme's substrate specificity?
A) by changing the enzyme's binding of allosteric regulator
B) by changing the enzyme's location in the cell
C) by changing the shape of an enzyme
D) by changing the enzyme's pH optimum
E) An amino acid change away from the active site cannot alter the enzyme's substrate specificity.





Activity of various enzymes at various temperatures (a) and at various pH (b). Use the image above to answer the following question(s).

51) Which curves on the graphs provided may represent the temperature and pH profiles of an enzyme taken from a bacterium that lives in a mildly alkaline hot springs at temperatures of 70°C or higher?

A) curves 1 and 5
B) curves 2 and 4
C) curves 2 and 5
D) curves 3 and 4
E) curves 3 and 5

52) Which temperature and pH profile curves on the graphs were most likely generated from analysis of an enzyme from a human stomach where conditions are strongly acid?
A) curves 1 and 4
B) curves 1 and 5
C) curves 2 and 4
D) curves 2 and 5
E) curves 3 and 4

Use the following information to answer the corresponding question(s).

A series of enzymes catalyze the reaction X → Y → Z → A. Product A binds to the enzyme that converts X to Y at a position remote from its active site. This binding decreases the activity of the enzyme.

53) What is substance X?
A) a coenzyme
B) an allosteric inhibitor
C) a substrate
D) an intermediate
E) the product

54) With respect to the enzyme that converts X to Y, substance A functions as
A) a coenzyme.
B) an allosteric inhibitor.
C) the substrate.
D) an intermediate.
E) a competitive inhibitor.

55) Some bacteria are metabolically active in hot springs because
A) they are able to maintain a lower internal temperature.
B) high temperatures make catalysis unnecessary.
C) their enzymes have high optimal temperatures.
D) their enzymes are completely insensitive to temperature.
E) they use molecules other than proteins or RNAs as their main catalysts.

56) Which term most precisely describes the cellular process of breaking down large molecules into smaller ones?
A) catabolism (catabolic pathways)
B) metabolism
C) anabolism (anabolic pathways)
D) dehydration
E) denaturation

57) Anabolic pathways
A) do not depend on enzymes.
B) are usually highly spontaneous chemical reactions.
C) consume energy to build up polymers from monomers.
D) release energy as they degrade polymers to monomers.
E) consume energy to decrease the entropy of the organism and its environment.

58) When ATP releases some energy, it also releases inorganic phosphate. What happens to the inorganic phosphate in the cell?
A) It is secreted as waste.
B) It is used only to regenerate more ATP.
C) It is added to water and excreted as a liquid.
D) It may be used to form a phosphorylated intermediate.
E) It enters the nucleus and affects gene expression.

59) The mechanism in which the end product of a metabolic pathway inhibits an earlier step in the pathway is most precisely described as _____ inhibition.
A) metabolic
B) feedback
C) allosteric
D) noncooperative
E) reversible

60) Choose the pair of terms that correctly completes this sentence: Catabolism is to anabolism as _____ is to _____.
A) exergonic; spontaneous
B) exergonic; endergonic
C) free energy; entropy
D) work; energy
E) entropy; enthalpy