# Chapter 2: Physical Biochemistry: Energy Conversion, Water, and Membranes

**MULTIPLE CHOICE**

1. Energy conversion in living systems is required for what three types of work?
   a. osmotic work, chemical work, mechanical work
   b. osmotic work, chemical work, potential work
   c. kinetic work, chemical work, mechanical work
   d. osmotic work, photosynthetic work, mechanical work

   ANS: A          DIF: Easy          REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Remembering

2. What chemical process is able to take place in the presence of solar energy?
   a. anaerobic respiration
   b. photosynthesis
   c. hydrogenation
   d. hydrolysis

   ANS: B          DIF: Medium          REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Remembering

3. Which of the following is the correct solar energy reaction that takes place on the sun?
   a. $4 \, He \rightarrow {}^4He$
   b. ${}^4He \rightarrow 4 \, He$
   c. $4 \, H \rightarrow {}^4He$
   d. ${}^4H \rightarrow 4 \, H$

   ANS: C          DIF: Medium          REF: 2.1
   OBJ: 2.1.a. Describe how sunlight is the source of all energy on Earth.
   MSC: Understanding

4. What is the final molecule made from the oxidation of $H_2O$ by solar energy?
   a. ozone
   b. glucose
   c. fructose
   d. carbon dioxide

   ANS: B          DIF: Medium          REF: 2.1
   OBJ: 2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
   MSC: Understanding

5. The difference between an oxidation reaction and a reduction reaction is that oxidation is the
   _____ and reduction is the _____.
   a. loss of electrons; gain of electrons
   b. gain of electrons; loss of electrons
   c. loss of protons; gain of protons
   d. gain of protons; loss of protons

   ANS: A          DIF: Medium          REF: 2.1
   OBJ: 2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
   MSC: Analyzing

6. Which of the following correctly describes the relationship between an ice cube melting on the table and the air surrounding it?
   a. The ice cube is the system and the air is the surroundings.
   b. The air is the system and the ice cube is the surroundings.
   c. The ice cube is the system and only the air is the universe.
   d. The air is the system and only the ice cube is the universe.

   ANS:  A              DIF:  Medium        REF:  2.1
   OBJ:  2.1.d. Differentiate between a system and its surroundings.
   MSC:  Evaluating

7. Which of the following is an example of a system?
   a. the universe
   b. the air
   c. a test tube with reaction components
   d. outer space

   ANS:  C              DIF:  Easy          REF:  2.1
   OBJ:  2.1.d. Differentiate between a system and its surroundings.
   MSC:  Understanding

8. A hot pack on your arm is an example of what kind of system?
   a. open
   b. closed
   c. isolated
   d. surroundings

   ANS:  B              DIF:  Medium        REF:  2.1
   OBJ:  2.1.e. Differentiate among open, closed, and isolated systems.
   MSC:  Applying

9. Which of the following best describes an open system?
   a. Matter and energy are freely exchanged with the surroundings.
   b. Energy is exchanged with the surroundings but matter is not.
   c. Matter is exchanged with the surroundings but energy is not.
   d. Neither matter nor energy is exchanged with the surroundings.

   ANS:  A              DIF:  Easy          REF:  2.1
   OBJ:  2.1.e. Differentiate among open, closed, and isolated systems.
   MSC:  Understanding

10. Which of the following best defines the first law of thermodynamics?
    a. All spontaneous processes in the universe tend toward dispersal of energy.
    b. Total amount of energy in the universe is a constant.
    c. There is no entropy at zero Kelvin.
    d. Entropy is a measure of disorder.

    ANS:  B              DIF:  Medium        REF:  2.1
    OBJ:  2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
    MSC:  Understanding

11. Energy conversion in a biological system operates under constant _____ and constant _____.
    a. heat; pressure

b. work; heat
c. pressure; volume
d. volume; heat

ANS: C          DIF: Medium        REF: 2.1
OBJ:  2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Applying

12. Given a biological system at 1 atm with $\Delta H = 16$ kJ/g, what is the internal energy of the system?
    a.  15 kJ/g
    b.  16 kJ/g
    c.  14 kJ/g
    d.  Not enough information is given to calculate the answer.

ANS: B          DIF: Difficult        REF: 2.1
OBJ:  2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Applying

13. The combustion of gasoline is considered exothermic because heat is
    a.  transferred from the surroundings to the system.
    b.  transferred from the system to the surroundings.
    c.  transferred to the universe.
    d.  not transferred.

ANS: B          DIF: Medium        REF: 2.1
OBJ:  2.1.g. Differentiate between endothermic and exothermic reactions.
MSC: Understanding

14. Given 80 grams of water, how many calories are required to raise the temperature $1^\circ C$?
    a.  4.184 calories
    b.  15.7 calories
    c.  80 calories
    d.  Not enough information is given to calculate the answer.

ANS: C          DIF: Medium        REF: 2.1
OBJ:  2.1.g. Differentiate between endothermic and exothermic reactions.
MSC: Applying

15. The oxidation of glucose releases 15.7 kJ/g. Is this reaction spontaneous?
    a.  Yes, because it is exothermic.
    b.  No, because it is exothermic.
    c.  Yes, because it is endothermic.
    d.  The answer cannot be determined.

ANS: D          DIF: Difficult        REF: 2.1
OBJ:  2.1.g. Differentiate between endothermic and exothermic reactions.
MSC: Analyzing

16. In the figure below, which state of matter has the highest entropy?
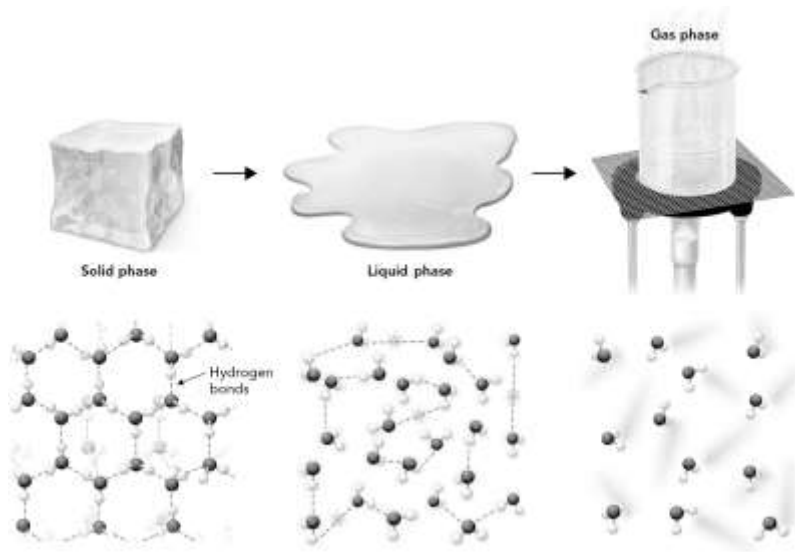
a. solid phase
b. liquid phase
c. gas phase
d. all are equal entropy.

ANS: C          DIF: Easy          REF: 2.1
OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Remembering

17. For a reaction to be spontaneous, the change in the entropy of the universe must be
    a. greater than zero.
    b. less than zero.
    c. equal to zero.
    d. equal to 1.

ANS: A          DIF: Easy          REF: 2.1
OBJ: 2.1.i. Explain the concept of entropy and its role in biological systems.
MSC: Understanding

18. The example of water freezing into ice shows
    a. an increase in entropy of the system.
    b. a decrease in entropy of the system.
    c. no change in the entropy of the system.
    d. a decrease in the entropy of the surroundings.

ANS: B          DIF: Medium          REF: 2.1
OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Applying

19. The change in entropy of a system is a function of a change in
    a. temperature and pressure.
    b. volume and pressure.
    c. enthalpy and pressure.
    d. enthalpy and temperature.

ANS: D          DIF: Difficult          REF: 2.1
OBJ: 2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
MSC: Understanding

20. *Gibbs free energy* can best be defined as the
    a. difference between the enthalpy and entropy of a system at a given temperature.
    b. difference between exothermic and endothermic energy of a system at a given temperature.
    c. addition of enthalpy and entropy of a system at a given temperature.
    d. difference between pressure and volume at a given temperature.

    ANS: A            DIF: Difficult        REF: 2.1
    OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium.            MSC: Understanding

21. For a given reaction with a $\Delta G < 0$, the reaction is
    a. favorable in the reverse direction.
    b. favorable in the forward direction.
    c. unfavorable in both directions.
    d. favorable in both directions.

    ANS: B            DIF: Medium        REF: 2.1
    OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium.            MSC: Understanding

22. If a reaction has a $\Delta H > 0$ and a $\Delta S < 0$, then _____ and the reaction is _____ at all temperatures.
    a. $\Delta G < 0$; spontaneous
    b. $\Delta G > 0$; spontaneous
    c. $\Delta G < 0$; nonspontaneous
    d. $\Delta G > 0$; nonspontaneous

    ANS: D            DIF: Medium        REF: 2.1
    OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium.            MSC: Applying

23. If $\Delta G = 0$ for a reaction, then this reaction
    a. is favorable in the forward direction.
    b. is favorable in the reverse direction.
    c. is at equilibrium.
    d. cannot occur.

    ANS: C            DIF: Medium        REF: 2.1
    OBJ: 2.1.j. Define Gibbs free energy, its relation to enthalpy and entropy, and its relation to equilibrium.            MSC: Analyzing

24. If a reaction has a $\Delta H < 0$ and $\Delta S < 0$, under which conditions would the reaction be spontaneous in the forward direction?
    a. low temperatures
    b. high temperatures
    c. high pressure
    d. low pressure

    ANS: A            DIF: Medium        REF: 2.1
    OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
    MSC: Evaluating

25. The standard free energy change is defined under what set of conditions?

a. 1 atm, 298 K, 1 M
b. 1 atm, 273 K, 1 M
c. 100 kPa, 273 K, 1 M
d. 100 kPa, 298 K, 1 M

ANS: A          DIF: Difficult          REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Understanding

26. If the equilibrium constant ($K_{eq}$) is greater than 1, which direction will the reaction proceed?
    a. spontaneously to products
    b. spontaneously to reactants
    c. neither direction
    d. Not enough information is given to determine the direction of reaction.

ANS: A          DIF: Easy          REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Applying

27. If the equilibrium constant ($K_{eq}$) is greater than 1, what is the value of $\Delta G°$?
    a. $\Delta G° > 0$
    b. $\Delta G° = 0$
    c. $\Delta G° < 0$
    d. $\Delta G° > 1$

ANS: C          DIF: Difficult          REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Applying

28. Under what conditions could a biological reaction spontaneously proceed to reactants if the $\Delta G° > 0$?
    a. Reactant concentrations are greater than product concentrations.
    b. Product concentrations are greater than reactant concentrations.
    c. Reactant concentrations are equal to product concentrations.
    d. There are no conditions where this could happen.

ANS: B          DIF: Difficult          REF: 2.1
OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
MSC: Evaluating

29. If the Gibbs free energy change value for a reaction is less than zero, this reaction is
    a. exergonic.
    b. endergonic.
    c. exothermic.
    d. endothermic.

ANS: A          DIF: Easy          REF: 2.1
OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems.          MSC: Remembering

30. What chemical reaction causes ATP to be a *high-energy* molecule?
    a. cleavage of phosphoanhydride bond
    b. transfer of an adenylyl group to form a reactive intermediate
    c. hydrolysis of phosphoryl group
    d. oxidation of phosphoanhydride bond

ANS: B                DIF: Difficult        REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard
free energy change for phosphoanhydride bond cleavage.        MSC: Analyzing

31. The transfer of a phosphate from ATP to another molecule produces a(n)
    a. low-energy intermediate.
    b. highly reactive intermediate.
    c. neutral energy intermediate.
    d. It is not possible to transfer a phosphate to another molecule.

ANS: B                DIF: Easy            REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard
free energy change for phosphoanhydride bond cleavage.        MSC: Understanding

32. The _____ system controls the interconversion among ATP, ADP, and AMP.
    a. phosphorylate
    b. adenylate
    c. energy conversion
    d. metabolism

ANS: B                DIF: Easy            REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP,
and AMP.            MSC: Remembering

33. Given the energy charge equation below, if a biological system has an EC = 0.8, what is true about
    the concentrations of ATP, ADP, and AMP in the system?

$$EC = \frac{[ATP] + 0.5[ADP]}{[ATP] + [ADP] + [AMP]}$$

    a. The concentrations are all equal.
    b. There is more ADP in the system than ATP or AMP.
    c. There is more ATP in the system than ADP or AMP.
    d. There is more AMP in the system than ATP and ADP.

ANS: C                DIF: Difficult        REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP,
and AMP.            MSC: Applying

34. Under steady-state conditions in a mammalian cell, the adenine nucleotide concentrations are
    [ATP] = 3.3 mM, [ADP] = 1.2 mM, and [AMP] = 0.2 mM. What is the energy charge of this cell?
    a. 0.83
    b. 0.95
    c. 0.72
    d. 1.2

ANS: A                DIF: Difficult        REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP,
and AMP.            MSC: Applying

35. In a hydrogen bond between a water molecule and another water molecule,
    a. a hydrogen ion on the water molecule forms an ionic bond with the oxygen ion on the
       other water.
    b. the hydrogen bond typically forms between the oxygen atom of the water and the
       hydrogen on the other water.

c.  a hydrogen on the water molecule forms a covalent bond to a hydrogen atom on the other water.
d.  the hydrogen atom forms an ionic bond with a carbon on the other water.

ANS:  B                DIF:  Medium        REF:  2.2
OBJ:   2.2.a. Identify hydrogen bond donors and hydrogen bond acceptors.
MSC:  Applying

36.  Hydrogen bonds in liquid water are formed between
    a.  two hydrogen atoms on the same molecule.
    b.  the oxygen of one molecule and the hydrogen of another.
    c.  protons and hydroxides.
    d.  two oxygen atoms on different molecules.

ANS:  B                DIF:  Medium        REF:  2.2
OBJ:   2.2.a. Identify hydrogen bond donors and hydrogen bond acceptors.
MSC:  Understanding

37.  Organisms on Earth cannot easily exist at temperatures below $0°C$ because at that temperature
    a.  hydrogen bonds cannot exist.
    b.  water does not exist in a tetrahedron.
    c.  ice crystals form in the organism.
    d.  proton hopping cannot occur.

ANS:  C                DIF:  Easy          REF:  2.2
OBJ:   2.2.b. Describe how an antifreeze protein functions.        MSC:  Understanding

38.  Describe how an antifreeze protein functions.
    a.  Regularly spaced tyrosine residues prevent the ice crystals from growing.
    b.  Regularly spaced threonine resides prevent the ice crystals from growing.
    c.  Flickering clusters of hydrogen bonds prevent the ice crystals from growing.
    d.  The antifreeze protein prevents the water wires from forming.

ANS:  B                DIF:  Medium        REF:  2.2
OBJ:   2.2.b. Describe how an antifreeze protein functions.        MSC:  Applying

39.  A hydrogen bond can form between a hydrogen atom on a(n)
    a.  electronegative donor group and another electronegative atom.
    b.  cationic atom and another hydrogen.
    c.  nonpolar donor group and an electronegative atom.
    d.  ionic atom and another anion.

ANS:  A                DIF:  Medium        REF:  2.2
OBJ:   2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions.
MSC:  Remembering

40.  The interaction between an amino group and a carboxylate group is best characterized as
    a.  hydrogen bonds.
    b.  ionic interactions.
    c.  van der Waals interactions.
    d.  a covalent bond.

ANS:  B                DIF:  Easy          REF:  2.2
OBJ:   2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions.

41.  The interaction between nonpolar molecules is best characterized as
      a.  a hydrogen bond.
      b.  ionic interactions.
      c.  van der Waals interactions.
      d.  a covalent bond.

      ANS:  C              DIF:  Easy            REF:  2.2
      OBJ:  2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals
      interactions.
      MSC:  Understanding

42.  An organism in equilibrium with its environment is no longer alive because
      a.  homeostasis is required for life.
      b.  heterostasis is required for life.
      c.  an organism requires only exergonic reactions to be alive.
      d.  an organism requires only endergonic reactions to be alive.

      ANS:  A              DIF:  Easy            REF:  2.1
      OBJ:  2.1.f. Explain the first law of thermodynamics as it applies to biological systems.
      MSC:  Understanding

43.  Hydrophobic interactions between nonpolar molecules result from the
      a.  tendency to maximize water's interaction with nonpolar molecules.
      b.  strong attractions between nonpolar molecules.
      c.  water becoming more ordered around the nonpolar molecule.
      d.  water ionically bonding to the nonpolar molecule.

      ANS:  C              DIF:  Medium          REF:  2.2
      OBJ:  2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
      MSC:  Applying

44.  Limonene is a nonpolar molecule. The water molecules around it forms
      a.  hydrogen bonds with itself and entropy decreases.
      b.  ionic bonds with itself and the entropy decreases.
      c.  hydrogen bonds with limonene and the entropy increases.
      d.  covalent bonds with limonene and entropy increases.

      ANS:  A              DIF:  Difficult        REF:  2.2
      OBJ:  2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
      MSC:  Applying

45.  As a protein folds, what are the stabilizing forces that help keep the protein folded?
      a.  hydrophilic amino acids on the interior and hydrophobic amino acids on the exterior
      b.  increase in entropy in the surrounding water
      c.  favorable change in free energy
      d.  hydrophobic amino acids on the interior and hydrophilic amino acids on the exterior

      ANS:  D              DIF:  Medium          REF:  2.2
      OBJ:  2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
      MSC:  Remembering

46.  Freezing point depression, boiling point elevation, and osmotic pressure are all what kind of
      properties?

a. intrinsic properties
b. colligative properties
c. state functions
d. hydrophobic effects

ANS: B            DIF: Easy            REF: 2.2
OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
MSC: Remembering

47. The effects of solutes on the colligative properties of a solution depend only on the
    a. chemical properties of the solutes.
    b. molecular mass of the solutes.
    c. overall charge of the solute.
    d. number of solute particles.

ANS: D            DIF: Easy            REF: 2.2
OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
MSC: Remembering

48. Osmosis occurs when water diffuses through a
    a. semipermeable membrane from high water to low water concentration.
    b. nonpermeable membrane from high water to low water concentration.
    c. semipermeable membrane from low water to high water concentration.
    d. semipermeable membrane from high solute to low solute concentration.

ANS: A            DIF: Easy            REF: 2.2
OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
MSC: Remembering

49. Red blood cells are placed into a solution of unknown solute concentration. After an hour they
    have all burst open. The best explanation is that the solution
    a. had no solutes.
    b. had a very high concentration of solutes.
    c. had a very high concentration of solvent
    d. was at equilibrium.

ANS: A            DIF: Difficult            REF: 2.2
OBJ: 2.2.e. Explain the impacts of hypotonic, isotonic, and hypertonic solutions on cells.
MSC: Analyzing

50. What is the expected osmotic pressure around the cells for the plant with low turgor pressure
    shown below?

a. hypotonic
b. hypertonic
c. isotonic
d. equilibrium

ANS: B                 DIF: Difficult        REF: 2.2
OBJ: 2.2.f. Identify the important aspects of plant, fungi, and bacterial cells that allow them to survive in a hypotonic environment.        MSC: Analyzing

51. How do plants, fungi, and bacteria avoid the damaging effects of a hypotonic environment?
a. flexible cells walls
b. rigid cells walls
c. semipermeable cell walls
d. photosynthesis

ANS: B                 DIF: Easy        REF: 2.2
OBJ: 2.2.f. Identify the important aspects of plant, fungi, and bacterial cells that allow them to survive in a hypotonic environment.        MSC: Applying

52. Which of the following is true?
a. A neutral solution contains $[H_2O] = [H^+]$.
b. A neutral solution does not contain any $H^+$ or $OH^-$.
c. An acidic solution has $[H^+] > [OH^-]$.
d. A basic solution does not contain $H^+$.

ANS: C                 DIF: Easy        REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

53. What is the concentration of $OH^-$ in a solution that contains $3.9 \times 10^{-4}$ M $H^+$?
a. $2.6 \times 10^{-11}$ M
b. $3.9 \times 10^{-4}$ M
c. $2.7 \times 10^{-2}$ M
d. $1.0 \times 10^{-14}$ M

ANS: A                 DIF: Medium        REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

54. What is the concentration of $H^+$ in a solution of 0.05 M NaOH?
a. $5 \times 10^{-16}$ M
b. $2 \times 10^{-13}$ M
c. $5 \times 10^{12}$ M
d. 140 M

ANS: B                 DIF: Medium        REF: 2.2
OBJ: 2.2.g. Calculate the concentration of H+ or OH– given the OH– or H+ concentration.
MSC: Applying

55. Which of the following is the $K_w$ value for pure water at $25°C$?
a. $1 \times 10^{14}$
b. $1 \times 10^{-14}$
c. 7
d. 14

56. Calculate the pH of a solution that contains $3.9 \times 10^{-4}$ M $H^+$.
    a. 4.59
    b. 10.59
    c. 3.41
    d. 9.41

57. Calculate the concentration of pH of a 0.023 M HCl solution.
    a. 12.36
    b. 3.68
    c. 1.64
    d. 2.30

58. Calculate the pH of a solution that contains $7.8 \times 10^{-6}$ M $OH^-$.
    a. 1.28
    b. 5.11
    c. 12.72
    d. 8.89

59. Which of the following acids is the strongest given their Ka values?
    a. HF ($3.5 \times 10^{-4}$)
    b. $HClO_2$ ($1.1 \times 10^{-2}$)
    c. HCN ($4.9 \times 10^{-10}$)
    d. $HNO_2$ ($4.6 \times 10^{-4}$)

60. If an unknown solution has low pKa value, it can be said with certainty that it is
    a. a weak acid.
    b. a strong acid.
    c. pure water.
    d. a nonpolar solution.

61. Weak acids have a high pKa because the
    a. HA concentration is high.

b. H⁺ concentration is high.
c. A⁻ concentration is high.
d. HA concentration is low.

ANS: A          DIF: Easy          REF: 2.2
OBJ: 2.2.i. Differentiate between weak acids and strong acids and between weak bases and strong bases. MSC:          Applying

62. You wish to prepare a solution with a pH of 5.44. If the pKa of the weak acid is 4.74, what ratio of weak base to weak acid should you use?
    a. 0.70
    b. 0.20
    c. 1.4
    d. 5.0

ANS: D          DIF:    Medium     REF:  2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Applying

63. Calculate the pH of a solution containing 0.105 M HA and 0.146 M A⁻. The Ka for the weak acid is $1.8 \times 10^{-5}$.
    a. 4.88
    b. 9.11
    c. 4.74
    d. 7.00

ANS: A          DIF:    Medium     REF:  2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Applying

64. Given a solution with pH > pKa, what are the relative concentrations of A⁻ and HA?
    a. $[HA] > [A^-]$
    b. $[HA] < [A^-]$
    c. $[HA] = [A^-]$
    d. $[HA] = [A^-] = 1$

ANS: B          DIF:    Difficult     REF:  2.2
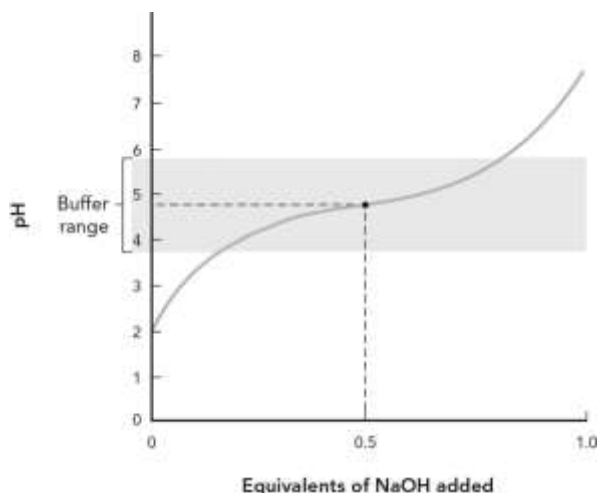OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Analyzing

65. Which of the following are true about buffers?
    a. An effective buffer is made from a strong acid and strong base.
    b. A buffer is most resistant to changes in pH when $[HA] = [A^-]$.
    c. A buffer is only resistant to changes in pH when acid is added.
    d. The pH range of a buffering system is 0 to 14.

ANS: B          DIF:    Medium     REF:  2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Remembering

66. Using the figure below, which of the following best describes the titration curve?

Equivalents of NaOH added

a. The equivalence point for the titration is pH = 7.
b. The midpoint of the titration is pH = 7.
c. The pKa for this weak acid is 4.76.
d. This is a titration of a weak base by NaOH.

ANS: C          DIF: Easy          REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Understanding

67. A solution of which of the following would be a good buffer system?
   a. HCl and NaOH
   b. HCl and $H_2O$
   c. $CH_3COOH$ and $NaCH_3COO$
   d. NaOH and KOH

ANS: C          DIF: Easy          REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Understanding

68. A molecule with hydrophobic and hydrophilic properties is best described as
   a. a zwitterion.
   b. amphipathic.
   c. polar.
   d. nonpolar.

ANS: B          DIF: Easy          REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.
MSC: Remembering

69. The characteristic(s) of a phospholipid is/are that they
   a. are overall nonpolar.
   b. have a polar charged head group and nonpolar hydrocarbon tails.
   c. have a nonpolar head group and polar hydrocarbon tails.
   d. are overall polar.

ANS: B          DIF: Easy          REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.
MSC: Understanding

70. The fluidity of a membrane depends on

a. the degree of saturation of the phospholipids.
b. the number of phospholipids in the membrane.
c. the size of the polar head group.
d. osmotic pressure.

ANS: A          DIF: Easy          REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.
MSC: Understanding

71. The lateral mobility of lipids with membrane depends on temperature as well as other factors. What would be expected to happen to the lateral mobility if the temperature was decreased?
a. Mobility would be unaffected.
b. Mobility would increase.
c. Mobility would decrease.
d. The membrane would decompose.

ANS: C          DIF: Medium          REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Applying

72. How are polar molecules like glucose transported across a membrane?
a. There are holes in the membrane.
b. There are proteins that allow the transportation of polar molecules across the membrane.
c. Polar molecules cannot ever enter the cell.
d. Polar molecules diffuse across the hydrophobic barrier.

ANS: B          DIF: Easy          REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Applying

73. The endomembrane system encompasses which part of the cell?
a. organelles
b. nucleus
c. cytoplasmic membrane structures
d. entire cell

ANS: C          DIF: Easy          REF: 2.3
OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
MSC: Remembering

74. The endomembrane system is/are
a. an intracellular network of lipid bilayers.
b. energy converting organelles.
c. a membrane surrounding the cell.
d. nucleotide-containing membranes.

ANS: A          DIF: Easy          REF: 2.3
OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
MSC: Remembering

75. The main function of the chloroplast is
a. protein biosynthesis.
b. to attach carbohydrates to lipids.
c. to convert light energy into chemical energy.
d. RNA synthesis.

ANS: C          DIF: Easy          REF: 2.3
OBJ: 2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
MSC: Remembering


**SHORT ANSWER**

1. Justify the following sentence: The conversion of carbon dioxide and water into glucose and oxygen is a decrease of entropy.

    ANS:
    The balanced chemical equation of 6 $CO_2$ (g) + 6 $H_2O$ (l) $\rightarrow$ $C_6H_{12}O_6$ (s) + 6 $O_2$ (g) shows that 12 molecules are being converted to 7 molecules. This is an example of decreasing the disorder of the system; therefore this reaction is a decrease in entropy.

    DIF: Difficult          REF: 2.1
    OBJ: 2.1.i. Explain the concept of entropy and its role in biological systems.
    MSC: Evaluating

2. Calculate $\Delta G$ for a reaction given $\Delta H$ = 15.4 kJ/mole and $\Delta S$ = 2.0 J/K at 298 K. Is this reaction spontaneous in the forward direction?

    ANS:
    Using the equation $\Delta G = \Delta H - T\Delta S$ and converting the units of entropy to kJ, the final answer is 14.8 kJ/mole.

    DIF: Medium          REF: 2.1
    OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
    MSC: Applying

3. Compare the reaction conditions for $\Delta G°$ and $\Delta G°'$.

    ANS:
    $\Delta G°$ is the standard free energy change and measured under 1 atm and 298 K, where all reactants and products are present at 1 M. $\Delta G°'$ is the biochemical standard condition where the free energy change is measured under 1 atm and 298 K, where all reactants and products are present at 1 M as well as at pH 7 and the concentration of $H_2O$ is 55.5 M.

    DIF: Medium          REF: 2.1
    OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
    MSC: Analyzing

4. Compare the reaction conditions under which you measure $K_{eq}$ versus Q.

    ANS:
    $K_{eq}$ is the equilibrium constant, so the reaction is at equilibrium at 1 atm, 298 K, and initial concentration of 1 M of all reactants and products. Q is the mass-action ratio measured at nonequilibrium concentrations.
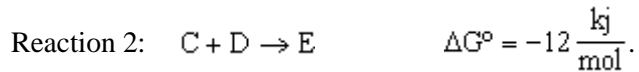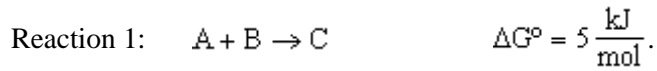
    DIF: Medium          REF: 2.1
    OBJ: 2.1.l. Differentiate between standard state condition and the biochemical standard state.
    MSC: Analyzing

5. Calculate the $\Delta G°$ for the net reaction given the following two reactions:

Reaction 1:     $A + B \rightarrow C$           $\Delta G° = 5 \dfrac{kJ}{mol}$.

Reaction 2:     $C + D \rightarrow E$           $\Delta G° = -12 \dfrac{kj}{mol}$.

ANS:
The net reaction is the addition of reaction 1 and 2. The net $\Delta G°$ is $5 - 12 = -7$ kJ/mol.

DIF: Medium      REF: 2.1
OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems.           MSC: Applying

6. Differentiate between autotrophs and heterotrophs.

ANS:
Autotrophs convert solar energy to chemical energy, whereas heterotrophs cannot.

DIF: Easy      REF: 2.1
OBJ: 2.1.b. Differentiate between autotrophs and heterotrophs.
MSC: Analyzing

7. How can a reaction that is endergonic occur in a biological system?

ANS:
It must be paired with an exergonic reaction for a reaction in a biological system to occur.

DIF: Easy      REF: 2.1
OBJ: 2.1.m. Differentiate between exergonic and endergonic reactions and explain how such reactions are coupled in biological systems.           MSC: Understanding

8. Compare a catabolic pathway versus an anabolic pathway.

ANS:
Anabolic pathways synthesize biomolecules, whereas catabolic pathways extract energy from metabolic fuels. Catabolic pathways also generate ATP and reduced coenyzmes.

DIF: Medium      REF: 2.1
OBJ: 2.1.o. Describe the relationship between energy charge and concentrations of ATP, ADP, and AMP.           MSC: Analyzing

9. The antifreeze proteins evolved independently through convergent evolution. What does that mean?

ANS:
Convergent evolution is the independent evolution of similar proteins for similar functions. For example, insect antifreeze proteins prevent the formation of ice crystals in the hemolymph by disrupting hydrogen bonding between $H_2O$ molecules. The structures of antifreeze proteins from four different organisms show that although they all contain numerous threonine residues on the protein surface, the overall structure of the proteins is quite different.

DIF: Medium      REF: 2.2
OBJ: 2.2.b. Describe how an antifreeze protein functions.           MSC: Remembering

10. List the three chemical properties of ATP that account for the large standard free energy change that occurs when a phosphoanhydride bond is cleaved.

ANS:
1. Electrostatic repulsion between the charged phosphoryl groups destabilizes ATP. Repulsion is reduced on hydrolysis, and therefore the products of ATP hydrolysis are more stable than ATP itself, which favors the hydrolysis reaction.
2. The released phosphate ion has more possible resonance forms than when it is covalently attached to adenylate. Entropically, this favors the free phosphate ions compared to ATP or ADP.
3. The phosphate ion and ADP have a greater degree of solvation than ATP. This means that the phosphate ion and ADP form hydration layers and are more stable than ATP.
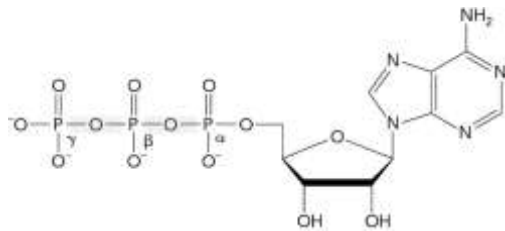
DIF: Easy          REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage.          MSC: Remembering

11. In the figure below, identify the adenine base, ribose, and phosphoanhydride bonds.
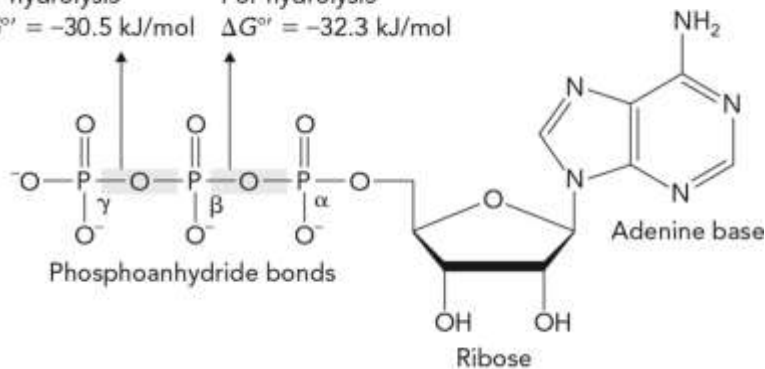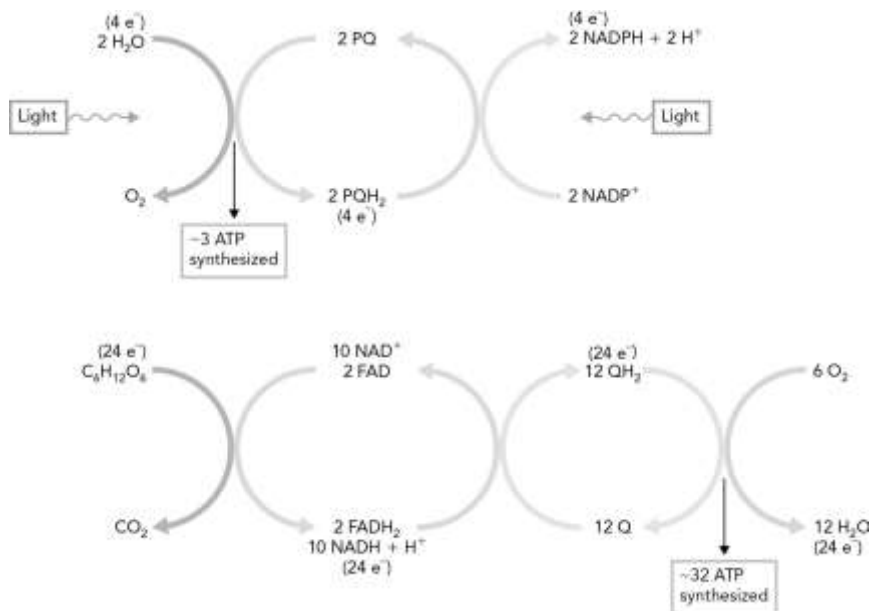


ANS:



DIF: Easy          REF: 2.1
OBJ: 2.1.n. Identify the characteristics of the ATP molecule that provide such a large standard free energy change for phosphoanhydride bond cleavage.          MSC: Understanding

12. In the figure below, label which reactions are oxidations and which are reduction.

ANS:

a.



b.
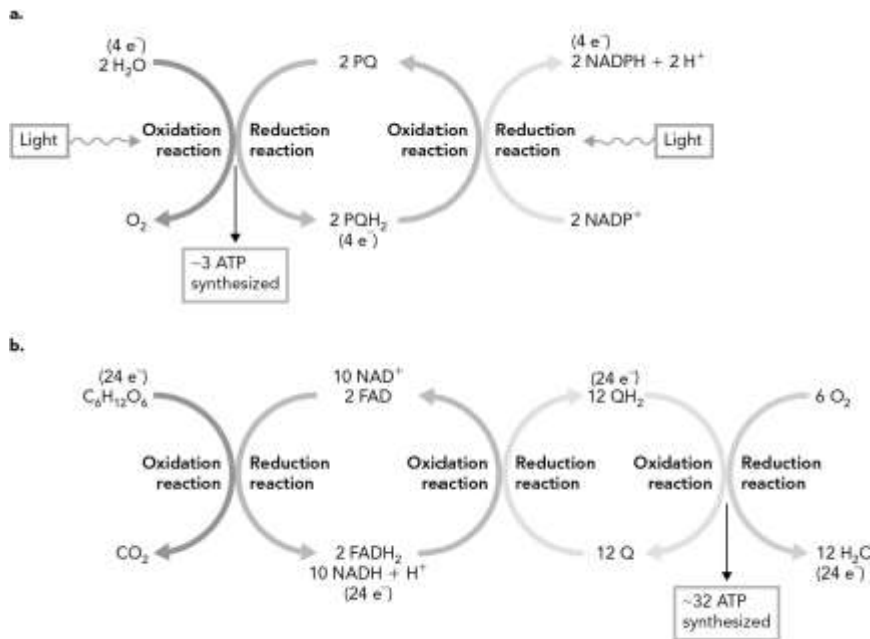


DIF:   Easy          REF:   2.1
OBJ:   2.1.c. Explain the role of oxidation-reduction reactions in biological systems.
MSC:   Remembering

13. Given the figure below, label the following: hydration layer, electrostatic interaction, hydrogen bond, van der Waals interaction.

ANS:
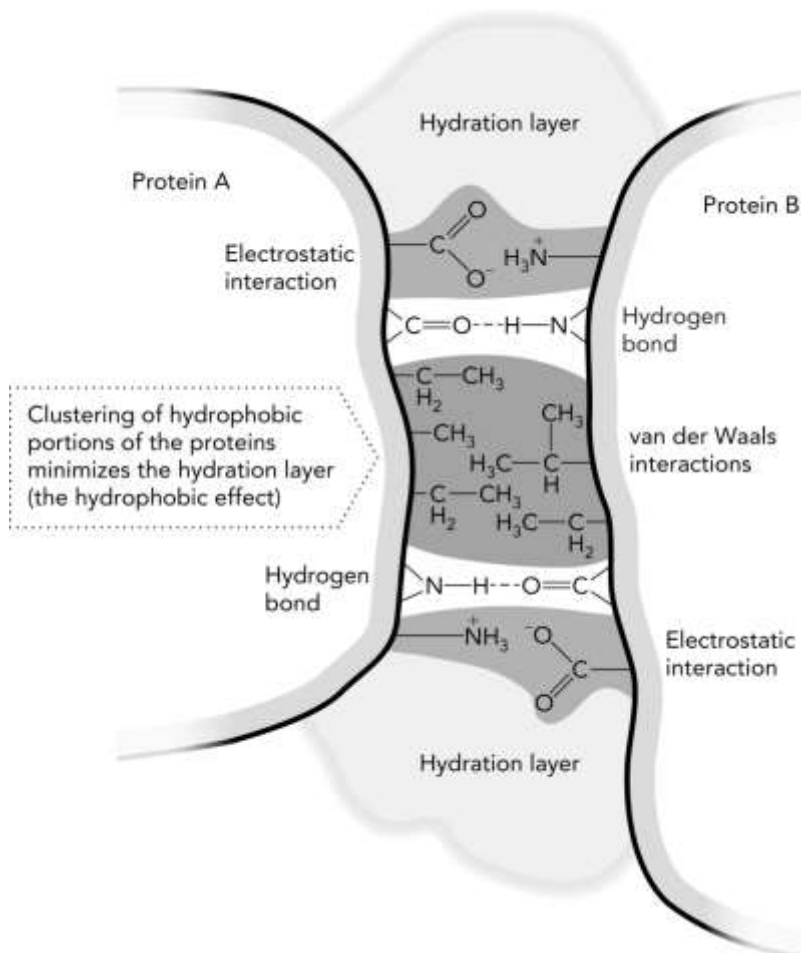


- Hydration layer
- Protein A
- Electrostatic interaction
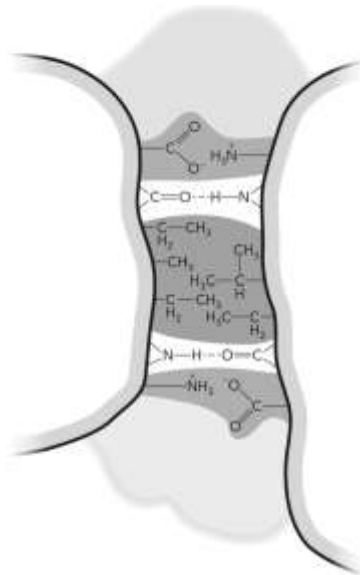- Protein B
- $C=O\cdots H-N$  Hydrogen bond
- Clustering of hydrophobic portions of the proteins minimizes the hydration layer (the hydrophobic effect)
- van der Waals interactions
- Hydrogen bond
- $N-H\cdots O=C$
- Electrostatic interaction
- Hydration layer

DIF: Easy          REF: 2.2
OBJ: 2.2.d. State the concept of the hydrophobic effect and how it impacts protein folding.
MSC: Remembering

14. If serum pH falls blow pH 7.4, a condition called acidosis, how does the body respond?

ANS:
The equilibrium of the carbonic acid–bicarbonate reaction is shifted toward $H_2CO_3$ formation to decrease $H^+$ concentration and thereby increase the pH. This is done by lowering $CO_2$ through hyperventilation and decreasing excretion of $HCO_3^-$ by the kidneys.

DIF: Difficult     REF: 2.2
OBJ: 2.2.j. Relate pH to pKa using the Henderson-Hasselbalch equation.
MSC: Analyzing

15. Compare the structure of a phospholipid bilayer and the structure of a micelle.

ANS:
Phospholipid bilayers are characteristic of biological membranes and create a hydrophobic barrier between two aqueous compartments. The hydrophilic polar head groups orient toward the aqueous environment, and the hydrophobic nonpolar hydrocarbon tails form a water impermeable barrier in the interior of the membrane. Micelles are structures in which the hydrophobic tails are in the center of a globular sphere and the polar head groups are facing outward toward the water.

DIF: Easy     REF: 2.3
OBJ: 2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.
MSC: Analyzing

16. The inclusion of cholesterol in a membrane can change the behavior of the membrane. Compare how the membrane behaves at low cholesterol concentration compared with high cholesterol concentration.

ANS:
When small amounts of cholesterol are added to a membrane, it prevents close packing by the phospholipids and helps the membrane increase fluidity. When large amounts are added, the cell membrane fluidity decreases due to the rigid ring structure of cholesterol.

DIF: Medium     REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Analyzing

17. It is known that lipid molecules in a membrane are able to move throughout the membrane. Propose a method to determine which mode of motion is MOST likely to happen and justify your answer.

ANS:
Fluorescence labeling of a phospholipid to determine that rotational movement would be the most likely to happen. This requires the least energy to perform and does not require the movement of another phospholipid.

DIF: Difficult     REF: 2.3
OBJ: 2.3.c. Explain the various ways cholesterol affects membrane structure.
MSC: Evaluating

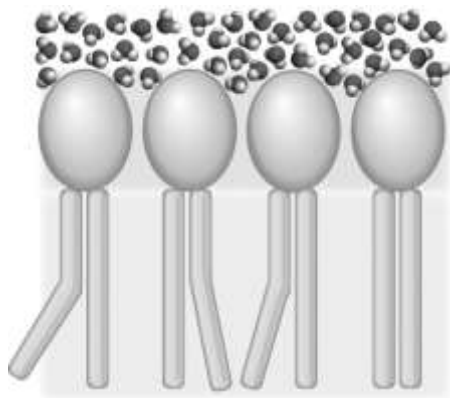18. What are the three major types of membranes?

ANS:

Plasma membrane, endomembrane, organelle membranes

DIF:   Easy              REF:  2.3
OBJ:   2.3.d. Differentiate among the different types of membranes found in a eukaryotic cell.
MSC:  Remembering

19.  Using the figure below, explain how having unsaturated fatty acid tails on phospholipids affects the fluidity of the membrane.



ANS:
The kink in the tails that occurs with the inclusion of a double bond prevents the tight packing of the fatty acid tails and increases the fluidity of the membrane.

DIF:   Medium        REF:  2.3
OBJ:   2.3.a. Identify the characteristics of a phospholipid that contribute to membrane formation.
MSC:  Understanding

20.  Fill in the table below.

| If the sign of $\Delta H$ is | and if the sign of $\Delta S$ is | then the sign of $\Delta G$ will be | Will it be spontaneous? |
|---|---|---|---|
| Negative | Positive | | |
| Positive | Negative | | |
| Negative | Negative | | |
| Positive | Positive | | |

ANS:

| If sign of $\Delta H$ is | and if the sign of $\Delta S$ is | then the sign of $\Delta G$ will be | Will it be spontaneous? |
|---|---|---|---|
| Negative | Positive | Negative | Yes at all temperatures |
| Positive | Negative | Positive | No at all temperatures |
| Negative | Negative | Negative when temperature is low Positive when temperature is high | Temperature dependent |
| Positive | Positive | Negative when temperature is high Positive when temperature is low | Temperature dependent |

DIF: Difficult    REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Understanding

21. Explain why a negative $\Delta G$ does not necessarily mean it will be a rapid reaction.

ANS:
$\Delta G$ tells you whether a reaction is likely to proceed to products as written. It is not a measure of the rate at which a reaction will take place. To determine rates of reactions you need to consider the kinetics of a reaction.

DIF: Difficult    REF: 2.1
OBJ: 2.1.k. Identify the impacts of enthalpy, entropy, and temperature on free energy.
MSC: Understanding

22. Water is a simple molecule that has three distinct properties. What are these properties and how are they critical for life processes?

ANS:
Water is less dense as a solid than a liquid, which allows water to float. Water is a liquid over a wide range of temperatures, which allows for the existence of aquatic life and oxygen content in the atmosphere. Water is an excellent solvent that is polar and can solvate ions and polar molecules. Hydrogen bonding within water is also important as it keeps water as a solvent over a much larger temperature range then would be expected.

DIF: Difficult    REF: 2.2
OBJ: 2.2.c. Differentiate among hydrogen bonds, ionic interactions, and van der Waals interactions.
MSC: Understanding

23. Explain the first and second laws of thermodynamics and how they are relevant to the field of biochemistry.

ANS:
The first law of thermodynamics states that energy is neither created nor destroyed, only converted from one form to another. This is what allows energy to be taken in by plants as light and converted to chemical energy. The second law of thermodynamics states that entropy in the universe is always increasing and therefore without the input of energy to restrain entropy, the highly ordered structures of organisms would fail and the organism would die.

DIF: Difficult    REF: 2.1
OBJ: 2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC: Understanding

24. Explain why adding nonpolar compounds to water is energetically unfavorable.

ANS:
The addition of nonpolar compounds to water breaks the hydrogen bonds between water molecules without replacing them and leads to the formation of ordered cagelike water structures, which is energetically unfavorable.

DIF: Medium    REF: 2.2
OBJ: 2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC: Understanding

25. Name and briefly describe the four types of weaker intermolecular forces found in biochemistry.

ANS:
Hydrogen bonds: form between a hydrogen atom on an electronegative donor group and another electronegative atom that serves as a hydrogen-bond acceptor.

Ionic interactions: weak interactions between oppositely charged atoms or groups.

van der Waals: weak interactions occurring between the dipoles of nearby electrically neutral molecule.

Hydrophobic effects: weak "interaction" is due to the tendency of hydrophobic molecules to pack close together away from water.

DIF:   Easy              REF:   2.2
OBJ:   2.1.h. State the second law of thermodynamics as it applies to biological systems.
MSC:  Understanding