CHAPTER 2
CHEMICAL COMPONENTS OF CELLS

Chemical Bonds

2-1 Figure Q2-1 depicts the structure of carbon. Use the information in the diagram to choose the correct atomic number and atomic weight, respectively, for an atom of carbon.

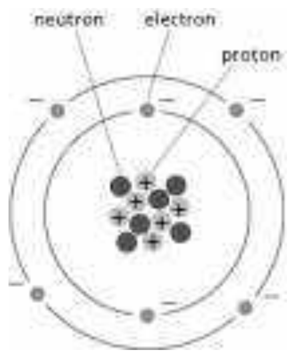


Figure Q2-1

(a) 6, 12
(b) 12, 12
(c) 6, 18
(d) 12, 6

2-2 An element may have more than a one isotope. Isotopes have different atomic weights, but exhibit the same chemical behavior. Carbon-14 is an unstable isotope of carbon that decays very slowly. Compared to the common, stable carbon-12 isotope, carbon-14 has two additional _______________.

(a) electrons
(b) neutrons
(c) protons
(d) ions

2-3 If the isotope ^{32}S has 16 protons and 16 neutrons, how many protons and how many neutrons will the isotope ^{35}S have?

2-4 A. If 0.5 mole of glucose weighs 90 g, what is the molecular weight of glucose?
B. What is the concentration, in grams per liter (g/l), of a 0.25 M solution of glucose?
C. How many molecules are there in 1 mole of glucose?

2-5 Which of the following elements is *least* abundant in living organisms?

(a) sulfur
(b) carbon
(c) oxygen
(d) nitrogen

2-6 Your friend learns about Avogadro's number and thinks it is so huge that there may not even be a mole of living cells on Earth. You have recently heard that there are about 50 trillion (50×10^{12}) human cells in each adult human body, so you bet your friend $5 that there is more than a mole of cells on Earth. Once you learn that each human contains more bacterial cells (in the digestive system) than human cells, you are sure that you have won the bet. The human population is now more than 6 billion (6×10^{9}). What calculation can you show your friend to convince him you are right?

2-7 Avogadro's number, calculated from the atomic weight of hydrogen, tells us how many atoms or molecules are in mole. The resulting base for all calculations of moles and molarity (how many molecules are present when you weigh out a substance or measure from a stock solution) is the following:

$$1 \text{ g of hydrogen atoms} = 6 \times 10^{23} \text{ atoms} = 1 \text{ mole of hydrogen}$$

Sulfur has a molecular weight of 32. How many moles and atoms are there in 120 grams of sulfur?
(a) 3.75 and 6×10^{23}
(b) 32 and 6×10^{23}
(c) 1.75 and 1.05×10^{24}
(d) 3.75 and 2.25×10^{24}

2-8 The first task you are assigned in your summer laboratory job is to prepare a concentrated NaOH stock solution. The molecular weight of NaOH is 40. How many grams of solid NaOH will you need to weigh out to obtain a 500 ml solution that has a concentration of 10 M?
(a) 800 g
(b) 200 g
(c) 400 g
(d) 160 g

2-9 You have a concentrated stock solution of 10 M NaOH and want to use it to produce a 150 ml solution of 3 M NaOH. What volume of water and stock solutions will you measure out to make this new solution?
(a) 135 ml of water, 15 ml of NaOH stock
(b) 115 ml of water, 35 ml of NaOH stock
(c) 100 ml of water, 50 ml of NaOH stock
(d) 105 ml of water, 45 ml of NaOH stock

2-10 An ionic bond between two atoms is formed as a result of the _______________.
(a) sharing of electrons

(b) loss of a neutron from one atom
(c) loss of electrons from both atoms
(d) loss of a proton from one atom
(e) transfer of electrons from one atom to the other

2-11 For each of the following sentences, fill in the blanks with the best word or phrase selected from the list below. Not all words or phrases will be used; each word or phrase should be used only once.

Whereas ionic bonds form a(n) ___________________, covalent bonds between atoms form a(n) ___________________. These covalent bonds have a characteristic bond ___________________ and become stronger and more rigid when two electrons are shared in a(n) ___________________. Equal sharing of electrons yields a(n) ___________________ covalent bond. If one atom participating in the bond has a stronger affinity for the electron, this produces a partial negative charge on one atom and a partial positive charge on the other. These ___________________ covalent bonds should not be confused with the weaker ___________________ bonds that are critical for the three-dimensional structure of biological molecules and for interactions between these molecules.

charge	length	polar
covalent	molecule	salt
double bond	noncovalent	single bond
ionic	nonpolar	weight

2-12 Indicate whether the statements below are true or false. If a statement is false, explain why it is false.

A. Electrons are constantly moving around the nucleus of the atom, but they can move only in discrete regions.
B. There is no limit to the number of electrons that can occupy the fourth electron shell.
C. Atoms with unfilled outer electron shells are especially stable and are therefore less reactive.
D. Covalent bonds are formed when electrons are either shared or transferred between atoms.

2-13 Table Q2-13 indicates the electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements are chemically inert?

atomic number	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

energy level (electron shell)

Table Q2-13

(a) carbon, sulfur
(b) helium, neon
(c) sodium, potassium
(d) magnesium, calcium

2-14 Table Q2-14 indicates the electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements will form ions with a net charge of +1 in solution?

atomic number	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

energy level (electron shell)

Table Q2-14

(a) carbon, sulfur
(b) helium, neon
(c) sodium, potassium
(d) magnesium, calcium

2-15 Table Q2-15 indicates the electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements will form ions with a net charge of +2 in solution?

atomic number ↓ — energy level (electron shell)

	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table Q2-15

(a) carbon, sulfur
(b) helium, neon
(c) sodium, potassium
(d) magnesium, calcium

2-16 Table Q2-16 indicates the electrons in the first four atomic electron shells for selected elements. On the basis of the information in the chart and what you know about atomic structure, which elements form stable but reactive diatomic gases?

atomic number ↓ — energy level (electron shell)

	element	I	II	III	IV
1	Hydrogen	●			
2	Helium	●●			
6	Carbon	●●	●●●●		
7	Nitrogen	●●	●●●●●		
8	Oxygen	●●	●●●●●●		
10	Neon	●●	●●●●●●●●		
11	Sodium	●●	●●●●●●●●	●	
12	Magnesium	●●	●●●●●●●●	●●	
15	Phosphorus	●●	●●●●●●●●	●●●●●	
16	Sulfur	●●	●●●●●●●●	●●●●●●	
17	Chlorine	●●	●●●●●●●●	●●●●●●●	
18	Argon	●●	●●●●●●●●	●●●●●●●●	
19	Potassium	●●	●●●●●●●●	●●●●●●●●	●
20	Calcium	●●	●●●●●●●●	●●●●●●●●	●●

Table Q2-16

(a) nitrogen, oxygen

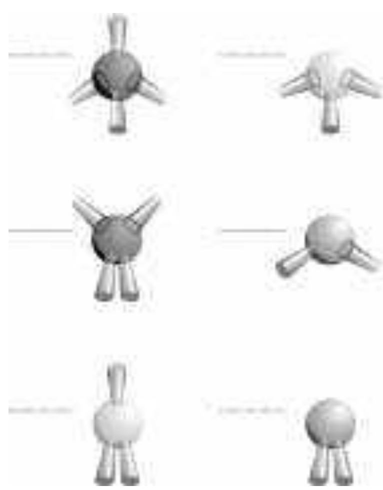
(b) helium, neon
(c) sodium, potassium
(d) magnesium, calcium

2-17 A. In what scientific units is the strength of a chemical bond usually expressed?
B. If 0.5 kilocalories of energy is required to break 6×10^{23} bonds of a particular type, what is the strength of this bond?

2-18 The pH of an aqueous solution is an indication of the concentration of available protons. However, you should not expect to find lone protons in solution; rather, the proton is added to a water molecule to form a(n) ______________ ion.
(a) hydroxide
(b) ammonium
(c) chloride
(d) hydronium

2-19 The relative strengths of covalent bonds and van der Waals interactions remain the same when tested in a vacuum or in water. However, this is not true of hydrogen bonds or ionic bonds, whose bond strength is lowered considerably in the presence of water in comparison with the bond strength observed in a vacuum. Explain these observations.

2-20 Oxygen, hydrogen, carbon, and nitrogen atoms are enriched in the cells and tissues of living organisms. The covalent bond geometries for these atoms influence their biomolecular structures. Match the elements on the left with the bond geometries illustrated on the right. Some elements assume more than one bond geometry.



A. oxygen
B. carbon
C. nitrogen

2-21 Which of the following expressions accurately describes the calculation of pH?

(a) $pH = -\log_{10}[H^+]$
(b) $pH = \log_{10}[H^+]$
(c) $pH = -\log_2[H^+]$
(d) $pH = -\log_{10}[OH^-]$

2-22 Larger molecules have hydrogen-bonding networks that contribute to specific, high–affinity binding. Smaller molecules such as urea can also form these networks. How many hydrogen bonds can urea (Figure Q2-22) form if dissolved in water?

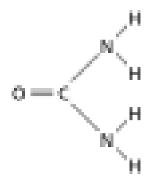


Figure Q2-22

(a) 6
(b) 5
(c) 3
(d) 4

2-23 A. Sketch three different ways in which three water molecules could be held together by hydrogen bonding.
B. On a sketch of a single water molecule, indicate the distribution of positive and negative charge (using the symbols δ^+ and δ^-).
C. How many hydrogen bonds can a hydrogen atom in a water molecule form? How many hydrogen bonds can the oxygen atom in a water molecule form?

2-24 A. What is the pH of pure water?
B. What concentration of hydronium ions does a solution of pH 8 contain?
C. Complete the following reaction:

$$CH_3COOH + H_2O \leftrightarrow \_\_\_\_\_\_\_\_\_\_.$$

D. Will the reaction in C occur more readily (be driven to the right) if the pH of the solution is high?

2-25 Aromatic carbon compounds such as benzene are planar and very stable. Double-bond character extends around the entire ring, which is why it is often drawn as a hexagon with a circle inside. This characteristic is caused by electron __________.
(a) resonance
(b) pairing
(c) partial charge
(d) stacking

2-26 The amino acid histidine is often found in enzymes. Depending on the pH of its environment, sometimes histidine is neutral and at other times it acquires a proton and becomes positively charged. Consider an enzyme with a histidine side chain that is known to have an important role in the function of the enzyme. It is not clear whether this histidine is required in its protonated or its unprotonated state. To answer this question you measure enzyme activity over a range of pH, with the results shown in Figure Q2-26. Which form of histidine is necessary for the active enzyme?

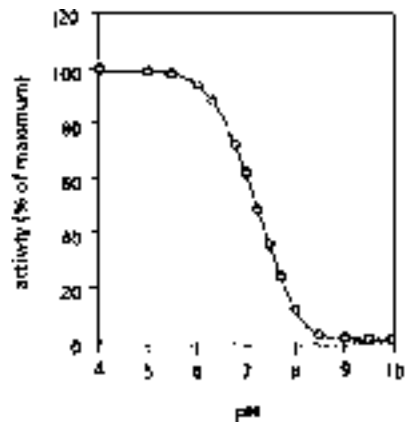


Figure Q2-26

2-27 Silicon is an element that, like carbon, has four vacancies in its outer electron shell and therefore has the same bonding chemistry as carbon. Silicon is not found to any significant degree in the molecules found in living systems, however. Does this difference arise because elemental carbon is more abundant than silicon? What other explanations are there for the preferential selection of carbon over silicon as the basis for the molecules of life?

Molecules in Cells

2-28 The variety and arrangement of chemical groups on monomer subunits contribute to the conformation, reactivity, and surface of the macromolecule into which they become incorporated. What type of chemical group is circled on the nucleotide shown in Figure Q2-28?

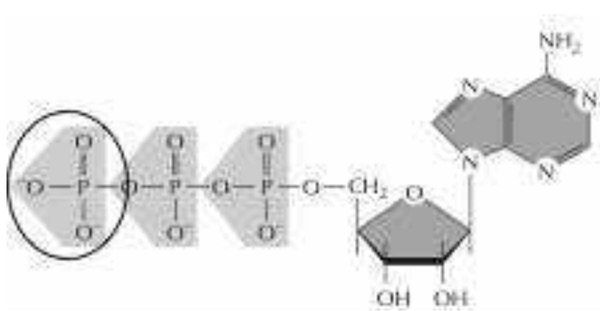


Figure Q2-28

(a) pyrophosphate
(b) phosphoryl
(c) carbonyl
(d) carboxyl

2-29 The amino acids glutamine and glutamic acid are shown in Figure Q2-29. They differ only in the structure of their side chains (circled). At pH 7, glutamic acid can participate in molecular interactions that are not possible for glutamine. What types of interaction are these?

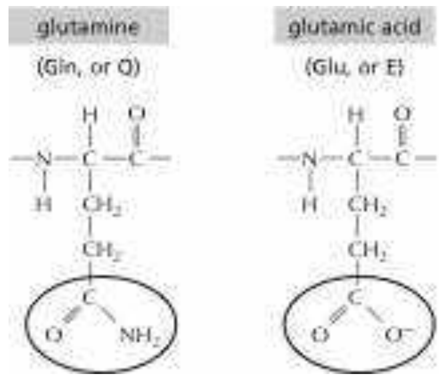


Figure Q2-29

(a) ionic bonds
(b) hydrogen bonds
(c) van der Waals interactions
(d) covalent bonds

2-30 Oligosaccharides are short sugar polymers that can become covalently linked to proteins and lipids through condensation reactions. These modified proteins and lipids are called glycoproteins and glycolipids. Within a protein, which of the amino acids (shown in Figure Q2-30) is the most probable target for this type of modification?

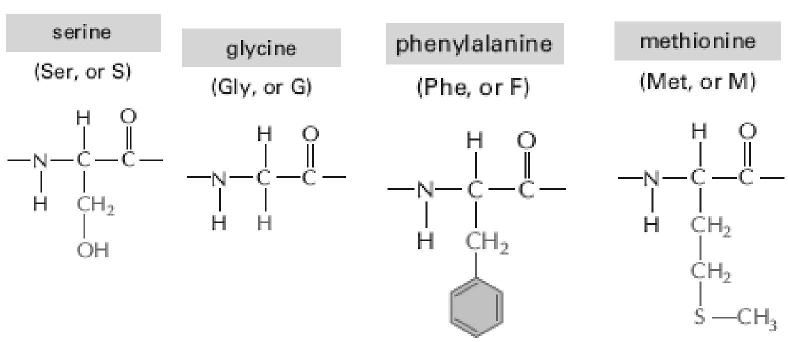


Figure Q2-30

(a) serine

(b) glycine
(c) phenylalanine
(d) methionine

2-31 Which of the following are examples of isomers?
(a) glucose and galactose
(b) alanine and glycine
(c) adenine and guanine
(d) glycogen and cellulose

2-32 A. How many carbon atoms does the molecule represented in Figure Q2-32 have?
B. How many hydrogen atoms does it have?
C. What type of molecule is it?

Figure Q2-32

2-33 Most types of molecule in the cell have asymmetric (chiral) carbons. Consequently there is the potential to have two different molecules that look much the same but are mirror images of each other and therefore not equivalent. These special types of isomer are called stereoisomers. Which of the four carbons circled in Figure Q2-33 is the asymmetric carbon that determines whether the amino acid (threonine in this case) is a D- or an L- stereoisomer?

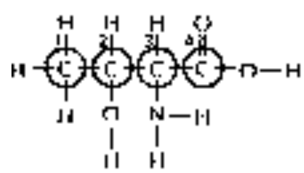


Figure Q2-33

(a) 1
(b) 2
(c) 3
(d) 4

2-34 Indicate whether the statements below are true or false. If a statement is false, explain why it is false.
A. A disaccharide consists of a sugar covalently linked to another molecule such as an amino acid or a nucleotide.
B. The hydroxyl groups on monosaccharides are reaction hotspots and can be replaced by other functional groups to produce derivatives of the original sugar.
C. The presence of double bonds in the hydrocarbon tail of a fatty acid does not greatly influence its structure.

D. Glycerol is a three-carbon compound that connects the fatty acid tails with the polar head group in phospholipids.

2-35 On the phospholipid molecule in Figure Q2-35 label each numbered line with a correct term selected from the list below.

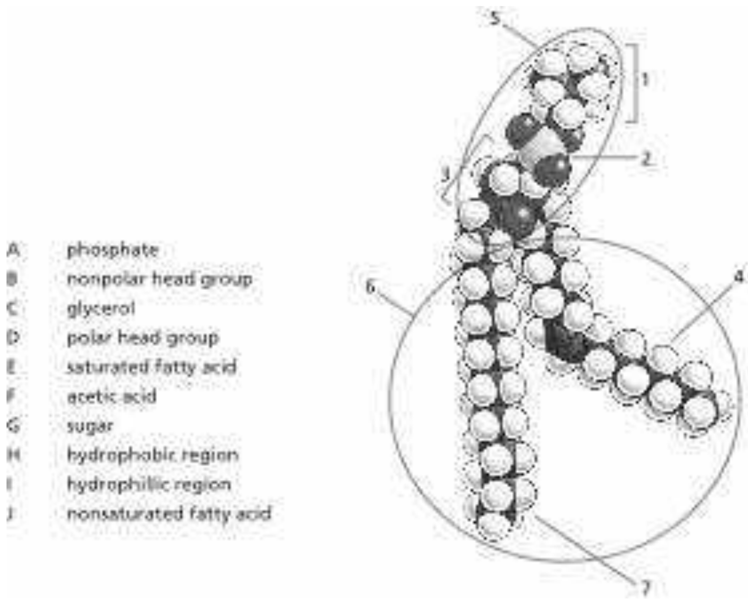


Figure Q2-35

2-36 Biological membranes are composed of specialized lipids that form bilayers. Which of the following is formed by unmodified fatty acids?

(a) fat droplets
(b) bilayers
(c) micelles
(d) planar lipid patches

2-37 Choose the answer that best fits the statement. Cholesterol is an essential component of biological membranes. Although it is much smaller than the typical phospholipids and glycoplipids in the membrane, it is a(n) ________________ molecule, having both hydrophilic and hydrophobic regions.

(a) polar
(b) oxygen-containing
(c) hydrophobic
(d) amphipathic

2-38 DNA and RNA are different types of nucleic acid polymer. Which of the following is true of DNA but *not* true of RNA?

(a) It contains uracil.
(b) It contains thymine.
(c) It is single stranded.
(d) It has 5′-to-3′ directionality.

2-39 Match each term related to the structure of nucleic acids (A–I) with one of the descriptions provided.

A. base
B. glycosidic bond
C. nucleoside
D. nucleotide
E. phosphoanyhydride bond
F. phosphoester bond
G. ribose
H. phosphodiester bond
I. deoxyribose

____ the linkage between two nucleotides
____ the linkage between the 5′ sugar hydroxyl and a phosphate group
____ the nitrogen-containing aromatic ring
____ five-carbon sugar found in DNA
____ sugar unit linked to a base
____ linkage between the sugar and the base
____ linkages between phosphate groups
____ sugar linked to a base and a phosphate
____ five-carbon sugar found in RNA

2-40 A. Write out the sequence of amino acids in the following peptide, using the full names of the amino acids.

Pro-Val-Thr-Gly-Lys-Cys-Glu

B. Write the same sequence with the single-letter code for amino acids.
C. According to the conventional way of writing the sequence of a peptide or a protein, which is the C-terminal amino acid and which is the N-terminal amino acid in the above peptide?

2-41 Which of the following statements about amino acids is *true*?

(a) Twenty-two amino acids are commonly found in proteins.
(b) Most of the amino acids used in protein biosynthesis have charged side chains.
(c) Amino acids are often linked together to form branched polymers.
(d) All amino acids contain an NH_2 and a COOH group

2-42 Which of the following statements is *false*?

(a) ATP contains high-energy phosphoanhydride bonds.
(b) ATP is sometimes called the “universal currency” in the energy economy of cells.
(c) ATP can be incorporated into DNA.
(d) ATP can be hydrolyzed to release energy to power hundreds of reactions in cells.
(e) ATP comprises a sugar, phosphate groups, and a nitrogenous base.

Macromolecules in Cells

2-43 Both DNA and RNA are synthesized by covalently linking a nucleotide triphosphate to the previous nucleotide, constantly adding to a growing chain. In the case of DNA, the new strand becomes part of a stable helix. The two strands are complementary in sequence and antiparallel in directionality. What is the principal force that holds these two strands together?
(a) ionic interactions
(b) hydrogen bonds
(c) covalent bonds
(d) van der Waals interactions

2-44 Each nucleotide in DNA and RNA has an aromatic base. What is the principal force that keeps the bases in a polymer from interacting with water?
(a) hydrophobic interactions
(b) hydrogen bonds
(c) covalent bonds
(d) van der Waals interactions

2-45 Because there are four different monomer building blocks that can be used to assemble RNA polymers, the number of possible sequence combinations that can be created for a RNA molecule made of 100 nucleotides is _______.
(a) 100^4
(b) 4^{100}
(c) 4×100
(d) 100/4

2-46 There are 20^{100} different possible sequence combinations for a protein chain with 100 amino acids. In addition to the amino acid sequence of protein, what other factors *increase* the potential for diversity in these macromolecules?
(a) free rotation around single bonds during synthesis
(b) noncovalent interactions sampled as protein folds
(c) the directionality of amino acids being added
(d) the planar nature of the peptide bond

2-47 Indicate whether the statements below are true or false. If a statement is false, explain why it is false.
A. “Nonpolar interactions” is simply another way of saying “van der Waals attractions.”
B. Condensation reactions occur in the synthesis of all the macromolecules found in cells.
C. All proteins and RNAs pass through many unstable conformations as they are folded, finally settling on one single, preferred conformation.
D. When nonpolar molecules are placed in an aqueous solution, the water molecules surrounding the nonpolar surface become completely disordered.

2-48 Macromolecules in the cell can often interact transiently as a result of noncovalent interactions. These weak interactions also produce stable, highly specific interactions between molecules. Which of the factors below is the most significant in determining whether the interaction will be transient or stable?

(a) the size of each molecule
(b) the concentration of each molecule
(c) the rate of synthesis
(d) surface complementarity between molecules

2-49 In a folded protein, most of the nonpolar amino acids are buried inside the protein fold, whereas the polar and charged side chains are exposed to the components in the cytosol. This fold is more stable because of the expulsion of nonpolar atoms from contact with water, favoring the interaction of nonpolar atoms with each other. What is this fourth type of noncovalent interaction called?

(a) hydrophobic interaction
(b) hydrophilic interaction
(c) apolar interaction
(d) hydrocarbon interaction

2-50 You are trying to make a synthetic copy of a particular protein but accidentally join the amino acids together in exactly the reverse order. One of your classmates says the two proteins must be identical, and bets you $20 that your synthetic protein will have exactly the same biological activity as the original. After having read this chapter, you have no hesitation in staking your $20 that it won't. What particular feature of a polypeptide chain makes you sure your $20 is safe and that your project will have to be redone.

2-51 A protein chain folds into its stable and unique three-dimensional structure, or conformation, by making many noncovalent bonds between different parts of the chain. Such noncovalent bonds are also critical for interactions with other proteins and cellular molecules. From the list provided, choose the class(es) of amino acids that are most important for the interactions detailed below.

A. forming ionic bonds with negatively charged DNA
B. forming hydrogen bonds to aid solubility in water
C. binding to another water-soluble protein
D. localizing an "integral membrane" protein that spans a lipid bilayer
E. tightly packing the hydrophobic interior core of a globular protein

acidic	nonpolar
basic	uncharged polar

2-52 It is now a routine task to determine the exact order in which individual subunits have been linked together in polynucleotides (DNA) and polypeptides (proteins). However, it remains difficult to determine the arrangement of monomers in a polysaccharide. Explain why this is the case.

2-53 Your lab director requests that you add new growth medium to the mammalian cell cultures before heading home from the lab on a Friday night. Unfortunately, you need to make fresh medium because all the pre-mixed bottles of medium have been used. One of the ingredients you know you need to add is a mix of the essential amino acids (those that cannot be made by the cells, but are needed in proteins). On the shelf of dry chemicals you find the amino acids you need, and you mix them into your medium, along with all the other necessary nutrients and replace the old medium with your new medium. On Sunday, you come in to the lab just to check on your cells and find that the cells have not grown. You are sure you made the medium correctly, but on checking you see that somebody wrote a note on the dry mixture of amino acids you used: "Note: this mixture contains only D-amino acids."

A. What is the meaning of the note and how does it explain the lack of cell growth in your culture?

B. Are there any organisms that could grow using this mixture? Justify your answer.

2-54 Eucaryotic cells have their DNA molecules inside their nuclei. However, to package the DNA all into such a small volume requires the cell to use specialized proteins called histones. Histones have amino acid sequences enriched for lysines and arginines.

A. What problem might a cell face in trying to package DNA into a small volume without histones, and how do these special packaging proteins alleviate the problem?

B. Lysine side chains are substrates for enzymes called acetylases. A diagram of an acetylated lysine side chain is shown in Figure Q2-54. How do you think the acetylation of lysines in histone proteins will affect the ability of a histone to perform its role (refer to your answer in part A)?

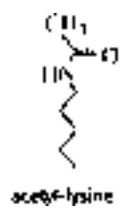


Figure Q2-54

Answers

2-1 (a)

2-2 (b)

2-3 16 proteins and 19 neutrons

2-4 A. 180 daltons. A mole of a substance has a mass equivalent to its molecular weight expressed in grams.

B. 45 g/l

C. 6×10^{23} molecules

2-5 (a). Sulfur is the least abundant element among the choices given.

2-6 Avogadro's number, or 6×10^{23}, is the number of atoms (or units) in a mole. If you multiply the number of people on Earth by the number of cells in the human body, then double it to account for the bacteria, you will calculate: $(6 \times 10^9) \times (50 \times 10^{12}) \times 2 = 6 \times 10^{23}$. Thus, there must be much more than a mole of living cells on Earth, and you win $5.

2-7 (d)

2-8 (b)

2-9 (d)

2-10 (e)

2-11 Whereas ionic bonds form a **salt**, covalent bonds between atoms form a **molecule**. These covalent bonds have a characteristic bond **length** and become stronger and more rigid when two electrons are shared in a **double bond**. Equal sharing of electrons yields a **nonpolar** covalent bond. If one atom participating in the bond has a stronger affinity for the electron, this produces a partial negative charge on one atom and a partial positive charge on the other. These **polar** covalent bonds should not be confused with the weaker **noncovalent** bonds that are critical for the three-dimensional structure of biological molecules and for interactions between these molecules.

2-12 A. True.

B. False. The fourth electron shell has the capacity to hold 18 electrons.

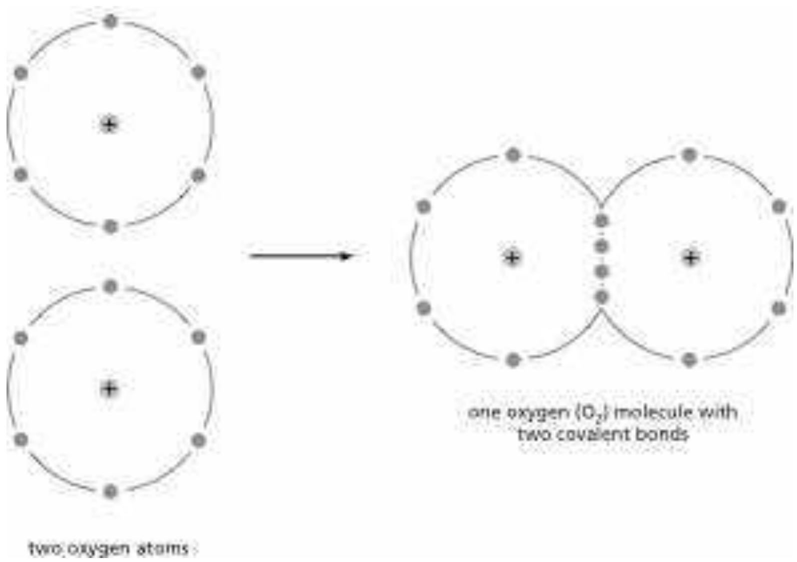
C. False. Atoms that have their outer electron shells filled are the most stable and least reactive. Atoms with unfilled outer shells are more reactive because they tend to share or transfer electrons to fill and therefore stabilize the outer shell.

D. False. Covalent bonds are formed exclusively when electrons are shared between atoms.

2-13 (b)

2-14 (c)

2-15 (d). An oxygen atom with six outer electrons needs two more to attain a stable outer shell. This can be achieved by forming two covalent bonds with a second oxygen as shown on the right. Similarly, a nitrogen atom needs three more electrons and makes three covalent bonds with another nitrogen atom.



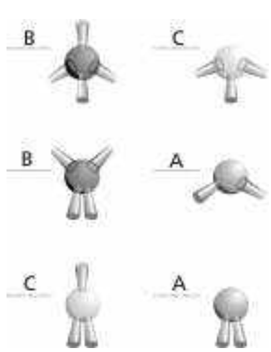
2-16 (a)

2-17 A. kilocalories per mole (*or* kilojoules per mole)
B. 0.5 kcal/mole

2-18 (d)

2-19 We estimate bond strengths by measuring the amount of energy needed to break them. In an aqueous solution, water may partly hydrogen bond with any charged or polar molecules, reducing the strength of the interaction they would otherwise have in the absence of water (in a vacuum). Covalent bonds and Van der Waals attractions have an intrinsic value that is independent of the environment.

2-20



2-21 (a)

2-22 (a). Urea can form at least six hydrogen bonds in water: two from the oxygen atom and one from each hydrogen atom.

2-23 A. See Figure A2-23A.
B. See Figure A2-23B.
C. Hydrogen can form one; oxygen two.

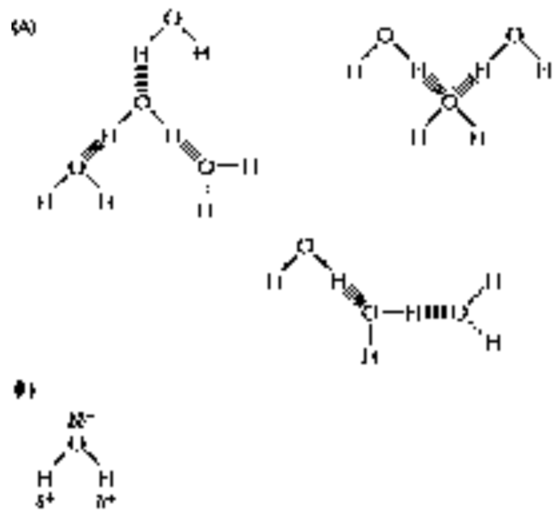


Figure A2-23

2-24 A. pH 7
B. 10^{-8} M
C. $CH_3COO^- + H_3O^+$
D. Yes. If the pH is high, then the concentration of hydronium ions will be low. Therefore the rightward reaction, which produces hydronium ions, will be favored.

2-25 (a)

2-26 Assuming that the change in enzyme activity is due to the change in the protonation state of histidine, the enzyme must require histidine in the protonated, charged state. The enzyme is active only at low, acidic, pH, where the proton (or hydronium ion) concentration is high; thus, the loss of a proton from histidine will be disfavored so that histidine is likely to be protonated.

2-27 On the basis of Figure 2–4 in your textbook, silicon is actually more abundant in Earth's crust than carbon, so this is not likely to be the reason that carbon was used preferentially. Carbon might have been the element of choice in living systems because it is lighter than silicon and forms shorter covalent bonds with other elements. Shorter bonds are typically stronger and more stable.

2-28 (b)

2-29 (a)

2-30 (a)

2-31 (a). Glucose and galactose are both six-carbon sugars and thus both have the formula $C_6H_{12}O_6$. They are therefore isomers of each other. Adenine and guanine are bases containing different numbers of nitrogen and oxygen atoms. Glycogen and cellulose are different polymers of glucose. Alanine and glycine are amino acids with quite different side chains, a methyl group and a hydrogen atom, respectively.

2-32 A. 20 carbon atoms

B. 31 hydrogen atoms

C. A fatty acid (Figure A2-32 is arachidonic acid, an essential fatty acid required by most mammals).

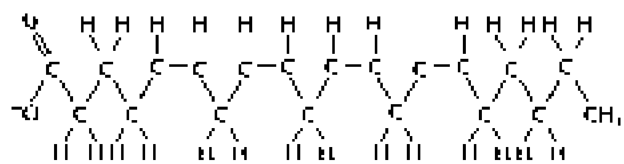


Figure A2-32

2-33 (c). Two of the carbon atoms of threonine are asymmetric (numbered 2 and 3 in Figure Q2-33) but by convention it is the α-carbon (number 3) that determines whether the amino acid is the D- or L-isomer.

2-34 A. False. A disaccharide consists of two sugar molecules undergo a condensation reaction to form a covalent bond (known as a glycosidic linkage).

B. True.

C. False. The presence of a double bond in the hydrocarbon chain of a fatty acid causes a kink in the chain, decreasing its flexibility and packing with neighboring hydrocarbon chains.

D. True.

2-35 1—D; 2—A; 3—C; 4—J; 5—I; 6—H; 7—E

2-36 (c)

2-37 (d)

2-38 (b)

2-39 H—the linkage between two nucleotides

F—the linkage between the 5′ sugar hydroxyl and a phosphate group
A—the nitrogen-containing aromatic ring
I—five-carbon sugar found in DNA
C—sugar unit linked to a base
B—linkage between the sugar and the base
E—linkages between phosphate groups
D—sugar linked to a base and a phosphate
G—five-carbon sugar found in RNA

2-40 A. proline-valine-threonine-glycine-lysine-cysteine-glutamic acid (*or* glutamate)
B. PVTGKCQ
C. C-terminal is glutamic acid (*or* glutamate); N-terminal is proline.

2-41 Choice (d) is true. As their name implies, all amino acids have at least one amino (NH_2) group and at least one acidic carboxylic (COOH) group. It is through these two groups that they form peptide bonds.

2-42 (c). ATP is used in energy conversions, contains ribose, and can be incorporated into RNA. But synthesis of DNA requires the deoxyribose form of the nucleotide, dATP. All the other statements about ATP are true.

2-43 (b)

2-44 (a)

2-45 (b)

2-46 (a)

2-47 A. False. Van der Waals attractions describe the general attractive forces between all atoms. The contact distance between any two non-bonded atoms is the sum of the van der Waals radii. Nonpolar interactions are based on the exclusion of hydrophobic molecules from a hydrophilic environment.
B. True.
C. True.
D. False. One reason that nonpolar groups are excluded from an aqueous environment is that a hydrophobic surface would organize water into a highly structured network of hydrogen bonds, which is energetically unfavorable.

2-48 (d)

2-49 (a)

2-50 As a peptide bond has a distinct chemical polarity, a polypeptide chain also has a distinct polarity. (See Figure A2-50.) The reversed protein chains cannot make the same noncovalent interactions during folding and thus will not adopt the same three-dimensional structure as the original protein. The activities of these two proteins will definitely be different, because the activity of a protein depends on its three-dimensional structure. It is unlikely that the reverse chain will fold into any well-defined, and hence functionally useful, structure at all, because it has not passed the stringent selective pressures imposed during evolution.

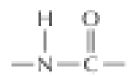


Figure A2-50

2-51 A. basic
B. uncharged polar
C. uncharged polar, basic, and acidic
D. nonpolar
E. nonpolar

2-52 Nucleotides and amino acids have an intrinsic directionality, and the mechanism by which monomers are added into a growing polymer is always the same. This yields a linear polymer with the same directionality as the monomers. Polysaccharides are produced by linking monosaccharides together. The monosaccharides can be either added directly or modified to produce various derivatives before addition. Beyond this, there are multiple sites on each monosaccharide where addition can occur, producing highly complex, branched polymers.

2-53 A. The note indicates that the mixture contains only one of the two possible stereoisomers (L- or D-). Because mammalian cells use only the L- stereoisomer, the D-amino acid mixture could not be used and therefore it is as though no amino acids were added at all.
B. Not unless L-amino acids were also mixed in. Certain types of bacteria use D-amino acids to produce their cell walls, but they would still require L-amino acids for the rest of the proteins they make.

2-54 A. DNA is a nucleic acid polymer in which each monomer has a negatively charged phosphate group. The negative charges will naturally repel each other, so in order to wrap the high density of negative charges into a small space, positively charged molecules must be present. Histones accomplish this because they are rich in lysines and arginines, which are positively charged in solution at pH 7.
B. A histone with acetylated lysine residues will not be as good at packaging the DNA. The addition of the acetyl group to the terminal amino on the lysine side chain lowers the histone's net positive charge, which makes it less effective at buffering the negative charges on the DNA backbone.