Unit 1 Metabolic Processes

ARE YOU READY?

(Pages 4–5)

Knowledge and Understanding

1. A: Cytoplasm—a gel-like substance in which all the cellular contents are suspended
   B: Mitochondria—organelles that produce ATP from pyruvate
   C: Cristae—parts of the inner mitochondrial membrane that hold proteins, enzymes, and other components that take part in the reactions of cellular respiration
   D: Chloroplast—an organelle that produces glucose in the process of photosynthesis
   E: Thylakoid membrane—the site of the light-dependent reactions of photosynthesis
   F: Polysaccharide—a chain of glucose monomers
   G: Glucose—a monosaccharide; used as a form of stored energy
   H: Chromosome—a single visible strand of DNA and associated proteins
   I: Deoxyribonucleic acid (DNA)—genetic material composed of four nucleotides arranged into a double helix
   J: Nucleotide—a subunit of DNA comprising a ribose sugar, a phosphate group, and a nitrogenous base
   K: Phospholipid bilayer—formed from the interactions of phospholipids with water, which forms a structure called a bilayer to "hide" the nonpolar, hydrophobic fatty acid tails from the water
   L: Phospholipid—an amphipathic molecule, meaning it has a polar and nonpolar region that forms a bilayer or micelle in water; contains glycerol, fatty acids, a phosphate group, and an additional charged group
2. 1.(e)
   2. (d)
   3. (f)
   4. (i)
   5. (h)
   6. (c)
   7. (a)
   8. (b)
   9. (g)
3. A: oxygen
   B: oxygen
   C: mitochondrion
   D: adenosine triphosphate
   E: carbon dioxide
   F: carbon dioxide

CHAPTER 1 THE CHEMICAL BASIS OF LIFE

Reflect on Your Learning

(Page 6)

1. (a) The polarity of water allows other polar molecules, such as sugar, salt, alcohol and acids, to dissolve.
   (b) The adhesion of water to clothing through hydrogen bonds cause wet clothing to require a long time to dry at room temperature.
2. The expression "like dissolves like" means that a polar solvent will dissolve polar solutes and a nonpolar solvent will dissolve nonpolar solutes.
3. Carbon-based molecules are common in living organisms because of the large variety of chemicals, with diverse physical and chemical properties, that carbon can form.
4. Cows can survive on grass, while humans cannot because cows have symbiotic bacteria in their digestive tracts to allow them break the β 1–4 linkage between β-glucose molecules in grass. Humans don't have these bacteria.

5. Peeled potatoes turn brown because browning enzymes are exposed to oxygen gas and oxidize the carbohydrates. Dipping the peeled potatoes in scalding water for a few seconds, a method called blanching, denatures these browning enzymes.

Try This Activity: The Cat's Meow

(Page 7)

(a) Hypothesis: The fat droplets in the milk are dissolved by the detergent on the surface of the milk and draw the milk and dye from the edges.

(b) Materials: Homogenized milk, 2% milk, 1% milk, skim milk, food colouring, dishwasher detergent, flat-bottomed bowl and toothpick

Method:
1. Record the fat content of the milk from the bag or carton.
2. Set up the experiment as stated on page 7 of the Student Text with the homogenized milk.
3. Record your observations every 15 seconds using a digital camera if available, or sketch your observations.
4. Using the same milk, insert a clean toothpick as a control.
5. Repeat steps 1 through 4 using milk with 0.3% (skim), 1%, and 2% fat.

(c) Results: The higher the fat content, the faster the dye moved toward the centre. The clean toothpick, without dishwasher detergent, did not cause the dye to move.

(d) Discussion: The dye moved faster when the fat content was higher because of the greater volume of fat on the surface that was spread out. There was no movement with a clean toothpick as the fat droplets did not dissolve.

1.1 CHEMICAL FUNDAMENTALS

PRACTICE

(Page 10)

Understanding Concepts

1. Potassium (K), Z = 19, number of neutrons = 20

2. (a) $^{52}_{24}\mathrm{Cr}$

   (b) $^{32}_{15}\mathrm{P}$

3. The proton.

4. $t_{1/2}$ = 8 days
   32 days = 4 half-lives
   100%:0%

50%:50%	1 half life
25%:75%	2 half-lives
12.5%:87.5%	3 half-lives
6.25%:93.75%	4 half-lives

   20 g × 0.0625 = 1.25 g

5. Carbon-14 is not useful in nuclear medicine because it does not localize in any specific area as it is metabolized into many different chemicals. Furthermore, carbon-14 has a very long half-life, 5730 years, which makes it dangerous to humans.

Applying Inquiry Skills

6. A radioactive isotope of calcium could be used to determine whether the intestinal cells or osteoblasts lack the ability to process calcium by observing the location of the isotope using nuclear imaging techniques. If the radioactive calcium was found in the blood stream, then the intestinal cells would be able to absorb calcium. The presence of radioactive calcium in the bone tissue would show that the osteoblasts are processing the calcium correctly. The amount of radiation absorbed during such a diagnostic test is directly proportional to the ability of the bone to absorb calcium. The more radiation absorbed, the more bone mass you have. If very little radiation is absorbed, it indicates osteoporosis.

Making Connections

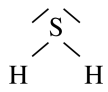
7. Student answers will vary. Students should convey the message that the statement refers to the risk of damage to germ-line reproductive cells. Any damage that occurs to reproductive cells will be transferred to all subsequent generations.

PRACTICE

(Page 16)

Understanding Concepts

8. (a)



(b) $E_{nS} = 2.4$; $E_{nH} = 2.1$; $\Delta E_n = 2.4 - 2.1 = 0.3$. The S–H bond is polar covalent.
(c) The shape of the hydrogen sulfide molecule is angular according to VSEPR.
(d) The hydrogen sulfide molecule is polar because the two polar S–H bonds are arranged asymmetrically.

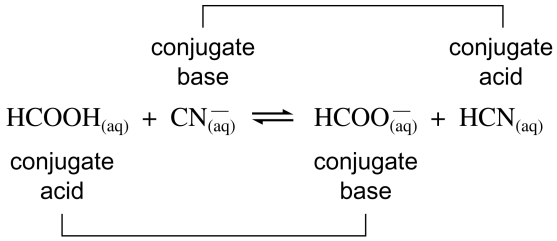
9. A molecule can have several polar covalent bonds but still be nonpolar if the bonds are arranged symmetrically around a central atom.

Section 1.1 Questions

(Page 23)

Understanding Concepts

1. (a) Sulfur contains 16 protons, 16 electrons, 16 neutrons, and has 6 valence electrons.
(b) Calcium contains 20 protons, 20 electrons, 20 neutrons, and has 2 valence electrons.
(c) Nitrogen has 7 electrons, 7 protons, 7 neutrons, and has 5 valence electrons.
2. The elements with the atomic numbers 8, 16, and, 34 have the same number of valence electrons, six. They each need two electrons to fill the outer orbital.
3. Cobalt-60 has 33 neutrons.
4. (a) Hydrogen bonds must be broken to melt ice, $H_2O_{(s)}$, into water, $H_2O_{(l)}$.
(b) London forces must be broken to melt ice, $I_{2(s)}$, into water, $I_{2(l)}$.
5. VSEPR theory is based on the mutual repulsion of electron pairs.
6. Based on VSEPR theory and electronegativity values, carbon tetrachloride, CCl_4, is nonpolar due to the symmetrical arrangement of its polar C–Cl bonds and ammonia, NH_4, is polar due to the nonsymmetrical arrangement of its polar N–H bonds.
7. Table salt, $NaCl_{(s)}$, is soluble in ethanol, $CH_3OH_{(l)}$, because the Na^+ and Cl^- ions are attracted to polar ethanol molecules. Na^+ and Cl^- ions are not attracted to nonpolar gasoline molecules ($C_8H_{18(l)}$).
8. A weak acid only partially dissociates to release H^+ ions, while a strong acid completely dissociates.
9.



10. A buffer is formed from a weak acid and a weak base in approximately equal concentrations. The weak acid will donate a hydrogen ion to a base, neutralizing it, and its conjugate base will accept a hydrogen ion from an acid, neutralizing it.
11. (a) tonic water: $[H_3O^+_{(aq)}] = 3.1 \times 10^{-9}$ mol/L
$pH = -\log_{10}[H_3O^+_{(aq)}]$
$= -\log_{10}(3.1 \times 10^{-9}\ mol/L)$
$= 8.5$
Tonic water is basic.
(b) wine: $[H_3O^+_{(aq)}] = 2.5 \times 10^{-3}$ mol/L
$pH = -\log_{10}[H_3O^+_{(aq)}]$
$= -\log_{10}(2.5 \times 10^{-3}\ mol/L)$
$= 2.6$
Wine is acidic.
12. Ionic bonds are formed because of a complete transfer of electrons from one element to another element. Polar covalent bonds result from the unequal sharing of electrons between two different elements.

13. Table sugar dissolves in water because of hydrogen bonding between the sugar and water molecules. Table salt dissolves in water because the Na^+ ions are stabilized by the negatively charged portion of the water molecule and the Cl^- ions are stabilized by the positively charged portion of the water molecule.

14.(a) $C_6H_{6(l)}$ is hydrophobic.
(b) $C_2H_5OH_{(l)}$ is hydrophilic.
(c) $CCl_{4(l)}$ is hydrophobic.

15.(a) A steel sewing needle floats on water because the surface tension of the water holds it there, while a large steel nail sinks because the force of gravity on the nail is greater than the surface tension of the water.
(b) Dogs pant 'to cool their bodies. The evaporation of water requires heat, due to its high latent heat of evaporation, which it gets from the dog's tongue.
(c) Water creeps up the walls of a flooded room due to the cohesion of water molecules to molecules in the wall because of hydrogen bonding.
(d) Hands are usually washed in water because water is considered the universal solvent and most substances will be dissolved and washed away.

Applying Inquiry Skills

16. Water and varsol are immiscible liquids because water is a polar substance and varsol is nonpolar.

Purpose:	To determine whether polystyrene is polar or nonpolar.
Hypothesis:	Polystyrene foam is a nonpolar substance.
Materials:	Polystyrene foam (e.g., coffee cup), water, and varsol.
Method:	1. Apply water to polystyrene foam and observe. 2. Apply varsol to polystyrene foam and observe.
Results:	Nothing would happen when water was added to the polystyrene. However, the varsol would dissolve the polystyrene. Like dissolves like, therefore, polystyrene foam is nonpolar.

Making Connections

17.(a) For technological uses of radioisotopes, see Table 2 on page 10 of the Student Text. Some possible uses include evaluation of the filtration rate of the kidneys, viewing and treatment of thyroid, liver, and kidney diseases, and alleviating the pain of secondary bone cancers.
(b) Radioisotopes are expensive for four main reasons: the cost of making them, the safe storage of the radioisotopes, safety requirements when using them, and the need for special disposal procedures.

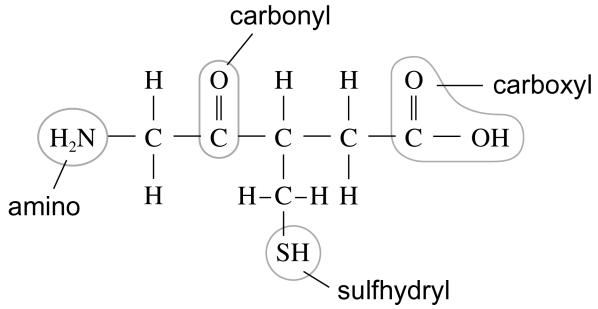
1.2 THE CHEMICALS OF LIFE

PRACTICE

(Page 27)

Understanding Concepts

1.



PRACTICE

(Page 34)

Understanding Concepts

2. The two functional groups found in the straight chain form of glucose are the hydroxyl and carbonyl groups.
3. Monosaccharides (a) and (d) are isomers.
4. The two differences between a ketotriose and an aldopentose are the number of carbons and the location of the carbonyl group. An example of a ketotriose is dihydroxyacetone and an example of an aldopentose is ribose.
5. A straight-chained monosaccharide forms a ring structure when placed in an aqueous solution.
6. (a) Glycogen and starch are called storage polysaccharides because they store excess glucose in animals as glycogen, and in plants as starch.
   (b) Cellulose and chitin are called structural polysaccharides because they form permanent structural molecules in plant cell walls, insect exoskeletons, and fungal cell walls.
7. Amylose contains α 1–4 glycosidic linkages between α-glucose subunits, while cellulose is formed with β 1–4 glycosidic linkages between β-glucose.
8. Humans cannot obtain energy from grass because they cannot break the β 1–4 linkages between β-glucose found in cellulose.

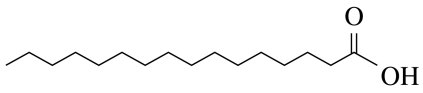
Making Connections

9. Some practical uses for discarded crab and lobster shells include the following:
   - the enrichment of compost by adding the carbon from the shells
   - recovery of protein from egg wastes for animal feed
   - crop protection (from fungi)
   - making glue
   - colour photography
10. The term "dietary roughage" refers to indigestible cellulose (fibre). Roughage is good for many reasons, including the following:
    - it stimulates mucous secretion in the large intestine to ease the movement and egestion of solid wastes (feces)
    - it holds water
    - roughage makes us feel more full by increasing dietary bulk (which also holds water)
    - it helps prevent problems of the digestive system, such as constipation, hemorhoids, and diverticulitis
    - roughage helps to lower cholesterol

PRACTICE

(Page 40)

Understanding Concepts

11. Fatty acids are linked to glycerols by an ester linkage in triacyglycerols (between the carboxyl and hydroxyl groups).
12. A saturated fatty acid has no carbon–carbon double bonds, while an unsaturated fatty acid has one or more carbon–carbon double bonds. A saturated fatty acid has no kinks in it and all the carbon–carbon bonds can rotate freely around each other. An unsaturated fatty acid has a kink at the carbon–carbon double bond and cannot rotate freely.
13. Polyunsaturated fatty acids are liquids at room temperatures, due to the relatively low number of van der Waals attractions. There are relatively few van der Waals attractions because the carbon–carbon double bonds cause kinks in the fatty acid chain, preventing a close association between molecules, therefore creating relatively weak attractive forces.
14. 

15. (a) The shiny substance on an apple is cutin.
    (b) The purpose of cutin is to waterproof the apple and protect it from infection.
    (c) Cutin's properties are related to its function by its being insoluble in water, pliable, and hydrophobic.
16. (a) Steroids are structurally different from other lipids in that they are composed of four linked carbon rings with various functional groups attached.
    (b) Steroids are converted into bile salts (which emulsify fats), vitamin D (which keeps bones and teeth healthy), and sex hormones (which are responsible for secondary sex characteristics and the ovarian cycle).

Making Connections

17.(a) The process of hydrogenation is used to produce vegetable oil margarine and shortening. During hydrogenation, hydrogen atoms are added to the double bonds between the carbon atoms of unsaturated fatty acids. This straightens out the kinks of an unsaturated fatty acid, allowing more van der Waals attractions, which, in turn, cause the liquid oil to take on the semi-solid consistency of margarine or shortening.

(b) Margarine producers add yellow food colouring to make it more appealing to the consumer and to make margarine look more like butter. In general, consumer surveys show that people prefer to spread butter on bread but may not be willing to purchase butter because of its higher cost or its saturated fat and cholesterol content.

18. Physicians recommend that people not eat diets rich in cholesterol and/or saturated fats, because these substances lead to the development of atherosclerosis. Atherosclerosis is the development of insoluble plaques on the inner lining of blood vessels, which blocks the flow of blood to tissues. If the vessels are blocked, cells cannot receive oxygen and other nutrients, so the cells die. This can lead to heart attacks and stroke. High fat diets also increase the risk of obesity and cancer.

Case Study: Sequencing a Polypeptide

(Page 50)

Understanding Concepts

1. Protein sequencing is useful because once the sequence of a polypeptide is known it can be synthesized artificially. Once the sequence is known, it is also possible to better understand the protein and its function in the body.
2. Insulin was the first protein fully sequenced. Fredrick Sanger was the first to sequence a protein (bovine insulin) in 1955. 2,4-dinitrofluorobenzene (DNF) was used to identify the N-terminal amino acid. After attaching DNF to the amino-terminal amino acid, the entire polypeptide is hydrolyzed into individual amino acids and the identity of the N-terminal amino acid is determined by chromatography. This requires relatively large quantities of the protein and lots of time to obtain the complete sequence.
3. High-pressure liquid chromatography (HPLC) followed by ultraviolet (UV) absorbance at 269 nm is used to identify the PTH derivative in an Edman degradation.
4. C-terminal analysis is another common method for sequencing a protein molecule. This analysis relies on enzymatic hydrolysis of the protein sequence by the protein-digesting enzyme carboxypeptidase-P.
5. Many hospital and university biochemistry departments provide protein-sequencing services to the public and to professionals. A typical pricing schedule for N-terminal analysis (automated Edman degradation process) is as follows:
   - Set–up fee: $150 to $200 (all set-up fees, including the first 5 amino acids)
   - Additional amino acids (after the first 5): $10 to $40 per cycle

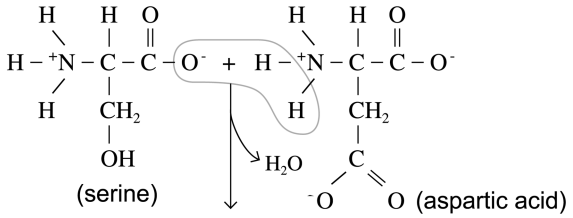
   Up to forty residues can be read but runs of fewer than 25 cycles are preferred. Samples should contain more than 20 picomoles of protein.

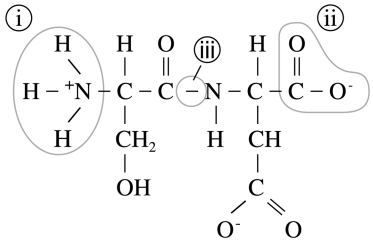
PRACTICE

(Page 50)

Understanding Concepts

19. The two common functional groups found in all amino acids are amino and carboxyl groups.
20.(a) Formation of a peptide bond between serine and aspartic acid.





(b) The amino terminus, carboxyl terminus, and peptide bond are labelled on diagram in (a). The amino terminus is labelled (i), the carboxyl terminus is labelled (ii), and the peptide bond is labelled (iii).

21. The primary structure of a protein refers to the sequence of amino acids. Genes in DNA determine this sequence.
22.(a) The two types of secondary protein structure are α-helices and β-pleated sheets.
(b) Hydrogen bonding stabilizes secondary protein structures.
23. The amino acid proline causes a kink in the secondary structure, thereby affecting tertiary structure.
24. A polypeptide refers to a single chain of amino acids with primary, secondary, or tertiary structure, while a protein consists of one or more polypeptide chains twisted and folded together into a specific shape. The amino acid sequence of a polypeptide chain determines the three-dimensional shape of the protein.
25. A protein is denatured if its three-dimensional shape is altered in any way (by temperature, pH, ionic concentration, etc.).
26. Proteins have more diverse functional roles than carbohydrates due to their greater number of possible shapes, functional groups, and chemical properties.

Applying Inquiry Skills

27.(a) The fresh uncooked egg white would appear white, solid, and opaque when placed in vinegar.
(b) The egg whites will not regain their original characteristics when removed from heat or vinegar because their tertiary and/or quaternary arrangement is destroyed during denaturation.

Making Connections

28. A hospital may treat someone who has had a high fever for several days with a liquid diet rich in essential amino acids to rebuild denatured proteins. The high body temperature will denature proteins in the body. Fever is usually caused by infection. The immune system depends on a supply of amino acids to fight off infection. The high temperature can also be brought down by lukewarm water baths; cold water or ice water are not used as they can cause the blood vessels in the skin to constrict and this can decrease the body's ability to get rid of excess heat.
29.(a) Fruits and vegetables are blanched by being dipped in boiling water for a few seconds.
(b) Blanching denatures browning enzymes found on the surface of the fruits.
(c) Food-processing companies would blanch fruits and vegetables before packaging in transparent jars to prevent colour loss. Consumers might not purchase the product if the fruits and vegetables looked brown. Blanching also prevents toughening of the fruit or vegetable and prevents food spoilage.

Explore an Issue Take a Stand: Functional Foods and Nutriceuticals

(Page 51)

Statement: Nutraceuticals should be regulated as drugs under the *Canada Food and Drug Act.*
Student answers will vary. Some things that students may discover in their research include the following:

- Nutraceuticals and functional foods are foods and food components that provide demonstrated health benefits beyond their basic nutritional functions. A functional food is a conventional food, while a nutriceutical is isolated from a food and sold in purified form. In both cases the active ingredients occur naturally in the food. Organizations that have addressed the issue include Agriculture and Agrifood Canada, International Food Focus Limited, and the Canadian Foundation of Dietetic Research.
- Biotechnology may be involved in developing these nutriceuticals, and many people believe that if the foods are genetically modified, the public has the right to know about it.
- Claims that a food has additional health benefits should be carefully investigated. It is unknown what the effects of high dosages of some of these supplements are.
- Nutriceuticals are products that are being developed for consumption by the public. They have supposed health benefits. If vitamins and medications have to undergo testing and development, nutriceuticals should go through the same process.

Section 1.2 Questions

(Page 56)

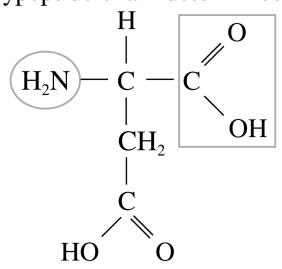
Understanding Concepts

1. Hydrocarbons are all nonpolar molecules because of the symmetrical arrangement of their C–C and C–H bonds.
2. The elements found in carbohydrates are carbon, hydrogen, and oxygen in the ratio 1:2:1, respectively.
3. (a) In organic chemistry, a functional group is a reactive cluster of atoms attached to the carbon backbone of organic molecules.
   (b) Biological molecules with functional groups are more reactive than molecules without functional groups.
4. Monosaccharides are more soluble in water than triacylglycerols because of the large number of asymmetrical polar bonds.
5.

Carbohydrate (or derivative)	Main function
glucose	primary source of energy in most living organisms
starch (amylose)	energy storage in plant cells
chitin	structural carbohydrate in insects, crustaceans, and mushrooms
cellulose	plant cell wall component
glycogen	energy storage in animal cells

6. A condensation reaction releases a water molecule in an anabolic reaction, while a hydrolysis reaction adds a water molecule across a chemical bond in a catabolic reaction.
7. (a) Bonding capacity refers to the number of covalent bonds an atom will form with other atoms.
   (b) The valence of carbon is four, nitrogen is three, and oxygen is two.
   (c) Hydrogen is never a central atom of a complex organic molecule, because it has only one valence and can therefore only form one bond.
8. Oligosaccharides comprise two or three monosaccharides attached to one another by glycosidic linkages, while polysaccharides comprise several hundred to several thousand linked monosaccharides. Oligosaccharides include maltose and sucrose, and polysaccharides include cellulose and glycogen.
9. Glucose and galactose are isomers because they have the same chemical formula ($C_6H_{12}O_6$) but different arrangements of atoms.
10. Animals use lipids as energy storage molecules instead of carbohydrates for two reasons. First, lipids contain more energy per gram than carbohydrates. Secondly, lipids offer greater thermal insulation than carbohydrates and allow animals to survive in frigid environments.

11.(a) Three fatty acids are attached to a glycerol molecule in a triacylglycerol and two fatty acids are attached to a glycerol molecule in a phospholipid.
(b) Hydroxyl and carboxyl groups react when a fatty acid molecule bonds to a glycerol molecule.
12. It's a good idea to wear rubber gloves when washing dishes with detergents because the detergents will remove the oils in your skin. The detergents will dissolve the oils found on the surface of your skin and be washed away with the water. Skin that lacks oils is dry and can crack and peel.
13. A polypeptide refers to a single chain of amino acids with primary, secondary, or tertiary structures, while a protein consists of one or more polypeptide chains twisted and folded together into a specific shape. The amino acid sequence of a polypeptide chain determines the three-dimensional shape of the protein.
14. (a)



(b) The functional group found on the R-group side chain is a carboxyl group.
(c) This amino acid is acidic because of its acidic functional group.
15. Essential amino acids cannot be synthesized from simpler compounds. They must be acquired through diet.
16. Two similarities between an alpha helix and a beta-pleated sheet are that they determine the secondary structure and occur because of hydrogen bonding. One difference between an alpha helix and a beta-pleated sheet is the type of structure formed, spiral helix versus flat sheets. The second difference is that an alpha helix is formed by hydrogen bonding between successive amino acids along a polypeptide chain, while a beta-pleated sheet is formed from hydrogen bonds between two parallel polypeptide chains.
17.(a) The four types of bonds that stabilize tertiary structure are hydrogen bonds (a type of van der Waals force), disulfide bridges (covalent bonds), ionic bonds, and hydrophobic interactions (a type of van der Waals force).
(b) The strongest of the above four bonds are the disulfide bridges because they are the only covalent bond.
18. Two differences between RNA and DNA are the sugar found in the nucleotide, RNA has ribose and DNA has deoxyribose, and that RNA is single stranded while DNA is double stranded. Another difference is that DNA contains the nitrogenous base thymine, (T) while RNA contains uracil (U) instead.
19. The rule for DNA base pairing is adenine with thymine, forming two hydrogen bonds, and cytosine with guanine, forming three hydrogen bonds.

Applying Inquiry Skills

20.(a) Some conclusions you could draw from the data would be that you get more than three times the amount of methanol by consuming a glass of tomato juice than in a diet soft drink. As well, you could conclude that diet soft drinks are not that bad for you (in terms of methanol toxicity).
(b) Studies could be done to determine whether people who consume aspartame-containing beverages drink more of them (each day) than do those who consume fruit juices. Other studies could be done to determine whether the methanol that is produced when aspartame is digested is absorbed into the circulatory system more efficiently than the methanol molecules contained in fruit juices.
21.(a) Student predictions will vary.
(b) The five amino acids are isoleucine, lysine, glutamate, alanine, and glycine.

Making Connections

22.(a) The expression "like dissolves like" means that a polar solvent will dissolve polar solutes and a nonpolar solvent will dissolve nonpolar solutes.
(b) An example in everyday life would be salad dressings such as Italian, which quickly separates into an oil soluble and water-soluble layer. The vinegar of the dressing would dissolve in a polar solvent, while the oil component would dissolve in a nonpolar solvent.
23.(a) Chitin is an ideal material for surgical thread because it is biodegradable, meaning it does not need to be removed, and it is strong enough to hold tissue together and allow healing.
(b) Chitin could be used effectively in biodegradable packaging.
(c) Products made with chitin could be mass-produced inexpensively because it is cheap and easy to grow insects, which have an exoskeleton composed of chitin.
24.(a) The carbohydrate found in dietary roughage is cellulose.

(b) Student answers will vary. A lunch that would provide a good amount of dietary roughage would be a glass of orange juice, a sandwich on brown bread, a salad, some carrots, and an apple. All the listed foods contain cellulose. Student solutions should include a lot of vegetables and fruits.

25.(a) Four nonfood uses are soy crayons, soy diesel, soybean oil hand cleaner, and industrial solvents.

(b) Soy crayons are brighter, smoother colours with no waxy flaking. They are environmentally friendly and nontoxic. Soy diesel provides similar engine performance as diesel produced from petroleum with up to 30% fewer harmful emissions. Soybean oil hand cleaner removes grease, tar, and paint from hands and washable fabrics while still being gentle to the skin. Industrial solvents remove tar, oil, grease, adhesives, asphalt, and oil-based paints from tools and equipment. Soybean oil solvents are nontoxic, biodegradable, and noncorrosive and have a lower flash point than petroleum-based solvents.

26.(a) Carnuba (carnauba) wax is obtained from a palm tree known as *Copernica cerifera* that grows in Brazil.

(b) Carnuba wax is the hardest of the natural waxes. It has the highest melting point of all natural waxes at 83ºC. Carnuba wax is brittle, nontacky, and has the ability to retain oil. It has excellent gelling properties and is emulsifiable.

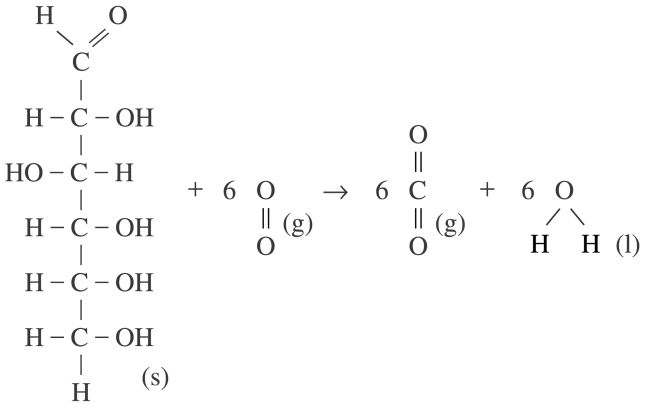
(c) Common uses of carnuba wax include candles; candy; auto, floor, and shoe polishes; inks, paper coatings; and fruit and vegetable coatings.

1.3 AN INTRODUCTION TO METABOLISM

Try This Activity: The Combustion Accountant

(Page 60)

(a)



(b)

Bond	Average bond energy (kJ/mol)	Number of bonds in glucose	Number of bonds in oxygen	Total bond energy (kJ/mol)
C–H	411	7	-	2877
O–H	459	5	-	2295
C–C	346	5	-	1730
C–O	359	5	-	1795
C=O	799	1	-	799
O=O	494	-	6	2964

Total bond energy of reactants = 9496 + 2964 = 12 460 kJ/mol

Bond	Average bond energy (kJ/mol)	Number of bonds in water	Number of bonds in carbon dioxide	Total bond energy (kJ/mol)
C–H	411	-	-	-
O–H	459	12	-	5508
C–C	346	-	-	-
C–O	359	-	-	-
C=O	799	-	12	9588
O=O	494	-	-	-

Total bond energy of products = 5508 + 9588 = 15 096 kJ/mol

(c) Heat of combustion = total bond energy of products – total bond energy of reactants = 15 096 – 12 460 = 2636 kJ/mol

(d) Percent difference = $\frac{\text{difference between values}}{\text{accepted value}} \times 100\%$

$= \frac{2870\ \text{kJ/mol} - 2636\ \text{kJ/mol}}{2870\ \text{kJ/mol}} \times 100\%$

$= 8.2\%$

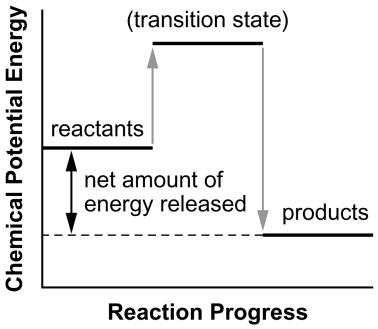
(e) The percentage difference could be because of variations in the values of the individual bond energies used in the two calculations.

Section 1.3 Questions

(Page 68)

Understanding Concepts

1. Energy is the ability to do work, while work is the transfer of energy from one place to another.
2. (a) Protein synthesis is anabolic.
   (b) Digestion is catabolic.
   (c) DNA synthesis is anabolic.
   (d) Photosynthesis is anabolic.
   (e) Cellular respiration is catabolic.
3. Metabolism represents the sum of all anabolic and catabolic reactions in a cell or organism.
4. Organisms have to continually harness energy because energy is continually lost as heat.
5. (a)



   (b) The products are more stable than the reactants in an exergonic reaction because of the lower total bond energies of the products compared to the reactants.
6. (a) an arm is raised: a decrease in entropy because potential energy is increased
   (b) protein is digested into amino acids in the duodenum: an increase in entropy, because a large number of individual amino acids are more randomly arranged than in a protein molecules in which the amino acids are attached to one another in a particular sequence
   (c) chromosomes move along spindle fibres: the cell's free energy is used to move chromosomes into a more ordered arrangement; entropy decreases as organization increases
   (d) oxygen diffuses into alveoli in the lungs: an increase in entropy as oxygen molecules trapped in alveoli diffuse into capillaries and move randomly through the circulatory system
   (e) a cell divides: an increase in entropy as the system is becoming more random, and much of the cell's free energy is used in cell division; two cells represent a more random arrangement of objects than a single cell
7. *Gibbs free energy* represents energy that can do useful work.
8. (a) Heat death of the universe refers to the state where all the particles and energy of the universe will move randomly, unable to do useful work. All energy will still be present, but it will be uniformly distributed and unable to apply a push or pull to anything.
   (b) Heat death of the universe is related to the death of an organism because a dead organism is unable to do work. Energy is still present, but it cannot perform the work that is necessary to keep the organism alive.
9. (a) The value of ΔG for a system at equilibrium is zero.
   (b) This is similar to the saying "Old biochemists never die, they just fail to react," because a dead organism is an example of a system at equilibrium. There is a lot of energy in the system (organism) but not enough free energy to allow the endergonic (anabolic) reactions to occur.
10. The terminal phosphate bond in ATP is relatively unstable because of the large number of negative charges in the terminal triphosphate portion of the molecule.

Making Connections

11.(a) The second law of thermodynamics relates to the production of pollution in our world because we are taking organized matter and increasing its randomness (e.g., burning fossil fuels such as gasoline [relatively ordered molecules] into carbon dioxide gas and water vapour [relatively disordered components of smoke] increases the entropy of the universe.

(b) Using free energy to create more order in a system (a localized part of the universe) creates a greater amount of disorder in the universe as a whole (second law of thermodynamics). Thus, the production of pollution (random particles or energy) is an inevitable outcome of work. The best we can do is to develop working systems that produce forms of pollution (waste products) that are less toxic or damaging to organisms and the environment. For example, an automobile engine that produces only water vapour as exhaust (waste) produces a less damaging form of pollution than a gasoline-burning engine that produces carbon dioxide, carbon monoxide, water vapour, nitrogen oxides, sulfur dioxide, and a host of other damaging and toxic gaseous products.

1.4 ENZYMES

Try This Activity: Synthesizing a Paper Clip Polymer with a Paper Enzyme

(Page 71)

(a) The action of a paper enzyme relates to a real enzyme-catalyzed reaction, because as the reactants are brought into close proximity, the reaction occurs much quicker than it would alone and the paper enzyme can perform the reaction again.

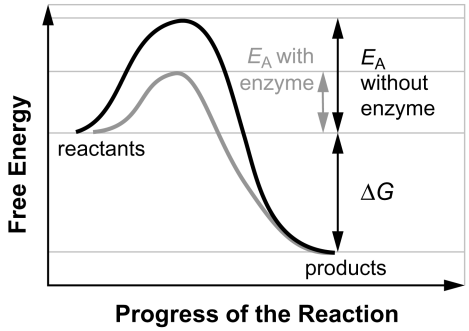
(b) Student design. A triclipide and tetraclipide can be produced by adding one or two more loops to the sheet of paper in Figure 4(a).

(c) Student design. Students may use molecular model kits to simulate a hydrolytic enzyme by adding a water molecule across a chemical bond.

Section 1.4 Questions

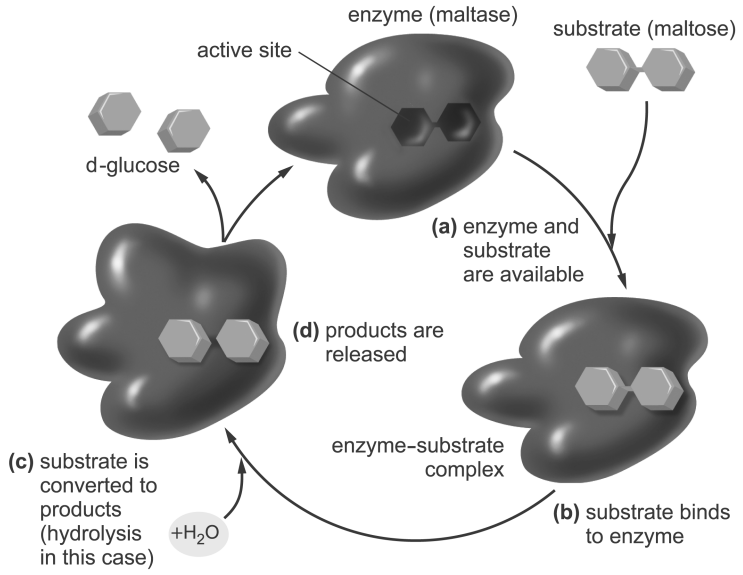
(Page 77)

Understanding Concepts

1. A catalyst is a chemical that speeds up the rate of a reaction without being consumed in the reaction.
2. 

3. The statement “an enzyme cannot affect the free-energy change of a reaction” means that the overall change in free-energy is always the same for a particular reaction. Enzymes only reduce the activation-energy required for the reaction to occur. Enzymes cannot change the free-energy of a reaction; they can decrease the potential energy of the transition state, allowing a greater proportion of reactants to reach the transition state and change into products.

4. The induced-fit model of enzyme activity refers to the changing of the enzyme's shape around the active site as the substrate's functional groups interact with the enzyme's functional groups.



5. An enzyme reduces the "path" that a reactant must follow to become a product. They speed up the rate at which equilibrium is reached. The enzymes do this by bringing the substrates into the correct geometry and by putting stress on the necessary chemical bonds.
6. A competitive inhibitor binds to the active site of an enzyme, preventing the substrate(s) from binding. In this case, the inhibitor competes with the substrate for the active site. A noncompetitive inhibitor attaches to an enzyme at a binding site other than the active site. This causes a conformational change in the enzyme's protein structure that causes a loss of affinity of the active site for its substrate.
7. (a) The scrotum keeps the testicles at a distance from the body (normal body temperature = 37.6ºC) and thus helps maintain the testicles at the optimum temperature of 33°C.
   (b) Two lifestyle choices that could affect sperm and/or testosterone production would include wearing tight underwear or trousers that keep the testes closer to the body and frequent use of hot tubs or saunas.
8. After an enzyme catalyzes a reaction, it will catalyze the same reaction again.

Applying Inquiry Skills

9. Hypothesis: Blanching of fruit will prevent browning by denaturing the enzyme polyphenol oxidase.

   Materials: Peeled apple, room temperature and boiling water, and stopwatch

   Method: 1. Peel an apple, cut it into quarters, and place two quarters of the apple into room temperature water and two quarters of the apple into boiling water for 15 seconds.
   2. Dry the apples.
   3. Observe the apples every 30 seconds and record your observations using a digital camera.

Making Connections

10.(a) Meat tenderizers are sprinkled on meat as a powder or in marinades mixed with oil and vinegar. Meat tenderizers are generally applied to beef, however, seafood such as squid (calamari), clams, and other very tough and chewy seafood can also be tenderized using these products.
   (b) Papain and bromelain are proteases. Their substrates are the amino acids of proteins.
   (c) Papain is obtained from the latex of papayas. Bromelain is obtained from the stump or root portion of the pineapple plant after harvest of the fruit.
   (d) The Milk Clot Assay is a test that measures the amount of time required to form clotted milk in the presence of a proteolytic enzyme under controlled conditions. The Milk Clot Assay value (e.g., 100 units per mg) provides a standard measure of the amount and quality of tenderization produced by a proteolytic enzyme application.
   (e) Student-generated position statement. Student solutions will vary.

11.(a) Debridement is the process of removing nonliving tissue from pressure ulcers, burns, or other wounds.
(b) Debridement speeds the healing of ulcers, burns, and other wounds.
(c) Surgical debridement (also known as sharp debridement), mechanical debridement, chemical debridement, and autolytic debridement.
(d) Collagenase (a proteolytic enzyme that hydrolyzes collagen, a major protein found in skin) is a common enzyme used in chemical debridement.
(e) Chemical debridement is more selective than mechanical debridement. Enzymes will debride only the tissue components that the enzyme acts on (i.e., collagen with collagenase).

INVESTIGATION 1.1.1 BUFFERS IN LIVING SYSTEMS

(Pages 78–79)

Questions

Students should discover that the 0.1 mol/L acetic acid + 0.1 mol/L acetate solution has a greater buffering capacity than 0.1 mol/L acetic acid solution.

Prediction

(a) Students should predict that the 0.1 mol/L acetic acid + 0.1 mol/L acetate solution has a greater buffering capacity than 0.1 mol/L acetic acid solution.
(b) Students should predict that the pH of a carbonic acid – bicarbonate buffer should remain stable when CO_2 is bubble through it.

Procedure: Part I

(c) It should take approximately nine (9) drops to neutralize the acetic acid–acetate buffer.
(d) It should take approximately five (5) drops to neutralize the acetic acid solution.
(e) The value obtained in (c) should be greater than the value obtained in (d).

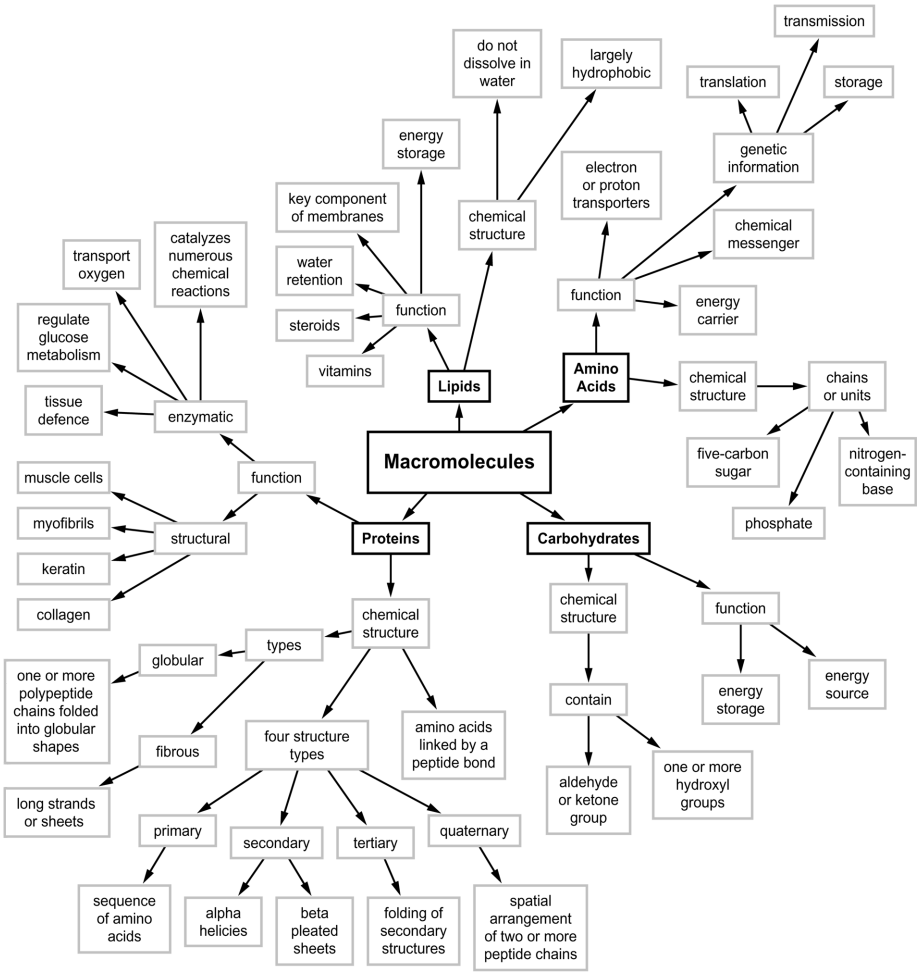
Part II

(f) The pH of the carbonic acid–bicarbonate buffer is eight (8).
(g) The plasma is neutral.
(h) The metabolic state of the plasma is alkylosis.
(i) The metabolic state of the plasma after blowing carbon dioxide into the buffer is a normal state.

CHAPTER 1 SUMMARY

(Page 84)

Make a Summary



Chapter 1 Self-Quiz

(Page 85)

1. True
2. True
3. True
4. False. Glycerol is hydrophilic.
5. True
6. True
7. False. Chaperone proteins help polypeptide chains fold into tertiary structure during protein synthesis.
8. False. The amount of adenine equals the amount of thymine in a molecule of DNA.
9. True
10. True
11. (b)
12. (a)
13. (d)
14. (b)

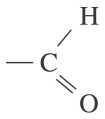
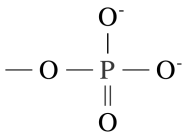
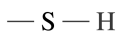
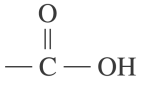
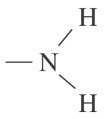
15. (b)
16. (d)
17. (b)
18. (c)
19. (d)
20. (c)

Chapter 1 Review

(Pages 86–87)

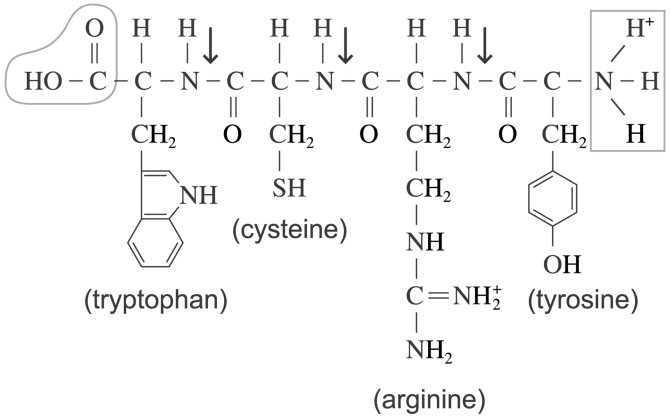
Understanding Concepts

1.

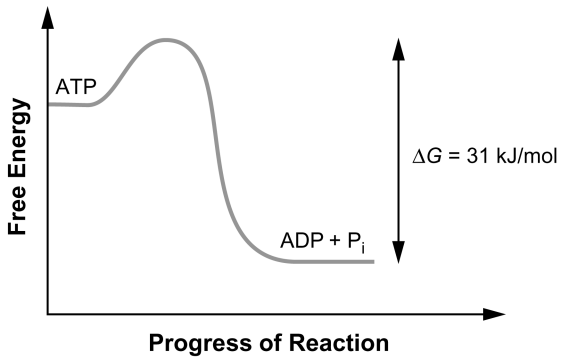
Functional group name	Functional group formula	Biological molecule
aldehyde		glucose
carbonyl		fructose
phosphate		nucleotide
sulfhydryl		amino acid
carboxyl		fatty acid
amino		amino acid

2. Amylose and amylopectin are similar in that they are polymers of α-glucose and contain α 1–4 glycosidic linkages; however, amylopectin also contains α 1–6 glycosidic linkages.
3. α-glucose has a hydroxyl group at carbon-1 that is below the plane of the ring, while β-glucose has a hydroxyl group at carbon-1 that is above the plane of the ring.
4. (a) Humans are not able to digest cellulose as they cannot break the β 1–4 linkages that hold β-glucose molecules together.
   (b) Ruminants are able to digest cellulose because of the bacteria in their digestive systems, which produce enzymes that may hydrolyze the β 1–4 linkages.
5. Cellulose can form strong fibres because the hydroxyl groups of parallel molecules form strong hydrogen bonds, as cellulose does not have any side branches. Conversely, the polysaccharides in starch (especially the amylopectin portion) have many branches and do not allow as many strong hydrogen bonds to occur along their lengths.
6. Humans need cholesterol in their bodies to produce bile salts, to help produce vitamin D, to form sex hormones, and as structural components of cell membranes. However, many people have high cholesterol levels, higher levels than the body requires to make these essential substances. Too much cholesterol can lead to the development of arterial plaques. Low levels of cholesterol are "good" but high levels can be "too much of a good thing."
7. A saturated fatty acid has no carbon–carbon double bonds, while an unsaturated fatty acid contains one or more carbon–carbon double bonds and less than the maximum number of hydrogen bonds.
8. (a) Vegetable oil is converted into margarine by the process of hydrogenation.
   (b) This process adds hydrogen atoms to carbon–carbon double bonds making the vegetable oil semisolid at room temperature.

9. Testosterone is a male sex hormone responsible for the development of sex traits and sperm cells. Progesterone and estrogens are female sex hormone responsible for the development of sex traits and egg cells.
10. Waxes make ideal coverings for plants and animals as they are hydrophobic and repel water.
11.(a) The structural characteristics that enable proteins to be so varied are the large number of functional R-groups; there are 20, which allows for many types of bonding and shapes.
(b) Three major functions of proteins are for structure, as enzymes, and as carriers.
12. Fats and carbohydrates are used for energy first. Fats store a relatively large amount of free-energy when compared with carbohydrates and proteins. Many organisms store fats in fat tissue and carbohydrates as starch or glycogen as a source of energy. Proteins and nucleic acids are highly functional molecules. Nucleic acids contain the genetic instructions needed to produce the proteins (primarily enzymes) that carry out virtually all the metabolic reactions in a living cell. Thus, when energy is needed, carbohydrates and fats are used first.
13.(a),(b) and (c)



(d) trp–cys–arg–tyr
14. Globular proteins comprise one or more polypeptide chains that take on a rounded, spherical shape. Fibrous proteins are linear in shape and are long because of hydrogen bonding. An example of a globular protein is hemoglobin, and spider web silk is an example of a fibrous protein.
15. Quaternary structure refers to the association of two or more polypeptide subunits that come together to form a functional protein. Two proteins that require quaternary structure to function are hemoglobin and gastrin.
16. Chaperone proteins help growing polypeptide subunits to orientate themselves as the protein is forming tertiary structures.
17. RNA nucleotides contain the five-carbon sugar ribose and contain the nitrogenous base uracil, whereas DNA contains the five-carbon sugar deoxyribose and the nitrogenous base thymine instead of uracil.
18. DNA possesses hydrogen bonds as two DNA strands run antiparallel to each other, allowing hydrogen bonds to form between nucleotide bases of opposite strands. RNA does not contain hydrogen bonds, because it is single stranded.
19.(a) blood flow: kinetic
(b) ATP: potential
(c) a concentration gradient: potential
(d) muscle contraction: kinetic
(e) glucose: potential
20. Living organisms use the energy released in exergonic processes to drive endergonic processes.
21. Heterotrophs are thermodynamically dependent on autotrophs because autotrophs can convert electromagnetic energy into chemical potential energy, but heterotrophs cannot.
22.(a)

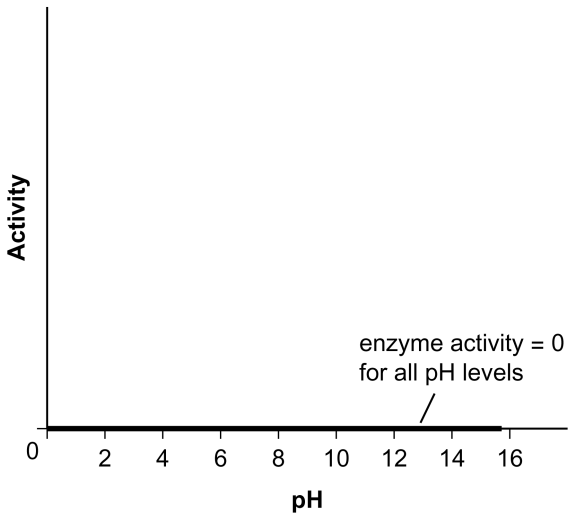


(b) This process is exergonic.
(c) The excess energy is either captured in the form of chemical potential energy or released as heat.

23. Oxidation is the loss of electron(s) from a molecule, while reduction is the gaining of electron(s) by a molecule.
24. Oxidation involves the loss of one or more electrons. The addition of oxygen to an atom constitutes an oxidation because the highly electronegative oxygen draws the shared electrons in the covalent bonds it forms so strongly toward itself that the rest of the molecule is considered to have lost those electrons.
25.(a) The enzyme pepsin, which is in the stomach, acts optimally between pH 0 and 4. Outside that range, the enzyme, which is a protein, may denature and not function properly. The specific pH allows the proper structural configuration for the enzyme to carry out its reaction.
(b) Enzymes also function at optimal temperatures. Human enzymes function best at approximately 37ºC. Enzyme activity decreases above and below this optimal temperature. Again, as in pH, outside the optimal range, the enzymes denature and will not function as efficiently.

Applying Inquiry Skills

26.(a) The protein in the study has an optimum temperature of 30°C, illustrated by the greater activity, as seen in line A compared with line B.
(b) There is no hump of activity in line C, at 100°C, because the protein has been completely denatured.
(c)

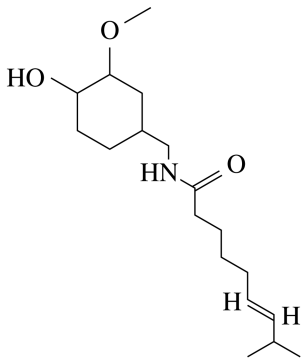


27.(a) Disulfide bridges are broken during the permanent-wave process.
(b) The tertiary structure is being changed.
(c) Gloves must be worn when adding the reducing agent to the hair because the chemicals would denature the proteins in your skin.
(d) Heating your hair breaks some of its disulfide bridges. If you heat your hair around a cylinder, such as a curling iron, you can curl it.

Making Connections

28. wood furniture, paper products, fruits, vegetables, lumber
29.(a) Saturated fats have a higher boiling point than unsaturated fats because they have many more van der Waals forces of attraction between individual molecules. This results in a greater overall intermolecular force of attraction.
(b) Restaurants should not be able to use saturated fatty acids because they lead to heart disease. If a restaurant uses saturated fatty acids, then it should warn the consumer.
30. Radioisotopes require special permits and special vehicles for transportation to reduce the risk of accidental environmental contamination. Storage of radioisotopes requires specialized venting and insulation to prevent contamination.

31.(a)



(b) Capsaicin's intense flavour results from the molecule's long hydrocarbon tail. The chain allows it to bind very strongly with its lipoprotein receptor, which has some hydrocarbon side chains of its own (like dissolves like!). The fatty tail also allows the molecule to slip through lipid-rich cell membranes, making the burn more persistent.

(c) The perception that peppers are "hot" is not an accident. Capsaicin allows calcium ions to move through the cell membrane from the extracellular fluid into the cell. That ultimately triggers a pain signal that is transmitted to the next cell. When the cells are exposed to heat, the same events occur. Chili burns and heat burns are similar at the molecular, cellular, and sensory levels.

(d) Capsaicin is found primarily in the pepper's placenta—the white ribs that run down the middle and along the sides of a pepper. Since the seeds are in such close contact with the ribs, they are also often hot.

(e) Capsaicin content is measured in parts per million and are converted into *Scoville heat units***,** the industry standard for measuring a pepper's intensity. One part per million is equivalent to 15 Scoville units. Bell peppers have a value of zero Scoville units; habaneras—the hottest peppers—register 200 000 to 300 000 Scoville units. Pure capsaicin has a Scoville heat unit score of about 16 million.

(f) Capsaicin, which is a largely nonpolar molecule, does not mix with water. Drinking water will have little effect on the burning sensation. The most useful liquid is milk (rinsing the mouth with it as you sip) or eating rice or bread, which absorb the capsaicin.

(g) As a medicine, capsaicin is used to help relieve the pain associated with neuralgia. Capsaicin is also used to temporarily help relieve pain from arthritis. It is also used as a repellent against dogs, birds, bears, and squirrels, and as an insect repellent. It is the active ingredient in commercially available "pepper sprays."