When a cell divides, the genetic information is transmitted via deoxyribonucleic acid (DNA), which has a double helical structure whose two strands are held together by hydrogen bonding between pairs of organic bases—one from each strand. The bases occur only in specific pairs. During cell division, the double helix unravels, and a new polymer forms along each strand of the original DNA to form two double helical DNA molecules. The DNA contains segments called genes, which store the structural information for specific proteins. Various types of ribonucleic acid (RNA) molecules assist in protein synthesis.

16. What is a disaccharide? What monosaccharide units make up the disaccharide sucrose? What is the bond called that forms between the monosaccharide units?
17. What forces are responsible for the solubility of starch in water?
18. What is optical isomerism? What do you look for to determine whether an organic compound exhibits optical isomerism?
19. The compounds adenine, guanine, cytosine, and thymine are called the nucleic acid bases. What structural features in these compounds make them bases?
20. Describe the structural differences between DNA and RNA. The deletion of a single base from a DNA molecule can constitute a fatal mutation. Substitution of one base for another is often not as serious a mutation. Explain.
21. Describe the complementary base pairing between the two individual strands of DNA that forms the overall double-helical structure. How is complementary base pairing involved in the replication of the DNA molecule during cell division?

---

**Questions**

The normal (unbranched) hydrocarbons are often referred to as the straight-chain hydrocarbons. What does this name refer to? Does this mean that the carbon atoms in a straight-chain hydrocarbon really have a linear arrangement? Explain.

2. A general rule for a group of hydrocarbon isomers is that as the amount of branching increases, the boiling point decreases. Explain why this would be true. Distinguish between isomerism and resonance.

4. Distinguish between structural and geometrical isomerism. Distinguish between substitution and addition reactions. Give an example of each type.

6. Define and give an example of each of the following:
   a. addition polymer
   b. condensation polymer
   c. copolymer
   Distinguish between a thermostet polymer and a thermostatic polymer.

8. How do the physical properties of polymers depend on chain length and extent of chain branching? Explain how crosslinking agents are used to change the physical properties of polymers.

10. Iso tactic polypropylene makes stronger fibers than atactic polypropylene. Explain.

12. In which polymer, polyethylene or polyvinyl chloride, would you expect to find the stronger intermolecular forces (assuming the average chain lengths are equal)? Distinguish between the primary, secondary, and tertiary structures of a protein. Give examples of the types of forces that maintain each type of structure.


---

**Exercises**

**Hydrocarbons**

23. Draw the five structural isomers of hexane (C₆H₁₃).
24. Name the structural isomers in Exercise 23.
25. Draw all the structural isomers for C₆H₁₄ that have the following root name (longest carbon chain). Name the structural isomers.
   a. heptane  b. butane
26. Draw all the structural isomers for C₆H₁₄ that have the following root name (longest carbon chain). Name the structural isomers.
   a. hexane  b. pentane
   Draw the structural formula for each of the following.
   a. 2-methylpentane
   b. 2,2,4-trimethylpentane, also called isooctane. This substance is the reference (100 level) for octane ratings.
   c. 2-tert-butylpentane
   d. The name given in part c is incorrect. Give the correct name for this hydrocarbon.
28. Draw the structure for 4-ethyl-2,3-diisopropylpentane. This name is incorrect. Give the correct systematic name.

Name each of the following:

a. \( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

b. \( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

\( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

\( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

d. \( \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

30. Name each of the following cyclic alkanes, and indicate the formula of the compound.

a. \( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \)

b. \( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \)

\( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)

32. Name each of the following alkenes or alkynes.

a. \( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \)
\( \text{C} \equiv \text{C} \text{CH}_3 \)

b. \( \text{CH}_3 \text{CH}_3 \)
\( \text{C} \equiv \text{C} \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

c. \( \text{CH}_3 \text{CH}_3 \)
\( \text{C} \equiv \text{C} \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CH}_3 \)

Give the structure for each of the following.

a. 3-hexene
b. 2,4-heptadiene
c. 2-methyl-3-octene

34. Give the structure for each of the following.

a. 4-methyl-1-pentyne
b. 2,3,3-trimethyl-1-hexene
c. 3-ethyl-4-decene

35. Give the structure of each of the following aromatic hydrocarbons.

a. o-ethyltoluene
b. p-di-tert-butylbenzene
c. m-diethylbenzene
d. 1-phenyl-2-butene

36. Cumene is the starting material for the industrial production of acetone and phenol. The structure of cumene is

\[
\text{CH}_3
\begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\]

Give the systematic name for cumene.

Name each of the following.

a. \( \text{Cl} \equiv \text{CH} \equiv \text{CH} \equiv \text{CH}_3 \)
\( \text{Cl} \)

b. \( \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CCl}_3 \)

c. \( \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CCl}_3 \)
\( \text{Cl} \text{CH}_3 \text{CH}_2 \text{CH}_3 \)

38. Name each of the following compounds.

a. \( \text{CH}_3 \text{CHCH} \equiv \text{CH}_2 \)
\( \text{Cl} \)

b. \( \text{CH}_3 \text{CH}_3 \text{CH}_3 \)
\( \text{Cl} \text{CH}_3 \text{CH}_3 \)

\( \text{CH}_3 \text{CH}_3 \)
\( \text{Cl} \text{CH}_3 \text{CH}_3 \)

\( \text{Cl} \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)

\( \text{CH}_3 \text{Br} \)
\( \text{CH}_3 \text{CH}_3 \)
\( \text{CH}_3 \text{CH}_3 \)
f. \( \text{CH}_3 \text{Br} \)
g. \( \text{CH}_3 \text{Br} \)

**Isomerism**

Which of the compounds in Exercises 31 and 33 exhibit cis-trans isomerism?

40. Which of the compounds in Exercises 32 and 34 exhibit cis-trans isomerism?

Draw all the structural isomers of C\(_5\)H\(_{10}\). Ignore any cyclic isomers.

42. Which of the structural isomers in Exercise 41 exhibit cis-trans isomerism?

Draw all the structural and geometrical (cis-trans) isomers of C\(_3\)H\(_3\)Cl.

44. Draw all the structural and geometrical (cis-trans) isomers of bromochloropropene.

Draw all structural and geometrical (cis-trans) isomers of C\(_3\)H\(_2\)F. Ignore any cyclic isomers.

46. cis-trans isomerism is also possible in molecules with rings. Draw the cis and trans isomers of 1,2-dimethylcyclohexane. In Exercise 45, you drew all of the noncyclic structural and geometric isomers of C\(_3\)H\(_2\)F. Now draw the cyclic structural and geometric isomers of C\(_3\)H\(_2\)F.

Draw the following.

a. cis-2-hexene
b. trans-2-butene
c. cis-2,3-dichloro-2-pentene

48. Name the following compounds.

a. \( \text{CH}_3 \text{C} = \text{C} \text{Br} \)

b. \( \text{CH}_3 \text{CH}_2 \text{C} = \text{C} \text{CH}_2 \text{CH}_3 \)

c. \( \text{CH}_2 \text{CH}_2 \text{CH}_2 \text{C} = \text{C} \text{CH}_3 \text{CH}_3 \)

If one hydrogen in a hydrocarbon is replaced by a halogen atom, the number of isomers that exist for the substituted compound depends on the number of types of hydrogen in the original hydrocarbon. Thus there is only one form of chloroethane (all hydrogens in ethane are equivalent), but there are two isomers of propane that arise from the substitution of a methyl hydrogen or a methylene hydrogen. How many isomers can be obtained when one hydrogen in each of the compounds named below is replaced by a chlorine atom?

a. n-pentane
b. 2-methylbutane
c. 2,4-dimethylpentane
d. methylcyclobutane

50. There are three isomers of dichlorobenzene, one of which has now replaced naphthalene as the main constituent of mothballs.

a. Identify the ortho, the meta, and the para isomers of dichlorobenzene.

b. Predict the number of isomers for trichlorobenzene.

c. It turns out that the presence of one chlorine atom on a benzene ring will cause the next substituent to add ortho or para to the first chlorine atom on the benzene ring. What does this tell you about the synthesis of m-dichlorobenzene?

d. Which of the isomers of trichlorobenzene will be the hardest to prepare?

**Functional Groups**

Identify each of the following compounds as a carboxylic acid, ester, ketone, aldehyde, or amine.

a. Anthraquinone, an important starting material in the manufacture of dyes:

   ![Anthraquinone](image)

b. ![Ester](image)

c. ![Ketone](image)

d. ![Aldehyde](image)

52. Identify the functional groups present in the following compounds.

a. ![Testosterone](image)
Mimosine is a natural product found in large quantities in the seeds and foliage of some legume plants and has been shown to cause inhibition of hair growth and hair loss in mice.

Mimosine, C_{8}H_{13}N_{2}O_{4}

a. What functional groups are present in mimosine?
b. Give the hybridization of the eight carbon atoms in mimosine.
c. How many $\sigma$ and $\pi$ bonds are found in mimosine?

Minoxidil (C_{11}H_{13}N_{2}O) is a compound produced by Pharmacia Company that has been approved as a treatment of some types of male pattern baldness.

60. Name the following compounds.
a. Cl
b. O

c. HCOOH

Reactions of Organic Compounds

Complete the following reactions.
a. CH_{3}CH\equiv CHCH_{3} + H_{2} \rightarrow
b. \( \text{CH}_2=\text{CHCH}_2=\text{CH} + 2\text{Cl}_2 \rightarrow \)

\[ \text{CH}_3 \quad \text{CH}_3 \]

c. \( \text{Cyclic structure} + \text{Cl}_2 \xrightarrow{\text{FeCl}_3} \)

d. \( \text{CH}_3\text{C}≡\text{CH}_2 + \text{O}_2 \xrightarrow{\text{Spark}} \)

62. Reagents such as HCl, HBr, and HOH (H\(_2\)O) can add across carbon-carbon double and triple bonds, with H forming a bond to one of the carbon atoms in the multiple bond and Cl, Br, or OH forming a bond to the other carbon atom in the multiple bond. In some cases, two products are possible. For the major organic product, the addition occurs so that the hydrogen atom in the reagent attaches to the carbon atom in the multiple bond that already has the greater number of hydrogen atoms bonded to it. With this rule in mind, draw the structure of the major product in each of the following reactions.

a. \( \text{CH}_3\text{CH}_2\text{CH}≡\text{CH}_2 + \text{H}_2\text{O} \rightarrow \)

b. \( \text{CH}_3\text{CH}_2\text{CH}≡\text{CH}_2 + \text{HBr} \rightarrow \)

c. \( \text{CH}_3\text{CH}_2\text{C}≡\text{CH} + 2\text{HBr} \rightarrow \)

d. \( \text{[Cyclic structure]} + \text{H}_2\text{O} \rightarrow \)

e. \( \text{CH}_3\text{CH}_2\text{C}≡\text{C}_2\text{H}_5 + \text{HCl} \rightarrow \)

66. Oxidation of an aldehyde yields a carboxylic acid:

\[
\begin{array}{c}
\text{O} \\
\text{R} \text{CH} \xrightarrow{[\text{ox}]} \text{R} \text{C} \text{OH}
\end{array}
\]

Draw the structures for the products of the following oxidation reactions.

a. propanal \( \rightarrow \)

b. 2,3-dimethylpentanal \( \rightarrow \)

c. 3-ethylbenzaldehyde \( \rightarrow \)

68. What tests could you perform to distinguish between the following pairs of compounds?

a. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3, \quad \text{CH}_3\text{CH}≡\text{CHCH}_2\text{CH}_3 \)

b. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}, \quad \text{CH}_3\text{CH}_2\text{CCH}_3 \)

c. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}, \quad \text{CH}_3\text{CCH}_3 \)

d. \( \text{CH}_3\text{CH}_2\text{NH}_2, \quad \text{CH}_3\text{OCH}_3 \)

How would you synthesize the following esters?

a. \( n\)-octylacetate \( \rightarrow \)

b. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{O} \xrightarrow{\text{CH}_2\text{CH}_3} \)

70. Salicylic acid has the following structure:

\[
\begin{array}{c}
\text{CO}_2\text{H} \\
\text{OH}
\end{array}
\]

Since salicylic acid has both an alcohol functional group and a carboxylic acid functional group, it can undergo two different esterification reactions depending on which functional group reacts. For example, when treated with ethanoic acid (acetic acid), salicylic acid behaves as an alcohol and the ester produced is acetylsalicylic acid (aspirin). On the other hand, when reacted with methanol, salicylic acid behaves as...
an acid and the ester methyl salicylate (oil of wintergreen) is produced. Methyl salicylate is also an analgesic and part of the formulation of many liniments for sore muscles. What are the structures of acetylsalicylic acid and methyl salicylate?

**Polymers**

7. Kel-F is a polymer with the structure

\[
\left( \begin{array}{cccccccc}
F & F & F & F & F & F & F & F \\
Cl & F & Cl & F & Cl & F & Cl & \ldots \\
\end{array} \right)
\]

What is the monomer for Kel-F?

72. What monomer(s) must be used to produce the following polymers?

a. \[
\left( \begin{array}{cccccccc}
CH_2-CH_2-CH-CH_2-CH-CH_2 \\
F & F & F & F \\
\end{array} \right)_n
\]

b. \[
\left( \begin{array}{cccccccc}
CH_2-CH_2-C-CH_2-CH_2-CH_2 \\
O & O & O \\
\end{array} \right)_n
\]

c. \[
\left( \begin{array}{cccc}
H & H & N & H \\
C-H_2 & C-H_2 & N & C-H_2-CH_2-CH_2-CH_2 \\
\end{array} \right)_n
\]

d. \[
\left( \begin{array}{cccccccc}
CH_3 & CH_3 & CH_3 \\
C-H_2 & C-H_2 & C-H_2 \\
\end{array} \right)_n
\]

e. \[
\left( \begin{array}{cccccccc}
CH_3 & CH_3 & \\
C-H_2 & C-H_2 & \\
\end{array} \right)_n
\]

f. \[
\left( \begin{array}{cccccccc}
C-Cl & C-Cl & C-Cl & C-Cl \\
Cl & Cl & Cl & Cl \\
\end{array} \right)_n
\]

g. \[
\left( \begin{array}{cccccccc}
H & O & O & H \\
C-H-CH-CH_2-CH_2-CH_2-CH_2 \\
\end{array} \right)_n
\]

(This polymer is Kodel, used to make fibers of stain-resistant carpeting.)

Classify these polymers as condensation or addition polymers. Which are copolymers?

74. Isoprene is the repeating unit in natural rubber. The structure of isoprene is

\[
\begin{array}{ccc}
CH_3 \\
\text{CH}_2=\text{C} & \text{CH} & \text{CH}_2 \\
\end{array}
\]

a. Give a systematic name for isoprene.

b. When isoprene is polymerized, two polymers of the form

\[
\left( \begin{array}{cccccccc}
CH_3 & \\
\text{CH}_2=\text{C} & \text{CH} & \text{CH}_2 \\
\end{array} \right)_n
\]

are possible. In natural rubber, the cis configuration is found. The polymer with the trans configuration about the double bond is called gutta percha and was once used in the manufacture of golf balls. Draw the structure of natural rubber and gutta percha showing three repeating units and the configuration about the carbon–carbon double bonds.

75. Kevlar, used in bulletproof vests, is made by the condensation copolymerization of the monomers

\[
\begin{array}{cccccccc}
H_2N- & -NH_2 & \text{and} & \text{HO}_2C- & -\text{CO}_2H \\
\end{array}
\]

Draw the structure of a portion of the Kevlar chain.

76. The polyester formed from lactic acid,

\[
\begin{array}{cccccccc}
\text{CH}_3 & \text{CH} & \text{CH}_2 & \text{CH}_2 & \text{CO}_2H \\
\text{OH} \\
\end{array}
\]

is used for tissue implants and surgical sutures that will dissolve in the body. Draw the structure of a portion of this polymer.

77. Polymides are polymers that are tough and stable at temperatures of up to 400°C. They are used as a protective coating on the quartz fibers used in fiber optics. What monomers were used to make the following polymide?

78. The Amoco Chemical Company has successfully raced a car with a plastic engine. Many of the engine parts, including piston skirts, connecting rods, and valve-train components, were made of a polymer called Torlon:
What monomers are used to make this polymer?

Polystyrene can be made more rigid by copolymerizing styrene with divinylbenzene:

\[
\begin{align*}
\text{CH} &= \text{CH}_2 \\
\text{CH} &= \text{CH}_2
\end{align*}
\]

How does the divinylbenzene make the copolymer more rigid?

80. Polymers containing double bonds are often crosslinked by reacting the polymer with styrene.
   a. Draw the structure of the copolymer of
      \[
      \text{HO} - \text{CH}_2\text{CH}_2 - \text{OH} \quad \text{and} \quad \text{HO}_2\text{C} - \text{CH} = \text{CH} - \text{CO}_2\text{H}
      \]
   b. Draw the structure of the crosslinked polymer (after the polyester has been reacted with styrene).

81. Which of the following polymers would be stronger or more rigid? Explain your choices.
   a. The copolymer of ethylene glycol and terephthalic acid
   b. The polymer of \([\text{HO} - (\text{CH}_2)_n - \text{CO}_2\text{H}]\)
   c. Polyacetylene or polyethylene (The monomer in polyacetylene is ethyne.)

82. Poly(lauryl methacrylate) is used as an additive in motor oils to counter the loss of viscosity at high temperature. The structure is

\[
\begin{align*}
\text{(CH}_3\text{)}_n
\end{align*}
\]

The long hydrocarbon chain of poly(lauryl methacrylate) makes the polymer soluble in oil (a mixture of hydrocarbons with mostly 12 or more carbon atoms). At low temperatures the polymer is coiled into balls. At higher temperatures the balls uncoil and the polymer exists as long chains. Explain how this helps control the viscosity of oil.

### Natural Polymers

83. Which of the amino acids in Fig. 22.18 contain the following functional groups in their R group?
   a. alcohol    c. amine
   b. carboxylic acid d. amide

84. When pure crystalline amino acids are heated, decomposition generally occurs before the solid melts. Account for this observation. (Hint: Crystalline amino acids exist as \(\text{H}_2\text{NCRHCOO}^-\), called zwitterions.)

85. Aspartame, the artificial sweetener marketed under the name Nutra-Sweet, is a methyl ester of a dipeptide:

\[
\begin{align*}
\text{H}_2\text{N} - \text{CH} - \text{C} - \text{NH} - \text{CH} - \text{CH} \quad \text{CO}_2\text{H}
\end{align*}
\]

   a. What two amino acids are used to prepare aspartame?
   b. There is concern that methanol may be produced by the decomposition of aspartame. From what portion of the molecule can methanol be produced? Write an equation for this reaction.

86. Glutathione, a tripeptide found in virtually all cells, functions as a reducing agent. The structure of glutathione is

\[
\begin{align*}
\text{OOCCCH}_2\text{CH}_2\text{CNHCHCNHCH}_2\text{COO}^- \\
\text{NH}_3 + \text{CH}_2\text{SH}
\end{align*}
\]

   What amino acids make up glutathione?

87. Draw the structures of the two dipeptides that can be formed from serine and alanine.

88. Draw the structures of the tripeptides gly–ala–ser and ser–ala–gly. How many other tripeptides are possible using these three amino acids?

89. Write the sequence of all possible tetrapeptides composed of the following amino acids.
   a. Two phenylalanines and two glycines
   b. Two phenylalanines, glycine, and alanine

90. How many different pentapeptides can be formed using five different amino acids?

91. Give an example of amino acids that could give rise to the interactions pictured in Fig. 22.24 that maintain the tertiary structures of proteins.

92. What types of interactions can occur between the side chains of the following amino acids that would help maintain the tertiary structure of a protein?
   a. cysteine and cysteine    c. glutamic acid and lysine
   b. glutamine and serine    d. proline and leucine

93. Oxygen is carried from the lungs to tissues by the protein hemoglobin in red blood cells. Sickle cell anemia is a disease
resulting from abnormal hemoglobin molecules in which a valine is substituted for a single glutamic acid in normal hemoglobin. How might this substitution affect the structure of hemoglobin?

94. Over 100 different kinds of mutant hemoglobin molecules have been detected in humans. Unlike sickle cell anemia (see Exercise 93), not all of these mutations are as serious. In one nonlethal mutation, glutamine substitutes for a single glutamic acid in normal hemoglobin. Rationalize why this substitution is nonlethal.

Draw cyclic structures for D-ribose and D-mannose.

96. Indicate the chiral carbon atoms found in the monosaccharides D-ribose and D-mannose.

In addition to using numerical prefixes in the general names of sugars to indicate how many carbon atoms are present, we often use the prefixes keto- and aldo- to indicate whether the sugar is a ketone or an aldehyde. For example, the monosaccharide fructose is frequently called a ketohexose to emphasize that it contains six carbons as well as the ketone functional group. For each of the monosaccharides shown in Table 22.8 classify the sugars as aldohexoses, aldopentoses, ketohexoses, or ketopentoses.

98. Glucose can occur in three forms: two cyclic forms and one open-chain structure. In aqueous solution, only a tiny fraction of the glucose is in the open-chain form. Yet tests for the presence of glucose depend on reaction with the aldehyde group, which is found only in the open-chain form. Explain why these tests work.

What are the structural differences between α- and β-glucose? These two cyclic forms of glucose are the building blocks to form two different polymers. Explain.

100. Cows can digest cellulose, but humans can’t. Why not?

Which of the amino acids in Fig. 22.18 contain more than one chiral carbon atom? Draw the structures of these amino acids and indicate all chiral carbon atoms.

102. Why is glycine not optically active?

Which of the noncyclic isomers of bromochloropropene are optically active?

104. How many chiral carbon atoms does the following structure have?

![Structure](attachment:image.jpg)

Part of a certain DNA sequence is G-G-T-C-T-A-T-A-C. What is the complementary sequence?

106. The codons (words) in DNA (that specify which amino acid should be at a particular point in a protein) are three bases long. How many such three-letter words can be made from the four bases adenine, cytosine, guanine, and thymine?

Which base will hydrogen bond with uracil within an RNA molecule? Draw the structure of this base pair.

108. Tautomers are molecules that differ in the position of a hydrogen atom. A tautomeric form of thymine has the structure

![Structure](attachment:image.jpg)

If the tautomer above, rather than the stable form of thymine were present in a strand of DNA during replication, what would be the result?

The base sequences in mRNA that code for certain amino acids are

Glu: GAA, GAG
Val: GUU, GUC, GUA, GUG
Met: AUG
Trp: UGG
Phe: UUU, UUC
Asp: GAU, GAC

These sequences are complementary to the sequences in DNA.

a. Give the corresponding sequences in DNA for the amino acids listed above.

b. Give a DNA sequence that would code for the peptide trp-glu-phe-met.

c. How many different DNA sequences can code for the butapeptide in part b?

d. What is the peptide that is produced from the DNA sequence T-A-C-C-T-G-A-A-G?

e. What other DNA sequences would yield the same tripeptide as in part d?

110. The change of a single base in the DNA sequence for normal hemoglobin can encode for the abnormal hemoglobin giving rise to sickle cell anemia. Which base in the codon for glu in DNA is replaced to give the codon(s) for val? (See Exercises 93 and 109.)

Additional Exercises

There is only one compound that is named 1,2-dichloroethane, but there are two distinct compounds that can be named 1,2-dichloroethene. Why?

112. In the presence of light, chlorine can substitute for one (or more) of the hydrogens in an alkane. For the following reactions, draw the possible monochlorination products.

a. 2,2-dimethylpropane + Cl₂ →

b. 1,3-dimethylcyclobutane + Cl₂ →

c. 2,3-dimethylbutane + Cl₂ →
Polychlorinated dibenzo-p-dioxins (PCDDs) are highly toxic substances that are present in trace amounts as by-products of some chemical manufacturing processes. They have been implicated in a number of environmental incidents—for example, the chemical contamination at Love Canal and the herbicide spraying in Vietnam. The structure of dibenzo-p-dioxin, along with the customary numbering convention, is:

The most toxic PCDD is 2,3,7,8-tetrachloro-dibenzo-p-dioxin. Draw the structure of this compound. Also draw the structures of two other isomers containing four chlorine atoms.

114. Draw the isomer(s) specified. There may be more than one possible isomer for each part.
   a. a cyclic compound that is an isomer of trans-2-butene
   b. an ester that is an isomer of propanoic acid
   c. a ketone that is an isomer of butanal
   d. a secondary amine that is an isomer of butylamine
   e. a tertiary amine that is an isomer of butylamine
   f. an ether that is an isomer of 2-methyl-2-propanol
   g. a secondary alcohol that is an isomer of 2-methyl-2-propanol

Explain why methyl alcohol is soluble in water in all proportions, while stearyl alcohol [CH₃(CH₂)₁₆OH] is a waxy solid that is not soluble in water.

116. Is octanoic acid more soluble in 1 M HCl, 1 M NaOH, or pure water? Explain. Drugs such as morphine (C₁₇H₁₉NO₃) are often treated with strong acids. The most commonly used form of morphine is morphine hydrochloride (C₁₇H₂₂ClNO₃). Why is morphine treated in this way? (Hint: Morphine is an amine.)

Consider the compounds butanoic acid, pentanal, n-hexane, and 1-pentanol. The boiling points of these compounds (in no specific order) are 69°C, 103°C, 137°C, and 164°C. Match the boiling points to the correct compound.

118. Consider the reaction to produce the ester methyl acetate:

\[ \text{CH}_3\text{OH} + \text{CH}_3\text{COH} \rightarrow \text{CH}_3\text{COCH}_3 + \text{H}_2\text{O} \]

Methyl acetate

When this reaction is carried out with CH₃OH containing radioactive oxygen-18, the water produced does not contain oxygen-18. Explain the results of this radioisotope tracer experiment.

A compound containing only carbon and hydrogen is 85.63% C by mass. Reaction of this compound with H₂O produces a secondary alcohol as the major product and a primary alcohol as the minor product (see Exercise 62). If the molar mass of the hydrocarbon is between 50 and 60 g/mol, name the compound.

120. The polymer nitrile is a copolymer made from acrylonitrile and butadiene; it is used to make automobile tires and gaskets. Draw the structure of nitrile. (Hint: See Table 22.7.)

Polyaramid is a term applied to polyamides containing aromatic groups. These polymers were originally made for use as tire cords but have since found many other uses.

a. Kevlar is used in bulletproof vests and many high-strength composites. The structure of Kevlar is

Which monomers are used to make Kevlar?

b. Nomex is a polyaramid used in fire-resistant clothing. It is a copolymer of

\[ \text{H}_2\text{N} \quad \text{NH}_2 \quad \text{HO}_2\text{C} \quad \text{CO}_2\text{H} \]

and

Draw the structure of the Nomex polymer. How do Kevlar and Nomex differ in their structures?

122. When acrylic polymers are burned, toxic fumes are produced. For example, in many airplane fires, more passenger deaths have been caused by breathing toxic fumes than by the fire itself. Using polyacrylonitrile as an example, what would you expect to be one of the most toxic, gaseous combustion products created in the reaction?

Ethylene oxide,

\[ \text{CH}_2=\text{CH}_2 \]

is an important industrial chemical. Although most ethers are unreactive, ethylene oxide is quite reactive. It resembles C₂H₄ in its reactions in that addition reactions occur across the C—O bond in ethylene oxide.

a. Why is ethylene oxide so reactive? (Hint: Consider the bond angles in ethylene oxide as compared with those predicted by the VSEPR model.)

b. Ethylene oxide undergoes addition polymerization, forming a polymer used in many applications requiring a nonionic surfactant. Draw the structure of this polymer.

124. Another way of producing highly crosslinked polyesters is to use glycerol. Alkyd resins are a polymer of this type. The polymer forms very tough coatings when baked onto a surface and is used in paints for automobiles and large appliances. Draw the structure of the polymer formed from the condensation of

\[ \text{CH}_2=\text{CH}_2\text{CH}_2 \quad \text{and} \quad \text{CO}_2\text{H} \]

Glycerol

Phthalic acid

Explain how crosslinking occurs in this polymer.
Monosodium glutamate (MSG) is commonly used as a flavoring in foods. Draw the structure of MSG.

126. a. Use bond energies (Table 8.4) to estimate $\Delta H$ for the reaction of two molecules of glycine to form a peptide linkage.
   
   b. Would you predict $\Delta S$ to favor the formation of peptide linkages between two molecules of glycine?
   
   c. Would you predict the formation of proteins to be a spontaneous process?

127. The reaction to form a phosphate ester linkage between two nucleotides can be approximated as follows:

   ![Phosphate linkage diagram]

Would you predict the formation of a dinucleotide from two nucleotides to be a spontaneous process?

128. Considering your answers to Exercises 126 and 127, how can you justify the existence of proteins and nucleic acids in light of the second law of thermodynamics?

129. All amino acids have at least two functional groups with acidic or basic properties. In alanine, the carboxylic acid group has $K_a = 4.5 \times 10^{-2}$ and the amino group has $K_b = 7.4 \times 10^{-5}$. Three ions of alanine are possible when alanine is dissolved in water. Which of these ions would predominate in a solution with $[H^+] = 1.0 \text{ M}$? In a solution with $[OH^-] = 1.0 \text{ M}$?

130. The average molar mass of one base pair of nucleotides in DNA is approximately 600 g/mol. The spacing between successive base pairs is about 0.34 nm, and a complete turn in the helical structure of DNA occurs about every 3.4 nm. If a DNA molecule has a molar mass of $4.5 \times 10^6$ g/mol, approximately how many complete turns exist in the DNA $\alpha$-helix structure?

131. The compound cisplatin appears to kill cancer cells by inhibiting DNA synthesis. Given the following structural information about cisplatin, the information in Exercise 130, and the fact that the chloride ion is easily displaced by other donor molecules in cisplatin, speculate on how cisplatin may interact with DNA.

   ![Cisplatin structure]

132. In glycine, the carboxylic acid group has $K_a = 4.3 \times 10^{-3}$ and the amino group has $K_b = 6.0 \times 10^{-5}$. Use these equilibrium constant values to calculate the equilibrium constants for the following.

   a. $\text{H}_2\text{NCH}_2\text{CO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{NCH}_2\text{CO}_2^- + \text{H}_3\text{O}^+$
   
   b. $\text{H}_2\text{NCH}_2\text{CO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{NCH}_2\text{CO}_2\text{H} + \text{OH}^-
   
   c. $\text{H}_3\text{NCH}_2\text{CO}_2\text{H} \rightleftharpoons 2\text{H}^+ + \text{H}_2\text{NCH}_2\text{CO}_2^-$

### Challenge Problems

133. The isoelectric point of an amino acid is the pH at which the molecule has no net charge. For glycine, that point would be the pH at which virtually all glycine molecules are in the form $\text{H}_2\text{NCH}_2\text{CO}_2^-$. This form of glycine is amphoteric since it can act as both an acid and a base. If we assume that the principal equilibrium at the isoelectric point has the best acid reacting with the best base present, then the reaction is:

   $2\text{H}_2\text{NCH}_2\text{CO}_2^- \rightleftharpoons \text{H}_2\text{NCH}_2\text{CO}_2^- + \text{H}_3\text{NCH}_2\text{CO}_2\text{H}$

   (i)

   Assuming this reaction is the principal equilibrium, then the following relationship must hold true:

   $[\text{H}_2\text{NCH}_2\text{CO}_2^-] = [\text{H}_3\text{NCH}_2\text{CO}_2\text{H}]$

   (ii)

   Use this result and your answer to part c of Exercise 132 to calculate the pH at which equation (ii) is true. It will be the isoelectric point of glycine.

134. In 1994 chemists at Texas A & M University reported the synthesis of a non-naturally occurring amino acid (C & E News, April 18, 1994, pp. 26–27):

   ![Amino acid structure]

   a. To which naturally occurring amino acid is this compound most similar?
   
   b. A tetrapeptide, phe–met–arg–phe—NH$_2$, is synthesized in the brains of rats addicted to morphine and heroin. (The

   —NH$_2$ indicates that the peptide ends in —NH$_2$ instead of —CO$_2$H.) The TAMU scientists synthesized a similar tetrapeptide, with the synthetic amino acid above replacing one of the original amino acids. Draw a structure for the tetrapeptide containing the synthetic amino acid.
   
   c. Indicate the chiral carbon atoms in the synthetic amino acid.

136. The structure of tartaric acid is

   ![Tartaric acid structure]

   a. Is the form of tartaric acid pictured below optically active? Explain.
Note: The dashed lines show groups behind the plane of the page. The wedges show groups in front of the plane.
b. Draw the optically active forms of tartaric acid.

136. Using one of the Lewis structures for benzene (C₆H₆), estimate ΔHᵢ for C₆H₆(g) using bond energies and given the standard enthalpy of formation of C(g) is 717 kJ/mol. The experimental ΔHᵢ value for C₆H₆(g) is 83 kJ/mol. Explain the discrepancy between the experimental value and the calculated ΔHᵢ value for C₆H₆(g).

Mycomycin, a naturally occurring antibiotic produced by the fungus Nocardia acidophilus, has the molecular formula C₁₃H₁₀O₂ and the systematic name 3,5,7,8-tetracetaetraene-10,12-diyndioic acid. Draw the structure of mycomycin.

138. Sorbic acid is used to prevent mold and fungus growth in some food products, especially cheeses. The systematic name for sorbic acid is 2,4-hexadienoic acid. Draw structures for the four geometrical isomers of sorbic acid.

Consider the following reactions. For parts b–d, see Exercise 62.

a. When C₆H₁₂ is reacted with Cl₂(g) in the presence of ultraviolet light, four different monochlorination products form. What is the structure of C₆H₁₅ in this reaction?
b. When C₆H₆ is reacted with H₂O, a tertiary alcohol is produced as the major product. What is the structure of C₆H₈ in this reaction?
c. When C₆H₁₂ is reacted with HCl, 1-chloro-1-methylcyclohexene is produced as the major product. What are the two possible structures for C₆H₁₂ in this reaction?
d. When a hydrocarbon is reacted with H₂O and the major product of this reaction is then oxidized, acetone (2-propanone) is produced. What is the structure of the hydrocarbon in this reaction?
e. When C₆H₁₂O is oxidized, a carboxylic acid is produced. What are the possible structures for C₆H₁₂O in this reaction?

140. Polycarbonates are a class of thermoplastic polymers that are used in the plastic lenses of eyeglasses and in the shells of bicycle helmets. A polycarbonate is made from the reaction of bisphenol A (BPA) with phosgene (COCl₂):

\[
\text{HO-} \begin{array}{c} \text{CH}_3 \\ \text{C} \\ \text{CH}_3 \\ \text{OH} \end{array} + n\text{COCl}_2 \xrightarrow{\text{Catalyst}} \text{BPA polycarbonate} + 2n\text{HCl}
\]

Phenol (C₆H₅OH) is used to terminate the polymer (stop its growth).

a. Draw the structure of the polycarbonate chain formed from the above reaction.

b. Is this reaction a condensation or addition polymerization?

A urethane linkage occurs when an alcohol adds across the carbon–nitrogen double bond in an isocyanate:

\[
\text{R-O-H + O==C==N-R' \xrightarrow{} RO-C-N-R'}
\]

Alcohol Isocyanate Urethane

Polyurethanes (formed from the copolymerization of a diol with a diisocyanate) are used in foamed insulation and a variation of other construction materials. What is the structure of the polyurethane formed by the following reaction?

\[
\text{HOCH}_2\text{CH}_2\text{OH} + \text{O==C==N-} \xrightarrow{} \n
142. ABS plastic is a tough, hard plastic used in applications requiring shock resistance. The polymer consists of three monomer units: acrylicnitrile (C₆H₃N), butadiene (C₆H₈), and styrene (C₆H₅). 

a. Draw two repeating units of ABS plastic assuming that the three monomer units react in a 1:1:1 mole ratio and react in the same order as the monomers listed above.

b. A sample of ABS plastic contains 8.80% N by mass. It took 0.605 g of Br₂ to react completely with a 1.20-g sample of ABS plastic. What is the percent by mass of acrylicnitrile, butadiene, and styrene in this polymer sample?

c. ABS plastic does not react in a 1:1:1 mole ratio among the three monomer units. Using the results from part b, determine the relative numbers of the monomer units in this sample of ABS plastic.

Stretch a rubber band while holding it gently to your lips. Then slowly let it relax while still in contact with your lips.

a. What happens to the temperature of the rubber band on stretching?
b. Is the stretching an exothermic or endothermic process?
c. Explain the above result in terms of intermolecular forces.
d. What is the sign of ΔS and ΔG for stretching the rubber band?
e. Give the molecular explanation for the sign of ΔS for stretching.

144. Read the label on an over-the-counter medication (Tylemol, cough syrup, etc.) or cosmetic. Look up the structures of the organic compounds listed in a reference such as The Merck Index. From the information given, determine the function of each of the compounds you looked up.
1. Open the Synthesis of Nylon Visualization on the student CD. What type of polymer is nylon? Nylon is a copolymer. What does this mean? Review Figure 22.16 in the text for the structures of the monomers useful to produce the nylon in the video. What small molecule is eliminated when the nylon in the video forms? For more practice with condensation polymers, do Exercises 22.75 and 22.77 in the text.

2. Explain why carbohydrates are also polymers. Open the Molecule Library on the student web site and view D-fructose and D-glucose to see two different monosaccharides.

3. Sucrose is a disaccharide. What does this mean and what two monosaccharides form sucrose? Open the Molecule Library on the student web site and view sucrose. Starch, cellulose, and glycogen are polysaccharides. What does this mean? What monomer is used to produce starch, cellulose, and glycogen?

4. DNA and RNA are also polymers. However, the monomers used to form these polymers are more complicated than in proteins and carbohydrates. For DNA and RNA, each monomer contains three parts. What are the three parts? Open the Molecule Library on the student web site and view the sugar part (deoxyribose in DNA and ribose in RNA) and the nitrogen-containing base part (uracil, cytosine, thymine, adenine, and guanine). What are the base pairs in the DNA double-helix structure?

5. Lipids are a class of substances that are water insoluble; they contain mostly carbon and hydrogen atoms. Does this make sense in view of the lipids inability to dissolve in water? Fats are one type of lipid. Open the Molecule Library on the student web site and view tristearin, the most common animal fat. Tristearin is a triglyceride.

6. Steroids are another type of lipid. Open the Molecule Library on the student web site and view the steroids cholesterol, testosterone, progesterone, estradiol, and cholic acid. What common structural characteristic do all steroids have?

7. Test your understanding of Chapter 22 material by taking the ACE quizzes on the student web site.

For additional web activities and other resources, visit the Zumdahl, Chemistry, Sixth Edition textbook site at http://chemistry.college.hmco.com/students.