Pearson

Chapter Summary and Review

Key Learning Outcomes

CHAPTER OBJECTIVES	ASSESSMENT
Write Structural Formulas for Hydrocarbons (21.3)	• Example 21.1 For Practice 21.1 Exercises 37, 38
Name Alkanes (21.4)	• Examples 21.2, 21.3, 21.4 For Practice 21.2, 21.3, 21.4 Exercises 43, 44
Name Alkenes and Alkynes (21.5)	• Example 21.5 For Practice 21.5 Exercises 53, 54, 55, 56
Write Addition Reactions (21.6)	• Example 21.6 For Practice 21.6 Exercises 59, 60, 61, 62
Write Reactions for Alcohols (21.9)	• Example 21.7 For Practice 21.7 Exercises 75, 76

Key Terms

Section 21.1

organic molecule
organic chemistry

Section 21.3

alkane
alkene
alkyne
aromatic hydrocarbon
aliphatic hydrocarbon
structural isomers
structural formula
stereoisomers
optical isomers
enantiomers (optical isomers)
chiral
dextrorotatory
levorotatory
racemic mixture

Section 21.4

saturated hydrocarbon

Section 21.5

unsaturated hydrocarbon
geometric (cis–trans) isomerism

Section 21.6

substitution reaction
addition reaction

Section 21.7

phenyl group

Section 21.8

functional group

Section 21.9

alcohol
hydroxyl group
elimination reaction

Section 21.10

aldehyde
ketone
carbonyl group

Section 21.11

carboxylic acid
esters
condensation reaction

Section 21.12

ether

Section 21.13

amine

Key Concepts

Fragrances and Odors (21.1)

- Organic chemistry is the study of organic compounds, which contain carbon (and other elements including hydrogen, oxygen, and nitrogen).

Carbon (21.2)

- Carbon forms more compounds than all the other elements combined.
- Carbon's four valence electrons (in conjunction with its size) allow carbon to form four bonds (in the form of

single, double, or triple bonds).

- Carbon also has the capacity to catenate (to form long chains) because of the strength of the carbon–carbon bond.

Hydrocarbons (21.3)

- Organic compounds containing only carbon and hydrogen are called hydrocarbons, the key components of fuels.
- Hydrocarbons are divided into four different types: alkanes, alkenes, alkynes, and aromatic hydrocarbons.
- Stereoisomers are molecules that feature the same atoms bonded in the same order but arranged differently in space. Optical isomerism, a type of stereoisomerism, occurs when two molecules are nonsuperimposable mirror images of one another.

Alkanes (21.4)

- Alkanes are saturated hydrocarbons—they contain only single bonds and are therefore represented by the generic formula C_nH_{2n+2}. Alkane names always end in *-ane*.

Alkenes and Alkynes (21.5)

- Alkenes and alkynes are unsaturated hydrocarbons—they contain double bonds (alkenes) or triple bonds (alkynes) and are represented by the generic formulas C_nH_{2n} and C_nH_{2n-2}, respectively.
- Alkene names end in *-ene* and alkynes end in *-yne*.
- Because rotation about a double bond is severely restricted, geometric (or cis–trans) isomerism occurs in alkenes.

Hydrocarbon Reactions (21.6)

- The most common hydrocarbon reaction is probably combustion, in which hydrocarbons react with oxygen to form carbon dioxide and water; this reaction is exothermic and is used to provide most of our society's energy.
- Alkanes can also undergo substitution reactions, where heat or light causes another atom, commonly a halogen such as bromine, to be substituted for a hydrogen atom.
- Unsaturated hydrocarbons undergo addition reactions. If the addition reaction is between two unsymmetrical molecules, Markovnikov's rule predicts that the positive end of the polar reagent adds to the carbon with the most hydrogen atoms.

Aromatic Hydrocarbons (21.7)

- Aromatic hydrocarbons contain six-membered benzene rings represented with alternating single and double bonds that become equivalent through resonance. These compounds are called aromatic because they often produce pleasant fragrances.
- Because of the stability of the aromatic ring, benzene is more stable than a straight-chain alkene, and it undergoes substitution rather than addition reactions.

Functional Groups (21.8)

- Characteristic groups of atoms, such as hydroxyl (—OH), are called functional groups. Molecules that contain the same functional group have similar chemical and physical properties, and they are referred to as families.

Alcohols (21.9)

- The family of alcohols contains the —OH group and is named with the suffix *-ol*.
- Alcohols are commonly used in gasoline, in alcoholic beverages, and in sterilization procedures.
- Alcohols undergo substitution reactions, in which a substituent such as a halogen replaces the hydroxyl group.
- Alcohols undergo elimination reactions, in which water is eliminated across a bond to form an alkene, and oxidation or reduction reactions.

- Alcohols also react with active metals to form alkoxide ions and hydrogen gas.

Aldehydes and Ketones (21.10)

- Aldehydes and ketones both contain a carbonyl group (a carbon atom double-bonded to oxygen).
- In aldehydes, the carbonyl group is at the end of a carbon chain, while in ketones it is between two other carbon atoms.
- Aldehydes are named with the suffix *-al* and ketones with the suffix *-one*.
- A carbonyl can be formed by the oxidation of an alcohol or reverted to an alcohol by reduction.
- Like alkenes, carbonyls undergo addition reactions; however, because the carbon–oxygen bond is highly polar, the electronegative component of the reagent always adds to the carbon atom, and the less electronegative part adds to the oxygen.

Carboxylic Acids and Esters (21.11)

- Carboxylic acids contain a carbonyl group and a hydroxide on the same carbon and are named with the suffix *-oic acid*.
- Esters contain a carbonyl group bonded to an oxygen atom that is in turn bonded to an R group; they are named with the suffix *-oate*.
- Carboxylic acids taste sour, such as acetic acid in vinegar, while esters smell sweet.
- Carboxylic acids react as weak acids but can also form esters through condensation reactions with alcohols.

Ethers (21.12)

- The family of ethers contains an oxygen atom between two R groups.
- Ethers are named with the ending *-yl ether*.

Amines (21.13)

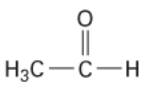
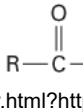
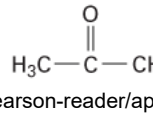
- Amines are organic compounds that contain nitrogen and are named with the suffix *-amine*.
- They are known for their terrible odors; the smell of decaying animal flesh is produced by cadaverine.
- Amines act as weak bases and produce a salt when mixed with a strong acid.
- The combination of an amine with a carboxylic acid leads to a condensation reaction; this reaction is used by our bodies to produce proteins from amino acids.

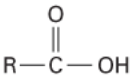
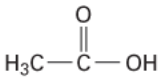
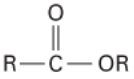
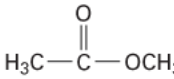
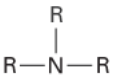
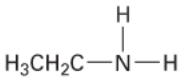
Key Equations and Relationships

Halogen Substitution Reactions in Alkanes (21.6)

$$\underset{\text{alkane}}{\text{R–H}} + \underset{\text{halogen}}{\text{X}_2} \xrightarrow{\text{heat or light}} \underset{\text{haloalkane}}{\text{R–X}} + \underset{\text{hydrogen halide}}{\text{HX}}$$

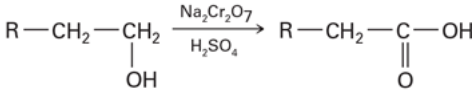
Common Functional Groups (21.8)

Family	General Formula	Condensed General Formula	Example	Name
Alcohols	R—OH	ROH	CH_3CH_2OH	ethanol (ethyl alcohol)
Ethers	R—O—R	ROR	CH_3OCH_3	dimethyl ether
Aldehydes		RCHO		ethanal (acetaldehyde)
Ketones		RCOR		propanone (acetone)

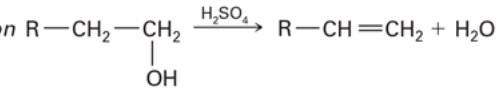
Carboxylic acids		RCOOH		acetic acid
Esters		RCOOR		methyl acetate
Amines		R_3N		ethylamine

Alcohol Reactions (21.9)

Substitution 

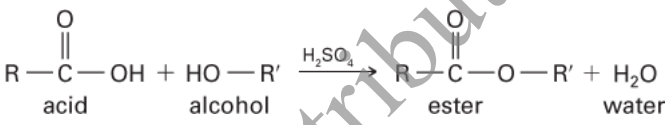
Oxidation 

alcohol carboxylic acid

Elimination 

alcohol

Carboxylic Acid Condensation Reactions (21.11)



acid alcohol ester water

Amine Acid–Base Reactions (21.13)

$$\mathrm{RNH_2}\,(aq) + \mathrm{H_2O}\,(l) \rightarrow \mathrm{RNH_3^+}\,(aq) + \mathrm{OH^-}\,(aq)$$

Amine–Carboxylic Acid Condensation Reactions (21.13)

$$\mathrm{CH_3COOH}\,(aq) + \mathrm{HNHR}\,(aq) \rightarrow \mathrm{CH_3CONHR}\,(aq) + \mathrm{H_2O}\,(l)$$