

TABLE 1.2

Classes and functional groups of organic compounds

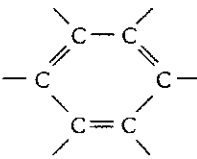


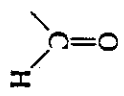
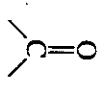
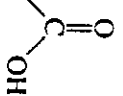
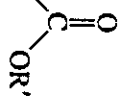

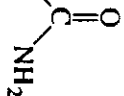
Class	Functional group	Example of expanded structural formula	Example of condensed structural formula	Common name
Alkane	None	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	CH_3CH_3	ethane
Alkene	$\text{C}=\text{C}$	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \quad \backslash \quad / \\ \quad \text{C}=\text{C} \\ \quad / \quad \backslash \\ \text{H} \quad \quad \text{H} \end{array}$	$\text{H}_2\text{C}=\text{CH}_2$	ethylene
Alkyne	$-\text{C}\equiv\text{C}-$	$\text{H}-\text{C}\equiv\text{C}-\text{H}$	$\text{HC}\equiv\text{CH}$	acetylene
Aromatic		$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \quad \backslash \quad / \\ \quad \text{C}-\text{C} \\ \quad / \quad \backslash \\ \text{H}-\text{C} \quad \quad \text{C}-\text{H} \\ \quad \backslash \quad / \\ \quad \text{C}=\text{C} \\ \quad / \quad \backslash \\ \text{H} \quad \quad \text{H} \end{array}$		benzene
Alcohol	$-\text{C}-\text{O}-\text{H}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\text{CH}_3\text{CH}_2-\text{OH}$	ethyl alcohol
Ether	$-\text{C}-\text{O}-\text{C}-$	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{O}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array}$	$\text{CH}_3-\text{O}-\text{CH}_3$	dimethyl ether
Amine	$-\text{N}-\text{H}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$	CH_3-NH_2	methylamine
Aldehyde	$-\text{C}-\text{H}$	$\begin{array}{c} \text{O} \\ \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	acetaldehyde
Ketone	$-\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{C}-$	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array}$	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_3$	acetone
Carboxylic acid	$-\text{C}-\text{O}-\text{H}$	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array}$	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	acetic acid
Ester	$-\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{C}-$	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \quad \text{H} \end{array}$	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_3$	methyl acetate
Amide	$-\text{C}-\overset{\text{O}}{\parallel}{\text{N}}-\text{H}$	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{NH}_2$	acetamide

Table 21.5
Classes of Organic Compounds

Compound Class	General Formula	Functional Group	Names*
Alcohol	R—OH	—OH	Alkyl group + <i>alcohol</i> ; methyl alcohol Alkane prefix + <i>-ol</i> : methanol
Ether	R—O—R'		Name both alkyl groups + <i>ether</i> : ethyl methyl ether Alkyl group + <i>-oxy-</i> + alkane: methoxyethane
Aldehyde	R—CHO		Common prefix + <i>-aldehyde</i> : formaldehyde Alkane prefix + <i>-al</i> : methanal
Ketone	R—CO—R'		Name both alkyl groups + <i>ketone</i> : methyl ethyl ketone; methyl <i>n</i> -propyl ketone (Number carbonyl carbon) + alkane prefix + <i>-one</i> : butanone; 2-pentanone
Acid	R—COOH		Common name + acid: formic acid Alkane prefix + <i>-oic</i> + <i>acid</i> : methanoic acid
Ester	R—CO—OR'		Alcohol alkyl group + acid anion: methyl acetate Alcohol alkyl group + acid alkane prefix + <i>-oate</i> : methyl ethanoate
Amine	RNH ₂ R ₂ NH R ₃ N		Name alkyl group(s) + <i>-amine</i> : methylamine <i>Amino-</i> + alkane: aminomethane
Amide	R—CONH ₂		Common acid prefix + <i>-amide</i> : formamide Alkane prefix + <i>-amide</i> : methanamide

*Common name followed by IUPAC name.

FUNCTIONAL GROUP KEY

CH ₃ CH ₂ CH ₃	CH ₃ COOH	CH ₃ COH	CHCH	CH ₃ CH ₂ OH	CH ₃ CHCH ₂	CH ₃ COCH ₃	CH ₃ CH ₂ NH ₂
1	2	3	4	5	6	7	8

Classify these ten molecules and write the number of the molecule into the box.

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graph TD
    Root[Molecule is a hydrocarbon. / Molecule is not a hydrocarbon.]
    Root --> HC[Molecule is a hydrocarbon.]
    Root --> NonHC[Molecule is not a hydrocarbon.]
    
    HC --> Alkane[Only has single bonded carbon atoms.]
    HC --> Alkene[Has a sp2-hybridized carbon.]
    HC --> Alkyne[Does not have a sp2-hybridized carbon but a sp-hybridized carbon.]
    
    Alkane --> AlkaneBox[alkane]
    Alkene --> AlkeneBox[alkene]
    Alkyne --> AlkyneBox[alkyne]
    
    NonHC --> Amide[Has a nitrogen atom.]
    NonHC --> NoN[Does not have a nitrogen atom.]
    
    Amide --> Amide1[The carbon atom bonded to the nitrogen atom is also double bonded to an oxygen atom.]
    Amide --> Amide2[The carbon atom bonded to the nitrogen atom is not also double bonded to an oxygen atom.]
    
    Amide1 --> AmideBox[amide]
    Amide2 --> AmineBox[amine]
    
    NoN --> TwoO[Has two oxygen atoms.]
    NoN --> NoTwoO[Does not have two oxygen atoms.]
    
    TwoO --> Alcohol[Has an oxygen atom bonded to a sp3-hybridized carbon atom.]
    TwoO --> Carbonyl[Has an oxygen atom not bonded to a sp2-hybridized carbon atom.]
    
    Alcohol --> AlcoholBox[alcohol]
    
    Carbonyl --> Carboxylic[Has C=O with an OH group.]
    Carbonyl --> Ester[Has C=O without an OH group.]
    Carbonyl --> Ketone[C atom in C=O is bonded to two other carbon atoms.]
    Carbonyl --> Aldehyde[C atom in C=O is not bonded to two other carbon atoms.]
    
    Carboxylic --> CarboxylicBox[carboxylic acid]
    Ester --> EsterBox[ester]
    Ketone --> KetoneBox[ketone]
    Aldehyde --> AldehydeBox[aldehyde]
    
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CH ₃ COOCH ₃	CH ₃ CONH ₂
9	10

Figure 1. The classification key and exercise for functional groups.

Appendix

Glossary

Hydrocarbon—a molecule that contains only hydrogen (H) and carbon (C) atoms.

sp^2 -Hybridized—consists of double bonds, e.g. C=C. Only two of the three p orbitals are used to form sp^2 hybrid orbitals; bond angle is 120° ; consists of one sigma (σ) bond and one pi (π) bond.

sp^3 -Hybridized—consists of single bonds, e.g. C-C. A set of hybrid orbitals constructed from one s orbital and three p orbitals; bond angle is 109.5° ; consists of one σ bond.

sp -Hybridized—consists of triple bonds, e.g. C \equiv C. The hybrid orbital consists of only one of the three p orbitals; consists of one σ bond and two π bonds; bond angle is 180° .

Hybrid orbitals—orbitals used to describe bonding, obtained by taking combinations of atomic orbitals of the isolated atoms.

Sigma (σ) bond—has a cylindrical shape about the bond axis. Formed either when two s orbitals overlap or when an orbital with directional character, such as a p orbital or a hybrid orbital, overlaps another orbital along the interatomic axis.

Pi (π) bond—has an electron distribution above and below the bond axis.

OH—hydroxyl group.

C=O—carbonyl group.

-NH₂—amino group.

Annotated Answer Key

A. Alkane

1. example is propane [C₃H₈], 1
2. single-bonded C atoms
3. saturated C atoms
4. carbon atoms can be bonded in chains or rings
5. sp^3 -hybridized carbon atoms
6. bonded either to other carbon atoms or to hydrogen atoms
7. each compound's name has suffix -ane
8. have densities between 0.6 and 0.8 g cm⁻³
9. pure alkanes are colorless, tasteless, and nearly odorless
10. nonpolar
11. not soluble in water
12. general formula C_nH_{2n+2} when bonded in a chain
13. low-molecular-weight alkanes are gaseous fuels at room temperature (methane, propane, ethane, butane)
14. rotate freely when bonded in a chain
15. undergo halogenation and oxidation reactions

B. Alkene

- B1. example is propene (methylene) [C₃H₆ or CH₂=CH-CH₂], 6
- B2. unsaturated carbon atoms
- B3. double-bonded carbon atoms
- B4. general formula C_nH_{2n}
- B5. insoluble in water
- B6. soluble in nonpolar solvents
- B7. each compound's name has suffix -ene
- B8. restricted rotation
- B9. geometric isomers
- B10. undergo addition of HX to the double bond and hydrogenation

C. Alkyne

- C1. example is ethyne [C₂H₂], 4
- C2. each compound's name has suffix -yne
- C3. triple-bonded carbon atoms
- C4. sp -hybridized
- C5. bond angle 180°
- C6. unsaturated carbon atoms
- C7. undergo hydrogenation and halogenation
- C8. general formula C_nH_{2n-2}

D. Amide

- D1. example is ethanamide [CH₃CONH₂], 10
- D2. form strong intermolecular hydrogen bonds between the amide hydrogen atom of one molecule and the carbonyl oxygen atom of a second molecule, resulting in high melting and boiling points
- D3. amides with low molecular weights dissolve in water
- D4. nitrogen atom is bonded to an sp^2 -hybridized carbon atom

E. Amine

- E1. example is ethanamine or ethylamine [CH₃CH₂NH₂], 8
- E2. derivative of ammonia in which one or more hydrogen atoms are replaced by alkyl or aryl groups
- E3. nitrogen atom is bonded to an sp^3 -hybridized carbon atom
- E4. smells like dead fish

F. Carboxylic acid

- F1. example is ethanoic (acetic) acid [CH₃COOH], 2
- F2. contains carbonyl group and -OH group attached to the carbonyl carbon
- F3. each compound's name has suffix -oic and term acid
- F4. undergo neutralization of base, esterification, and high-temperature decomposition reactions

G. Ester

- G1. example is methyl ethanoate [CH₃COOCH₃], 9
- G2. the carbonyl carbon atom is bonded to an alkoxy group such as -OCH₃
- G3. undergo acid hydrolysis and saponification reactions
- G4. smells sweet

H. Alcohol

- H1. example is ethanol [CH₃CH₂OH], 5
- H2. each compound's name has suffix -ol
- H3. organic compound with hydroxyl group bonded to sp^3 -hybridized carbon atom
- H4. undergo oxidation to form aldehydes or ketones, dehydration to form alkenes, formation of esters, conversion to halides

I. Ketone

- I1. example is propanone [CH₃COCH₃], 7
- I2. carbonyl group C=O
- I3. each compound's name has suffix -one
- I4. undergo reactions with Grignard reagents, HCN, and alcohols

J. Aldehyde

- J1. example given is ethanal (acetaldehyde) [CH₃CHO], 3
- J2. contains carbonyl group
- J3. compound's name has suffix -al
- J4. bond angles around the carbonyl carbon atom are approximately 120° ; sp^2 -hybridized C
- J5. the lower-molecular-weight compounds dissolve in water in all proportions
- J6. undergo reactions with Grignard reagents, HCN, and alcohols