Functional Groups

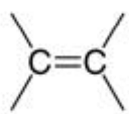
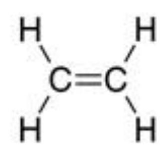
- A functional group is an atom or a group of atoms with characteristic chemical and physical properties. It is the reactive part of a molecule.
- Organic compounds having only C—C and C—H bonds are called Hydrocarbons. There are four classes of hydrocarbons: alkanes, alkenes, akynes and aromatics. Alkanes are saturated structures and the others contain some unsaturations.
- Many organic molecules contain atoms <u>other than</u> carbon or hydrogen.

Organic Molecules and Functional Groups

Functional Groups: Hydrocarbons

Hydrocarbons are compounds made up of only the elements carbon and hydrogen. They may be aliphatic or aromatic.

Table 3.1 **Hydrocarbons**

Type of compound	General structure	Example	Functional group
Alkane	R—H	CH_3CH_3	– –
Alkene			double bond
Alkyne	—C≡C—	H—C≡C—H	triple bond
Aromatic compound			phenyl group

Organic Molecules and Functional Groups

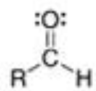
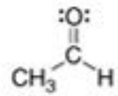
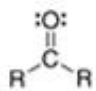
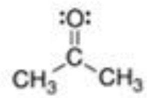
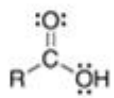
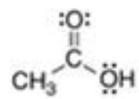
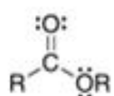
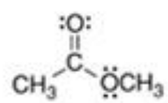
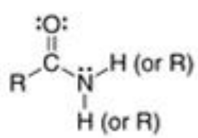
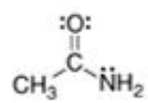
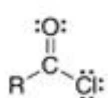
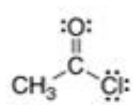
Functional Groups: atoms other than carbon and hydrogen

Table 3.2 Compounds Containing C–Z σ Bonds

Type of compound	General structure	Example	3-D structure	Functional group
Alkyl halide	$R-\ddot{X}:$ (X = F, Cl, Br, I)	$CH_3-\ddot{Br}:$		**–X** halo group
Alcohol	$R-\ddot{O}H$	$CH_3-\ddot{O}H$		**–OH** hydroxy group
Ether	$R-\ddot{O}-R$	$CH_3-\ddot{O}-CH_3$		**–OR** alkoxy group
Amine	$R-\ddot{N}H_2$ or $R_2\ddot{N}H$ or $R_3\ddot{N}$	$CH_3-\ddot{N}H_2$		**$-NH_2$** amino group
Thiol	$R-\ddot{S}H$	$CH_3-\ddot{S}H$		**–SH** mercapto group
Sulfide	$R-\ddot{S}-R$	$CH_3-\ddot{S}-CH_3$		**–SR** alkylthio group

Functional Groups: Carbonyl groups

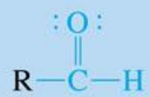
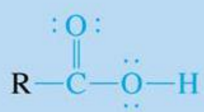
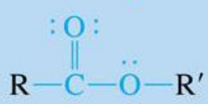
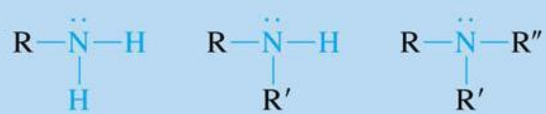
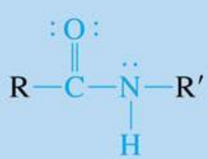
Table 3.3 **Compounds Containing a C=O Group**

Type of compound	General structure	Example	3-D structure	Functional group
Aldehyde				C=O carbonyl group
Ketone				C=O carbonyl group
Carboxylic acid				–COOH carboxy group
Ester				–COOR
Amide				$-CONH_2$, –CONHR, or $-CONR_2$
Acid chloride				–COCl

List of Organic Functional Groups

Table 24.7

Some Organic Functional Groups

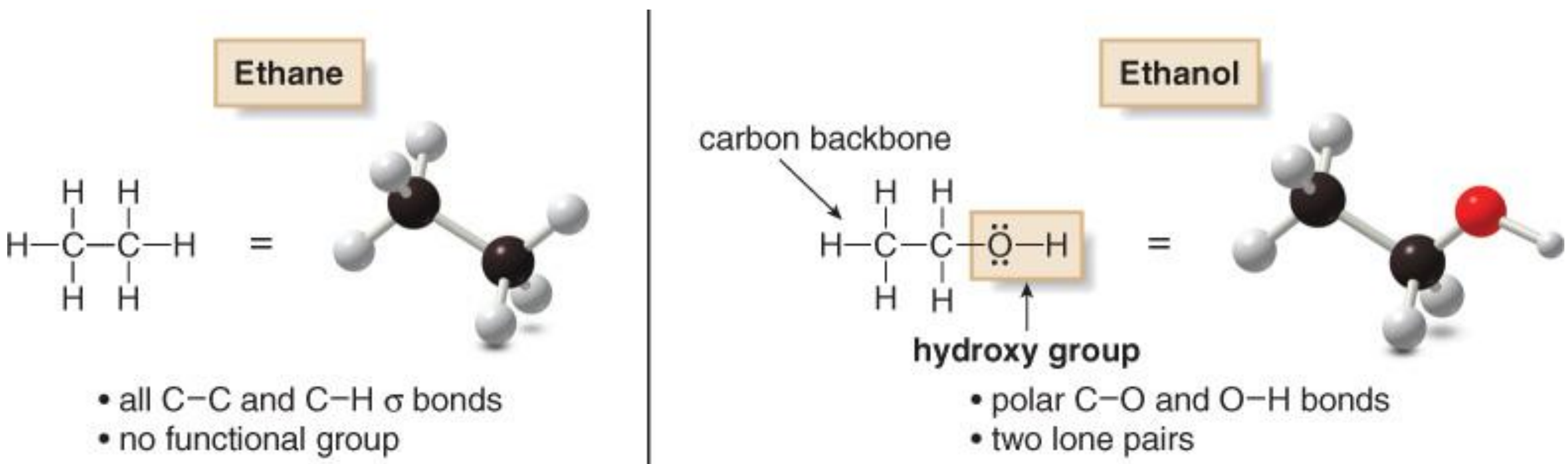
Structure of General Compound* (Functional Group in Color)	Name of Functional Group
	Organic halide
	Alcohol
	Ether
	Aldehyde
	Ketone
	Carboxylic acid
	Ester
	Amine
	Amide

*R, R′, and R″ are general hydrocarbon groups.

Organic Molecules and Functional Groups

Functional Groups:

- Ethane: This molecule has only C—C and C—H bonds, so it has no functional group. It has no polar bonds, no lone pairs, and so it has no reactive sites. It is very unreactive.
- Ethanol: This molecule has an OH group attached to its backbone. It is called a hydroxy functional group. Ethanol has lone pairs and polar bonds that make it reactive with a variety of reagents.
  - The hydroxy group makes the properties of ethanol very different from the properties of ethane.



Organic Molecules and Functional Groups

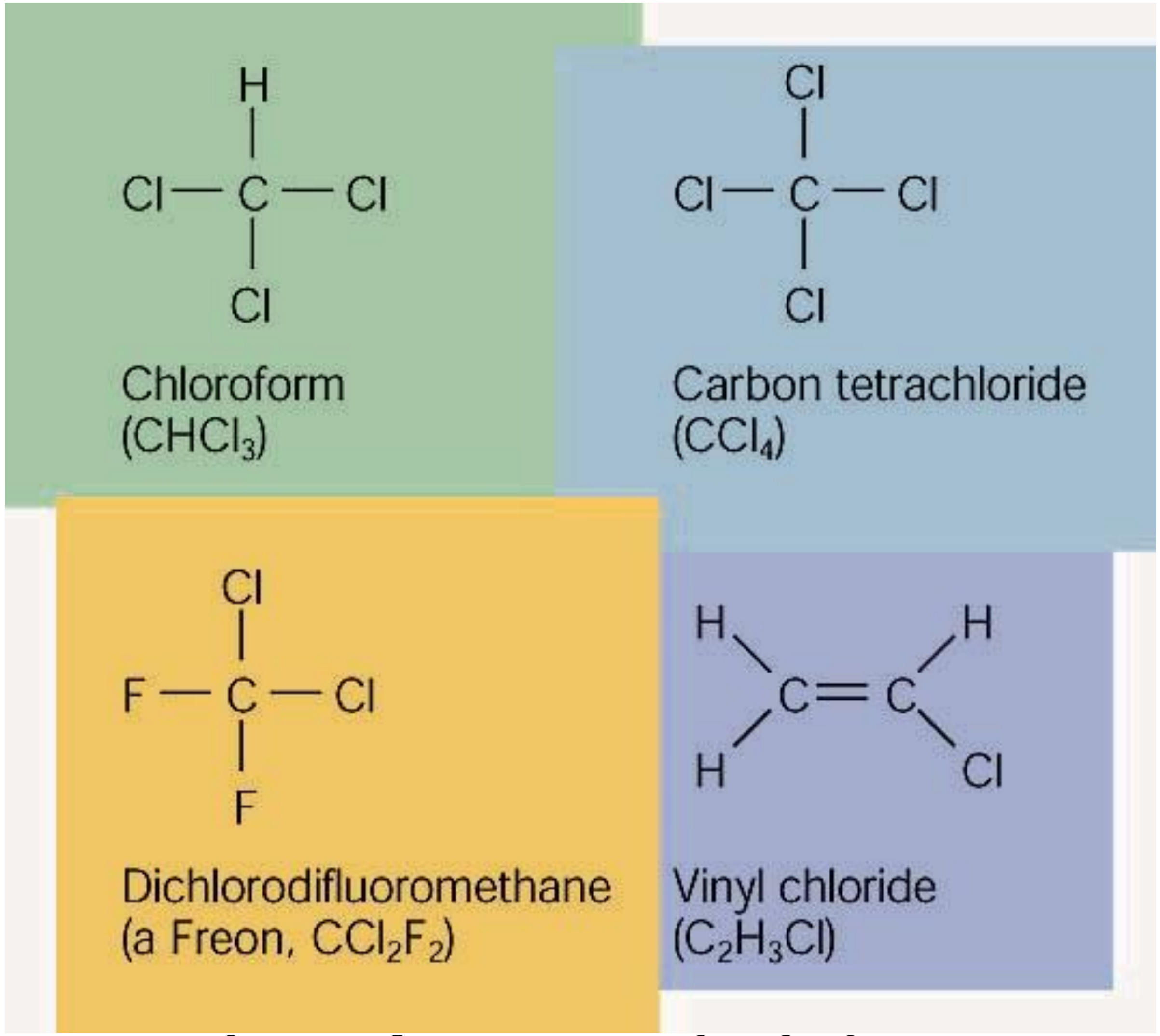
Functional Groups:

It should be noted that the importance of a functional group cannot be overstated.

A functional group determines all of the following properties of a molecule:

- Bonding and shape
- Chemical reactivity
- Type and strength of intermolecular forces
- Physical properties
- Nomenclature

Organic Halides



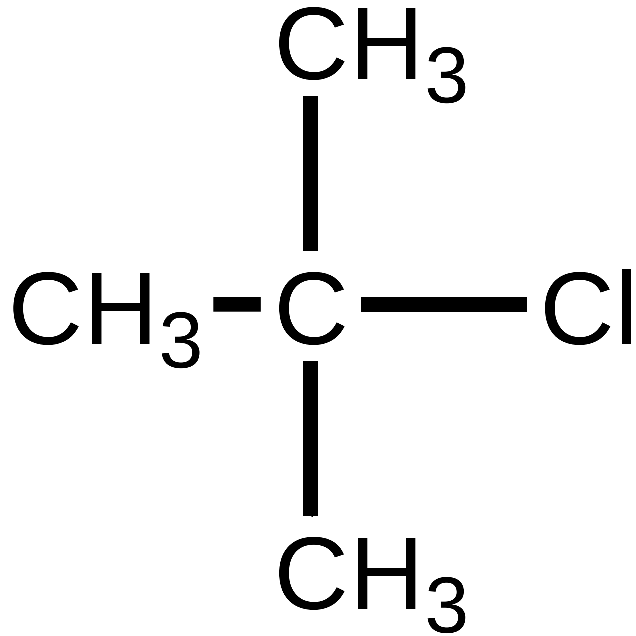
- **Common examples of organic halides**

Halogens as side groups

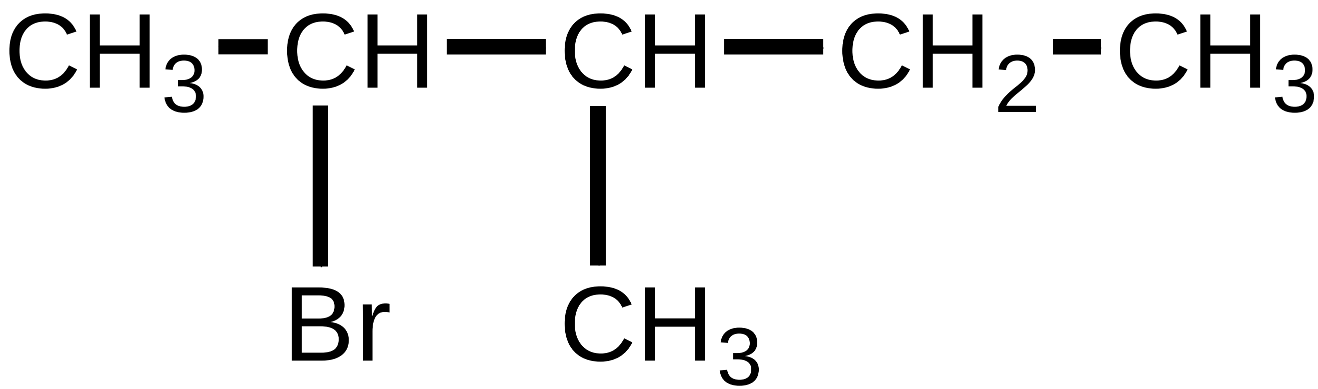
- Fluoro –F
- Chloro –Cl
- Bromo –Br
- Iodo –I

CH_3-CH_2-Br

Bromoethane

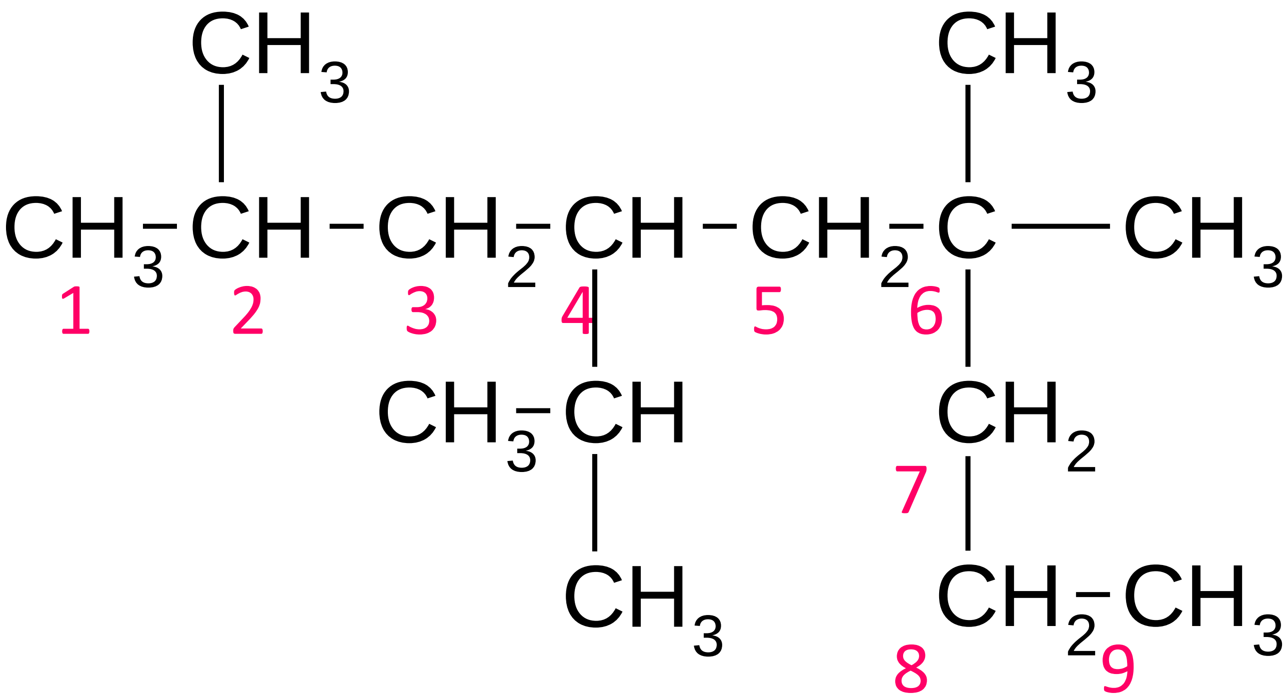


2-chloro-2-methylpropane



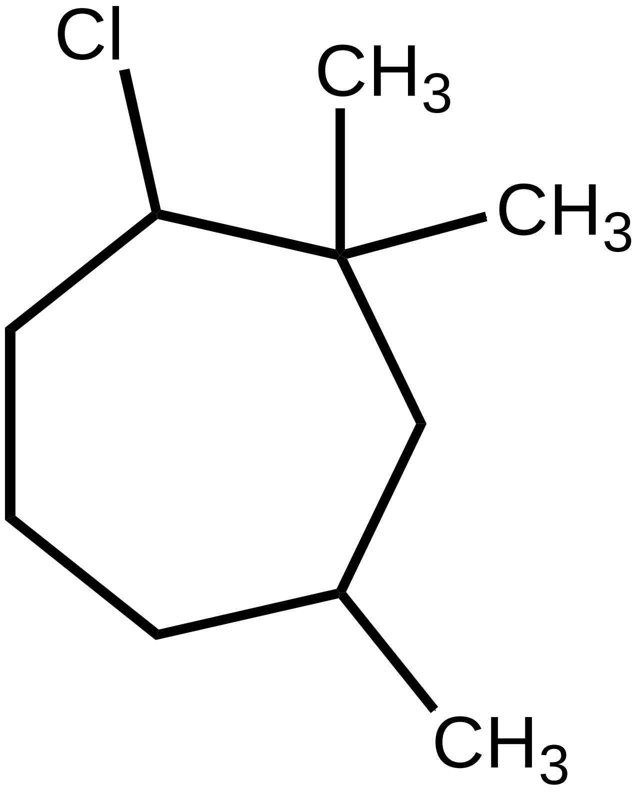
2-bromo-3-methylpentane

If you can name this, you can name almost anything!



4-isopropyl-2,6,6-trimethylnonane

Numbering Starts so that the lowest numbers are obtained and then consider the Most Complex Branch



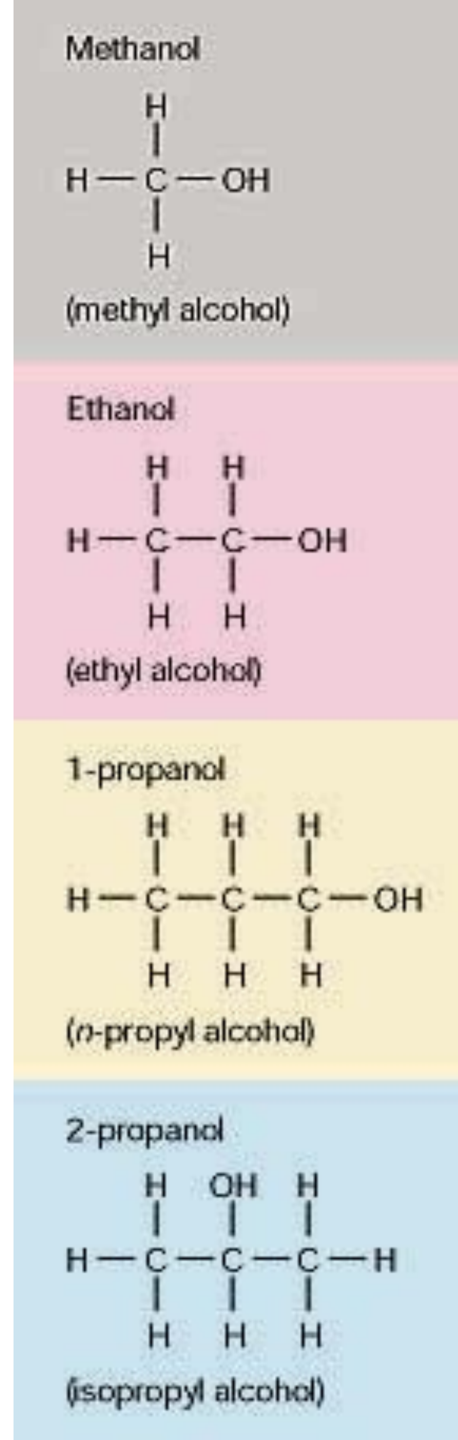
1-chloro-2,2,4-trimethylcycloheptane

Remember! Common Nomenclature Pitfalls

- Did not find the longest carbon chain
- Numbered chain from the wrong end
- Forgot to repeat number for each identical substituent; forgot to use di- tri- tetra-, etc.
- Confusing propyl / isopropyl, etc.
- Writing the name as more than one word
- Incorrect punctuation

- ## Alcohols
  - An alcohol has a hydrogen replaced by a **hydroxyl** (-OH) group.
  - The name of the hydrocarbon that was substituted determines the name of the alcohol.
  - The alcohol is named using the hydrocarbon name and adding the suffix –ol.
    - If methane is substituted with an OH group it becomes **methanol**
    - If a pentane group is substituted with an OH group it is **pentanol**.
    - For alcohols with more than two carbon atoms we need to number the chain so as to keep the alcohol group as low as possible.

- **Four different alcohols. The IUPAC name is given above each structural formula, and the common name is given below.**

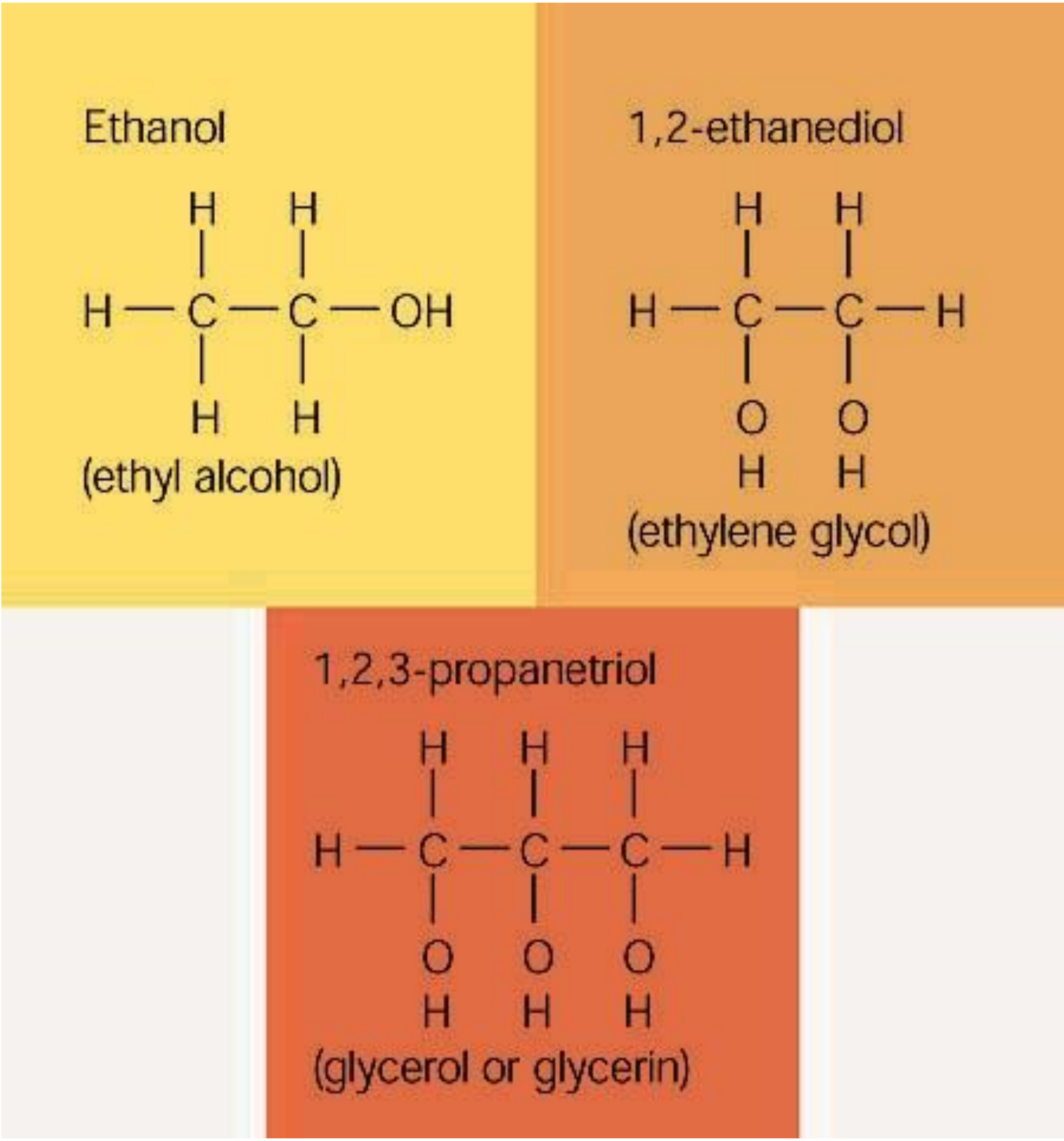


- The OH group is polar and short chain alcohols are soluble in both **nonpolar** alkanes and water (**polar** molecule).

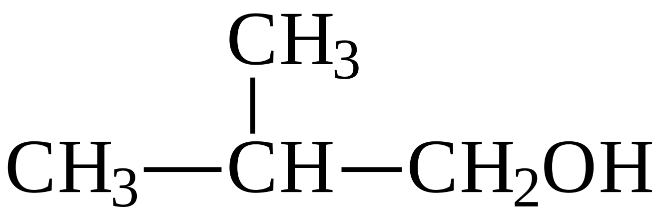
- If an alcohol contains two OH groups it is a **diol** (sometimes called a glycol).

- An alcohol with three OH groups is called a **triol** (sometimes called a glycerol).

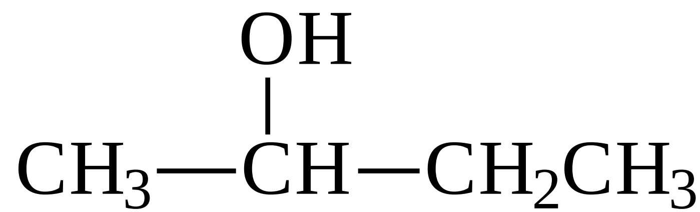
- Common examples of alcohols with one, two, and three hydroxyl groups per molecule. The IUPAC name is given above each structural formula, and the common name is given below.



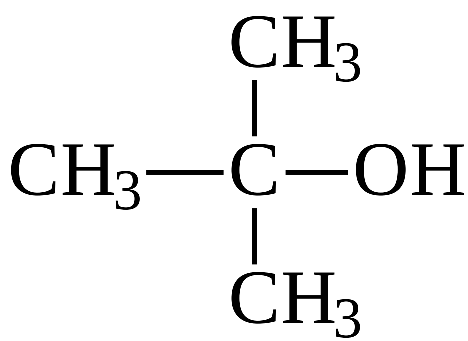
Name these:



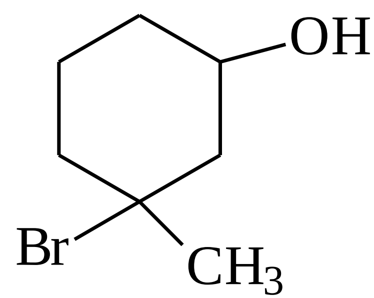
2-methyl-1-propanol



2-butanol



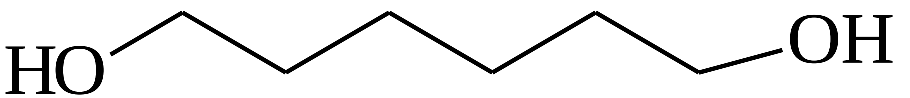
2-methyl-2-propanol



3-bromo-3-methylcyclohexanol

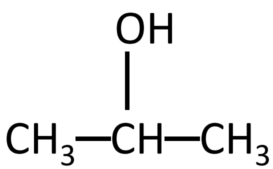
More Practice

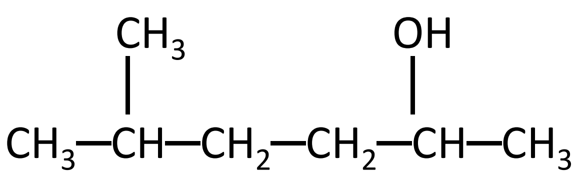
1,6-hexanediol



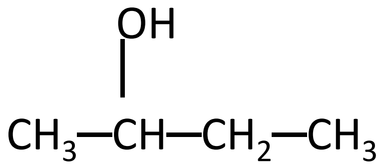
Naming Alcohols

$CH_3-CH_2-CH_2-OH$ 1-propanol

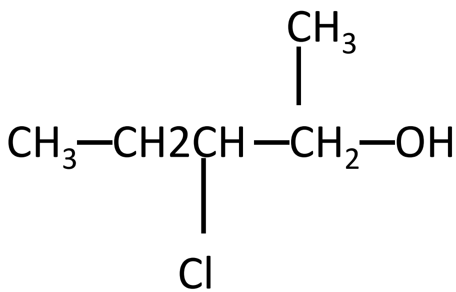

2-propanol


5-methyl-2-hexanol

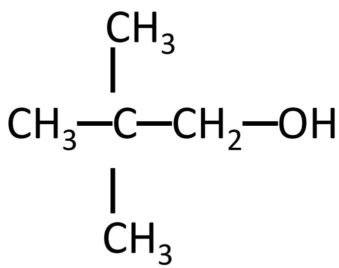
Naming Alcohols



2-butanol



3-chloro-2-methyl-1-butanol



2,2-dimethyl-1-propanol

Unsaturated Alcohols

- Hydroxyl group takes precedence unless you name it as a branch.
- Use alkene or alkyne name.

4-penten-2-ol (old)

Or 4-hydroxy-1-pentene

pent-4-ene-2-ol

(1997 revision of IUPAC rules)

Alcohols

– alcohols are also classified as primary (1°), secondary (2°), or tertiary (3°) depending on the number of carbon atoms bonded to the carbon bearing the -OH group

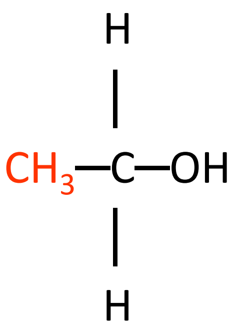
Classification

- Primary: carbon with –OH is bonded to one other carbon.
- Secondary: carbon with –OH is bonded to two other carbons.
- Tertiary: carbon with –OH is bonded to three other carbons.
- Aromatic (phenol): -OH is bonded to a benzene ring.

=>

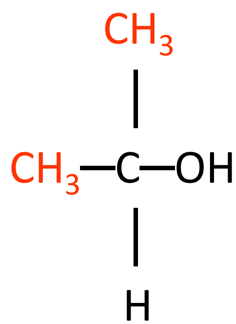
Different types of Alcohols

Primary (1º)



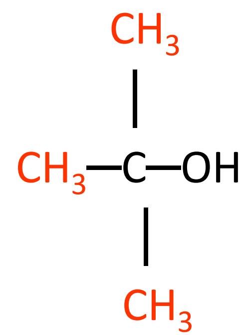
1 C
attached
to C-OH

Secondary (2º)



2 C
attached
to C-OH

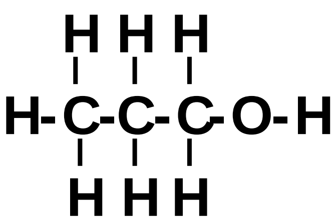
Tertiary (3º)



3 C
attached
to C-OH

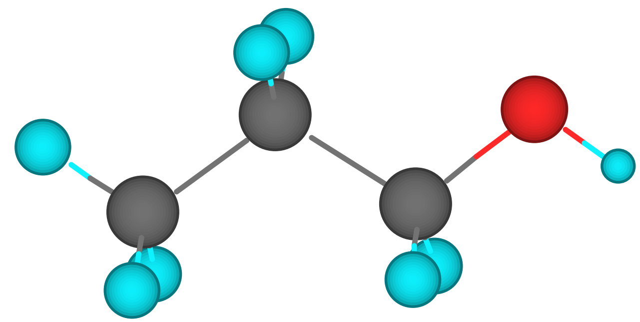
Alcohols

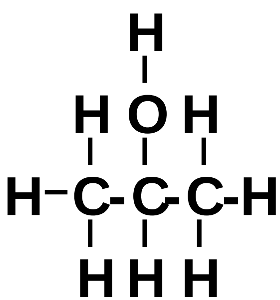
– there are two alcohols with molecular formula C_3H_8O



or $CH_3CH_2CH_2OH$

a 1° alcohol

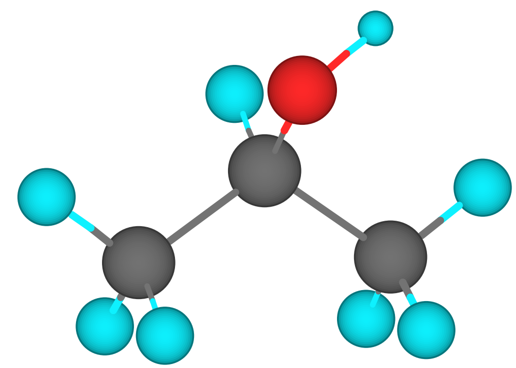




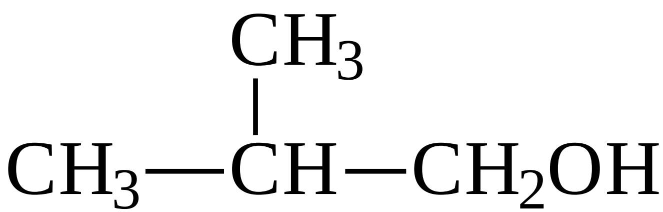
or

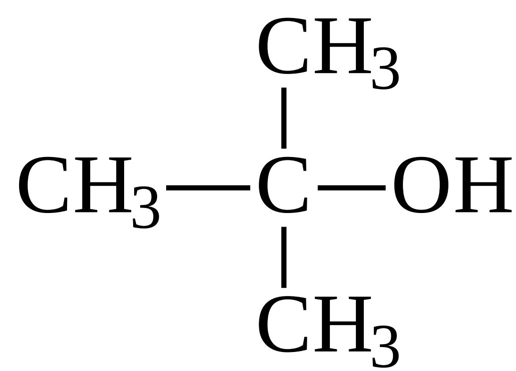
OH
CH_3CHCH_3

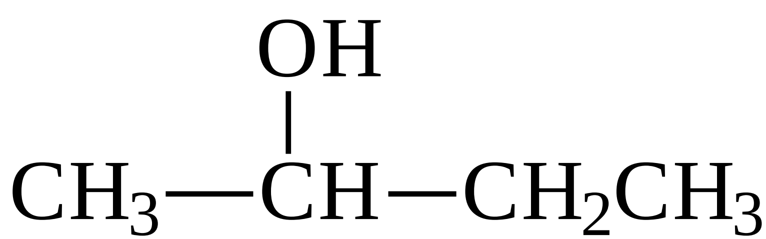
a 2° alcohol



Name and Classify these:







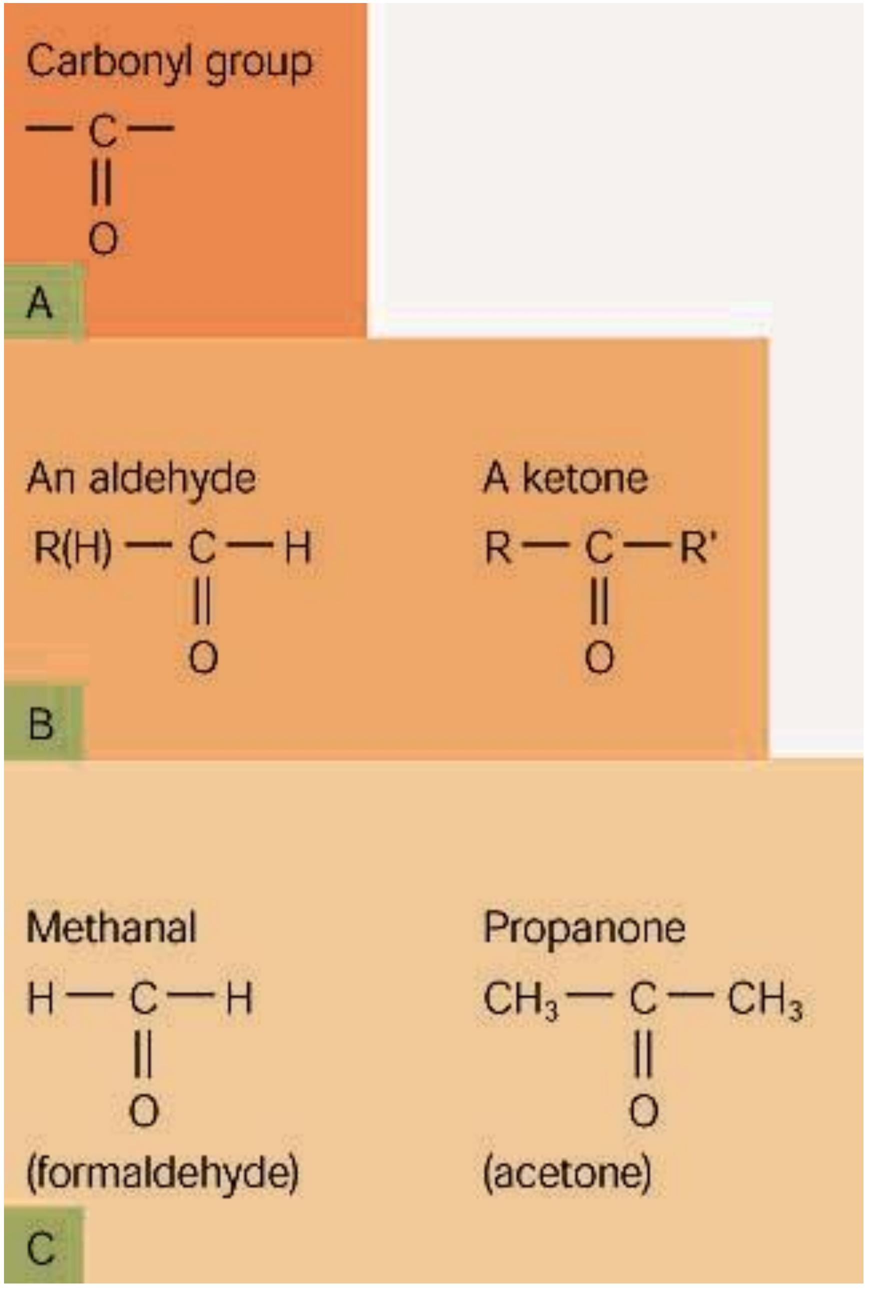
• Ethers, Aldehydes, and Ketones

– An **ether** has a general formula ROR’
  - Diethyl ether, for example, would have the following formula
  - The proper IUPAC name is ethoxy ethane.
  - $CH_3CH_2OCH_2CH_3$

– An **aldehyde** has a carbonyl group (carbon double bonded to an oxygen) attached to an end carbon atom

– A **ketone** has a carbonyl group attached to an internal carbon atom.

- The carbonyl group (A) is present in both aldehydes and ketones, as shown in (B).
- (C) The simplest example of each, with the IUPAC name above and the common name below each formula.



- # Organic Acids and Esters
  - **Carboxylic acids or Organic acids** are those acids that are derived from living organisms, usually from metabolism, but sometimes as a defense mechanism.
  - Long chain organic acids are known as fatty acids.
  - These are also called carboxylic acids as they contain the carboxyl functional group (COOH)
    - One oxygen is double bonded to the carbon and the other is bonded to the carbon and to the hydrogen both with single bonds.
  - **Esters** are condensation products of carboxylic acids with the removal of water (also called a dehydration synthesis).

- These red ants, like other ants, make the simplest of the organic acids, formic acid. The sting of bees, ants, and some plants contains formic acid, along with some other irritating materials. Formic acid is HCOOH.