2.17
Physical Properties of Alkanes and Cycloalkanes

Overview of attractive forces

Cation-anion	very strong
Covalent bonds	strong (140-523 kj/mol)
Ion-dipole	moderate
Hydrogen bonds	moderate to weak (4-38 kj/mol)
Dipole-dipole	weak
van der Waals	weak

Boiling Points of Alkanes

governed by strength of intermolecular attractive forces

alkanes are nonpolar, so dipole-dipole and dipole-induced dipole forces are absent

only forces of intermolecular attraction are induced dipole-induced dipole forces

Induced dipole-Induced dipole Attractive Forces

two nonpolar molecules

center of positive charge and center of negative charge coincide in each

Induced dipole-Induced dipole Attractive Forces

movement of electrons creates an instantaneous dipole in one molecule (left)

Induced dipole-Induced dipole Attractive Forces

temporary dipole in one molecule (left) induces a complementary dipole in other molecule (right)

Induced dipole-Induced dipole Attractive Forces

temporary dipole in one molecule (left) induces a complementary dipole in other molecule (right)

Induced dipole-Induced dipole Attractive Forces

the result is a small attractive force between the two molecules

Induced dipole-Induced dipole Attractive Forces

the result is a small attractive force between the two molecules

Boiling Points

Increase with increasing number of carbons

- more atoms, more electrons, more opportunities for induced dipole-induced dipole forces

Decrease with chain branching

- branched molecules are more compact with smaller surface area—fewer points of contact with other molecules

Boiling Points

Increase with increasing number of carbons

more atoms, more electrons, more opportunities for induced dipole-induced dipole forces

Heptane
bp 98°C

Octane
bp 125°C

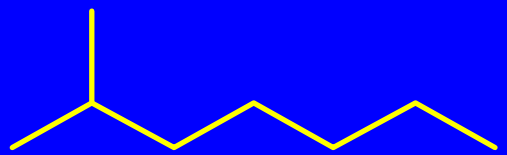
Nonane
bp 150°C

Boiling Points

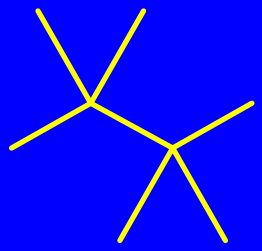
Decrease with chain branching

branched molecules are more compact with smaller surface area—fewer points of contact with other molecules

Octane: bp 125°C



2-Methylheptane: bp 118°C

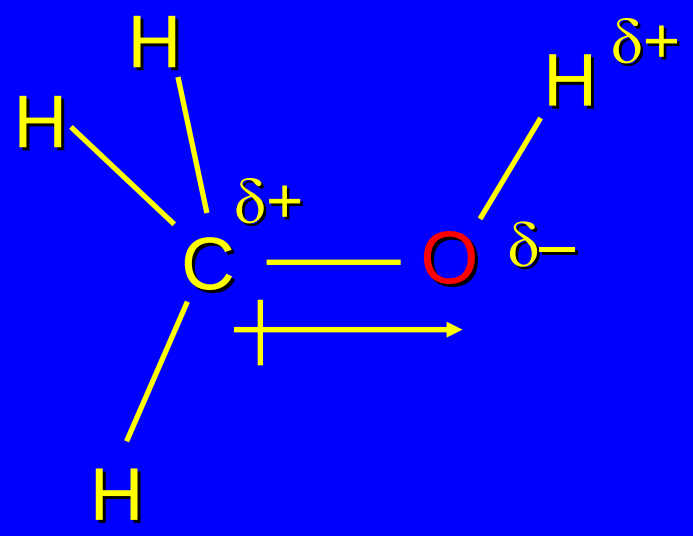


2,2,3,3-Tetramethylbutane: bp 107°C

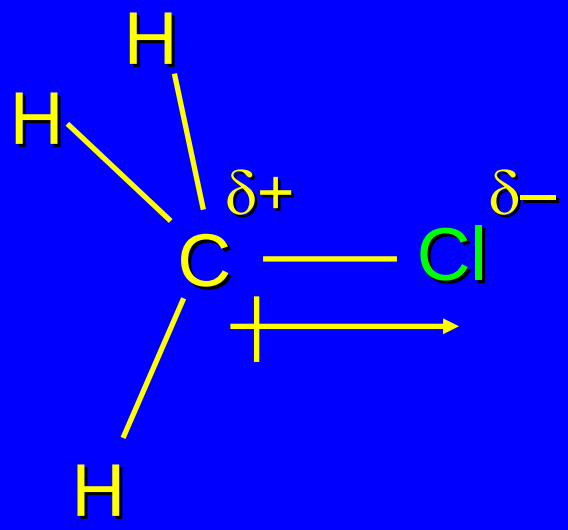
4.5
Bonding in Alcohols and Alkyl Halides

Dipole Moments

alcohols and alkyl halides are polar



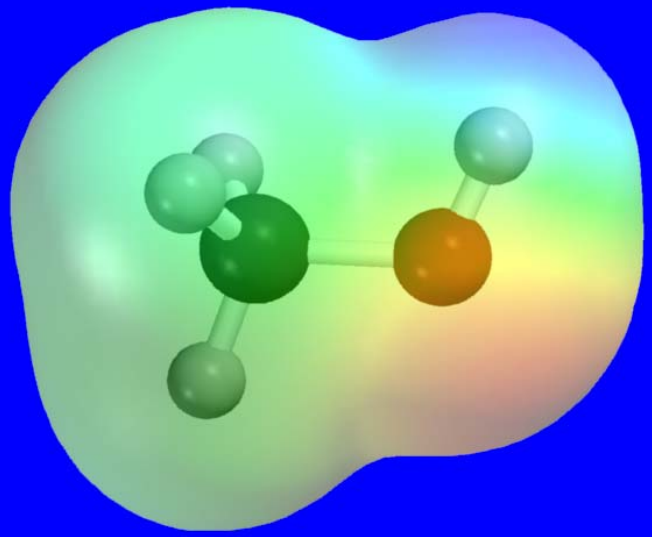
μ = 1.7 D



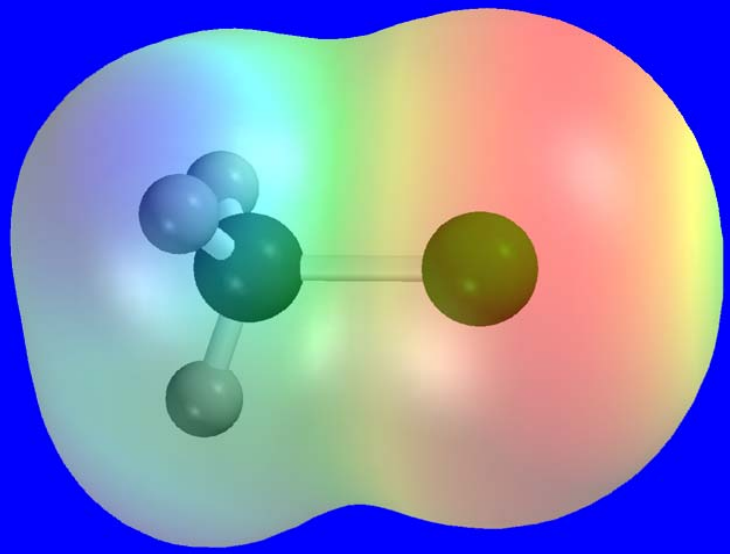
μ = 1.9 D

Dipole Moments

alcohols and alkyl halides are polar

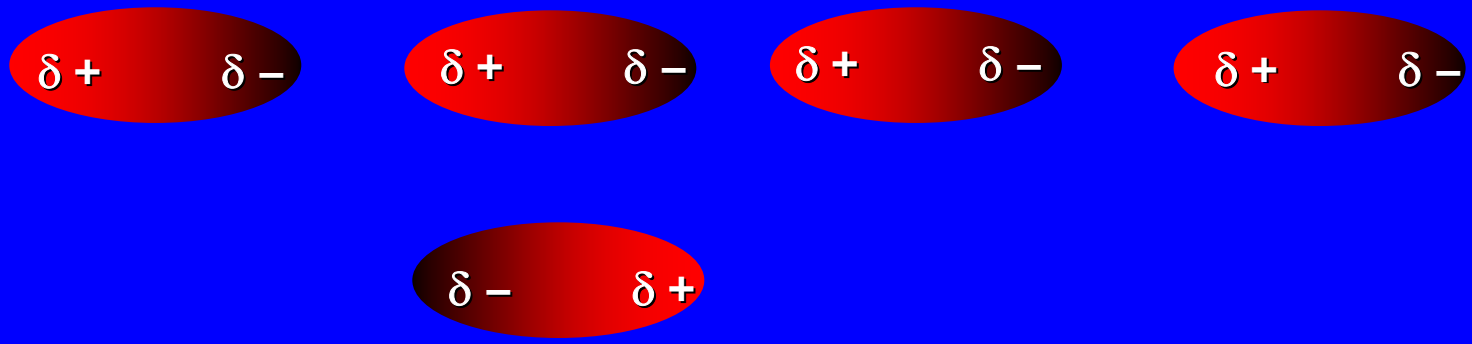


μ = 1.7 D

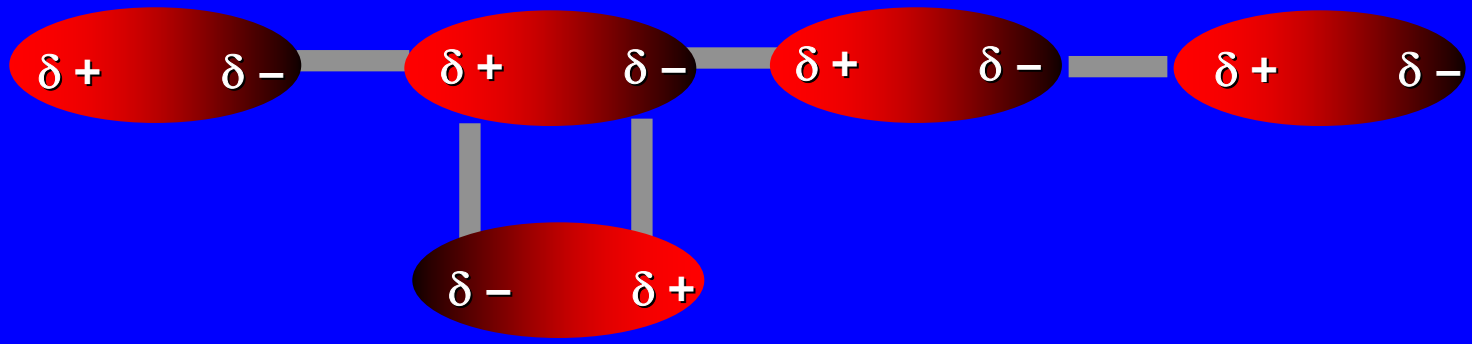


μ = 1.9 D

Dipole-Dipole Attractive Forces



Dipole-Dipole Attractive Forces



4.6
Physical Properties of Alcohols and Alkyl Halides: Intermolecular Forces

Boiling point

Solubility in water

Density

Effect of Structure on Boiling Point

	$CH_3CH_2CH_3$	CH_3CH_2F	CH_3CH_2OH
Molecular weight	44	48	46
Boiling point, °C	-42	-32	+78
Dipole moment, D	0	1.9	1.7

Effect of Structure on Boiling Point

	$CH_3CH_2CH_3$	
Molecular weight	44	Intermolecular forces are weak.
Boiling point, °C	-42	Only intermolecular forces are induced dipole-induced dipole attractions.
Dipole moment, D	0	

Effect of Structure on Boiling Point

	CH_3CH_2F
Molecular weight	48
Boiling point, °C	-32
Dipole moment, D	1.9

A polar molecule; therefore dipole-dipole and dipole-induced dipole forces contribute to intermolecular attractions.

Effect of Structure on Boiling Point

	CH_3CH_2OH
Molecular weight	46
Boiling point, °C	+78
Dipole moment, D	1.7

Highest boiling point; strongest intermolecular attractive forces.

Hydrogen bonding is stronger than other dipole-dipole attractions.

Figure 4.4 Hydrogen bonding in ethanol

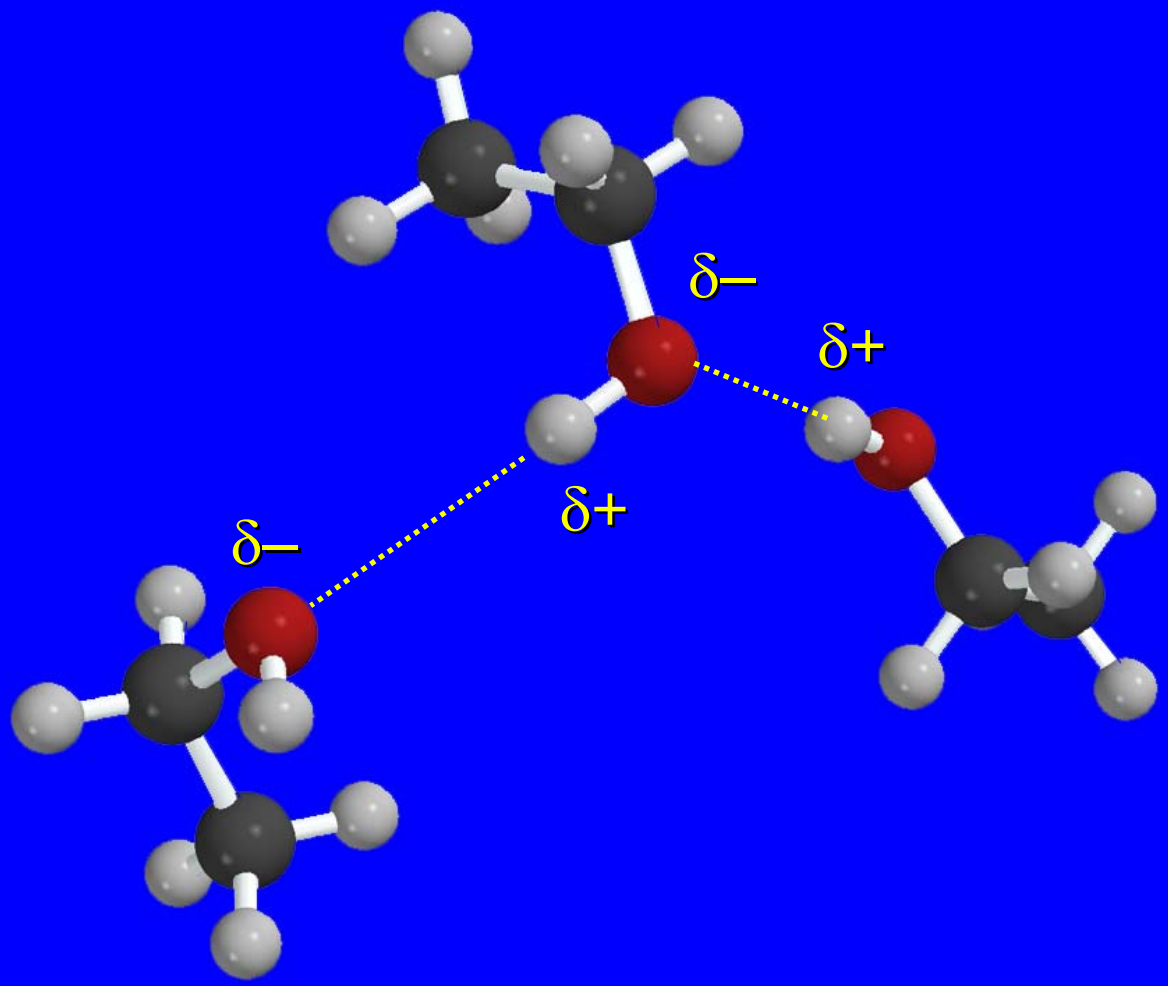
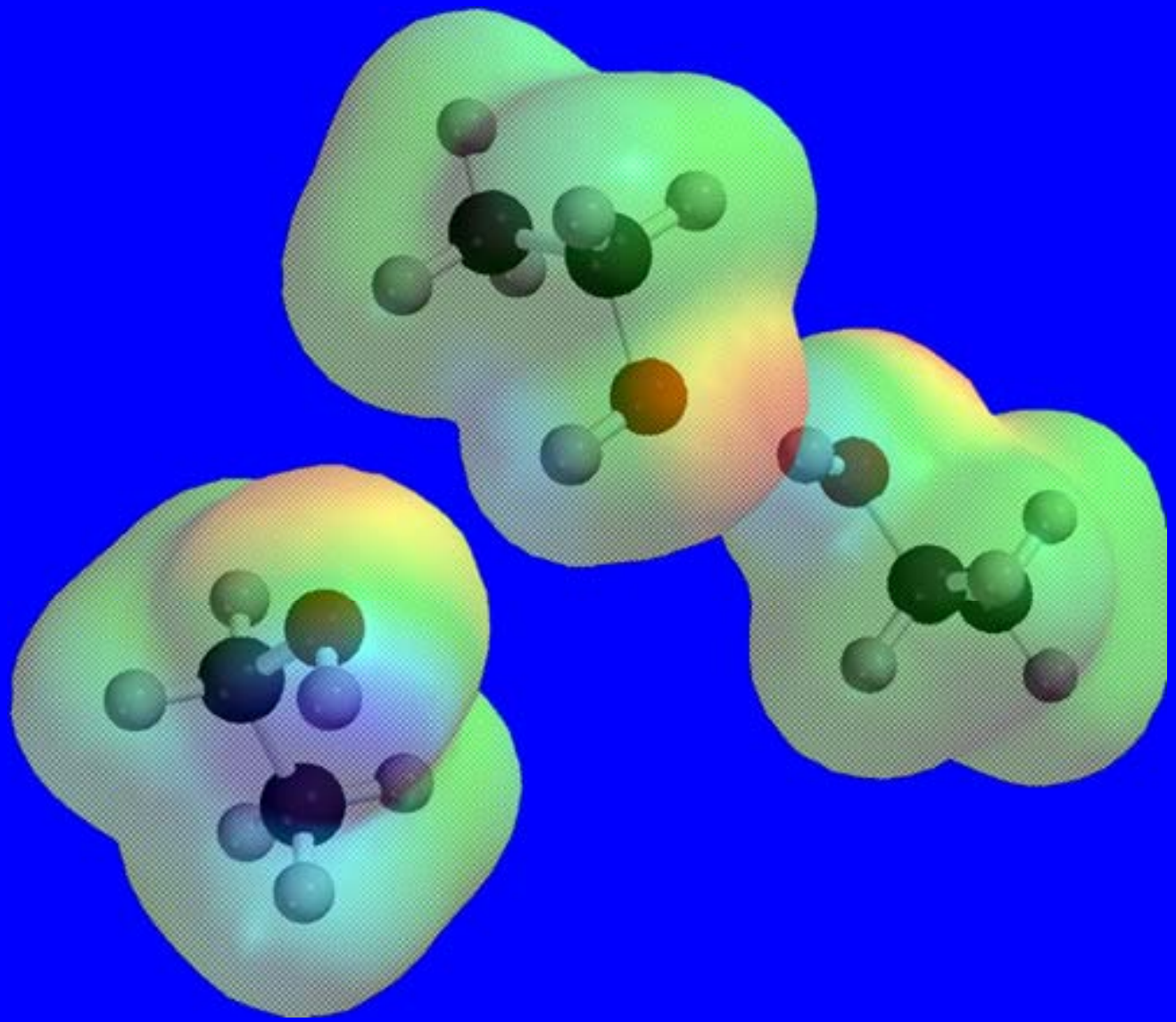


Figure 4.4 Hydrogen bonding in ethanol



Boiling point increases with increasing number of halogens

Compound	Boiling Point
CH_3Cl	-24°C
CH_2Cl_2	40°C
$CHCl_3$	61°C
CCl_4	77°C

Even though CCl_4 is the only compound in this list without a dipole moment, it has the highest boiling point.

Induced dipole-induced dipole forces are greatest in CCl_4 because it has the greatest number of Cl atoms. Cl is more polarizable than H.

But trend is not followed when halogen is fluorine

Compound	Boiling Point
CH_3CH_2F	-32°C
CH_3CHF_2	-25°C
CH_3CF_3	-47°C
CF_3CF_3	-78°C

But trend is not followed when halogen is fluorine

Compound	Boiling Point
CH_3CH_2F	-32°C
CH_3CHF_2	-25°C
CH_3CF_3	-47°C
CF_3CF_3	-78°C

Fluorine is not very polarizable and induced dipole-induced dipole forces decrease with increasing fluorine substitution.

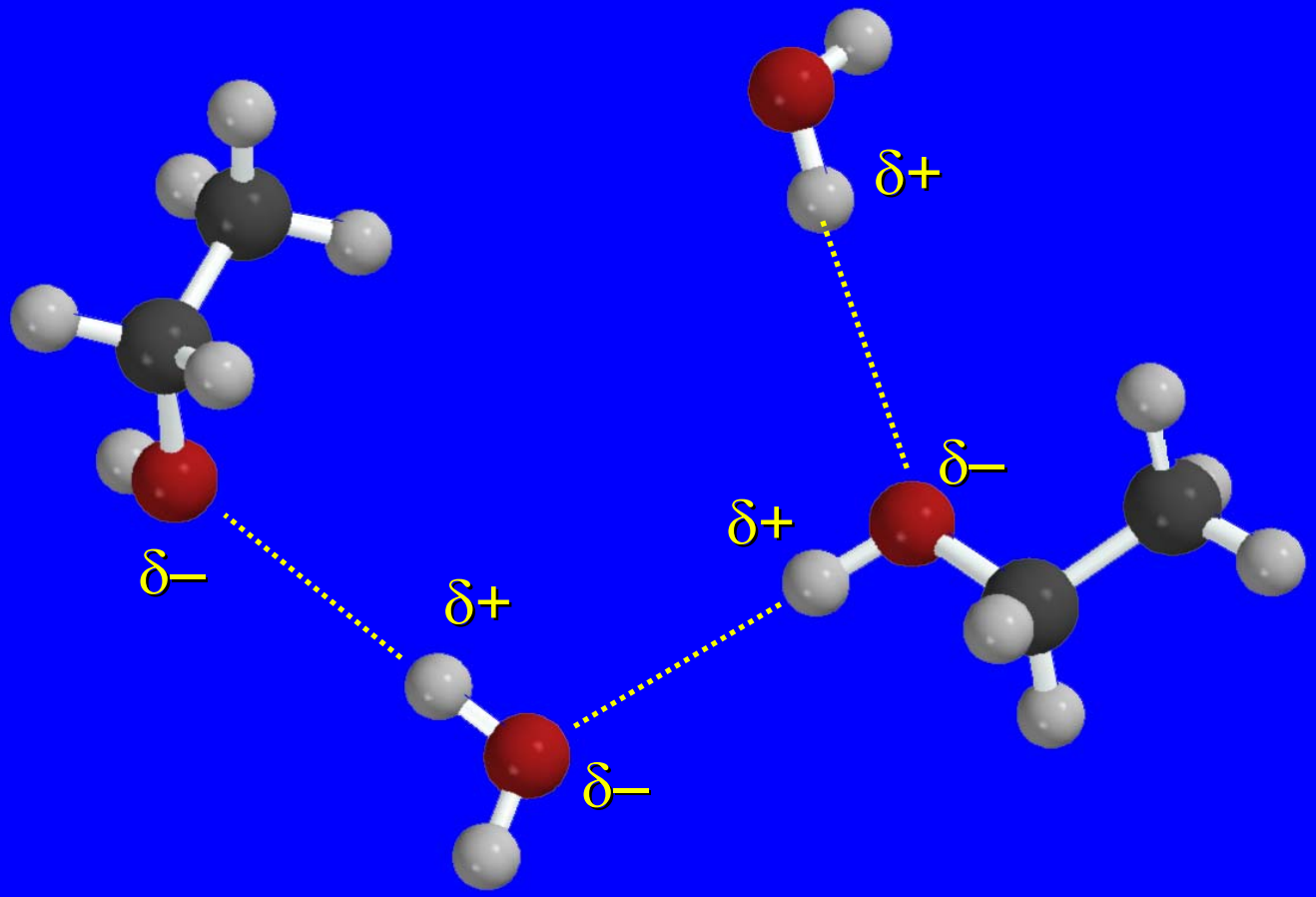
Solubility in water

Alkyl halides are insoluble in water.

Methanol, ethanol, isopropyl alcohol are completely miscible with water.

The solubility of an alcohol in water decreases with increasing number of carbons (compound becomes more hydrocarbon-like).

Figure 4.5 Hydrogen Bonding Between Ethanol and Water



4.1
Functional Groups

Functional Group

A structural unit in a molecule responsible for its characteristic behavior under a particular set of reaction conditions.

Families of Organic Compounds and their Functional Groups

Alcohol	ROH
Alkyl halide	RX (X = F, Cl, Br, I)
Amine	primary amine: RNH_2
	secondary amine: R_2NH
	tertiary amine: R_3N

Classification

Alcohols and alkyl halides are classified as

- primary
- secondary
- tertiary

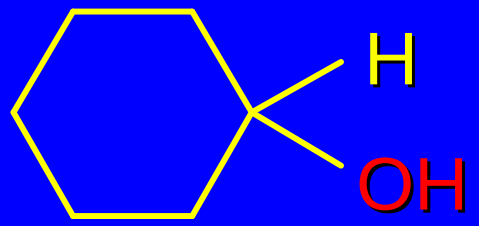
according to their "degree of substitution."

Degree of substitution is determined by counting the number of carbon atoms directly attached to the carbon that bears the halogen or hydroxyl group.

Classification

$CH_3CH_2CH_2CH_2CH_2F$

primary alkyl halide



secondary alcohol

$CH_3CHCH_2CH_2CH_3$
|
Br

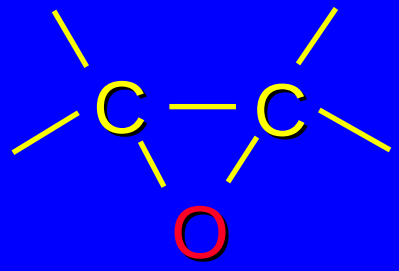
secondary alkyl halide

CH_3
|
$CH_3CCH_2CH_2CH_3$
|
OH

tertiary alcohol

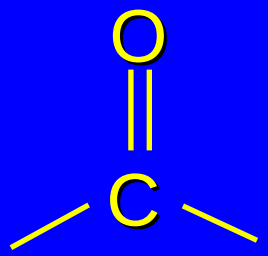
Families of Organic Compounds and their Functional Groups

Epoxide

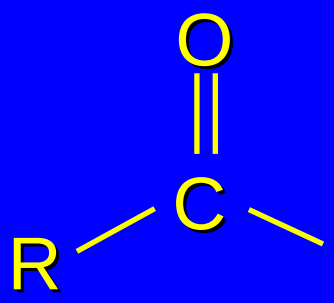


Ether	ROR'
Nitrile	RCN
Nitroalkane	RNO_2
Sulfide	RSR'
Thiol	RSH

Many Classes of Organic Compounds Contain a Carbonyl Group

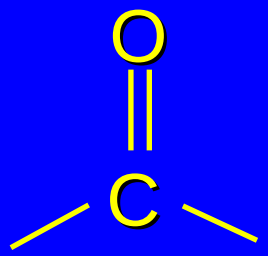


Carbonyl group

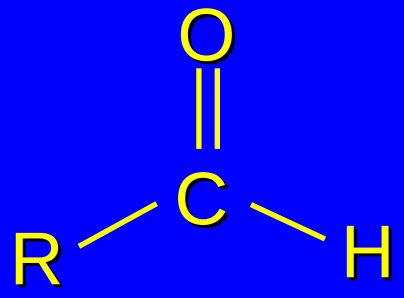


Acyl group

Many Classes of Organic Compounds Contain a Carbonyl Group

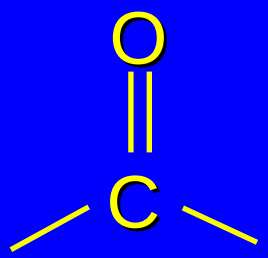


Carbonyl group

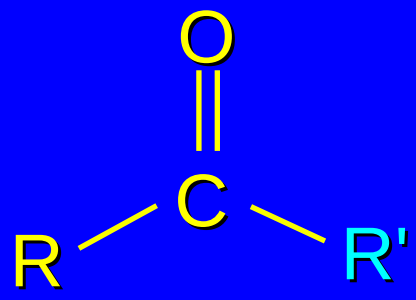


Aldehyde

Many Classes of Organic Compounds Contain a Carbonyl Group

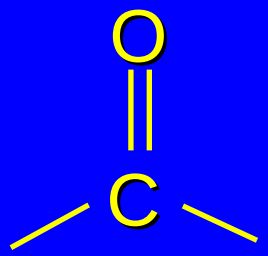


Carbonyl group

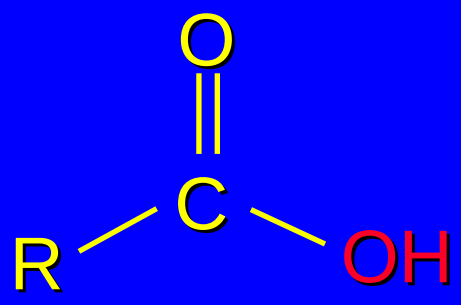


Ketone

Many Classes of Organic Compounds Contain a Carbonyl Group

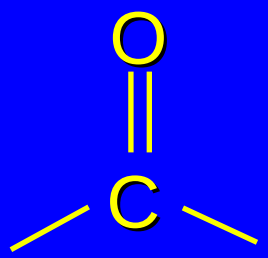


Carbonyl group

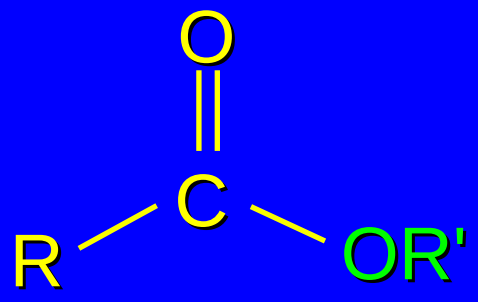


Carboxylic acid

Many Classes of Organic Compounds Contain a Carbonyl Group

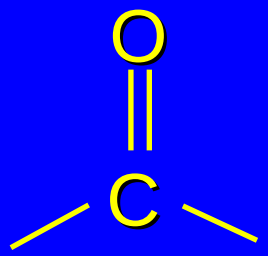


Carbonyl group

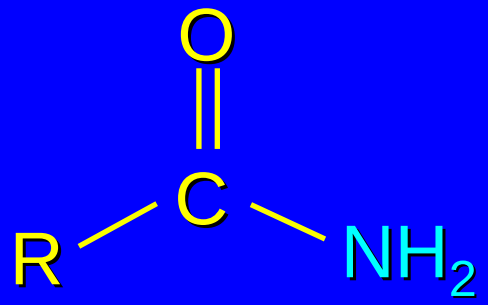


Ester

Many Classes of Organic Compounds Contain a Carbonyl Group

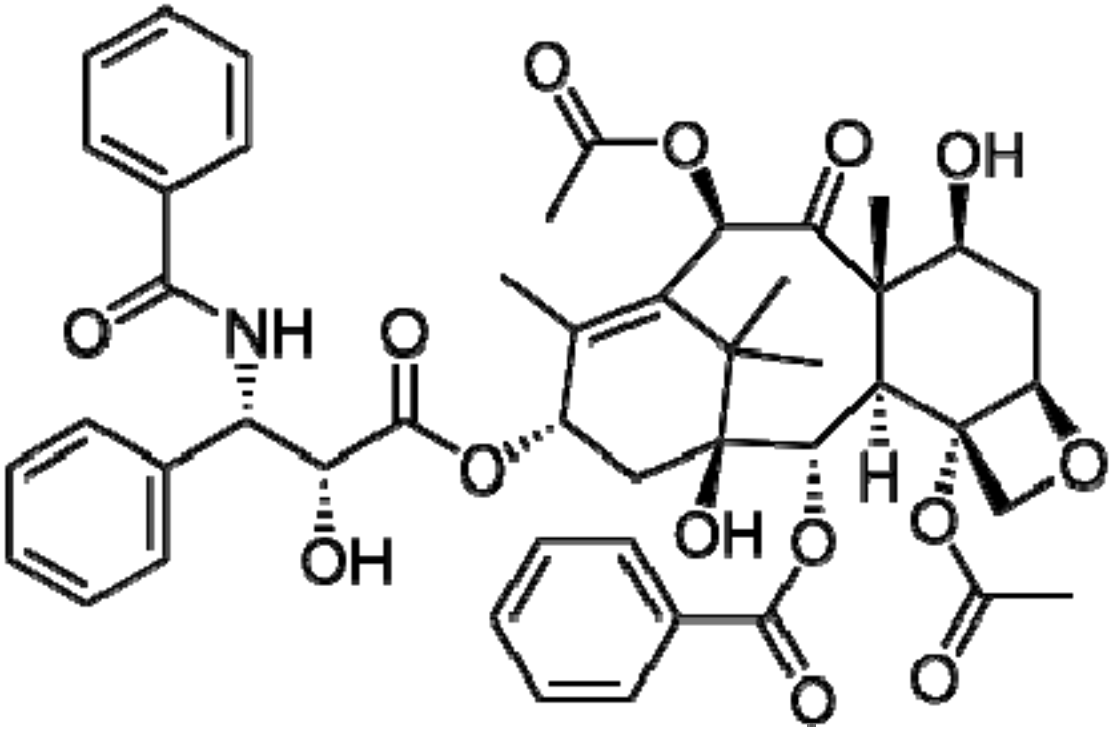


Carbonyl group



Amide

In-class exercise



Paclitaxel “taxol” is now used to treat patients with lung, ovarian, breast cancer, head and neck cancer, and advanced forms of Kaposi's sarcoma.

How many of each functional group are present:

Alkene

Phenyl ring

Alcohol

Ether

Ester

Ketone

Amide

Chapter 2 Homework Problems

- 2.20; 2.21; 2.22; 2.24; 2.25; 2.26; 2.28; 2.29; 2.33; 2.37; 2.38; 2.41; 2.42; 2.43