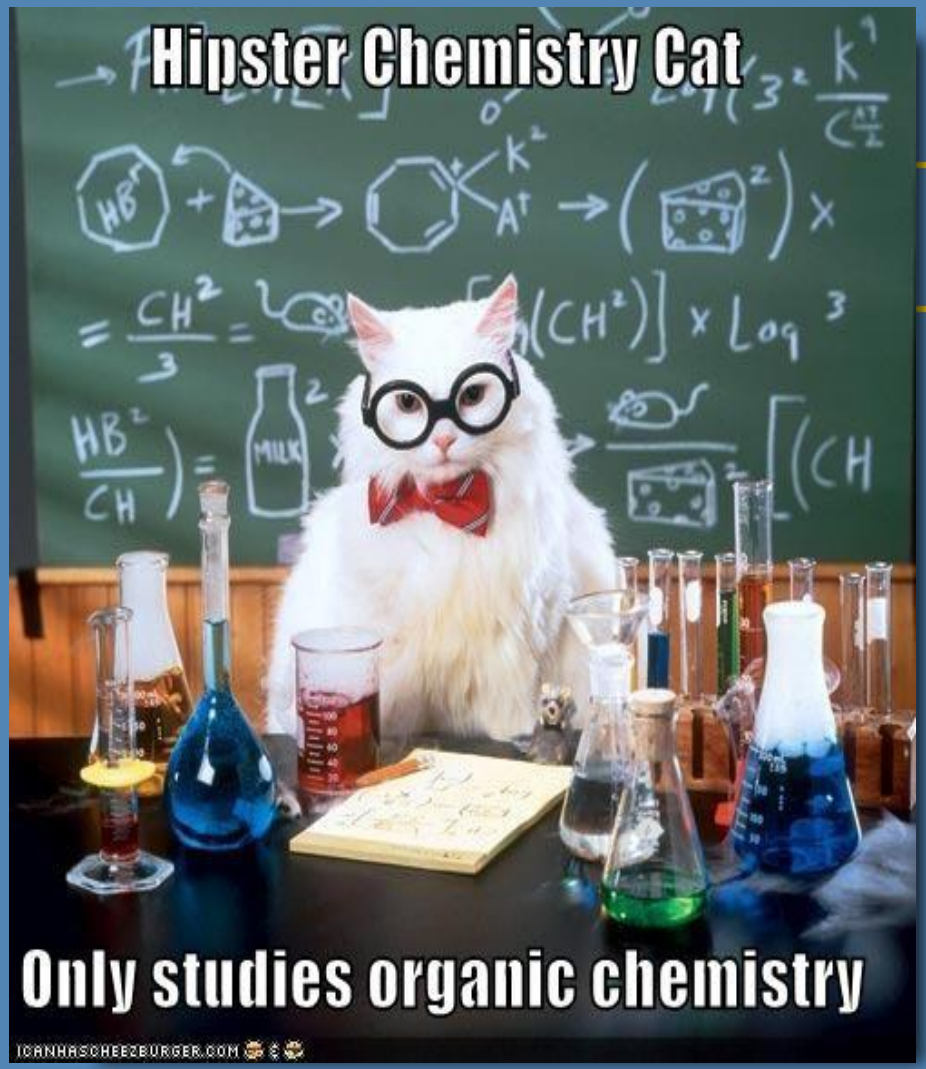


Organic Chemistry

Chapter 10 in Hebden 11

Chapter 8 in BC Science Chem 11

Organic Chemistry - Introduction

- Organic chemistry is the study of carbon compounds.
- Animals, plants, and other forms of life consist of organic compounds.
  - *Nucleic acids, proteins, fats, carbohydrates, enzymes, vitamins, and hormones are all organic compounds.*
- Biochemistry was developed later as the study of the chemical compounds and reactions in living cells.

Organic Chemistry - Introduction

- Scientists had originally thought that organic compounds contained a “vital force” due to their natural origin.
  - *This was disproved by Friedrich Wöhler in 1828.*
- Wöhler was able to make urea, a carbon compound in human urine, in the laboratory from a mineral.
- Organic chemistry is an enormous field.
- In this chapter we will investigate some of the fundamental concepts.

Bonding in Organic Compounds

- Besides carbon, the most common elements in organic compounds are hydrogen, oxygen, nitrogen, sulfur, and the halogens.
- All of the preceding elements are non-metals, therefore organic compounds have covalent bonding.
- Any structural formula that obeys the bonding rules in the following table probably represents a possible compound.
  - *A drawn structure that breaks the bonding rules is unlikely to exist.*

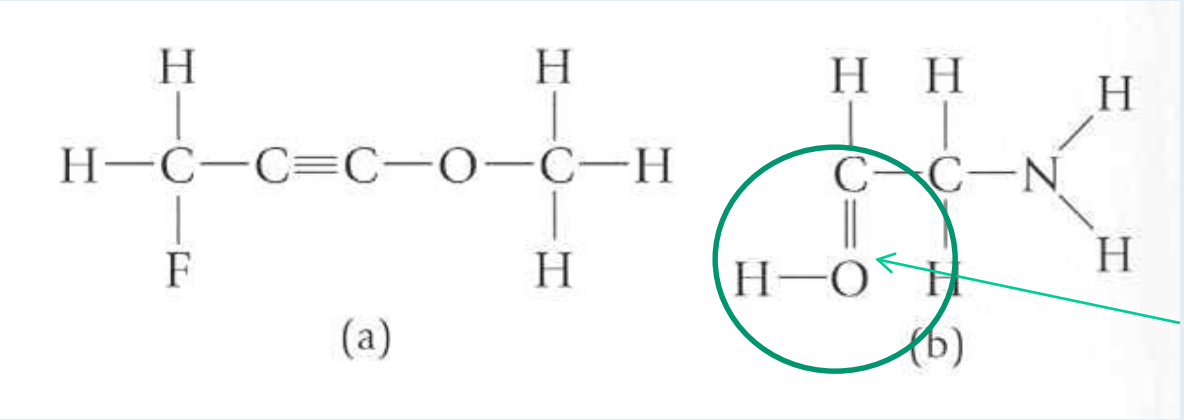
Numbers and Types of Bonds for Common Elements in Organic Compounds

Application of the octet rule indicates that these elements should bond as shown below:

Element	Total Number of Bonds	Distribution of Total Number of Bonds and Examples		
C	4	4 singles —C—	2 singles, 1 double —C=	1 single, 1 triple —C≡
N	3	3 singles —N—	1 single, 1 double —N=	1 triple N≡
O (or S)	2	2 singles O—	1 double O=	
H or halogens	1	1 single H—, Cl—, etc.		

Identifying Valid & Incorrect Structural Formulas

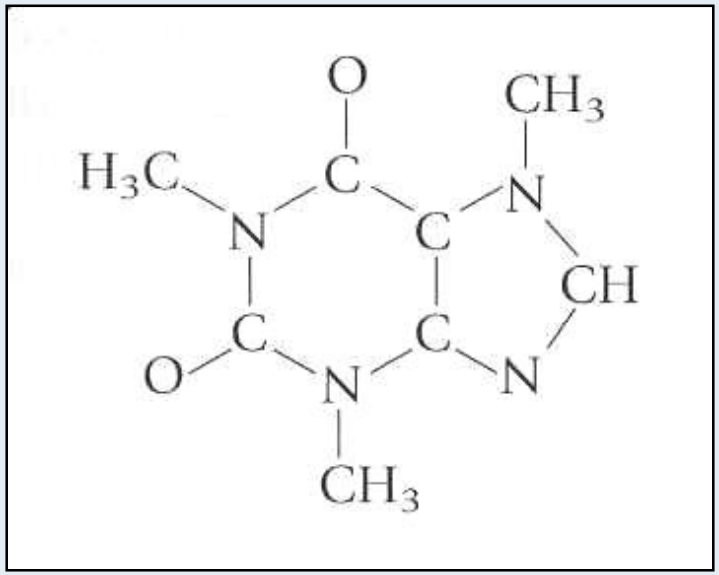
An Example



- *Two structural formulas are shown above. Which on does not represent a real compound?*
- In structure (a) each H and halogen has one bond, each C has four bonds, and each O has two bonds.
- This is a valid structure.

Identifying Incorrect Structural Formulas

Confidence Exercise



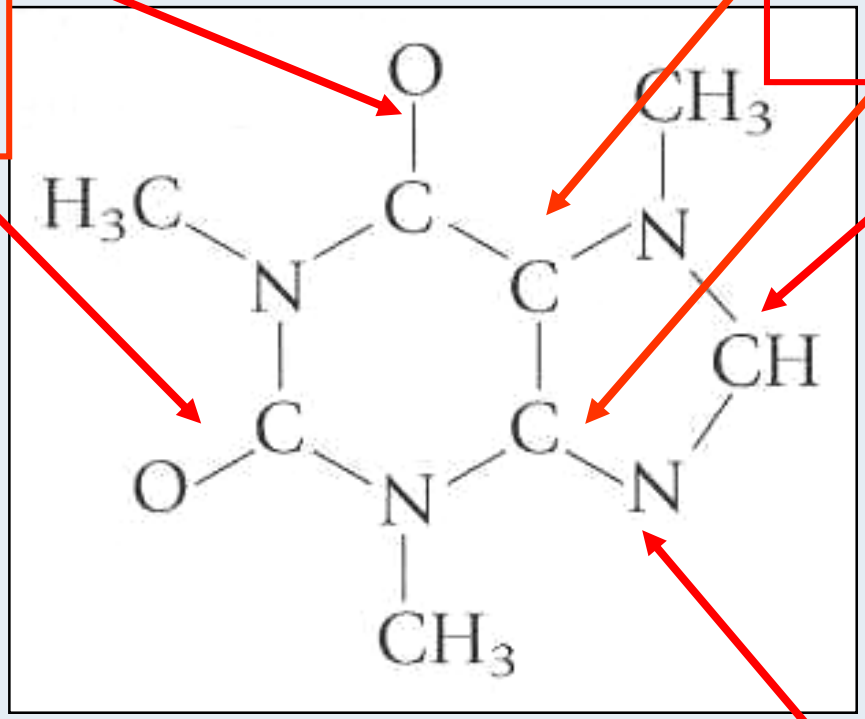
- *The structural formula above appears in a recent chemistry book. Check the number of bonds to each atom and determine whether any bonding rules are violated.*

Identifying Incorrect Structural Formulas

Confidence Exercise

O should have two bonds, C should have 4 bonds

Each C should have 4 bonds



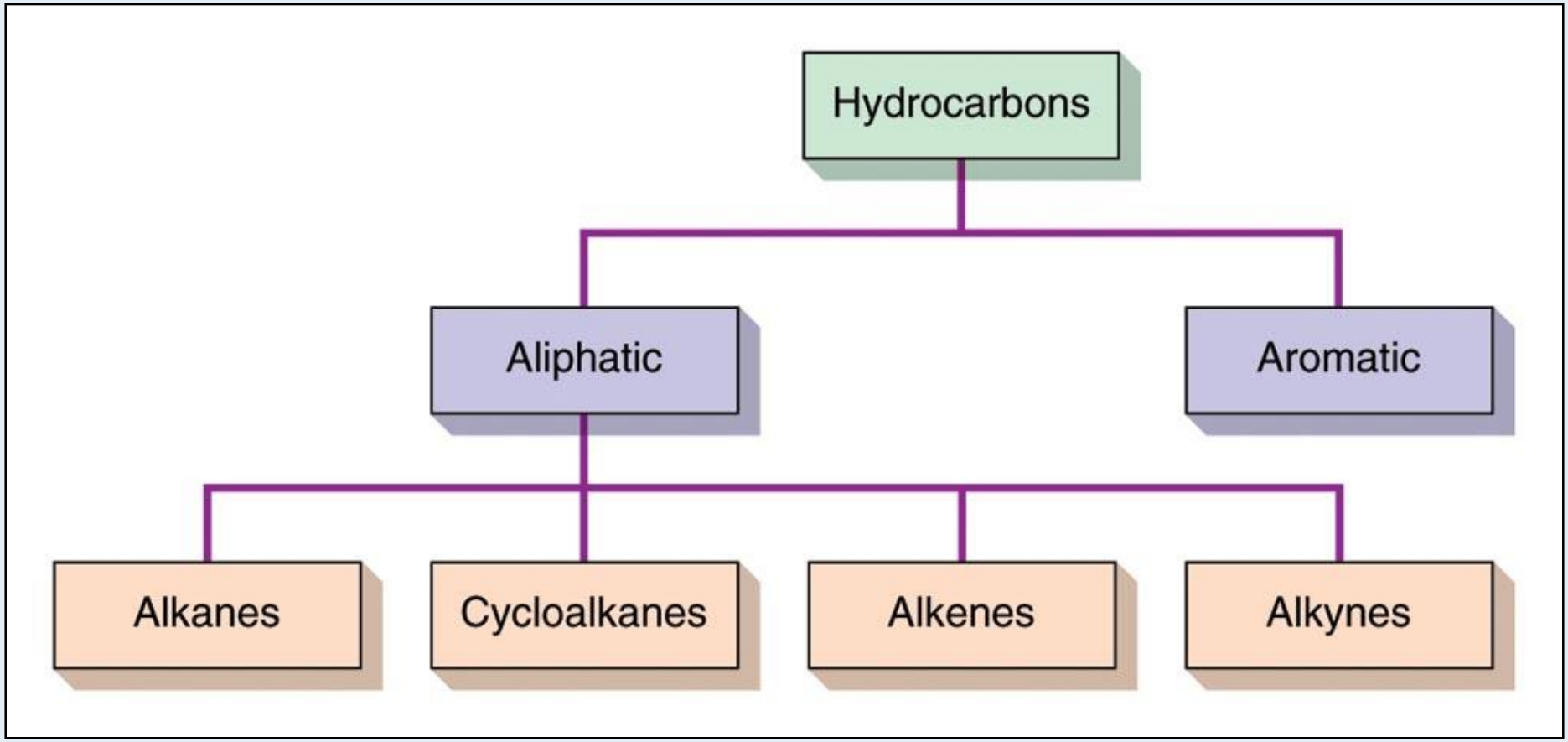
This is not a valid structure for caffeine!

Each N should have 3 bonds

Hydrocarbons

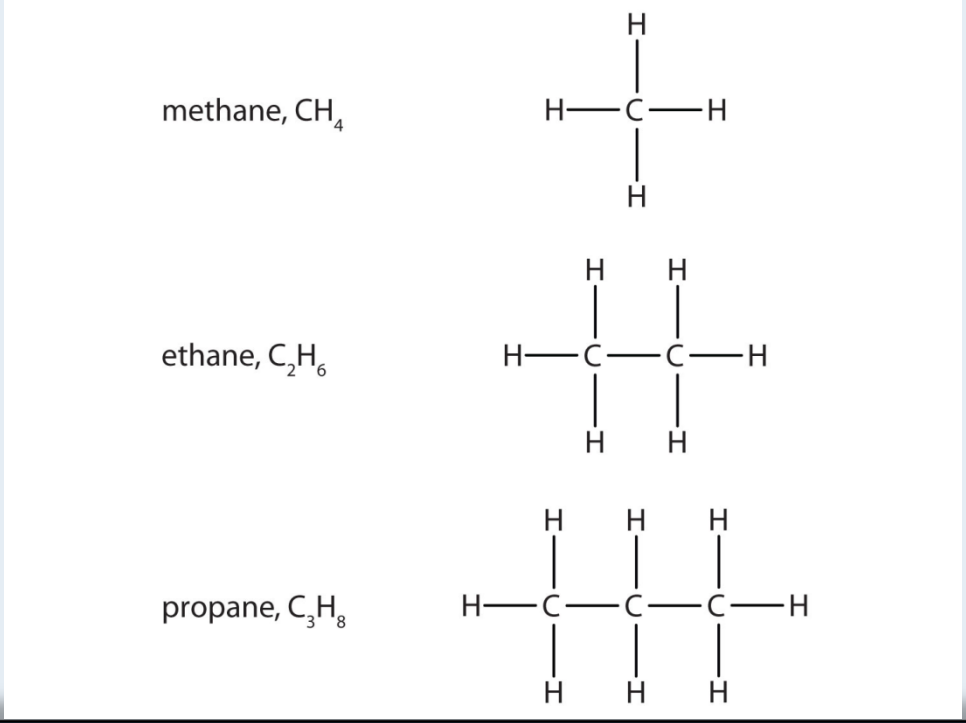
- Hydrocarbons are the most simple organic compounds.
- Hydrocarbons contain only carbon (C) and hydrogen. (H)
- For classification purposes, all other organic compounds are considered derivatives of hydrocarbons.
- Hydrocarbons can be divided into aromatic and aliphatic hydrocarbons.

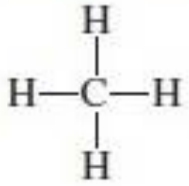
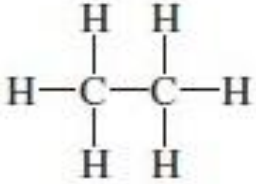
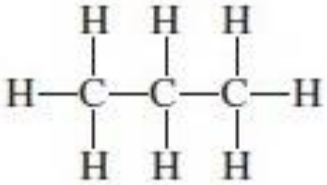
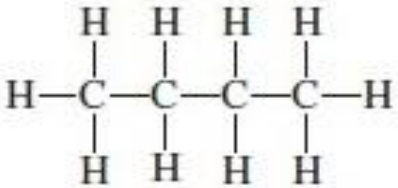
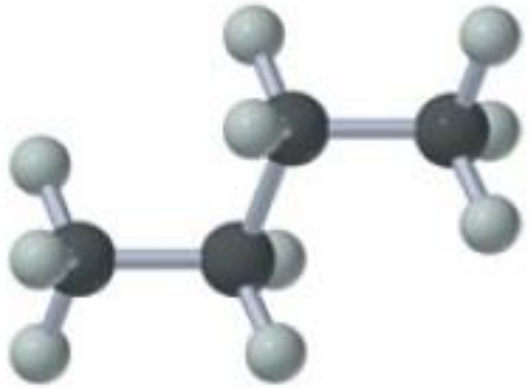
Classification of Hydrocarbons



Alkanes

- Alkanes are hydrocarbons that contain only single bonds.
- Alkanes are said to be saturated hydrocarbons
  - *Because their hydrogen content is at a maximum.*



name	Kekulé structure	condensed structure	ball-and-stick model
methane		CH_4	
ethane		CH_3CH_3	
propane		$CH_3CH_2CH_3$	
butane		$CH_3CH_2CH_2CH_3$	

- Alkane general formula → C_nH_{2n+2}
- The names of alkanes all end in "-ane."
- Methane → butane are gases
- Pentane → $C_{17}H_{36}$ are liquids
- $C_{18}H_{38}$ and higher are solids

TABLE 21.1 First Ten Members of the Straight-Chain Alkane Series

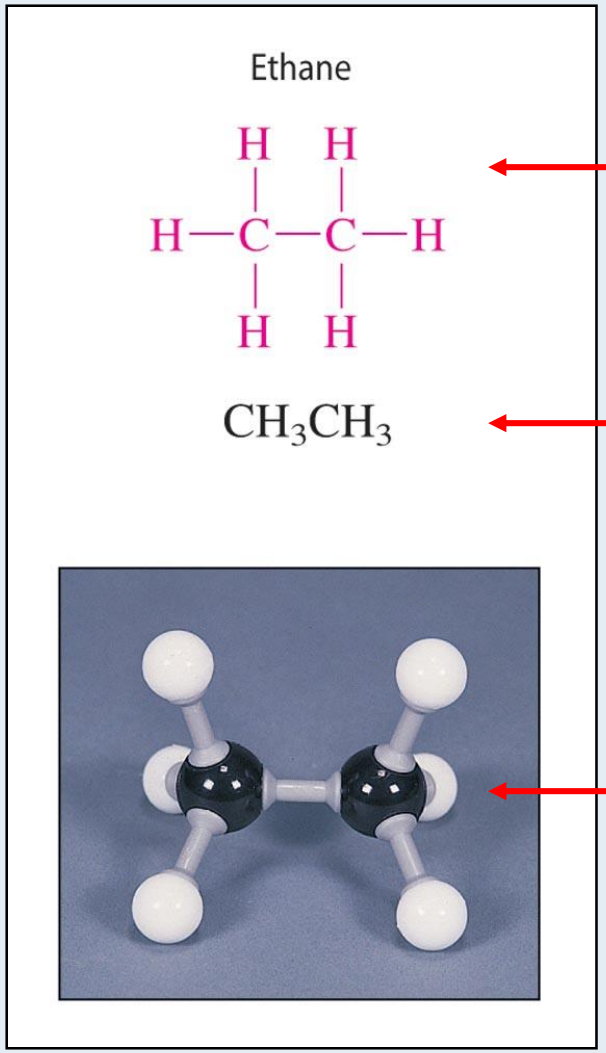
Molecular Formula	Condensed Structural Formula	Name	Boiling Point (°C)
CH_4	CH_4	Methane	−161
C_2H_6	CH_3CH_3	Ethane	−89
C_3H_8	$CH_3CH_2CH_3$	Propane	−44
C_4H_{10}	$CH_3CH_2CH_2CH_3$	Butane	−0.5
C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	Pentane	36
C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	Hexane	68
C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	Heptane	98
C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Octane	125
C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Nonane	151
$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	Decane	174

The First Eight Members of the Alkane Series

All satisfy the general formula C_nH_{2n+2}

Name	Molecular Formula	Condensed Structural Formula
Methane	CH_4	CH_4
Ethane	C_2H_6	CH_3CH_3
Propane	C_3H_8	$CH_3CH_2CH_3$
Butane	C_4H_{10}	$CH_3(CH_2)_2CH_3$
Pentane	C_5H_{12}	$CH_3(CH_2)_3CH_3$
Hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$
Heptane	C_7H_{16}	$CH_3(CH_2)_5CH_3$
Octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$

Visualization of an Alkane's Structure



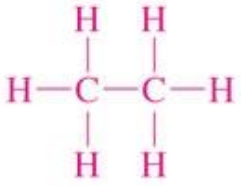
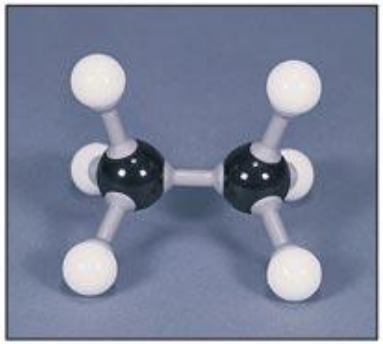
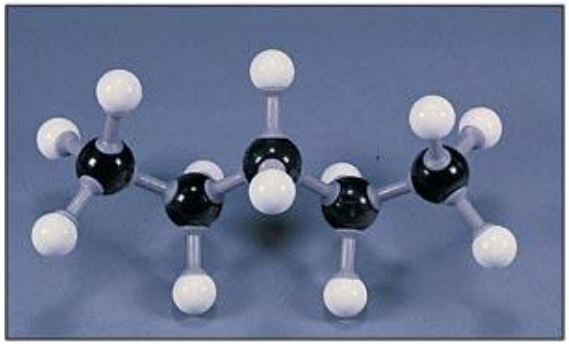
Structural formula – a graphical representation of the way atoms are connected

Condensed structural formula – save time/space and are convenient

Ball-and-Stick models – 3D models that can be built by students

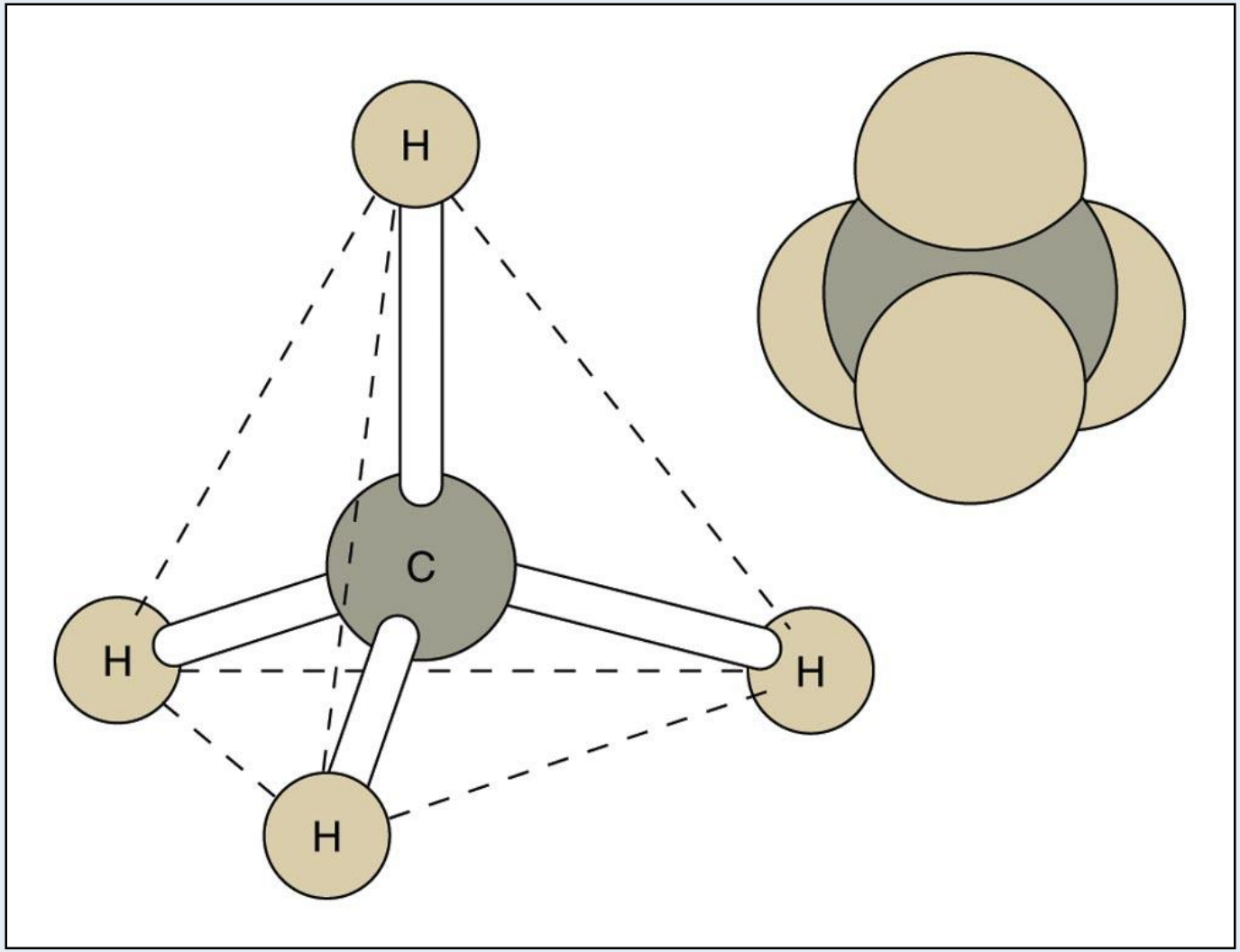
Models of Three Alkanes

- *Names, Structural Formulas, Condensed Structural Formulas, and Ball-and-Stick Models*

	Methane	Ethane	Pentane
Full structural formula:			
Condensed structural formula:	CH_4	CH_3CH_3	$CH_3CH_2CH_2CH_2CH_3$
Ball-and-stick model:			

Methane – Tetrahedral Geometry

Ball-and-Stick & Space-Filling Models Carbon's four single bonds form angles of 109.5°



Alkanes – Energy Related Products

- Methane = primary component of natural gas
- Propane & Butane = primary component of bottled gas
- Gasoline = pentane to decane
- Kerosene = alkanes with n = 10 to 16
- Alkanes with $n > 16$ → diesel fuel, fuel oil, petroleum jelly, paraffin wax, lubricating oil, and asphalt

Alkane Products

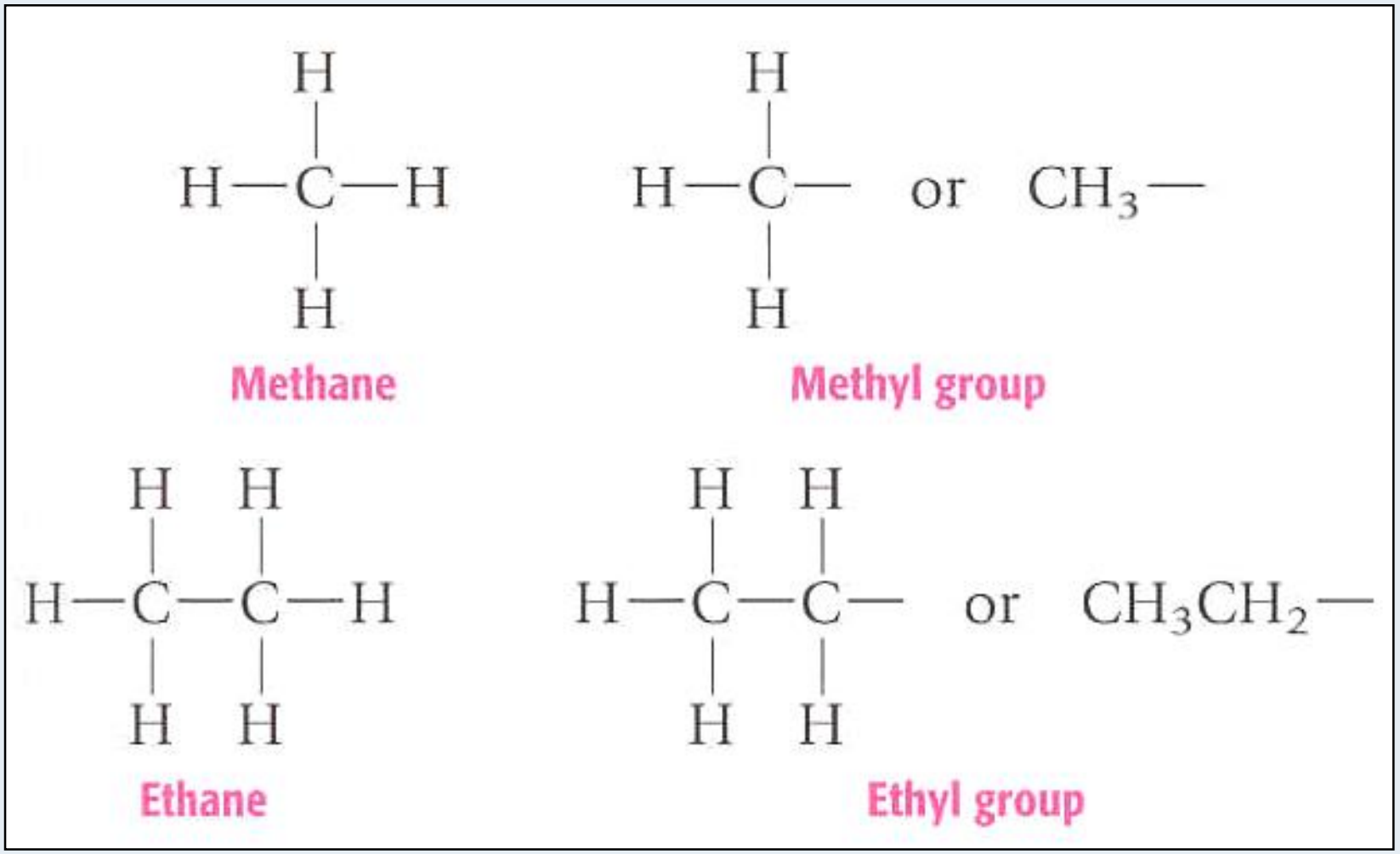
- Alkanes are also found in paints, plastics, drugs, detergents, insecticides, and cosmetics.
  - *Only 6% of the petroleum consumed goes into making these products.*
- The remaining 94% of the petroleum is burned as one of the various energy-related products.
- Although alkanes are highly combustible, they are otherwise not very reactive.
  - *Any reaction would require the breaking of the strong C—H and C—C bonds.*

Alkyl Group

- Alkyl group contains one less hydrogen than the corresponding alkane.
- In naming this group the “-ane” is dropped and “-yl” is added.
- For example, *methane* becomes *methyl.*
- *Ethane* becomes *ethyl.*

Alkyl Group

This group does not exist independently but occurs bonded to another atom or molecule.



Rule: The first step in naming a substituted hydrocarbon is to find the longest continuous chain of carbon atoms. This longest chain is called the “ Parent” hydrocarbon.

Examples Teacher put examples on smartboard. If you don’t have a smart board it sucks to be you

Rule: A substituted hydrocarbon is named by writing the following one after another

-The carbon number at which the alkyl group is attached
-A dash
-The name of the alkyl group
-The name of the longest or parent hydrocarbon, to which the alkyl group is attached.

Teacher put examples on smartboard. If you don't have a smart board it sucks to be you

Note: the carbon atoms in the parent hydrocarbon are numbered Consecutively from the end of the hydrocarbon which gives the lowest Possible set of numbers to the attached group.

Rule: If more than one different alkyl group is attached to a hydrocarbon, then

- List the alkyl groups alphabetically
- Precede each alkyl group by its number, and
- Put a dash between each alkyl group and its number

Teacher put examples on smartboard. If you don't have a smart board it sucks to be you

Substituents in Organic Compounds

Formula of Substituent	Name of Substituent
Br—	Bromo
Cl—	Chloro
F—	Fluoro
I—	Iodo
CH_3—	Methyl
CH_3CH_2—	Ethyl

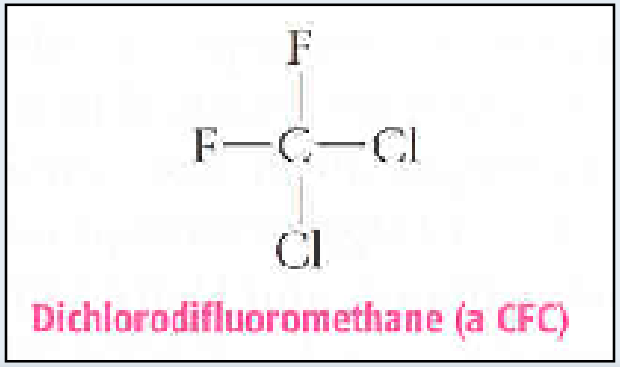
Alkyl halides

Examples of alkanes with alkyl halides

Teacher put examples on smartboard. If you don't have a smart board it sucks to be you

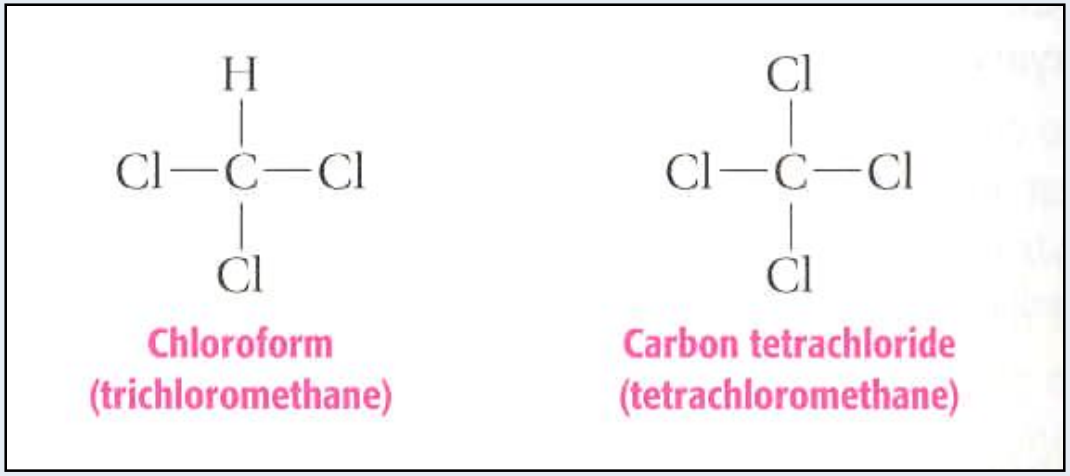
Alkyl Halides

- Alkyl halides have the general formula R—X, where X is a halogen and R is an alkyl group
- CFC's (chlorofluorocarbons) are examples of alkyl halides.
- A well known CFC is dichlorodifluoromethane (Freon-12)
  - *Extensively used in the past in cooling devices.*



Alkyl Halides

- Another example of an alkyl halide is chloroform.
  - *In the past it was used as a surgical anesthetic but it is now a known carcenogen.*
- Carbon tetrachloride was also used extensively in the past, until it was linked to liver damage.



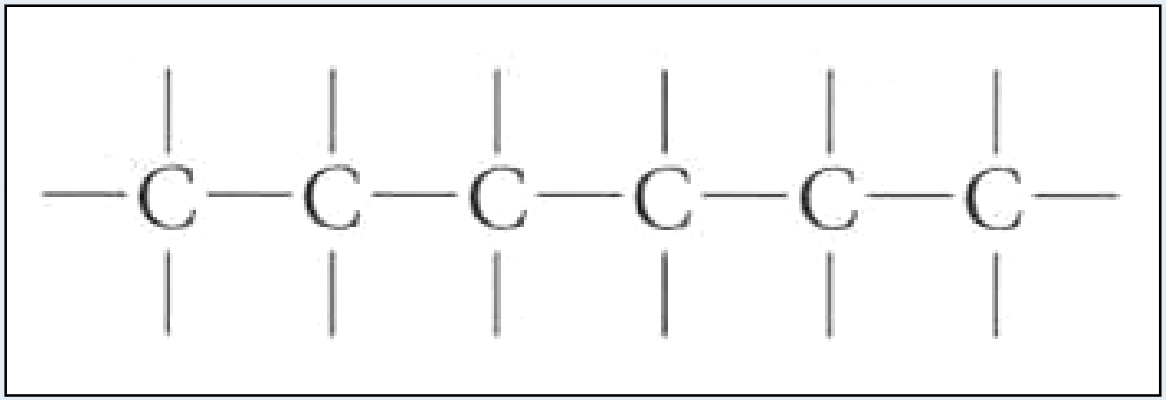
Rule: if an alkyl group is repeated, then

- List each carbon number where the repeated group is attached, separated by commas,and
- Prefix the repeated group name by **di, tri, tetra**, etc. to show how many identical groups are attached

Teacher put examples on smartboard. If you don't have a smart board it sucks to be you

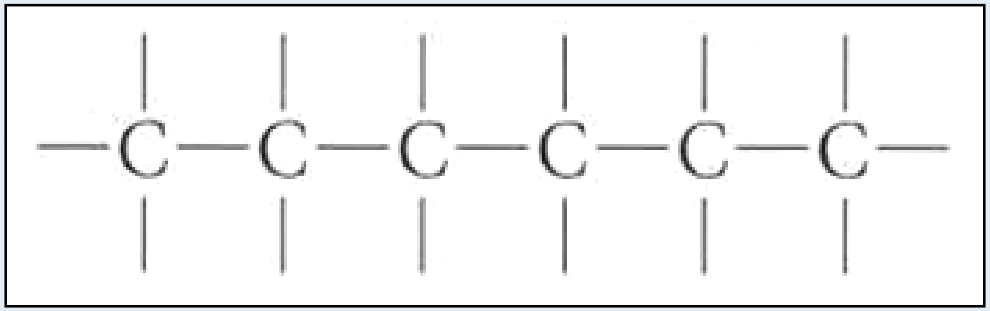
Drawing a Structure from a Name
An Example

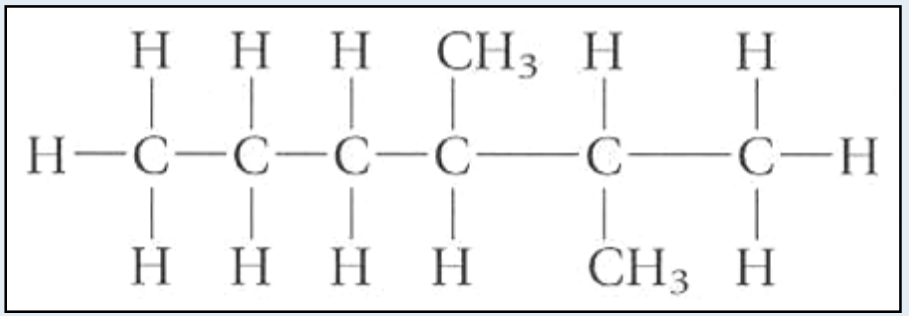
- *Draw the structural formula for 2,3-dimethylhexane.*
- Note that the end name is *hexane* .
- Draw a continuous chain of six carbon (C) atoms, with four bonds around each.



Drawing a Structure from a Name
An Example (cont.)

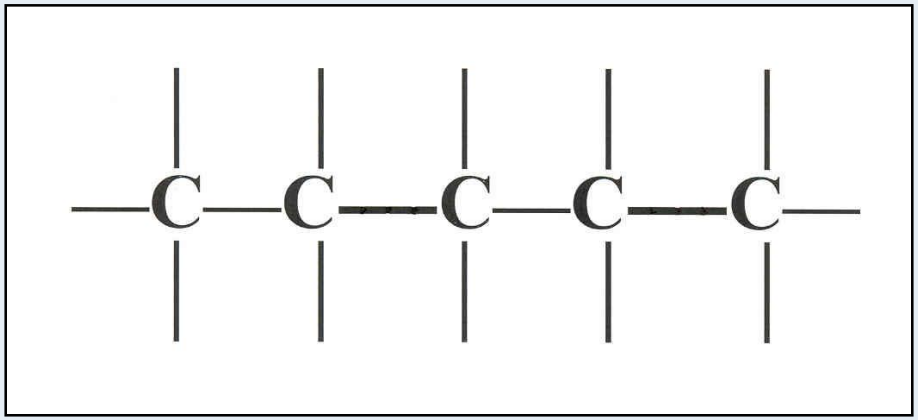
- Number the C atoms from right to left.
- Attach a methyl group (CH_3--) to carbon number 2 and number 3.
  - *Add necessary H atoms.*
- 2,3-dimethylhexane



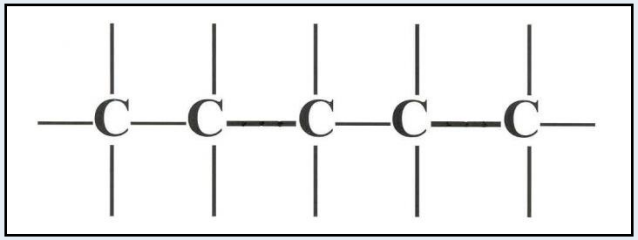


Drawing a Structure from a Name *Confidence Exercise*

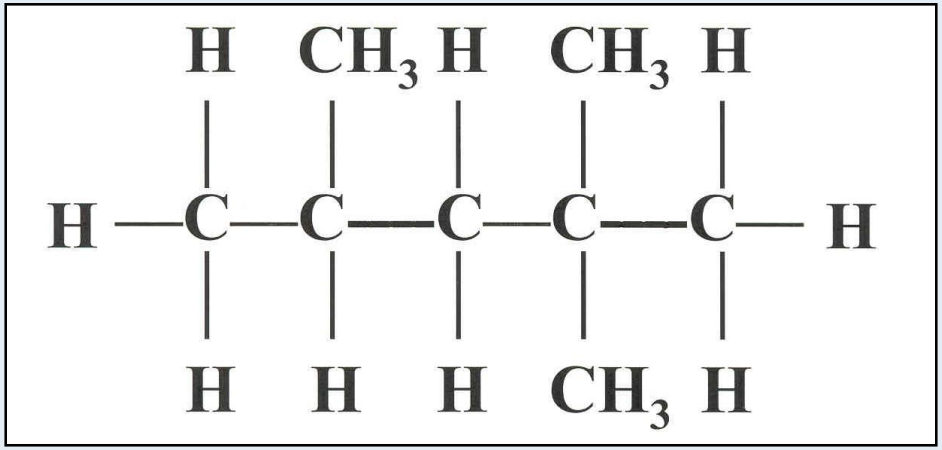
- *Draw the structural formula for 2,2,4-trimethylpentane.*
- Note that the end name is *pentane* .
- Draw a continuous chain of five carbon (C) atoms, with four bonds around each.



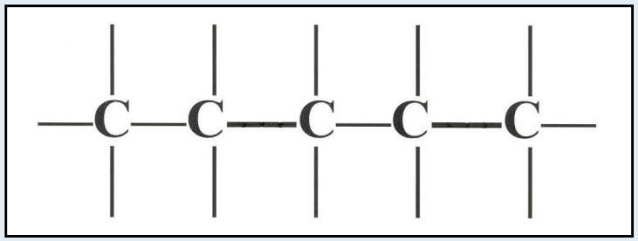
Drawing a Structure from a Name
Confidence Exercise (cont.)



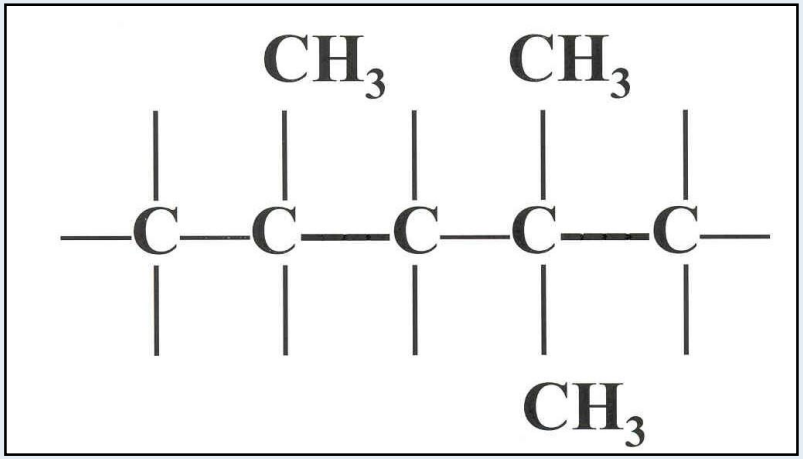
- Add necessary H atoms.
- 2,2,4-trimethylpentane



Drawing a Structure from a Name
Confidence Exercise (cont.)

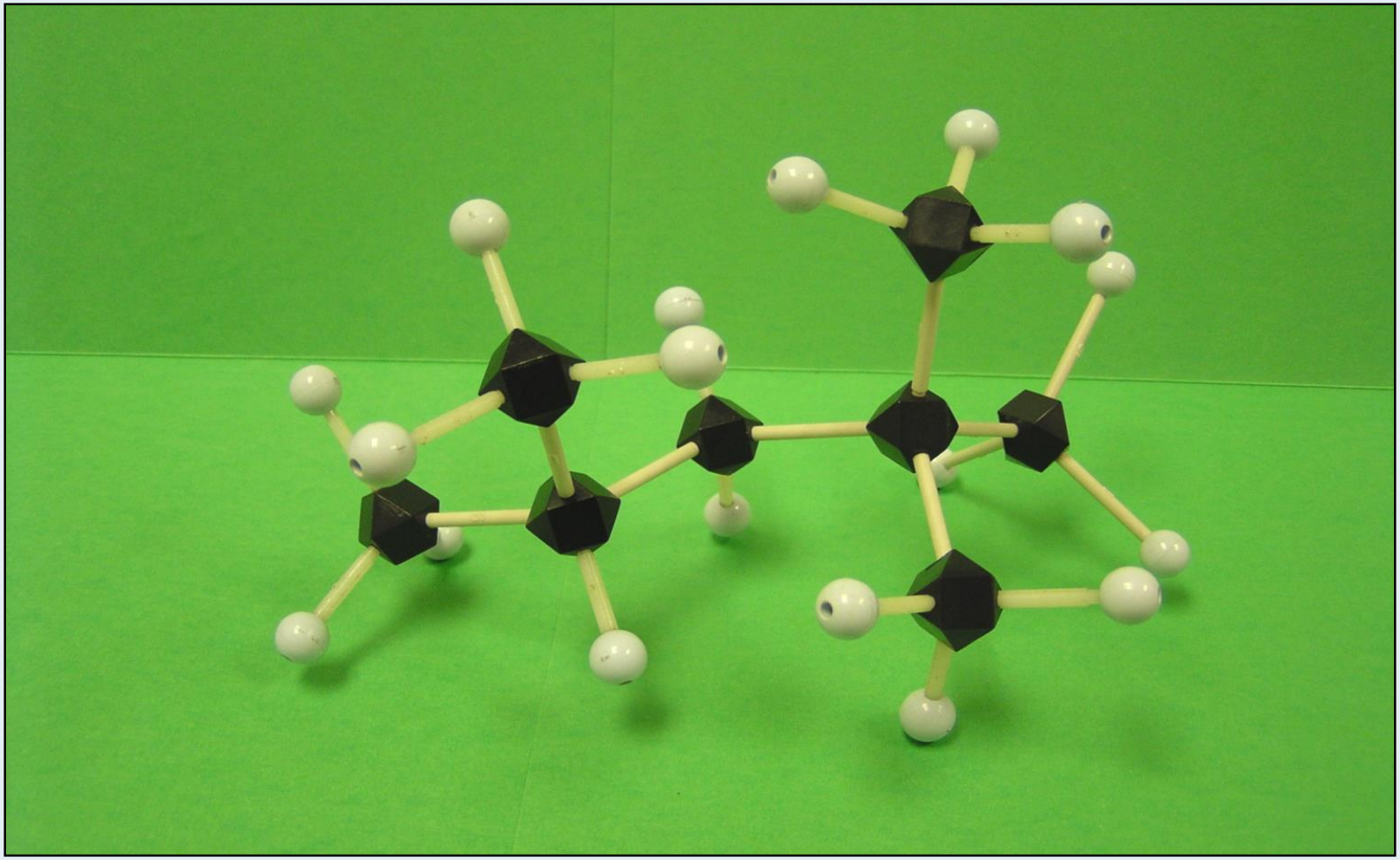


- Number the C atoms from right to left.
- Attach two methyl groups (CH_3--) to carbon number 2 and one to number 4.



2,2,4-trimethylpentane

Ball-and-Stick Model



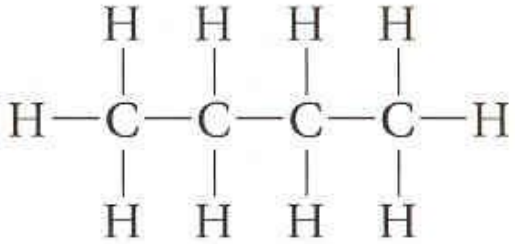
Constitutional Isomers

- Compounds that have the same *molecular formula* but different *structural formulas*
- In the case of many alkanes there is more than one way to arrange the atoms
- For example butane and isobutane
- Both of these alkanes have the molecular formula of C_4H_{10}
- But their structural formula and arrangement is quite different

Butane

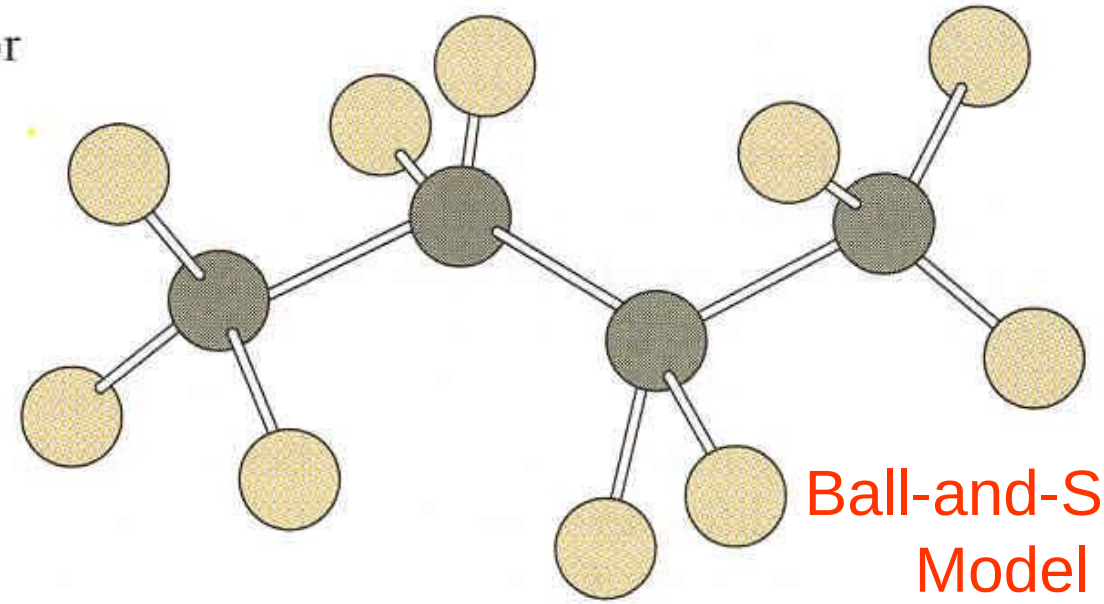
Continuous-Chain or Straight-Chain Structure

Structural Formula



C_4H_{10}

or

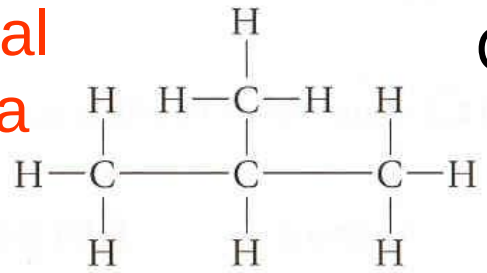


Ball-and-Stick Model

Isobutane (2-methylpropane)

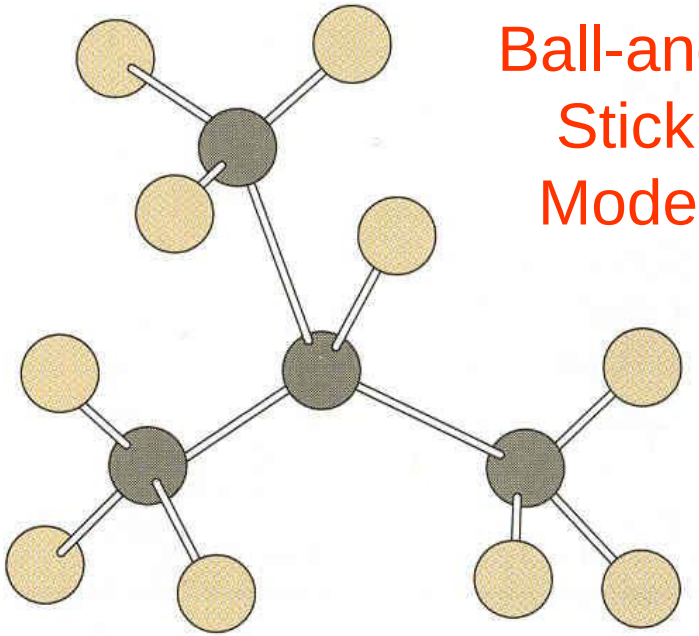
Branched-chain Structure

Structural Formula



C_4H_{10}

or



Ball-and-Stick Model

Constitutional Isomers

- Constitutional Isomers may exist whenever it is possible to construct a different structural arrangement:
  - *Using the same number and types of atoms*
  - *Without violating the octet rule*
- In other words, the same atoms may be connected to one another in different, but valid, ways.

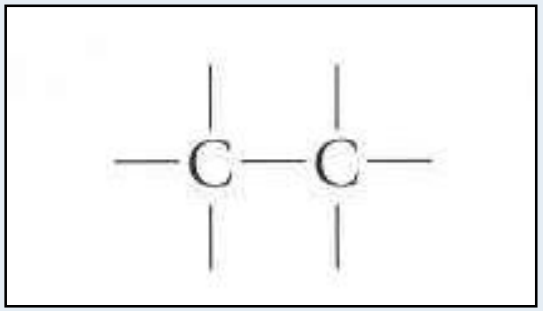
Number of Possible Isomers of Alkanes

- *Carbon Atoms can bond in many different ways*

Molecular Formula	Total Isomers
CH_4	1
C_2H_6	1
C_3H_8	1
C_4H_{10}	2
C_5H_{12}	3
C_6H_{14}	5
C_7H_{16}	9
C_8H_{18}	18
C_9H_{20}	35
$C_{10}H_{22}$	75
$C_{15}H_{32}$	4,347
$C_{20}H_{42}$	366,319
$C_{30}H_{62}$	4.11×10^9

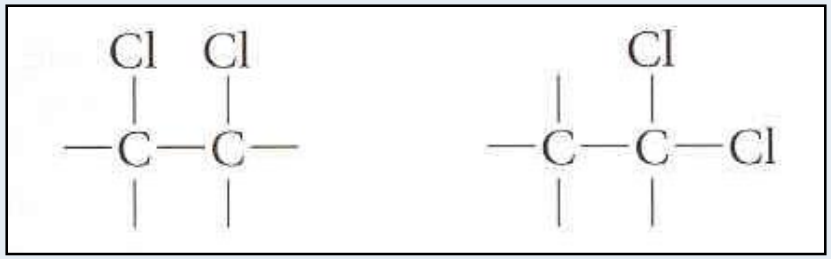
Drawing Constitutional Isomers
An Example

- *Draw the structural formulas for the two alkyl halide isomers that have the molecular formula $C_2H_4Cl_2$.*
- Recall that C atoms form four bonds, H & Cl form one bond each.
- Draw a two-carbon backbone.
  - *Add enough bonds so that each C has four.*

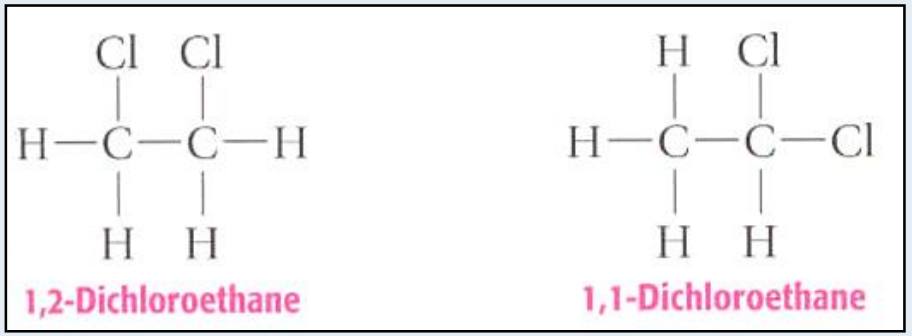


Drawing Constitutional Isomers
An Example (cont.)

- Note, there are just enough open bonds to attach the four H and two Cl atoms.
- Fill in the Cl atoms in as many ways as possible.
- Remember that you are constrained by the tetrahedral geometry (109.5°) of the four C bonds.

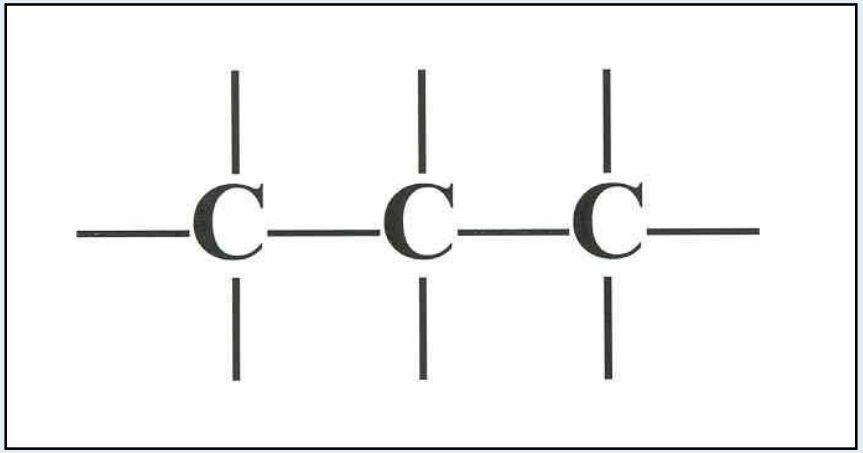


- Fill in the open bonds with H atoms and name the compounds.



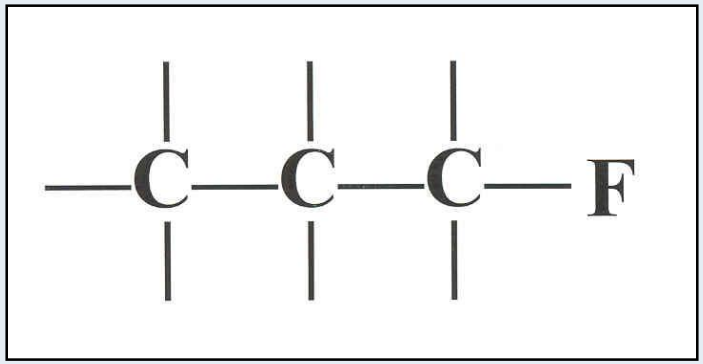
Drawing Constitutional Isomers *Confidence Exercise*

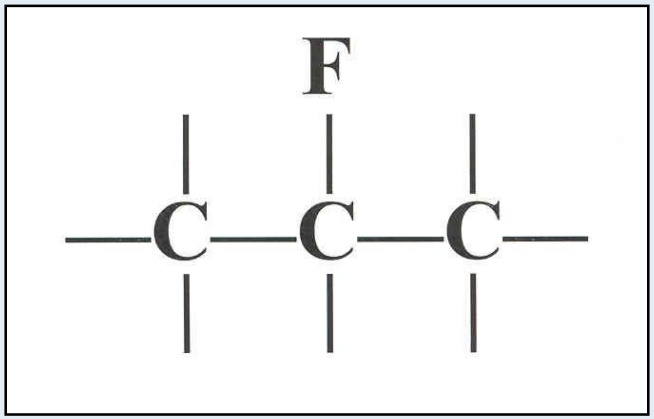
- *Two constitutional isomers of C_3H_7F exist. Draw the structure for each.*
- Note that the formula ratio is that of an alkane.
- Draw a three-carbon backbone.
  - *Add enough bonds so that each C has four.*



Drawing Constitutional Isomers
Confidence Exercise (cont.)

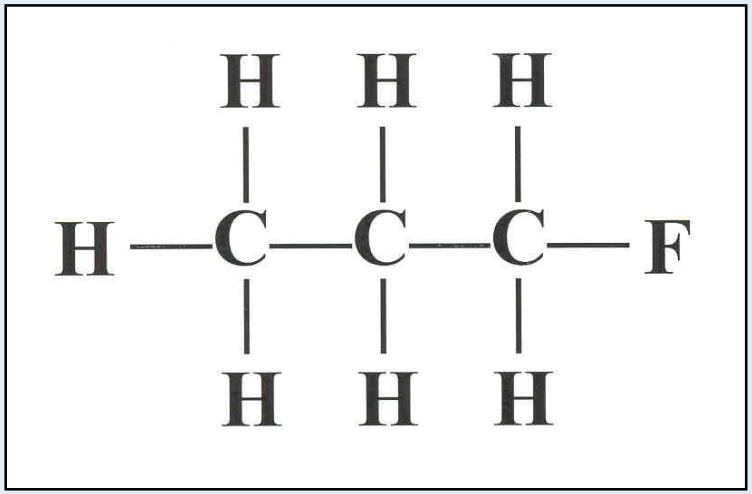
- Note, there are just enough open bonds to attach the seven H and the one F atoms.
- Fill in the F atoms in as many ways as possible.
- Remember that you are constrained by the tetrahedral geometry (109.5º) of the four C bonds.



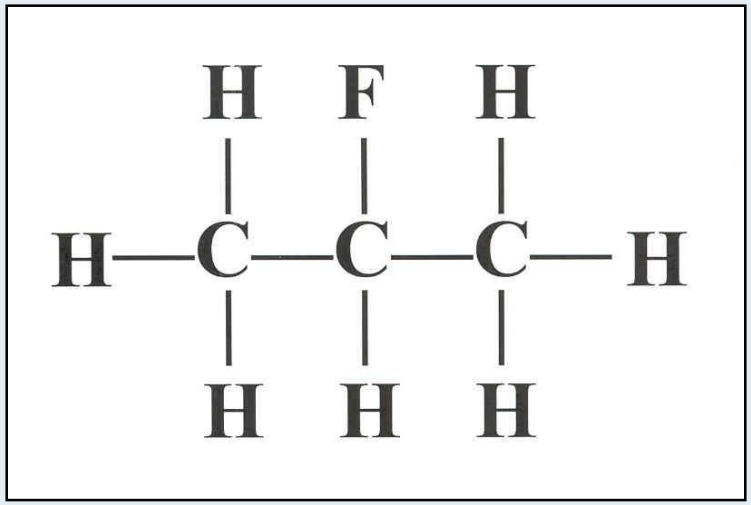


Drawing Constitutional Isomers
Confidence Exercise (cont.)

- Fill in the open bonds with H atoms and name the compounds.



1-Fluoropropane

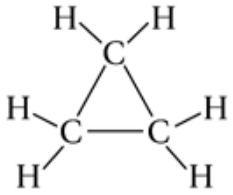
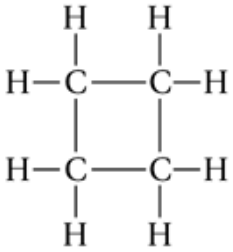
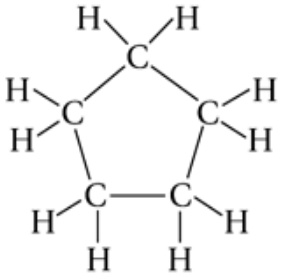
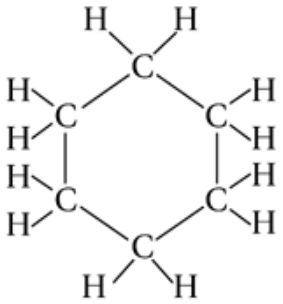


2-Fluoropropane

Cycloalkanes

- Members of the cycloalkane group possess rings of carbon atoms.
- They have the general formula C_nH_{2n}.
- Each carbon atom is bonded to a total of four carbon or hydrogen atoms.
- The smallest possible ring consists of cyclopropane, C_3H_6.

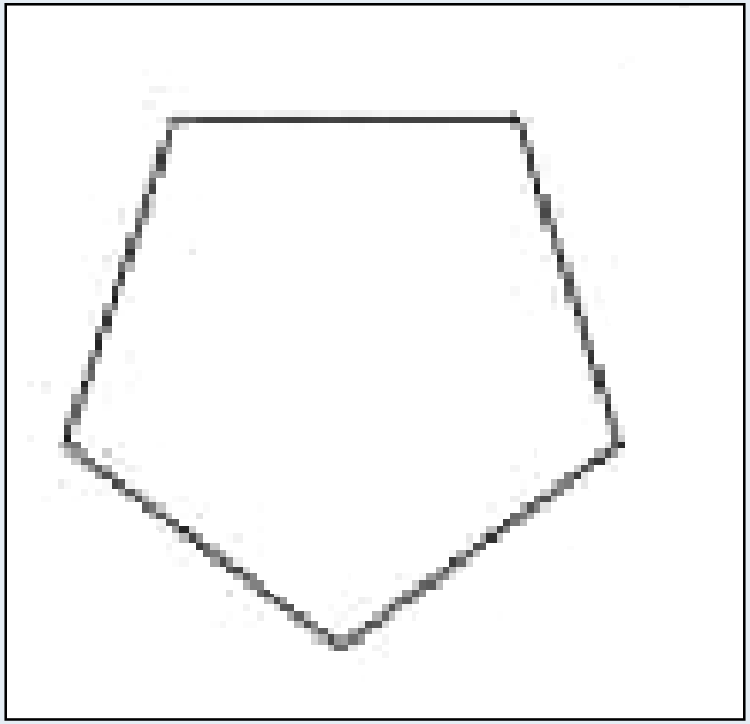
The First Four Cycloalkanes

Molecular formula	C_3H_6	C_4H_8	C_5H_{10}	C_6H_{12}
Full structural formula				
Condensed structural formula				
Name	Cyclopropane	Cyclobutane	Cyclopentane	Cyclohexane

Note that in the condensed structural formulas, there is a carbon atom at each corner and enough hydrogens are assumed to be attached to give a total of four single bonds.

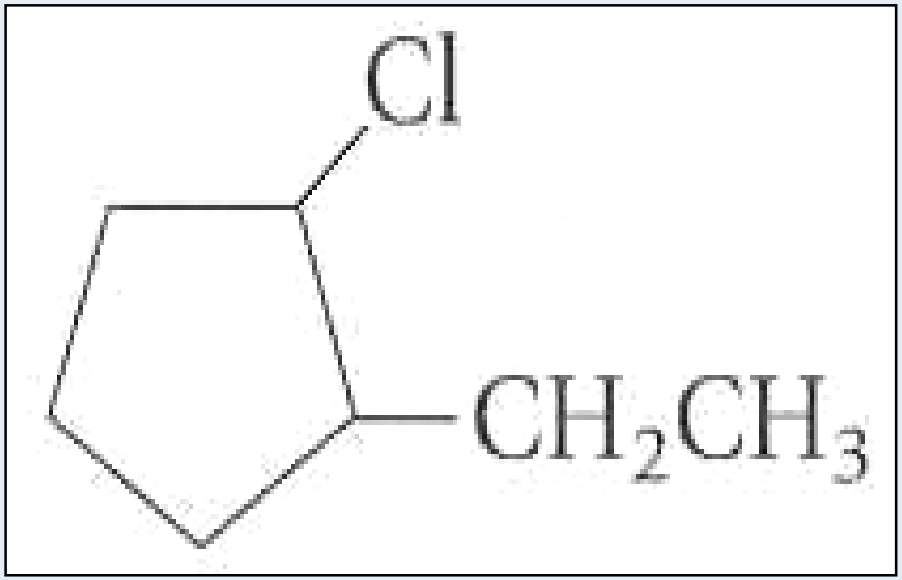
Drawing the Structure of a Cycloalkane

- Draw the geometric figure indicated by the compound's name , "pentane."



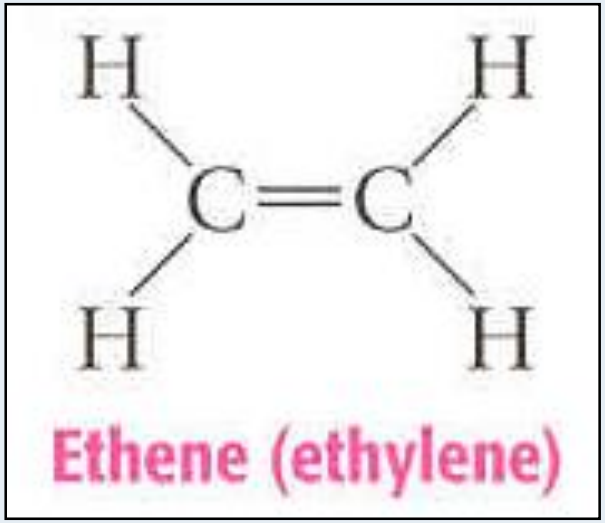
Drawing the Structure of a Cycloalkane

- Place each substituent on the ring in the numbered position → “1 chloro-2-ethyl-”
- 1-chloro-2-ethylcyclopentane



Alkenes

- Members of the alkene group have a double bond between two carbon atoms.
- One hydrogen atom has been removed from two adjacent carbon atoms, thereby allowing the two adjacent carbon atoms to form a double bond.
- General formula is C_nH_{2n}
- Begins with ethene (ethylene)
- C_2H_4

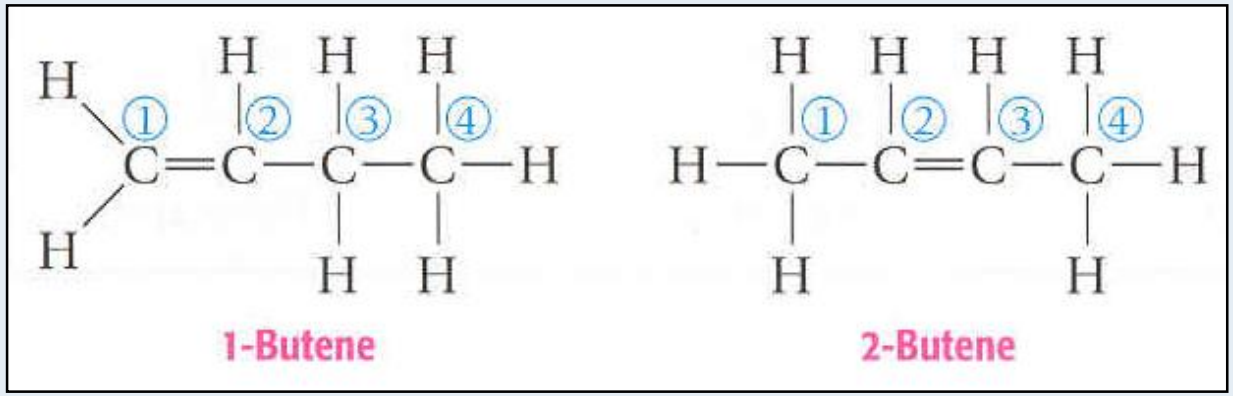


Some Members of the Alkene Series

Name	Molecular Formula	Condensed Structural Formula
Ethene (ethylene)	C_2H_4	$CH_2{=}CH_2$
Propene	C_3H_6	$CH_3CH{=}CH_2$
1-Butene	C_4H_8	$CH_3CH_2CH{=}CH_2$
2-Butene	C_4H_8	$CH_3CH{=}CHCH_3$
1-Pentene	C_5H_{10}	$CH_3(CH_2)_2CH{=}CH_2$

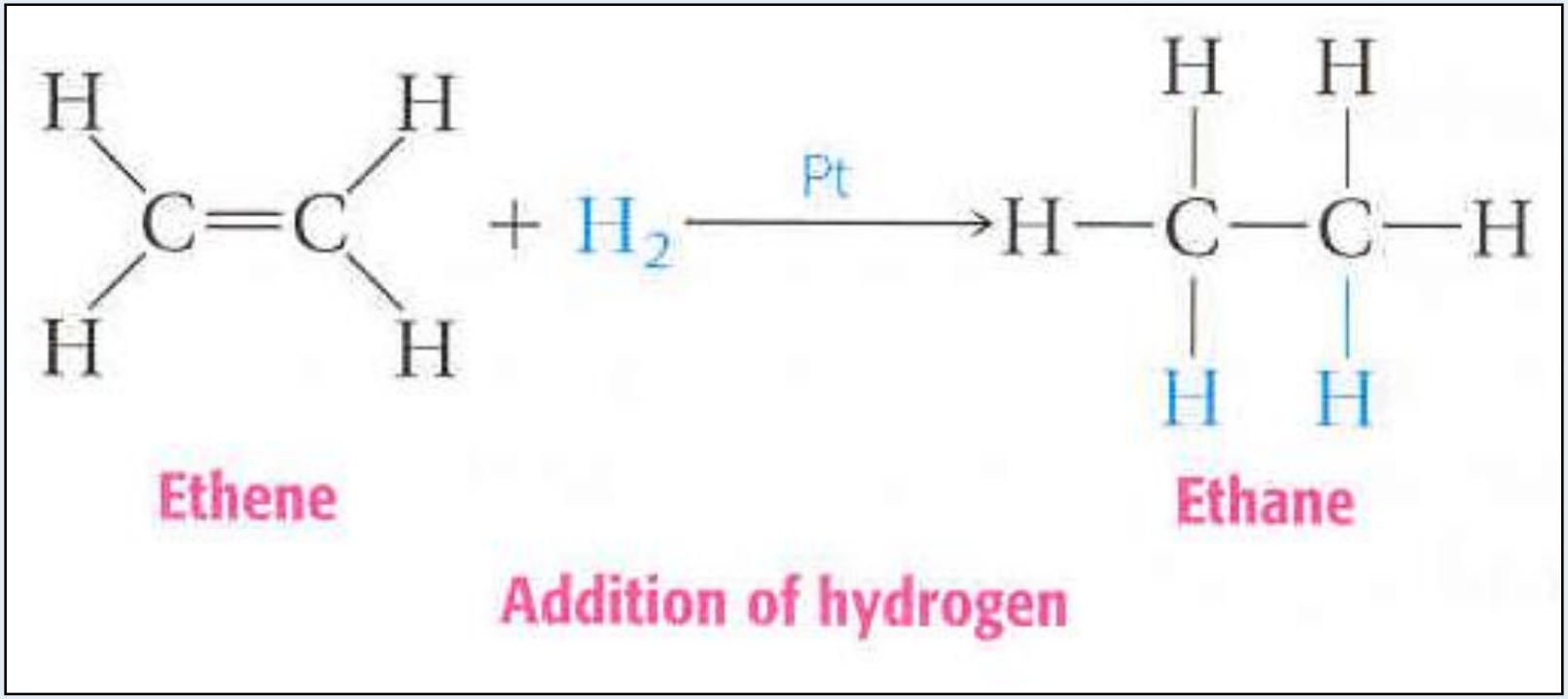
Naming Alkenes

- *"-ane"* suffix for the corresponding alkane is changed to *"-ene"* for alkenes.
- A number preceding the name indicates the C atom on which the double bond starts.
  - *The carbons are numbered such that the double bond has the lowest number.*
- For example, 1-butene and 2-butene



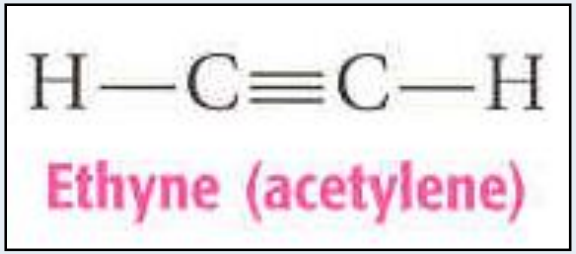
Alkenes are very Reactive and are termed "*unsaturated hydrocarbons*"

- *Alkenes will characteristically react with hydrogen to form the corresponding alkane.*



Alkynes

- Members of the alkyne group have a triple bond between two carbon atoms.
- Two hydrogen atoms have been removed from each of two adjacent carbon atoms, thereby allowing the two adjacent carbon atoms to form a triple bond.
- General formula is C_nH_{2n-2}
- Begins with ethyne (acetylene)
- C_2H_2

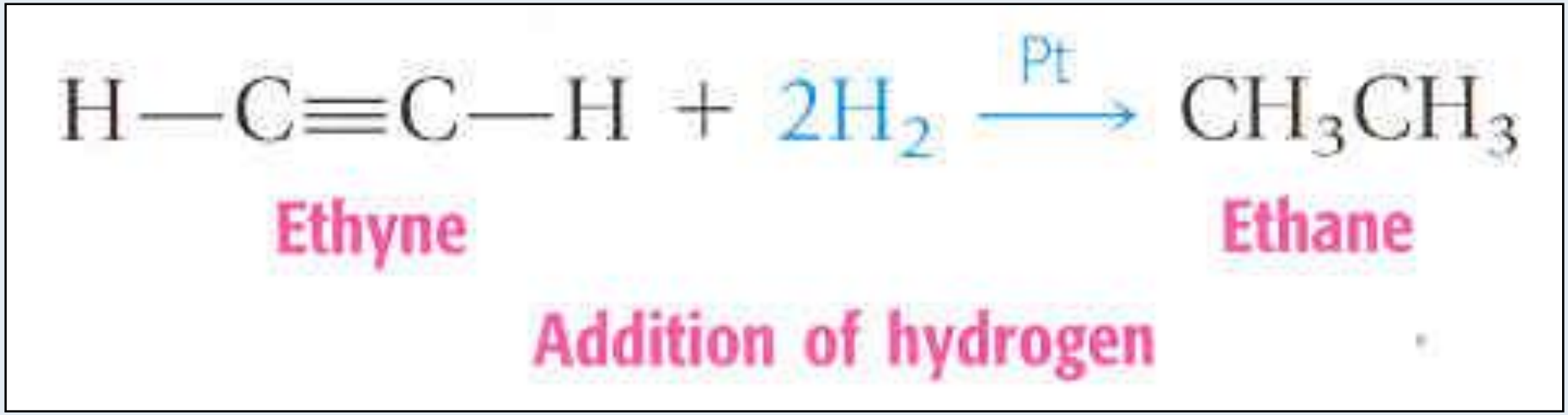


Some Members of the Alkyne Series

Name	Molecular Formula	Condensed Structural Formula
Ethyne (acetylene)	C_2H_2	$HC{\equiv}CH$
Propyne	C_3H_4	$CH_3C{\equiv}CH$
1-Butyne	C_4H_6	$CH_3CH_2C{\equiv}CH$
2-Butyne	C_4H_6	$CH_3C{\equiv}CCH_3$
1-Pentyne	C_5H_8	$CH_3(CH_2)_2C{\equiv}CH$

Alkynes are Unsaturated Hydrocarbons

- *Due to the triple carbon bond, each alkyne molecule can react with two molecules of hydrogen.*



Derivatives of Hydrocarbons

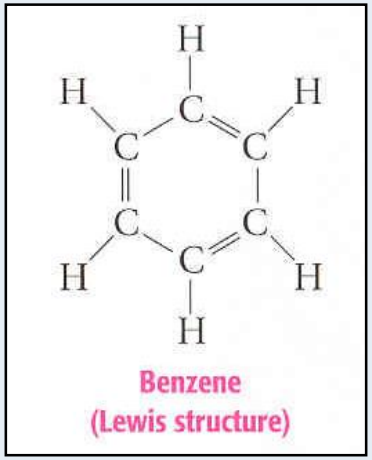
- Organic molecule characteristics depend on the number, arrangement, and type of atoms.
- Functional Group – any atom, group of atoms, or organization of bonds that determine specific properties of a molecule
  - *Generally the functional group is the reactive part of the molecule.*
  - *Due to the functional group's presence, certain predictable properties ensue.*

Derivatives of Hydrocarbons

- Examples of functional groups include:
  - *The double bond in alkenes & triple bond in alkynes.*
  - *Cl atom, F atom, –OH group, methyl (CH_3–) group.*
- Derivatives of hydrocarbons are organic compounds that contain atoms other than C and H.

Aromatic Hydrocarbons

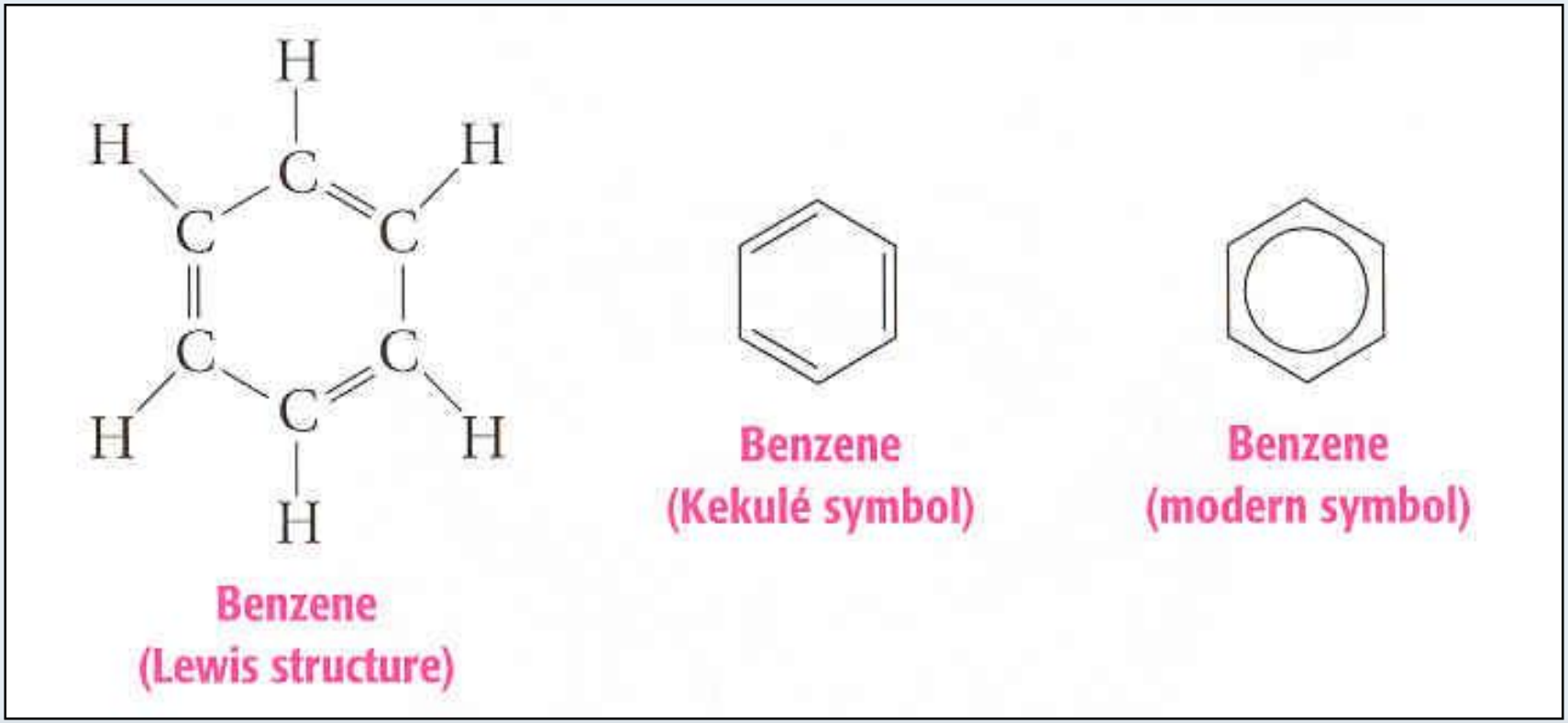
- Aromatic hydrocarbons contain one or more benzene ring.
- Benzene (C_6H_6) is the most important aromatic hydrocarbon.
- It is a clear, colorless liquid with a distinct odor, and is a carcinogen (cancer-causing agent.)
- *Traditional Lewis Structure*



Benzene
(Lewis structure)

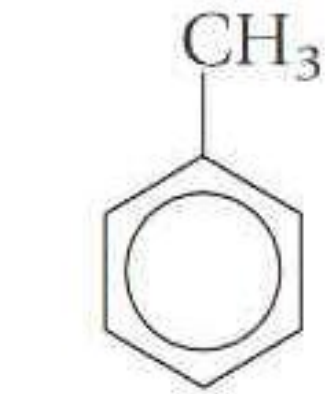
Benzene
Structural Formulas and Short-hand Symbols

- *The Lewis structure and the Kekulé symbol both indicate that the carbons in the ring have alternating double and single bonds.*

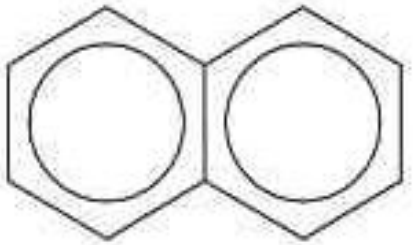


Other Aromatic Hydrocarbons

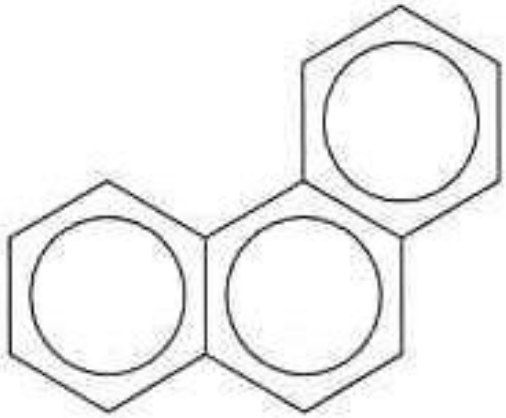
- *Toluene is used in modeling glue. Naphthalene is use in mothballs, and Phenanthrene are used in the synthesis of dyes, explosives, and drugs.*



Toluene
(methylbenzene)

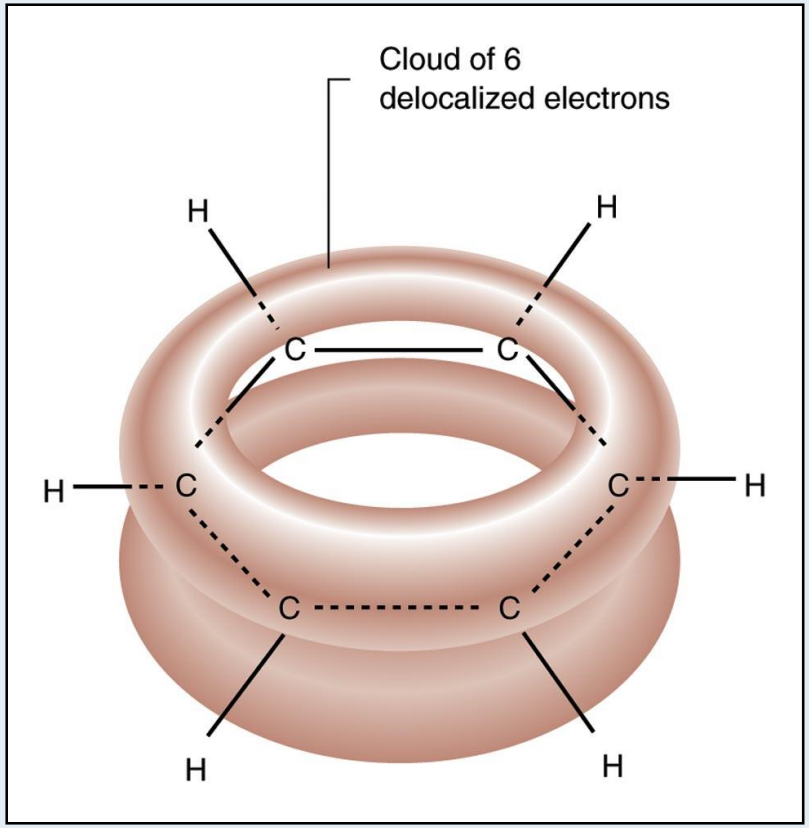


Naphthalene



Phenanthrene

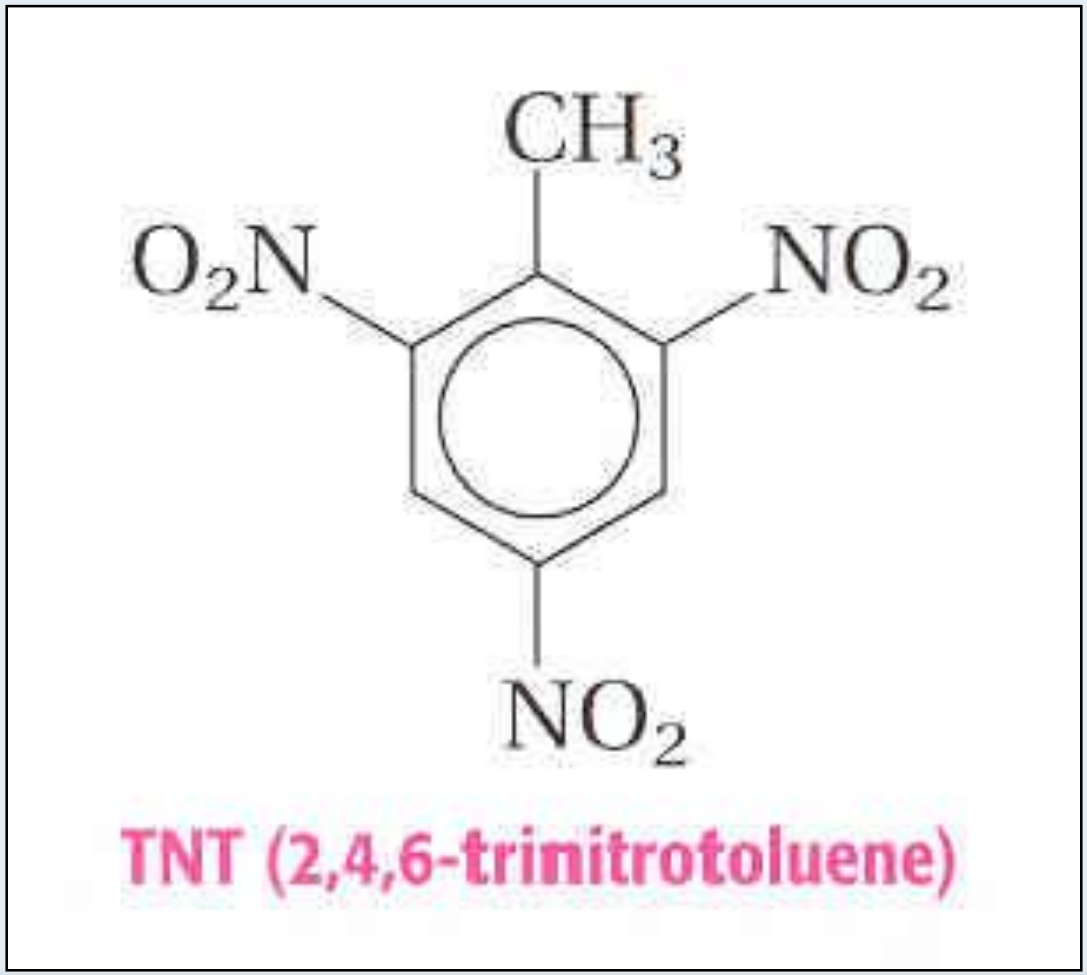
Benzene representation



- Benzene representation howing a flat molecule with six delocalized electrons forming an cloud above and below the plane of the ring.
- Properties of the benzene molecule and advanced bonding theory indicate this structure.
  The six electrons appear to be shared by all the carbon atoms in the ring.

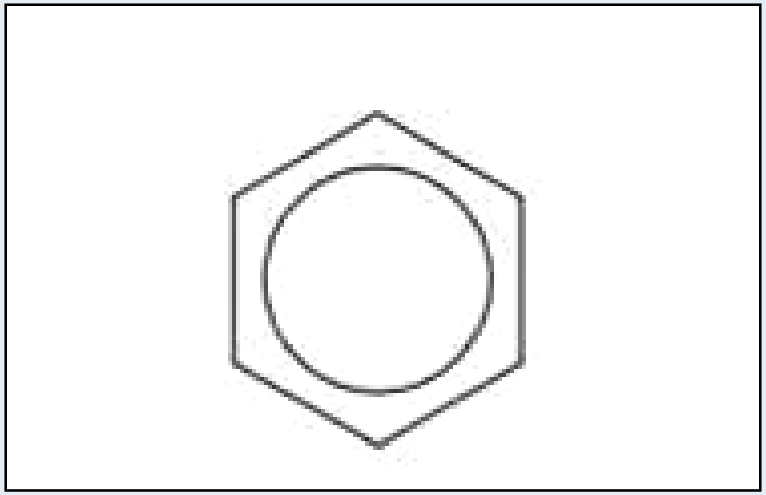
When Other Atoms are Substituted for the H's in the Benzene Ring

A vast array of other compounds can be produced



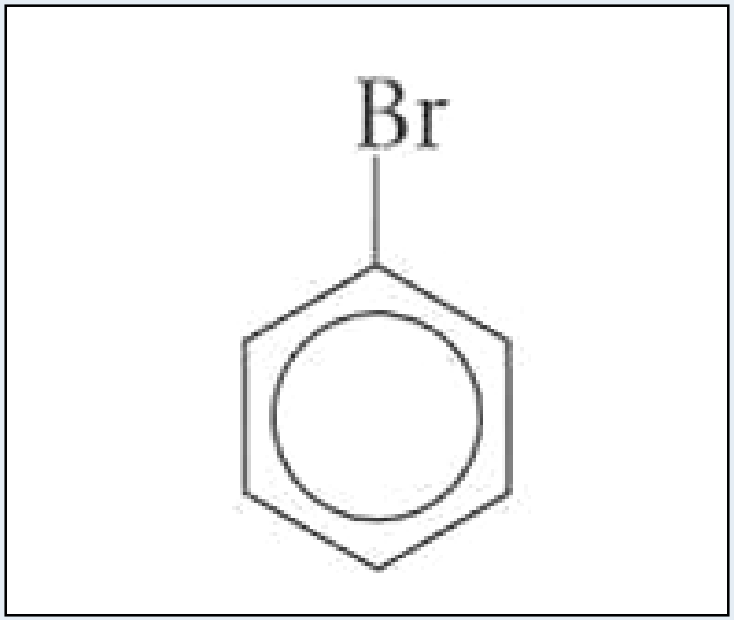
Drawing Structures for Benzene Derivatives
An Example

- *Draw the structural formula for 1,3-dibromobenzene.*
- First, Draw a benzene ring.



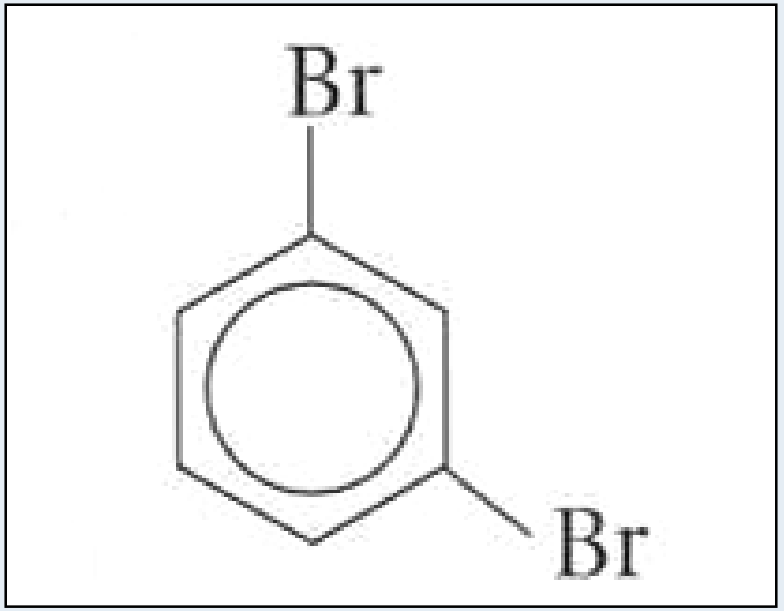
Drawing Structures for Benzene Derivatives
An Example (cont.)

- Second, attach a bromine atom (“bromo”) to the carbon atom at the ring position you choose to be number 1.



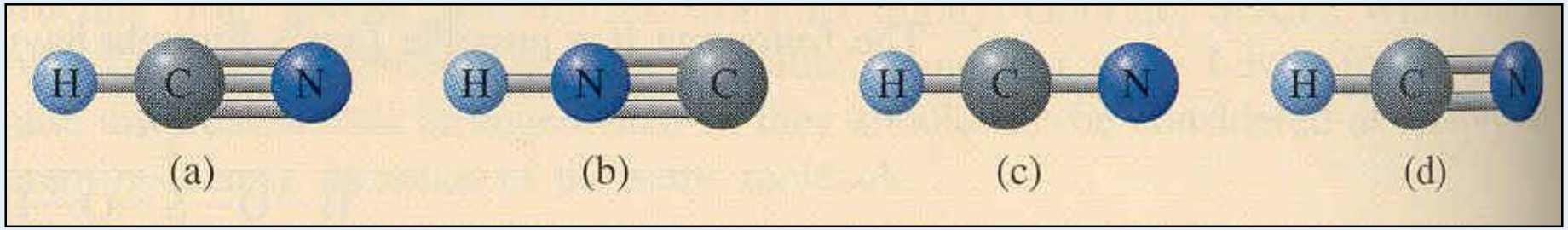
Drawing Structures for Benzene Derivatives
An Example (cont.)

- Third, attach a second (“di”) bromine atom to ring position 3 (you may number either clockwise or counterclockwise from carbon 1) and you have the answer.
- 1,3-dibromobenzene



Structures for Benzene Derivatives
Confidence Exercise

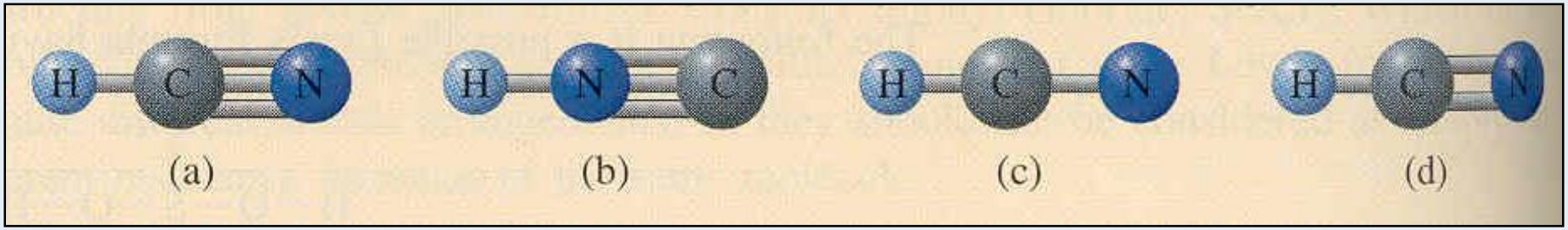
- *Which of the models below most accurately represents the hydrogen cyanide molecule, HCN?*



From *Ebbing/Gammon 7th Ed., p. 380*

Structures for Benzene Derivatives
Confidence Exercise (cont.)

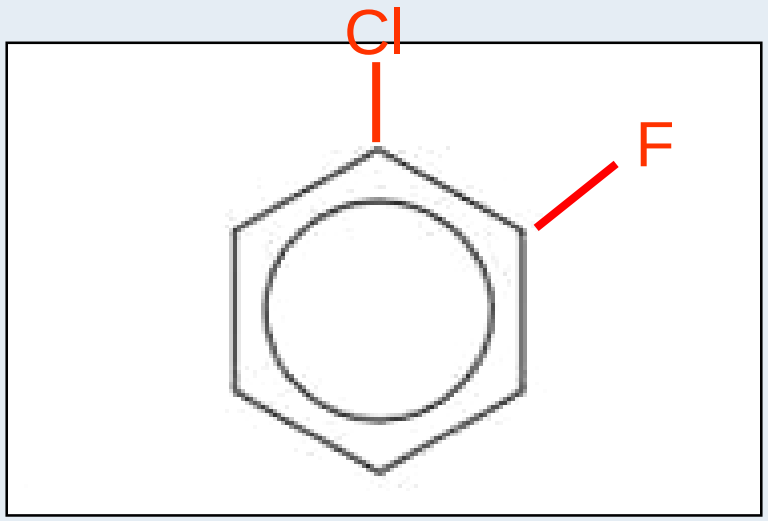
- C in (b) only has three bonds.
- C in (c) only has two bonds & N only has one.
- C in (d) only has three bonds & N only has two.
- Therefore, (a) appears to be the most accurate representation of the hydrogen cyanide molecule, HCN.
  - *N has three bonds, C has four bonds, H has one*



From *Ebbing/Gammon 7th Ed., p. 380*

Drawing Structures for Benzene Derivatives
Confidence Exercise

- *Draw the structural formula for 1-chloro-2-fluorobenzene.*
  1. Draw a benzene ring.
  2. Attach a chlorine atom (“chloro”) to the carbon atom at the ring position you choose to be number 1.
  3. Attach a fluorine atom to ring position 2 and you have the answer.
- 1-chloro-2-fluorobenzene

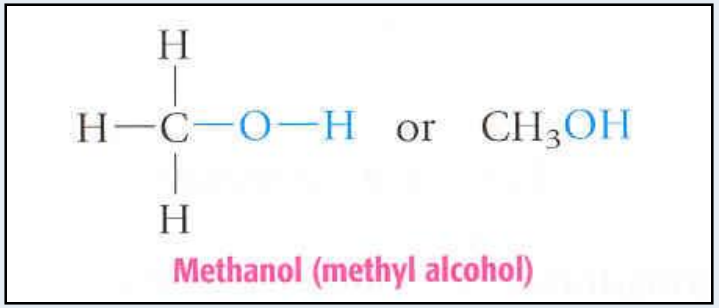


Aliphatic Hydrocarbons

- Aliphatic hydrocarbons are hydrocarbons having no benzene rings.
- Aliphatic hydrocarbons can be divided into four major divisions:
  - *Alkanes*
  - *Cycloalkanes*
  - *Alkenes*
  - *Alkynes*

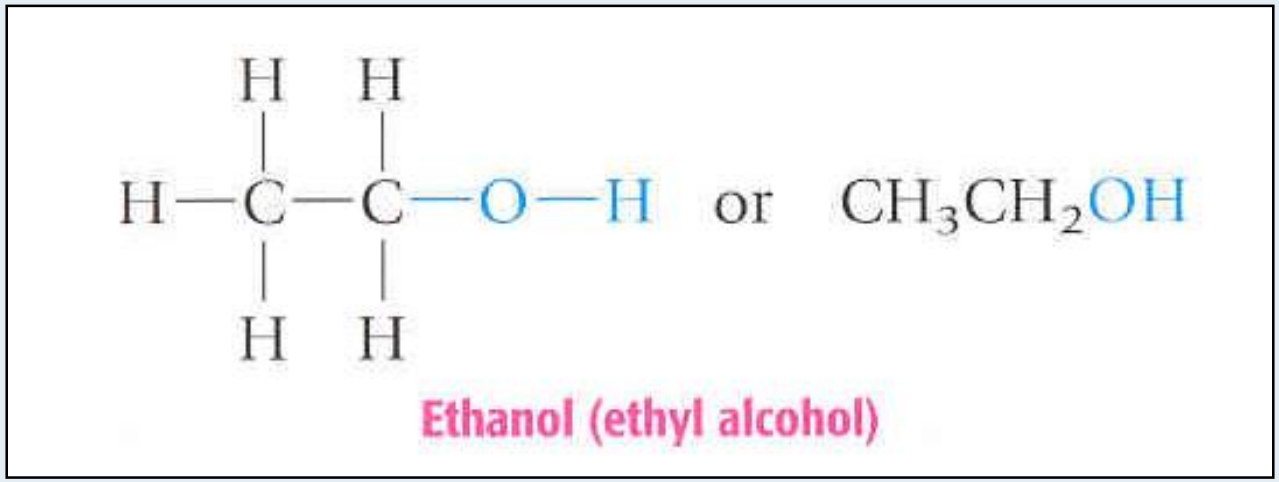
Alcohols

- Alcohols are organic compounds containing the hydroxyl group, —OH, attached to an alkyl group.
  - *General formula is R—OH*
- Their IUPAC (*International Union of Pure and Applied Chemistry*) names end in "-ol."
- The most simple alcohol is methanol
  - *Also called methyl alcohol or wood alcohol. (poisonous)*



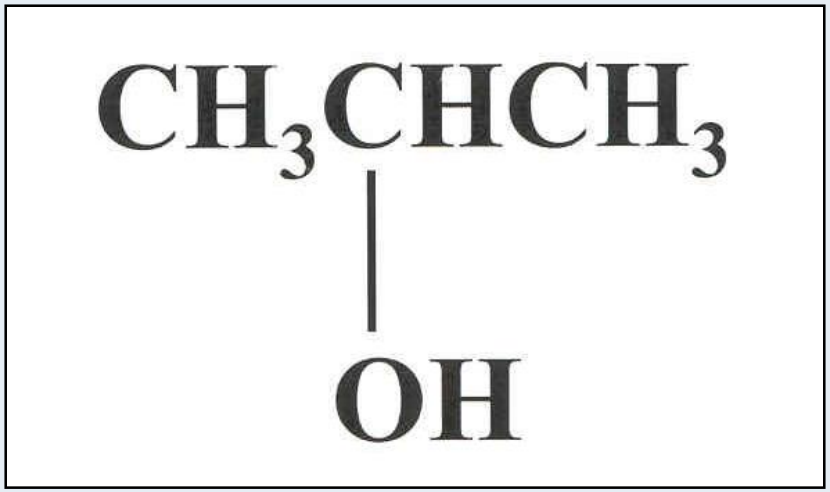
Alcohols

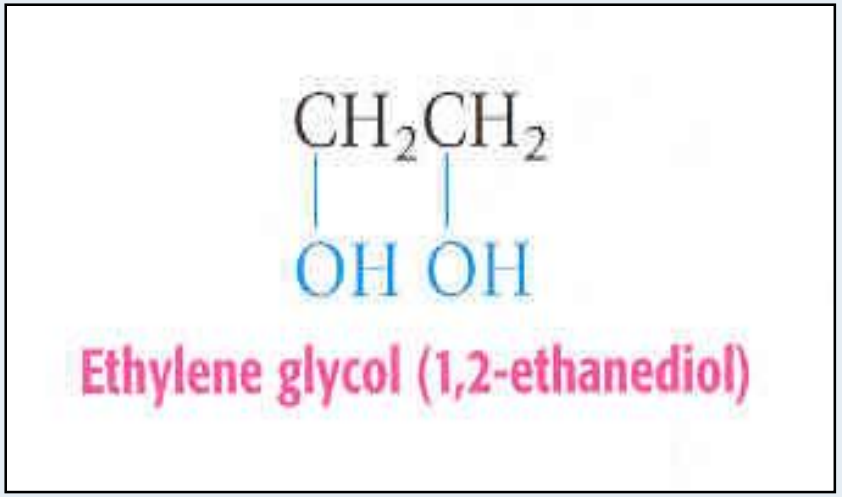
- Another common alcohol is ethanol. (CH_3CH_2OH)
  - *Also known as ethyl alcohol or grain alcohol*
  - *Least toxic and most important of the alcohols*
- Ethanol is used in alcoholic beverages, perfumes, dyes, and varnishes.



Other Alcohol Examples

- Rubbing alcohol is another alcohol example.
  - *Also known as 2-hydroxypropane or isopropyl alcohol*
- Ethylene glycol is an alcohol used widely as an antifreeze and coolant.



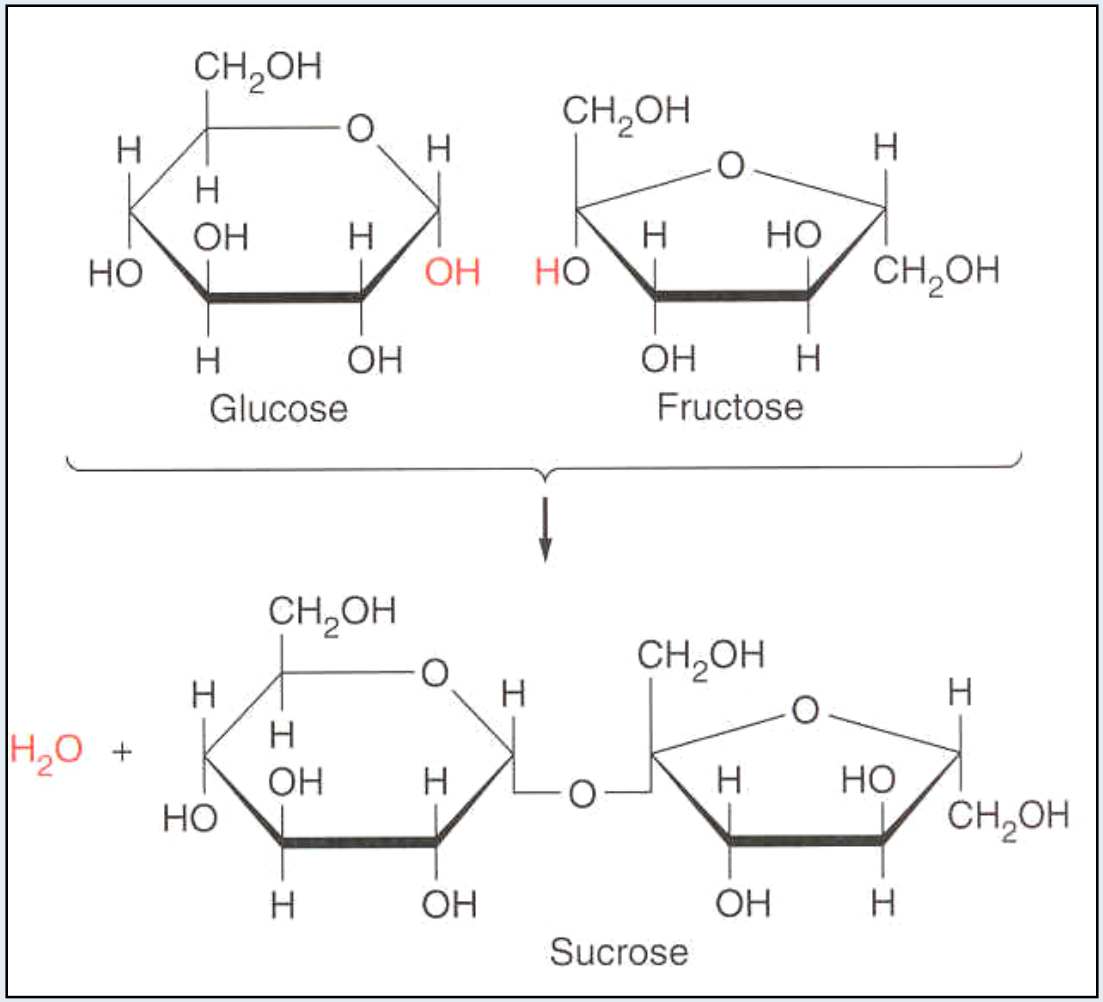


Carbohydrates

- Compounds that contain multiple hydroxyl groups in their molecular structure.
  - *Names end in "-ose"*
- Sugars, starches, and cellulose are the most important carbohydrates.
- Glucose ($C_6H_{12}O_6$) and fructose ($C_6H_{12}O_6$) are important sugars.
  - *Note that glucose and fructose are isomers.*

Structures of Glucose, Fructose, and Sucrose

- *Glucose & Fructose bond together to form Sucrose + H_2O*



Carbohydrates - Sugars

- Fructose is the sweetest of all sugars and is found in fruits and honey.
- Glucose (also called dextrose) is found in sweet fruits, such as grapes and figs, in flowers, and in honey.
- Carbohydrates must be broken down into glucose for circulation in the blood.

Carbohydrates - Starch

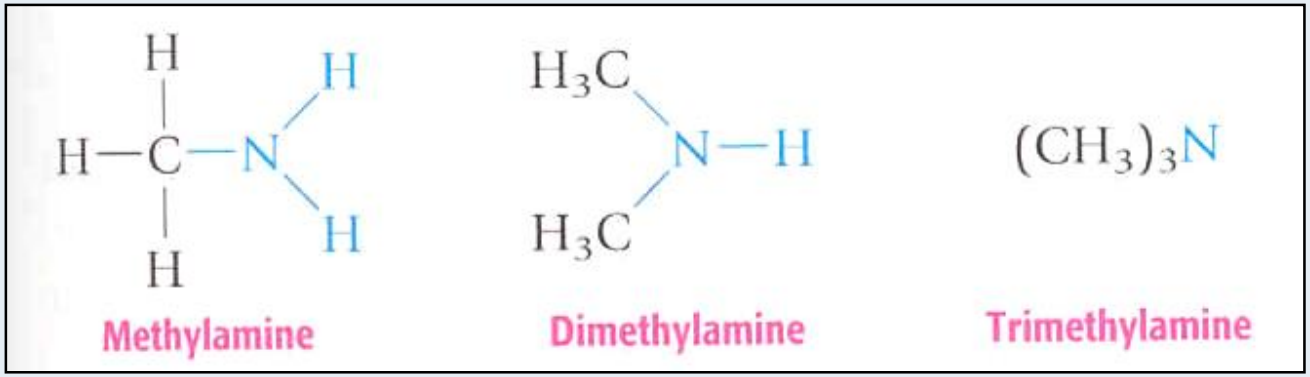
- Starch consists of very long chains (up to 3000 units) of glucose.
- Produced by plants in their seeds, tubers, and fruits
- When these plants parts are eaten, our digestive processes covert the starches back into glucose.

Carbohydrates - Cellulose

- Cellulose is also a polymer of glucose and has the general formula $(C_6H_{10}O_5)_n$.
  - *Slightly different structure with different properties than starches*
- Cell walls of plants are dominantly composed of cellulose.
- Humans do not have the appropriate enzymes (called cellulases) to break cellulose down.
- Termites and many herbivores contain bacteria that allow the breakdown of cellulose.

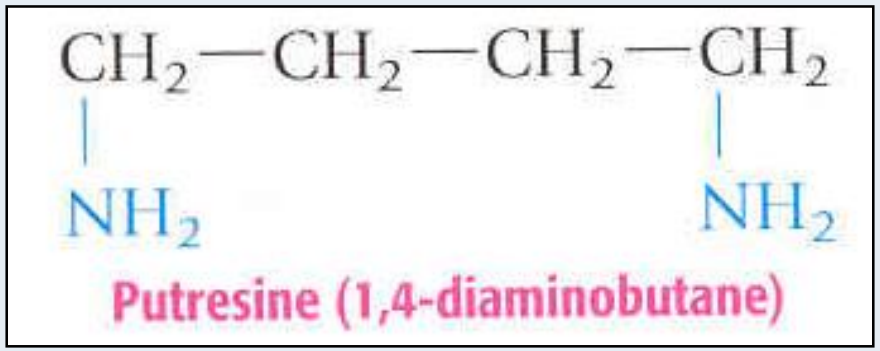
Amines

- Organic compounds that contain nitrogen and are basic (alkaline) are called <u>amines</u>.
- General formula for an amine is R—NH_2.
  - *One or two additional alkyl groups could be attached to the N atom, in place of H atoms.*
- Amine examples include methylamine, dimethylamine, and trimethylamine.



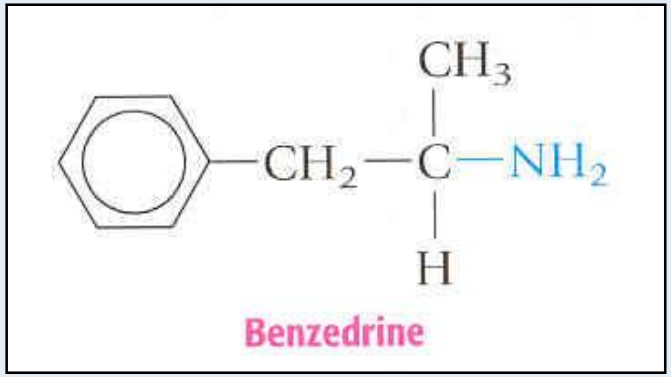
Amines – Strong Odors

- Most simple amines have strong odors.
- The odor given off by raw fish is due to an amine that it contains.
- Two particularly foul smelling amines are formed by decaying flesh.
  - *Cadaverine (1,5-diaminopentane)*
  - *Putresine (1,4-diaminobutane)*



Amines - Medicinal

- Many amines have medicinal applications.
- Amphetamines raise the glucose level in the blood resulting in less fatigue and hunger.
  - *These synthetic drugs certainly have legitimate medical uses, but can be addictive and lead to insomnia, excessive weight loss, and paranoia.*
- Benzedrine is one type of amphetamine.

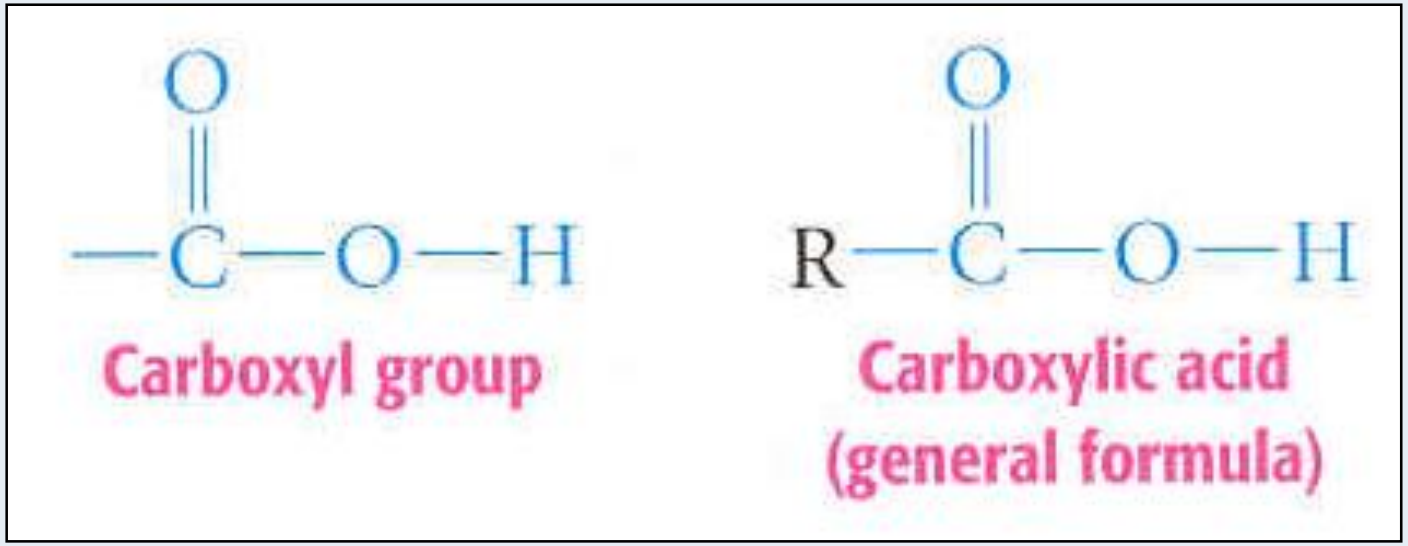


Benzedrine

The French artist David portrays *The Death of Socrates* due to the deadly alkaloid coniine

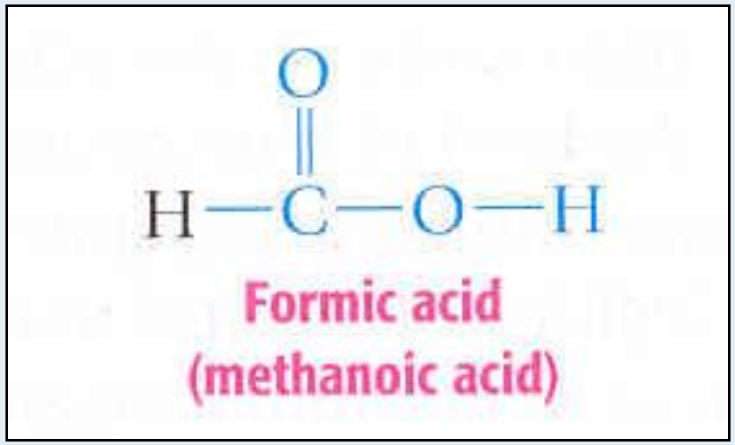
Carboxylic Acids

- Carboxylic acids contain the carboxyl group . (–COOH)
- They have the general formula RCOOH.

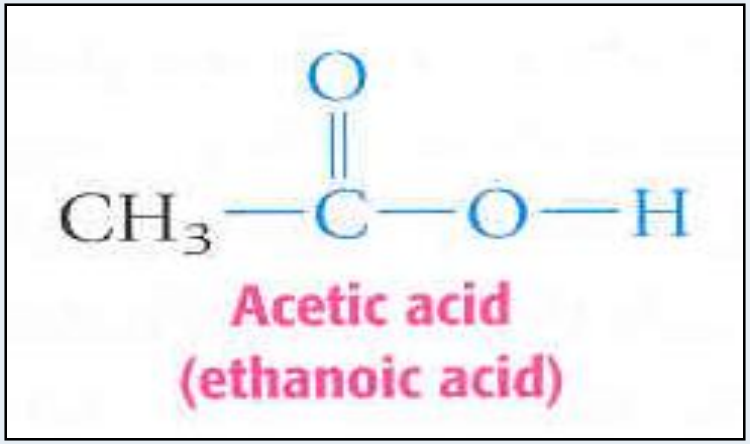


Carboxylic Acids

- Formic acid is the simplest carboxylic acid.
  - *This is the substance that causes the painful sting of insect bites.*

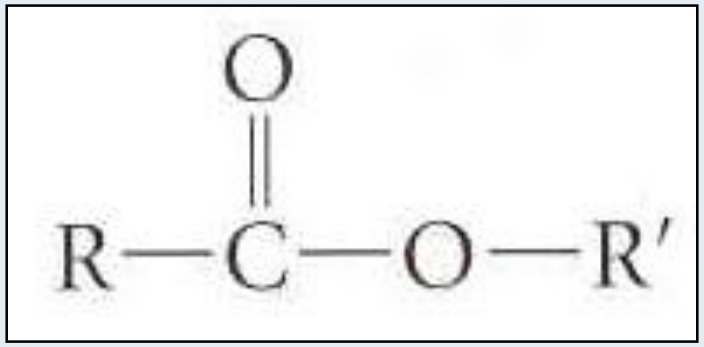


- Vinegar is a 5% solution of acetic acid.



Esters

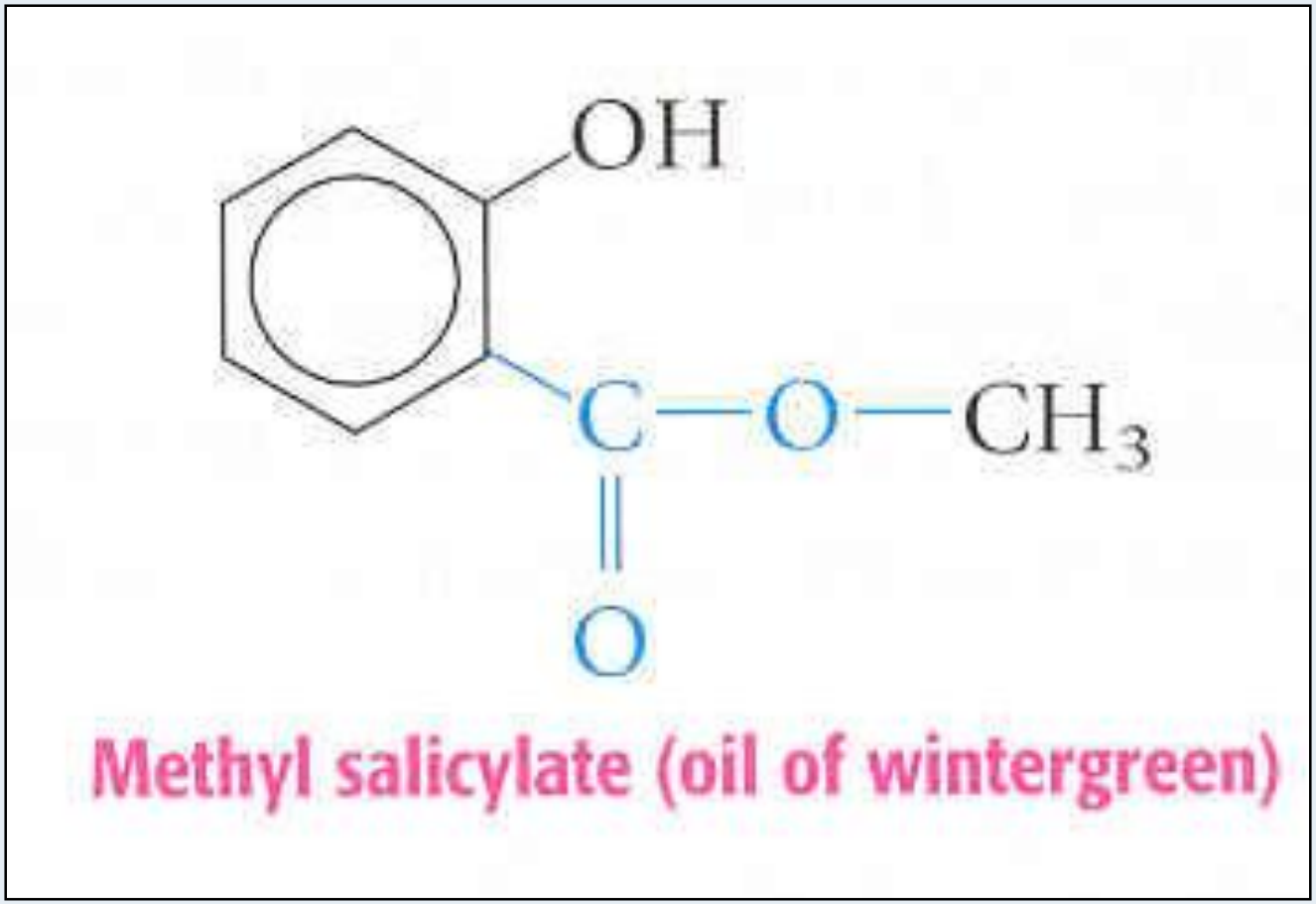
- Ester – a compound that has the following general formula RCOOR’



- In the general formula for an ester the R and R’ can be any alkyl group.
  - *Although R and R’ can be identical, they are usually different.*
- Contrary to amines, most esters have pleasant odors.
  - *Many flowers and ripe fruits have fragrances and tastes due to one or more esters.*

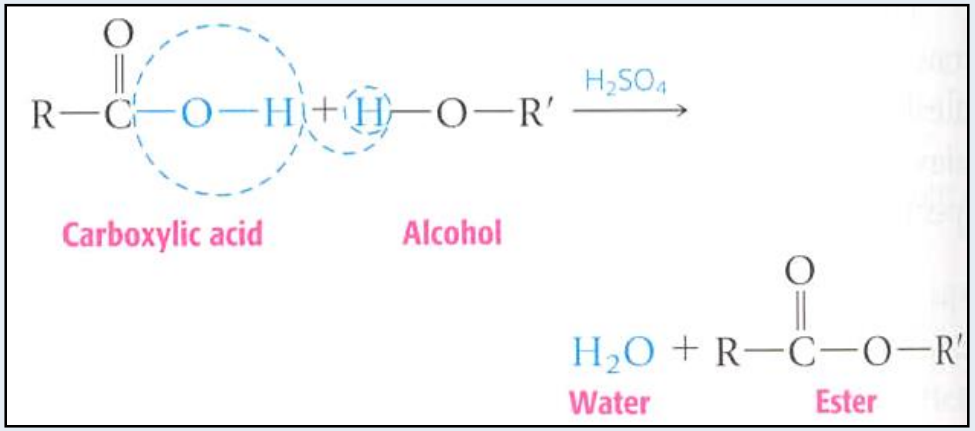
Odors of Esters

Natural flavors are generally complex mixtures of esters and other constituents



Formation of an Ester

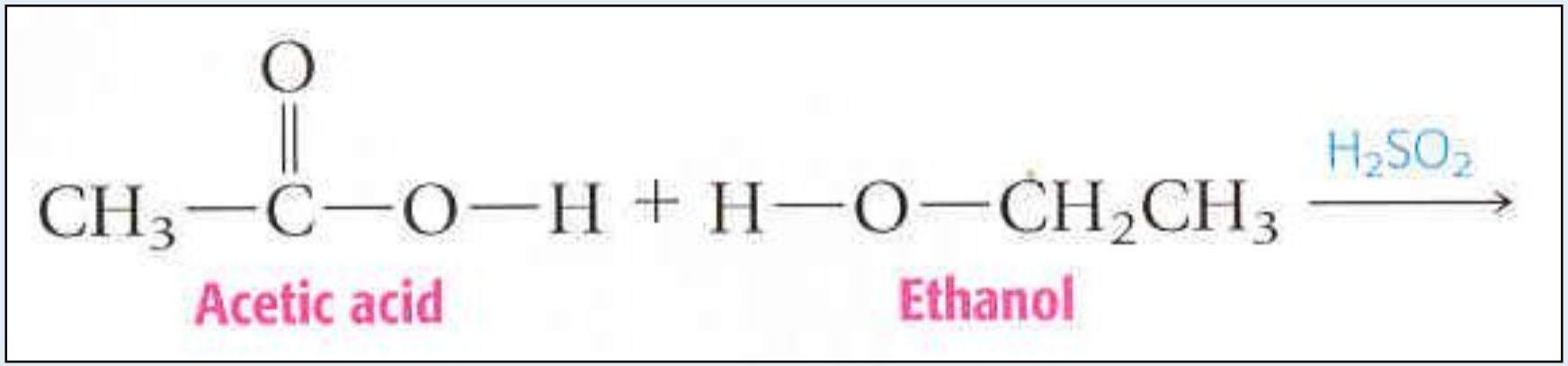
- Ester formation – the reaction of a carboxylic acid and an alcohol give an ester and water
  - *Heat is required and sulfuric acid is a catalyst.*



- Note, in this reaction that the –OH from the carboxylic acid unites with the H from the alcohol to form H_2O.
- The remaining two fragments bond together to form the ester.

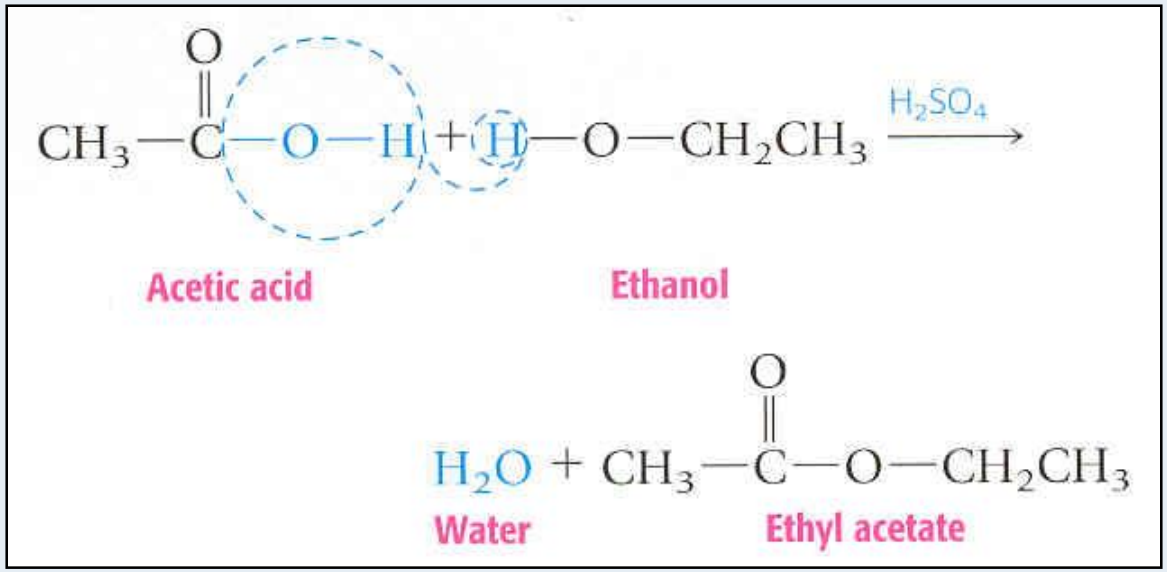
Writing an Equation for Ester Formation
An Example

- *Complete the equation for the sulfuric acid-catalyzed reaction between acetic acid and ethanol.*



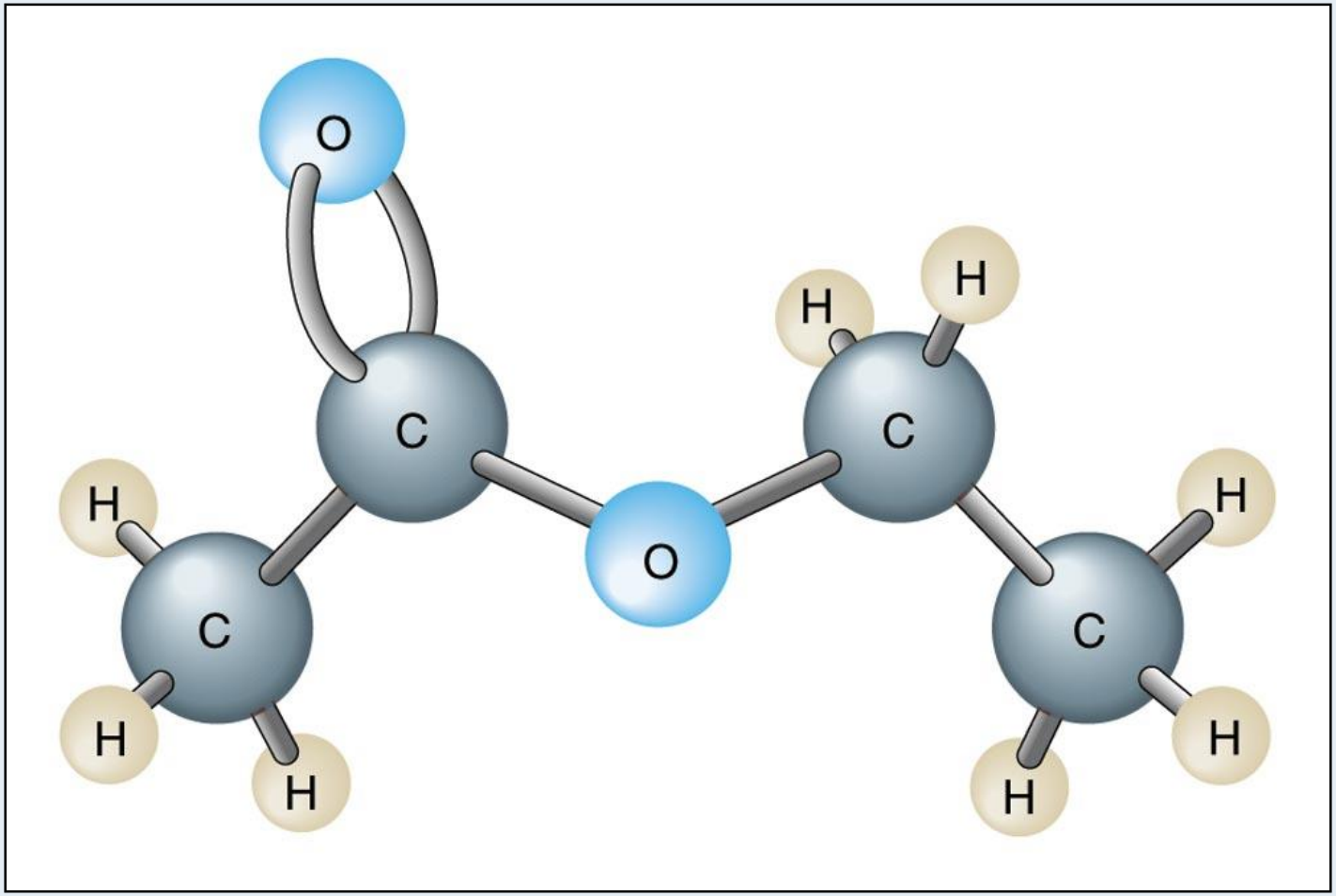
Writing an Equation for Ester Formation
An Example (cont.)

- "Lasso" the –OH from the acetic acid and the H from the ethanol to form H_2O.
- Attach the remaining acid and alcohol fragments together – forming ethyl acetate.



Ethyl Acetate Molecule

An ester used as a solvent in lacquers and other protective coatings



From Ebbing, *General Chemistry, 6th Ed.*

Fats

- Fats are a type of ester formed by the combination of the trialcohol named glycerol and fatty acids.
  - *Glycerol is $CH_2(OH)CH(OH)CH_2(OH)$*
  - *Stearic Acid ($C_{17}H_{35}COOH$) is found in beef fat, and is a typical fatty acid.*

Fats

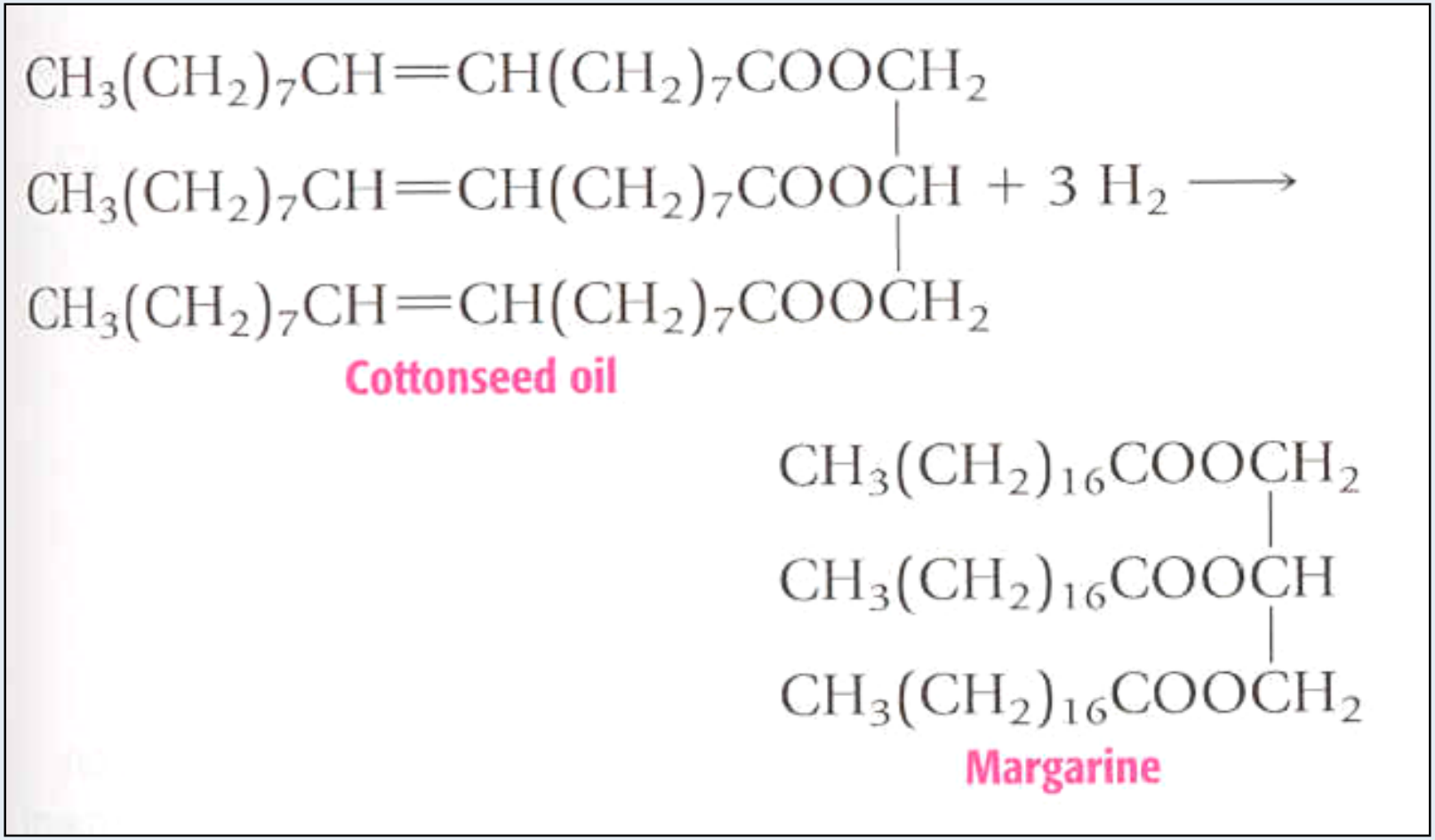
- Generally fats from animals are solid at room temperature.
- Fats from plants and fish are generally liquid at room temperature.
- Liquid fats are referred to as oils.

Hydrogenation

- Liquid fats contain double bonds between some of the carbon atoms.
  - *These liquids fats are termed unsaturated.*
- Hydrogenation is the process of adding H to the C atoms that have a double bond.
  - *The hydrocarbon chains become saturated or nearly saturated and the liquid fat is changed to a solid.*
- A common example of hydrogenation is the reaction cottonseed oil to margarine.

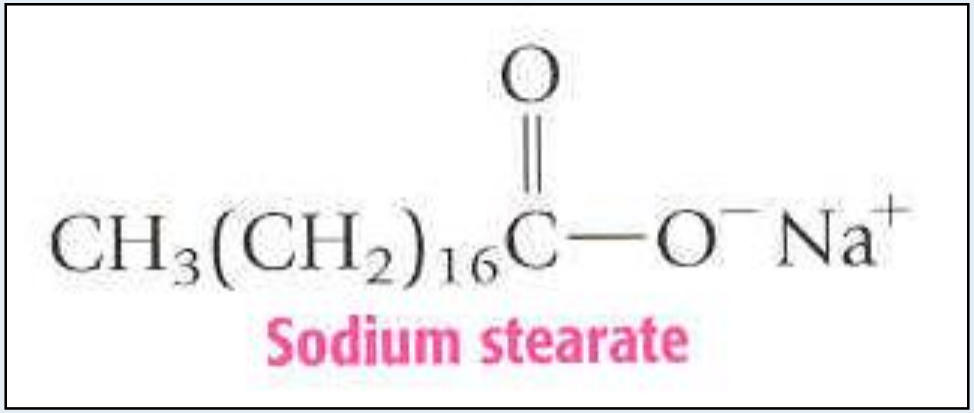
Hydrogenation

When Cottonseed Oil (liquid) is hydrogenated, Margarine (solid) is the result.



Soaps

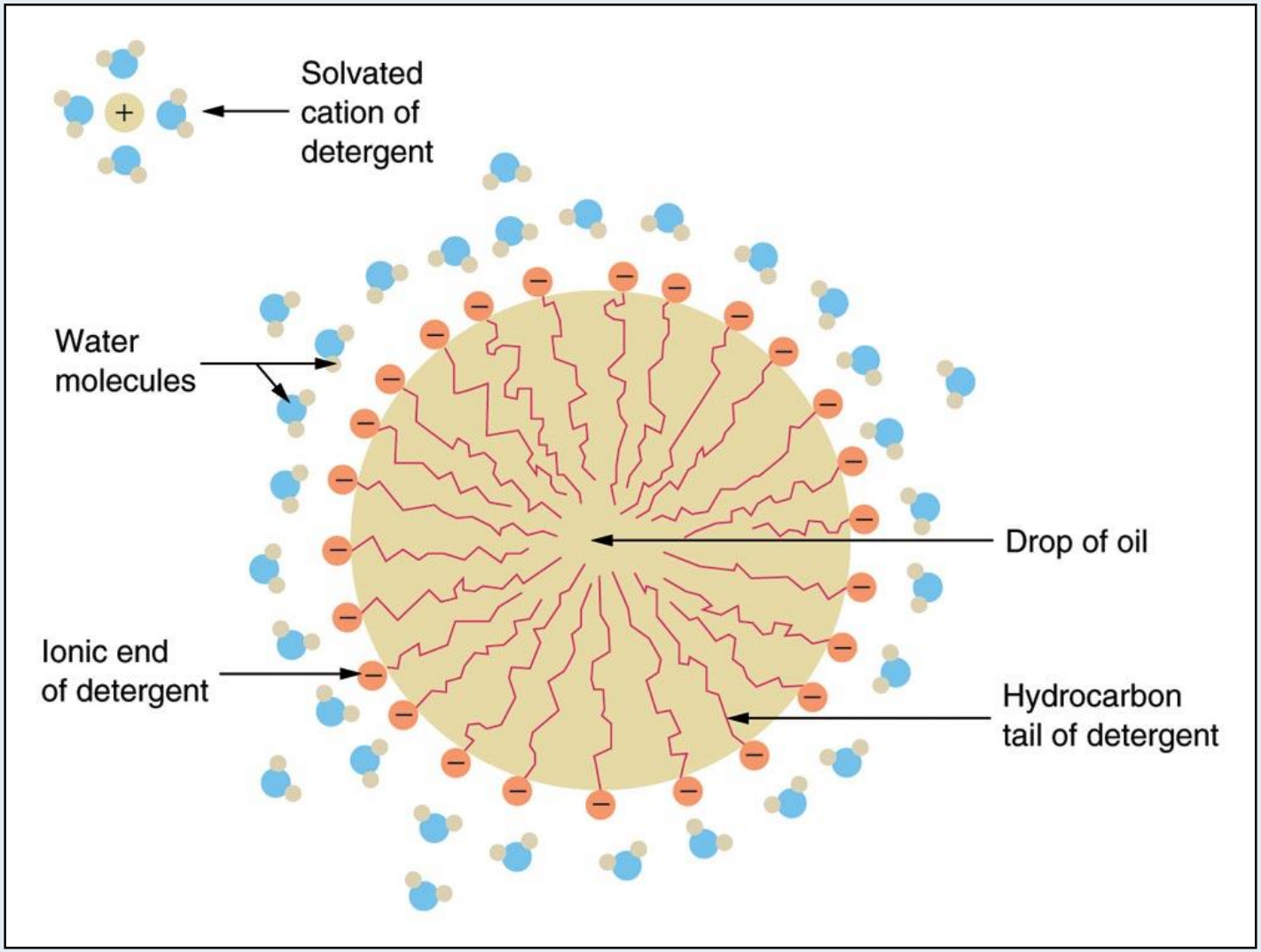
- Soap – the sodium slats of fatty acids
- Soap is formed by reacting a fat with sodium hydroxide (NaOH, lye.)
- The ester bonds break giving rise to glycerol and sodium salts of the fatty acids.
- Sodium stearate is a typical soap.



Soap – *Like Dissolves Like*

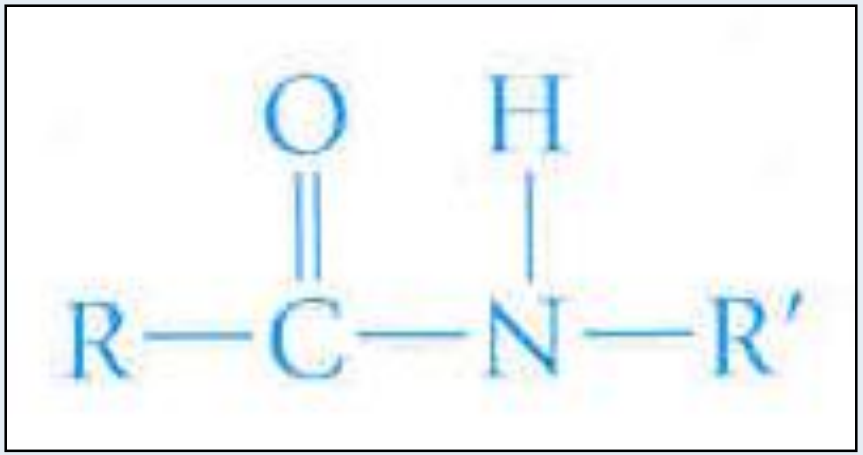
- Generally we want to dissolve stains made by nonpolar compounds such as grease.
- The polar end of the soap dissolves in water.
- The other end of the soap molecule is long and nonpolar.
  - *This nonpolar end dissolves in the grease.*
  - *The emulsified grease droplets can be rinsed away.*

The long nonpolar chains of the detergent molecule dissolve the grease.



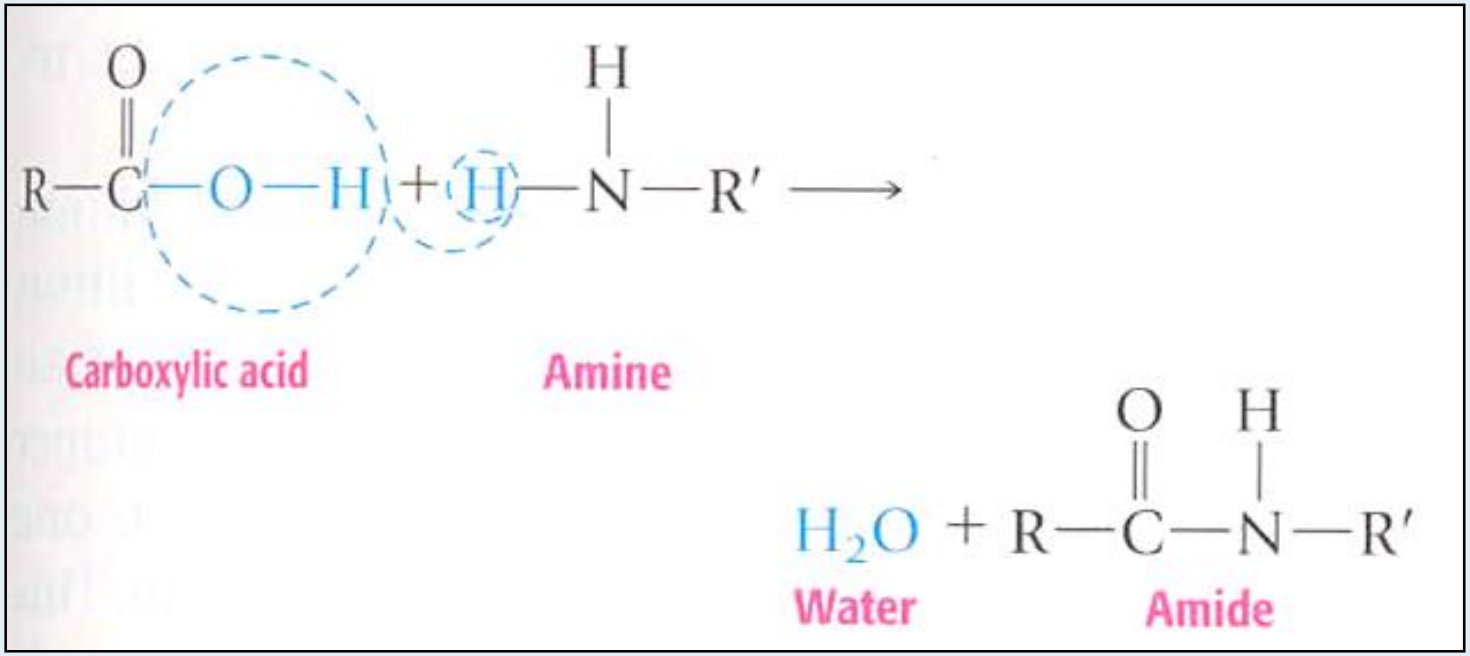
Amides

- Amides are nitrogen-containing organic compounds with the general formula RCONHR'.



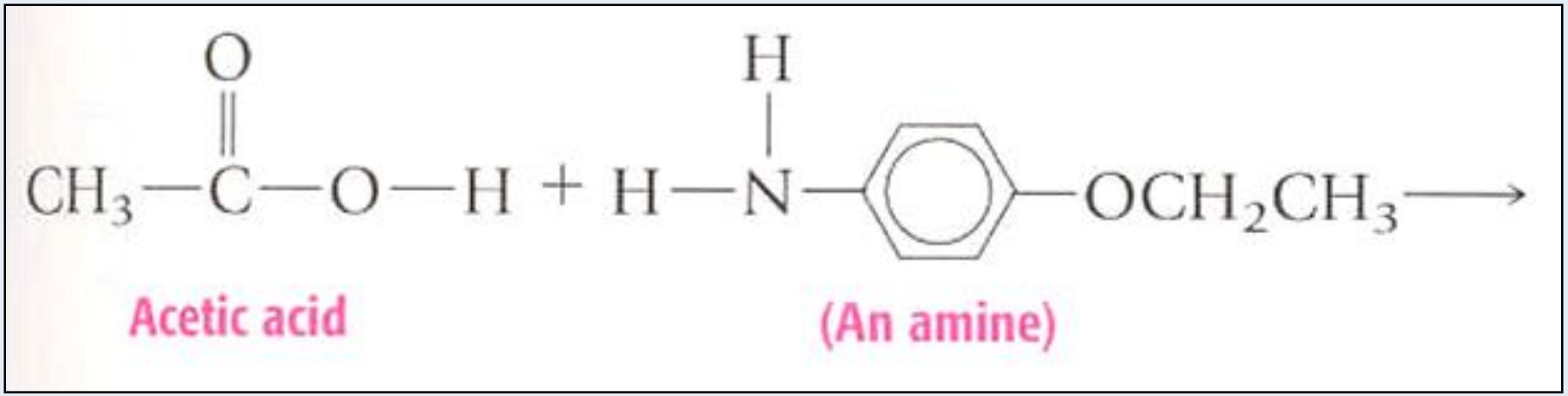
Amide Formation

- Amide formation is similar to ester formation.
- A carboxylic acid reacts with an amine to form water and an amide, as shown below.



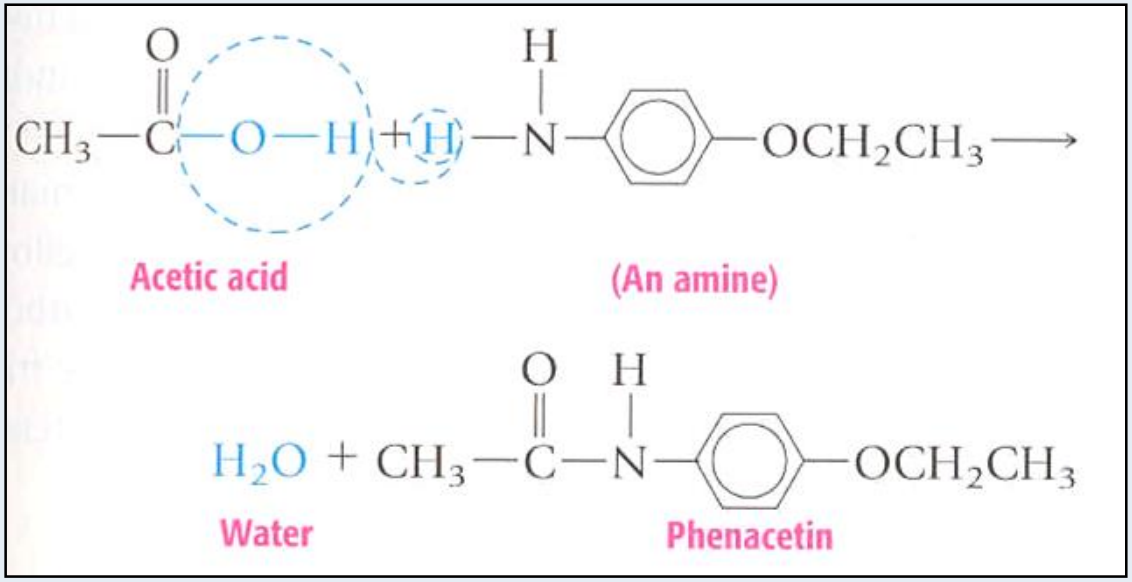
Writing an Equation for Amide Formation
An Example

- *Complete the equation for the reaction to form Phenacetin.*



Writing an Equation for Amide Formation *An Example (cont.)*

- "Lasso" the –OH from the acid and the H from the amine to form H_2O.
- Attach the remaining acid and amine fragments together – forming Phenacetin.

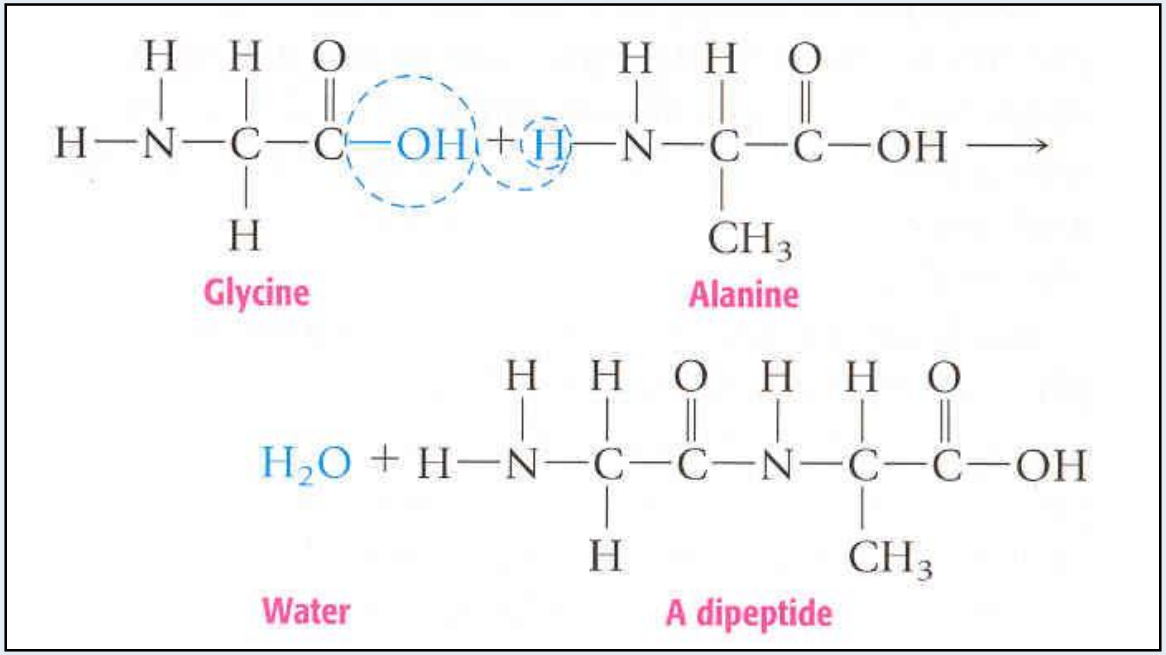


Amino Acid

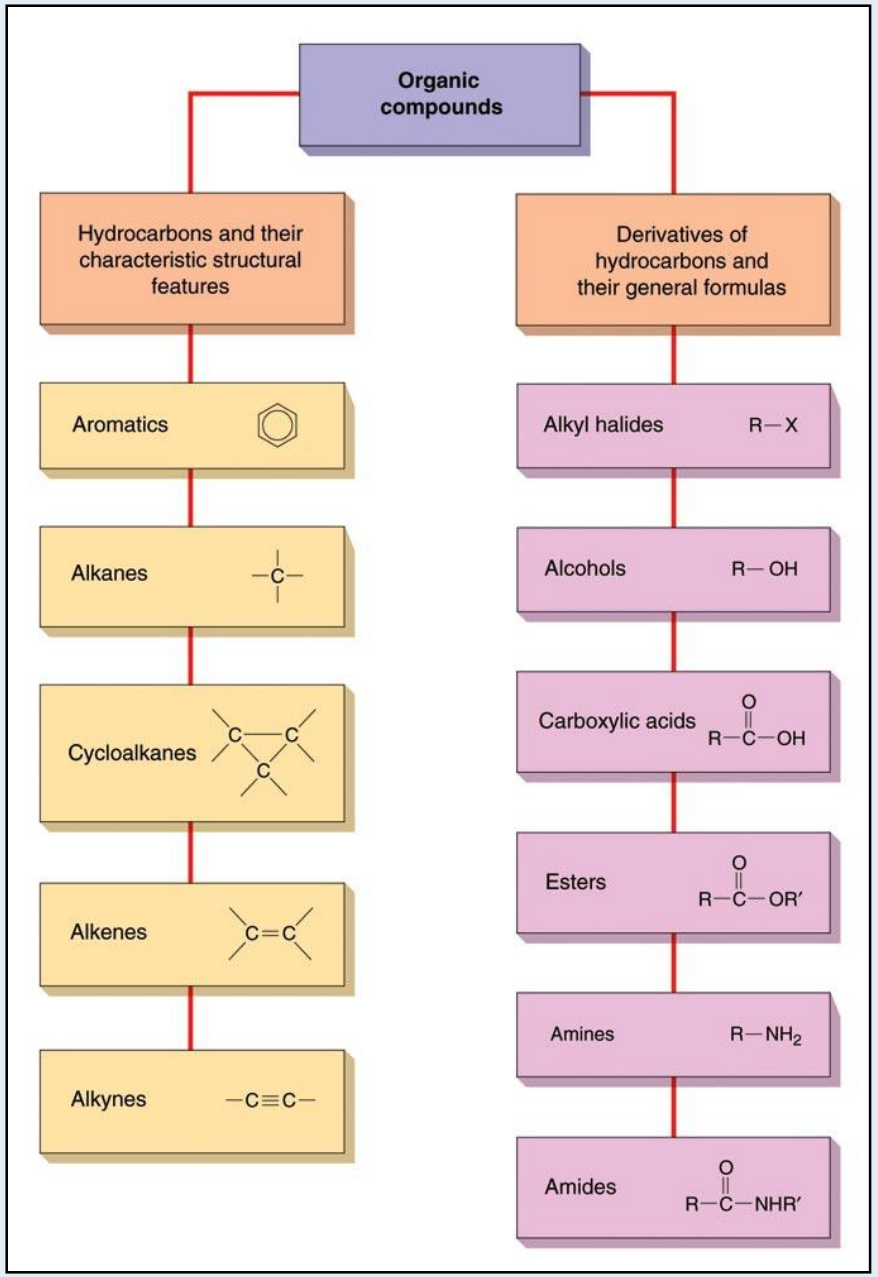
- Amino acids are organic compounds that contain both an amino and carboxyl group.
- Glycine and alanine are the simplest amino acids.
- Proteins are extremely long polyamides, formed by the condensation of amino acids.
  - Proteins can range from a few thousand formula units (insulin) to several million formula units.
  - Proteins serve as both structural components and enzymes.

Linking Amino Acid Molecules

- Glycine and alanine react to form water and another amino acid.
  - *This process can be repeated, eventually forming a protein.*



Hydrocarbons and their Derivatives Names and General Formulas



Synthetics

- Attempts to duplicate nature have long been a goal of chemists.
- Basic formulas and structures became known as the science of chemistry progressed.
- As attempts were made to synthesize natural compounds, synthetic compounds were created.
- Synthetics are materials whose molecules have no duplicate in nature.

Synthetic Polymers

- The first synthetic polymer was prepared by Leo Baekeland in 1907.
- Commercially this substance was used as an electrical insulator, called Bakelite.
- Chemists soon discovered that only slight substitutions to a molecule could create new substances with very different properties.
  - *Knowing the chemical properties of the original molecules and the substitutes allowed chemists to predict the resulting properties.*

Synthetic Polymers

- Due to the scientific approach, chemists were able to tailor new molecules for specific purposes.
- Plastics are probably the best known of this group of synthetic polymers.
- They can be molded and hardened for many different purposes.

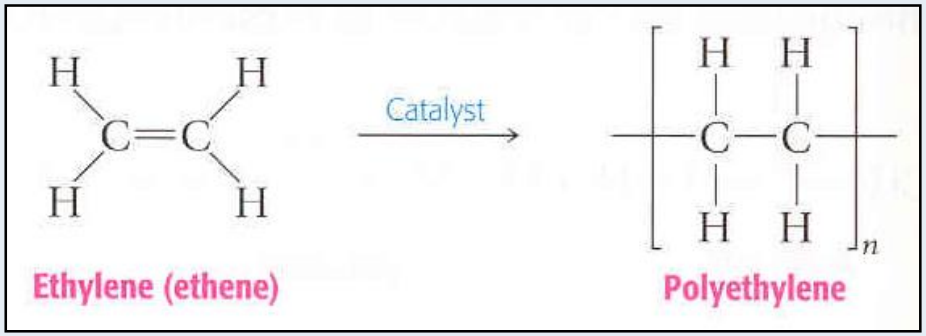
Synthetic Polymers

- A polymer is a compound of very high formula mass whose long chain molecules are made of repeating units.
- Monomer is the fundamental repeating unit of a polymer.
- There are two major types of polymers:
  - *Addition polymers*
  - *Condensation polymers*

Addition Polymers

- Addition polymers are formed when molecules of an alkene monomer add to one another.
- Recall that alkenes have a double bond between two carbon atoms.
- Under the proper reaction conditions the double bond opens up and attaches itself by single bonds to two other monomer molecules.
- Each of these monomers will then in turn attach to another monomer, and so on and on…

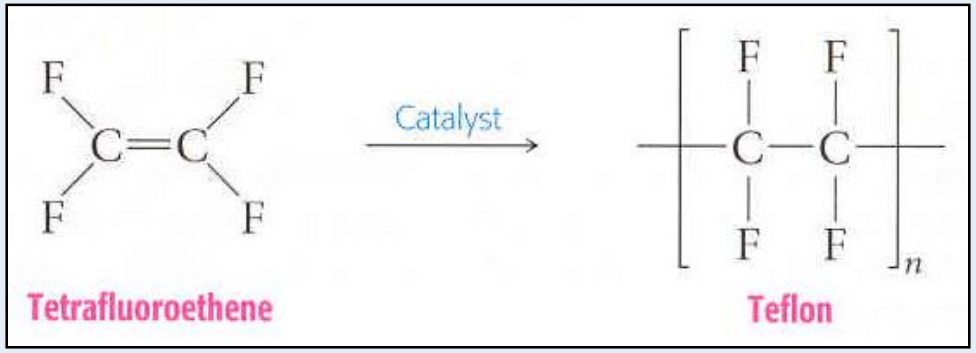
Polymerization of Ethene



- The subscripted *n* on polyethylene indicates that the unit shown in brackets is repeated thousands of times.
- Polyethylene is the simplest of the synthetic polymers.
  - *It is significantly inert chemically and is used to make containers.*

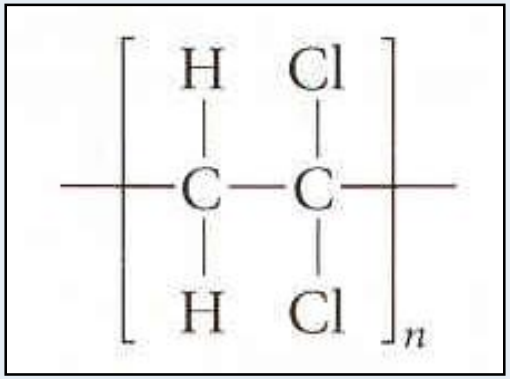
Teflon

- Teflon is made by the polymerization of tetrafluoroethene.
- This polymer is a hard, strong, chemically resistant compound with a high melting point and very low surface friction.

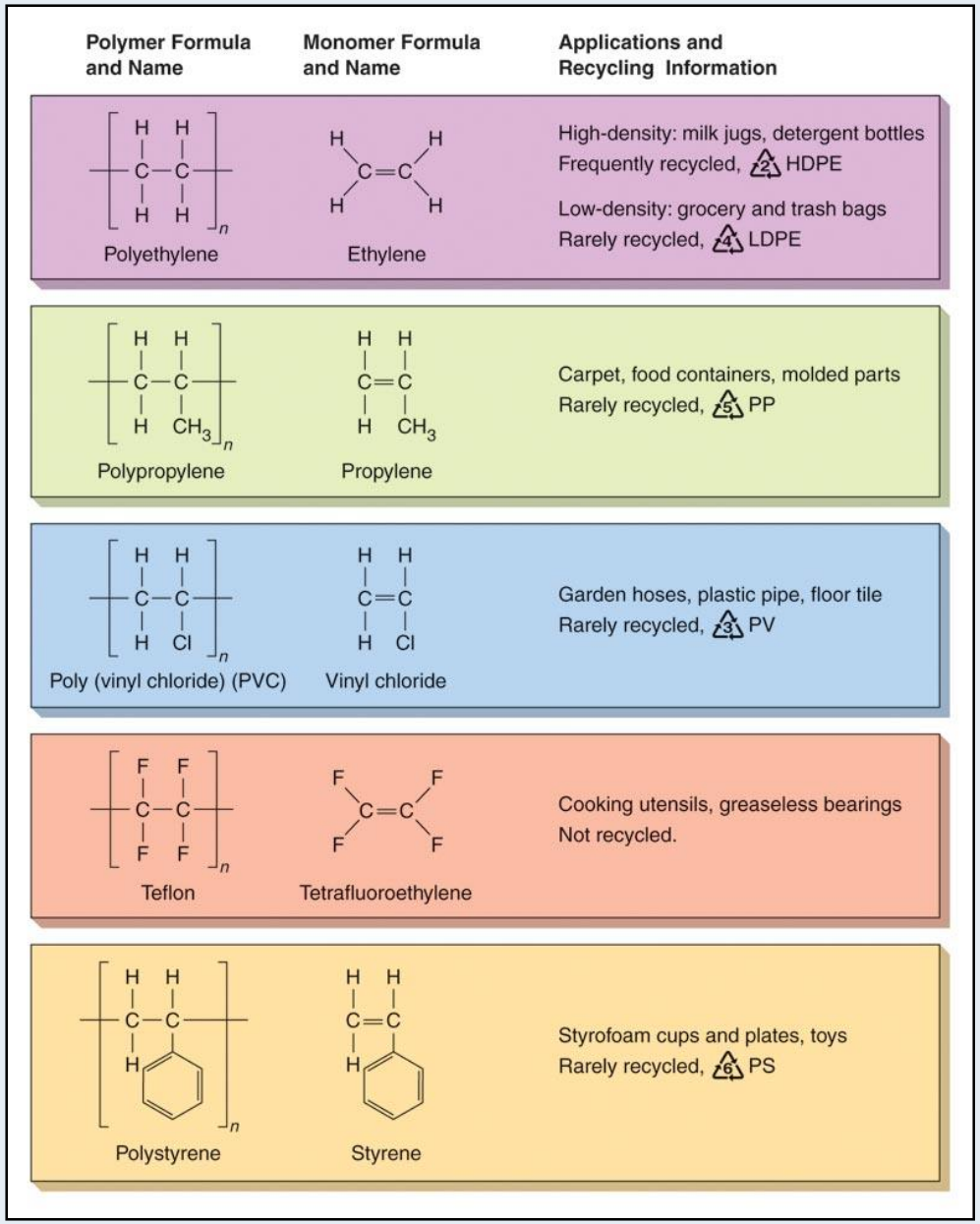


Drawing the Structure of an Addition Polymer - *An Example*

- *An addition polymer can be prepared from vinylidene chloride, $CH_2{=}{=}CCl_2$. Draw the structure of the polymer.*
- To form the polymer the double bonds of all the monomers ($CH_2{=}{=}CCl_2$) must open up and repeatedly bond to the growing chain of monomers.
- The structure is shown as:

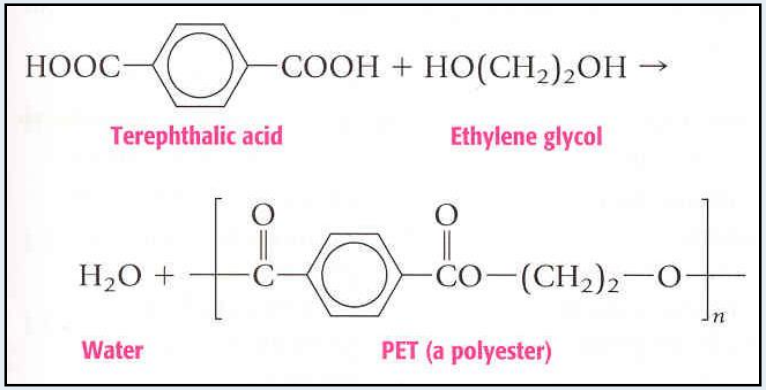


Some Common Addition Polymers



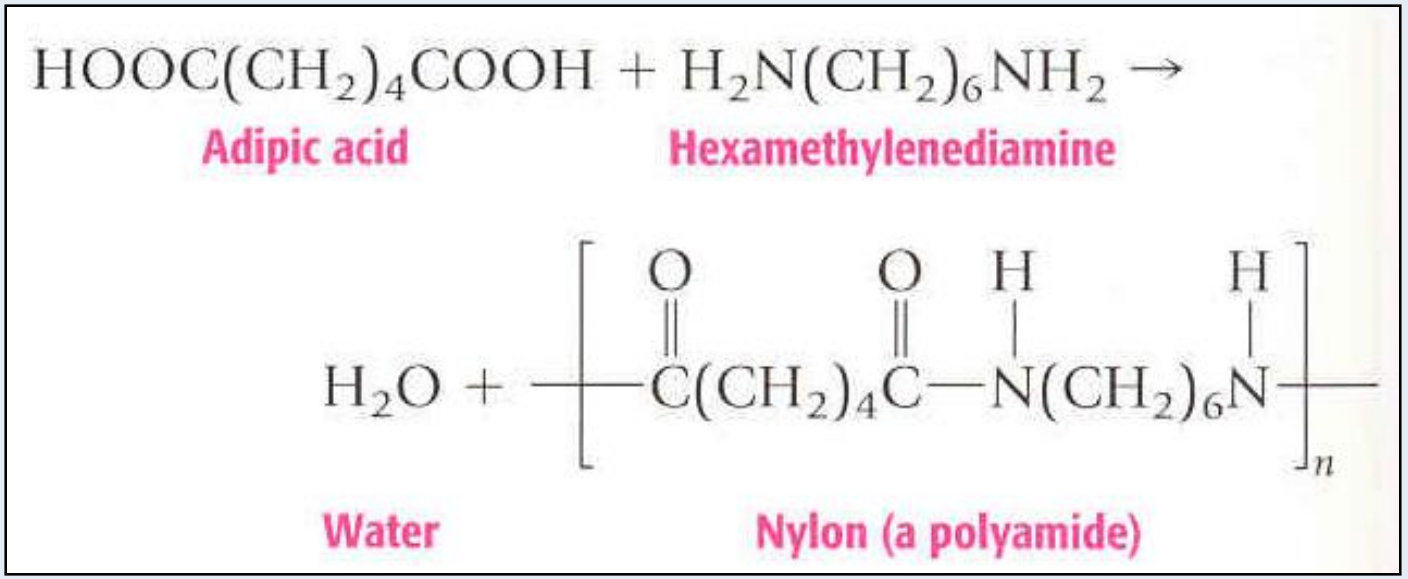
Condensation Polymers

- Condensation polymers are formed from molecules of two or more reactive groups.
  - *Water is the other product, hence the name condensation polymers.*
- Polyethylene terephthalate (PET) is formed from the polymerization of tetephthalic acid and ethylene glycol.



Nylon – A Condensation Polymer

- Nylon was first introduced to the public in 1939 at the New York World's Fair.
- Nylon is formed from the polymerization of adipic acid and hexamethylenediamine.



Velcro

- Velcro is a popular fastener made of nylon.
- The hooks of one surface entangle the loops of the other surface.