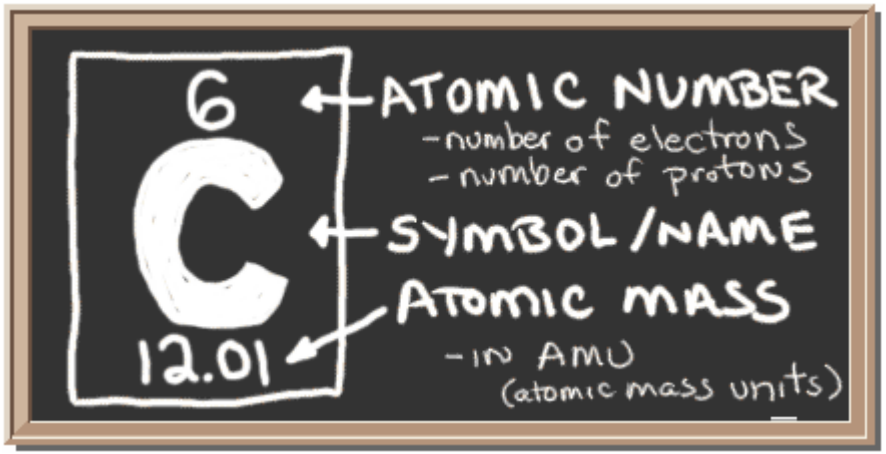
Alkanes

Chapter 1.1

Organic Chemistry

- The study of carbon-containing compounds and their properties

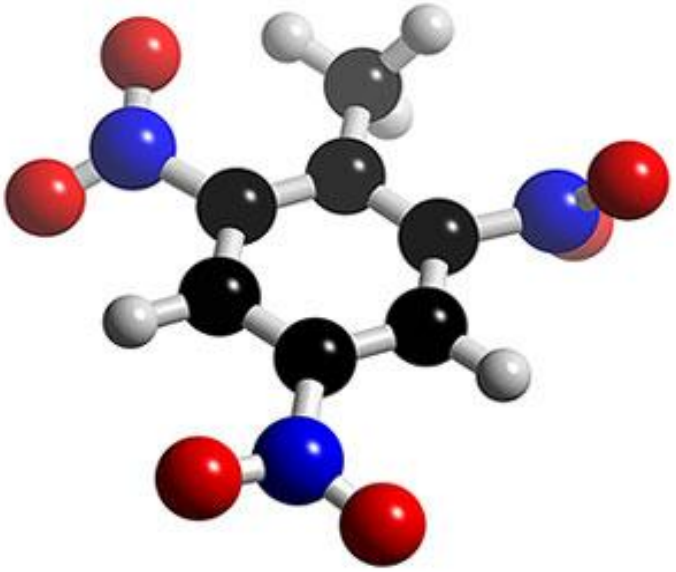


What's so special about carbon?

- Carbon has 4 bonding electrons. Thus, it can form 4 strong covalent bonds (with itself, H, O, N, P, S, and halogens)
- Carbon can form single, double, and triple bonds with itself
- Carbon can bond together to form a variety of geometrical structures (straight chains, branched chains, rings, sheets, tubes, spheres)

Organic Compound

- An **organic compound** is a molecular compound of carbon, not including carbon monoxide, carbon dioxide, and hydrogen cyanide



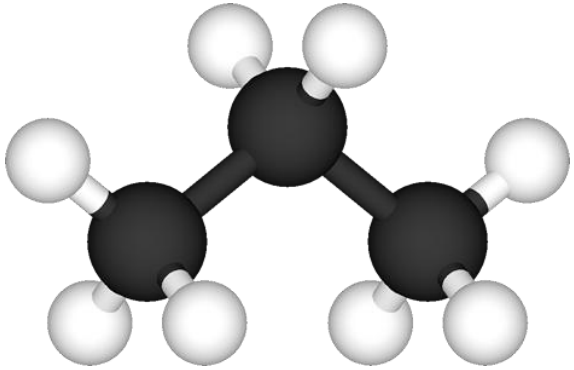
Representing Organic Compounds

1. IUPAC name
2. Common name
3. Molecular Formula
4. Expanded Molecular Formula
5. Complete Structural Diagram
6. Condensed Structural Diagram
7. Line Structural Diagram

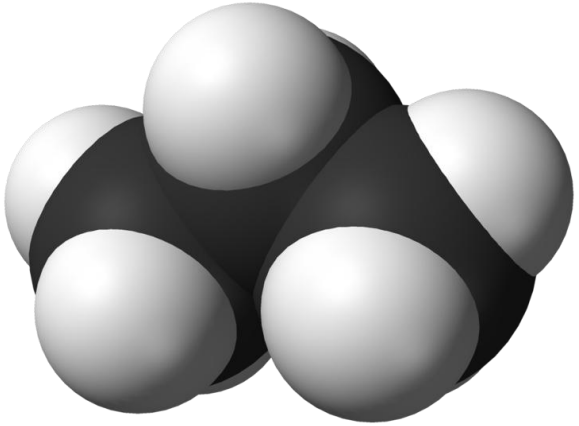
Representing Organic Compounds

8. Molecular Model

    a) Ball-and-stick model



    a) Space-filling model



Hydrocarbons

- **Hydrocarbons** are molecules that consist only of carbon atoms and hydrogen atoms connected by covalent bonds
- Most fuels are hydrocarbons (ex: methane, butane, propane)
- Burning hydrocarbons is a major contributor to global warming

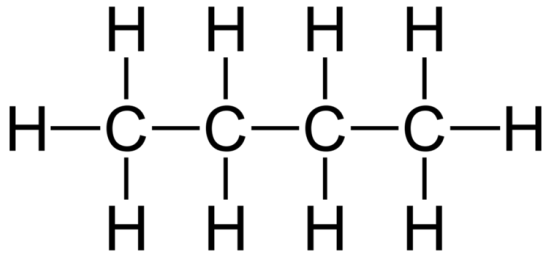
$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

(combustion of methane)

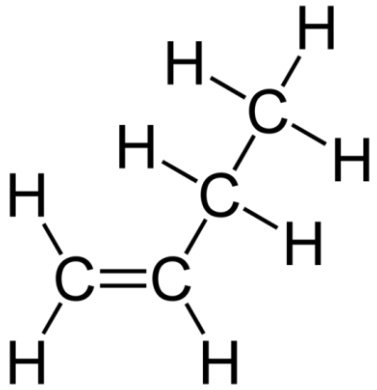
Saturated vs. Unsaturated

Hydrocarbons can either be saturated or unsaturated

- A **saturated hydrocarbon** is a hydrocarbon with only single covalent bonds between its carbon atoms. **Saturated hydrocarbons** are also called **alkanes**

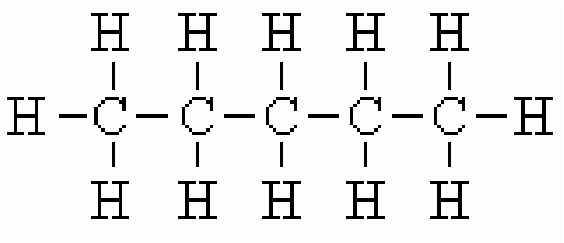


- An **unsaturated hydrocarbon** is a hydrocarbon with one or more double or triple bonds joining pairs of carbon atoms within the molecule



Alkanes

- The general chemical formula for an alkane is C_nH_{2n+2}



Naming Alkanes

- Use the suffix “–ane”
- Use a Greek root word to indicate the number of carbon atoms in the molecule

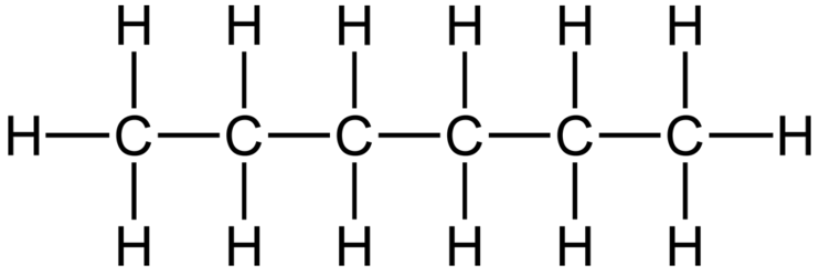
Table 1 The First Ten Alkanes

Number of C atoms	Name	Molecular formula	Condensed formula
1	methane	CH_4	
2	ethane	C_2H_6	CH_3CH_3
3	propane	C_3H_8	$CH_3CH_2CH_3$
4	butane	C_4H_{10}	$CH_3(CH_2)_2CH_3$
5	pentane	C_5H_{12}	$CH_3(CH_2)_3CH_3$
6	hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$
7	heptane	C_7H_{16}	$CH_3(CH_2)_5CH_3$
8	octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$
9	nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$
10	decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

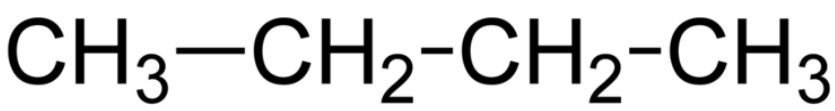
Practice

Name the following alkanes:

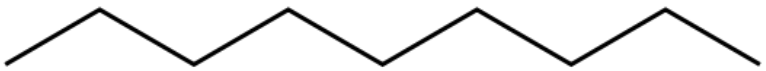
a)



b)



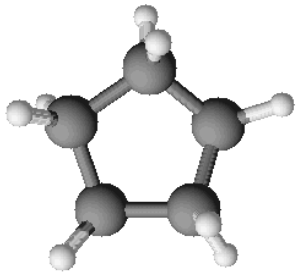
c)



Practice

Draw the complete structural diagram, the condensed structural diagram, and the line structural diagram for **pentane**.

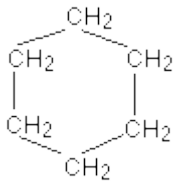
Cyclic Alkanes

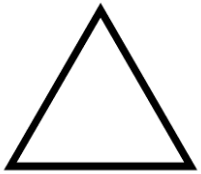


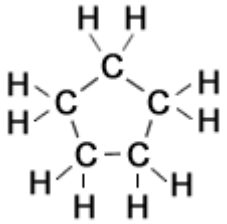
- Not all alkanes are straight-chain alkanes (in which the carbon atoms form long chains)
- A cyclic alkane, or cycloalkane, is a hydrocarbon in which the carbon atoms form a closed loop instead of a chain
- The general formula for a cyclic alkane is C_nH_{2n}
- When naming cyclic alkanes, simply add the prefix *cyclo-*

Practice

Name the following cyclic alkanes:

a) 

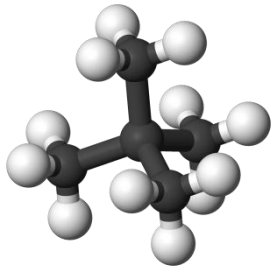
b) 

c) 

Practice

- Draw the complete structural diagram, the condensed structural diagram, and the line structural diagram for **cyclobutane**.

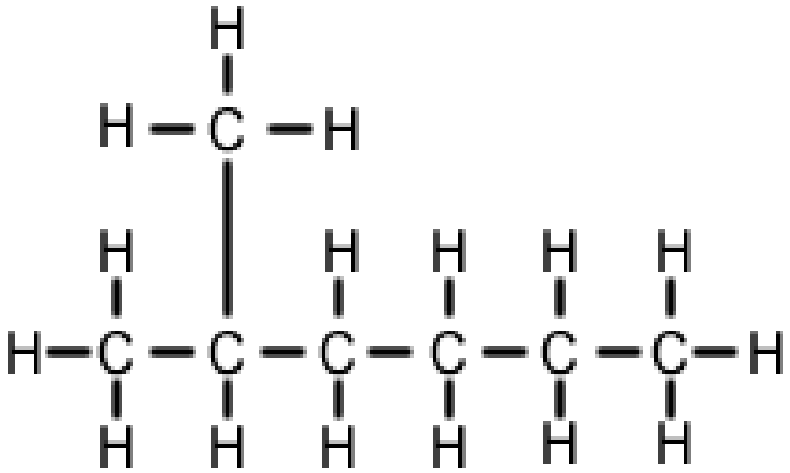
Branched Alkanes



- A **substituent group** is an atom or group of atoms that replaces a hydrogen atom in an organic compound
- An **alkyl group** is a type of substituent group made up of one or more carbon atoms
- Branches are named using a three part prefix
    1. A number to indicate which carbon on the main chain holds the branch (# should be as low as possible)
    2. A root to indicate how many carbons the branch is made up of (meth, eth, prop, etc.)
    3. The suffix “-yl” to indicate that it is a branch

Practice

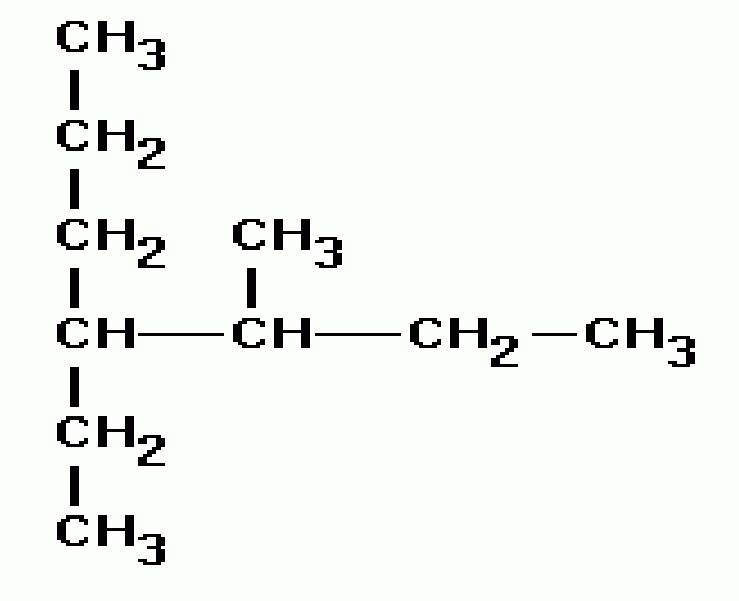
Name the following:



- Note: use dashes between numbers and words

Practice

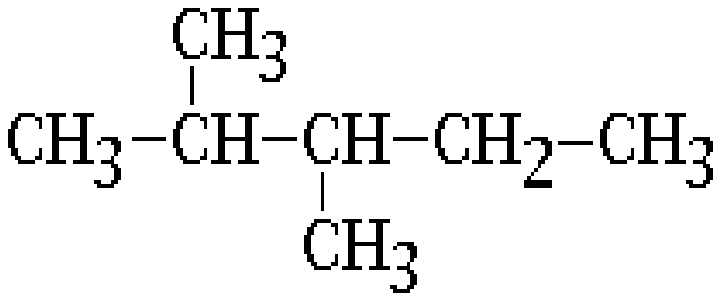
Name the following:



- Note: branches are named in alphabetical order

Practice

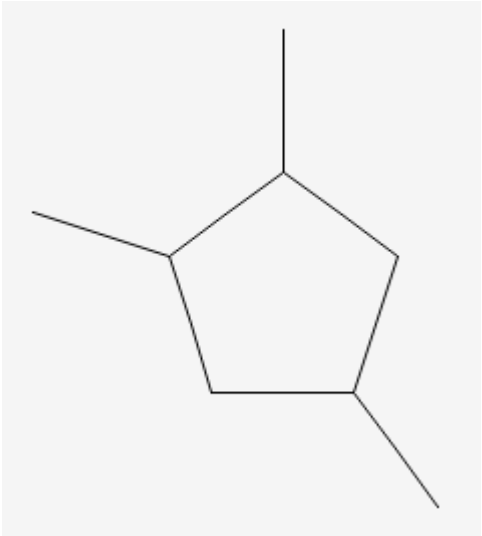
- Name the following:



- Note: commas between numbers
- Note: if there are more than one of the same branch use the prefixes *di*, *tri*, *tetra*, etc.

Practice

Name the following:



Practice

Draw the complete structural diagram, the condensed structural diagram and the line structural diagram for

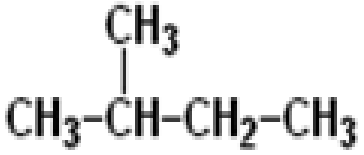
4-ethyl-2,2-dimethyl-5-propyldecane

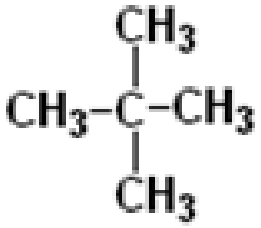
Redundency in Nomenclature

- The IUPAC system strives to use the simplest, least redundant name for each organic molecule
- Ex: Why is the name 2-methyl propanol redundant?

Structural Isomers

- Structural isomers are compounds that have the same molecular formula but different structural arrangements





- These three compounds have the same molecular formula but have very different names and properties

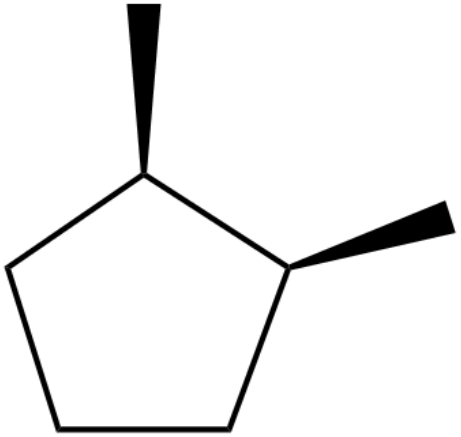
Stereoisomers

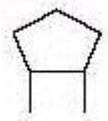
- **Stereoisomers** (sometimes called geometric isomers) are molecules that have the same chemical formula and structural backbone, but with a different arrangement of atoms in space
- **Cis isomer**: a stereoisomer in which the groups of interest are located on the same side
- **Trans isomer**: a stereoisomer in which the groups of interest are located on opposite sides
- Stereoisomers cannot be changed from one to the other by simple rotation. Bonds would have to be broken and reformed. Stereoisomers are distinct compounds with different properties, such as different melting points.

Stereoisomers

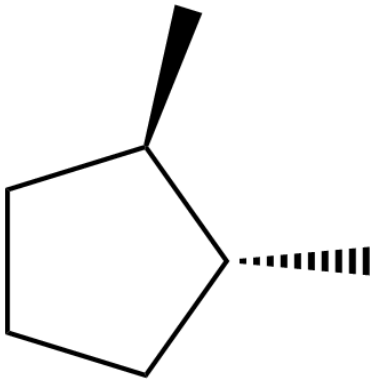
Dimethylcyclopentane's ring structure restricts the rotation of the bonds, thus enabling both a "cis-" and a "trans-" isomer

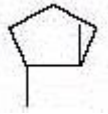
cis-1,2-dimethylcyclopentane





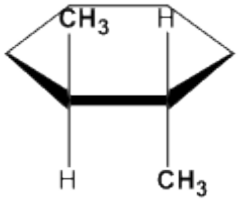
trans-1,2-dimethylcyclopentane

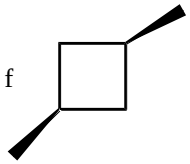


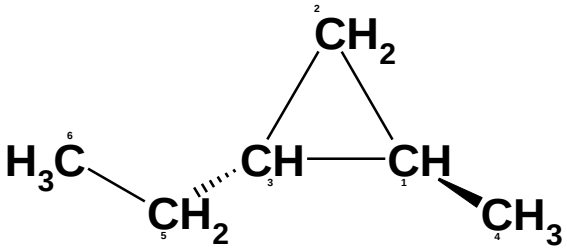


Practice

Name the following:

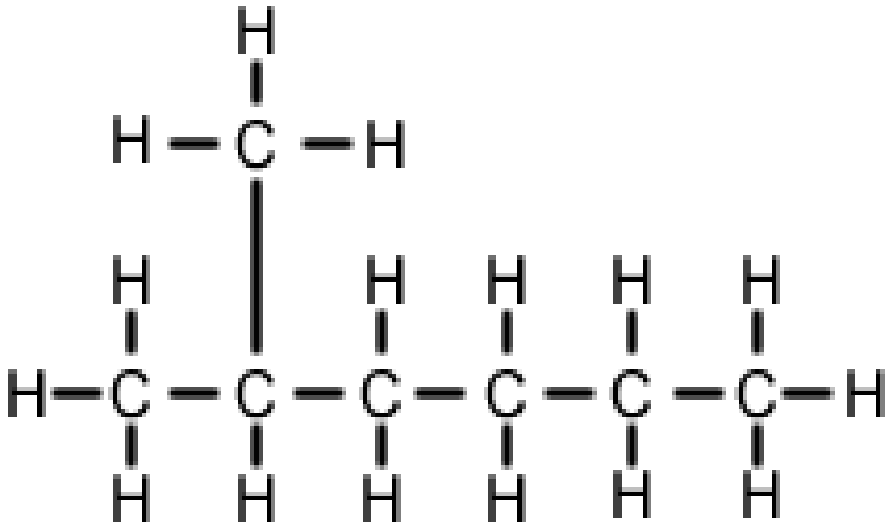
a) 

b) 

c) 

Properties of Alkanes

Do alkanes have the ability to hydrogen bond?



Properties of Alkanes

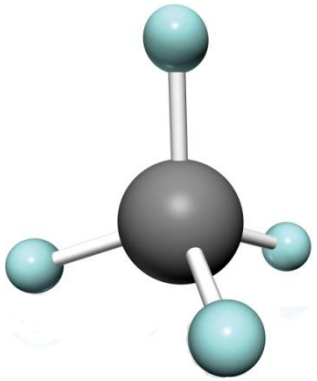
Are alkanes polar or non-polar?

Alkanes have two types of bond:

C—C and C—H

Bond polarity

Molecular Polarity

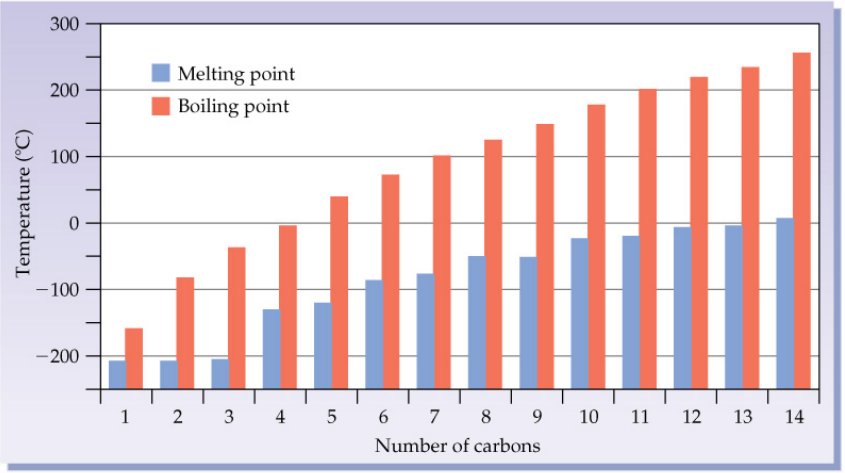


Properties of Alkanes

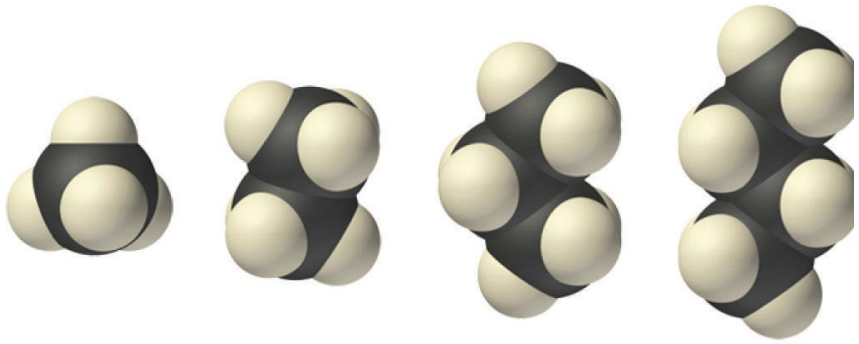
- The London Dispersion Force is the only intermolecular force active in alkanes
- London Dispersion forces increase with:
  1. Increasing molecular size
  2. Increasing surface area of contact (or proximity)

Properties of Alkanes

Melting points and boiling points of straight chain alkanes increase with molecular size



A larger molecule means a stronger London force and thus a higher boiling point

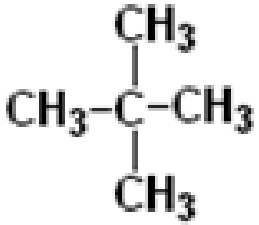


Methane	Ethane	Propane	*n*-Butane
16 g/mol	30 g/mol	44 g/mol	58 g/mol
−161.5°C	−88.6°C	−42.1°C	−0.5°C

Properties of Alkanes

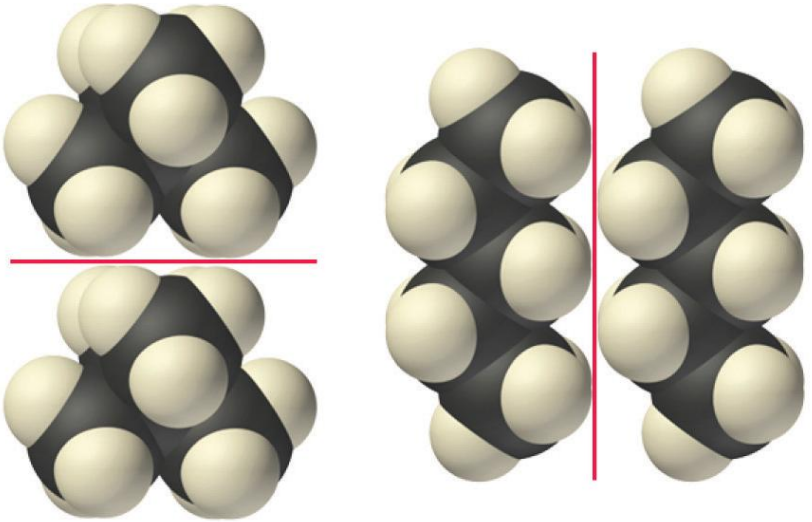
Consider the structural isomers pentane and dimethylpropane:

Pentane
(boiling point: 36.1°C)



dimethyl propane
(boiling point: 9.5°C)

Linear pentane molecules have a larger surface area of contact and stronger intermolecular forces than branched dimethylpropane molecules. As a result, pentane is a gas at room temperature, whereas *dimethylpropane* is a volatile liquid.



Properties of Alkanes

- The first four alkanes (methane, ethane, propane, butane) are gases
- Alkanes with 5-40 carbons are liquids
- Alkanes with 40 or more carbon atoms are waxy solids

Table 3 Selected Uses of Alkanes

Length of carbon chain	Uses
1–4	Fuels such as natural gas for heating and cooking, propane for barbecues and soldering torches, and butane for lighters (**Figure 10**)
5–12	Fuels such as gasoline
12–18	Fuels such as jet fuel
18–20	Fuels such as home heating oil
20–30	Lubricating oils such as engine oil
30–40	Fuel oils such as ship fuel
40–50	Waxes and thick oils such as paraffin wax and petroleum jelly
More than 50	Tars used in road surfacing

Properties of Alkanes

- Alkanes are insoluble in water but soluble in nonpolar organic solvents, including other alkanes
- Alkanes are generally less dense than water, as a result they float on water
- Low molecular weight alkanes are volatile and their vapours are highly flammable

Practice

a) Why is methane a gas at room temperature while octane is a liquid?

a) Arrange the following in order of increasing boiling point:

1. hexane
2. 2-methyl pentane
3. pentane
4. propane

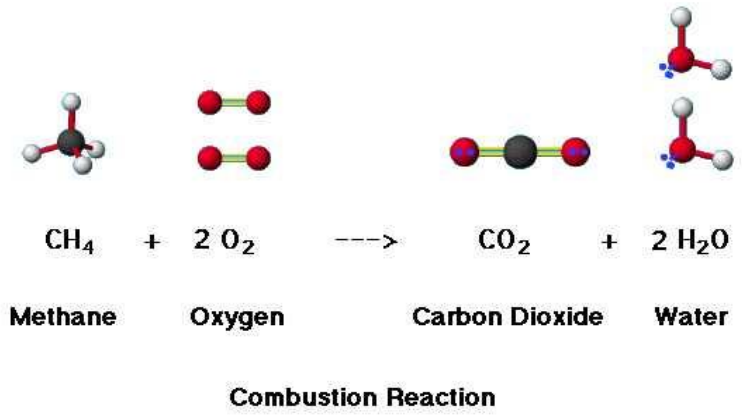
Reactions of Alkanes

- Alkanes are fairly unreactive
- They do not react with acids, bases, or strong oxidizing agents
- This chemical inertness makes them valuable as lubricating materials and as the backbone for structural materials such as plastics

Reactions of Alkanes

1) Combustion

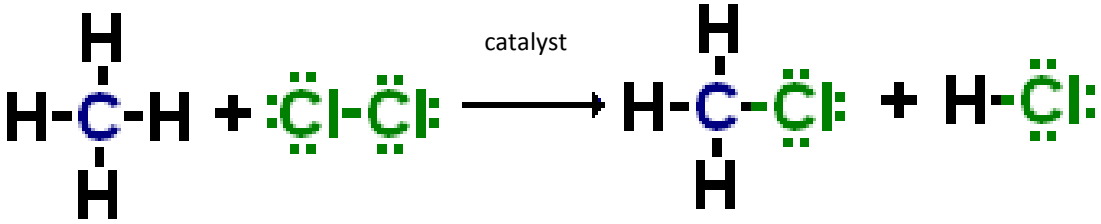
   A chemical reaction in which a compound reacts with oxygen to produce carbon dioxide, water, and thermal energy



Reactions of Alkanes

2) Substitution – Halogenation

- A **substitution** reaction is one in which an atom or group of atoms in a molecule is replaced by another atom or group of atoms
- Alkanes react in a specific type of substitution reaction called **halogenation** where a hydrogen atom is replaced by a halogen atom (Cl, Br, etc.) to form an alkyl halide

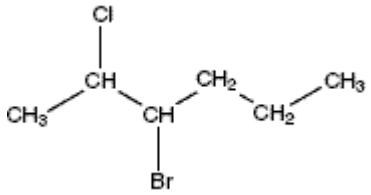


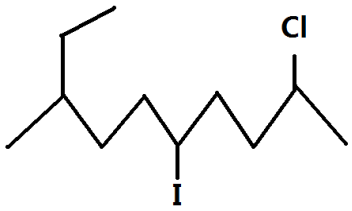
Alkyl Halides

- When naming organic halides consider the halogen atom a substituent group and name it using the prefix *fluoro-*, *chloro-*, *bromo-*, or *iodo-*

Practice:

1) Name the following alkyl halides

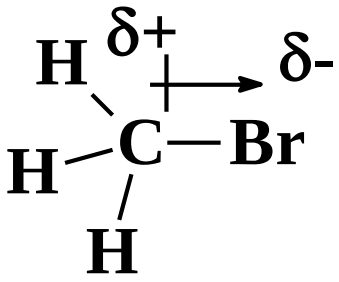
a) 

b) 

2) Draw a structural diagram for 1,1-dibromocyclohexene

Alkyl Halides

- Since halogens are much more electronegative than carbon, the carbon-halogen bond is polar



- If the overall molecule is polar, this increases the strength of the intermolecular forces (dipole-dipole force) which means that the boiling and melting points of alkyl halides are higher than those of corresponding alkanes.

Table 1 Boiling Points of Some Hydrocarbons and Corresponding Organic Halides

Hydrocarbon	Boiling point (°C)	Alkyl halide	Boiling point (°C)
CH_4	−164	CH_3Cl	−24
C_2H_6	−89	C_2H_5Cl	12
C_3H_8	−42	C_3H_7Cl	46
C_4H_{10}	−0.5	C_4H_9Cl	78

HOMEWORK

Required Reading:

p. 6-17

Questions:

p. 14 #1-2

p. 17 #1-9