Grade 12 Chemistry

Organic Chemistry

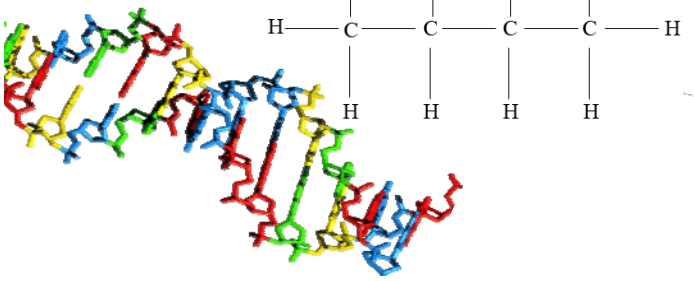
Class 1

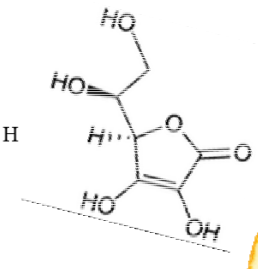
Overall Expectations

- Assess the social and environmental impact of organic compounds used in everyday life, and propose a course of action to reduce the use of compounds that are harmful to human health and the environment
- Investigate organic compounds and organic chemical reactions, and use various methods to represent the compounds
- Demonstrate an understanding of the structure, properties, and chemical behavior of compounds within each class of organic compounds

Organic Chemistry

- The study of molecular compounds of carbon
- What is so special about carbon compounds?
  - Carbon atoms can form single, double and triple bonds with other carbon atoms forming long chains and rings





- Before 1828, the only organic compounds on Earth were those that occurred naturally
- Scientists assumed that only living or once-living organisms could be the source of organic compounds; Living matter had an invisible “vital force”

- In 1828, Wohler synthesized urea, an organic compound from ammonium cyanate NH_4OCN, an inorganic compound

Checkpoint

Identify the following as organic or inorganic.

a) CH_4

b) CH_3OH

c) NH_4SCN

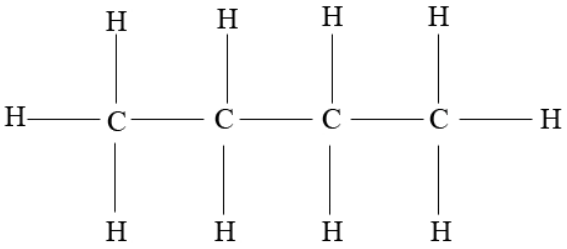
d) $CaCO_3$

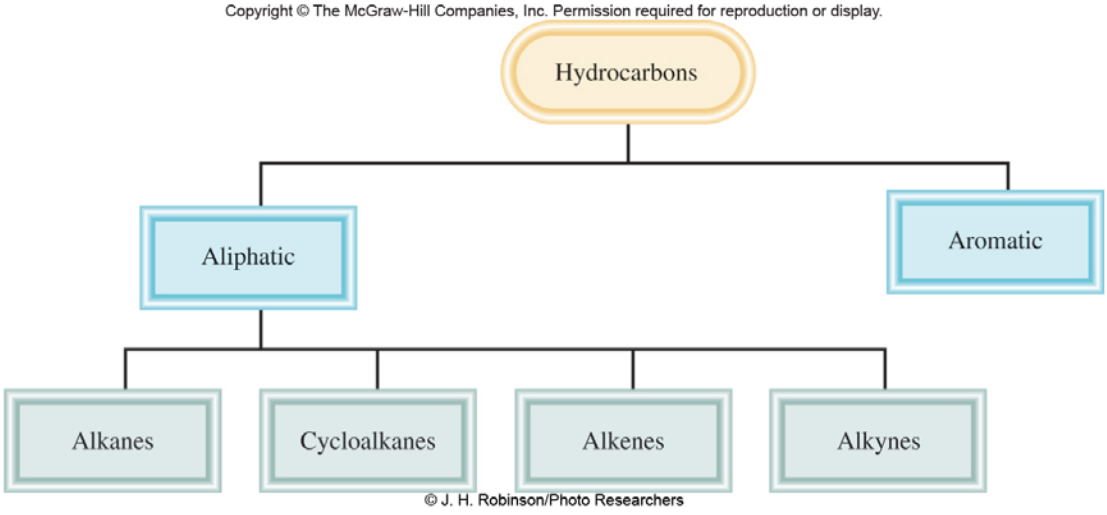
e) NaCl

f) $C_6H_{12}O_6$

Hydrocarbons

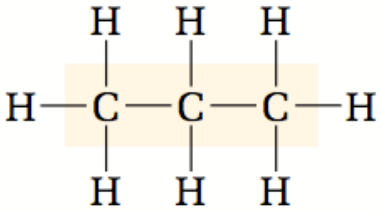
- Hydrocarbons are the simplest type of organic compounds
- **Hydrocarbons** – molecules that contain only carbon and hydrogen
  - Widely used in fuels (i.e. gasoline, propane, butane)



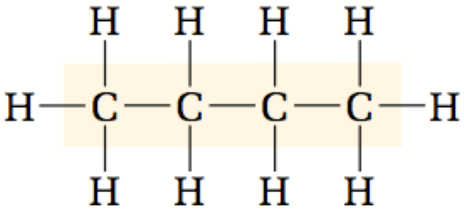


Alkanes

- Formula: $C_nH_{(2n+2)}$
- Hydrocarbons joined by a single covalent bond; saturated hydrocarbons
- Nonpolar with weak intermolecular forces



propane

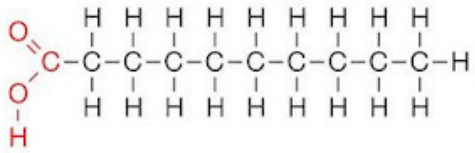


butane

Saturated vs. Unsaturated

- **Saturated** – molecules that contain only single carbon-carbon bonds
  - No more bonding can occur
- **Unsaturated** – molecules that contain double or triple carbon-carbon bonds
  - Potential for more bonding

Saturated



Unsaturated

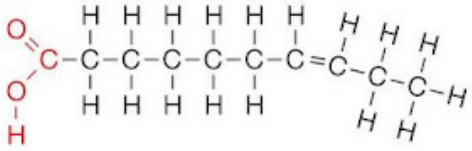
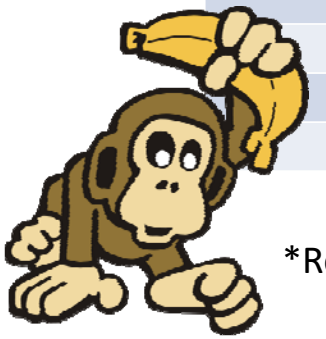


Table 13.1 Comparing the Sizes and Boiling Points of Alkanes

Size (number of atoms per molecule)	Boiling point range (°C)	Examples of products
1 to 5	below 30	gases: used for fuels to cook and heat homes
5 to 16	30 to 275	liquids: used for automotive, diesel, and jet engine fuels; also used as raw materials for the petrochemical industry
16 to 22	over 250	heavy liquids: used for oil furnaces and lubricating oils; also used as raw materials to break down more complex hydrocarbons into smaller molecules
over 18	over 400	semi-solids: used for lubricating greases and paraffin waxes to make candles, waxed paper, and cosmetics
over 26	over 500	solid residues: used for asphalts and tars in the paving and roofing industries

Names of Straight Alkanes

Number of Carbons	Name
1	Methane
2	Ethane
3	Propane
4	Butane
5	Pentane
6	Hexane
7	Heptane
8	Octane
9	Nonane
10	Decane



*Remember: **M**onkeys **E**at **P**urple **B**ananas

Checkpoint

What are the names of the following molecules?

a) $CH_3CH_2CH_2CH_3$

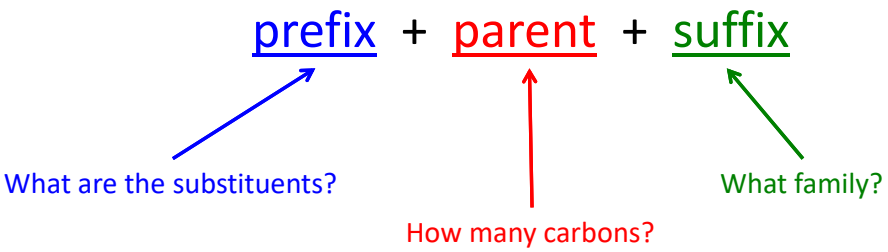
b) $CH_3CH_2CH_3$

c) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

d) CH_4

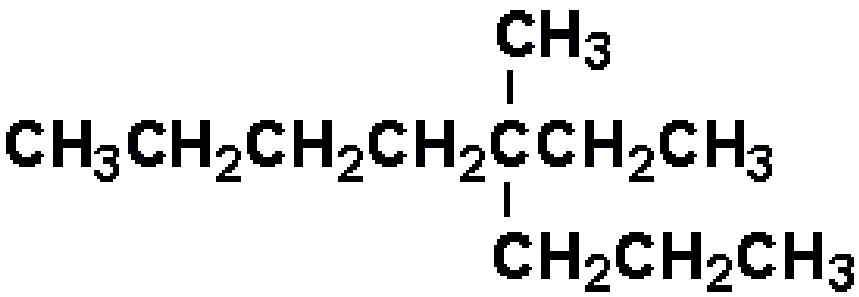
Naming Alkanes

- System of naming was devised by International Union of Pure and Applied Chemistry (IUPAC)
- 3 parts:



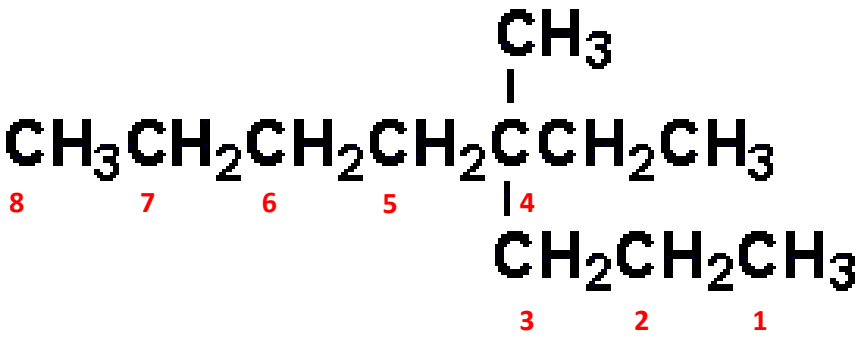
Alkane Nomenclature

1) Find the longest continuous chain and use that as the parent name.



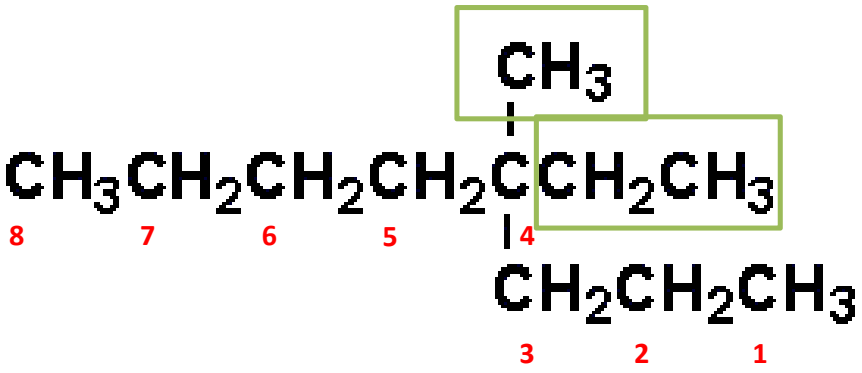
Alkane Nomenclature

2) Number the carbon atoms in the main chain beginning at the end nearer the first branch.



Alkane Nomenclature

3) Identify and number the branching substituent. Change the ending from –*ane* to –yl. Ex: Methane → Methyl (Alkyl Group)

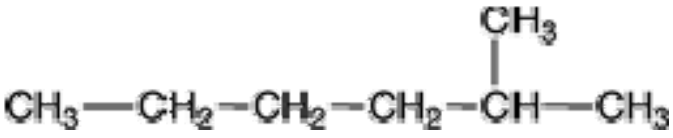


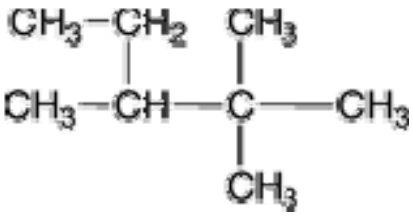
Alkane Nomenclature

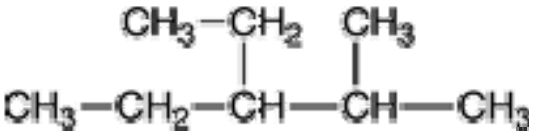
4) Write the name as a single word.
   - Use hyphens to separate the different prefixes and commas to separate numbers.
   - If 2 or more different substituents are present, list them in alphabetical order.
   - If 2 or more identical substituents are present, use one of the prefixes *di-*, *tri-*, *tetra*, etc. (DON'T use these prefixes for alphabetizing).

Checkpoint

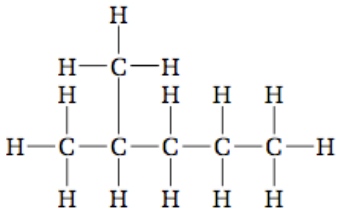
- Name the following:



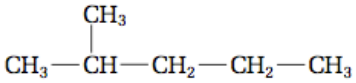




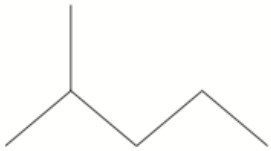
Drawing Organic Compounds



A **complete structural diagram** shows all the atoms in a structure and the way they are bonded to one another. Straight lines represent the bonds between the atoms.



A **condensed structural diagram** simplifies the presentation of the structure. It shows the bonds between the carbon atoms but not the bonds between the carbon and hydrogen atoms. Chemists assume that these bonds are present. Notice how much cleaner and clearer this diagram is, compared with the complete structural diagram.



A **line structural diagram** is even simpler than a condensed structural diagram. The end of each line, and the points at which the lines meet, represent carbon atoms. This kind of diagram gives you a sense of the three-dimensional nature of a hydrocarbon. **Note:** Line structural diagrams are used only for hydrocarbons, not for other organic compounds.

Checkpoint

Draw the following compounds:

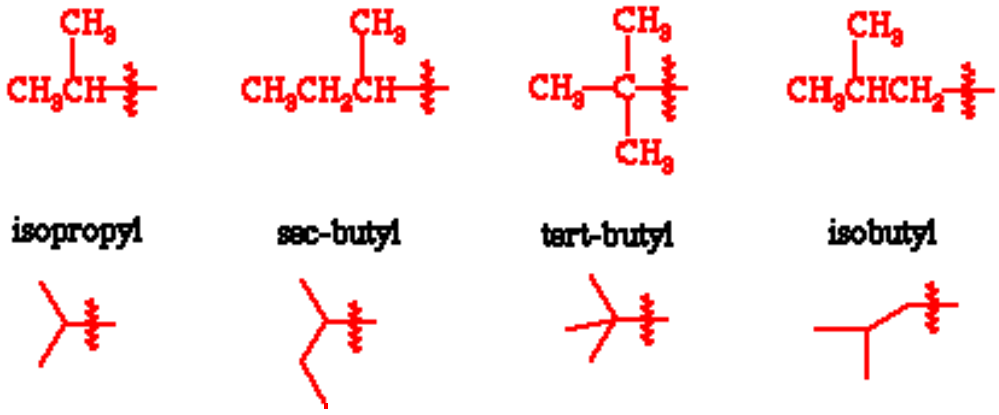
a) 3-ethyl-3,4-dimethylhexane

b) 2,3,4-trimethylpentane

c) 4-butyl-6-ethyl-2,5-dimethylnonane

Branched Chain Alkanes

- Some common names:



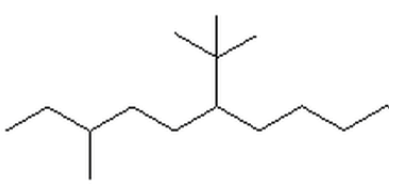
Checkpoint

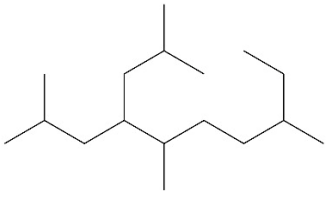
Draw the following compounds:

a) 3-isopropyl-2-methylhexane

b) 5-sec-butyl-4-isopropylnonane

Name the following compounds:

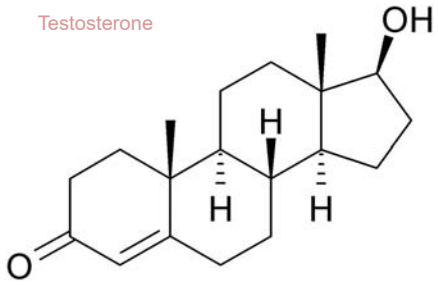




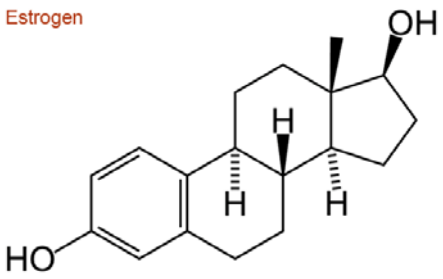
Cycloalkanes

- Formula: C_nH_{2n}
- Alkanes that fold and join together in rings
- Commonly found in steroid hormones such as estrogen and testosterone

Testosterone

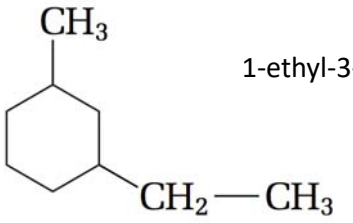


Estrogen



Naming Cycloalkanes

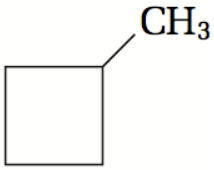
- Find the longest ring and name that as the parent. All carbons are treated as equal.
- Number the carbon atoms to give the alkyl groups the lowest numbers. The group that comes first alphabetically gets the lowest number.

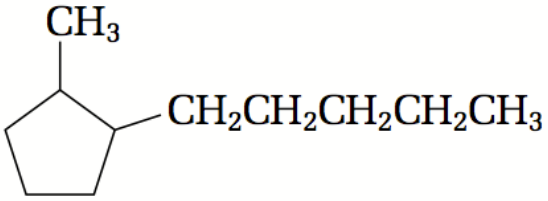


1-ethyl-3-methylcyclohexane

Checkpoint

Name the following compounds:



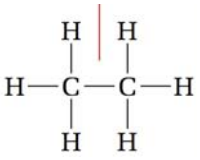


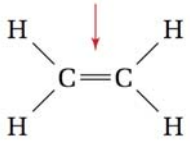
Draw 1,2,3,4-tetramethylcyclohexane

Alkene

- Formula: C_nH_{2n} (same as cycloalkane)
- Hydrocarbons joined by one or more double bonds; unsaturated hydrocarbons
- Nonpolar but more reactive
- Lower boiling points than alkanes due to fewer intermolecular forces

Ex: Ethane = -89°C Ethene = -104°C

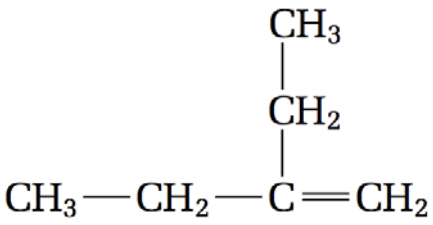


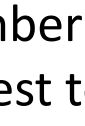


Naming Alkenes

- Find the longest continuous chain that contains the double bond, change ending to *-ene*
- Number the main chain from the end that is closest to the double bond; the double bond must have the lowest possible position number
- Name the branches

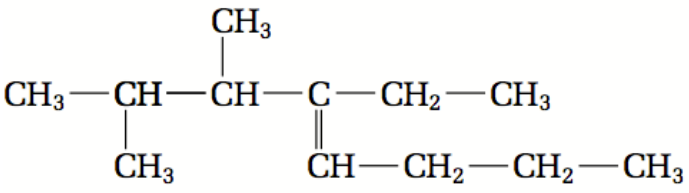
2-ethylbut-1-ene

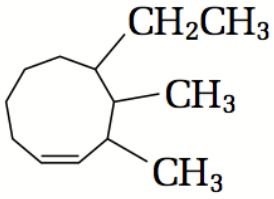




Checkpoint

Name the following compound:





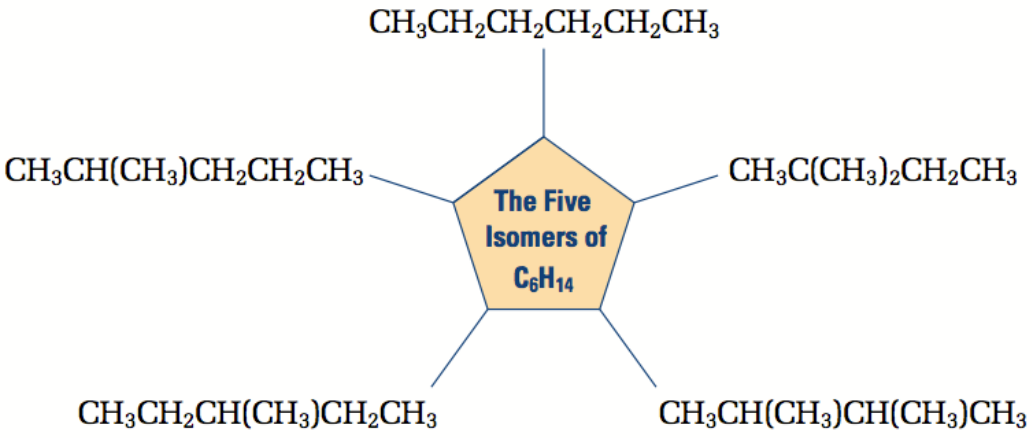
Draw:

a) 5-ethyl-3,4,6-trimethyloct-2-ene

b) 2,3-dimethylcyclopentene

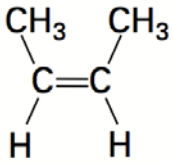
Isomers

- Compounds with the same formula but different structural arrangements

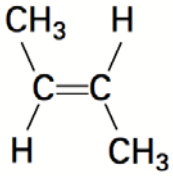


Cis-Trans Isomers

cis-2-Butene



trans-2-Butene



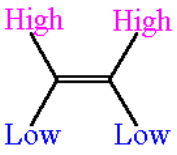
- The double bond cannot rotate
- **Cis** – two larger groups attached on the **same side**
- **Trans** – two larger groups attached on **opposite sides**

Checkpoint

Draw and name all four possible pairs of cis-trans isomers for C_6H_{12}

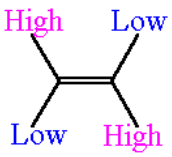
E/Z Designation

- Cis/trans naming system only works with disubstituted alkenes. For tri- and tetrasubstituted alkenes we use the E/Z designation



If both High priority groups are on the same side, we designate it **Z**

Z = (zusammen) = together



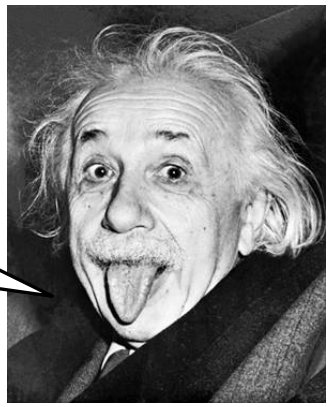
If both High priority groups are on opposite sides, we designate it **E**

E = (entegegen) = opposite

Rules for Ranking Priority

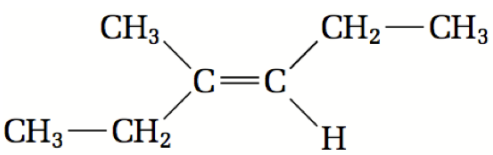
1. Atom with higher atomic number receives higher priority
2. If there is a tie, look at the second, third or fourth atoms away from the double bond until the first difference is found

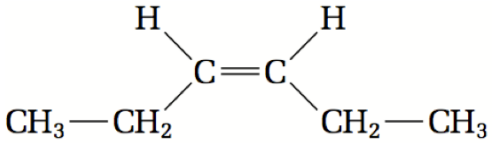
*Remember:
"ze zame zide"



Checkpoint

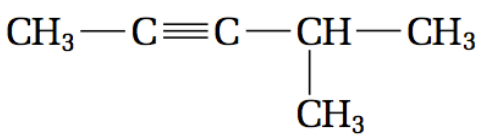
Name the following:





Alkyne

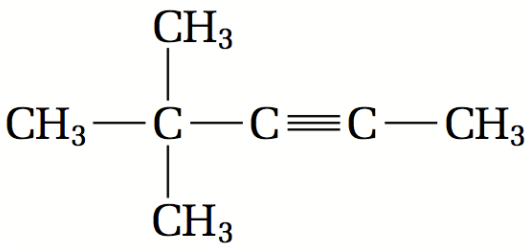
- Formula: C_nH_{2n-2}
- Hydrocarbons joined by one or more triple bonds; unsaturated hydrocarbons; linear
- Few in nature because they are very reactive



Naming Alkynes

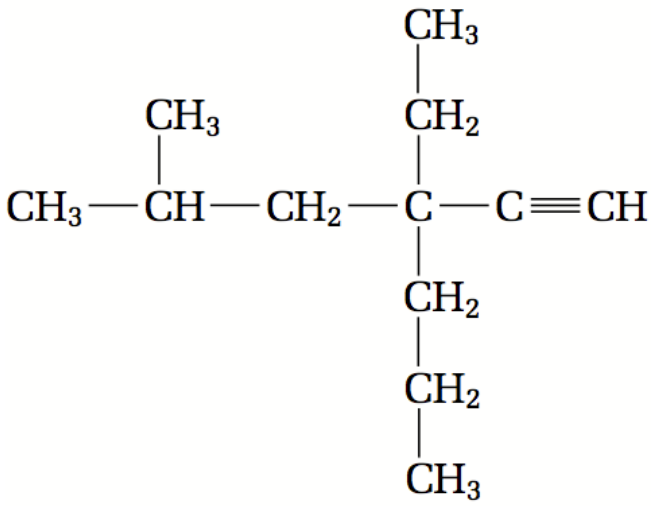
- Find the longest continuous chain that contains the triple bond, change ending to *-yne*
- Number the main chain from the end that is closest to the triple bond; the triple bond must have the lowest possible position number
- Name the branches

4,4-dimethylpent-2-yne



Checkpoint

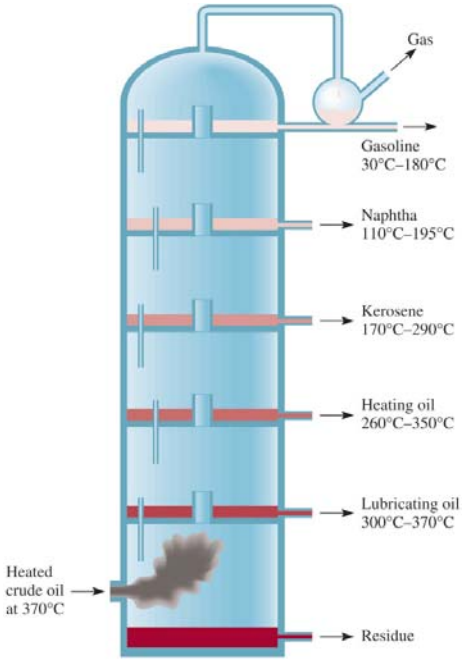
Name the following:



Refining Hydrocarbons

- Petroleum – basic hydrocarbons that are converted into plastics and other synthetic materials
  - Unrefined petroleum is called crude oil
  - Crude oil is taken directly from the ground

Separating Crude Oil



- Fractional Distillation – separates crude oil into different components by boiling point
- Larger hydrocarbons at the lower levels
- Smaller hydrocarbons at the higher levels

Cracking and Reforming

- Techniques to increase the yield of certain hydrocarbons from each barrel of crude oil
- **Cracking** – use heat to break larger hydrocarbon molecules into smaller gasoline molecules
- **Reforming** – use heat, pressure and catalysts to convert large hydrocarbons into other compounds such as aromatic compounds

Cracking

Reforming