Petroleum - Notes

Unit 11, Chemistry Themed

What is petroleum?

- Petroleum is a mix of hydrocarbons
- Hydrocarbons vary in length - the number of carbons chained together
- Smaller hydrocarbons are typically gases and are either used directly as fuel, or reacted to make polymers (plastics)

Petroleum: Distribution of Resources

Regions	Consumption 2004 10^3 Barrels/day	Consumption 2004 Percent	Reserves 2007 10^9 Barrels	Reserves 2007 Percent	Population 2004 Millions	Population 2004 Percent
North America	25,046.0	30.4	69.295	5.6	430.25	6.8
Central and South America	5,349.1	6.5	111.211	9.0	442.77	7.0
Europe	16,259.8	19.7	15.570	1.3	587.57	9.2
Eurasia	4,040.8	4.9	128.146	10.4	286.10	4.5
Africa	2,819.5	3.4	117.482	9.5	874.75	13.7
Middle East	5,539.4	6.7	755.325	61.0	180.15	2.8
Asia and Oceania	23,353.2	28.3	40.847	3.3	3,565.50	56.0
Total	82,407.7	100.0	1,237.876	100.0	6,367.10	100.0

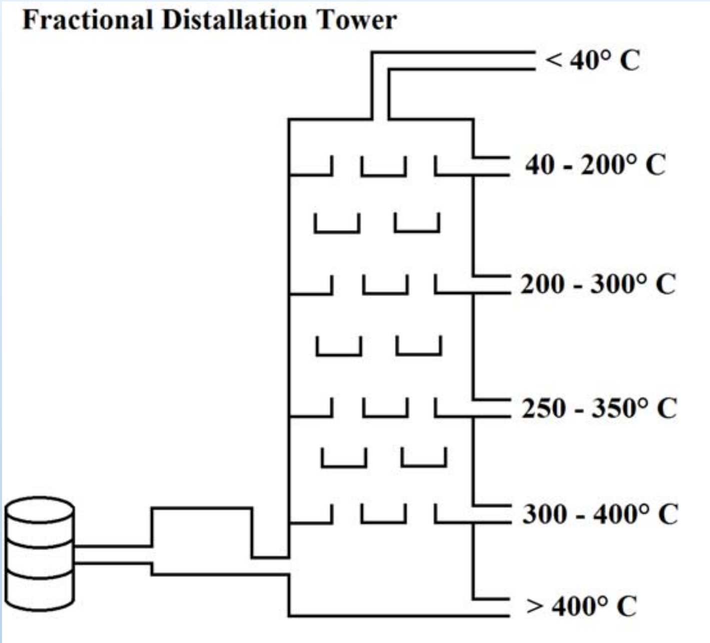
- Life is not fair: Some places NEED more oil than what they have; others, make money off of this need
- North America consumes the most oil & the Middle East has the most
- In USA - Burning vs. Building: 89% of oil used for energy (burning), 11% to make things (building)

Petroleum Properties - IMF

- Petroleum properties can be explained by IMF (intermolecular forces)
- Hydrocarbons basically “sticky” to each other
- IMF are the attractive forces between hydrocarbon molecules
- Longer molecules are “stickier” than shorter ones (they’re sticky, so if they’re longer, they stick more)
- Viscosity = resistance to flow
  - Big IMF = stickier → longer molecules = bigger IMF
  - Stickier (longer) molecules don’t slide by each other (don’t flow) as easily as short ones
  - Long molecules have high viscosity (big resistance to flow)
- Molecules evaporate quickly if they don’t stick to their fellow molecules strongly
- Liquids boils easier (lower temp.) if they’re not very sticky
- Molecules that are sticky tend to be close to each other (big density)

Fractional Distillation Tower

- Petroleum is a mixture
- Refining uses distillation to separate the long chain hydrocarbons from the shorter ones
- Boiling point is used to separate
- Barrel of petroleum is heated and then gas is expanded up a cooling tower
- Tower gets cooler as it ascends
- Longer chain hydrocarbons condense first (where tower is warmest
- Shorter chain hydrocarbons condense last
- Liquid hydrocarbons collect in trays (levels) of tower and pumped to holding tanks



IMF – Summary of Property Trends

- As IMF ↑:
  - Molecule size ↑ (more carbons in the hydrocarbon)
  - Density ↑ (molecules are attracted to each other and huddle close to each other)
  - Boiling point ↑ (liquid molecules must be very energetic to escape attractive forces)
  - Viscosity ↑ (hard for sticky things to slide by each other)
  - Evaporation rate ↓ (sticky things stay stuck as liquids)
  - Position in refining (distillation) tower ↓ (lower in tower - where BP is high)

How we measure viscosity in our lab

- Viscosity is the resistance to flow
- High viscosity means “very viscous”, or lots of resistance to flow
- Molasses has high viscosity (pours slowly), water has low viscosity (pours easily)
- We time how long it takes an air bubble to rise through a liquid
  - Long time = high viscosity
  - Short time (bubble rises quickly) = low viscosity
- Motor oil viscosity:
  - Viscosity decreases as lubricate (oil) warms up
  - Viscosity increases with increasing IMF (longer molecules more viscous)
  - High viscosity = gooey, sticky – hard to start car with cold engine (winter)
  - High viscosity = better sealing/lubricating between engine parts (less wear)
  - Low viscosity = easy to start a cold engine, but less protective of engine

Water displacement volume measurement

- “Stuff” a sample into water and measure the rise in volume
- Rise (change) in volume = sample volume
- Use a graduated cylinder, beakers are too imprecise
- Density is: d = m/v, measured in g/mL
- Bigger density generally means more IMF (longer molecules, more viscous, higher BP, etc.)

Organic Chemistry

- Organic chemistry is the chemistry of carbon compounds
- Carbon is known for making four covalent bonds
    - A (single) covalent bond is a bond where a pair of electrons is shared (in ionic bonds, the non-metal “steals” the electron)
    - Know of double and triple bonds where two or three pairs of electrons are equally shared (count as two or three bonds)
- Always look to make sure each carbon has exactly four bonds

Ionic vs. covalent bonds

- Ionic bonds
  - Bond between a metal and non-metal
  - Electrons: given up by metal making cation; received by non-metal making anion
  - Results in ionic compounds
- Covalent bonds
  - A (single) covalent bond is a bond where a pair of electrons is shared
  - Also called a molecular bond resulting in covalent compounds (molecular compounds)
  - Double and triple bonds have two or three electron pairs shared
  - Like ionic bonds, octet rule is typically the driving force
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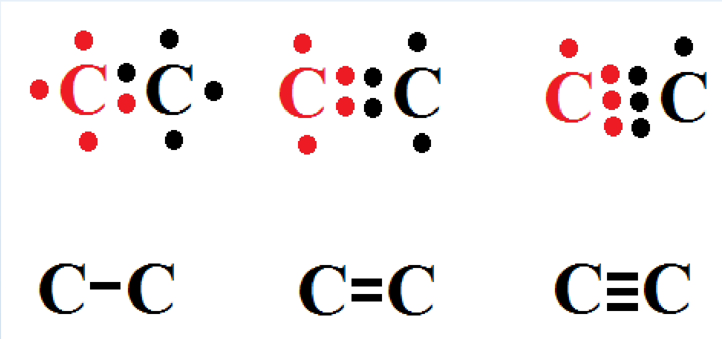
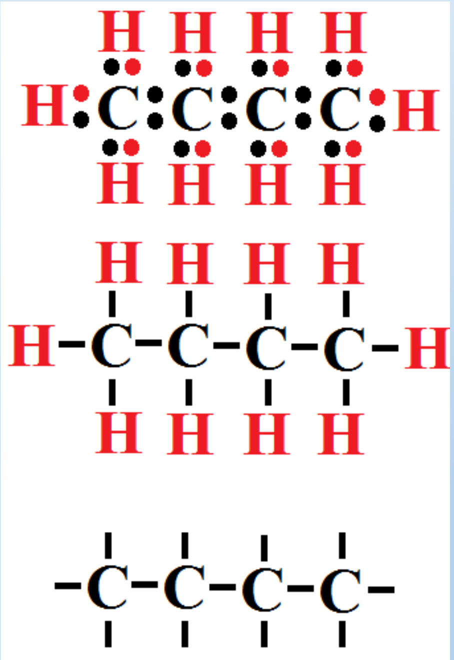
Carbon’s four valence electrons

- Top: valence electrons including single, double and triple (covalent) bonds
  - Notice how each carbon atoms contributes equally (contributes the same number of electrons shared)
- Bottom: Notation for covalent (molecular) bonds
  - Each horizontal line represents a covalent bond
  - Each horizontal line represents a pair of electrons
  - Notice two lines = double bond, three lines = triple bond
- Each carbon will have four bonds, the other bonds are not shown (often bonded to hydrogen)



Formula Versions: Molecular, Electron dot, Structural

- Molecular formula is a very "basic recipe" – just a list of the number of each atom: C_4H_{10}
- Electron dot shows more detail:
- Structural formula gives the same information, but with less work
- For hydrocarbons, there's no compelling reason to show the hydrogens, so we abbreviate with just the C's (sometimes no dashes either)



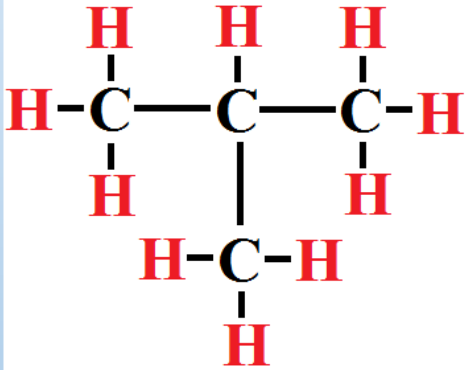
Electron dot formula (AKA, Lewis diagram or electron dot diagram)

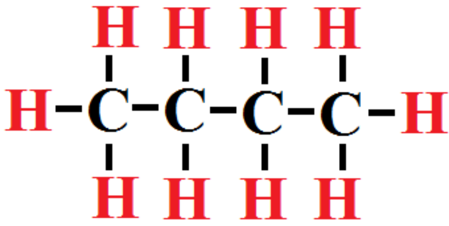
Structural formula

Abbreviated structural formula (because we don't like to do un-necessary work)

Isomers

- Isomers – don't confuse with isotopes!
- Compare these two:
  - Isomer: Same molecular formula, different structural formula
  - Isotope: Same # of protons, different number of neutrons
- Example: Butane, C_4H_{10}
- See how both butane isomers (top and bottom)
  - Have 4 carbons
  - Have 10 hydrogens
  - Have all carbons with 4 bonds and all hydrogens with 1 bond
- The top isomer has a carbon branch on the 2nd carbon. Do you see it?
- Branches make hydrocarbons less "sticky", lower IMF
- Top isomer has lower BP, is higher in distillation tower less dense, etc. than its isomer with no branches

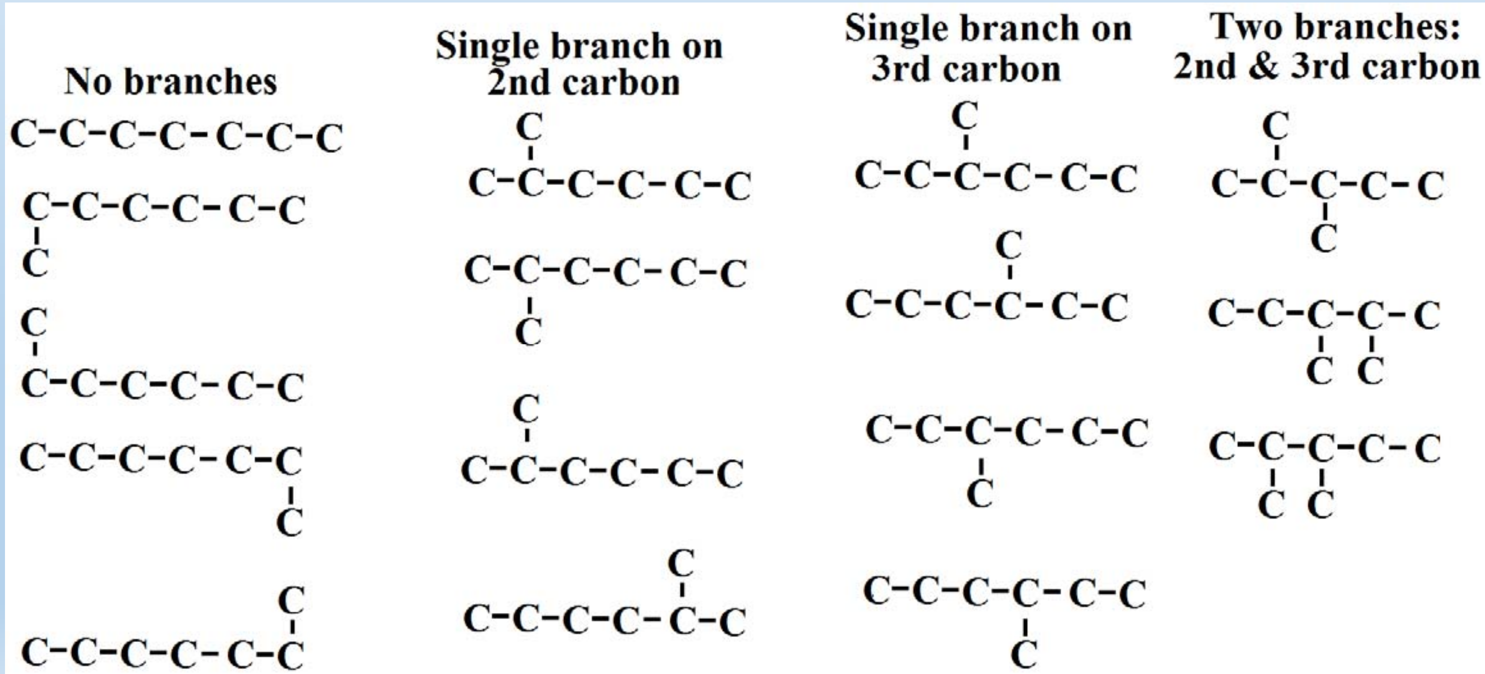




Isomers – recognizing what is a distinct isomer

- Below are four isomers of C_7H_{16}.
- Each column consists of the same isomer redrawn in 3 to 5 ways that may look like different isomers to you. In spatial view, first and last carbon are same. Up and down are same too.
- Find the longest chain and see where branches are attached. Keep track of longest chain and branch locations. Use the smallest carbon number possible for branches.
- Double and triple bonds work like carbon branches → different place for bond = isomer

- *1st column: C7 is longest chain.*
- *2nd column: C6 is longest chain. Single branch attached to 2nd carbon.*
- *3rd column: C6 is longest chain. Single branch attached to 3rd carbon.*
- *4th column: C5 is longest chain. Two branches. One on 2nd carbon and one of 3rd carbon.*
- *See how there are only 4 distinct isomers here?*



Naming alkanes

- An alkane is a hydrocarbon with only single covalent bonds. Alkanes are “saturated”. Saturated means “full”, with no double or triple bonds, alkanes are full of the most hydrogens possible.
- All the names end in “ane”, just like alkane does
- The general molecular formula is C_nH_{2n+2}
  - Example, n = 5 is for pentane: C_5H_{12}
- Use “Monkeys East Peanut Butter” to memorize the first four; the rest are like you learned in geometry:
  - 1: Methane (Monkeys)
  - 2: Ethane (Eat)
  - 3: Propane (Peanut)
  - 4: Butane (Butter)
  - 5: Pentane
  - 6: Hexane
  - 7: Heptane
  - 8: Octane
  - 9: Nonane
  - 10: Decane

Alkenes and Alkynes

- Alkenes have a least 1 double bond; Alkynes have at least 1 triple bond
- General molecular formulae: Alkanes: C_nH_{2n+2} Alkenes: C_nH_{2n} Alkynes: C_nH_{2n-2}
  - Examples: pentane: C_5H_{12} pentene: C_5H_{10} pentyne: C_5H_8 octene: C_8H_{16} octyne: C_8H_{14}
  - Structural formula for pentene: C=C-C-C-C, or C-C=C-C-C (two isomers of pentene)
  - Pentyne works the same, except triple bond instead of double bond
- Naming first ten alkenes and alkynes:
  - 1: Methene, Methyne
  - 2: Ethene, Ethyne
  - 3: Propene, Propyne
  - 4: Butene, Butyne
  - 5: Pentene, Pentyne
  - 6: Hexene, Hexyne
  - 7: Heptene, Heptyne
  - 8: Octene, Octyne
  - 9: Nonene, Nonyne
  - 10: Decene, Decyne

Naming covalent (molecular) compounds

- Do you know the name for CO_2?
  - It's carbon dioxide, use that as your guide if you ever get confused
- Covalent compounds are made from bonding two non-metals
- They have a first name and a last name
  - Last name ALWAYS has a prefix indicating subscripts (as in the "di" in dioxide)
  - First name as a prefix for the subscript, except if subscript is 1 (don't use mono for 1st name!)
- Example: CO: name = carbon monoxide
- diphosphorus pentasulfide: Formula = P_2S_5

Prefixes

1 – mono	6 – hexa
2 – di	7 – hepta
3 – tri	8 – octa
4 – tetra	9 – nona
5 – penta	10 – deca

Electron dot structures

- AKA electron dot diagrams, or Lewis diagrams
- Help us to understand how electrons are shared in COVALENT compounds
- Attach elements to a central atom and make sure all elements have 8 electrons around them
  - Hydrogen should only have two electrons
  - Central atom is first atom in formula, except hydrogen (think about it: can it be central with only a single electron to share? How can is be the center of anything?)
  - You may have to use double or triple bonds to make this work (example: try carbon dioxide…how else can you get four bonds for carbon without double bonds?)
  - Put electrons in the four positions (up, down, left, right), then double up.
  - Number of single (unpaired) electrons = number of bonds atom can make

Petrochemicals

- Petroleum is used to build (plastics, etc.) or to burn (create energy)
- In the US, we use 89% of petroleum to burn and only 11% to build
- Plastics are made by polymerizing alkenes
  - Polymerizing means linking the alkenes together chemically, like links in a chain make a long chain
  - The individual alkene "chain links" are called monomers
  - Three monomers you have to know (right →)