Nuggets of Knowledge for Chapter 2 – Introduction to Organic Molecules
Chem 2310

I. Ways to Represent Organic Molecules

- There are a variety of ways to represent organic molecules. Each gives different information about the molecule.
  - <u>Molecular formula:</u> gives the number of atoms of each element that are present in the molecule
    - In organic chemicals, C is given first, then H, then the other elements in alphabetical order.
    - The molecular formula is not specific enough to identify a compound; more than one compound may have the same formula.
  - <u>Lewis structure:</u> gives all atoms, all bonds, electron pairs, and charges.
    - Lewis structures are specific enough to identify a compound.
    - They are often drawn with incorrect angles.
    - Unless the molecule is very small, they take too long to draw and contain too much information, making it difficult to decipher what is going on with the molecule.
  - <u>Condensed structure:</u> hydrogen atoms are written next to the atom they are attached to; nonbonding electron pairs are sometimes omitted.
    - They are also sufficient to identify a compound.
    - They are also often drawn with incorrect angles.
    - They are commonly used in textbooks, catalogs, and other printed materials because they are easier to represent without special drawing tools.
    - If the compound is very complex, they may also be difficult to decipher unless you are used to using them.
    - Highly condensed structures often use parenthesis to represent repeated elements or those attached to a chain.

- Line structure: carbon atoms are not shown, only the bonds between them; hydrogen atoms and their bonds are not shown, unless they are attached to an atom other than carbon; nonbonding electron pairs are always shown.

    - Correct angles are used (tetrahedral angles must be flattened).

    - These are the easiest to draw and to interpret. This is the form we will use most often in class.

- Name: names of organic compounds are composed using an elaborate system of rules. There are sometimes alternate names for a compound.

    - These names allow you to decipher the structure of the compound.

    - Names are commonly used in print and computer resources.

    - We will learn the rules for creating and interpreting names of organic compounds throughout the year.

II. Classification of Organic Molecules

- There are so many kinds of organic molecules that it is necessary to group them into categories.

    - These categories are based on physical properties and on what kinds of chemical reactions they undergo, so that each category can be studied together.

- General terms: can be used with any compound

    - hydrocarbon – a compound containing only carbon and hydrogen

    - aromatic – compounds containing a benzene ring (a six-membered ring with alternating double and single bonds)

    - aliphatic – a compound which is not aromatic

    - unsaturated – a compound containing a carbon-carbon double or triple bond (except benzene rings)

    - saturated – a compound which does not contain any carbon-carbon double or triple bonds or benzene rings

- Functional group – a specific combination of atoms and bonds which is stable and undergoes a given set of reactions

- Hydrocarbon functional groups
    - alkane – a hydrocarbon containing only single bonds between carbon atoms
        - names end in “ane”
    - alkene – a hydrocarbon containing a carbon-carbon double bond (not as part of a benzene ring)
        - names end in “ene”
    - alkyne – a hydrocarbon containing a carbon-carbon triple bond
        - names end in “yne”
- Functional groups containing carbon, hydrogen, and oxygen
    - alcohol – a compound containing an O-H connected to a carbon atom
        - names end in “ol” or “alcohol” or contain “hydroxy”
    - carboxylic acid – a compound containing a C=O with an O-H connected to the carbon
        - names end in “ic acid”
    - ether – a compound containing an O between two C’s
        - names end in “ether” or contain “-oxy”
    - ester – a compound containing an O between two C’s, one of which has a double bond to another O
        - names end in “ate”
    - anhydride – a compound containing an O between two C’s, both of which have a double bond to another O
        - names end in “anhydride”
    - aldehyde – a compound with a C=O on the end of a molecule, having a H attached to the carbon
        - names end in “al” or “aldehyde” or contain “oxo”
    - ketone – a compound with a C=O in the middle of the molecule, between two other C’s
        - names end in “one” or “ketone” or contain “oxo”

- Functional groups containing N
    - amine – a compound containing a carbon bonded to a nitrogen
        - names end in “amine” or contain “amino”
    - amide – a compound containing a C=O with a nitrogen attached to the carbon
        - names end in “amide”
    - nitrile – a compound containing a carbon triple bonded to a nitrogen
        - names in end “nitrile” or contain “cyano”
    - nitro – a compound containing an NO_2 group
        - names contain “nitro”
- Functional groups containing a halogen
    - alkyl halide – a compound containing a carbon bonded to a halogen
        - names end in “fluoride”, “chloride,” “bromide,” or “iodide,” or contain “fluoro,” “chloro,” “bromo,” or “iodo”
    - aryl halide – a compound containing a benzene ring bonded directly to a halogen
        - names end in “fluoride”, “chloride,” “bromide,” or “iodide,” or contain “fluoro,” “chloro,” “bromo,” or “iodo” (same as above)
    - acid chloride – a compound containing a C=O with a chloride attached to the carbon
        - names end in “chloride”

III. Physical Properties of Organic Molecules

- The physical properties of organic molecules are the things about them that can be observed and measured, such as state of matter, melting point, boiling point, solubility in water, viscosity, and so on.
    - These properties are determined by the molecular structure of the compound.
    - By looking at the structure, we can predict some of the physical properties. We can also compare one compound to another.

- Intermolecular forces: The forces that attract molecules to each other are called intermolecular forces. They have a strong influence on physical properties. The three intermolecular forces are Van der Waals forces (London forces), dipole forces, and hydrogen bonding.

    - Don't confuse intermolecular forces with covalent and ionic bonds, which hold the molecules themselves together. Intermolecular forces operate between molecules, and are much weaker than actual chemical bonds.

    - <u>Van der Waals forces</u> are the weakest intermolecular forces.

        - They arise in nonpolar molecules because collisions of molecules cause small, temporary dipoles, which weakly attract the molecules to each other.

        - All molecules will experience Van der Waals forces. However, they will only be important in molecules with only nonpolar bonds. All other molecules will have dipole or hydrogen bonds, which will be much stronger than the Van der Waals forces.

        - Van der Waals forces are affected by the shape of a molecule. Molecules with more elongated shapes will have more surface area and therefore experience more Van der Waals forces than molecules with more rounded shapes, which will have less surface area.

    - <u>Dipole forces</u> are intermediate in strength.

        - They are caused by polar bonds in the molecules that create an attraction between the partially positive atoms in one molecule and partially negative atoms in another molecule. (These atoms may not be hydrogen.)

        - Molecules which have polar bonds will experience dipole forces.

        - Dipole forces are affected by the strength of the polar bond: molecules with more polar bonds will experience greater dipole forces than molecules with a less polar bonds.

        - Dipole forces are also affected by the ratio of polar and nonpolar bonds in a molecule: molecules with a polar bond but lots of nonpolar bonds will experience weaker dipole forces than molecules with a polar bond but only a few nonpolar bonds. The nonpolar bonds basically dilute the effect of the polar bonds.

    - <u>Hydrogen bonding</u> is the strongest intermolecular force. However, the name is a bit misleading, because they are not chemical bonds. Even though they are the strongest intermolecular force, they are much weaker than covalent or ionic bonds.

        - They are caused by the attraction of partially positive hydrogen atoms with electron pairs on electronegative atoms.

      - Molecules with N-H and O-H bonds, with an electron pair on the N or O, will experience hydrogen bonds.

      - Hydrogen bonding is affected by the electronegativity of the atom with the electron pair. Molecules with a more electronegative atom will experience more hydrogen bonding than molecules with a less electronegative atom.

      - Hydrogen bonding is also affected by the number of H's attached to the electronegative atom. Molecules with more H's attached will experience stronger hydrogen bonding than molecules with fewer H's attached. However, this effect is weaker than the electronegativity of the atom.

- States of matter and transitions between them

  - Organic compounds may exist in one of three states of matter – solid, liquid, and gas. (Plasma, the forth state of matter, can only exist when atoms have been broken down into electrons and nuclei, at which point no molecules exist.)

    - In a gas, the molecules are moving freely and rapidly, with lots of space between them, having lots of energy and no organization.

    - In a liquid, the molecules are still moving but not as rapidly, they are closer together, and they have less energy, but still no organization.

    - In a solid, the molecules are not moving, only vibrating in place. They are closely packed together, usually in an orderly arrangement, and have less energy than a liquid or gas.

  - The transition between a solid state and liquid state is called melting or freezing. When a solid melts, the molecules break out of their orderly arrangement and begin to move around, with more space between them. When a liquid freezes, the molecules settle down into an orderly arrangement.

    - The temperature at which this transition occurs in a particular compound is called the melting point of that compound.

    - The melting point is affected by the size of the molecules and the strength of the intermolecular forces.

      - It takes more energy to get a larger molecule moving than a small molecule.

      - Likewise, it takes more energy to pull molecules out of their orderly arrangement if they have stronger intermolecular forces than if they have weaker intermolecular forces.

      - The melting point is not affected by the atmospheric pressure.

        - If the melting point of a compound is higher than 25° C, the compound will be a solid at room temperature. If the melting point is lower than 25° C, the compound will be a liquid (or a gas) at room temperature.

    - The transition between a liquid state and a gaseous state is called evaporating, boiling or condensing. When a liquid evaporates or boils, the molecules separate from each other and go flying through the air. When a gas condenses, the molecules come together and form a loose association.

        - Boiling differs from evaporation because it can only happen at the boiling point. When a liquid boils, molecules go to a gas state inside the liquid, rather than just at the surface. This happens when the vapor pressure of the gas is equal to the atmospheric pressure around the container. The temperature at which this occurs in a particular compound is called the boiling point of that compound.

        - The boiling point is affected by the size of the molecules, the strength of the intermolecular forces, and the atmospheric pressure.

            - It takes more energy to get larger molecules flying through the air than smaller molecules.

            - It takes more energy to pull apart molecules with stronger intermolecular forces than molecules with weaker intermolecular forces.

            - It takes more energy to get the vapor pressure up to the atmospheric pressure when the atmospheric pressure is high. Boiling points are measured at sea level, or 1 atm. At higher elevations, boiling points are lower.

        - If the boiling point of a compound is higher than 25° C, the compound will be a liquid (or a solid) at room temperature. If the boiling point is lower than 25° C, the compound will be a gas at room temperature.

- Solubility

    - When molecules (or ions) of different compounds mix together, they are said to be soluble in each other. If they do not mix, they are said to be insoluble.

        - All gases mix freely, and so are soluble in each other.

        - Solids can also be melted, mixed, and solidified. Mixtures of metals, or alloys, are the most common solid solutions.

        - Solids and gases can dissolve in liquids, and liquids can dissolve in each other. These are the kind of solutions that we will be concerned with.

            - When a solid, liquid, or gas dissolves in a liquid, the original material seems to disappear as the mixing process occurs.

- Solubility (or insolubility) is caused mostly by intermolecular forces. It is not affected by the size of the molecules.
    - When molecules of different kinds have the same kind of intermolecular attractions in about the same strength, they will be soluble in each other.
    - When molecules of different kinds of different kinds or strengths of intermolecular forces, they will not be soluble in each other.
        - The molecules with the stronger intermolecular forces will be attracted to each other rather than to the other kind of molecules, leaving the other kind undissolved.