Chemistry 203: Organic Chemistry

- a branch of chemistry involving the study of compounds of carbon
- most “organic” compounds also contain hydrogen
- many contain N, O, P, S, Se or other elements

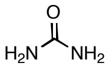
- Organic chemistry (and organic compounds) is (are) *very important* in human life

- “the chemistry of life” – fats, proteins, sugars, DNA, enzymes ➔ bioorganic chemistry
- medicines
- organic polymers (nylon, polyester, Styrofoam)
- gasoline, oil products

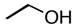
- Of the >10 million chemicals that are known, 90% are *organic*. Thousands of new compounds prepared each year.

- can be simple or very complex:

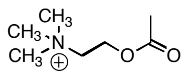
A Sampling of Organic Compounds



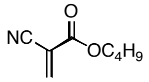
***urea**-the first organic compound made from "inorganic" starting materials*



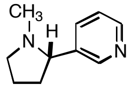
***ethanol (ethyl alcohol)**-yeast fermentation product*



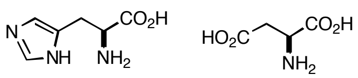
***acetylcholine**-a neurotransmitter*



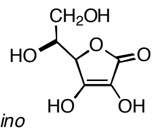
***butyl α-cyanoacrylate**-monomer of Superglue*



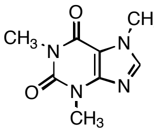
***nicotine**-a tobacco alkaloid*



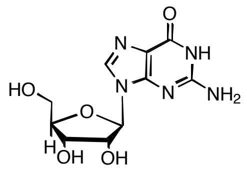
***histidine** and **aspartic acid**-examples of α-amino acids*



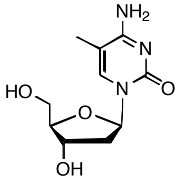
***ascorbic acid**-Vitamin C*



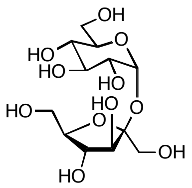
***caffeine**-an alkaloid*



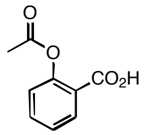
***guanosine**-a component of RNA*



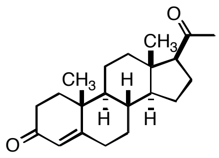
***2'-deoxythymidine**-a component of DNA*



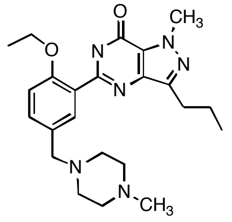
***sucrose**-table sugar*



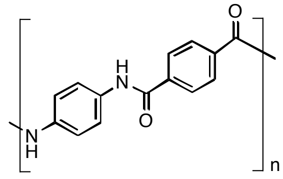
***acetylsalicylic acid**-Aspirin*



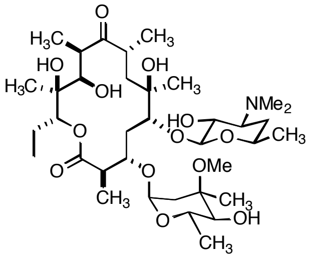
***progesterone**-female sex hormone*



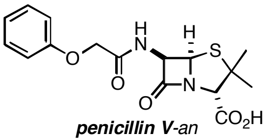
***Viagra**-male impotence drug*



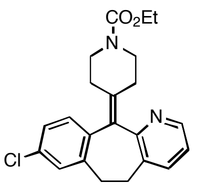
***Kevlar**-an organic polymer*



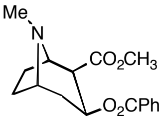
***erythromycin A**-an antibiotic*



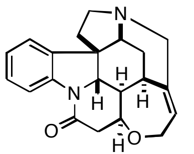
***penicillin V**-an antibiotic*



Claritiin-antihistimine (i.e. antiallegic)



cocaine-illegal narcotic



***strychnine**-a poison*

In this course, we will discuss primarily the following aspects of organic substances:

a) structure: constitution and stereochemical configuration
b) physical properties, including the effect of structure on physical properties
c) spectroscopic properties: obtaining structural information from spectroscopic techniques
d) chemical reactivity:
  - conversion of one functional group into another
  - synthesis of complex organic compounds from simple organic compounds
  - the mechanism of organic reactions

Why are so many chemicals based on carbon?

This diversity is the result of the ability of carbon atoms to form chains with itself and other atoms.

chemical bonds:

Atoms will interact in a way that gives them the same electronic configuration as the nearest noble gas (usually *eight* valence electrons)

Two general types:

1) ionic bond: formed by the donation of electrons.

2) covalent bond: formed by the sharing of electrons between atoms

hybridization: when atoms participate in covalent bonding, their atomic orbitals can combine, or hybridize to give molecular orbitals. This improves overlap between orbitals, better sharing of electrons, stronger bonds

Polar covalent bonds

- many covalent bonds are said to be polar
- caused by unequal sharing of electrons between two atoms which, in turn, is caused differences in electronegativity of the two atoms

electronegativity: ability of an atoms to attract electrons in a covalent bond

The polar nature of many covalent bonds is helpful to understand chemical and physical properties of organic molecules (e.g. solubility)

Polar molecules. Polar bonds often, but not always, impart dipole moments to the molecule as a whole.

Unshared electron pairs (non-bonding electrons, lone pairs)

Organic compounds possessing certain elements (particularly halogen, N, O, S) contain on these "heteroatoms" *unshared pairs of electrons*. These play an important role in the chemistry of these substances. Particularly, these unshared "lone pairs" can be shared with electron-deficient species.

It is *very important* in organic chemistry to keep track of the electrons!

formal charge: helps us keep track of the electron density around an atom

Use of curved arrows in depicting reactions:

Organic chemists use curved arrows to indicate the *direction of electron flow*. The arrows do NOT represent the movement of atoms.

The arrows **always** begin at the electron-rich species and end at the electron-poor species.

Resonance structures

- most molecules may be accurately represented by a single valence structure

but there are systems that need *further* description to describe them well:

Consider the sulfate anion:

Resonance structures are contributors to the “real” structure. They are related by movement of electrons only.

Resonance structures do *not* have to be equal contributors.

Important:

- resonance structures are NOT real; it is not EQUILIBRIUM
- more resonance structures implies more stability
- they must be valid Lewis structures → full octets are better

- refers to resonance, not equilibrium ( )
- pretend the molecule is “glued” to the page and move electrons only using curved arrows
- look for 3-atom groupings with a multiple bond (a π system); these typically have resonance forms
- resonance occurs almost always through π-bonds and p orbitals
- atoms do not change hybridization or their shape in different resonance forms!
- “good” resonance forms have: full octets
  are uncharged
  if charged, - charge on more EN atoms
  if charged, + charge on less EN atoms
  structures with -, + charges close together usually better

An Introduction to Aromaticity (Chapter 21.2)

Structure of and Bonding in Benzene

• benzene, C_6H_6, was first isolated in 1825 (Michael Faraday), but it was not until more than 100 years later that an adequate structure was formulated.

Benzene has a number of unusual properties.

a) the C-C bonds are all equal in length

b) the C=C double bonds of benzene do not react like simple C=C bonds (covered in Chem 204)

Benzene is ~36 kcal/mol (~150 kJ/mol) more stable than expected!

All of these characteristics can be rationalized on the basis of resonance stabilization of benzene. The 36 kcal/mol "extra stability" of benzene is called the resonance energy of benzene.

Aromaticity. The Hückel 4n+2 Rule

Compounds such as benzene that are stabilized by resonance are said to have aromatic character or to exhibit aromaticity. Such compounds obey the Hückel rule.

Hückel rule: continuous, closed, planar rings of conjugated atoms display unusual stability if the number of π electrons in the conjugated loops is 4n+2, where n=0,1,2…etc.

Compounds that have 4n electrons in a closed, continuous planar ring are said to be “anti-aromatic” and are extremely unstable (usually cannot be formed using normal laboratory conditions).