IB Chemistry

Chapter 10: Organic Chemistry

Notes

**10.1: Fundamentals**

When learning organic nomenclature, it is important to know the prefixes that are commonly used. The prefixes are based off the number of carbons in the molecule.

|  |  |  |  |
| --- | --- | --- | --- |
| 1 carbon | Meth- | 6 carbons | Hex- |
| 2 carbons | Eth- | 7 carbons | Hept- |
| 3 carbons | Prop- | 8 carbons | Oct- |
| 4 carbons | But- | 9 carbons | Non- |
| 5 carbons | Pent- | 10 carbons | Dec- |

When drawing organic compounds, this is the method you’re most likely to see on the quizzes and tests. The carbons are located at the bent places and each carbon is attached to either two or three hydrogen atoms, depending on their location. The “Hs” do not need to be drawn. Another name for these compounds is “hydrocarbons,” meaning that they include hydrogen and carbon atoms.

Examples:

|  |
| --- |
|  |

*Homologous series* are families of compounds that possess certain common features. You will learn more about homologous series when we get to functional groups.

\*\*You have to count the carbons from either L to R or R to L, whichever gives you the lowest number. Then you can determine the numeric prefix depending on where the homologous series is attached to the carbon chain. For example, 2-pentanol has an –OH group attached to the *second* carbon

Alkanes

Alkanes are compounds with single bonds between the central carbon atoms and the terminal hydrogen atoms. The formula for determining alkane molecules is as follows:

CnH2n + 2

Alkanes end in the suffix –*ane.*

We will practice sketching and naming some simple alkanes using this formula and the rules for drawing organic compounds.

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|  |

Alkenes

Alkenes are organic compounds that contain at least one double bond between two carbon atoms. The formula for determining alkene molecules is as follows:

CnH2n

Alkenes end in the suffix *–ene.*

We will practice sketching and naming some simple alkanes using this formula and the rules for drawing organic compounds.

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Alkynes

Alkynes are organic molecules that contain a triple bond between two carbon atoms. Alkynes end in the suffix *–yne.*

We will practice sketching and naming some simple alkanes using this formula and the rules for drawing organic compounds.

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Alkanes are saturated hydrocarbons. Alkenes and alkynes are unsaturated hydrocarbons.

Organic Compound Formulas

There are three types of formulas used for hydrocarbons. There is the *empirical formula*, which shows the simplest whole number ratio of the atoms it contains. The *molecular formula* shows the actual number of atoms of each element present in the molecule. *Structural formulas* show the arrangement of the molecule and how the atoms bond to one another. Page 312 in your text breaks down the different types of structural formulas. There is also a shorthand way of writing hydrocarbons that you’ll see regularly. It’s called a condensed structural formula. Here’s an example:

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Molecular Formula** | **Structural Formula** | **Condensed** |
| Ethane | C2H6 |  |  |
| Ethanoic acid | C2H4O2 |  |  |
| Butane | C4H10 |  |  |

Functional Groups

These are homologous series that are attached to a hydrocarbon to give it special reactive properties. Your textbook provides a comprehensive list on page 314. I’m providing a shorthand version in these notes, but you do need to study the chart in the text.

|  |  |  |
| --- | --- | --- |
| **Homologous Series** | **Functional Group Name** | **Suffix** |
| alkane |  | -ane |
| alkene | alkenyl | -ene |
| alkyne | alkynyl | -yne |
| halide | halogen | -(depends on halogen) |
| alcohol | hydroxyl | -anol |
| aldehyde | aldehyde | -anal |
| ketone | carbonyl | -anone |
| carboxylic acid | carboxyl | -anoic acid |
| ester | ester | -anoate |
| ether | ether | -oxyalkane |
| arene | phenyl | -benzene |

**Halides** have a halogen (fluorine, chlorine, bromine, iodine) attached to one of the carbons. For example, if you replace one of the H atoms with a Br atom in propane, it becomes bromopropane. If you replace two H atoms with two Cl atoms in ethane, it becomes dichloroethane. See below.

|  |  |
| --- | --- |
| bromopropane | 1, 2-dichloroethane |

**Alcohols** have an –OH group attached to the carbon chain. Carbon chains use an “R” as a substitute. The suffix for any alcohol is –*ol*. Replacing an H atom with –OH in methane changes it to methanol. See below.

|  |  |
| --- | --- |
| methanol | 2-pentanol |

**Aldehydes** have a O=C-H attached to the end of a carbon chain. Replacing a H atom with O=C-H turns methane into methanal, which is formaldehyde. The suffix for an aldehyde is *–al*.

|  |  |
| --- | --- |
| methanal | propanal |

**Ketones** have a O=C-R’ attached to the end of the carbon chain. R’ (read as R prime) is a different combination of carbons and hydrogens. The double bond between carbon and oxygen should be in the middle of the compound. Replacing an H atom with a ketone will turn butane into butanone, as the suffix for ketones is –*one*.

|  |  |
| --- | --- |
| butanone | Other example: |

**Carboxylic acids** have a O=C-OH attached to the end of the carbon chain. Replacing one of the H atoms at the end of butane with a carboxylic acid yields butanoic acid. The suffix for carboxylic acid is –*oic acid*.

|  |  |
| --- | --- |
| Butanoic acid | Other example |

**Esters** have a O=C-O-R’ that replaces a H atom at the end of the carbon chain. The suffix for esters is –anoate. Let’s do examples for propane and octane.

|  |  |
| --- | --- |
| propanoate | octanoate |

**Ethers** have an R – O – R’ that replaces an H atom at the end of the carbon chain. The suffix for ethers is –oxyalkane. Let’s do examples for ethane and pentane.

|  |  |
| --- | --- |
| ethanoxyalkane | pentanoxyalkane |

**Arenes** are benzene derivatives. Let’s spend a little time discussing benzene. Benzene’s formula is C6H6 and it forms a hexagon.

|  |  |  |
| --- | --- | --- |
|  |  |  |

This ring is stable because of delocalized electrons. See the image on page 323. This stability leads to specific physical and chemical properties (page 324). Benzene has no isomers and does not undergo addition reactions.

When halogens are added to the benzene ring, the locations of the halogens have unique prefixes:

1, 2 (halogen attached to C1 and C2): ortho-

1, 3 (halogen attached to C1 and C3): meta-

1, 4 (halogen attached to C1 and C4): para-

|  |  |  |
| --- | --- | --- |
| orthodichlorobenzene | metadifluorobenzene | paradichlorobenzene |

Adding functional groups follows the same pattern:

|  |  |  |
| --- | --- | --- |
| orthodimethylbenzene | metadiethylbenzene | paradimethylbenzene |

Arenes form a special branch of organic compounds called *aromatics,* which have properties distinct from other organic compounds (*aliphatics*). Arenes have a benzene base, but contain the phenyl functional group C6H5.

Nomenclature Rules

1. Identify the longest straight chain of carbon atoms. Number them. This gives you the stem of the name using the prefixes. “Straight chain” refers to continuous or unbranched chains of carbon atoms.
2. Identify the functional group. This provides the suffix.
3. Identify side chain or substituent groups. Side chains (or functional groups) in addition to the suffix are known as substituents and are given as the first part or prefix.

Ex: Class Alkane Prefix: methyl, ethyl, propyl, etc.

Class Halide Prefix: fluoro, chloro bromo, iodo

The position of a substituent group is given by a number followed by a dash in front of the name to denote the carbon to which it is attached. Chains are numbered to give the smallest number to the group.

IUPAC nomenclature has three possible parts, which are usually written together as a single word.

**PREFIX -- STEM -- SUFFIX**

**Prefix:** position, number and name of substituents

**Stem:** Number of carbon atoms in longest chain

**Suffix:** Class of compound determined by functional group

**Let’s Practice! Page 316, #1-4**

Structural Isomers

These are different arrangements of the same atoms. Isomers are distinct compounds that have unique properties. The number of isomers that exist for a formula increases as the size of the molecule increases.

Example: butane and 2-methylpropane

|  |  |
| --- | --- |
| butane | 2-methylpropane |

What’s the difference? Can you explain what you’re seeing?

Another example: butene

|  |  |
| --- | --- |
| but-1-ene | but-2-ene |

The difference here is the location of the double bond. Alkynes work the same way.

Pages ~~317-319~~ provide several examples of isomers. Try to understand how they’re named.

Primary, secondary and tertiary compounds

The activity of a functional group is influenced by its position in the carbon chain. A primary carbon atom is attached to the functional group and also to at least two hydrogens. Molecules with this arrangement are known as primary molecules. A secondary carbon atom is attached to the functional group and also to one H atom and two alkyl groups. A tertiary carbon atom is attached to the functional group and is also bonded to three alkyl groups, but no H atoms. See below (comes from p. 320):

|  |  |  |
| --- | --- | --- |
| Primary | Secondary | Tertiary |

Trends in physical properties

The increase in boiling point with alkane carbon number (page 310, table) applies to other homologous series. In general, the lower members of a series are likely to be gases or liquids at room temperature, while the higher members are more likely to be solids. Branching the hydrocarbon chain also affects volatility as it influences the strength of the molecular forces. Branched chains have less contact with each other and thus have weaker intermolecular forces and therefore, lower boiling points.

**MOST VOLATILE LEAST VOLATILE**

alkane > halogenoalkane > aldehyde > ketone > alcohol > carboxylic acid

dispersion force 🡪 dipole-dipole force 🡪 hydrogen bonding

increasing strength of intermolecular attraction 🡪

increasing boiling point 🡪

**Let’s Practice! Page 326 #5-8**