Introduction to Organic Chemistry

Contain hydrogen and carbon atoms only

Influence reactivity – give similar chemical and physical properties

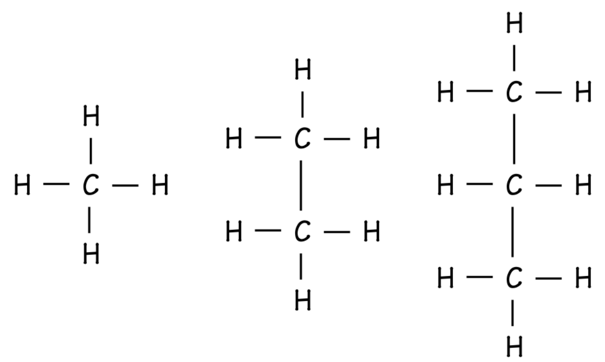
- alkanes C-C
- alkenes C=C
- alkynes C≡C
- haloalkanes R-X (where X is F, Cl, Br, I)
- alcohols R-OH
- carboxylic acids R-COOH
- amines $R-NH_2$

R is rest of molecule

# of C atoms in the molecule. 1 meth- 2 eth- 3 prop- 4 but- 5 pent- 6 hex - 7 hept- 8 oct-

C_nH_{2n+2}

Each C atom bonded to 4 other atoms; no spare bonds within molecule for further atoms to be added, contain only C-C single bonds



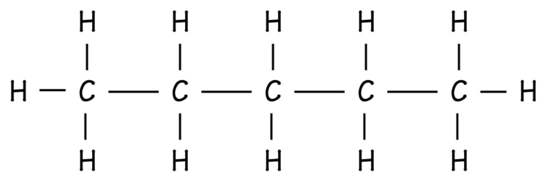
SUMMARY: Organic chemistry is study of compounds containing carbon. Homologous series have fixed functional groups which give the compound its characteristic properties. Alkanes are saturated hydrocarbons having single bonds between carbon atoms.

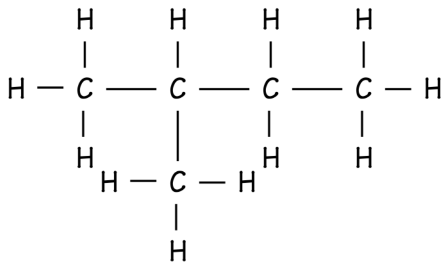
Types of Formula

Identifies the number and type of atoms

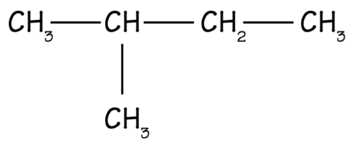
e.g. C_5H_{12}

Shows how the atoms are arranged and bonded to each other





$CH_3—CH_2—CH_2—CH_2—CH_3$ or $CH_3CH_2CH_2CH_2CH_3$



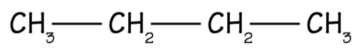
or $CH_3CH(CH_3)CH_2CH_3$

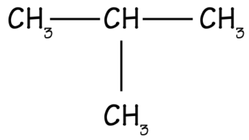
SUMMARY: We can write the formulae of organic molecules in a number of different ways; molecular, structural and condensed structural formula.

Alkanes & Isomers

C_nH_{2n+2} where n is the # of carbon atoms

Can be straight chain or branched chain



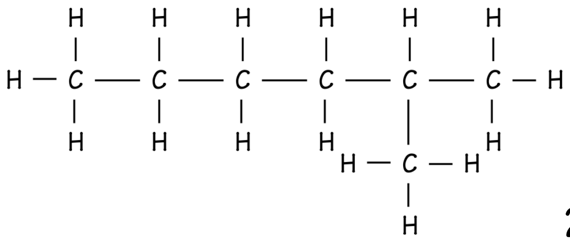


Side chains named methyl (CH_3-), ethyl (C_2H_5-), propyl (C_3H_7-) etc

Find longest carbon chain.

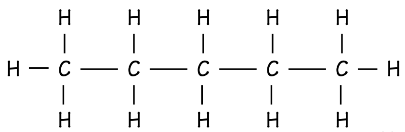
Find side chain and name it based on # of C atoms, using yl

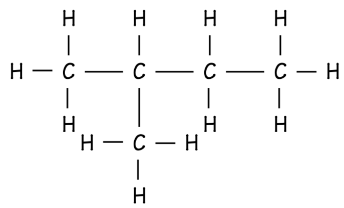
Count from end that gives lowest number for the side chain

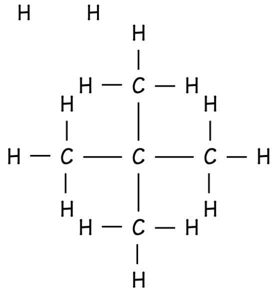


2-methylhexane

Have the same molecular formula but different structures e.g.







SUMMARY: Alkanes with general formula C_nH_{2n+2} can be straight or branched. They are named based on the longest carbon chain, with numbers used to show the position of the side chains, numbering from the end so as to give the side chain position the lowest possible number. Structural isomers have the same molecular formula but have different physical structures. They are also known as conformational isomers.

Alkane physical properties & chemical reactions

Melting and boiling points increase in a regular way as the length of the carbon chain increases.

@ room temperature C1 – 4 are gases, C5 upwards are liquids; larger alkanes are solids e.g. candle wax

Forces of attraction between molecules increases as carbon chain length increases, which means that more energy is needed overcome these forces to change the substances state.

Alkanes (non polar) are insoluble in water – a polar solvent. Form 2 layers – are immiscible in water.

Are used extensively as fuels

Plentiful oxygen – complete combustion to produce CO_2, H_2O and max. amount of energy.

Limited oxygen – incomplete combustion to produce C and CO and H_2O and less energy.

C (soot) is dirty, CO is colourless, odourless, very toxic.

CO_2 linked to global warming / climate change.

React slowly with Br_2 water in presence of UV light and/or heat. Orange bromine colour is slowly decolourised.

Is a substitution reaction. Two products are made.

$$C_6H_{14} + Br_2 \rightarrow C_6H_{13}Br + HBr$$

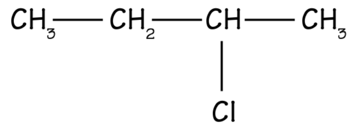
(The reaction would continue with further substitution but you only need to write an equation for monosubstitution).

SUMMARY: Alkanes are non-polar molecules that are insoluble in water. Their m.pt and b.pt increase as the number of carbon atoms in the molecule increase. Their two most important chemical reactions are combustion reactions (complete & incomplete) & substitution reaction with orange bromine.

Haloalkanes

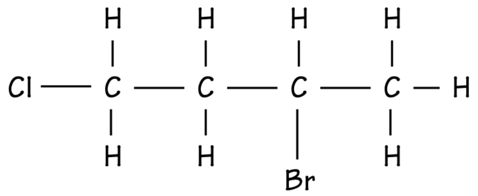
Molecules when H atom or H atoms in an alkane are replaced by X, where X is a halogen (F, Cl, Br, I)

Fluoro, chloro, bromo, iodo (listed alphabetically if a molecule contains more than one type of halogen).



2-chlorobutane

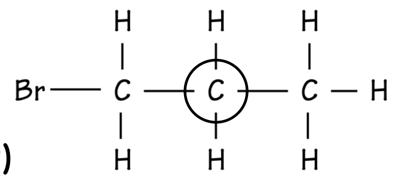
Naming similar to naming branched alkanes with numbering from end to give smallest number.



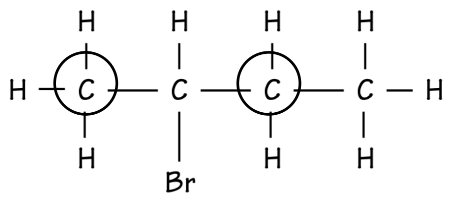
3-bromo-1-chlorobutane

Primary (1°), secondary (2°) and tertiary (3°) used to classify haloalkanes. Identify the carbon atom bonded to the halogen and count the number of C atoms directly bonded to that C atom.

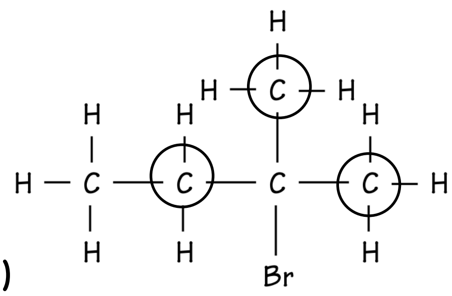
(1°)



(2°)



(3°)

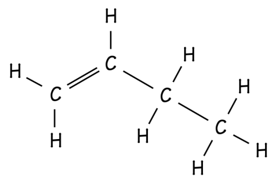


SUMMARY: Haloalkanes contain halogen atom(s) in place of H atoms and can be classified as primary, secondary or tertiary depending on how many carbon atoms are directly bonded to the carbon atom that has the halogen bonded to it.

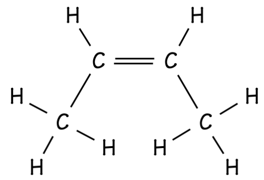
Alkenes

C_nH_{2n} ethene, propene, butene etc. Hydrocarbon molecules with one (or more) double covalent bonds between carbon atoms (C=C)

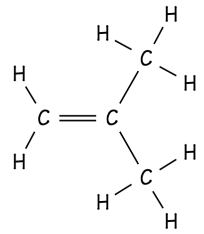
C=C functional group makes them more reactive than alkanes. The C=C means more atoms can be added to the molecule which is described as unsaturated; not every C atom is bonded to 4 other atoms.



but-1-ene



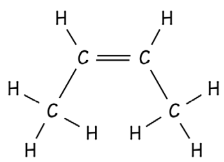
but-2-ene



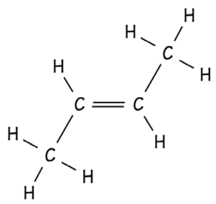
methylpropene

But-1-ene, but-2-ene and methylpropene are structural isomers (same molecular formula, different arrangement of carbon atoms)

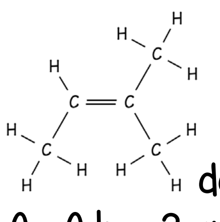
The C=C bond prevents rotation and so atoms / groups of atoms attached to either side of C=C are fixed in position. Alkenes with same molecular formula can be cis or trans. This is geometric isomerism.



cis-but-2-ene



trans-but-2-ene



doesn't exist as cis or trans as right hand C of C=C has 2 groups the same

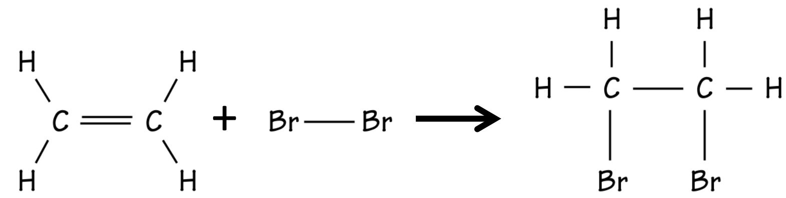
SUMMARY: Alkenes are unsaturated hydrocarbons containing a C=C double bond. The bond does not allow rotation and can give rise to cis and trans isomers as long as each carbon joined by the double bond has 2 different atoms/groups attached to it.

Addition reactions of alkenes

C=C makes alkenes reactive. One of the bonds in the double bond breaks and atoms / groups of atoms can join to make a new molecule.

Addition reaction with bromine water. Orange bromine water is rapidly decolourised: Useful test for C=C / unsaturation

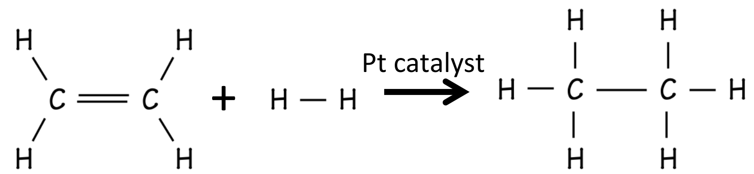
Halogenation - e.g. addition of Br_2 or Cl_2



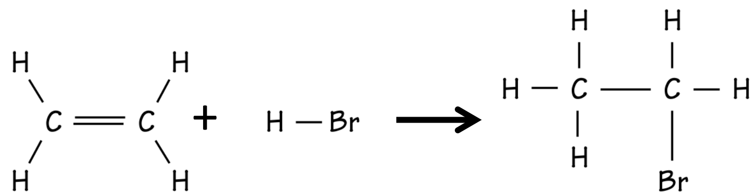
There is one product which is saturated (C-C).

Other addition reactions

Hydration



Addition of HX – e.g. HCl or HBr



Hydration – addition of water. H^+, H_2O, heat – to form an alcohol

Polymerisation (ethene → polyethene)

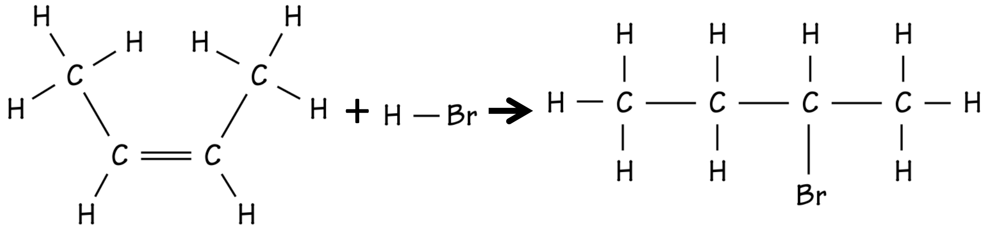
SUMMARY: Alkenes undergo addition reactions where one bond of the C=C double bond opens up and atoms join to the carbon atoms. The one product molecule is now unsaturated.

Shaking a small amount of bromine water with an alkane and an alkene lets you easily distinguish between them as the bromine water decolourises instantly with the alkene (and only very slowly with the alkane in uv light).

Markovnikov's Rule

Reaction of HX or H_2O with alkenes.

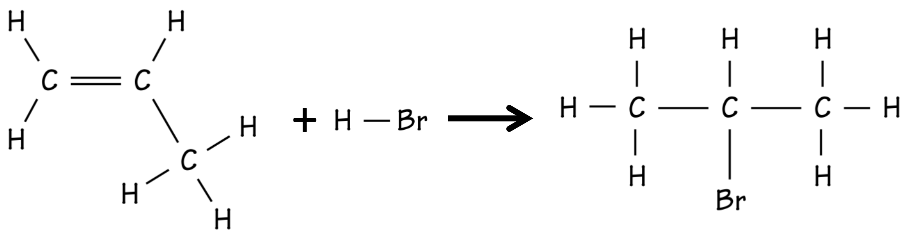
For symmetrical alkenes (even # of C atoms and C=C in middle of molecule) there is only one possible product.



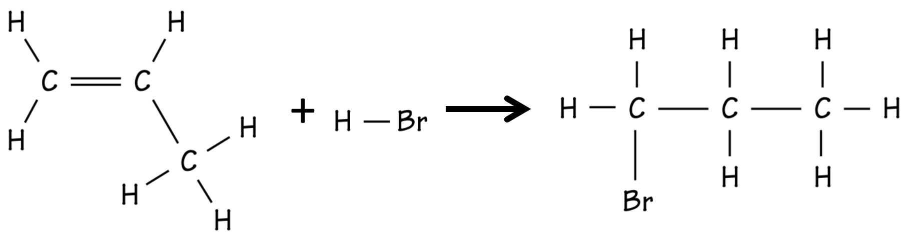
2-bromobutane

HBr is an unsymmetrical reagent (as is HCl, and H_2O - think of it as H-OH). When it reacts with an unsymmetrical alkene there are 2 possible products. Most common = major product, least common = minor product.

e.g.



major product



minor product

Major product - The H atom adds on to the C atom in the C=C that had most H atoms already attached.

Sometimes remembered as "the rich get richer" rule

SUMMARY: Addition of an unsymmetrical reagent to an unsymmetrical alkene produces 2 products, a major and a minor, which can be predicted by applying Markovnikov's rule.

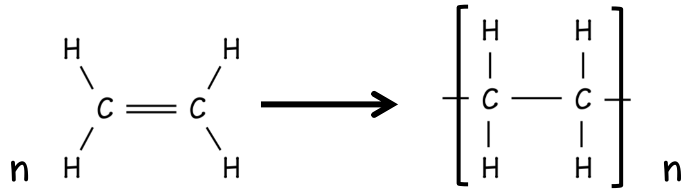
Addition Polymerisation

Linking together of many alkene molecules; Can react with each other because of C=C bonds.

Monomer is the single molecule building block;

Polymer is a macromolecule (very large molecule) made from many linked monomers. n =large number.

Polymerisation reaction needs heat + catalyst.



ethene monomers   section of polyethene

Polythene is long molecule – solid at room temperature.

Unreactive polymer as now saturated C-C. Resistant to attack by chemicals.

Propene → polypropene; rope, carpet, crates, clothing

Vinylchloride → PVC; raincoats, pipes, wire insulation

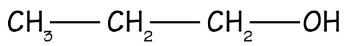
Tetrafluoroethene → PTFE: non stick pans, waterproofing

SUMMARY: Addition polymers are made from alkene monomers which can join together in a polymerisation reaction to make large solid molecules, the polymer molecules. Different polymers with different properties are made from different monomers. Their different properties give them different uses but they are now all unreactive as they are saturated.

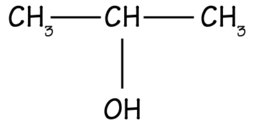
Alcohols

Alkane chain with –OH group replacing a H atom. $C_nH_{2n+1}OH$
Names based on # of C atoms, methanol, ethanol, propanol etc.

For alcohols with more than 3 C atoms it is necessary to show the C atom that the –OH group is attached to.



propan-1-ol / 1-propanol
$CH_3CH_2CH_2OH$



propan-2-ol / 2-propanol
$CH_3CH(OH)CH_3$

Classified as 1°, 2°, or 3°. Identify the carbon atom bonded to the -OH and count the number of C atoms directly bonded to that C atom. e.g. $CH_3CH(OH)CH_3$ is a secondary alcohol

As # of carbon atoms increases, the m.pt. and b.pt of alcohols increase. As the molecules get bigger the intermolecular attractions between the molecules get stronger so more heat energy is needed to separate the molecules to bring about a change in state.

Alcohols have higher m.pt. and b.pt than their corresponding alkanes because of the polar nature of the –OH group.

As # of carbon atoms increases, the solubility of alcohols decreases. C1-3 are soluble in water, C4 onwards are not because the longer non polar hydrocarbon regions.

SUMMARY: Alcohols have the –OH functional group, with –OH replacing the H of an alkane. Their melting and boiling points increase as the molecules get bigger due to stronger intermolecular attractions but their solubility in water decreases as the non-polar portion of the molecule increases in length. They can be classified as primary, secondary or tertiary depending on how many carbon atoms are directly bonded to the carbon atom that has the –OH group bonded to it.

SUMMARY: