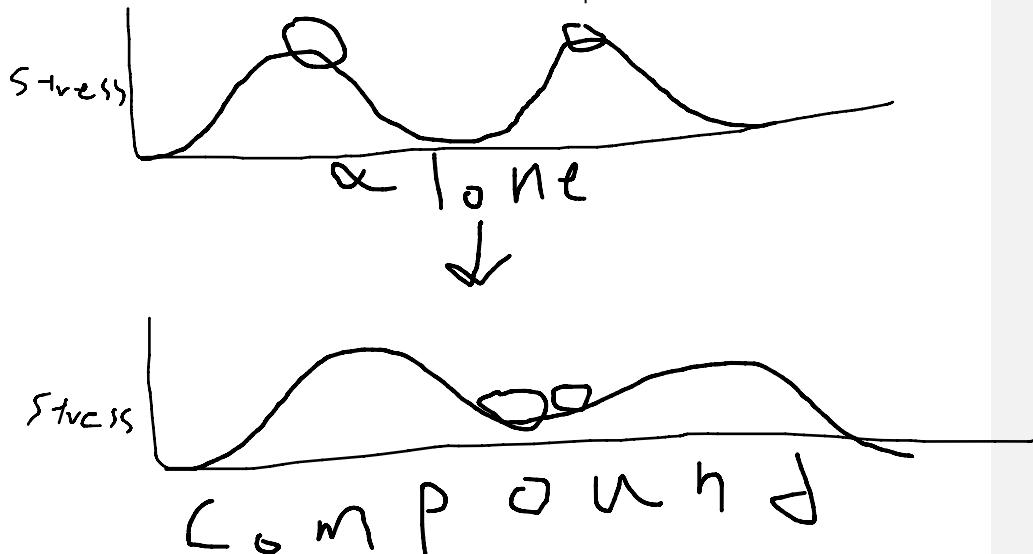


BONDS

Are relationships between different atoms, each type require different type of energy, the reason it exists is to make all the related atoms settle in the lowest-stress situation possible



CHEMICAL BONDS

Are connections between atoms in a molecule, these bonds include strong intramolecular interactions like covalent and ionic, and weak intramolecular interactions such as dipole-dipole interactions and London dispersion forces and hydrogen bondings

In short, chemical reactions are forces that hold atoms together to make compounds of molecules

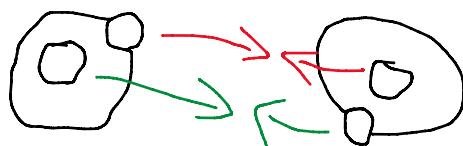
Atoms arrange themselves in the most stable patterns, they get stable by filling their outermost energy level, they do that by joining with other atoms, the force holding them is called a chemical bond



Atoms try to reduce their energy by achieving a balance between attractive and repulsive force

When atoms get close to each other, the electrons of an atom are attracted by the protons of another

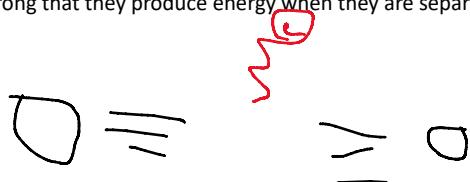
$$E_{\text{LJ}} = \text{High}$$



The electrostatic force gets stressed by the attraction force and tries to relieve it by getting closer



The pull between them gets so strong that they produce energy when they are separated



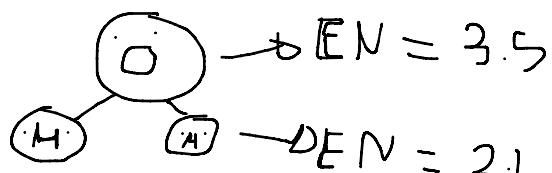
Their nuclei "plural of nucleus" rebel each other, they rebel just enough to find the perfect distance called "bond length" it's the distance between two nuclei where the attraction and repulsive force are 0



COVALENT BONDS

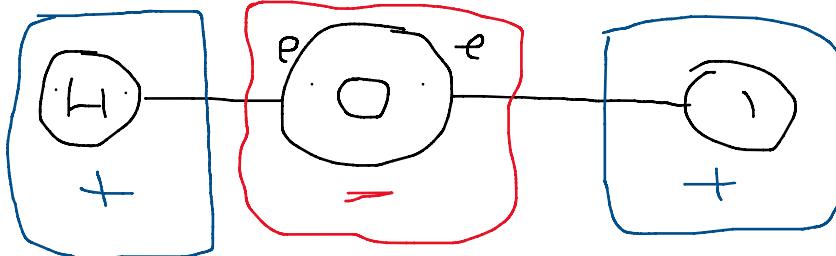
They are bonds where electrons are shared between nuclei, this happens because when both nuclei are pulling on the electron, the electron will tend to stay in a space between the two atoms or what we call "covalent bonds"

but not all sharing are equal, there is a property in an atom called electronegativity, it's the strength in which an atom holds a shared electron



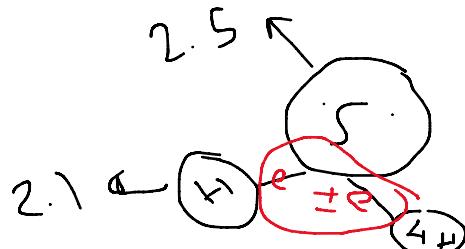
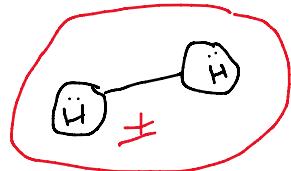
When an atom has more electronegativity, electrons will spend more time near it, creating a slightly negative charge in the area where they reside and a slightly positive charge in the area of the weaker atom

"polarity" or "separation of charges" these covalent bonds are called **polar covalent bonds**, like H₂O



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When atoms have very similar or identical electronegativities, atoms will not concentrate in one place as much, this will lead to a **nonpolar covalent bond**



Covalent bonds typically have lower melting and boiling points than ionic compounds, that is because atoms are not in their most stable state as they are **sharing** electrons, so what goes comes back and vice versa

They are in a liquid or gaseous state at room temperature, they have a definite shape and rarely break unexpectedly

They are not soluble in water, they tend to be **softer solids or liquids or gases**

IONIC BONDS

Metals have loosely-held valence electrons because their **ionization energy** is so low, they tend to lose these electrons and become **positive ions**

Commented [SD1]: Required energy to remove a valence electron from orbit

nonmetals will gain lost electrons because of their nuclear charge "positive charge from proton that pulls", and become a negative ion

when a positive ion meets a negative ion, they are attracted to each other because of their electrostatic force "positive love to stick to negative", but the nuclei will repel each other, so they create a point of minimum energy, aka

a **bond** that is formed by **transferring electrons** from one atom to another "**ionic bond**"

this bond results in a more **stable configuration** for both atoms where their latest energy level is filled

an ionic bond is based on the electrostatic forces between the two ions

we can calculate the energy using **coulomb's law**

it works only with ionic bonds because it requires the charge of the ions where covalent bonds don't have

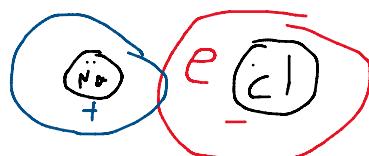
$$E \text{ (between two ions)} = (2.31 \times 10^{-19} \text{ J} \cdot \text{nm}) (Q_1 \times Q_2 / R)$$

Q_1 = charge of ion 1

Q_2 = charge of ion 2

R = radius between two nuclei

Because ionic compounds consist of positive ions and negative ions, they are extremely polar

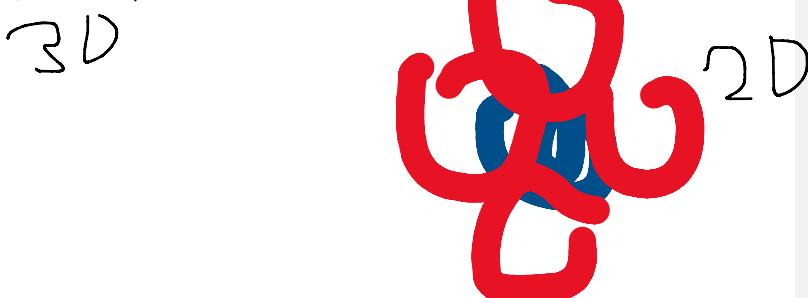


Because of their very high connection, they have higher melting points and they conduct electricity when melted

They are called **electrolytes** because of their ability to conduct electricity

They are solid in room temperature

They form **crystal lattices**, which are symmetrical three dimensional structures of arrangements of atoms



There is nothing called a **purely ionic bond**

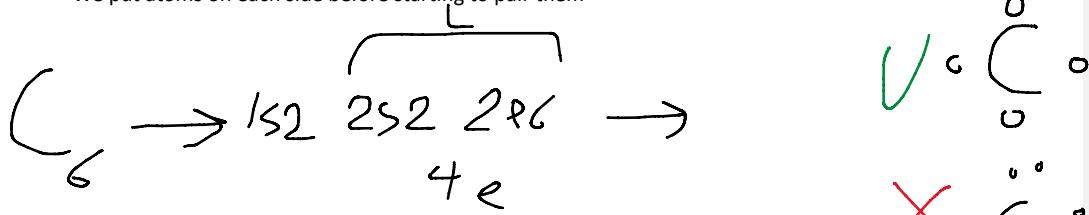
Because all bonding interactions have some covalent characteristics

Because the electron density remains shared but in ionic, the difference in electronegativity is much more larger than that of covalent bonds

LEWIS DOT STRUCTURES (electron dot diagram)

We represent the atom by its chemical symbol, then we draw the dots representing the atom's valence numbers, we draw the electrons in the right, up, left, down

We put atoms on each side before starting to pair them



elements in the same group will have the same lewis dot structure as they have the same number of valence electrons

drawing molecules, let's say we have Hydrogen and Chloride to make HCl

Cl valence number = 7

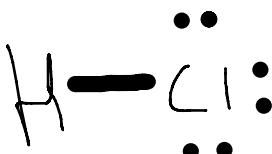
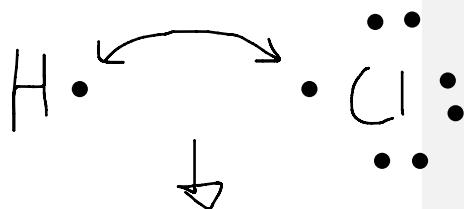


H valence number = 1

1-just draw the atoms' structures

You would find that there is an unpaired electron in both atoms

You connect them with a line



The line is a covalent bond that contains 2 electrons

Line = 2 electrons

Dot = 1 electron

Covalent bond

Lewis's structure will have all electrons paired either inside covalent bonds or in **two dot pairs**

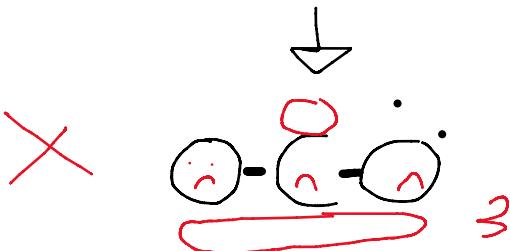
The number of valence electrons indicates how many bonds are able to form

"Probable" Number of bonds = number of lone electrons

Sigma bond is 1 covalent bond between atoms like HCl



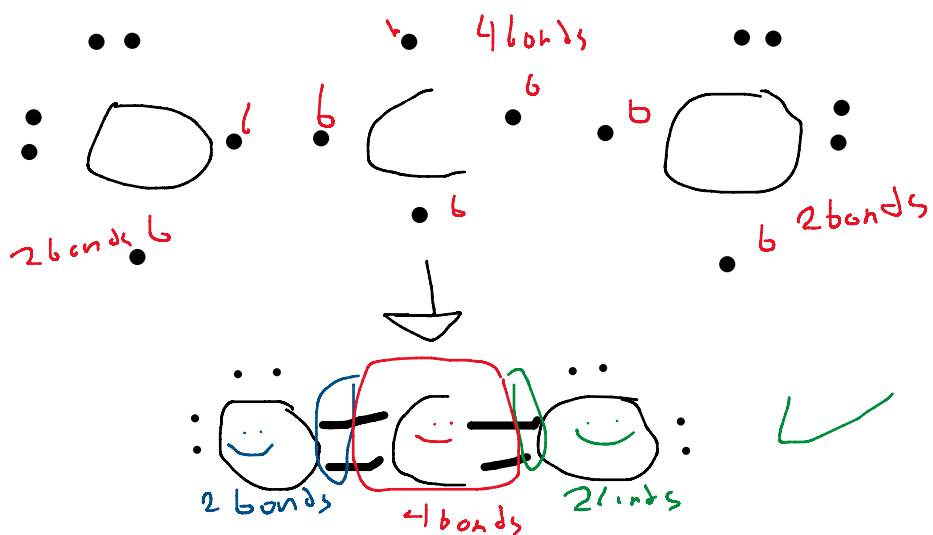
3 bonds
You can have double or triple sigma bonds like CO₂



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As you can see in this one, there are still 2 unpaired electrons in the carbon atom and an unpaired electron in each oxygen atom

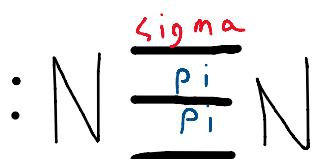
If adjacent atoms each have unpaired electrons, they will make another bond, creating a double bond, that second covalent bond is called a **pi bond**



Now 2 covalent bonds \rightarrow **sigma bond** and **pi bond** π

Sigma \rightarrow 1st bond

Pi \rightarrow any other bond



A triple bond consists of 3 bonds, 1 sigma bond and 2 pi bonds

The length of the bonds

Single $>$ double $>$ triple

As more bonds increase, the shorter they get

Lewis structure will sometimes have formal charge, when the atom contributing in the structure has a different valence number than typical, so for example

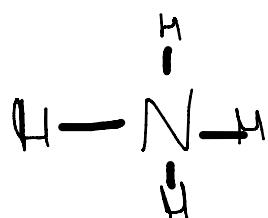


A nitrogen atom that has 5 valence electrons

In ammonia, it combines with 3 hydrogens, there are 3 sigma bonds and one lone pair



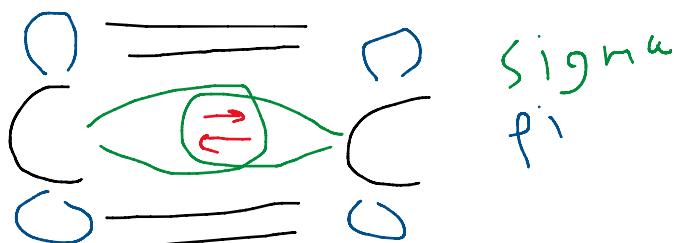
But in ammonium ion, nitrogen will only have 4 electrons, which means one fewer negative charged particles, which will give the nitrogen atom a formal positive charge



Sigma bonds are the strongest type of covalent interaction

Because of their overlapped orbitals will allow the electrons that are shared to move freely between atoms

Pi bonds are weaker covalent interactions and result from the overlap of two lobes of the interacting atomic orbitals above and below the orbital axis, aka there is no overlap between the actual orbitals



Covalent bonds can be **single or double or triple**

Single bonds



- occur when two electrons (1 from each atom) are shared
- they are composed of a single sigma bond
- this covalent bond is weaker and less dense than double or triple bonds, but it is more stable

Double bonds

- occur when four electrons (2 from each atom) are shared
- they are composed of a single sigma bond and another pi bond
- this covalent bond is much stronger and denser than a single bond but it is less stable

Triple bonds

- occur when six electrons (3 from each atom) are shared
- they are composed of a single sigma bond and two pi bonds
- this covalent bond is the strongest but least stable

ORGANIC COMPOUNDS

They are compounds that **MUST** have carbon



1s2 2s2 2p2

They can be

- **Natural** -> found in plants, animals, and fossil fuels, all of these rely on the fixing of C from CO₂
- **Synthetic** -> derived from fossil fuels or plant material

Organic chemistry = carbon chemistry

There are compounds that contain **C** but are not organic, like

- Oxides of carbon (CO, CO₂)
- Carbonates, bicarbonates (NaHCO₃, CaCO₃)
- Cyanides (NaCN, etc)

HYDROCARBONS



Are organic compounds that contain carbon and hydrogen, they are generally 4 classes

Alkanes – alkenes – alkynes - aromatic

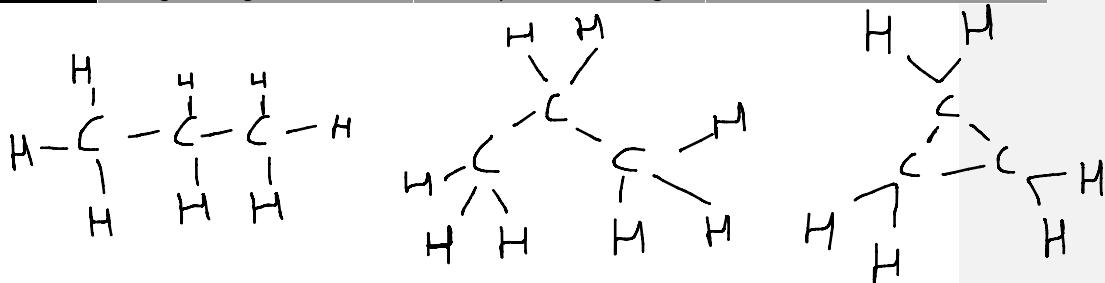
Alkanes

Organic compounds that consist of **hydrogen & carbon** they are **single bonded** (only 1 bond connecting them)

They have a general formula (C_nH_{2n+2})

They are separated into 3 groups

Feature	Linear Straight-Chain Alkanes	Branched Alkanes	Cycloalkanes
Structure	Straight, continuous chain	Non-linear, branching off main chain	Closed ring structure
Example	Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8)	Isopropane (C_3H_8), Isobutane (C_4H_{10})	Cyclopropane (C_3H_6), Cyclohexane (C_6H_{12})
General Formula	C_nH_{2n+2}	Depends on branching pattern	Depends on ring size
Boiling Point	Generally higher with increasing number of carbons	Lower compared to straight-chain isomers	Can be higher due to ring strain
Melting Point	Generally higher with increasing number of carbons	Lower compared to straight-chain isomers	Can be higher due to ring strain
Stability	Lower tendency for steric hindrance	Higher tendency for steric hindrance	Ring strain affects stability
Isomer Count	Fewer isomers due to linear structure	More isomers due to branching	Many possible structural isomers
Physical Properties	Typically less compact, more easily packed	More compact due to branching	Can have unique physical properties due to ring structure
Chemical Properties	Generally similar reactivity among homologous series	May exhibit different reactivity due to branching	Ring strain affects reactivity

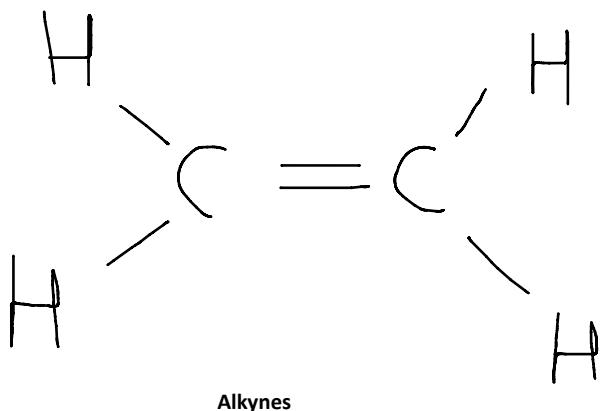


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Alkenes

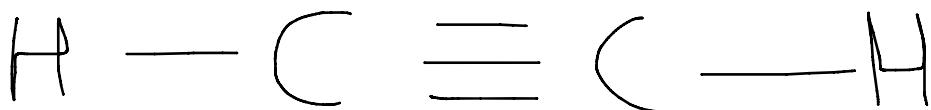
They are unsaturated hydrocarbons with at least one carbon-to-carbon double bond and written in the formula C_nH_{2n}

They are more reactive than alkanes because of their double bond, which makes them less stable



Alkynes

They are organic molecules made of one or more carbon-carbon triple bonds, they are unsaturated hydrocarbons and are written in the formula C_nH_{2n-2}



Alkyl groups

They are formed by removing one hydrogen from an alkane chain, resulting in a stem change from -ane to -yl

We will study them in the skeletal structure, they are alkanes that connect to a carbon chain in C-C bond



NOTES

In alkynes and alkenes, single bonds can still occur between carbon atoms

SKELETAL STRUCTURE (alkanes)

It's a structure that represents organic molecules where

- We get rid of hydrogen
- A carbon is an **end point of a line**
- a single bond is represented by –
- a double bond is represented by =
- a triple bond is represented by ≡
- each carbon must be bonded with 4 things, either it's hydrogen that **we get rid of**, or other carbons

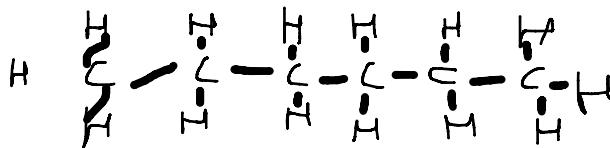
how to get the skeletal structure of alkanes

1. uncondensed the formula, for example, instead of $(CH_4)_2$, make it $CH_4\ CH_4$
2. get the lewis dot structure
3. remove the hydrogen
4. draw lines between carbons
5. make the main chain zig-zaggy

EXAMPLE

$CH_3(CH_2)_4CH_3$

- $CH_3\ CH_2\ CH_2\ CH_2\ CH_2\ CH_3$
- Do the dot structure



→ Remove the hydrogen, connect the lines, do a zig-zag

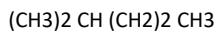


6 carbons
Single bonds → alkane

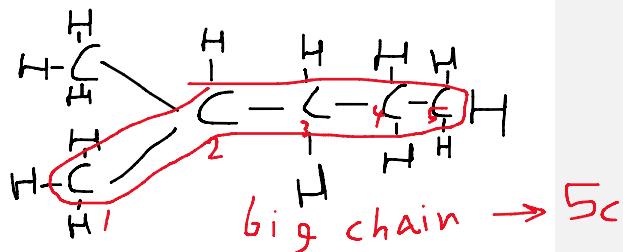
→ Done

In skeletal structures, you can instantly get the amount of carbon in the main chain and if the molecule is an alkane or alkene or alkyne

EXAMPLE 2



→ CH₃ CH₃ CH CH₂ CH₂ CH₃
→ Dot structure



→ Now turn it into skeletal



When there are branches, you take the longest continuous chain and then add the substituents (side chains)

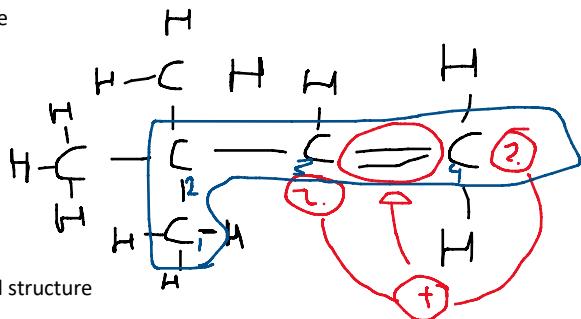
EXAMPLE 3



→ CH₃ CH₃ CH₃ C CH CH₂



→ Dot structure



→ Now skeletal structure



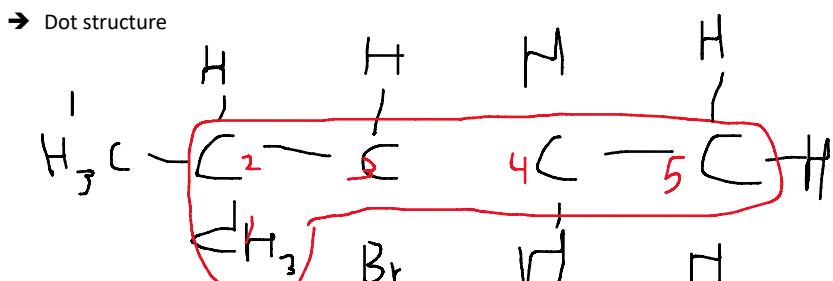
as you can see, in the last two, there is 1 missing bond from each, you can fix that by making the bond between them a double bond instead of a single bond, making that molecule an alkene

EXAMPLE 4

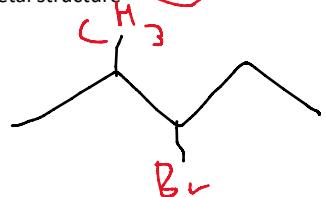


→ CH₃ CH₃ CH CH Br CH₂ CH₃

→ Dot structure



→ Skeletal structure



You would see that we didn't cut off the carbon chain by the Br, instead we made it a side chain



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IUPAC NAMES

- The International Union of Pure and Applied Chemists ([IUPAC](#)) developed a system for naming organic compounds.
- This system eliminated many of the ambiguities that plagued previous naming systems.
- Common names for many substances are still widely used.

A name of an average alkane consists of 4 parts

Prefix + cyclo + parent + suffix

Parent

Is determined by the amount of carbon atoms in the longest chain

TABLE 4.1 PARENT NAMES FOR ALKANES

NUMBER OF CARBON ATOMS	PARENT	NAME OF ALKANE	NUMBER OF CARBON ATOMS	PARENT	NAME OF ALKANE
1	meth	methane	11	undec	undecane
2	eth	ethane	12	dodec	dodecane
3	prop	propane	13	tridec	tridecane
4	but	butane	14	tetradec	tetradecane
5	pent	pentane	15	pentadec	pentadecane
6	hex	hexane	20	eicos	eicosane
7	hept	heptane	30	triacont	triacontane
8	oct	octane	40	tetracont	tetracontane
9	non	nonane	50	pentacont	pentacontane
10	dec	decane	100	hect	hectane

If there is a **cyclo** just choose the carbons on the ring, any other carbons are side chains

Cyclo

Is determined by if the skeletal structure is a ring or not, if it's a ring then add cyclo, if not then do not add it

Suffix

Is determined by the type of the hydrocarbon

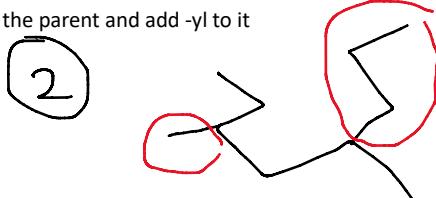
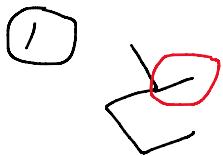
- -ane -> if there are only single bonds
- -ene -> if there are double bonds
- -yne -> if there are triple bonds



Prefix

It determines the substituants or "side chains", do not add it if there are no side chains

Take each side chain and make it into a separate chain, get the parent and add -yl to it

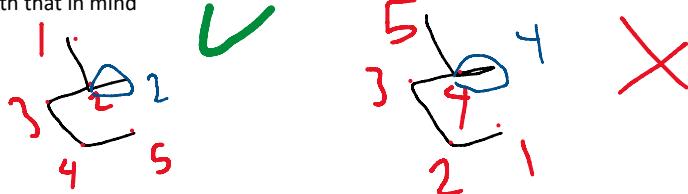


In number 1 we have a **methyl**

In number 2 we have a **methyl** and a **propyl**

When you get the longest chain, number the carbons from 1 to the amount of carbons in the chain

KEEP IN MIND -> the number of the chain needs to be the **LOWEST** possible number, so arrange the carbons with that in mind



Get the order of the carbon atom that the side chain is on and add it to its name

So we have 2-methyl

EXAMPLE 1

Prefix -> none because no side chains

Cyclo -> none because no rings

Parent -> 7 carbons

Suffix -> ane because there are only single bond chains

name -> Heptane



EXAMPLE 2

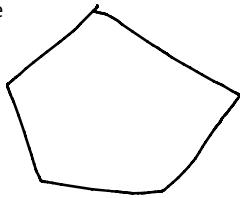
Prefix -> none because no side chains

Cyclo -> exists because there is a ring

Parent -> 5 carbons

Suffix -> ane because only single chains

Name Cyclopentane



EXAMPLE 3

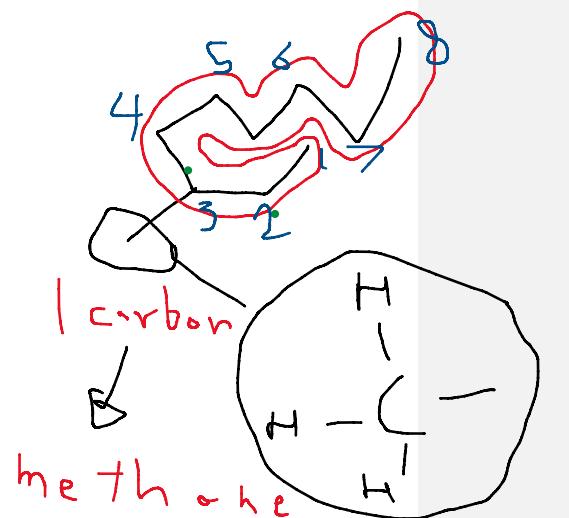
prefix -> 3 methyl

cyclo -> no

parent -> non

suffix -> ane

name -> 3-methylnonane



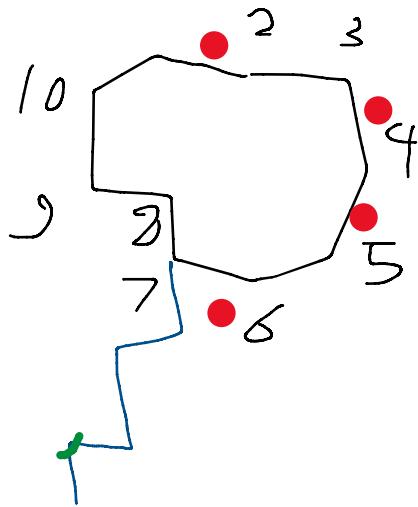
methyl because side chain rule



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LAST EXAMPLE

1,7-Pentylcyclodecane



There are two types of formulas

Molecular formulas always show the number of each atom present in one molecule.

Empirical formula shows the simplest ratio of the atoms present

They do not show the structure of the molecule, however

Displayed formulas show the arrangement of atoms as well as bonds, they are lewis dot structures in short

Functional formulas show how atoms are arranged with their functional groups present, they are lewis dot structures but in text

Skeletal formula has already been discussed before



Functional groups and homologous groups

A **functional group** is an atom or a group of atoms responsible for the typical chemical reactions, they are the stuff that **react**.

a **homologous** group is a group of molecules with the same functional group but a different number of -CH₂ groups

so if we had a **propane** and a **2-chloropropane**, the chlorine is the functional group and the propane is the homologous group

or when we have **propane** and **cyclopropane**, those are two different functional groups

functional groups determine the pattern of reactivity of a homologous series, whereas the carbon chain length determines stuff such as melting/boiling points

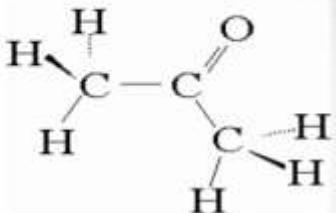
the general formula of a **homologous series** can be used to calculate the molecular formula of any member of the series by replacing **n** with the number of **carbon atoms**

3D Structural formulas

They are like normal skeletal structures, but there are extra graphic for **depth** "Z>0, Z=0, Z<0"

3D Structural Formula

- Sample:
- Acetone
- IUPAC Name:
2-propanone



Names of types of chemical bonds used to draw 3D molecular structures:	Orientations of chemical bonds indicated by these styles:
"normal" bond	bond lies in the plane of the paper (or screen, when viewed electronically)
dashed bond	bond extends backwards, away from the viewer, so effectively "into" the paper (or screen)
wedged bond	bond protrudes forwards, towards the viewer, so effectively "out of" the paper (or screen)



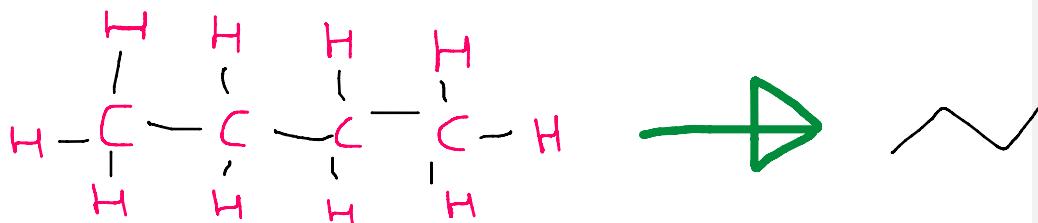
Isomers of alkanes

An **isomer** is a molecule that has the same chemical formula but a different structure

For example

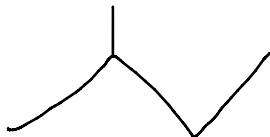
C₄H₁₀ or **butane**

The structure of a butane is CH₃ CH₂ CH₂ CH₃ with the chemical formula



Now if we imagined an isomer of butane

Where we take a single carbon and put it in the middle



This molecule is entirely different as the first one is **butane** but this one is **2-methylbutane**

But they have the same display formula **C₄H₁₀**

To get the number of isomers in an alkane (C_nH_{2n+2})

Number of isomers = $2^n - 1$



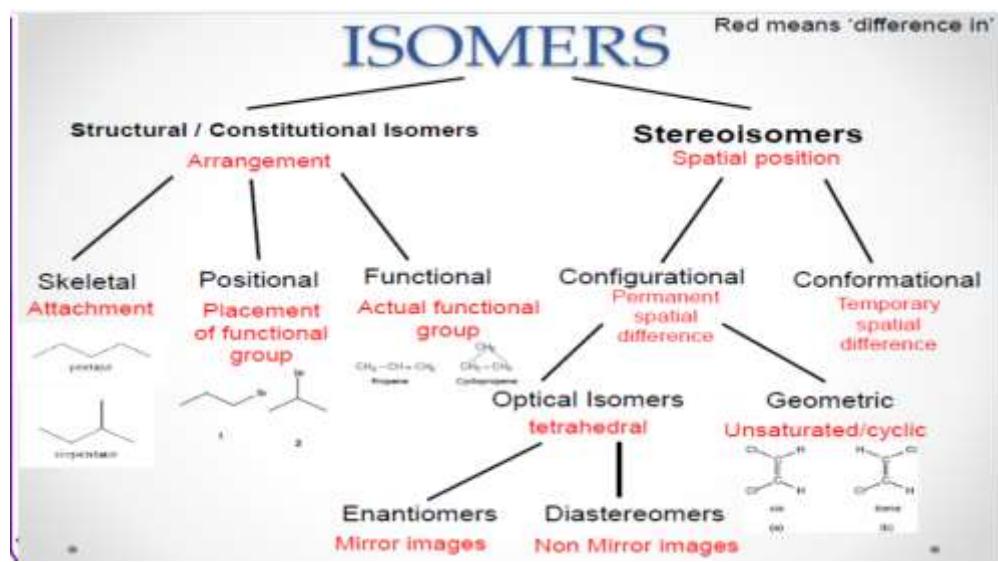
IT HAS MULTIPLE TYPES

STRUCTURAL ISOMERS

Have different structural formulae, and they get sliced into **chain isomerism**, **positional isomerism**, **functional group isomerism**

STEREOISOMERS

Have same structural formulae but the **3D arrangement** of atoms is different, they get sliced into **cis-trans isomerism**, **optical isomerism**



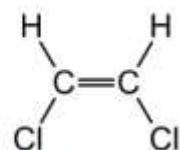
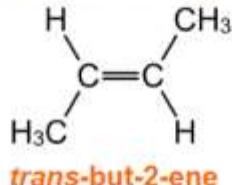
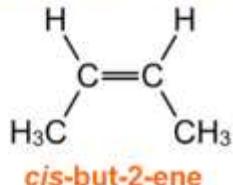
Stereoisomerism



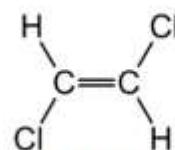
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Cis-trans isomerism

If an alkyl group or atom other than hydrogen is attached to each carbon then the isomers can be named either **cis** ('on the same side') or **trans** ('on the opposite side').



cis-1,2-dichloroethene



trans-1,2-dichloroethene



We want to determine who is cis and who is trans

But what if there are 4 different stuff instead of 2

We use E-Z notation

E-Z isomerism



The **E-Z notation** is used to identify stereoisomers that cannot be called *cis* or *trans*.

Isomers are identified as either E or Z depending on what 'priority' is given to the groups attached to the carbon atoms in the double bond. The priority of these groups is determined by a complex series of rules.

- **E** represents the German word 'entgegen', and corresponds to *trans* isomers. The highest priority groups are on the **opposite** side of the double bond.
- **Z** represents the German word 'zusammen', and corresponds to *cis* isomers. The highest priority groups are on the **same** side of the double bond.

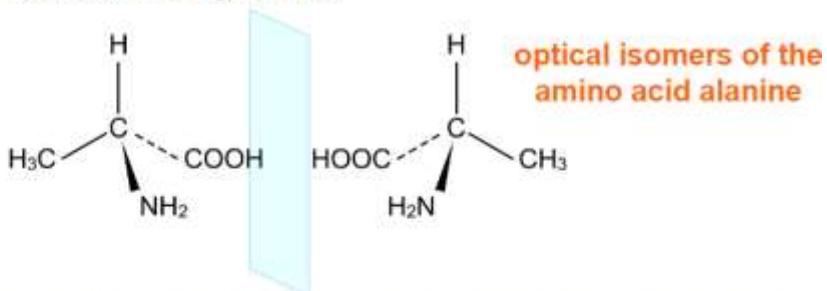


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Optical isomerism



Another form of stereoisomerism is **optical isomerism**, in which a molecule can exist as two isomers that are non-superimposable, mirror images of each other, just like a left hand and right hand.



Optical isomers have the same physical properties, but they rotate **polarized light** in opposite directions.



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