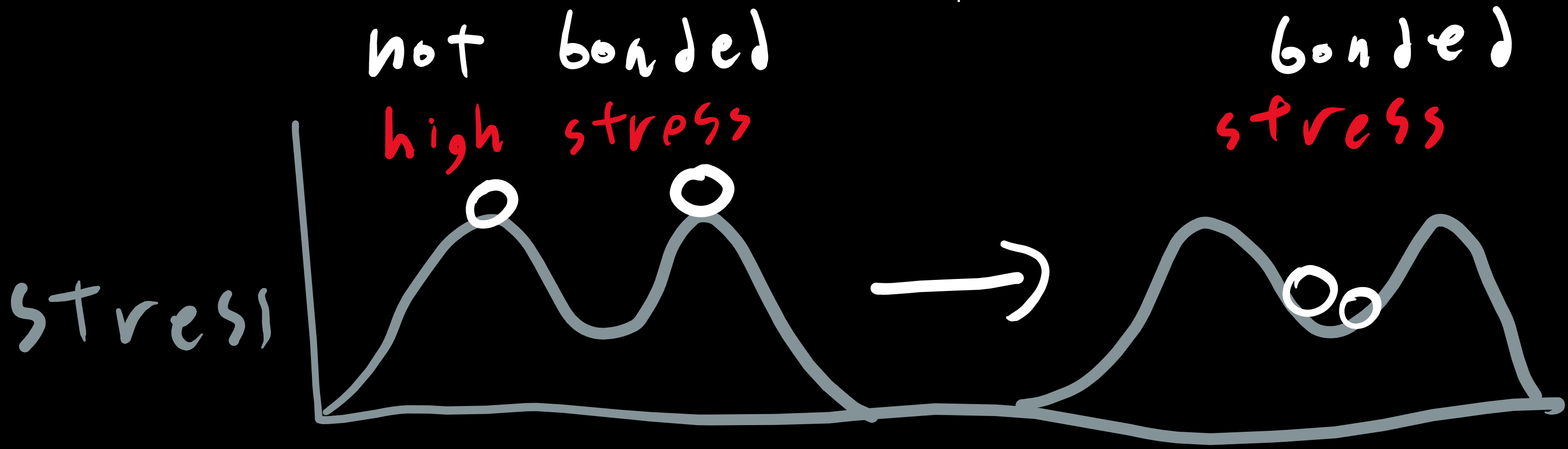
Bonds

Are the relationships between different atoms, each type of bonds require different types of energy, the reason bonds exist is to make all related atoms settle in the lowest stress possible



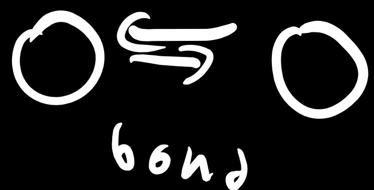
Chemical bonds

Are connections between atoms in a molecule, these bonds include **STRONG** intramolecular interactions like **covalent or ionic**, and **WEAK** intramolecular interactions such as **dipole-dipole** interactions, **London dispersion** forces, and **hydrogen** bondings "these will be explained later"

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

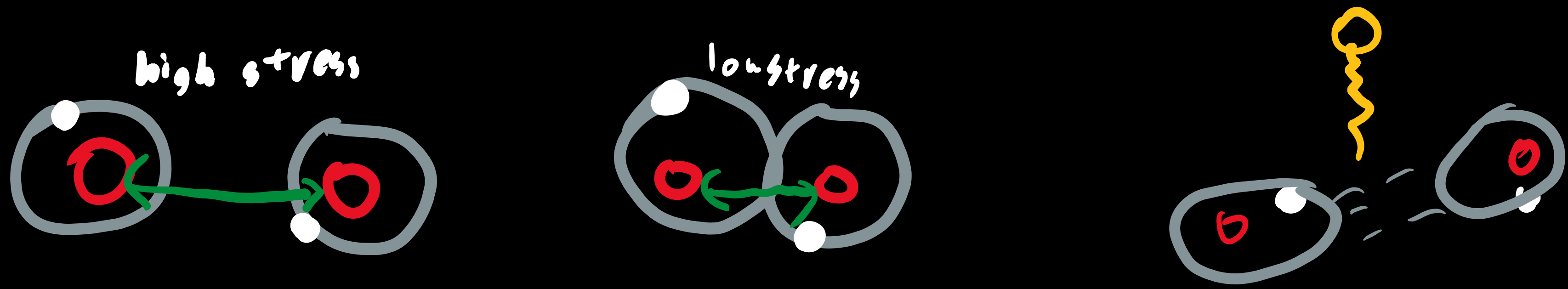
Another definition for chemical bonds?

atoms arrange themselves in the most stable patterns by **filling their outermost energy level**, they fill it by joining with other atoms, the forces holding them are **chemical bonds**



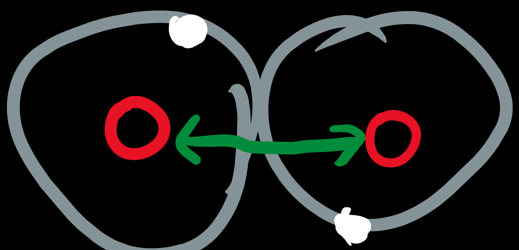
Why do chemical bonds happen?

Atoms try to reduce their energy, by achieving a balance between attractive and repulsive forces, because when atoms get close to each other, the electrons of an atom are attracted by the nucleus of the other atom and vise versa, this causes a stress on the electrostatic force between the parts of the atom, so it tries to relieve that stress by getting closer



This pulling force gets so strong that energy in the form of **photons** in produced when separating the atoms

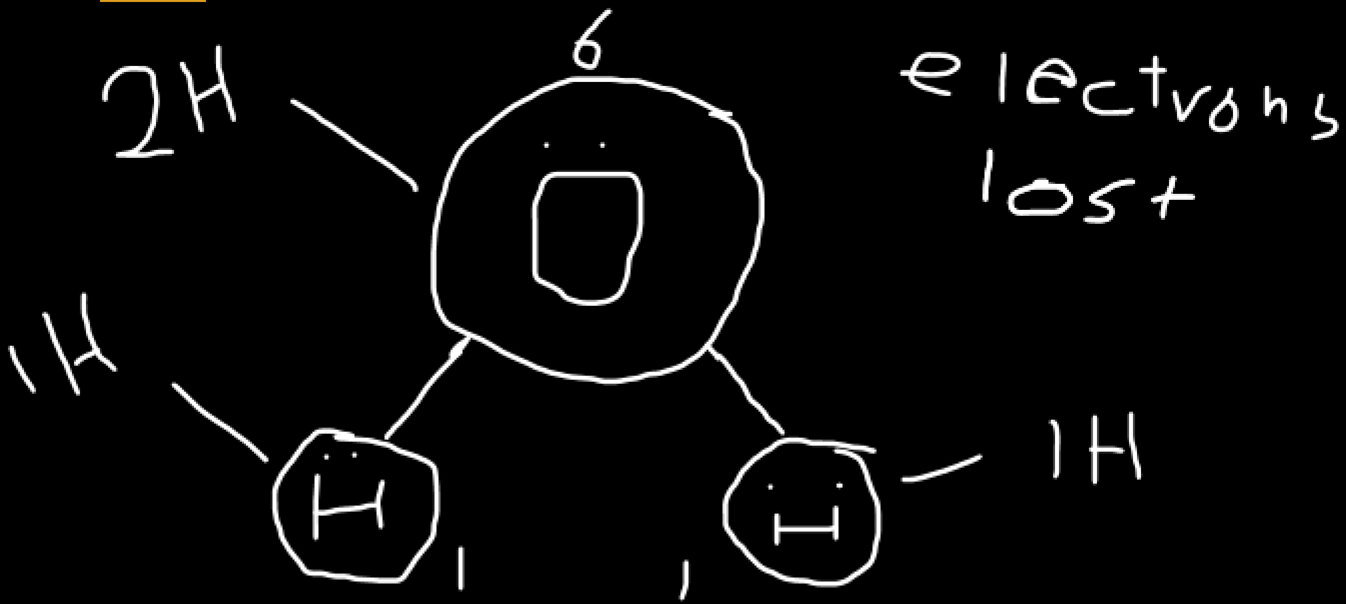
Their nuclei counter the pulling force by rebelling each other, this leads to them finding the perfect distance where both forces cancel out and it's called **"bond length"**

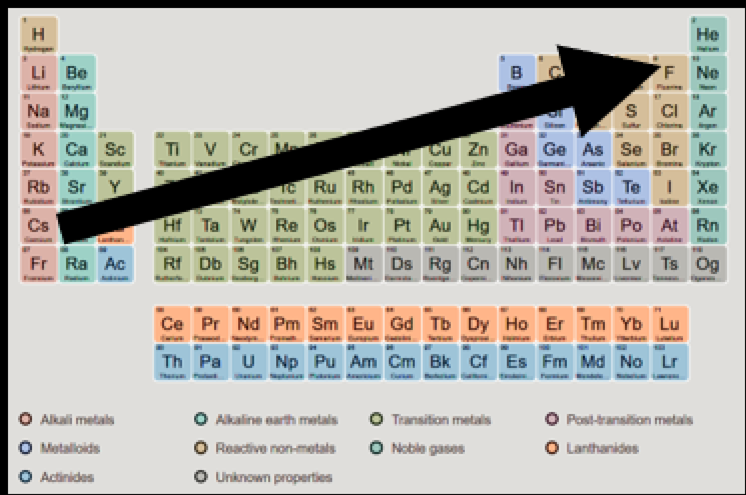


Electronegativity

It's the tendency of an atom to attract a shared electron closer to it from other atoms in a covalent bond

Covalent bond : is a bond where atoms share electrons and shit





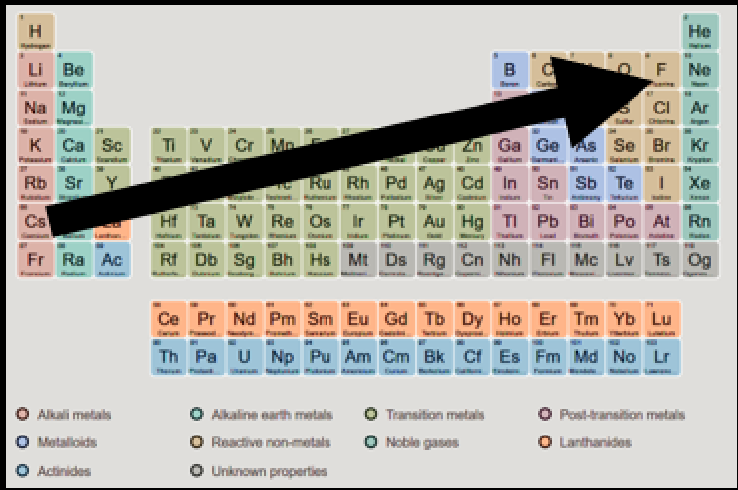
- It increases from **left to right** because when the atomic number increases, the nuclear charge increases, and the electromagnetic pull increases
- It increases from **down to up** because when the energy level count decreases, they ae closer to the nucleus, so the nuclear charge increases
- Disregarding noble gasses, highest element with electron negativity is fluorine in 7A
- The least element with electronegativity is Francium 1A

Ionization energy or Ionization potential

Ionization is the process of atoms becoming ions

ionization energy It’s the energy required to **remove a valence electron** from the atom

Aka how much the nucleus is holding on to a valence electron
it goes against the atomic radius, because when the atomic radius increases, the distance from the atom to the nucleus increases, and the electromagnetic pull decreases, so the ionization energy decreases



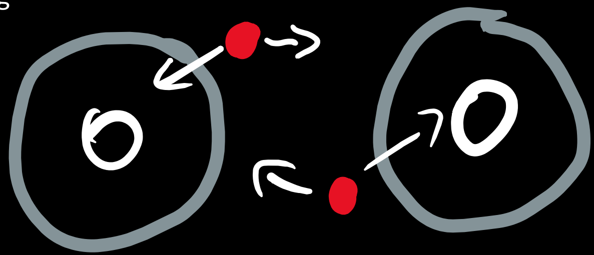
Disregarding the noble gasses, fluorine is the largest in ionization energy and cesium is the least, not francium because it decays quickly

When an element loses more than a valence electron

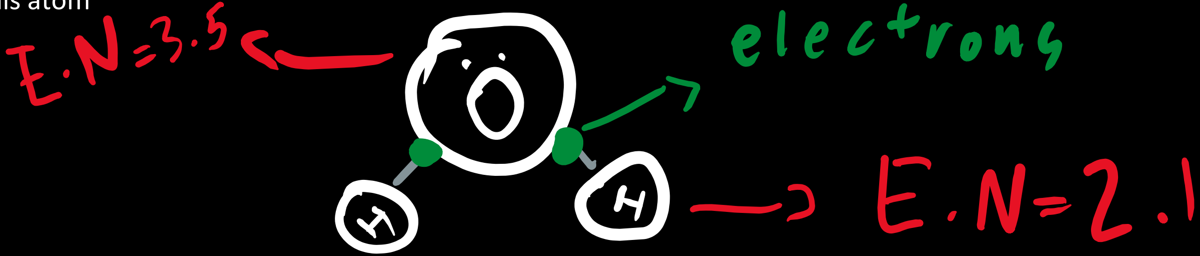
The ionization energy is of the first valence electron, is less than the second electron, until all the valence electrons are lost and you go to the next energy level, there will be a spike in ionization energy, because this atom is stable with electron filling its outermost energy level (noble gass), so it will spend more energy to make it stay

Covalent bonds

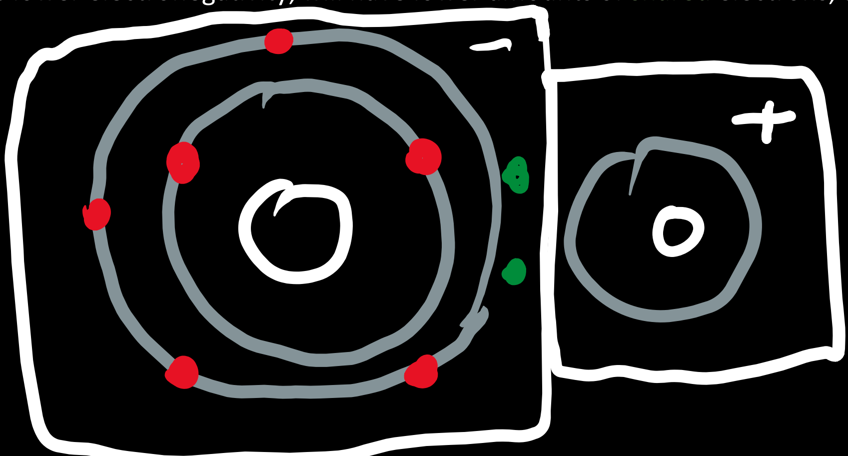
They are bonds where electrons are shared between the nuclei, this happens because both of the nuclei are pulling on the electrons, making the electrons stay in a space between the two nuclei



But not all sharing is equal, **electronegativity** is the strength in which an atom holds a shared electron in a bond, where an atom has more electronegativity than the other, electrons will spend more time with this atom



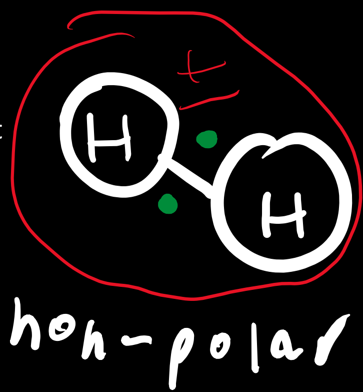
the atom that has higher electronegativity, will have higher amounts of shared electrons, thus a **slightly negative charge**
the atom that has lower electronegativity, will have lower amounts of shared electrons, thus a **slightly positive charge**

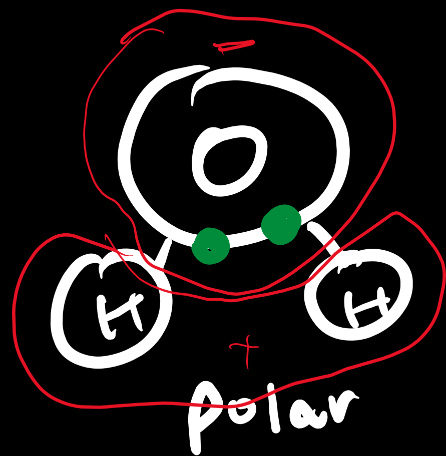


"polarity" is the amount of separation of electrical charge in a covalent bond, the higher it is, the higher the **difference in electronegativity** between the atoms

when atoms have different electronegativities, they are **polar covalent bonds** and they have a slightly positive area and a slightly negative area

when atoms have similar electronegativities, they are **nonpolar covalent bonds** and they have a more neutral area than polar bonds





PHYSICAL PROPERTIES OF COVALENT BONDS

- They have lower melting and boiling points than *ionic* **compounds,** because sharing electrons makes the bonds less stable and easier to break
- They are mostly in a liquid or gaseous state at room temp, they have a definite shape and rarely break unexpectedly
- They are not soluble in polar solvents like **water**
- they tend to be softer solids, or just gases/liquids
- They are very ductile

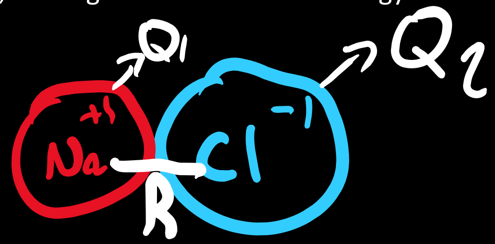
Metals have loosely-held valence electrons because of their ionization energy is so low, so they tend to lose them and become **positive ions**
NonMetals will gain these lost electrons because of their **nuclear charge** “the positive pull from the nucleus on the electrons” and become **negative ions**

Ionic bonds

They are bonds that works by **transferring electrons** from 1 atom to another
They are basically **VERY POLAR** covalent bonds, where the difference in electronegativities is **HUGE**,

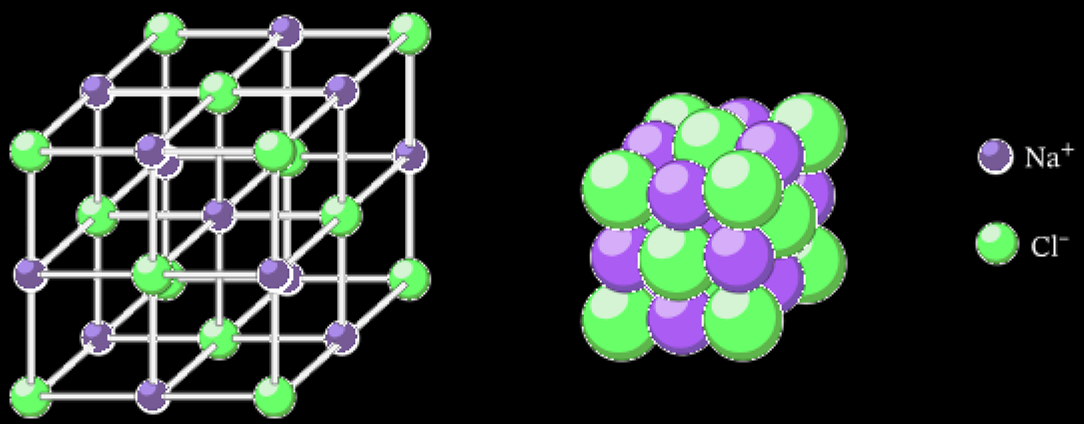
this means that all ionic bonds are covalent bonds, but not all covalent bonds are ionic bonds

the ionic bond makes both atoms very stable as their last energy level is filled, making them take a lot of energy to break apart
We can calculate this energy with **coulombs law**



E (between two ions) = $(2.31 \times 10^{-19}\,j.nm)\,(Q_1 \times Q_2/R)$
- Q_1 = charge of ion 1
- Q_2 = charge of ion 2
- R = distance between two nuclei

PHYSICAL PROPERTIES OF IONIC BONDS
- They have very high melting and boiling points
- They are soluble in polar solvents like **water**
- They are solid in room temperature
- They are very conductive
    - They are called **electrolytes** because of their ability to conduct electricity
- They form crystal **lattices**, which are symmetrical 3D structures



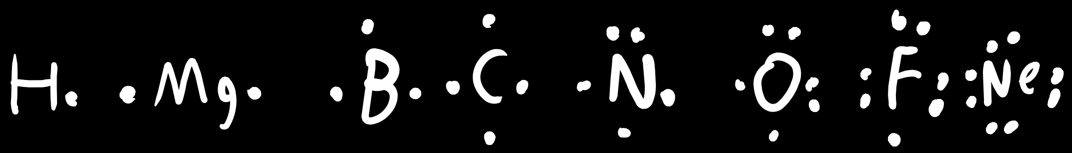
Lewis dot structure

Unlike ionic bonds, covalent bonds need to be visualized in more fancy ways like the Lewis dot structure

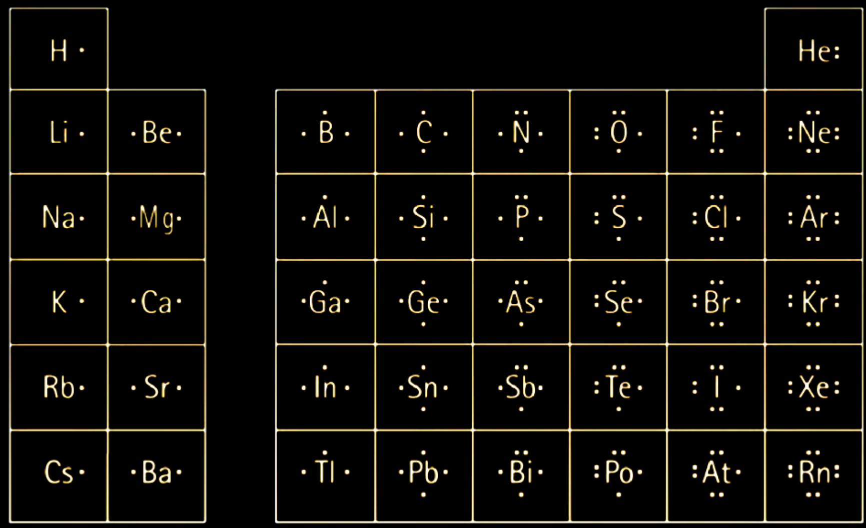
DRAWING ATOMS

When you draw an atom in this structure,

- you start with its letter, for example
  - here is **carbon**
- then you draw the atom's valence electrons as **dots** around the atom
  - Carbon is 1s2 2s2 2p2
    so there are 4 valence electrons around the carbon atom
  - For carbon and other small atoms, we assume that there are 4 coordinates that can have electrons / bonds, because that is how carbon can fill its octet (outermost energy level)
  - When we draw the valence electrons, we put one in each coordinate before we pair them up, so we start by filling the 4 main spots when the valence number is 4 or less, then pairing them when its more than 4, so carbon in the Lewis dot structure would look like this



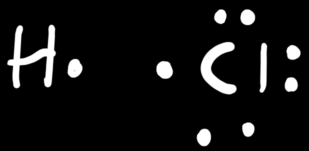
- Elements in the same group, will have the same Lewis dot structure



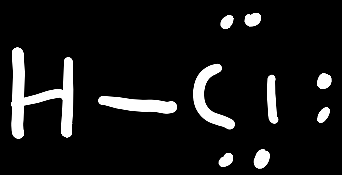
DRAWING MOLECULES

When you a draw a molecule in this structure

- Start with each atom and its valence electrons, for example
  - HCL

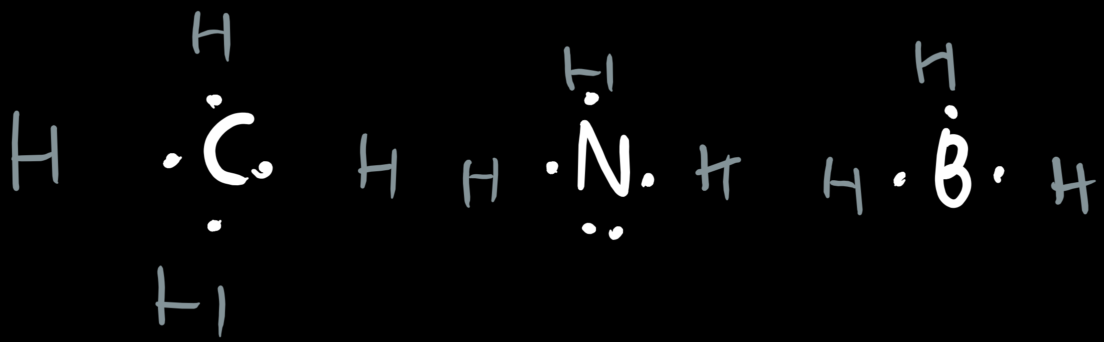


- Unpaired electrons from two different atoms can come together and create a **bond**, we represented by replacing the two dots with a **line**



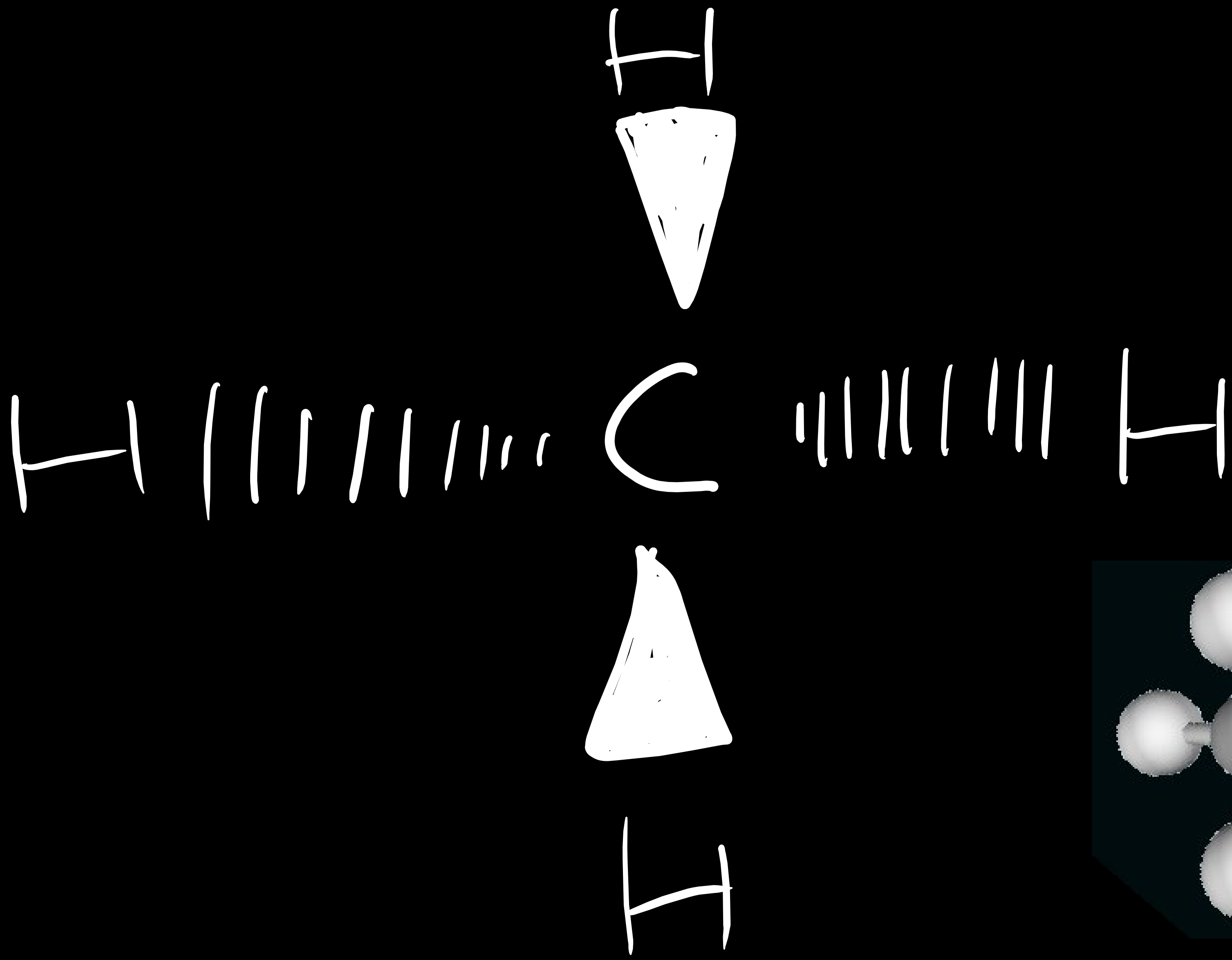
a line here represents a covalent bond, and is equal to 2 bonded electrons

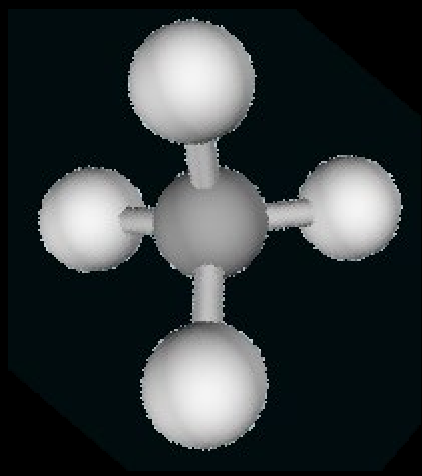
  - The number of lone dots in an atom, shows us how many bonds it likes to form, so here, carbon makes **4 bonds**, nitrogen has 5 electrons, so it likes to make **3 bonds**, boron has 3 electrons so it likes to make **3 bonds**



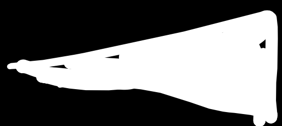
3D LEWIS DOT STRUCTURE

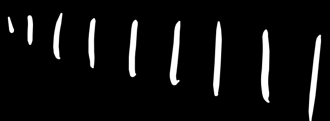
To represent 3D molecules later one, we do it like this





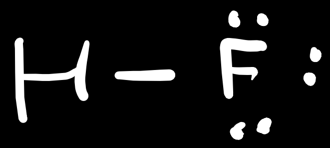
 normal

 front

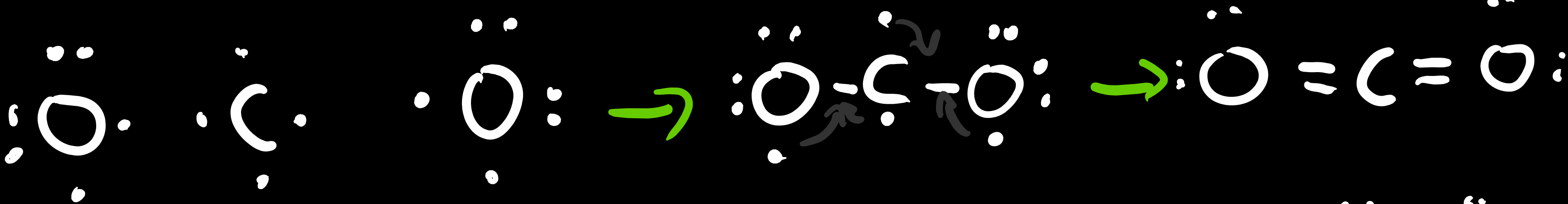
 back

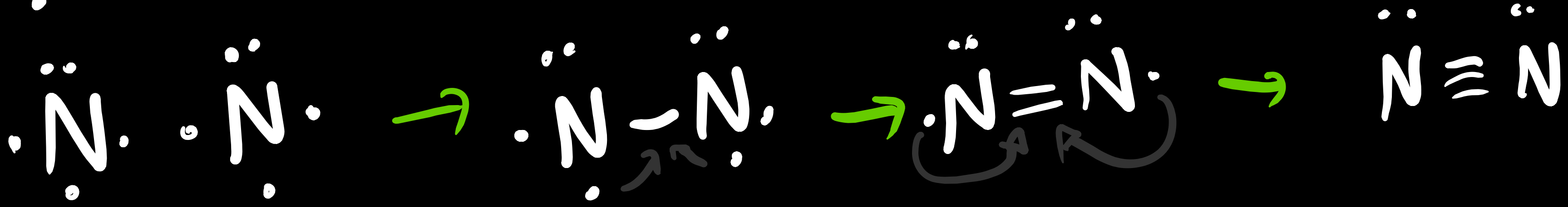
Types of bonds

Single covalent bonds are called a **sigma bond**



but there can be double or even triple covalent bonds, imagine carbon dioxide



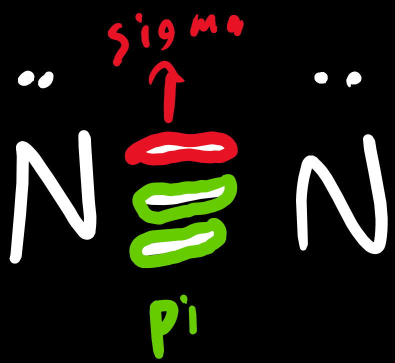


if adjacent atoms each have unpaired electrons, they can form another covalent bond, so we symbolize two covalent bonds with = and triple covalent bonds with ≡

One rule to have

the first bond is always sigma, any after is pi

So there is always 1 sigma bond between two connected atoms



Covalent bond lengths
Single > double > triple

Sometimes atoms in a lewis structure will have a formal charge

Formal charge

is the hypothetical charge assigned to an atom in a molecule

$$FC = V - N - \frac{B}{2}$$

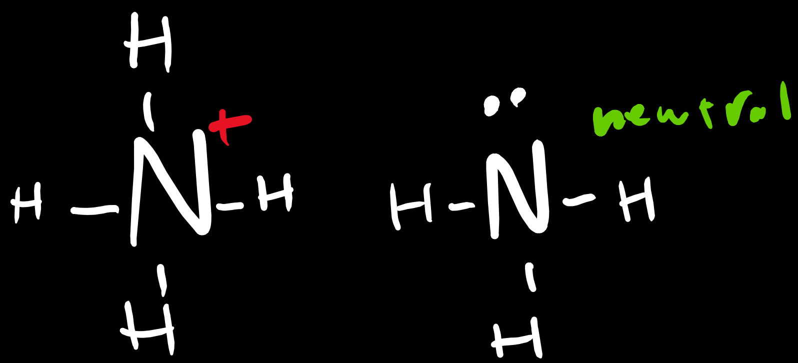
FC = formal charge

V = number of valence electrons

N = number of nonbonding valence electrons

B = total number of electrons shared in bonds

So let's say we have ammonium ion and ammonia
in ammonia, the nitrogen contributes 3 electrons which equals to its lone valence electrons, so its neutral
In ammonium, the nitrogen contributes 4 electrons which is higher than its lone valence electrons, so it gets a formal positive charge



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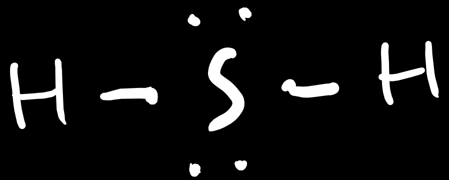
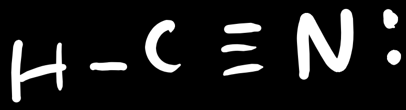
EXCERSICE

Draw lewis dot structures for the following compoun

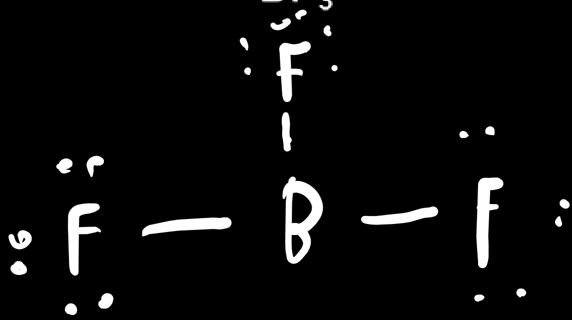
H_2S



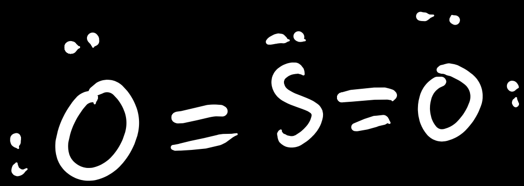
HCN



BF_3

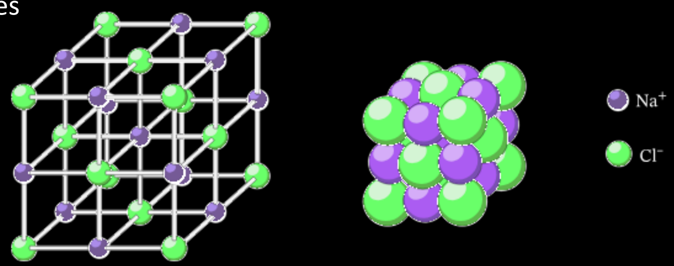


SO_2

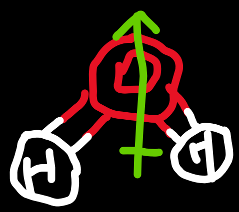


INTRAMOLECULAR FORCES (forces between the atoms **inside** a molecule)
INTERMOLECULAR FORCES (forces between the molecules)
We all know that there are forces and interactions between atoms which create molecules
But did you know that there are forces and interactions between said molecules as well, this is the reason for stuff like boiling points, melting points, etc.
They have a lot of types

ION-ION INTERACTIONS
They are the strongest intermolecular forces because of the formal charges between the ions, they exist in metals/crystals like **salt**

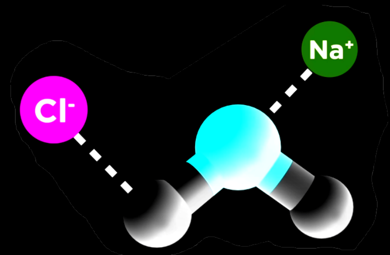


DIPOLE
Is a molecule where there one side has an electron **excess** and the other side has an electron **deficiency**, basically a polar molecule

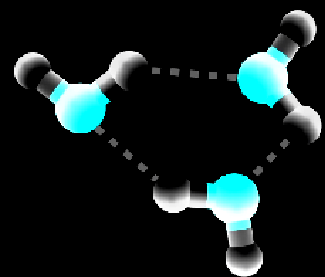


ION-DIPOLE INTERACTIONS
Dipoles can make electrostatic forces because one side is positive and is attracted to negative
And another side is negative and is attracted to positive

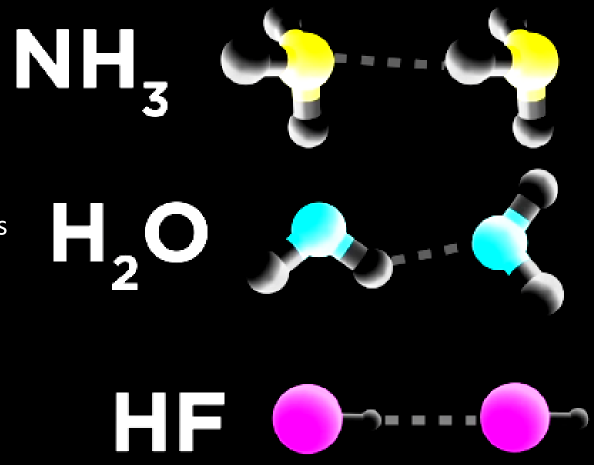
So ion-dipole interactions are when ionic compounds dissolve
and the positive ions make electrostatic interaction with the negative part of a dipole
and the negative ions make electrostatic interaction with the positive part of a dipole



DIPOLE-DIPOLE
They are where the negative part of a dipole makes electrostatic interaction with the positive part of another dipole
and when the positive part of a dipole makes electrostatic interaction with the negative part of another dipole



Hydrogen bonds
Is a special state of dipole-dipole interactions, where it's generated by **hydrogen atoms** bonded with **electronegative atoms** like nitrogen, oxygen, and Florine in a molecule making electrostatic force with the negative part of another dipole, stuff like **NH_3 or H_2O or HF**



Hydrogen bonds are specially stronger than normal dipole dipole interactions as these elments are the most electronegative

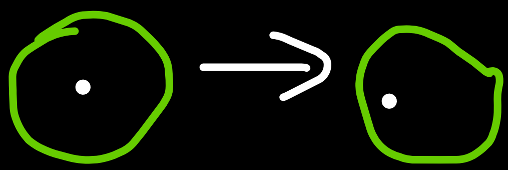
Dipole interacrtions in general rely on **partial charges** which can be thought of as the formal charges like in ionic molecules, but the partial charge is weaker than the formal charge

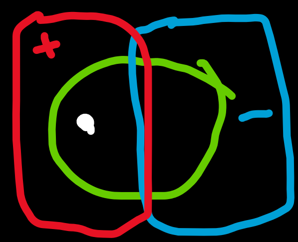
making ion-ion interactions by far the strongest

Van der Waals (London Dispersion force)
Unlike dipole-dipole / ion-ion interactions that require special conditions, any element/molecule can do the London dispersion force

For example
let's imagine an element like helium, which is noble, so when you put a lot of helium atoms next to each other, they won't bond

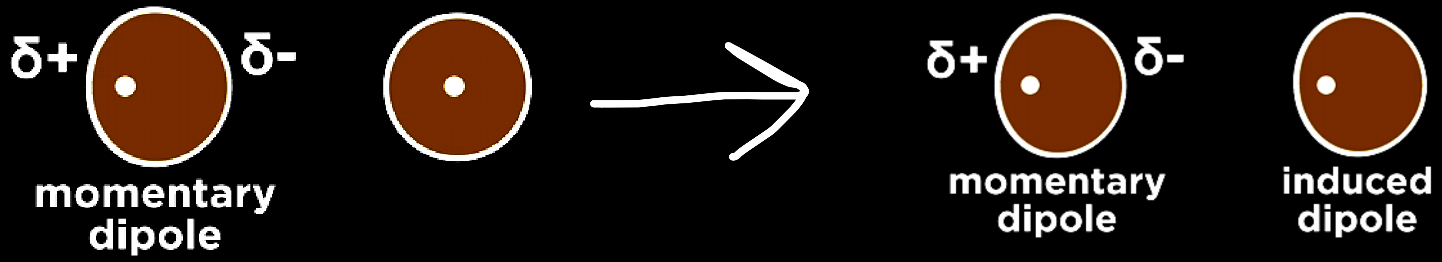
But sometimes, a helium atom, will lop side, skewing towards a direction,





this will cause the creation of something called a **momentary dipole**, where the skewed side will have more electrons than the other side, this dipole is far weaker than a formal dipole, but it still can be measured

When a momentary dipole meets another helium atom, this will cause that helium atom to become a dipole like it, but now it's called an **induced dipole**



this induced dipole will interact with the momentary dipole generating a **momentary dipole-dipole interactions** which is called the **van der Waals force**

This force is small and temporary but it is the only thing non-polar covalent molecules can do and when done by bigger molecules like **hydrocarbons**, the force can be significant

INTERMOLECULAR FORCES TEIRLIST

STRONGEST

Ion-ion are the strongest because they consist of pure formal charges

THEN

Ion-dipole are next because they consist of partial and formal charges

THEN

dipole-dipole are next because they consist of pure partial charges

THEN

van der waals are next because they consist of induced dipoles

THOUGHT EXPERIMENT – THE ABSOLUTE ZERO

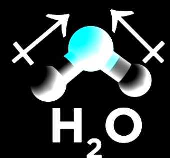
If we put helium, water, and sodium chloride in 0 kelvin where no heat energy exists for motion
This will lead to all 3 being solids
Because without any heat that induces motion that overwhelms the intermolecular forces
This will lead to the intermolecular forces connecting the molecules generating solids

Conclusion

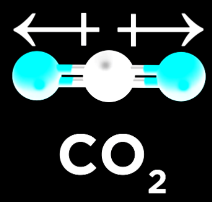
The stronger the force between the molecules, the higher temperature we need to overwhelm it and move it to another state of matter

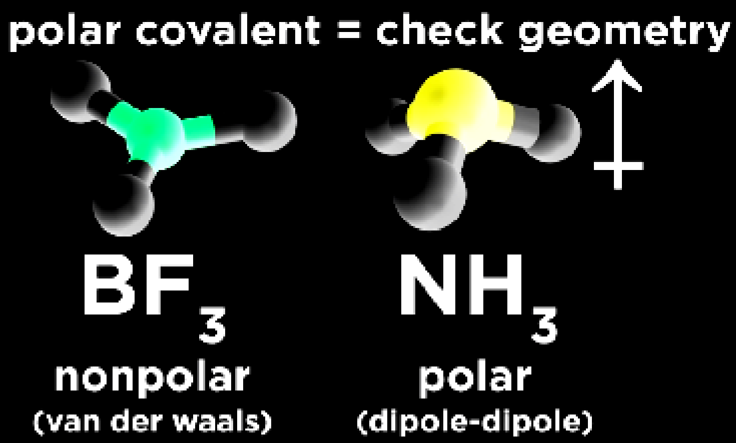
DECIDING THE INTERACTION BASED ON A MOLECULE

- Non-polar covalent molecule -> **van der waals**
- Polar covalent bonds -> it depends on the direction of the polarity
  - If the majority of the dipoles are in the same direction like in water, this will lead to **dipole-dipole interactions**



  - If the dipoles are in opposite directions like CO2, they will cancel each other out making the molecule do **van der waals** interactions





- Formally charged ionic molecules -> **ion-ion interactions**

State which molecule in each pair has the higher boiling point, and why.

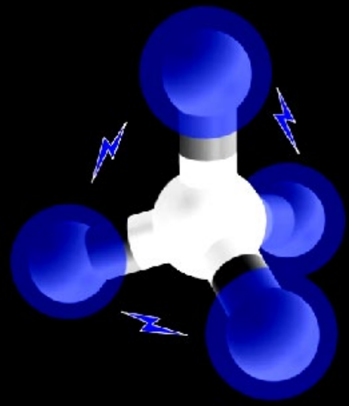
HF vs. HI fluorine is more electronegative so HF has a stronger dipole than HI

O_2 vs. CH_3Cl van der waals vs. dipole-dipole

H_2O vs. NaCl dipole-dipole vs. ion-ion

He vs. Ar larger atom = better van der waals

VSEPR THEORY (molecular geometry)



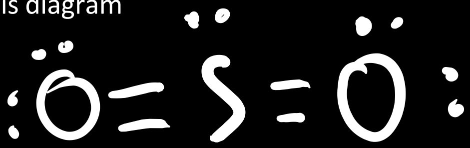
VSEPER stands for **Valence shell electron pair repulsion**

Because atoms are surrounded by clouds of negatively charged electrons
and molecules are made of said atoms
these clouds will repel each other while still being bonded, causing a certain geometry of the atoms so the electron clouds can be as faraway from each other while still being bonded

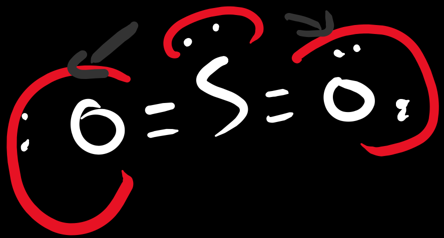
DETERMINING THE SHAPE OF A MOLECULE

Let's take SO_2 (BENT)

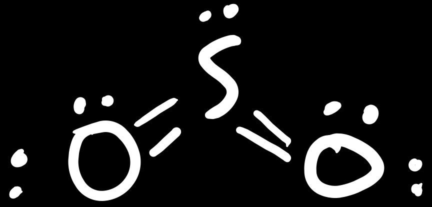
- Draw the lewis diagram



- Count "things" on the central atom (if it's just two, just take one with the highest amount of "things")
    - "thing" = bond (single or double or triple)
    - "thing" = lone pair
    - "thing" = electron domain



- Things get as far apart as possible



- Lone pairs occupy more space than bonds
    - So if the lone pair was replaced with a bond, then the angles will be split to 120 each

- But the pair takes more space so the angle will be slightly less, more like 119

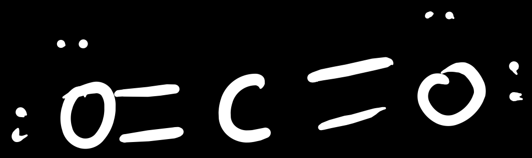
2 ATOM MOLECULES (2D)

Are always linear, because there are no central atoms that will act as an anchor for other atoms

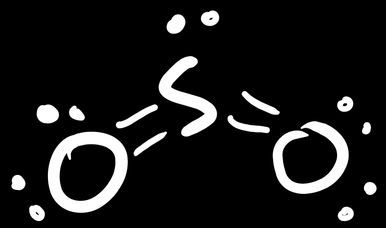
3 ATOM MOLECULES (2D)

It depends, if there is a lone pair on the central atom, then it is bent, if not, then it's linear

- carbon dioxide (LINEAR)

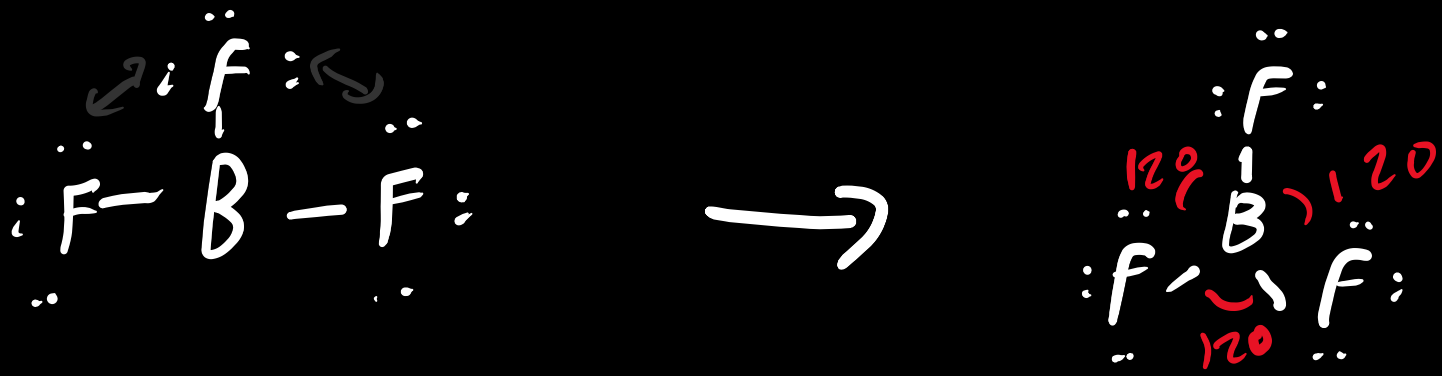


- Sulfur dioxide (BENT)

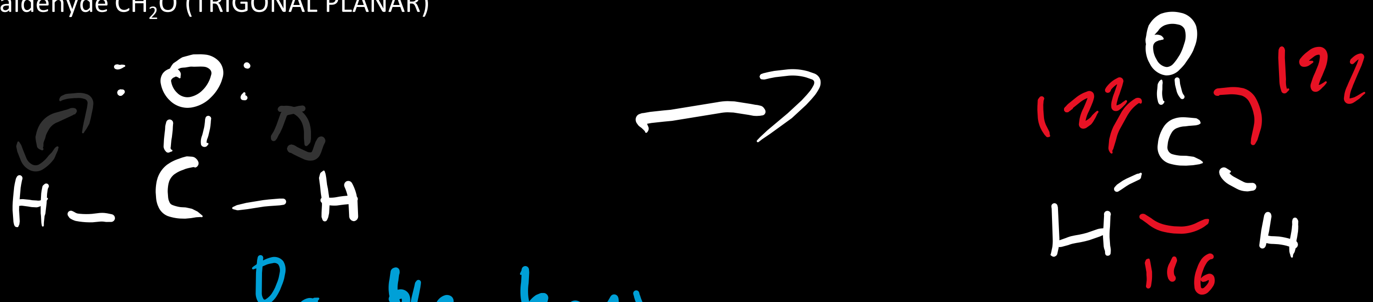


4 ATOM MOLECULES (2D)

- Boron trifluoride (TRIGONAL PLANAR)



- Formaldehyde CH_2O (TRIGONAL PLANAR)

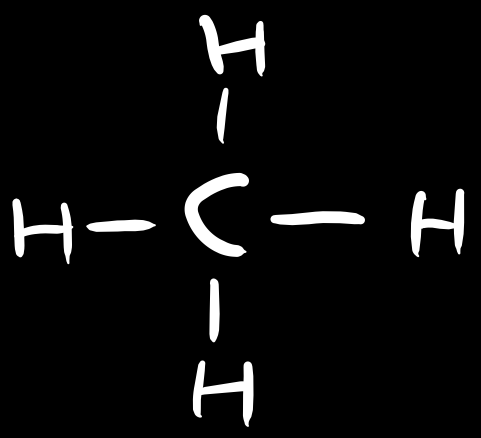


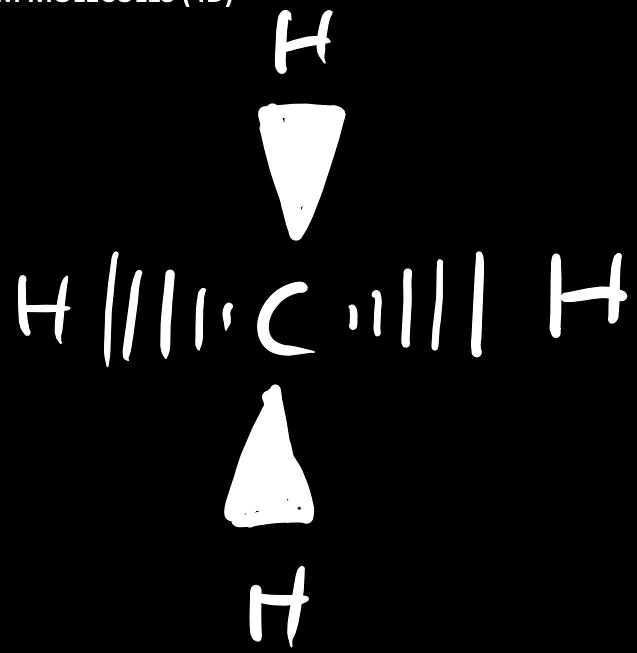
Double bonds occupy more space

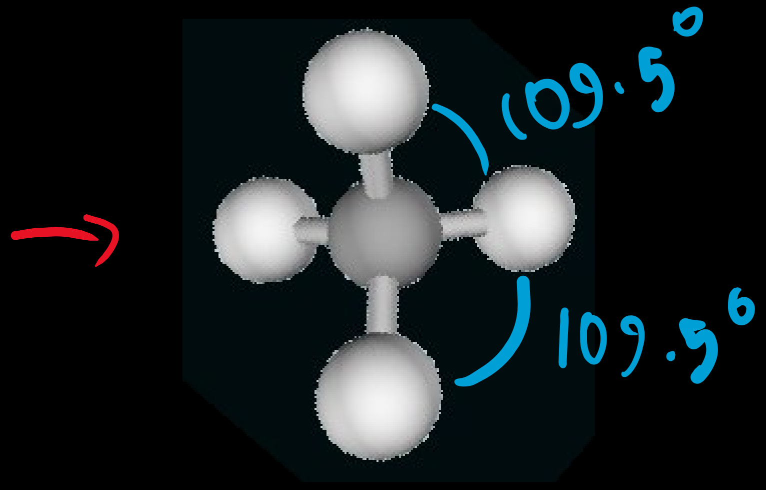
5 ATOM MOLECULES (4D)

Methane CH_4 (TETRAHEDRAL)

When you look at it in 2D, it seems that the atoms a



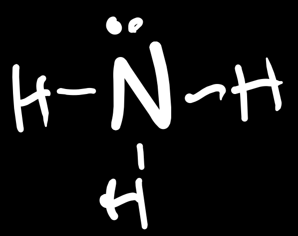


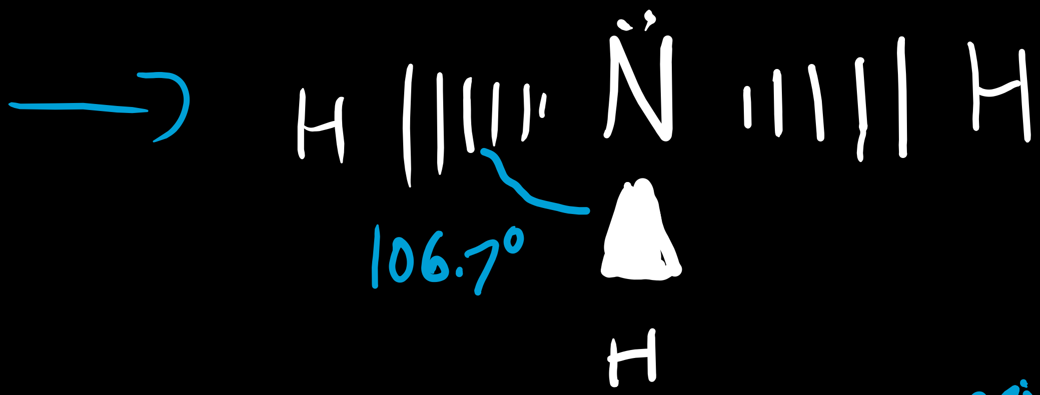


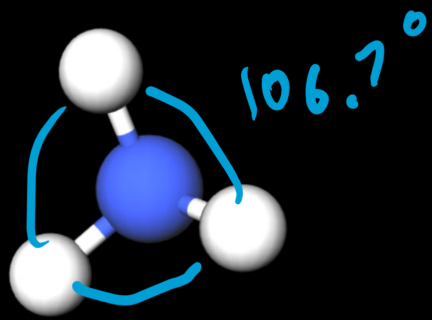
Same # things on central atom = same electron-domain geometry = similar bond angles

lone pairs of electrons occupy space but are not observed as part of the shape

Ammonia NH_3 (TRIGONAL PYRAMIDAL)







because the lone pair occupies more space

SUMMARY

3 atom molecule → lone pair on central atom?
- no → linear: CO_2
- yes → bent: SO_2

4 atom molecule → lone pair on central atom?
- no → trigonal planar: BH_3, CH_2O
- yes → trigonal pyramidal: NH_3

2 atom molecule → linear: N_2

5 atom molecule → tetrahedral: CH_4

Total number of things: 2, 3, 4

Number of things attached to central atom	0 lone pairs	1 lone pair	2 lone pairs
2 atoms	linear 180°	bent 120°	bent 109.5°
3 atoms	trigonal planar 120°	trigonal pyramidal 109.5°	
4 atoms	tetrahedral 109.5°		

EXERCISE WATER