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VCE Chemistry ½
Polarity [1.7]
Workbook

Outline:

Learning Objectives:

- ☐ **CH12 [1.7.1] –** Identify polar & non-polar bonds within a covalent molecule, with reference to electronegativity
- ☐ **CH12 [1.7.2] –** Draw partial charges & corresponding polarity arrows on covalent molecules
- ☐ **CH12 [1.7.3] –** Identify polar & non-polar molecules with reference to polar & non-polar bonds, as well as molecular geometry

Section A: Polar Bonds

Sub-Section: Electronegativity

Active Recall: What is electronegativity?

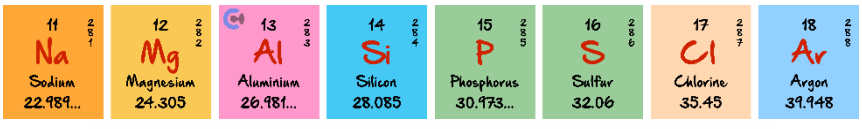
Electronegativity is an atom's ability to attract an electron towards itself.

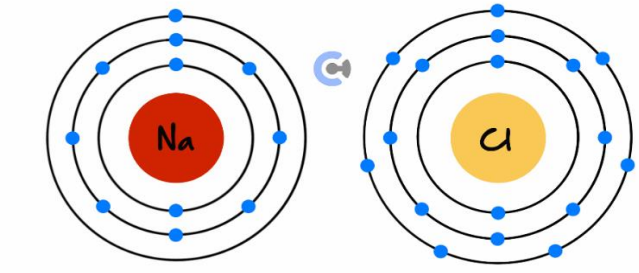
Discussion: What two factors influence an atom's electronegativity?

Let's recap how electronegativity varies for substances in the periodic table!

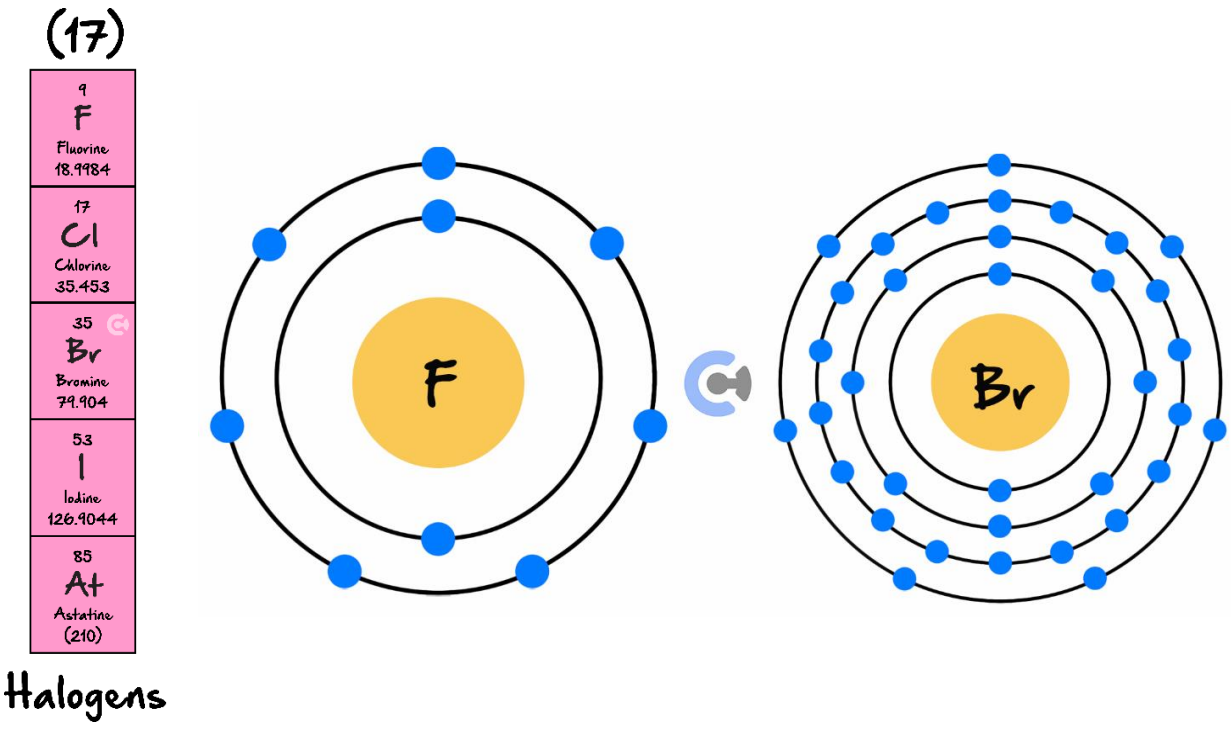
Exploration: Electronegativity

- Electronegativity is based on two factors:
  - core charge
  - atomic radius
- If we first consider Sodium (Na) vs Chlorine (Cl):





- As we move across a period:
  - What happens to the number of protons in the nucleus? [Increases] / [Decreases] / [Stays the same]
  - As such, what happens to the core charge? [Increases] / [Decreases] / [Stays the same]
  - Hence, what happens to electronegativity? [Increases] / [Decreases] / [Stays the same]
- If we now consider Fluorine (F) vs Bromine (Br) in group 17 of the periodic table:



- As we go down a group:
  - What happens to the number of shells? [Increases] / [Decreases] / [Stays the same]
  - As such, what happens to the distance between the nucleus and an external electron? [Increases] / [Decreases] / [Stays the same]
  - Hence, what happens to electronegativity? [Increases] / [Decreases] / [Stays the same]

Active Recall: What is the most electronegative element in the periodic table?

Fluorine

1. Periodic table of the elements

1 **H** 1.0 hydrogen																	**2** **He** 4.0 helium
3 **Li** 6.9 lithium	**4** **Be** 9.0 beryllium											**5** **B** 10.8 boron	**6** **C** 12.0 carbon	**7** **N** 14.0 nitrogen	**8** **O** 16.0 oxygen	**9** **F** 19.0 fluorine	**10** **Ne** 20.2 neon
11 **Na** 23.0 sodium	**12** **Mg** 24.3 magnesium											**13** **Al** 27.0 aluminium	**14** **Si** 28.1 silicon	**15** **P** 31.0 phosphorus	**16** **S** 32.1 sulfur	**17** **Cl** 35.5 chlorine	**18** **Ar** 39.9 argon
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atomic number **79** symbol of element
relative atomic mass **Au** name of element
197.0
gold

57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium

89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

Electronegativity

Electronegativity increases across a period.

Electronegativity decreases down a group.

1	2	13	14	15	16	17
Li	Be	B	C	N	O	F
1.0	1.6	2.0	2.6	3.0	3.4	4.0
Na	Mg	Al	Si	P	S	Cl
0.9	1.3	1.6	1.9	2.2	2.6	3.2
K	Ca	Ga	Ge	As	Se	Br
0.8	1.0	1.8	2.0	2.2	2.6	3.0
Rb	Sr	In	Sn	Sb	Te	I
0.8	1.0	1.8	2.0	2.1	2.1	2.7
Cs	Ba	Tl	Pb	Bi	Po	At
0.8	0.9	2.0	2.3	2.0	2.0	2.2
Fr	Ra					
0.7	0.9					

Let's try a question together!

Question 1 (3 marks) **Walkthrough.**

Mike and Joey are investigating atoms, and they both bring along an atom of their own. Mike brings along Arsenic, while Joey brings along Tin.

Who is more likely to have a more electronegative atom? Justify your answer.

- Arsenic
- Arsenic group is → Tin is graph 4
  ∴ arsenic ↑ core charge.
- Arsenic has smaller atomic radius
  → valence electrons more → smaller distance needs to be covered

Your turn!

Question 2 (2 marks)

State whether carbon or O is expected to be more electronegative. Justify your reasoning.

- Oxygen
- Further to right, ↑ core charge, ↑ e⁻ attraction

Question 3 (2 marks) **Additional Question.**

Predict whether sulphur or selenium will have a greater electronegativity. Justify your answer.

S. Se has 1 more shell and so less attraction between nucleus and an external electron. (2)

Space for Personal Notes

Sub-Section: Polar Bonds

Active Recall: What happens with valence electrons in a covalent bond?

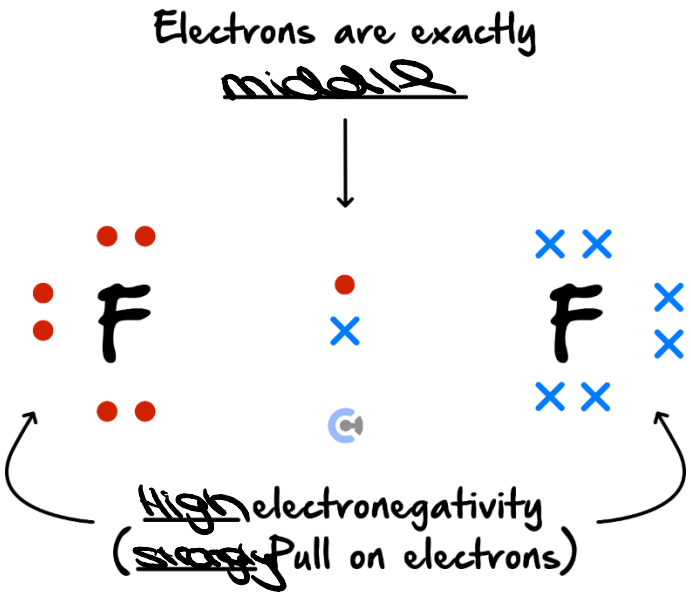
Share e⁻

Discussion: Are the electrons in a covalent bond shared evenly?

No!

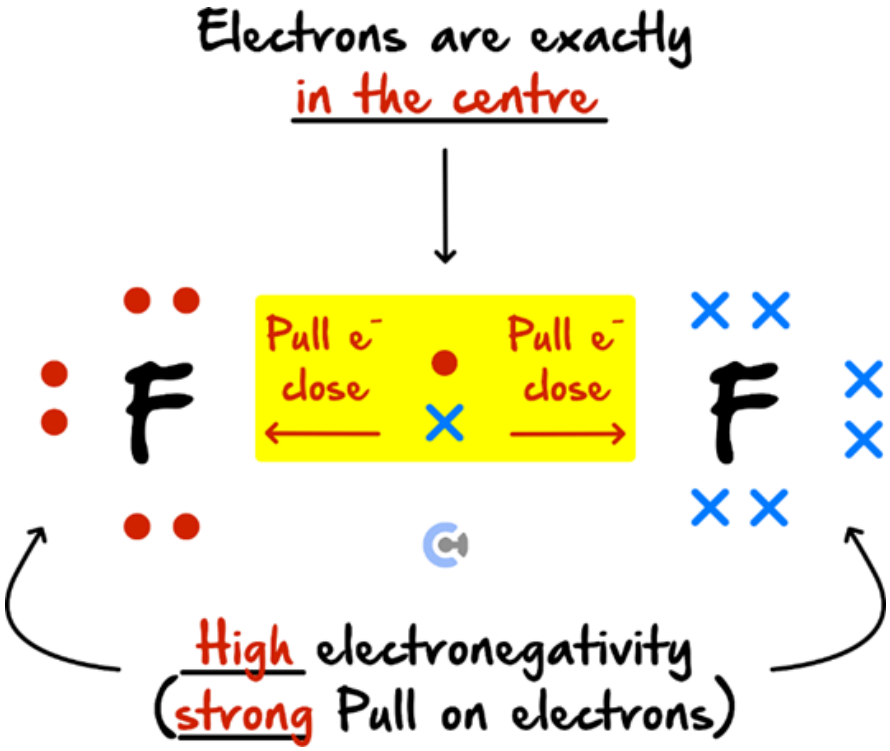
Exploration: F – F covalent bond

- Consider a F – F covalent bond:
- What will both fluorine atoms do with the shared pair of electrons to get a full outer shell? *(Label Below)*
- For fluorine: What is its electronegativity? As such, what is its pull on the shared electrons? *(Label Below)*
- Will the two fluorine atoms pull with [equal] / [different] strength?
- Ultimately, where will the shared pair of electrons be positioned? *(Label Below)*



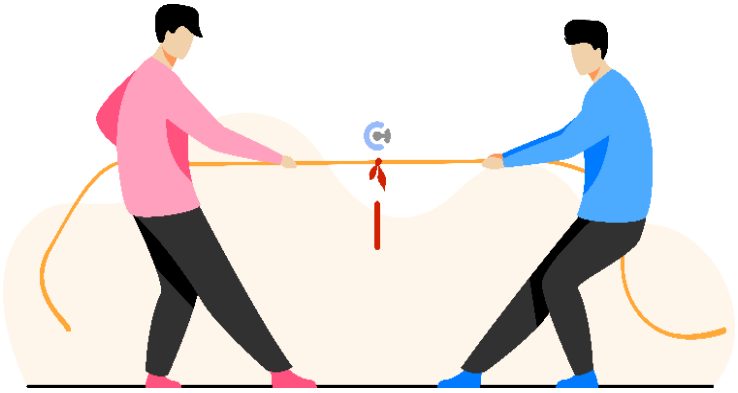
F – F Covalent Bond

- In a F – F bond, both fluorine atoms pull on the electrons **equally strongly**, and thus the electrons are located exactly in the **centre** of the bond.



Analogy: Tug of War 1.0

- Imagine two people who are **equally strong** in a game of tug of war.



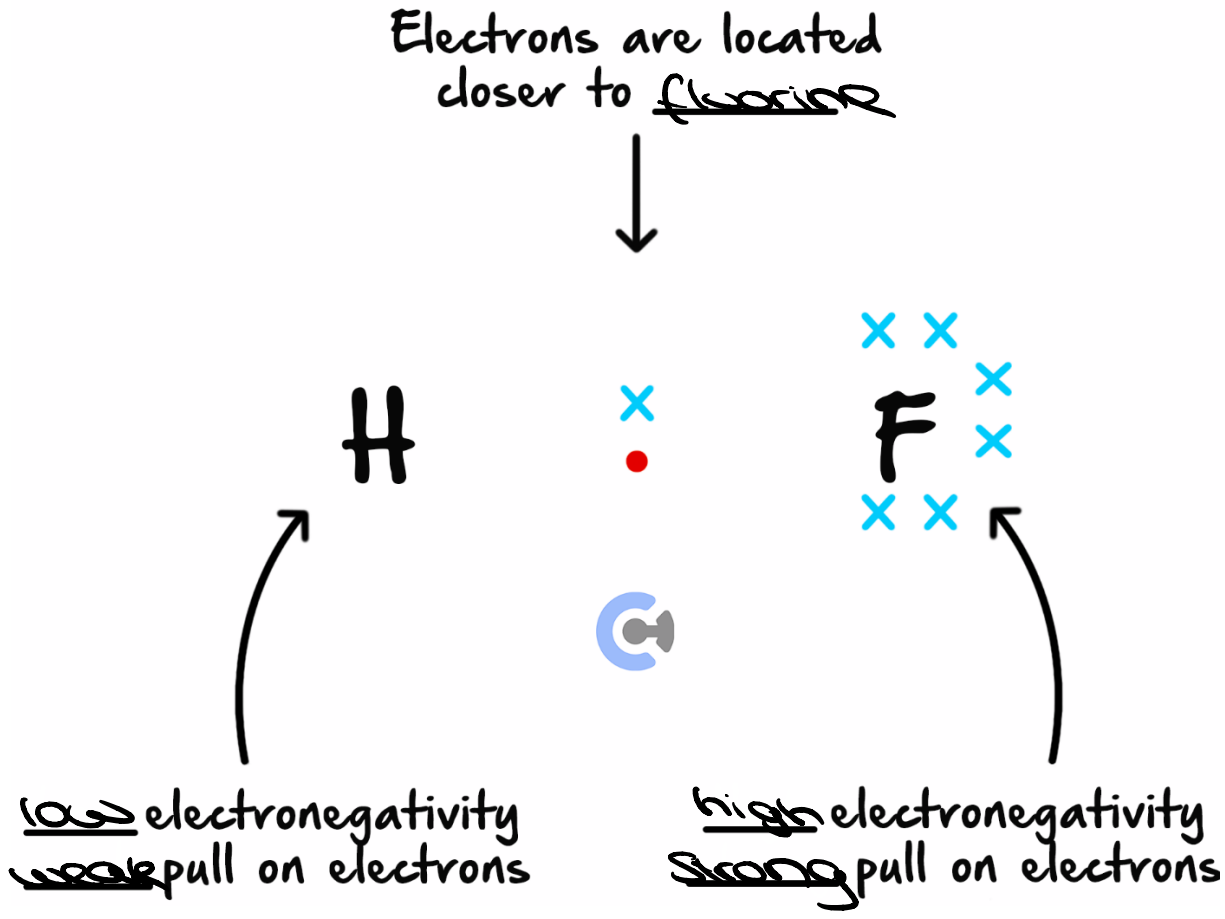
- On which person's side, will the centre of the rope (red line) be closer to?

Be in the centre.

What if the two elements aren't identical?

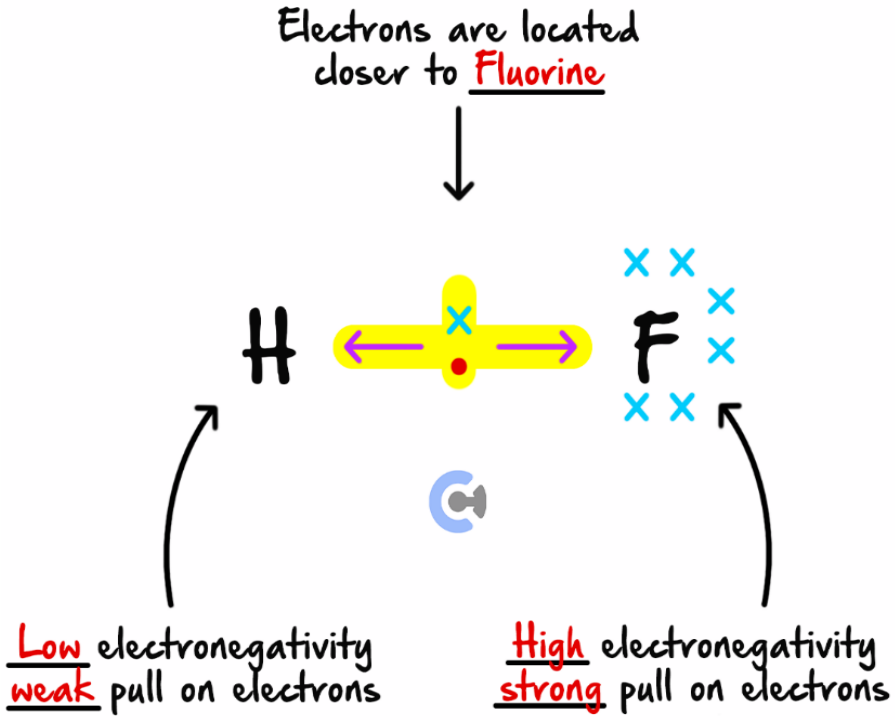
Exploration: $H - F$ bond

- Consider a $H - F$ covalent bond:
- What will both atoms do to the shared pair of electrons to get full outer shells? *(Label Below)*
- For fluorine: What is its electronegativity? As such, what is its pull on the shared electrons? *(Label Below)*
- For hydrogen: What is its electronegativity? As such, what is its pull on the shared electrons? *(Label Below)*
- Thus, will the hydrogen atom and fluorine atom pull with [equal] / [different] strength?
- Ultimately, which atom will the shared pair of electrons be closer to? *(Label Below)*



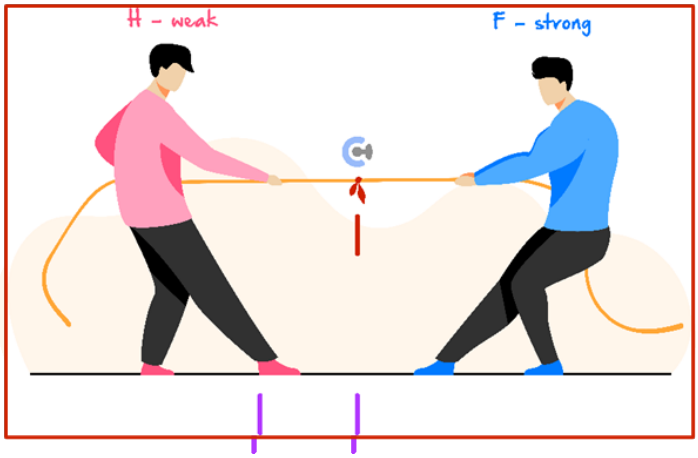
H – F Covalent Bond

- In a H – F bond, fluorine has a **higher** electronegativity and thus, pulls **stronger** on the electrons, thus resulting in the electrons being located **closer** to the F atom than the H atom.



Analogy: Tug of War 2.0

- Imagine there's a weakling (pink) against a super buff dude (blue):



- On whose side, will the centre of the rope be?

Buff/blue guy

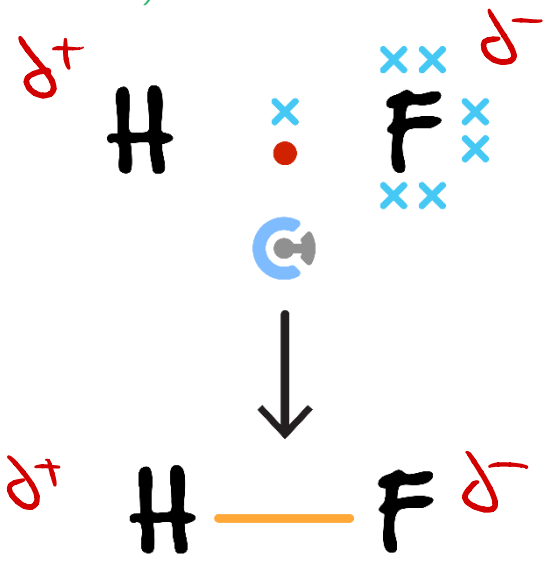
How does electronegativity within a bond, affect the charge of the molecule?

Partial Charges (δ) δ^- δ^+

- Definition: Partial charges are given when the overall charge of a substance is non-integer, due to asymmetrical distribution of electrons.

Exploration: Polar Covalent Bond

- Consider $H - F$:
- Which atom, are the shared **electrons** being pulled closer towards? [Hydrogen] / [Fluorine]
- What charge do electrons have? [Positive] / [Negative]
- As such, what will fluorine's charge be? **Partially** [positive] / [negative].
- Since hydrogen is **almost** 'losing' these shared electrons, it will become **partially** [positive] / [negative].
- What will this look like? *(Label Below)*

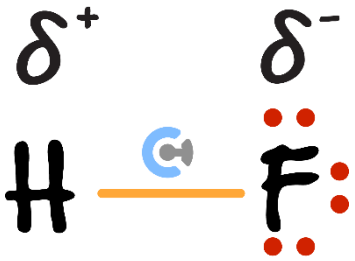


- As such, this **asymmetric** distribution of charges forms a dipole.
- And thus, we call the bond polar.

NOTE: These charges are ___partial___ as the electrons are being [shared] / [transferred], and not completely lost/gained like they are in an ionic bond, where the ions have **full** charges!

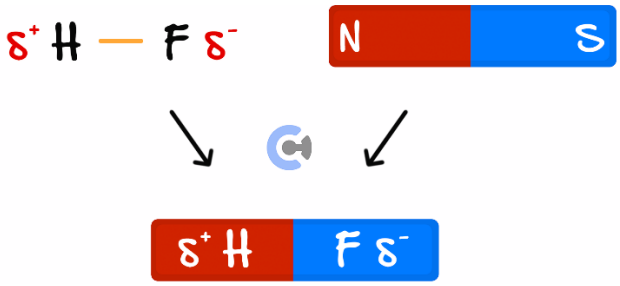
Polar Covalent Bonds

- **Definition**: A covalent bond is determined to be polar if there is an ___balance___ electron distribution.
- That is, one side of the molecule is ___partially positive___, and the other side is partially ___negative___, meaning a ___dipole___ is formed.



Analogy: Magnets

- Think about a polar molecule having two poles just like a magnet!



- This is why it's called a **dipole** - it has **di poles!** *(Label Below)*

TIP: A substance which is polar usually contains a dipole!

How does the bond look if both atoms have the same electronegativity?

Exploration: Non-Polar Covalent Bond

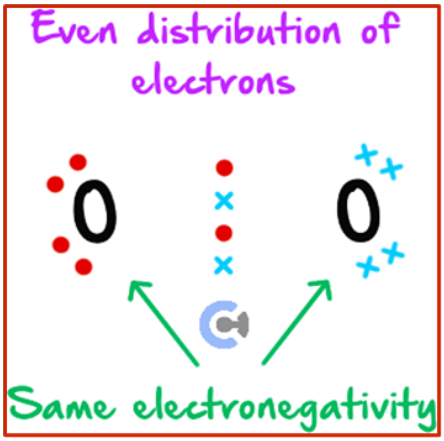
- Do oxygen atoms (O) have high or low electronegativity?

high

- If we consider a $O = O$ bond, what is the **difference** in the electronegativity between the two oxygen atoms?

0

- This is what the O_2 molecule looks like, as we have seen previously:
  - How does the left oxygen atom's electronegativity compare to the right one's? *(Label Below)*
  - As such, how will the shared electrons be distributed? *(Label Below)*



- Even though oxygen is highly electronegative, their **strong** pull cancels out, and thus, there is an [even] / [uneven] distribution of electrons.
- As such, there are no **partial charges**, and consequently, **no** dipole.
- Hence, this $O = O$ covalent bond is a non-polar bond.

Space for Personal Notes

1. Periodic table of the elements

1 **H** 1.0 hydrogen																	**2** **He** 4.0 helium
3 **Li** 6.9 lithium	**4** **Be** 9.0 beryllium											**5** **B** 10.8 boron	**6** **C** 12.0 carbon	**7** **N** 14.0 nitrogen	**8** **O** 16.0 oxygen	**9** **F** 19.0 fluorine	**10** **Ne** 20.2 neon
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atomic number — **79** **Au** 197.0 gold — symbol of element

relative atomic mass — name of element

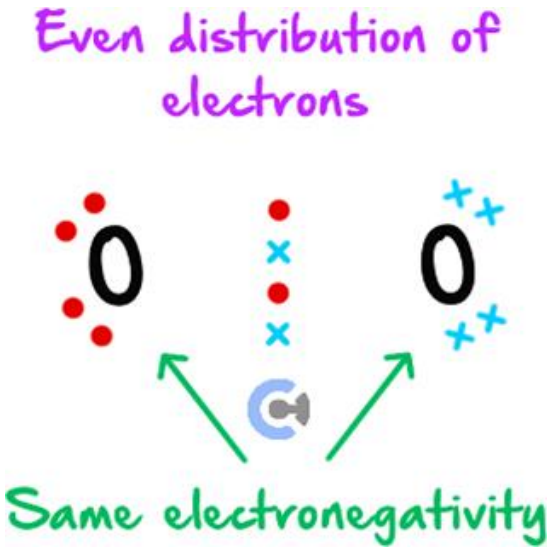
57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium

89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

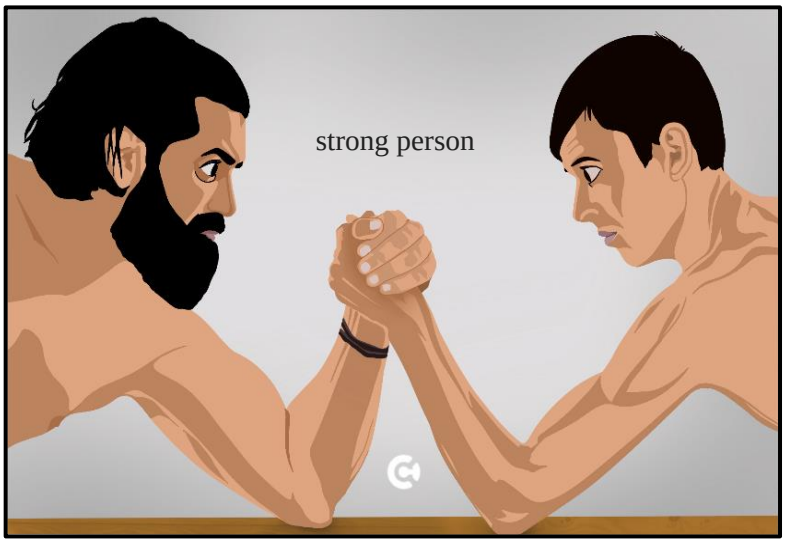
Non-Polar Covalent Bond

- Definition: When two atoms have similar electronegativities, their shared electrons are roughly **evenly** distributed, resulting in **no net dipole**.



Analogy: Arm Wrestling 1.0

- If we think about a super strong person arm wrestling a regular person, who would win? (Circle Below)



- This is just like the $H-F$ example we saw earlier, wherein **F was much more electronegative** than H, resulting in a [polar] / [non-polar] bond.

- Now, think about two very strong people who are equal in strength, who will win the arm wrestle?

tie

- Just like the two strong men, the two oxygen atoms have **high electronegativity**, but because they are **equally strong**, their effect **cancels out,** so the bond is [polar] / [non-polar] overall!

Let's try a question together!

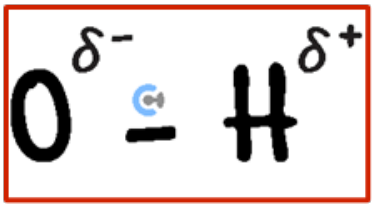
Question 4 (3 marks) **Walkthrough.**

Kaushik is investigating various types of covalent bonds, and he stumbles upon the O – H bond.

a. Explain why the O – H bond is considered to be polar. (2 marks)

There is an uneven distribution of electrons between H and O as O is more electronegative than H (1). As such, a dipole is formed (2), making the bond polar.

b. Draw and label the O – H bond with the appropriate partial charges. (Ignore lone pairs.) (1 mark)



NOTE: In general, you should always show lone pairs unless otherwise specified!

Your turn!

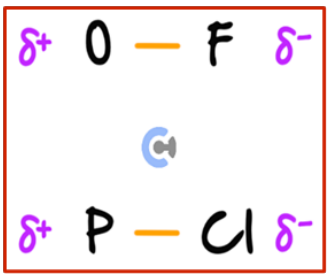
Question 5 (2 marks)

Explain whether the S = S bond is considered to be polar or non-polar.

Non-polar (1).
They are equally electronegative and so the shared electrons will not be pulled closer to either atom, so no dipole is formed. (2)

Question 6

Label the partial charges on the following bonds by comparing their electronegativities.



Question 7 Additional Question.

State whether a bond between sulphur and phosphorus is expected to be polar or non-polar, and state the electronegativity difference.

Non-polar; 0.4

Space for Personal Notes

Sub-Section: Level of Polarity

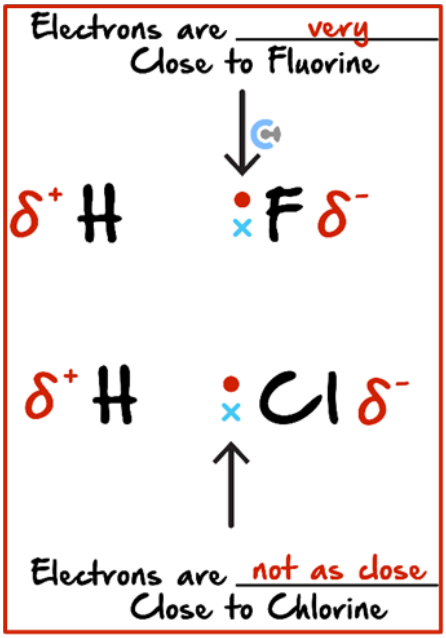
Discussion: Is every polar bond identical?

Exploration: HF vs HCl Polarity

- If we consider fluorine (F) and chlorine (Cl), which is more electronegative?

  [Chlorine] / [Fluorine]

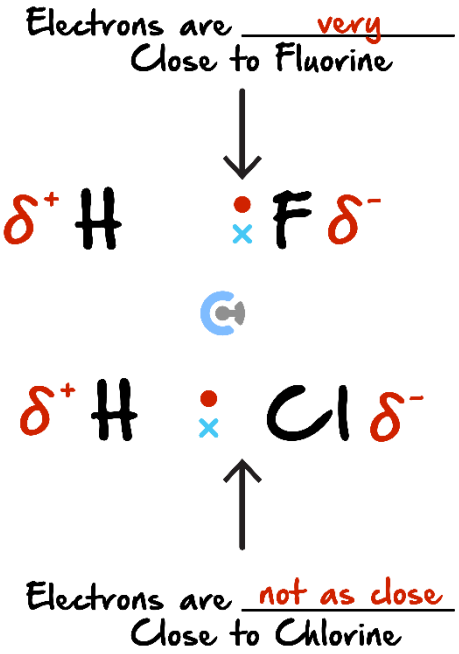
- What does HF and HCl look like? *(Label Below)*



- Are the shared electrons right in the centre for either molecule? [Yes] / [No]
- As such, both molecules have a **dipole**, and thus, **both** molecules have a [polar] / [non-polar] bond.
- However, which molecule has a **greater electronegativity difference** between its two atoms? [HF] / [HCl]
- As such, which molecule has a **stronger dipole?** [HF] / [HCl]
- Therefore, which molecule will be **more polar?** [HF] / [HCl]

Level of Polarity

- The level of polarity depends on the **difference** in electronegativity between the atoms.
- For example, H has a greater electronegativity difference with F than with Cl, which is why HF has a **stronger dipole,** and thus is a **more polar** bond than HCl.



Let's have a look at a question together!

Question 8 (2 marks) **Walkthrough.**

Explain whether a N – H or O – H bond would be more polar.

The electronegativity difference between O and H is greater than that of N – H, as O is more electronegative than N (1). As such, O – H will have a stronger dipole than N – H, and will thus be a more polar bond (2).

Space for Personal Notes

Your turn!

Question 9

Select the type of atom that would produce the most polar bond if bonded to an oxygen atom. **Do not** refer to the electronegativity values.

A. Silicon, Si

B. Phosphorus, P

C. Sulphur, S

D. Chlorine, Cl

Question 10

Order the polarity of the following covalent bonds from lowest to highest. **Do not** refer to the electronegativity values.

Sulphur – Nitrogen, Oxygen – Nitrogen, Nitrogen – Nitrogen, Hydrogen – Nitrogen, Carbon – Nitrogen.

N-N,O-N,S-N,C-N,H-N

Question 11 Additional Question.

Select the correct description of how the electrons are distributed in a polar, diatomic molecule.

A. The electrons are located halfway between the two atoms.

B. On average, the electrons are distributed evenly across the entire molecule.

C. On average, the electrons stay closer to the most electronegative atom.

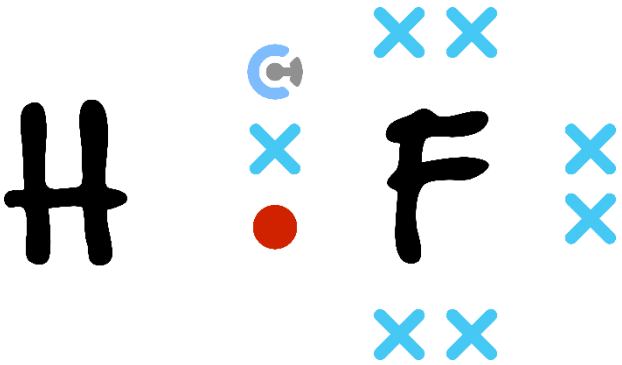
D. On average, the electrons stay closer to the least electronegative atom.

Sub-Section: Covalent vs Ionic Bonding

Discussion: Can an atom be so electronegative that it steals the electron entirely?

yes

Exploration: HF Large Electronegativity Difference

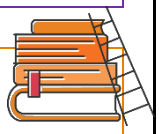


- For this scenario:
  - The hydrogen is **[more]/[less]** electronegative than the fluorine and thus, has a **[stronger]/[weaker]** pull than the fluorine.
  - Will hydrogen desperately try to still have some electrons in its outer shell? [Yes] / [No]
  - As such, it will barely **hang on** to the electrons, so they **[will] / [will not]** be entirely taken by fluorine.

Analogy: Arm Wrestling 2.0

- Think about an arm wrestle between two opponents - one slightly stronger than the other.

- While one opponent is slightly stronger than the other and will be dominating, the weaker opponent (given that they are not too weak) **can** hold on **for a long time**!
- This is the same with bonds, while the **fluorine is more electronegative than the hydrogen**, the hydrogen wants a full outer shell. As such, it will hold on to the electrons as much as it can!



Extension

- For **HF**, the bond is covalent when HF is a vapour, but the bond is ionic when HF is dissolved in water and is in aqueous state. (This is covered more in Uni Chemistry.)

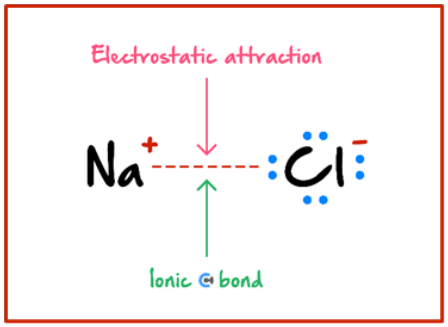
Active Recall: What type of bonding occurs when electrons are completely taken by one species and donated by the other?

ionic

Why do ionic bonds even form? What's stopping every bond from being covalent?

Exploration: Sodium chloride (NaCl) Bonding

- Consider sodium chloride (NaCl):
  - What charge does chlorine have when it gains an electron? *(Label Below)*
  - What charge will sodium have when it donates its valence electron? *(Label Below)*
  - What do we call the attraction between them and the resulting bond formed? *(Label Below)*



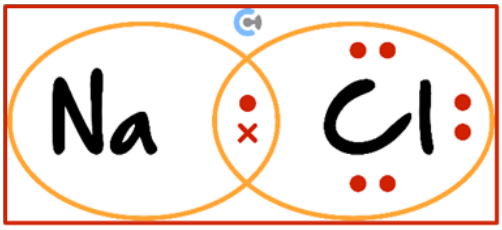
- What is the electron configuration for each element before and after?

Element	Sodium (Na)	Chlorine (Cl)
Electron Configuration Before Ionic Bond	2, 8, 1	2, 8, 7
Electron Configuration After Ionic Bond	2, 8	2,8,8

- Is this stable? Does each element have a full outer shell?

yes

- Why don't Sodium (Na) and Chlorine (Cl) **share electrons** instead, like the following?
  - What will the valence electrons look like for each atom? *(Label Below)*



- What is the electron configuration for each element before and after?

Element	Sodium (Na)	Chlorine (Cl)
Electron Configuration Before Covalent Bond	2,8,1	2,8,7
Electron Configuration After Covalent Bond	2, 8, 2	2, 8, 8

- Is this stable? Does each element have a full outer shell?

No – Sodium does not have a full outer shell – it wants to lose an electron not gain one.

Ionic Bonding

- Definition: When a metal **donates** electron(s) to a non-metal whereby ___both___ elements obtain a full outer shell and are held together by electrostatic attraction.

NOTE: Metals do ___not___ partake in covalent bonding as they wish to **[gain] / [lose]** electrons!

Likewise , why do covalent bonds even form? What's stopping all bonds from being ionic?

Exploration: HCl Bonding

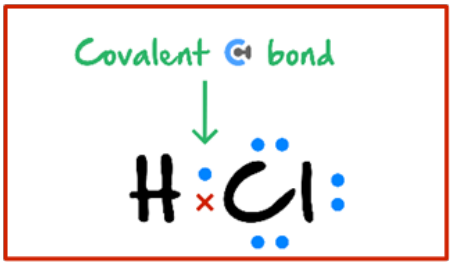
- If we consider the unique element Hydrogen:

H

- How many valence electrons does Hydrogen have?

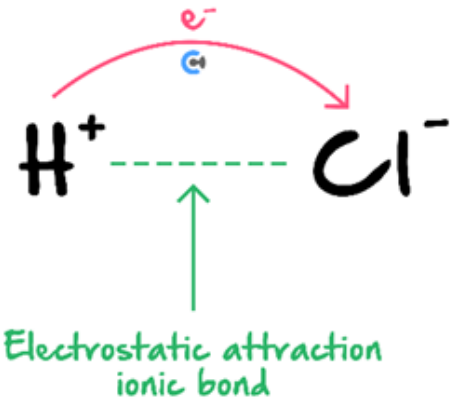
1

- What two things can hydrogen do to obtain a full outer shell?
  - ___Lose 1___ electron.
  - ___Gain 1___ electron.
- As such, H can hypothetically partake in both **covalent bonds** where it [gains] / [loses] an electron and in ___ionic___ **bonds** where it **loses** an electron.
- Consider hydrochloric acid (HCl):
  - What type of bond exists between the H and Cl atoms? *(Label Below)*



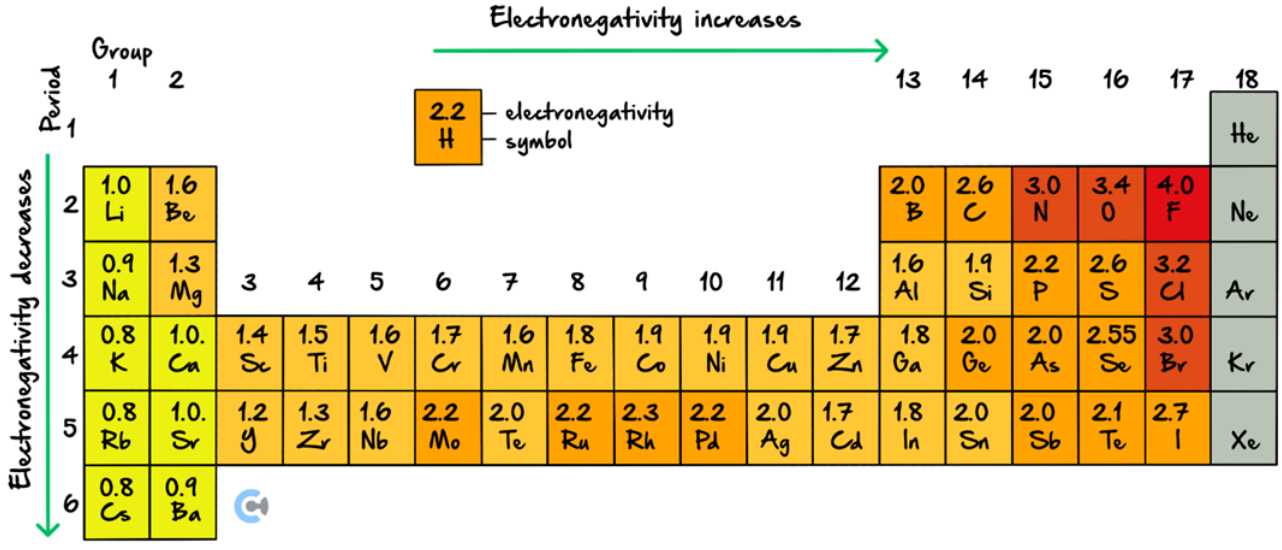
- We see that **both** Hydrogen (H) and Chlorine (Cl) are ___gaining___ an electron from sharing a pair.

Discussion: Why does chlorine not take hydrogen's electron entirely? How do we know when the electron will be taken vs when it will be shared?



Exploration: Electronegativity Difference

- Essentially, Chlorine is not _____electronegative_____ enough to completely _____pull_____ the electron off the Hydrogen into itself.
- If we reconsider the electronegativity table:



- What's the electronegativity difference between Hydrogen (H) atom and the Chlorine (Cl) atom?

3.2-2.2 = 1.0

- If we consider the following table:

	Non-Polar Covalent Bond	Polar Covalent Bond	Ionic Bond
Electronegativity Difference	$0 - 0.4$	$0.4 - 1.8$	> 1.8
Distribution of Electrons	Electrons are shared roughly equally.	Electrons are attracted to the more electronegative atom.	Electrons are completely transferred to the more electronegative atom.
Examples	$F_2, C-H, N_2$	$N-H, O-H, HCl$	$NaCl, MgF_2$

- What type of bond can HCl be classified as? [Non-polar covalent] / [Polar covalent] / [Ionic]
- What's the electronegativity difference between Sodium (Na) atom and the Chlorine (Cl) atom?

$$3.2\text{-}0.9 = 2.3$$

- We see that Sodium chloride ($NaCl$) is considered to be an _____ionic_____ bond.

Space for Personal Notes

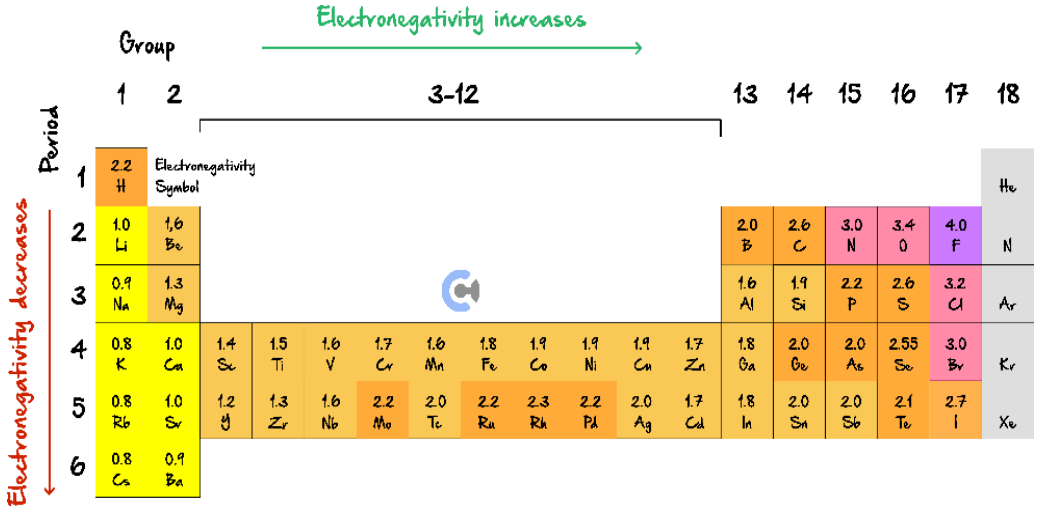
Misconception

"We can see whether the bonding atoms are the same or different to determine whether the bond is polar or non-polar."

- If the two bonding atoms are the same, the bond is a **non-polar covalent bond.**
- If the two bonding atoms are different, the bond is a **polar covalent bond.**

TRUTH:

- Whether a bond is polar or non-polar is based upon its electronegativity difference.



- For example, what is the difference in electronegativity between carbon and hydrogen? 0.4
- Thus, how can we classify the bond? [Polar] / [Non-Polar] / [Ionic]

Type of Bonding

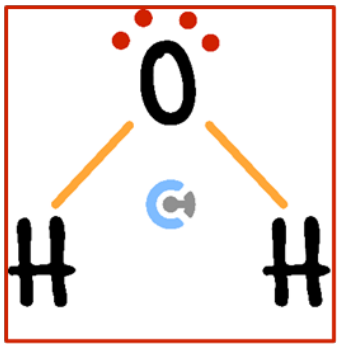
	Non-Polar Covalent Bond	Polar Covalent Bond	Ionic Bond
Electronegativity Difference	$0 - 0.4$	$0.4 - 1.8$	> 1.8
Distribution of Electrons	Electrons are shared roughly equally.	Electrons are attracted to the more electronegative atom.	Electrons are completely transferred to the more electronegative atom.
Examples	$F_2, C-H, N_2$	$N-H, O-H, HCl$	$NaCl, MgF_2$

Let's have a look at a question together!

Question 12 (6 marks) **Walkthrough.**

Isabelle is investigating the composition of a water molecule, and is trying to understand how polar bonds work.

a. Draw the Lewis structure of a water molecule. (2 marks)



b.

i. Explain whether the bonds within water would be polar or non-polar, without using electronegativity values. (2 marks)

Polar. (1)
This is because O is much more electronegative than H,
causing an imbalanced electron distribution and thus a dipole. (2)

ii. Verify your answer to **part b. i.** by referencing electronegativity values of O and H. (2 marks)

Electronegativity difference is 3.4 – 2.2 = 1.2 (1)
This is between 0.4 and 1.8, thus classifying it as a polar covalent bond. (2)

Space for Personal Notes

Your turn!

Question 13

Determine whether a bond between each of the following atoms will be **non-polar covalent, polar covalent, or ionic** *without using electronegativity values.*

a. K & F

ionic

b. H & Br

polar covalent

c. Al & F

ionic

d. O & O

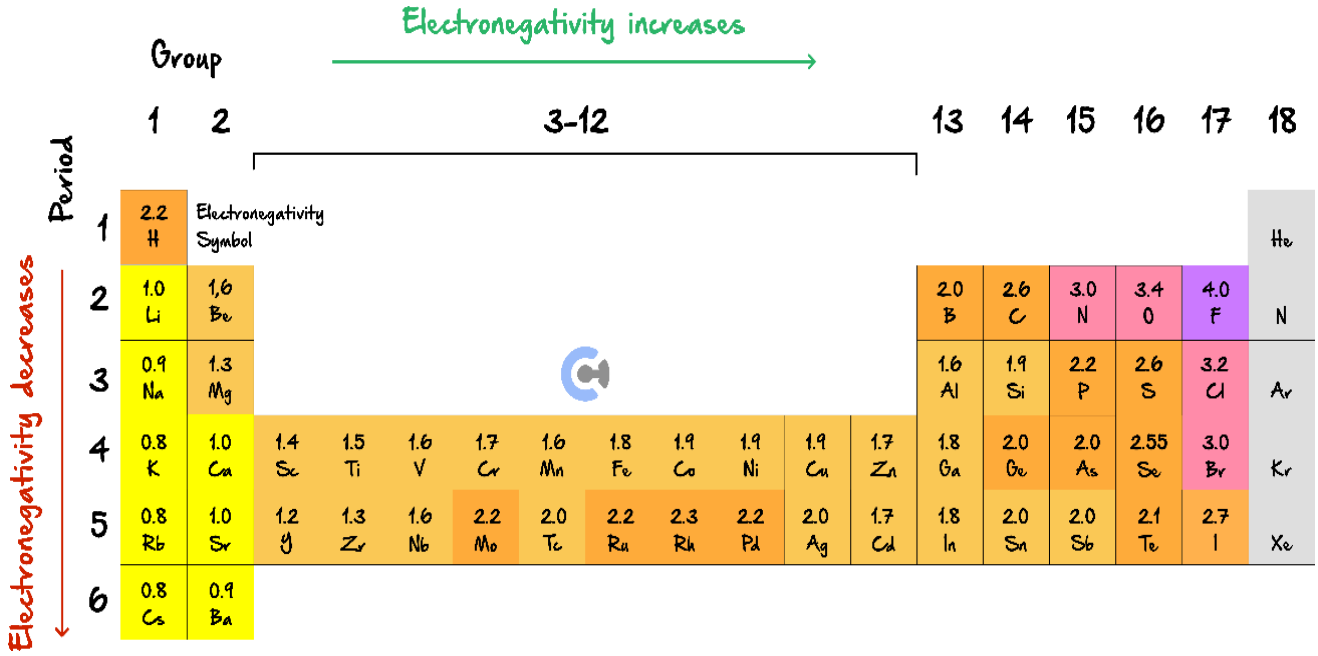
Non-polar covalent

e. F & O

polar covalent

Space for Personal Notes

Question 14 Additional Question.



Use the table of electronegativity values to decide which of the following lists the symbols of the elements carbon, caesium, fluorine, and oxygen in order of **decreasing electronegativity.**

A. Cs, C, O, F

B. O, F, C, Cs

C. F, C, Cs, O

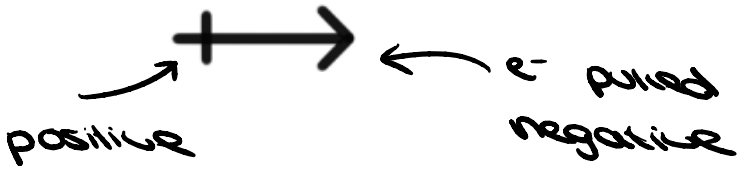
D. F, O, C, Cs

Space for Personal Notes

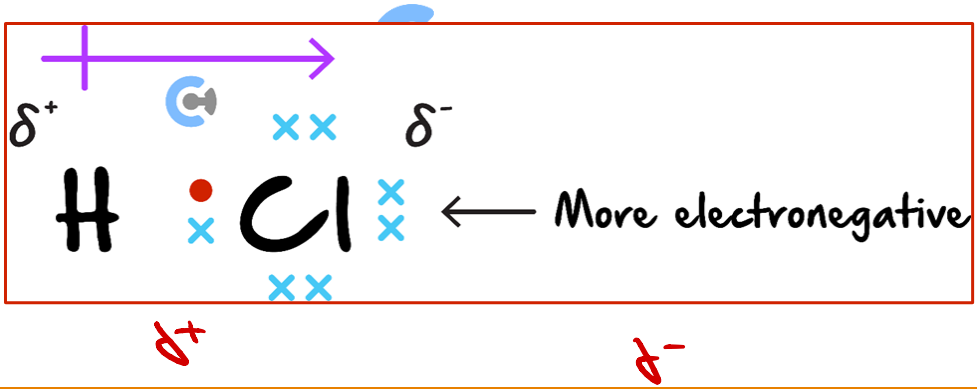
Sub-Section: Polarity Arrows

Exploration: Polarity Arrows

- A polarity arrow can also be drawn on molecules. A polarity arrow looks like the following:
- Which side is positive? *(Label Below)*
- What does the arrow head point towards? *(Label Below)*



- Consider HCl:
  - Which atom is more electronegative? *(Label Below)*
  - As such, what will the partial charges be? *(Label Below)*
  - Thus, what will the polarity arrow look like? *(Label Below)*



TIP: The **plus** sign on the polarity arrows denotes the partially **positive** side.

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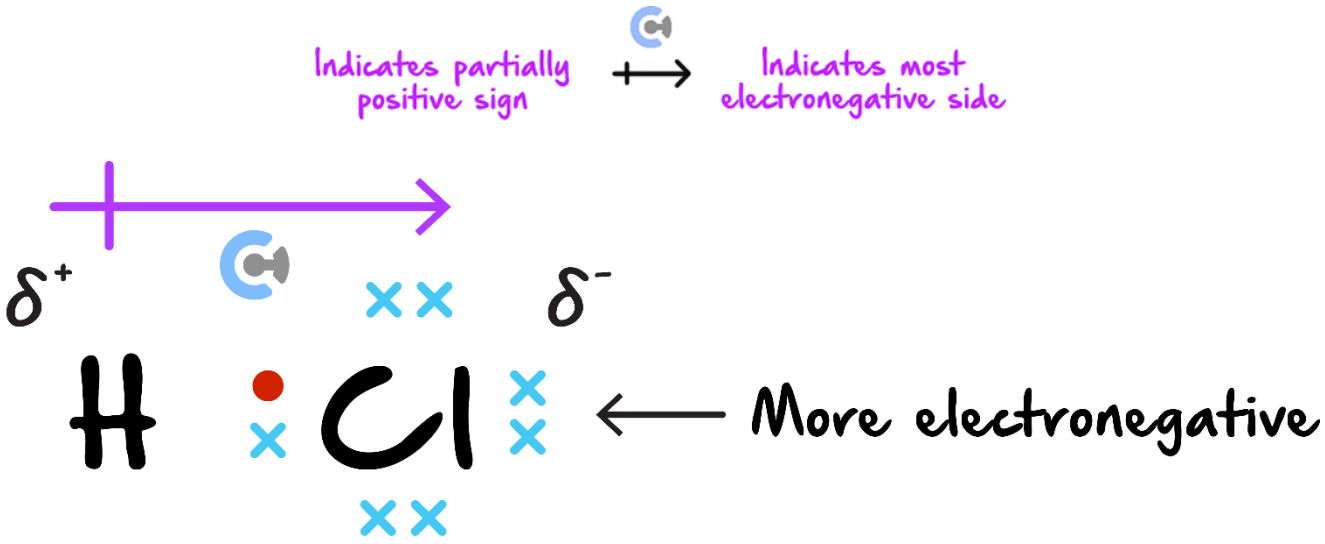
Definition

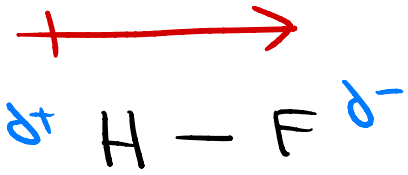
Polarity Arrow



Let's have a look at a question together!

Question 15 Walkthrough.

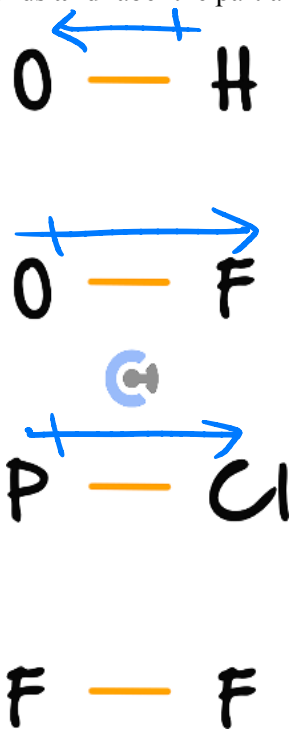
Draw the polarity arrow for hydrogen fluoride (HF). Ensure to label partial charges.



TIP: Think about it as, the direction in which the arrow points is the direction where the electrons will want to go towards!

Question 16

Draw the polarity arrows for the following bonds **and** label the partial charges.



Question 17 Additional Question.

Draw the polarity arrows on KF.

N/A, as it's ionic, not covalent

Space for Personal Notes

Section B: Polar Molecules

Sub-Section: Molecular Geometry

Context

- We've covered how bonds can be polar or non-polar and how diatomic molecules (molecules with two atoms) can be polar or non-polar.
  - What about molecules where there are more than two atoms?

Discussion: Can a molecule be non-polar whilst having polar bonds?

Exploration: Carbon dioxide (CO_2)

- Consider carbon dioxide (CO_2):
  - What is the **Lewis Structure** of Carbon Dioxide (CO_2)? *(Label Below)*
  - What are the **partial charges** of each atom? *(Label Below)*
  - As such, what are the **polarity arrows** for each of the bonds? *(Label Below)*

- Since the polarity arrows are in [the same] / [opposite] directions, what can be said about the two polarity arrows? They [cancel each other out] / [combine into one].
- As such, there [is] / [is no] **net dipole**.
- Hence, what is the **overall polarity** of the molecule? [Polar] / [Non-polar]

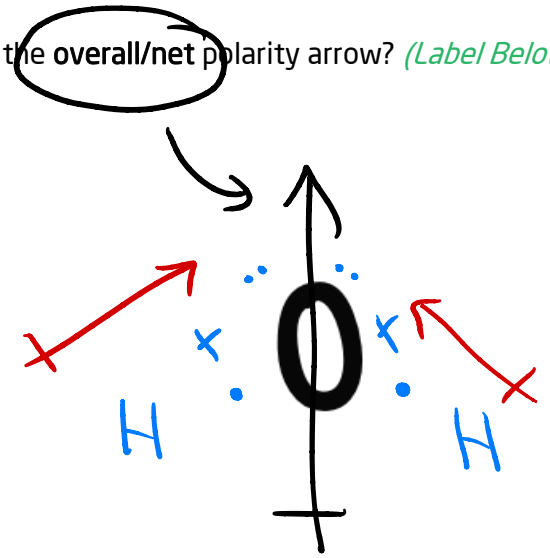
What if the molecule isn't linear?

Active Recall: What is the molecular geometry of water?

bent

Exploration: Water (H_2O)

- Consider water (H_2O):
  - What is the **Lewis Structure** of water? *(Label Below)*
  - What are the **partial charges** of each atom? *(Label Below)*
  - As such, what are the **polarity arrows** for each of the bonds? *(Label Below)*
  - Hence, what will be the **overall/net** polarity arrow? *(Label Below)*



- Since the polarity arrows [are] / [are not] exactly in opposite directions, they **do not** oppose one another.
- Thus, what can be said about the polarity arrows? They [cancel each other out] / [combine into one].
- As such, there [is] / [is not] a **net dipole**.
- Hence, what is the **overall polarity** of the molecule? [Polar] / [Non-polar]

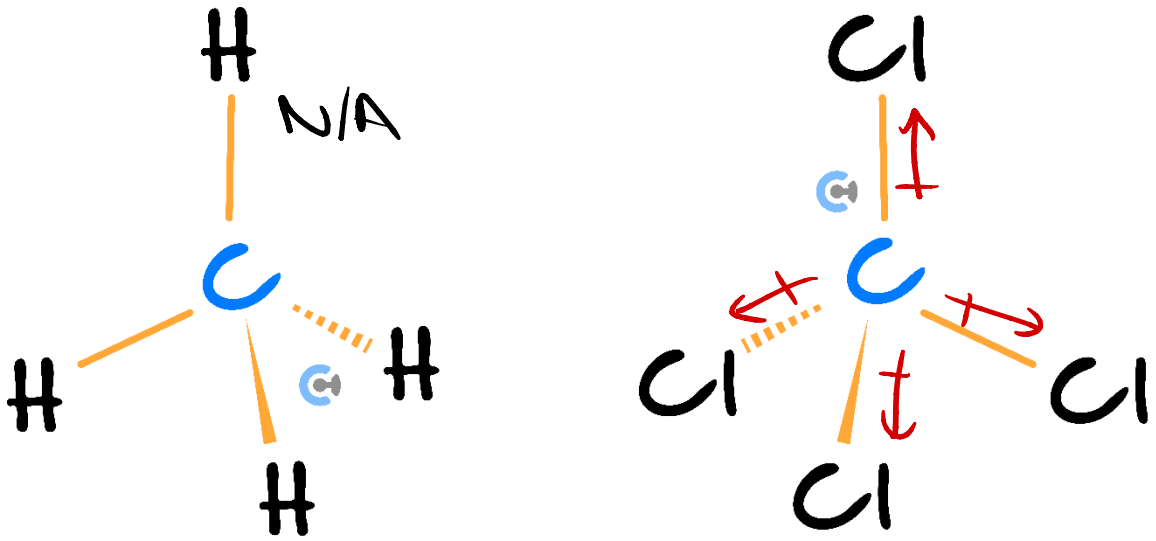
What if there are more bonds?

Active Recall: What is the geometry of CH_4 and CCl_4?

tetrahedral

Exploration: Tetrahedral Molecule Polarity

- Let's consider methane (CH_4) and carbon tetrachloride (CCl_4):
- Is the $C-H$ bond polar?
- Is the $C-Cl$ bond polar?
- As such, what do the polarity arrows look like? *(Label Below)*



- For tetrahedral geometries, if **all bonds are the same,** it doesn't matter whether the **bonds** themselves are polar or non-polar.
- This is because the bonds pull equally on **all sides**, so the polarity arrows [cancel each other out] / [combine into one].
- As such, there [is] / [is no] **net dipole**.
- Hence, the whole molecule is [polar] / [non-polar].

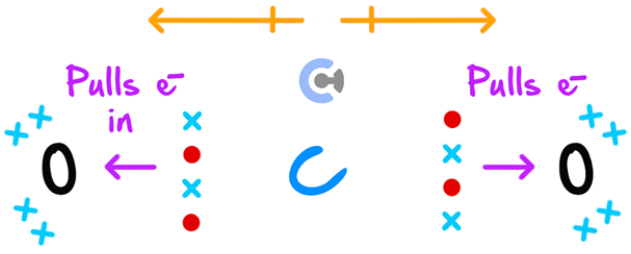
NOTE: Symmetrical Molecules with the same bonds are non-polar, as the bond **dipoles** **cancel** each other out.

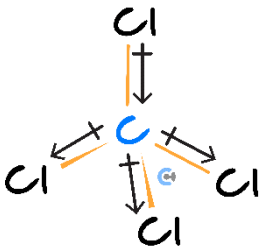
ALSO NOTE: Asymmetrical Molecules that contain **polar bonds** are polar molecules, as a **net dipole** is created in the molecule.

Definition

Polarity of Molecules

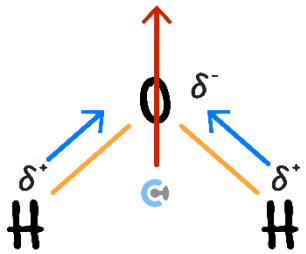
- If the molecule is **symmetrical** and the bonds are **equally polar:**
  - The polarity arrows for the polar bonds **cancel**, resulting in **no net dipole**, rendering the molecule **non-polar**.
  - For example:



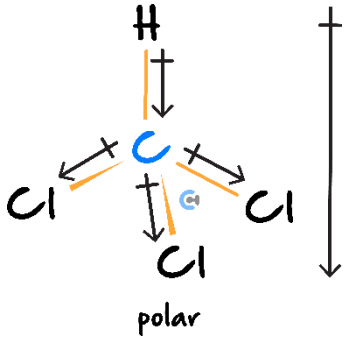


Non - polar

- If the molecule is **asymmetrical:**
  - The polarity arrows for the polar bonds **do not cancel**, resulting in a **net dipole**, rendering the molecule **polar**.
  - For example:

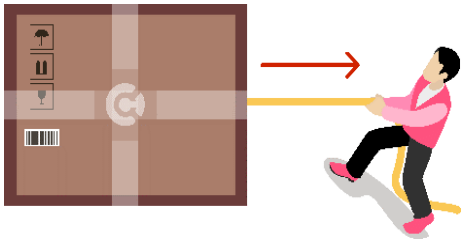


- If the molecule is **symmetrical** and the bonds **are not equally polar:**
  - The polarity arrows for the polar bonds **do not cancel,** resulting in a **net dipole**, rendering the molecule **polar**.
  - For example:



Analogy: Tug of War 3.0

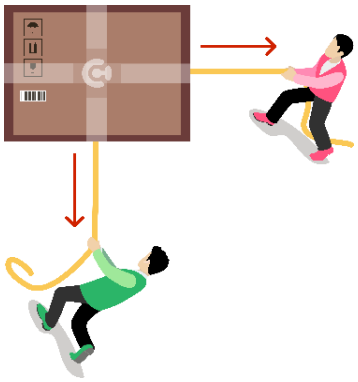
- Imagine a massive box in the centre of a room, and only one person pulling on it with a rope.



- Will the box move? Is this 'polar' or 'non-polar'?

polar

- Consider a massive box in the centre of the room with two people pulling on it as shown.

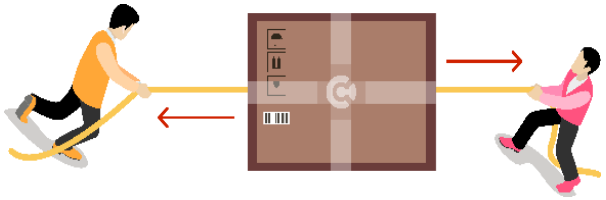


Yes

- Will the box move? Is this 'polar' or 'non-polar'?

Yes - polar

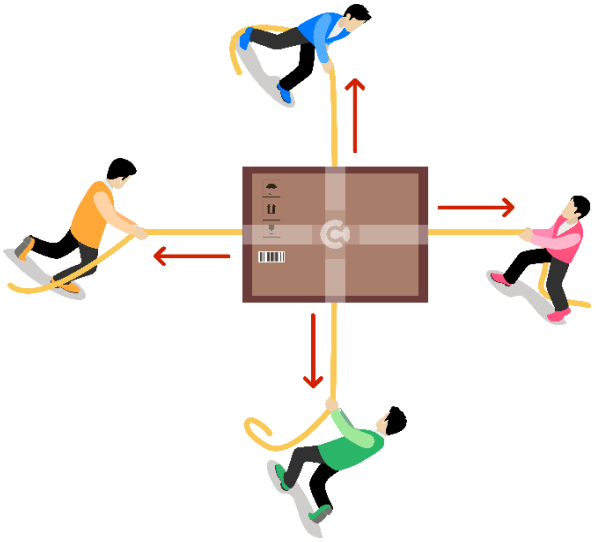
- Consider a massive box in the centre of the room with two people **of equal strength** pulling on it in opposite directions.



- Will the box move? Is this 'polar' or 'non-polar'?

non - polar

- Consider a massive box in the centre of the room with four people **of equal strength** pulling on it as shown.



- Will the box move? Is this 'polar' or 'non-polar'?

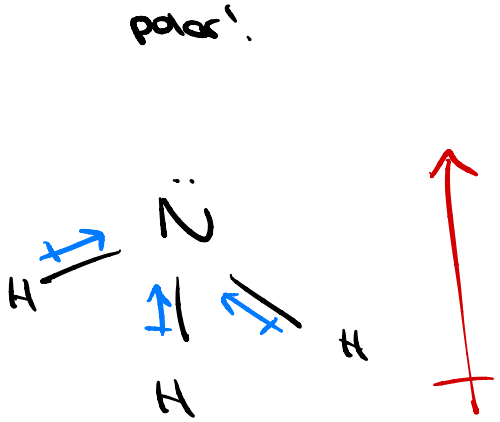
non - polar

Space for Personal Notes

Let's have a look at a question together!

Question 18 Walkthrough.

Is ammonia (NH_3) polar or non-polar?

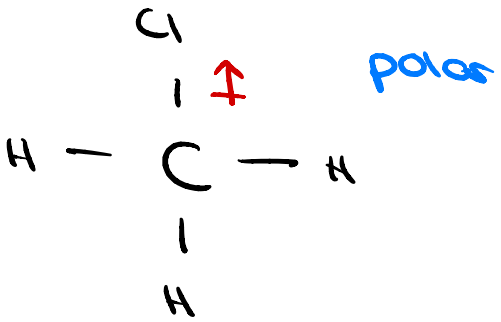


REMINDERS: For a **molecule** to be polar:

- There must be **polar bonds** between the atoms.
- **AND** there must be a **net dipole** (polarity arrows **do not** cancel out).

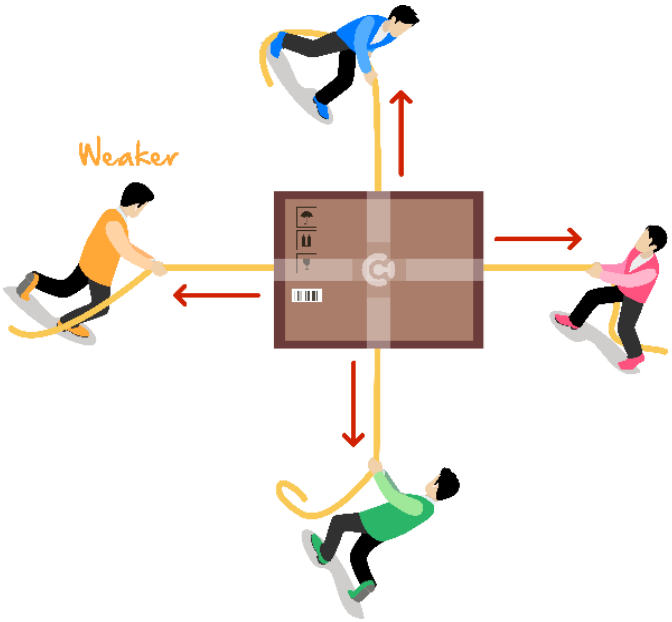
Question 19 Walkthrough.

What is the polarity of chloromethane (CH_3Cl)?



Analogy: Tug of War 4.0

- Consider a massive box in the centre of the room with four people pulling on it, three being strong and one being weak.



- Will the box move? Is this 'polar' or 'non-polar'?

polar

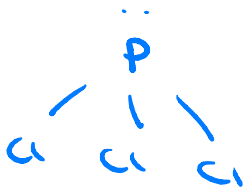
Space for Personal Notes

Your turn!

Question 20

For each of the following, state their molecular geometries and determine whether they are polar or non-polar molecules overall.

a. PCl_3



polar

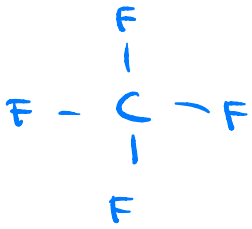
b. CS_2

non-polar

c. FOH

polar

d. CF_4



non-polar

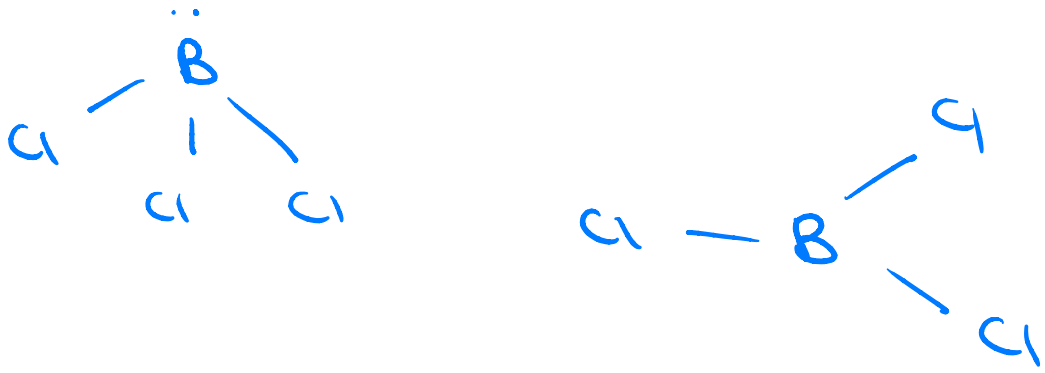
e. HCN

polar

Question 21 Walkthrough.

State the following molecule's geometry, as well as its polarity.

BCl_3



NOTE: As BH_3 is trigonal planar, which is **symmetrical,** it is non-polar.

ALSO NOTE: BH_3 does not have eight electrons in boron's outer shell, but why this is the case is not covered in VCE chemistry.

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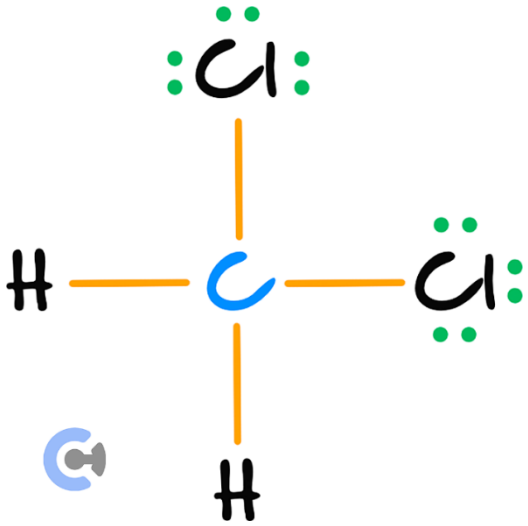
Sub-Section: Atom Arrangement

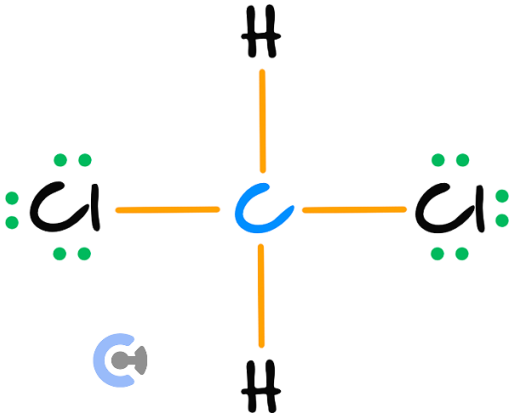
Does the arrangement of the atoms within the molecule matter?

Discussion: Is dichloromethane (CH_2Cl_2) arranged in the following way polar or non-polar?



[Polar] / [Non-polar]

Discussion: How about dichloromethane (CH_2Cl_2) arranged in the following way? Is it polar or non-polar?



polar.

Exploration: Shape of CH_2Cl_2

- What is the molecular geometry of CH_2Cl_2?

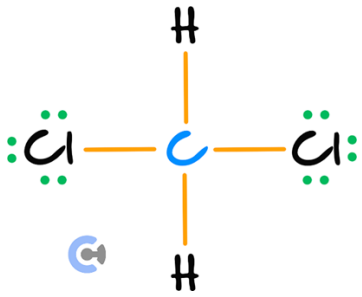
tetrahedral

- Let's look at the following simulation.
- **Simulation**: https://phet.colorado.edu/sims/html/build-a-molecule/latest/build-a-molecule_en.html
  - Go to 'Playground'.
  - Construct CH_2Cl_2, then click '3D' once completed.
- As CH_2Cl_2 has a tetrahedral shape, the two Cl atoms [do] / [do not] directly oppose each other.
  - As such, the polarity arrows [do] / [do not] **cancel each other out**.
  - Hence, there [is] / [is not] a **net dipole**, resulting in the overall molecule being [non-polar] / [polar].

REMINDERS: Even though it is drawn on 2D paper, remember that the molecule is 3D altogether!

Arrangement of Atoms

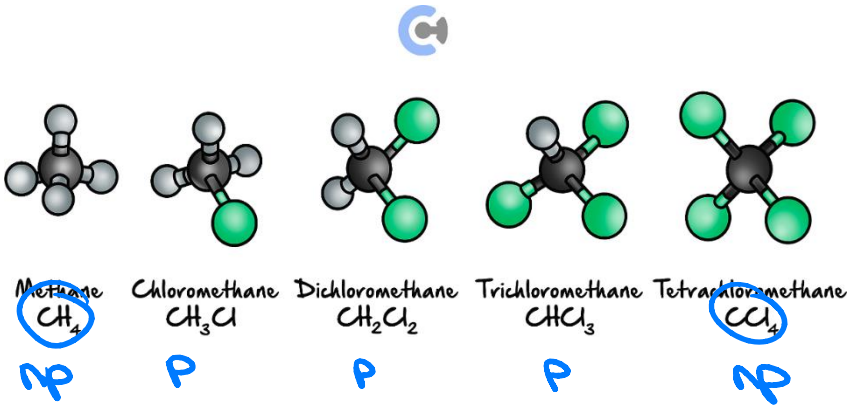
- Since molecules exist in **3D space**, the arrangement of atoms **does not** matter in terms of creating a **net dipole**.
- If there are **polar bonds** within a tetrahedral molecule with all 4 groups **not** being identical, the molecule will be **polar**, regardless of the way the atoms are arranged.
- This arrangement of CH_2Cl_2 **is still polar**:



Try some questions!

Question 22

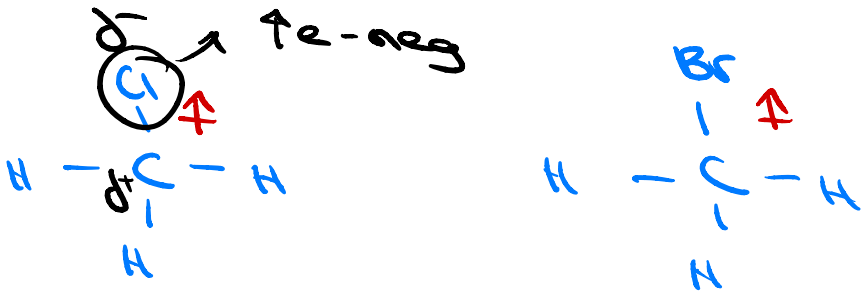
For each of the following molecules, state whether the molecule is polar or non-polar.



Question 23

Chloromethane (CH_3Cl) and bromomethane (CH_3Br) are two simple organic compounds.

a. Draw the structures and indicate them with polarity arrows.



b. State which compound is **more polar** overall.

more e- neg difference

CH_3Cl

REMINDER: The level of polarity of a polar bond is dependent on the **difference in electronegativity** between atoms.

Question 24 Additional Question.

Select which of the following options is true regarding polar molecules.

A. Water is non-polar as the polarity arrows cancel.

B. Tetrafluoromethane (CF_4) is polar due to the polar bonds between C and F.

C. Molecules that have polar bonds are polar overall.

D. CH_3Cl will have a net dipole and thus, be polar.

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Contour Checkoff

☐ Learning Objective: [1.7.1] – Identify polar & non-polar bonds within a covalent molecule, with reference to electronegativity

Study Design

"Polar and non-polar character with reference to the shape of the molecule."

Key Takeaways

- electronegativity is an atoms' ability to attract an electron towards itself.
- A covalent bond is determined to be **polar** if there is an [even] / [imbalanced] electron distribution.
- If the two atoms in a covalent bond are **equally electronegative**, there [is] / [is no] **net dipole,** meaning the bond is [polar] / [non-polar].
- The **level of polarity** depends on the e- neg difference between the atoms.
- The reason some bonds are **ionic** is because [metals] / [non-metals] wish to **lose** electrons, and as such, **do not** form covalent bonds.
- To figure out what type of bond is formed between atoms, **complete the table below**:

	non-polar Bond	polar Bond	ionic Bond
Electronegativity Difference	$0 - 0.4$	$0.4 - 1.8$	> 1.8
Distribution of Electrons	Electrons are: [Attracted to the more electronegative atom] / [Shared roughly equally] / [Completely transferred to the more electronegative atom].	Electrons are: [Attracted to the more electronegative atom] / [Shared roughly equally] / [Completely transferred to the more electronegative atom].	Electrons are: [Attracted to the more electronegative atom] / [Shared roughly equally] / [Completely transferred to the more electronegative atom].
Examples	$F_2, C-H, N_2$	$N-H, O-H, HCl$	$NaCl, MgF_2$

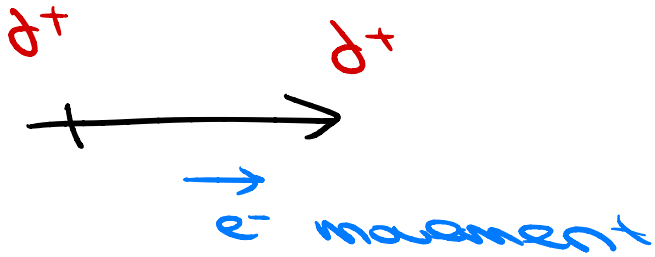
Learning Objective: [1.7.2] – Draw partial charges & corresponding polarity arrows on covalent molecules

Study Design

"Polar and non-polar character with reference to the shape of the molecule."

Key Takeaways

- The **more electronegative** atom within a covalent bond gets a **partially** [positive] / [negative] charge.
- The **less electronegative** atom within a covalent bond gets a **partially** [positive] / [negative] charge.
- The two partial charges create two 'poles', known as a dipole.
- The charges are **partial** as the electrons are still being [shared] / [transferred], unlike in an **ionic** bond, where they are [shared] / [transferred].
- polarity arrows can be drawn to label the direction in which e⁻ wish to move.
- What does each end of a polarity arrow represent?



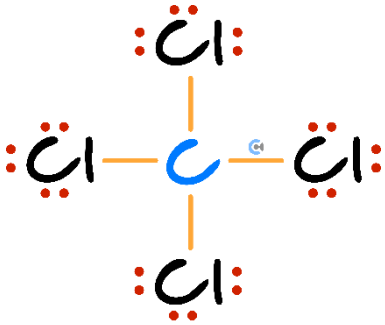
Learning Objective: [1.7.3] – Identify polar & non-polar molecules with reference to polar & non-polar bonds, as well as molecular geometry

Study Design

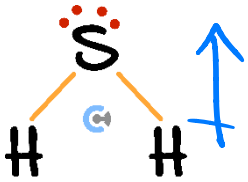
"Polar and non-polar character with reference to the shape of the molecule."

Key Takeaways

- **Symmetrical Molecules with the same bonds** are [polar] / [non-polar] as the **bond dipoles** [cancel] / [do not cancel] each other out. For example:

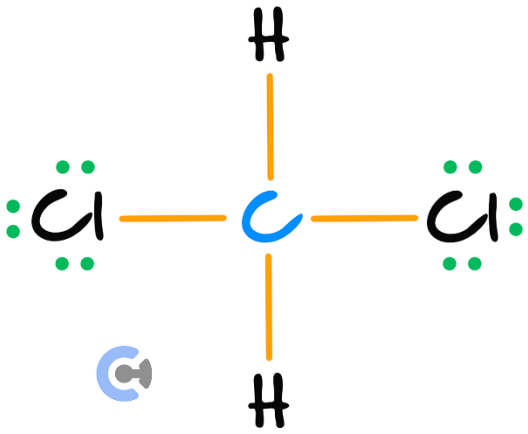


- **Asymmetrical Molecules** that contain **polar bonds** are [polar] / [non-polar] molecules, as a **net** dipole is created in the molecule. For example:



- For a **molecule** to be **polar:**
  - There must be [polar] / [non-polar] **bonds** between the atoms.
  - **AND** there must [be] / [not be] a **net dipole** (polarity arrows [do] / [do not] cancel out).
- For a **molecule** to be **non-polar:**
  - [Some] / [All] of the bonds must be **non-polar.**
  - **OR** The bonds may be polar, but the molecule is [symmetrical] / [asymmetrical], so there [is] / [is no] **net dipole** (polarity arrows [do] / [do not] cancel out).

- Since molecules exist in [2D] / [3D] space, the **arrangement of atoms** [does] / [does not] matter in terms of creating a **net dipole**.
- For example, if there are **polar bonds** within a tetrahedral molecule with all 4 groups **not** being identical, the molecule will be [polar] / [non-polar] **regardless** of the way the atoms are arranged.
- As such, this arrangement of CH_2Cl_2 is [polar] / [non-polar]:



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