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VCE Chemistry ½
Isomerism in Organic Chemistry [2.6]
Workbook

Outline:

Learning Objectives:

- ☐ **CH12 [2.6.1]** - Apply IUPAC Conventions to Identify, Draw & Write Names of Straight-Chained & Branched Alkenes
- ☐ **CH12 [2.6.2]** - Identify & Explain What Structural Isomers Are
- ☐ **CH12 [2.6.3]** - Find Possible Structural Isomers (Chain, Positional, Functional) of Alkanes, Alkenes & Haloalkanes From a Given Molecular Formula
- ☐ **CH12 [2.6.4]** - Apply IUPAC Conventions to Identify, Draw & Write Iupac Names of Straight-Chained & Branched Alcohols

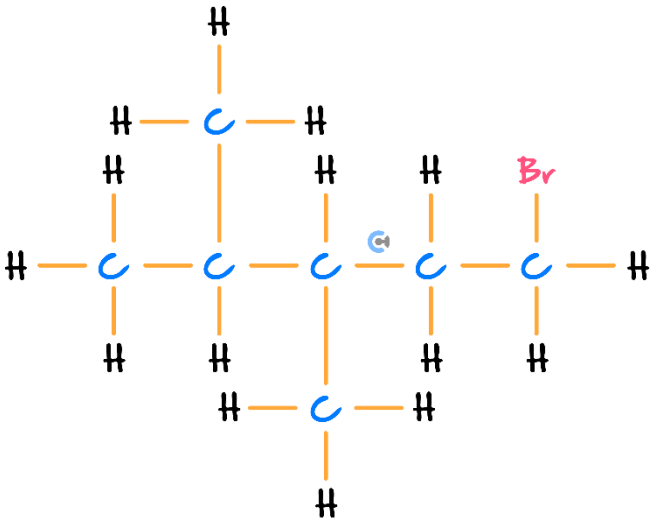
Section A: Alkenes

Sub-Section: Recap

Let's recap last week's work!

Question 1 Walkthrough.

For the following molecule:



a. Fill out the table:

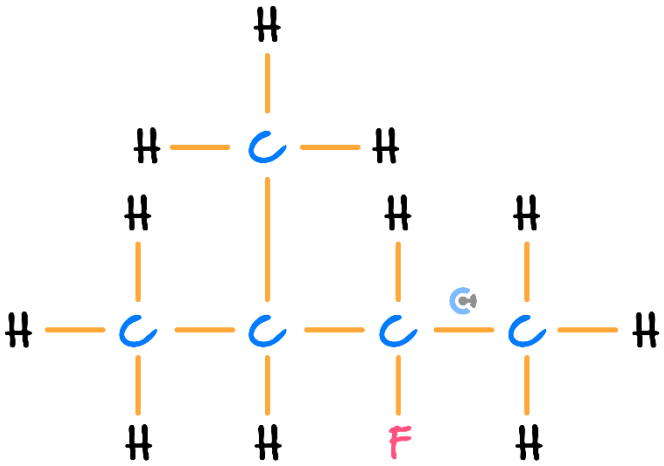
Name	Semi-Structural Formula

b. Draw the skeletal formula.

Your turn!

Question 2

For the following molecule:



a. Fill out the table:

Name	Semi-Structural Formula

b. Draw the skeletal formula.

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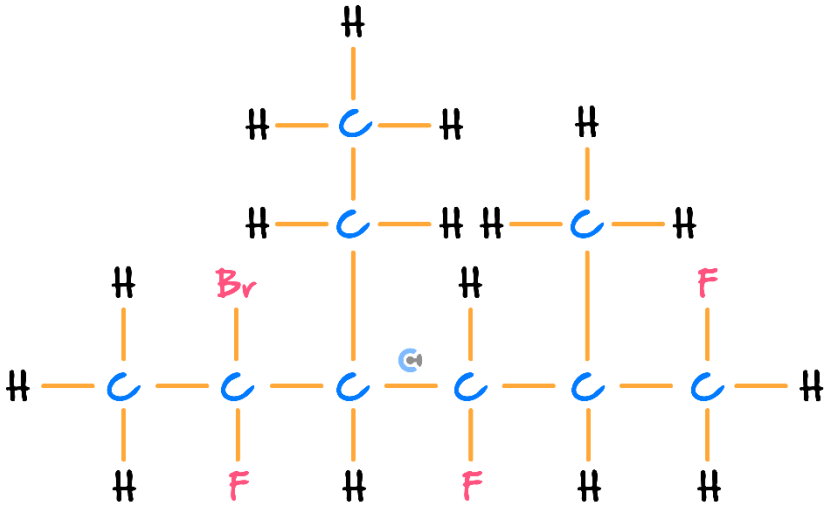
Question 3

a. Name the following molecule :



_____

b. Draw the structural formula for the 3,3-dimethyl-2-iodobutane.

Active Recall: What is the general molecular formula for alkanes? (e.g. C_xH_y)

_____

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Active Recall: Prefixes:

Longest Carbon Chain Length	Prefix
1	
2	
3	
4	
5	
6	
7	
8	

Let's have a look at the homologous series!

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Sub-Section: Introduction to Alkenes

Homologous Series

- **Definition:** A group of organic compounds which differ from each other by a _____.

TIP: Think of molecules in the same homologous series as belonging to the same 'family'!

NOTE: A homologous series is also known as a _____ of molecules

Context

- **Last week:** Homologous series explored: _____.
- **This week:** Homologous series explored: Alkenes.

Let's explore this new class of organic molecules!

Active Recall: How are alkanes named?

_____

_____

- **Suffix:** _____
- **Infix:** _____

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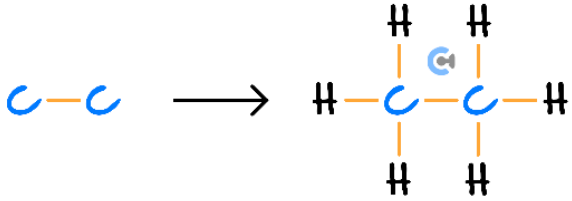
Exploration: Alkenes

- **So far:** Assumed carbons joined together, forming **one bond** with each other. *(Label Below)*



- **Reality:** Carbon can form double bonds. *(Label Below)*

- Hydrogens on each carbon: _____
- **Classification:** _____.

Alkenes

- **Definition**: A hydrocarbon containing one or more **carbon-carbon** [single] / [double] bonds.
- **Class/Homologous Series**: Alkene
- **Infix**: _____
- **Functional group name:** _____

Functional Group

- **Definition:** A group of atoms responsible for the characteristics of a compound.
- E.g. In alkenes, the _____ is its functional group.

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NOTE: If an organic compound contains one or more double bonds, it is instantly classified as an alkene even if it contains carbon-carbon single bonds as well.

NOTE: We will cover more functional groups in the next booklet. For now, just know that the double bond itself is called an alkenyl group!

Level of Saturation

- Molecules that have carbon-carbon **single** bonds are considered to be _____.
- Molecules with carbon-carbon **double** or **triple** bonds are considered _____.

Exploration: Naming Breakdown

- Each organic molecule's name is comprised of **3 parts:**
  - **Prefix:** Indicating the number of _____
  - **Infix:** Indicating the level of _____
  - **Suffix:** Indicating the primary _____
  - **Visualised** *(Label Below)*

propane

propene

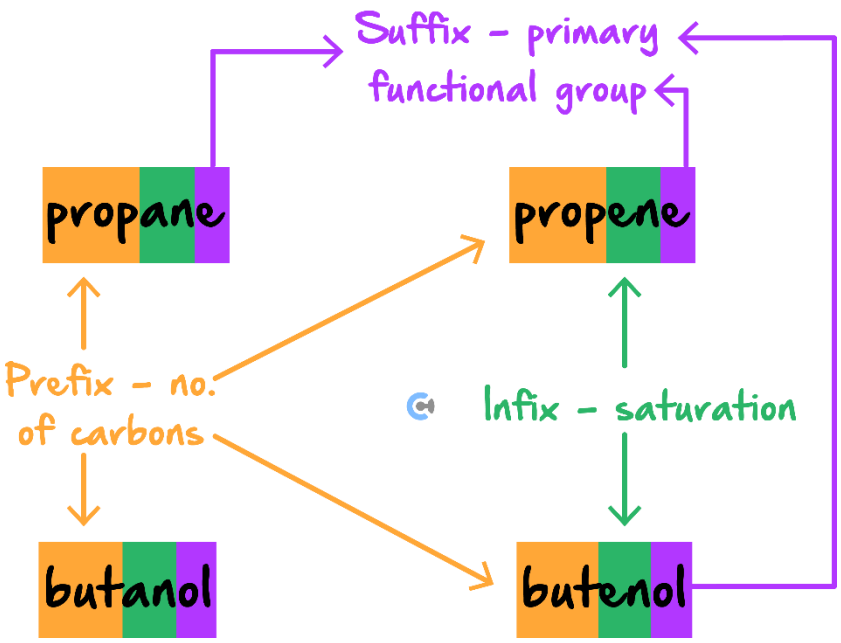
butanol

butenol

NOTE: The suffix '-e' is the 'default' one when there are no primary functional groups (more on this later!).

Definition

Naming Breakdown



TIP: Remember **alkane** v/s **alkene** as:

Alkane	Alkene
$alk - an - e$	$alk - en - e$
'-an-' starts with 'a': _____ vowel → _____ bonds	'-en-' starts with 'e': _____ vowel → _____ bonds

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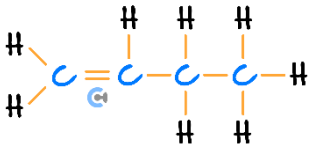
Exploration: Alkenes

- **One** carbon-carbon double bond:

Number of Carbons	2	3	4
Name			
Structural Formula			
Semi-Structural Formula			
Skeletal Formula			
Molecular Formula			C_4H_8

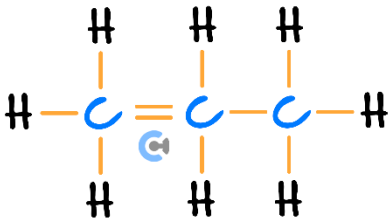
- General molecular formula: _____

NOTE: The double bond can be drawn on the inside or outside of the molecule for skeletal diagrams.

TIP: When drawing semi-structural formulas for alkenes, it's a good idea to draw the double bond in using '='.

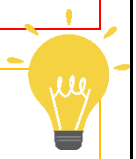
Misconception

" Adding a double bond doesn't change anything else to the molecule, and thus, the molecule will look like the following:"



Truth: The molecule changes its structure as the amount of bonds has changed

- Bonds on each carbon atom? *(Label Above)*
- Carbon can only form a maximum of _____ covalent bonds.
- **'Correct' representation:**



TIP: Think of hydrogen as the substance used to 'fill in the blanks' -

1. Start with the basic skeleton carbon structure of the molecule.
2. Then **add hydrogen** to each carbon until each of them has _____ total covalent bonds.

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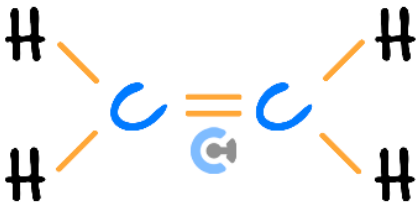
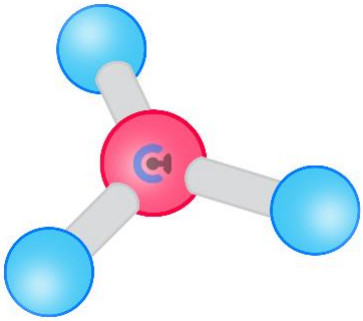
Discussion: What is the geometry of each carbon in ethene?



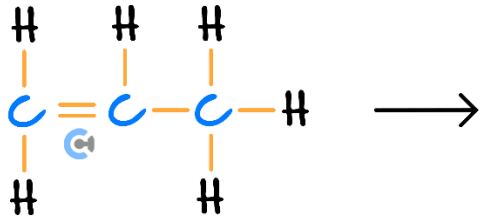
_____

Exploration: Molecular Geometry of Alkenes

- There are only _____ bonding sites instead of four!



- Double bond = _____ shape = bonds drawn at _____ angles to each other.
- **Propene Accurately:**



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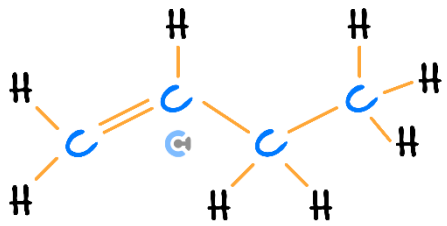
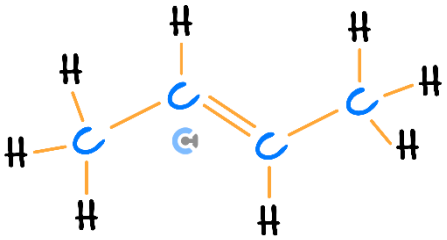
Sub-Section: Positions of C = C double bonds

Similar to branching, the double bond can appear in different locations!

Exploration: Positions of C = C double bonds

- Are the following arrangements the same? [Yes] / [No]

Arrangement 1	Arrangement 2
	
Which carbons is the double bond between? _____	Which carbons is the double bond between? _____
Name _____	Name _____

- To indicate where the double bond is, a **number** is placed in front of the '-en-' **infix.**

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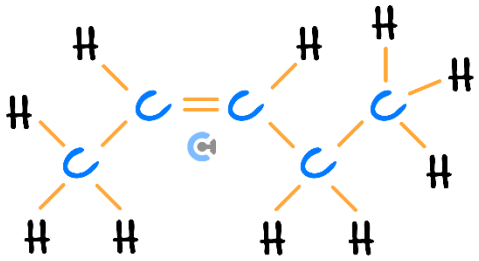
Try some questions!

Question 4

For each of the following, name the molecule and draw the semi-structural formula & skeletal diagram.

a.

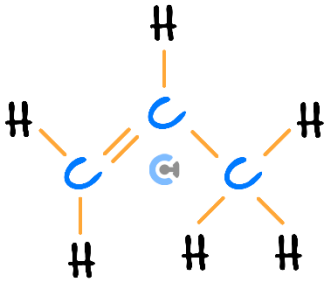


i. Name and write the semi-structural formula for each of the following:

Name	Semi-Structural Formula

ii. Draw the skeletal structure.

b.



i. Name and write the semi-structural formula for each of the following:

Name	Semi-Structural Formula

ii. Draw the skeletal structure.

TIP: Always look out for reductant numbers! Functional groups such as alkene groups are no different.

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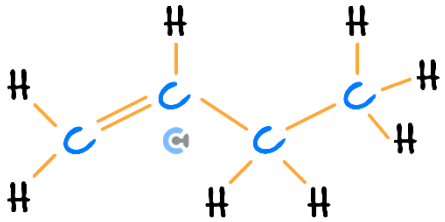
There are actually two different ways to name alkenes!

Exploration: Different methods of naming alkenes.

- Consider the following:



Naming Method #1	Naming Method #2

Which one is recommended?

[Naming Method #1] / [Naming Method #2]

- Naming method #2 seems cleaner but can become **more confusing** when molecules are complicated.
- **Example**:
  - 3-methylbut-1-en-2-ol v/s 3-methyl-1-buten-2-ol
- However, either is accepted!

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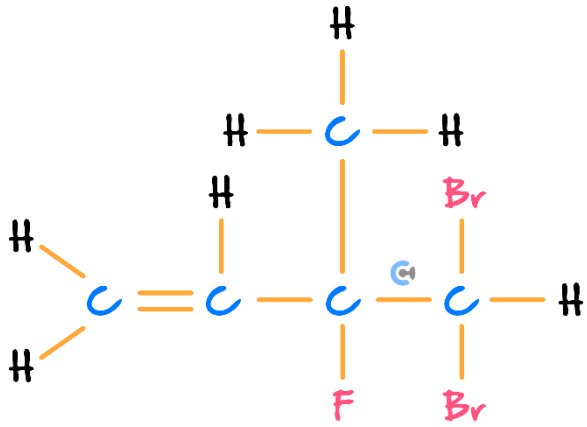
How does the priority of these functional groups compare?

Exploration: Priority

- Consider the following molecule:



- What has priority when numbering? [alkenyl] / [alkyl] / [halogens]
- Number the carbons accordingly. *(Label Above)*
- **Name**: _____

Alkene Priority

- When naming alkenes, the alkenyl functional group [takes priority] / [does not take priority] over halogens and alkyl chains, and thus receives the [biggest] / [smallest] number possible.

NOTE: Remember to go by _____ order when writing the name!

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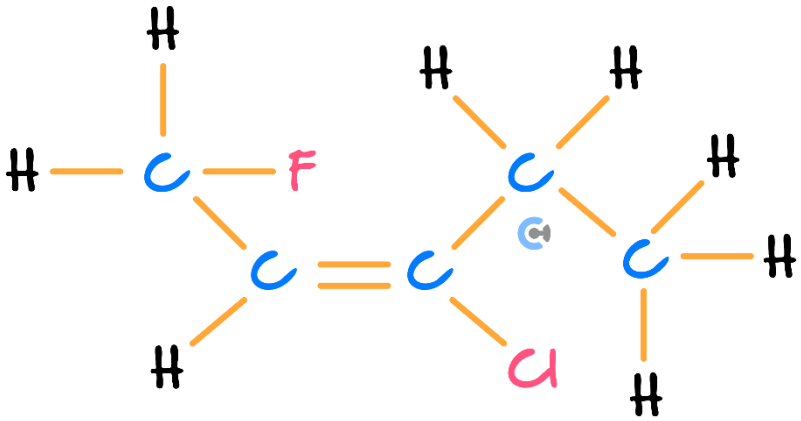
Try some questions!

Question 5

For each of the following, name the molecule and draw the semi-structural formula & skeletal diagram.

a.

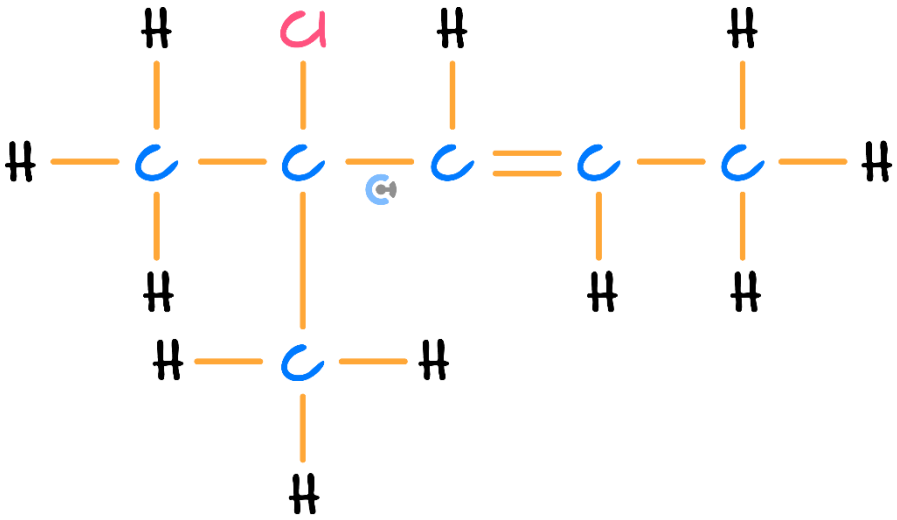


i. Name and write the semi-structural formula for each of the following:

Name	Semi-Structural Formula

ii. Draw the skeletal structure.

b.

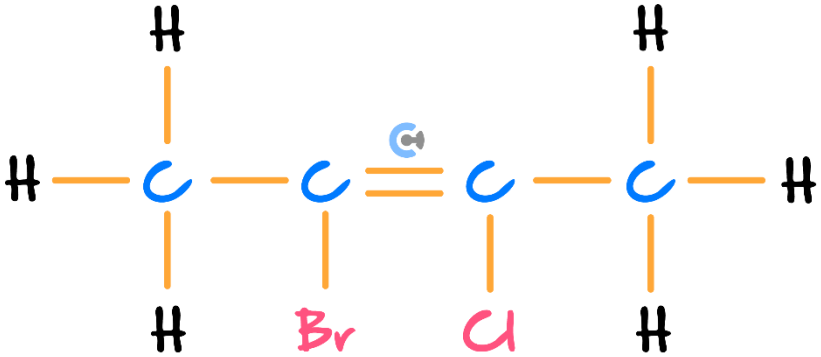


i. Name and write the semi-structural formula for each of the following:

Name	Semi-Structural Formula
	$CH_3CCl(CH_3)CH = CHCH_3$

ii. Draw the skeletal structure.

c.



i. Name and write the semi-structural formula for each of the following:

Name	Semi-Structural Formula
	$CH_3CBr = CClCH_3$

ii. Draw the skeletal structure.

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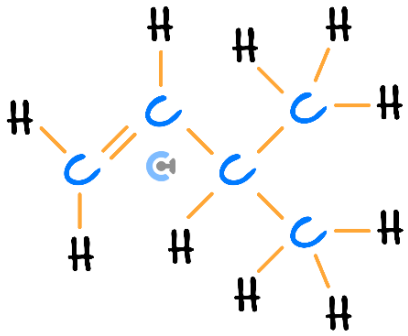
Question 6 Additional Question.



a. Complete the table below:

Name	Semi-Structural Formula

b. Draw the skeletal structure.

REMINDER: Don't forget, when there is a tie, the halogen with a greater molar mass gets priority!

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Sub-Section: Multiple Double Bonds

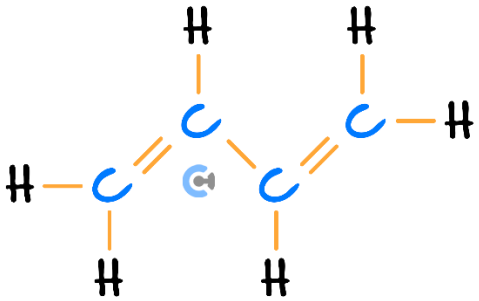
Molecules can also have multiple double bonds!

Active Recall: What prefix do we use to indicate we have $2, 3$ or 4 of the same functional group?

Number of Duplicate Functional Groups	Prefix
2	
3	
4	

Exploration: Multiple Double Bond Naming

- Consider the following:



- 'Correct' Name:

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Misconception

" The above molecule is named 'but-1, 3-diene' or '1, 3 – butdiene "

Truth: This is not correct!

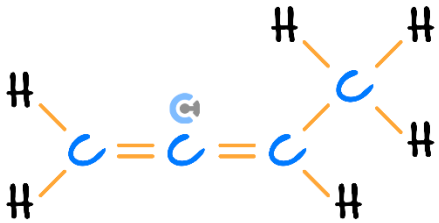
- Because it is hard to pronounce the sounds 'but-' and then '-di' without a vowel, the vowel 'a' is inserted in between!
- Correct Name: _____

Try more questions!

Question 7

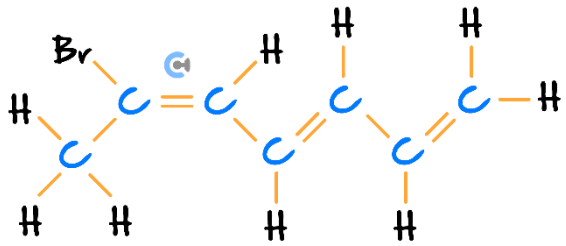
Name each of the following and draw the semi-structural formula.

a.



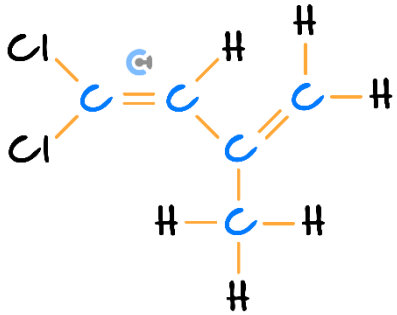
Name	Semi-Structural Formula

b.



Name	Semi-Structural Formula

c.



Name	Semi-Structural Formula

NOTE: Since the double bonds (highest priority) are on carbon numbers 1 and 3 regardless of counting direction, the next highest priority functional group gets numbering priority: [Halogens] / [Alkyl Groups].

Space for Personal Notes

Section B: Isomers

Discussion: What was the major downside of molecular formula?

Exploration: Potential structures for C_4H_{10}

- General molecular formula of C_4H_{10}: _____
- Potential homologous series: C_4H_{10}: [Alkanes] / [Alkenes] / [Cycloalkanes]
- What might it look like?

	Arrangement #1	Arrangement #2
Structural Formula		
Name		
Molecular Formula		

- **Conclusion:** They have [same] / [different] molecular formula, but [same] / [different] structural formula.
- Known as _____!

Structural Isomers

- **Definition:** Molecules with the _____ molecular formula but a _____ arrangement of atoms.
- In VCE Chemistry ½, **three** different types:
  - Chain Isomers
  - Positional Isomers
  - Functional Isomers

NOTE: Functional Isomers will be covered later on in this booklet!

Space for Personal Notes

Sub-Section: Chain Isomers

Let's look at chain isomers!

Chain Isomers

- **Definition**: Chain isomers are a consequence of carbon's ability to _____.

Exploration: Chain Isomers

$$C_6H_{14}$$

- Different chain arrangements:

Arrangements	

NOTE: Chain isomers have relatively [similar] / [different] names.

How about positional isomers?

Space for Personal Notes

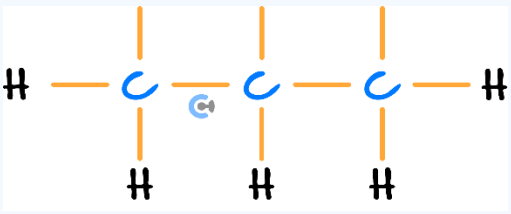
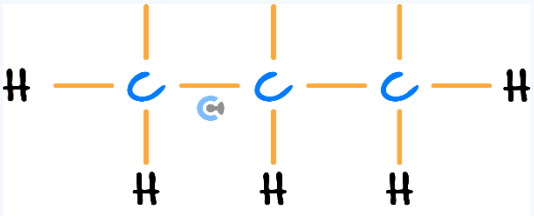
Sub-Section: Positional Isomers

Positional Isomers

- Positional isomers tend to occur for organic molecules that contain _____
- Occur when functional groups exist in different _____!

Exploration: Haloalkane Position Isomers

- Consider chloropropane: C_3H_7Cl
- Where can the chlorine be positioned on the molecule?

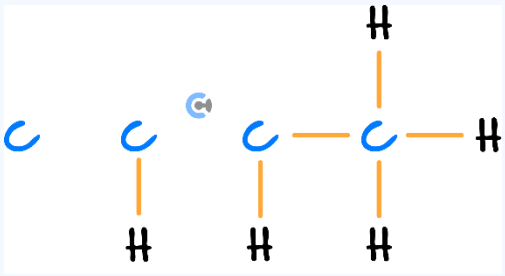
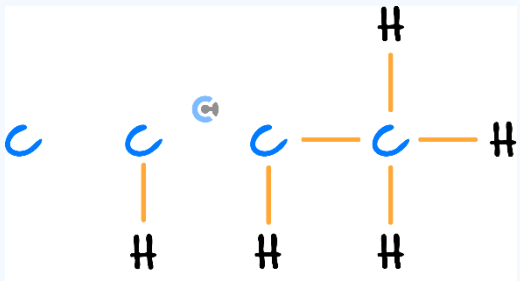
	Arrangement #1	Arrangement #2
Structural Formula		
Name		

Space for Personal Notes

How about alkenes?

Exploration: Alkene Positional Isomers

- Consider butene, C_4H_8 with a singular $C = C$ double bond:
  - Where can the $C = C$ double bond be positioned on the molecule?

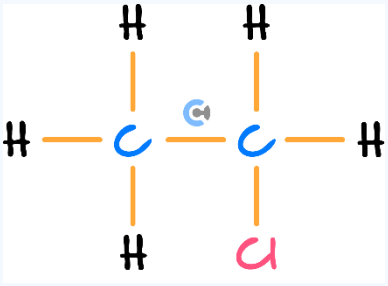
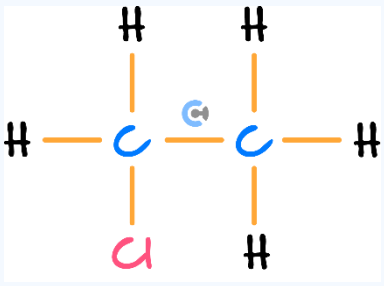
	Arrangement #1	Arrangement #2
Structural Formula		
Name		

NOTE: Positional isomers have [different] / [same] names, just with different numbers!

Space for Personal Notes

Misconception

" The following two configurations are positional isomers "

Arrangement #1	Arrangement #2
	

Truth

- What is the name of each of the arrangements?

Arrangement #1	Arrangement #2

- The molecules are actually the _____!

NOTE: Be careful that when drawing positional isomers, you _____ just draw the **same** molecule from a **different perspective.**

Active Recall: What is a chain isomer?

_____

Active Recall: What is a positional isomer?

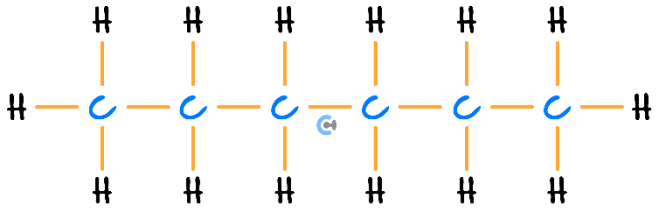
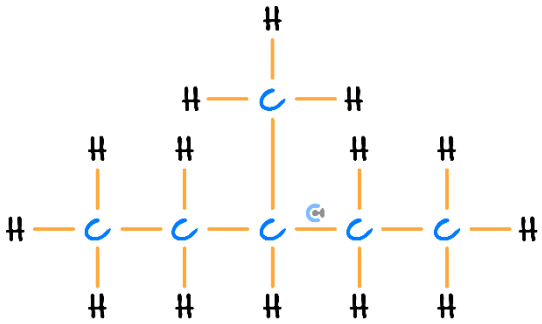
_____

Try some questions!

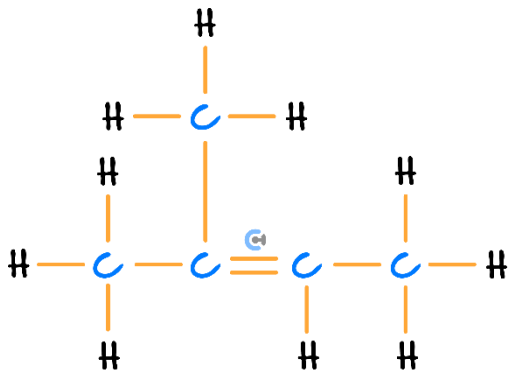
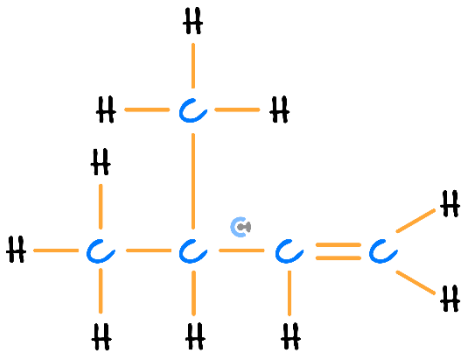
Question 8

Identify what type of isomers each of the two arrangements are.

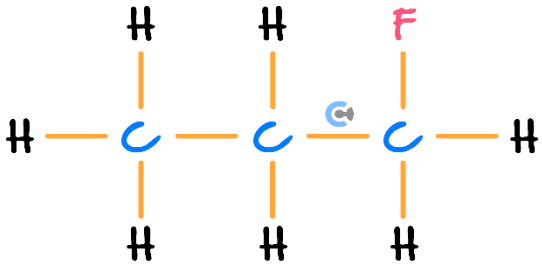
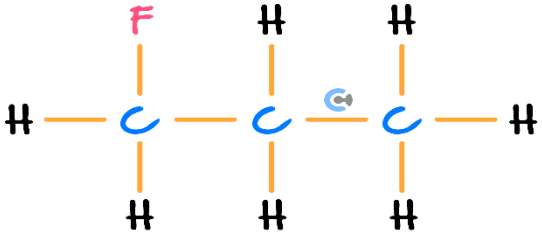
a.

Arrangement #1	Arrangement #2
	

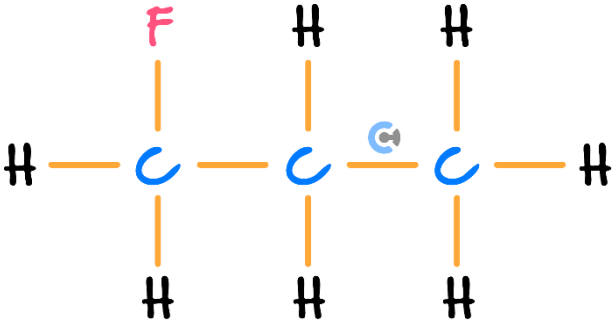
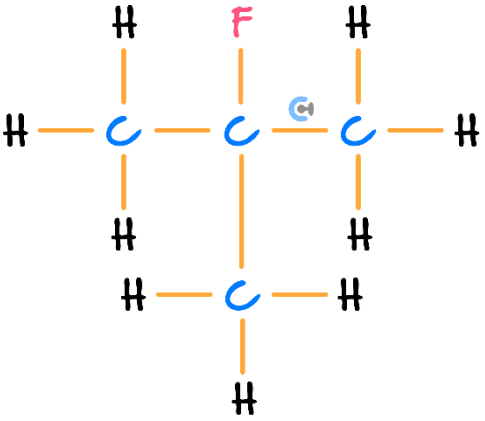
b.

Arrangement #1	Arrangement #2
	

c.

Arrangement #1	Arrangement #2
	

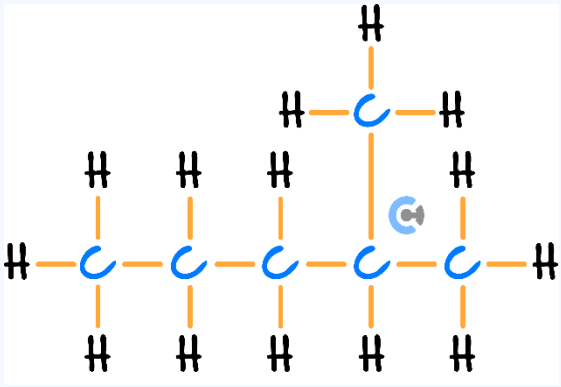
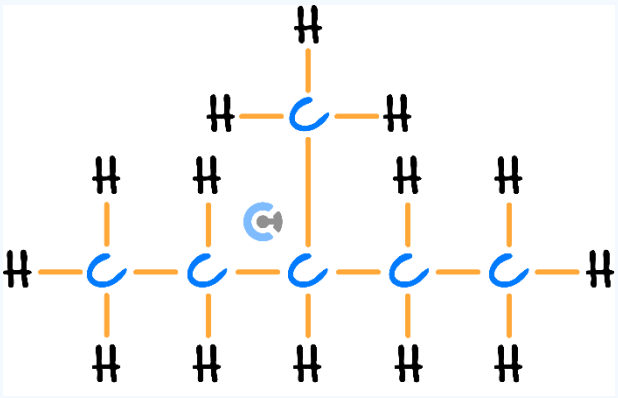
d.

Arrangement #1	Arrangement #2
	

NOTE: Sometimes, two molecules might be both chain and positional isomers!

ALSO NOTE: Sometimes, the molecules are identical, so they are neither!

Discussion: What type of isomers are these pairs of molecules? Chain Isomers or Positional Isomers?

Arrangement #1	Arrangement #2
	
2-methylpentane	**3-methylpentane**

[Chain] / [Positional]

NOTE: Methyl groups are considered a _____ , and because it is in a different location, it is considered a [Chain Isomer] / [Positional Isomer].

ALSO NOTE: Chain isomers only exist when the **type of branch** changes, not its position!

Space for Personal Notes

Sub-Section: Drawing Out Potential Isomers

Context

- Sometimes, questions will ask for multiple different isomers to be drawn out.

Active Recall: What are the general molecular formulas (e.g., C_xH_y) for alkanes, alkenes, and cyclic molecules?

Alkanes	Alkenes	Cyclic Molecules

Let's have a look at how to approach these questions!

Exploration: C_4H_8 Structural Isomers

- C_4H_8 - general formula: _____
- Possible functional groups: [Alkanes] / [Alkenes] / [Cyclic]

- Structures:

Name	Structural Formula/Skeletal Diagram

NOTE: While we went through this example, cyclic molecules will not be heavily tested in VCE Chemistry ½!

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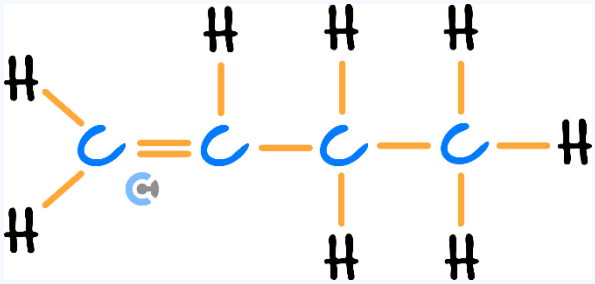
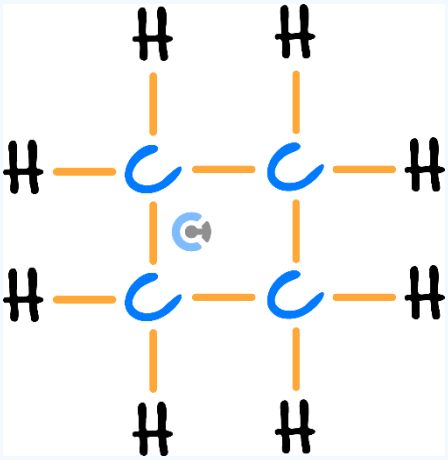
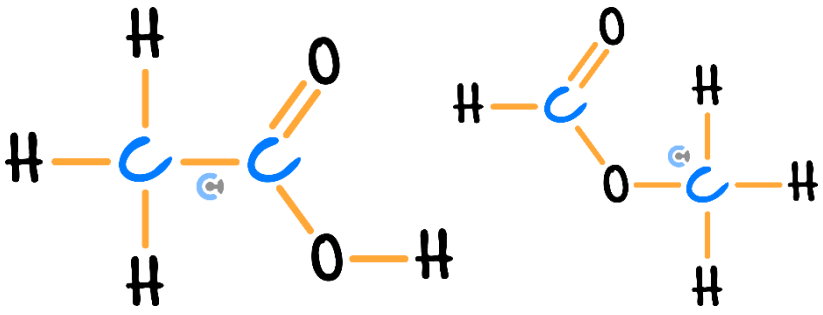
Discussion: Are the two isomers of C_4H_8 below chain or positional?

Arrangement #1	Arrangement #2
	
But-1-ene	Cyclobutane

[Chain] / [Positional] / [Both] / [Neither]

Functional Isomers

- **Definition**: Isomers which have the same molecular formula, but have _____ groups.
- For example:



NOTE: Functional isomers are more prevalent when we cover other functional groups such as carboxyl groups and ester groups, as shown above!

TIPS: When finding different isomers

1. Find what _____ it can have by looking at the general molecular formula.
2. Select one **chain isomer**, then **move** the functional groups around to find all _____ isomers.
3. Find another _____ isomer and find all possible **positional isomers** of this new chain!

Space for Personal Notes

Let's have a look at a question together!

Question 9 Walkthrough.

State how many possible isomers of $C_5H_{11}Br$ can be found.

NOTE: Having a **halogen** (e.g., Br or Cl) '**counts**' as **having another hydrogen**, so $C_5H_{11}Br$ is effectively the same as C_5H_{12} which follows the general molecular formula of C_nH_{2n+2}, and is thus classified as an alkane!

ALSO NOTE: Usually there won't be that many possible isomers present!

Space for Personal Notes

Your turn!

Question 10

State how many possible isomers of C_4H_9Cl can be found.

Question 11

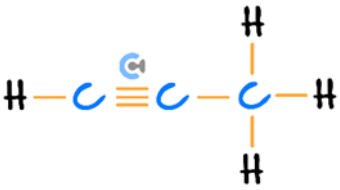
State how many possible isomers of C_3H_6 can be found.

Question 12 Additional Question.

Draw the **skeletal structure** for **all** the potential isomers of C_5H_{10}, given that there are 10 possible isomers in total.

Extension: Carbon – Carbon triple bonds (C ≡ C)

- Carbon – Carbon triple bonds (C ≡ C) are no longer tested in the study design, but look like the following:
- They are called **alkynes**, and have the infix of '-yn'.

Number of Carbons	2	3
Name	Ethyne	Propyne
Structural Formula		
Semi-Structural Formula		
Skeletal Formula		
Molecular Formula	C_2H_2	C_3H_4

Space for Personal Notes

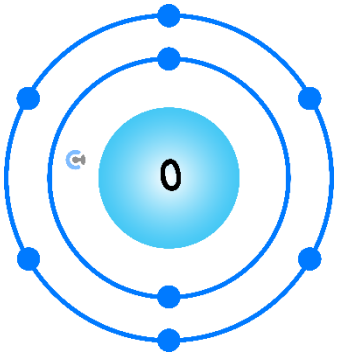
Section C: Oxygen-Containing Functional Groups

Context

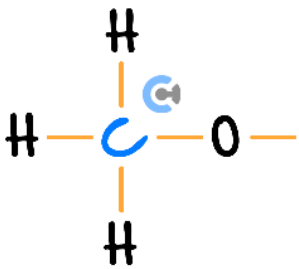
- **So far:** Hydrocarbons.
- **Now:** Oxygen within the molecule.

Exploration: Oxygen-Containing Functional Groups

- If we look at **oxygen** which is a **group 16** element with **6 valence electrons**:

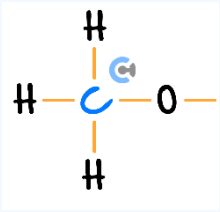
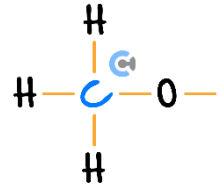


- Covalent bonds: _____
- Possible bonds:
  - _____ single covalent bonds.
  - 1 _____ covalent bond.
- Consider **a single covalent bond** between carbon and oxygen:



- As oxygens need to form **two** covalent bonds, something else needs to be attached to the other side.

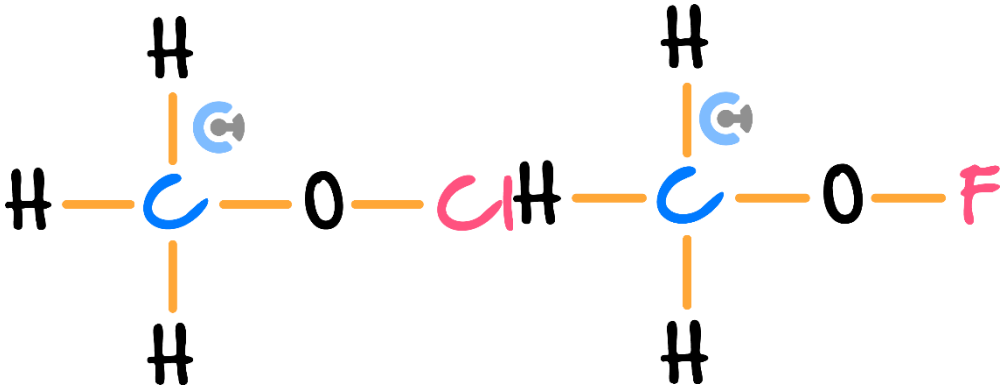
- What can be attached to the other side?

Element	Structural Formula	Type of Functional Group
		
		

NOTE: Ethers are not in the study design, but **hydroxyl groups ($-OH$)** are!

Extension: Can a halogen be attached to the other end of the oxygen?

- While this can happen, it is not in the study design either!



Let's have a look at hydroxyl groups in depth!

Sub-Section: Alcohols

Alcohols

- An alkanol / alcohol is an organic compound that carries at least one _____ functional group _____.
- **Functional Group Visualised:**

- **Class / Homologous Series:** _____
- **Functional Group Name:** _____
- **Suffix:** _____
- **Priority:** _____

The numbering priority of the functional groups can be found on page 15 of the Databook

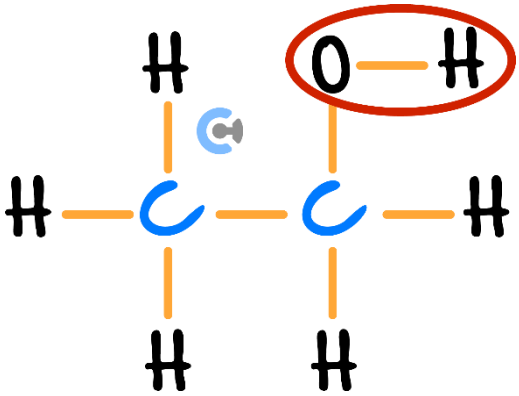
19. Functional group nomenclature in organic chemistry

The following table shows the priority of functional groups when naming organic compounds that contain more than one functional group. The functional group with the highest priority determines the suffix of the compound.

Class of compound	Functional group name	Prefix	Suffix
carboxylic acid	carboxyl	–	-oic acid
ester	ester	–	-oate
amide	amide	–	-amide
aldehyde	carbonyl	–	-al
ketone	carbonyl	–	-one
alcohol	hydroxy/ hydroxyl	hydroxy-	-ol
amine	amino	amino-	-amine
alkene	alkenyl	–	-ene
halogen	'halo' (i.e. bromo, chloro, fluoro, iodo)	bromo- chloro- fluoro- iodo-	–

Misconception

" The following circled functional group is an alcohol functional group."

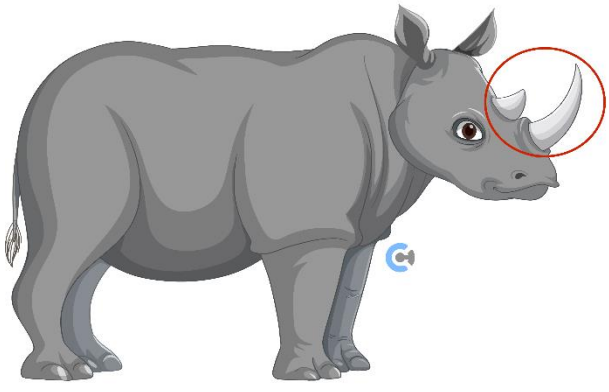


Truth: This is wrong!

- The functional group is called a _____ group!
- The whole molecule is an _____!
- VCAA is quite strict on this!

Analogy: Animals

- Consider the following two animals:

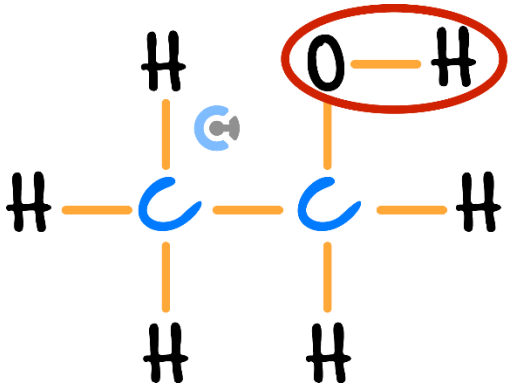


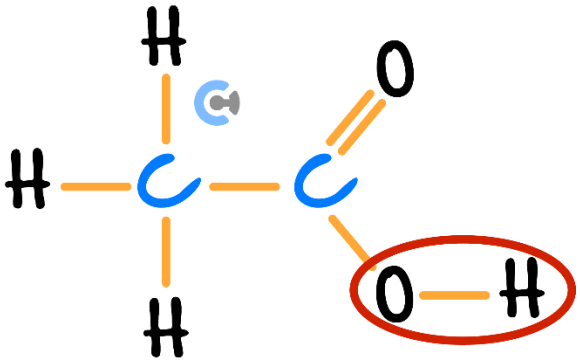
- What is the circled feature? _____

- What animal are they?

Animal #1	Animal #2

- Consider the following two molecules:





- What is the circled functional group? _____

- What class of molecules are they?

Class of Molecule #1	Class of Molecule #2

NOTE: Carboxylic Acids will be covered next week!

Active Recall: What is the suffix for alcohols?

_____

Exploration: Alcohols

Number of Carbons	1	2
Name		
Structural Formula		
Semi-Structural Formula		
Skeletal Formula		
Molecular Formula		

NOTE: We still include the '-an-' infix as the molecule contains carbon-carbon single bonds.

REMINDER: Don't forget that in structural formulas, every bond must be shown, even between the O and H!

Let's have a look at more examples together!

Active Recall: What is the numbering priority of hydroxyl groups?

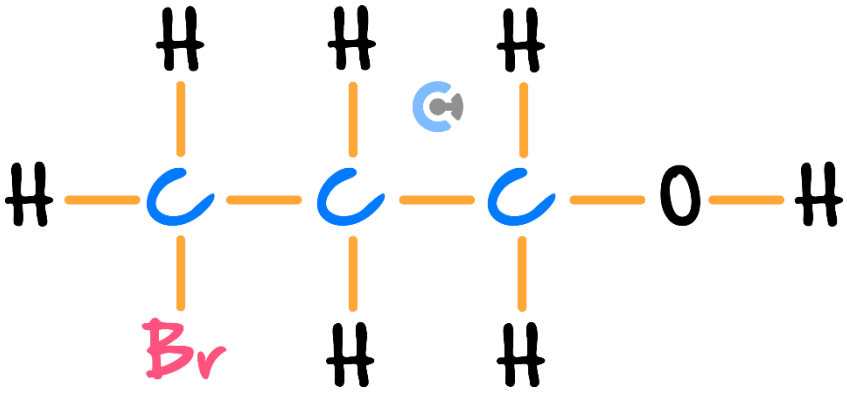
Numbering Priority
[High] / [Medium] / [Low]

Active Recall: When there are multiple of the same functional group, what is the prefix used?

Two of the same functional group	Three of the same functional group	Four of the same functional group

Exploration: Naming Alcohols

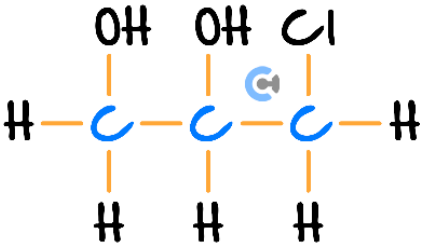
- Consider Molecule #1:



- Number the carbons according to their priority. *(Label Above)*

Name: _____

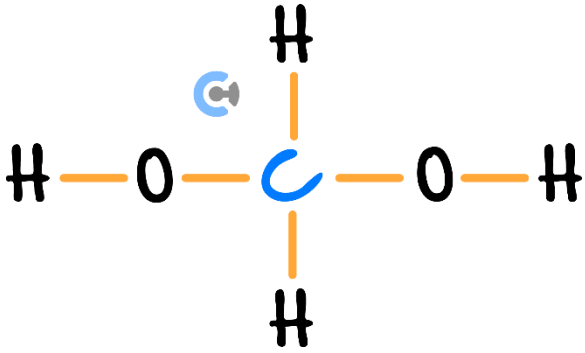
- Consider molecule #2:



- Number the carbons according to their priority. *(Label Above)*
- Suffix for two hydroxyl groups: _____.
- Name: _____

Misconception

" The following molecule is called methandiol "



TRUTH:

- Similar to alkenes, because the 'methan' and 'diol' is hard to pronounce.
- The letter _____ is added in between to aid with pronunciation!
- Name: _____
- This is different to alkenes, whereby the letter _____ was added!

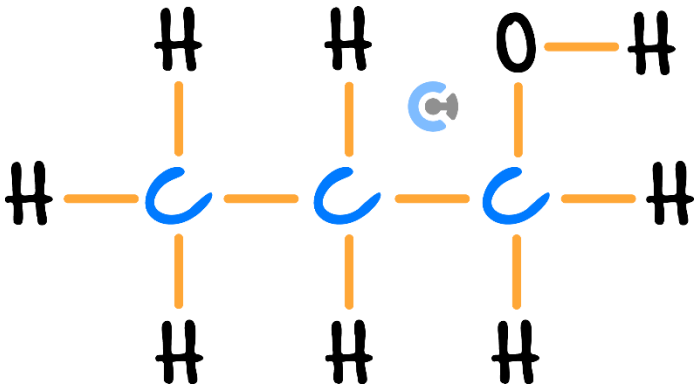
Space for Personal Notes

Try some questions!

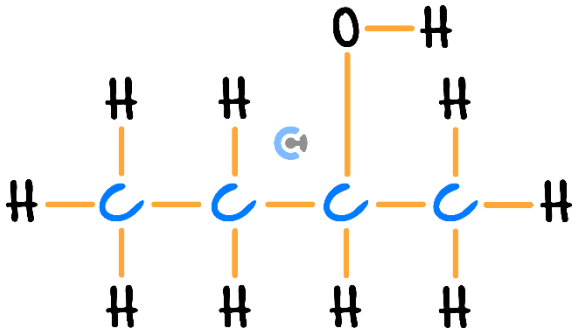
Question 13

Name the following molecules:

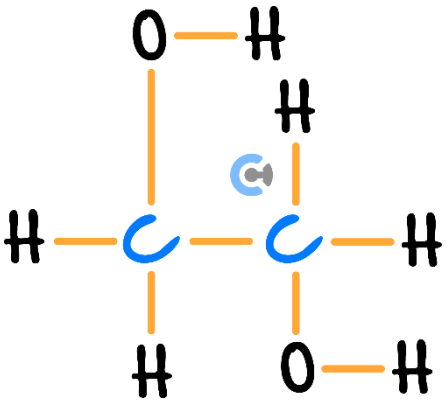
a.



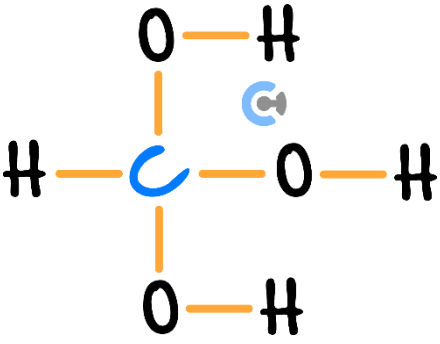
b.



c.



d.



NOTE: As there is only one carbon in methanetriol, the numbers do not need to be specified!

Question 14

Draw the structural formula for following molecules.

a. Ethanol

b. 4-chlorobutan-2-ol

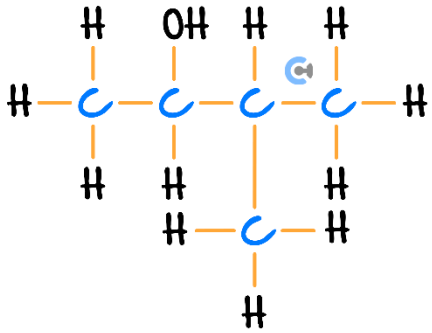
c. Propane-1,3-diol

Space for Personal Notes

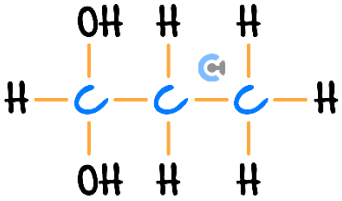
Question 15

For each of the following, name the molecules:

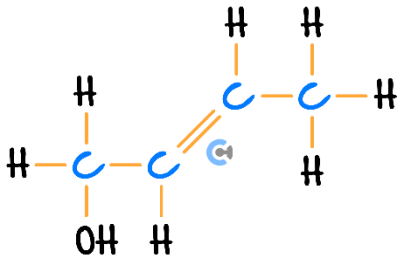
a.



b.



c.



NOTE: For the above example, the [alkenyl] / [hydroxyl] group gets priority.

ALSO NOTE: The **infix** is changed to [-an-] / [-en-] when a C = C is present!

Space for Personal Notes

Question 16 Additional Question.

Draw the skeletal structure for all possible isomers of $C_4H_{10}O$ (there are 4 total).

Space for Personal Notes

Contour Check

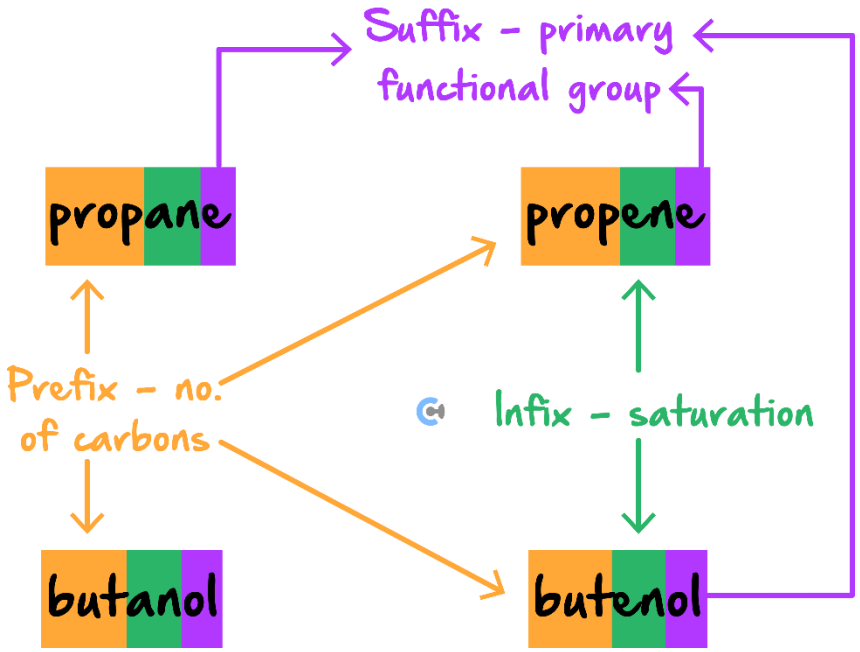
☐ Learning Objective: [2.6.1] – Apply IUPAC conventions to identify, draw & write names of straight-chained & branched alkenes

Study Design

"The grouping of hydrocarbon compounds into families (alkanes, haloalkanes, alkenes, alcohols, carboxylic acids) based upon similarities in their physical and chemical properties, including general formulas and general uses based on their properties."

Key Takeaways

- ☐ A _____ is a group of organic compounds which differ from each other by a -CH_2 – unit.
- ☐ An **alkene** is a hydrocarbon containing one or more **carbon-carbon** [single] / [double] bonds.
- ☐ **Infix:**
- ☐ **Functional group name:**
- ☐ Molecules that have carbon-carbon **single** bonds are considered to be [saturated] / [unsaturated].
- ☐ Molecules with carbon-carbon **double** or **triple** bonds are considered [saturated] / [unsaturated].
- ☐ Each organic molecule's name is comprised of **3 parts:**
  - **Prefix:** indicating the number of _____.
  - **Infix:** indicating the level of _____.
  - **Suffix:** indicating the primary _____.



- When naming alkenes, the alkenyl functional group [takes priority] / [does not take priority] over halogens and alkyl chains, and thus receives the [biggest] / [smallest] number possible.
- When there are multiple double bonds, remember to add an _____ for pronunciation purposes.

☐ Learning Objective: [2.6.2] – Identify & explain what structural isomers are

Study Design

"Representations of organic compounds (structural formulas, semi-structural formulas) and naming according to the International Union of Pure and Applied Chemistry (IUPAC) systematic nomenclature (limited to non-cyclic compounds up to $C8$, and structural isomers up to $C5$)."

Key Takeaways

- ☐ Structural isomers have the [same] / [different] molecular formula, but [same] / [different] structural formulas.
- ☐ [Chain] / [Positional] / [Functional] isomers are a consequence of carbon's ability to **branch.**
- ☐ Chain isomers have relatively [similar] / [different] names to one another.
- ☐ [Chain] / [Positional] / [Functional] isomers occur when functional groups exist in different **positions.**
- ☐ Positional isomers have relatively [similar] / [different] names to one another.
- ☐ [Chain] / [Positional] / [Functional] isomers have the same molecular formula, but have **different functional** groups.

☐ Learning Objective: [2.6.3] – Find possible structural isomers (chain, positional, functional) of alkanes, alkenes & haloalkanes from a given molecular formula

Study Design

"Representations of organic compounds (structural formulas, semi-structural formulas) and naming according to the International Union of Pure and Applied Chemistry (IUPAC) systematic nomenclature (limited to non-cyclic compounds up to $C8$, and structural isomers up to $C5$)."

Key Takeaways

☐ When finding different isomers:

1. Find what _____ groups it can have by looking at the **general molecular formula.**
2. Select one [chain] / [positional] **isomer**, then **move** the functional groups around to find all [chain] / [positional] isomers.
3. Find another [chain] / [positional] isomer and find all possible [chain] / [positional] **isomers** of this new chain!

☐ Learning Objective: [2.6.4] – Apply IUPAC conventions to identify, draw & write IUPAC names of straight-chained & branched alcohols

Study Design

"The grouping of hydrocarbon compounds into families (alkanes, haloalkanes, alkenes, alcohols, carboxylic acids) based upon similarities in their physical and chemical properties, including general formulas and general uses based on their properties."

Key Takeaways

- ☐ An alkanol / alcohol is an organic compound that carries at least one _____ functional group _____.
- ☐ **Class/Homologous Series:** _____
- ☐ **Functional Group Name:** _____
- ☐ **Suffix:** _____
- ☐ **Priority:** _____
- ☐ Multiple hydroxyl groups: The letter _____ is added in between to aid with pronunciation!

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