CHM 103

ORGANIC CHEMSTRY I

Department of Chemical Sciences
Faculty of Science and Technology
Bingham University, Karu

Course Lecturer: Joseph C. Oguegbulu
Joseph.oguegbulu@binghamuni.edu.ng

COURSE CONTENT

PART A – Mr. Joseph

- Introduction. History, classifications — 0.5 week
- Carbon: Bonding in organic compounds, structure — 0.5 week
- Functional groups — 0.5 week
- IUPAC nomenclature — 1 week
- Isomerism – Structural & Stereo-isomerism — 2 weeks
- Hybridisation – Resonance effects & others — 2 weeks

PART B – Assoc. Prof. Okoli

- Alkanes, Alkenes, Alkynes
- Alkyl halides, Alkanols
- Carbonyl compounds: Alkanals and Alkanones.

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LECTURE III

- WRITING CHEMICAL FORMULARS
- GENERAL FORMULAS
- MOLECULAR FORMULAS
- STRUCTURAL FORMULAS
  - EXPRESSED
  - CONDENSED
  - SKELETAL

OBJECTIVES: At the end, you should be able to…

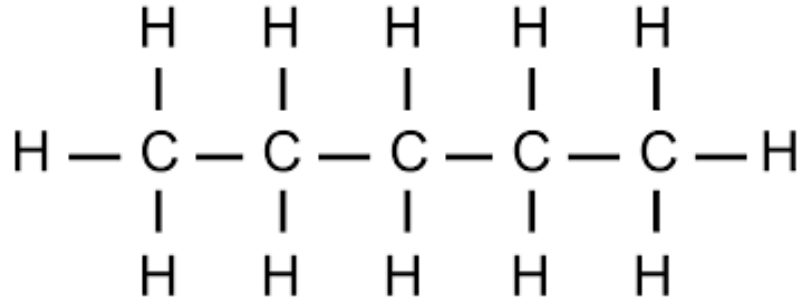
- Differentiate between the different formulas of organic compounds
- Draw the expressed, condensed & skeletal formulas of simple and semi-complex organic compounds
- Show the classifications of organic compounds

FORMULARS OF COMPOUNDS

- General formula e.g. C_2H_6O
- Empirical Formula e.g. C_2H_6O
- Molecular Formula e.g. C_2H_5OH
- Structural Formula e.g. CH_3CH_2OH
  - Expressed
  - Condensed
  - Skeletal

STRUCTURAL FORMULARS

- Expressed
  - All atoms are written out
  - All bonds shown
- Condensed
  - All atoms are written out
  - Bonds not shown unless double, triple
- Skeletal
  - Carbons and Hydrogens not drawn
  - Lines drawn at angle 120^{o}



$CH_3CH_2CH_2CH_2CH_3$

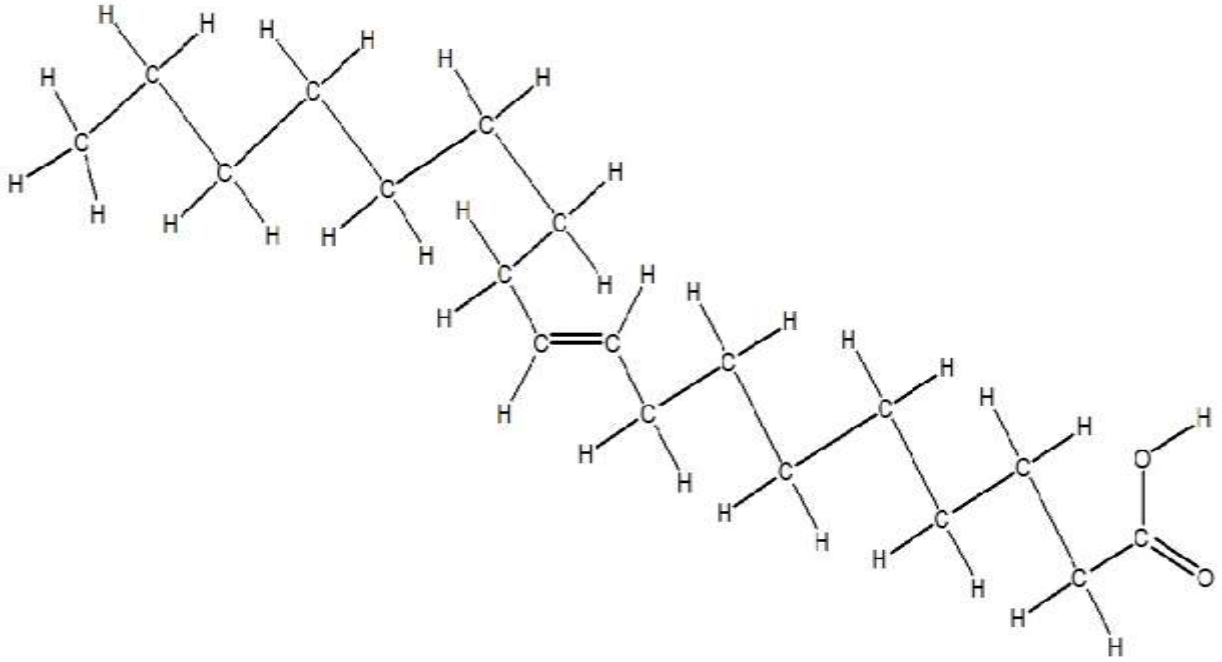
Pentane

DRAWING *CONDENSED* FORMULARS

EXAMPLE:

- $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

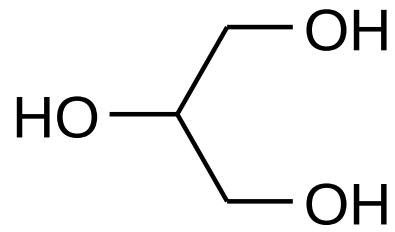
  condenses to……



- **HOW?**
- ***Solution:*** *Start by drawing out the CH_3. The $(CH_2)_7$ represents a repeating unit, meaning you must draw seven CH_2's one after another, which are bonded to a CH which is bonded (double bond) to another CH, and then draw out another seven CH_2's. The COOH represent a carboxylic acid, which means you have a C=O connected to an O-H.* ***Always double check your structure to ensure every carbon is making FOUR (4) bonds.*** *When you do this, you will see why the two CH needed to be double bonded.*

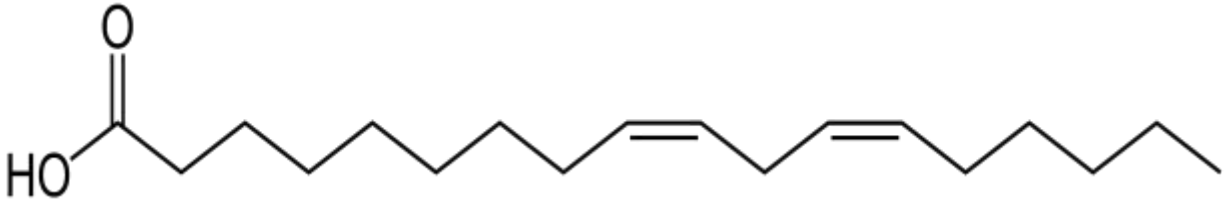
DRAWING *SKELETAL* FORMULAS

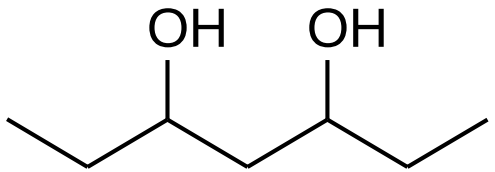
Pentane

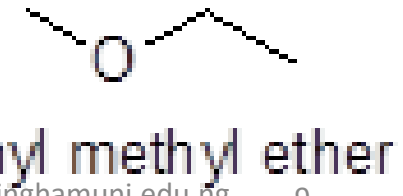


Glycerol

- C and H not shown
  - H is only shown when; -NH, -OH, -SH, etc
- Other elements, O,S,N, etc **MUST** be shown
- Lines represent bonds
  - Drawn at 120^{o} for convention
- End of line represent C (e.g. CH_3)
- Edges represent C (e.g CH_2)
- Octet rule always obeyed
  - **E.g. C must always have 4 bonds, O = 2 bonds, N= 3 bonds, H= 1 Bond, etc**
  - When you don't see 4 bonds on C, it means H is attached but not shown as usual
  - Or a double or triple bond is present



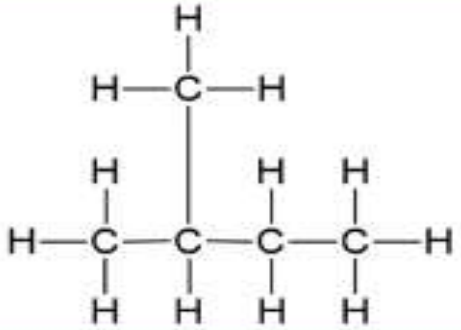
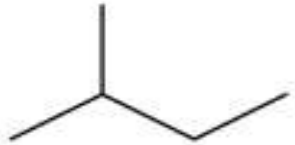
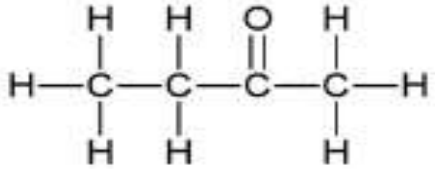
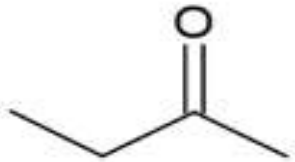




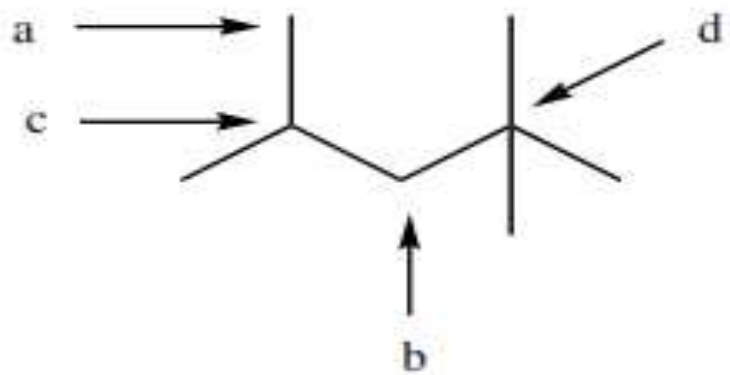
ethyl methyl ether

DIFFERENT STRUCTURAL FORMULAS

- See how same compound can be expressed in all three ways

Displayed	Condensed	Skeletal
	$CH_3CH(CH_3)CH_2CH_3$	
	$CH_3CH_2COCH_3$	

It is very important at this time to stress that since carbon must always have four covalent bonds in a neutral compound, the number of hydrogen atoms present at any carbon atom may simply be obtained by subtracting the number of bonds from four. Using this method, for the molecule 2,2,4-trimethylpentane (shown below), carbon a is connected to three hydrogen atoms, carbon b is connected to two hydrogen atoms, carbon c is connected to one hydrogen atom and carbon d is connected to no hydrogen atoms.



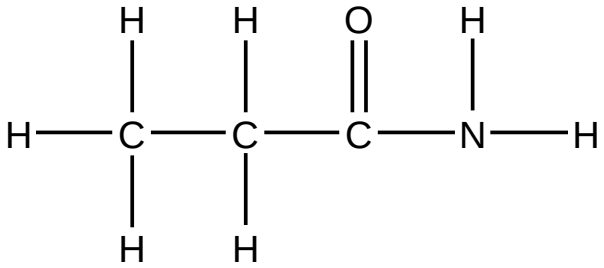
2,2,4-trimethylpentane

Carbon a is classified as being **primary** as it is attached to only one other carbon atom, and the hydrogen atoms bonded to carbon a are known as primary hydrogen atoms. Extending this concept leads to the designation of **secondary** for carbon b, **tertiary** for carbon c and **quaternary** for carbon d. You should be able to quickly determine that the compound above contains fifteen primary hydrogen atoms, two secondary hydrogen atoms and one tertiary hydrogen atom.

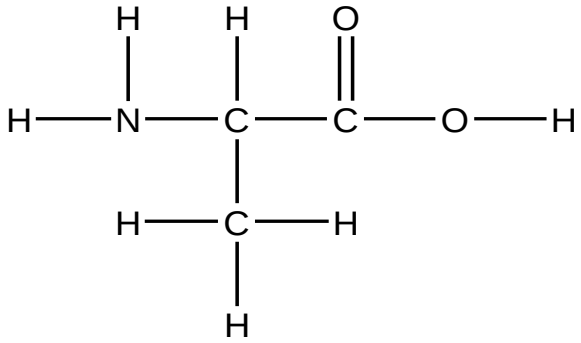
TUTORIAL 1

- **Q1: Draw the CONDENSED and SKELETAL formulas of…**

1.

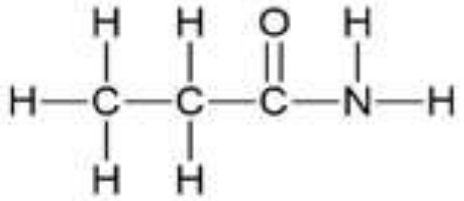
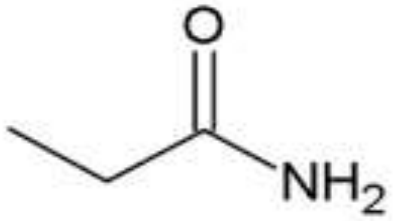
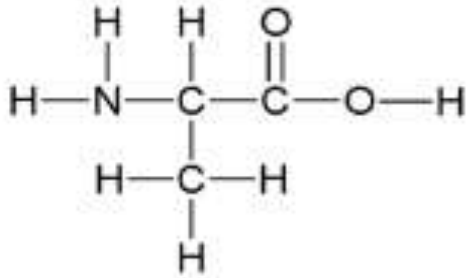
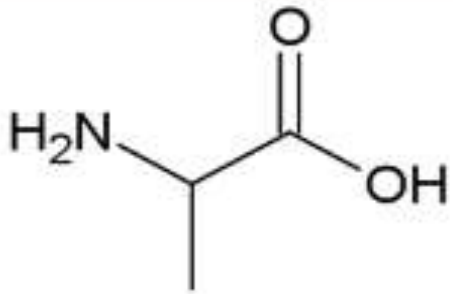


2.



TUTORIAL 1

- **Q1: ANSWER**

	Displayed	Condensed	Skeletal
1.		$CH_3CH_2CONH_2$	
2.		$CH_3CH(NH_2)CO_2H$	

TUTORIAL 1

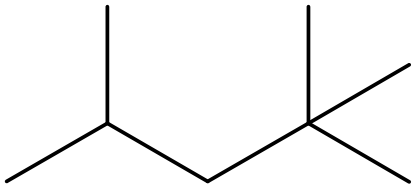
- Here are some more cute YouTube videos to help you with you with drawing skeletal formulas. Please click the links and watch carefully.

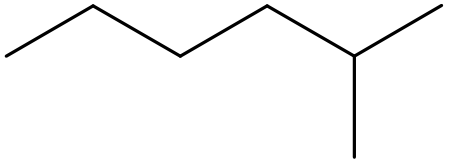
1. https://www.youtube.com/watch?v=RP6AS7XVIC8 *(most recommended)*

2. https://www.youtube.com/watch?v=TcvR_-d0wCU
3. https://www.youtube.com/watch?v=RP6AS7XVIC8
4. https://www.youtube.com/watch?v=U58E0xvVAig
5. https://www.youtube.com/watch?v=d2pBajWN3DI

TUTORIAL 1

- **Q1:** Convert the following skeletal structures into expressed formulas





- **Q1:** Convert the following condensed formuas to skeletal formulas
  - $CH_3CH_2CH_2CH(CH_3)CH(CH_3)_2$
  - CH_3CHFBr


Question

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LECTURE IV

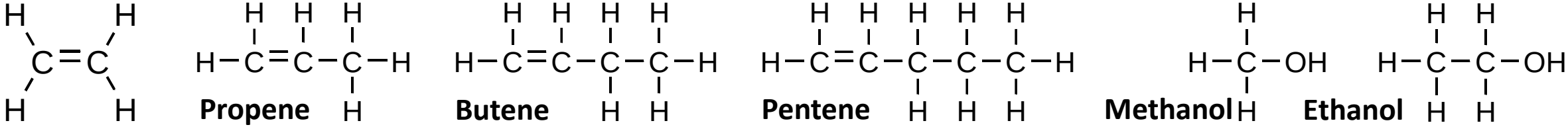
- HOMOLOGOUS SERIES
- IDENTIFICATION OF FUNCTIONAL GROUPS
- IUPAC NUMENCLATURE OF ORGANIC COMPOUNDS

OBJECTIVES: At the end, you should be able to…

- Appreciate the gradual variations in properties across a homolgs. series
- Identify functional groups from their general forml. or molecular formula
  - Show how 2name them as prefix/suffix
- Understand the rules governing the naming of cmpds & apply them
- Be able to convert drawn structures into IUPAC names and *vice verse*

HOMOLOGOUS SERIES

- Family of compounds with same functional group where…
  - Members (homologues) differ by a methylene group (i.e. CH_2)
- They have same empirical formula & same general formula
  - Hence **similar chemical properties**
  - With **gradual variations in the properties** as series progresses
- Eg Alkenes **(C_nH_{2n}):** Members **CH_4, C_2H_6, C_3H_8** all differ by **CH_2**
- Eg2: Alcohols **($C_nH_{2n+2}O$)** (R-OH). Members; CH_3OH, C_2H_5OH



Perhaps the easiest example would be…

Homologous Series of Alkanes

methane CH_4 ethane CH_3CH_3  propane $CH_3CH_2CH_3$ 

butane $CH_3CH_2CH_2CH_3$  pentane $CH_3(CH_2)_3CH_3$ 

hexane $CH_3(CH_2)_4CH_3$  heptane $CH_3(CH_2)_5CH_3$ 

octane $CH_3(CH_2)_6CH_3$ 

nonane $CH_3(CH_2)_7CH_3$ 

decane $CH_3(CH_2)_8CH_3$ 

HOMOLOGOUS SERIES: Characteristics

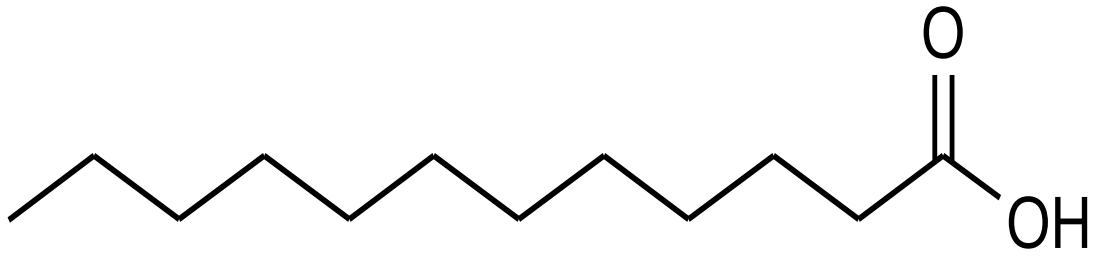
Organic compounds in the *same* homologous series:	Example: alkene
• possess the *same* general formula	C_nH_{2n}
• *differ* from the previous member in the series by a $-CH_2-$ group	$CH_2{=}CH_2$, $CH_2{=}CHCH_2{-}H$, $CH_2{=}CHCH_2CH_3$, $CH_2{=}CHCH_2CH_2CH_3$
• possess *similar* chemical properties, due to the presence of *same* functional group	• Alkenes possess a carbon-carbon double bond. • Alkenes undergo electrophilic addition reactions.
• show gradual change in physical properties due to increased molecular size and mass, caused by longer carbon chains	Ethene b.p. = −102 °C Propene b.p. = −48 °C 1-Butene b.p. = −6.5 °C 1-Pentene b.p. = 30 °C

HOMOLOGOUS SERIES

Q6

- **Show five (5) homologues of the compound below?**

Don't skip



QUESTIONS???

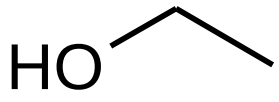
FUNCTIONAL GROUPS

- A functional group is a group of atoms bound together in a particular manner which…
  - Are responsible for the characteristic properties of the compound
  - Determines the kind of chemical reactions a compound undergoes

- e.g carboxylic acid (R-COOH), alcohol (R-OH), amine ($R-NH_2$).

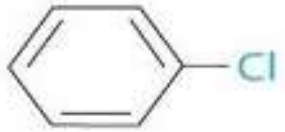
IDENTIFICATION OF FUNCTIONAL GROUPS

- It is important for the student to be able to recognise/ identify functional groups
  - **THE MORE YOU LOOK THE MORE YOU SEE!!!**
- You must be able to tell the following about them…
  - Name — e.g. Alcohol
  - General formula — e.g. R-OH
  - Examples — e.g. Ethanol
  - Structural formula — e.g CH_3CH_2OH
  - Naming as Suffix — -ol
  - Naming as Prefix — Hydroxy



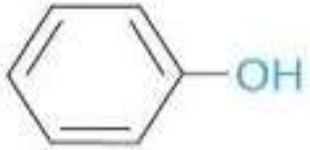
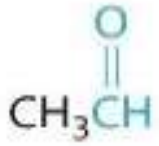
Ethanol

IDENTIFICATION OF FUNCTIONAL GROUPS

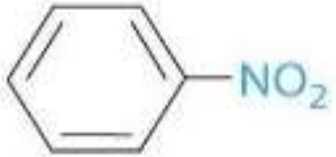
Class	General Formula	Example	Common Name (Systematic Name)	Common Suffix/Prefix (Systematic)
		Hydrocarbons		
Alkanes	RH	CH_3CH_3	ethane	-ane
Alkenes	$RR'C{=}CR''R'''$	$H_2C{=}CH_2$	ethylene (ethene)	-ene
Alkynes	$RC{\equiv}CR'$	$HC{\equiv}CH$	acetylene (ethyne)	(-yne)
Arenes	ArH^a		benzene	-ene
		Halogen-Containing Compounds		
Alkyl halides	RX	CH_3CH_2Cl	ethyl chloride (chloroethane)	halide (halo-)
Aryl halides	ArX^a		chlorobenzene	halo-

IDENTIFICATION OF FUNCTIONAL GROUPS

Oxygen-Containing Compounds

Alcohols	ROH[a]	CH_3CH_2OH	ethyl alcohol (ethanol)	-ol
Phenols	ArOH[b]		phenol	-ol
Ethers	ROR′	$H_3CH_2COCH_2CH_3$	diethyl ether	ether
Aldehydes	RCHO		acetaldehyde (ethanal)	-aldehyde (-al)
Ketones	RR′C═O		acetone (2-propanone)	-one
Carboxylic acids	RCO_2H		acetic acid (ethanoic acid)	-ic acid (-oic acid)

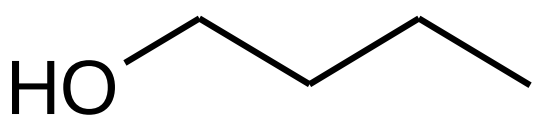
IDENTIFICATION OF FUNCTIONAL GROUPS

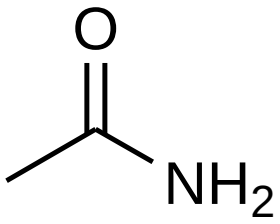
Carboxylic Acid Derivatives				
Esters	RCO_2R'	CH_3COCH_3	methyl acetate (methyl ethanoate)	-ate (-oate)
Amides	RCONHR′	CH_3CNHCH_3	*N*-methylacetamide	-amide
Nitrogen-Containing Compounds				
Amines	RNH_2, RNHR′, RNR′R″	$CH_3CH_2NH_2$	ethylamine	-amine
Nitriles	$RC{\equiv}N$	$H_3CC{\equiv}N$	acetonitrile	-nitrile
Nitro compounds	$ArNO_2$[a]		nitrobenzene	nitro-

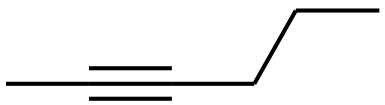
TUTORIAL III: FUNCT. GRP IDENTIFICATION

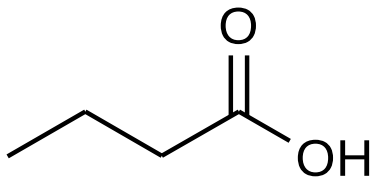
Q7

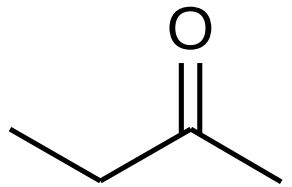
- **Identify the following functional groups**

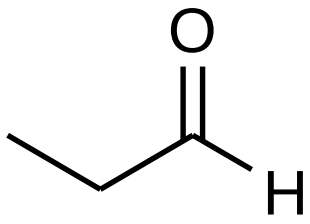


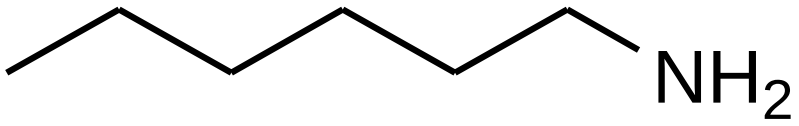


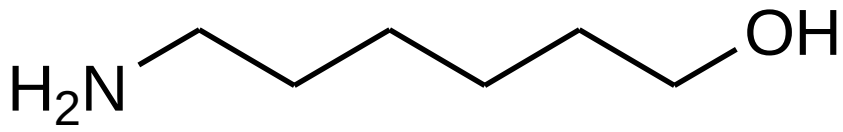












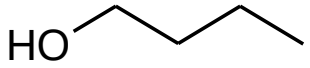
An AMINO ALCOHOL
OR
A HYDROXY AMINE

- **Note: Compounds may have more than one functional group**

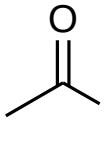
TUTORIAL III: FUNCT. GRP IDENTIFICATION

Q7: **Answers:**

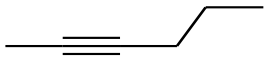
Alcohol



Amide (NOT AMINE!!)

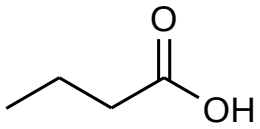


Alkyne

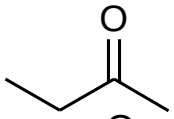


Hex-2-yne

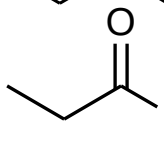
Carboxylic acid



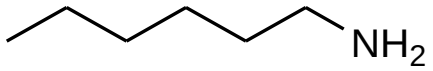
Ketone



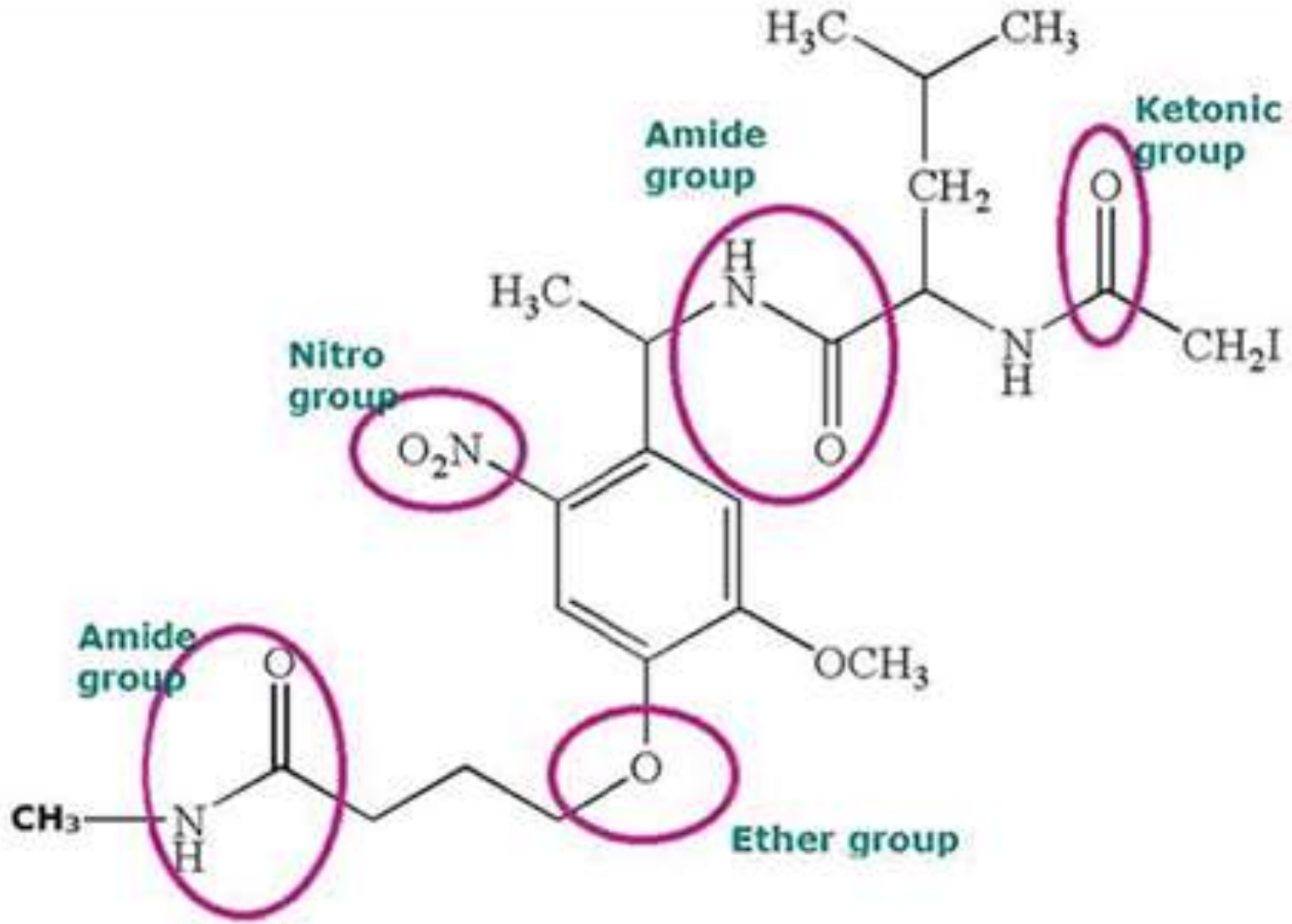
Aldehyde



Amine

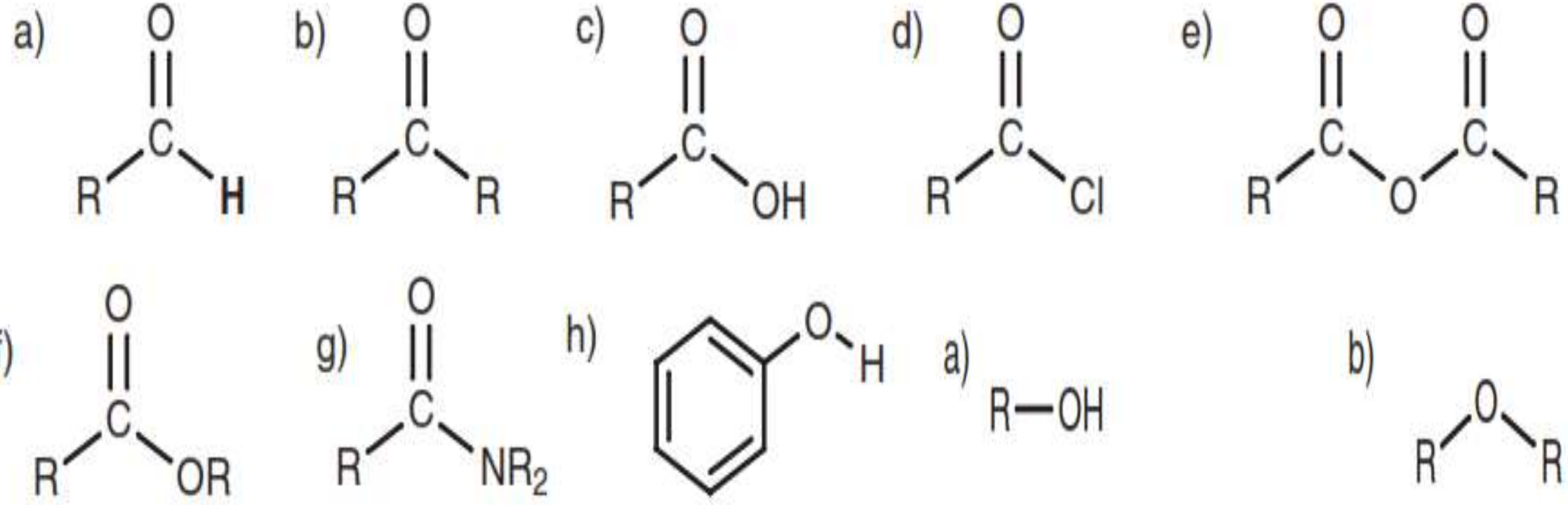


Functional Groups



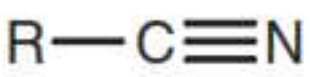
IDENTIFICATION OF FUNCTIONAL GROUPS

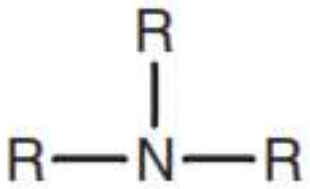
- Functional groups containing Oxygen (double &single bonds)

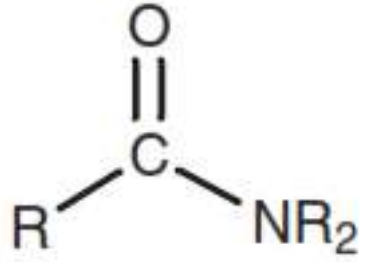


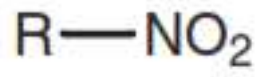
IDENTIFICATION OF FUNCTIONAL GROUPS

- Functional groups containing Nitrogen

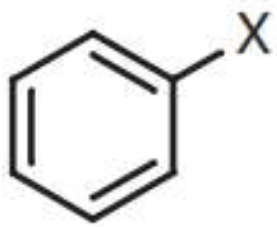
a) 

b) 

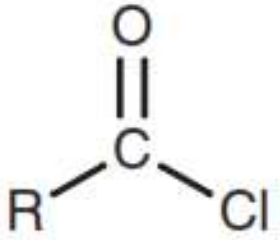
c) 

d) 

- Functional groups containing Halides (Cl, Br, I, F, etc.)

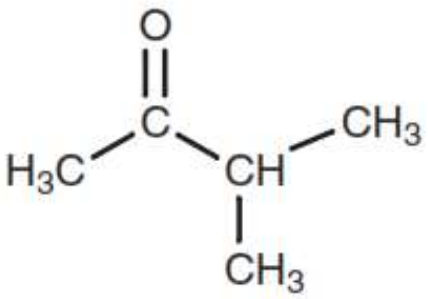
a) 

b) 

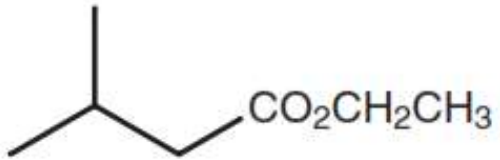
c) 

IDENTIFICATION OF FUNCTIONAL GROUPS

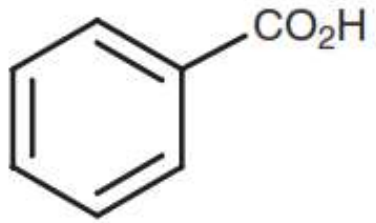
- Aromatic vs Aliphatic Functional groups



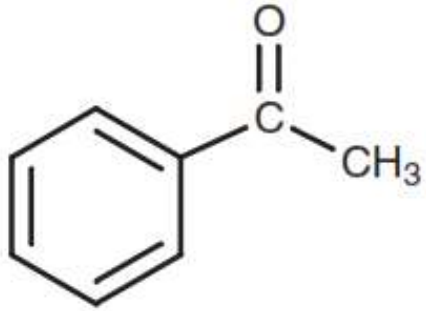
b)



c)



d)



- As you can see, a and b are aliphatic groups while c and d are aromatic groups

QUESTIONS???

IUPAC NUMENCLATURE

IUPAC: International Union of Pure and Applied Chemists

- Unified system for naming organic compounds (SYSTEMIC)
- OLD NAMES were not good enough bc there was no system
  - E.g. ethylene, iso-butane, acetaldehyde, formaldehyde, ether
- Wit.h IUPAC system, every cmpd can have a distinct name
  - Eg Ethene, 2-methylpropane, ethanol, methanol, diethyl ether, etc
- Some cmpds are still commonly known by their Old names,
  - E.g. Acetone (IUPAC Name: Propan-2-one)

IUPAC NUMENCLATURE

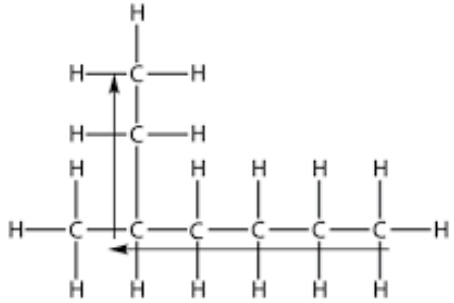
- Learning IUPAC rules, you should be able to…
  - Determine systematic name of a cmpd from its structural formula
  - Identify compounds by their systemic names
  - Draw the structure of a compound from its systematic name

IUPAC NUMENCLATURE: Rules

1. **Identify the parent chain (longest connected carbons)**
2. **Choose the principal functional group**
3. **Identify the side chains (substituents)&other funct groups**
4. **Number everything correctly (locants)**
5. **Combine the names...** *(Remember to use correct punctuations)*

IUPAC NUMENCLATURE: Rule 1

1. **Identify the parent chain**



- Choose the longest carbon chain…carefully
- This will be the name of the root part of the name,
- Eth- == 2 Carbons, prop- == 3, but- == 4, hept- == 7, etc
- Cyclic aliphatics are simply named with the term cyclo-
  - E.g. cyclohexane, cyclopropane, etc

Note: Longest carbon chain **must NOT be the horizontal one**

IUPAC NUMENCLATURE: Rule 2

2. Choose the principal functional group

- If there are multiple functional groups, there is an order of priority for choosing the main one
  - E.g. Carboxilic acid > Ester > Amide > Aldehyde = Ketone > Alcohol = Amine > Alkene/yne > Halide > Nitro, etc
- The principal functional group will be named as **SUFFIX**
  - E.g. CARBOXILIC ACID is named…. –oic acid
  - Alkanol === -ol Alkanal == -al
  - Ether === ether Alkanone == -one etc

Functional Group Priorities & Prefixes/Suffi

GROUP ONE

Functional Group	Prefix	Suffix
carboxylic acid		oic acid
ester		oate
amide		amide

GROUP TWO

Functional Group	Prefix	Suffix
aldehyde	oxo	al
ketone	oxo	one
alcohol	hydroxy	ol
amine	amino	amine
alkene	enyl	ene
alkyne	ynyl	yne

SUBORDINATE GROUPS

Functional Group	Prefix	Suffix
alkyl halide	halo	
ether	oxy	ether
alkyl benzene	phenyl	benzene
alkane	yl	ane

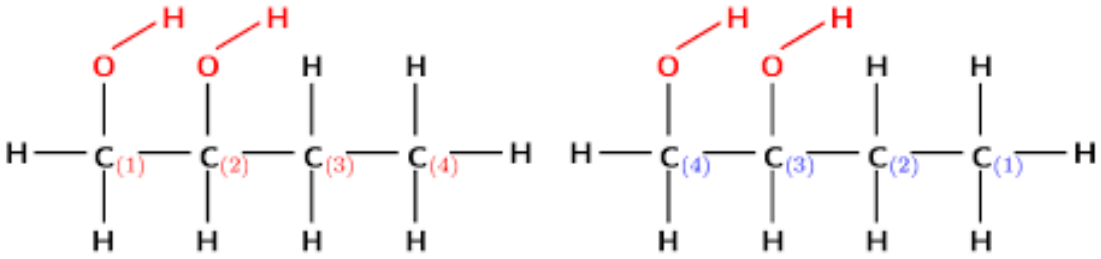
Principal functional groups are listed in decreasing priority.

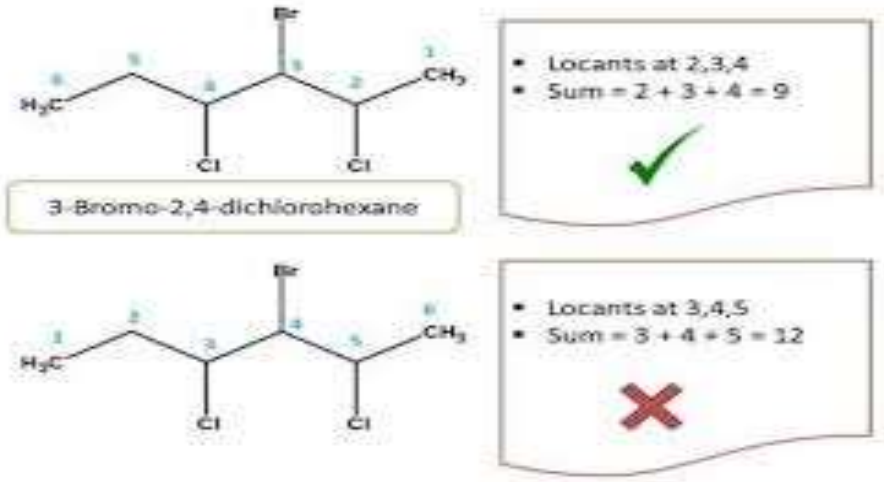
IUPAC NUMENCLATURE: Rule 3

3. **Identify the side chains (Substituents) &other funct groups**
   - They will be named as prefixes
   - When combining them, they will be placed in alphabetical order
   - If there are more than one of the same, use ***di, tri, tetra…etc***
     - ***E.g. dimethyl-, trihydroxy-, tetrachloro-, etc***
     - The *di, tri, tetra* used are not considered in the alphabtcl. order
   - Identify the multiple bonds, ‘ene’ or ‘yne’

IUPAC NUMENCLATURE: Rule 4

4. **Number correctly (locants)**
   - Number the parent chain in such a way that the principal functional group is at lowest locant (number)
   - Use that numbering as reference to know positions of substituents
   - If there are long side chains, number them too
   - If alternatives exist, choose numbering that gives the least sum



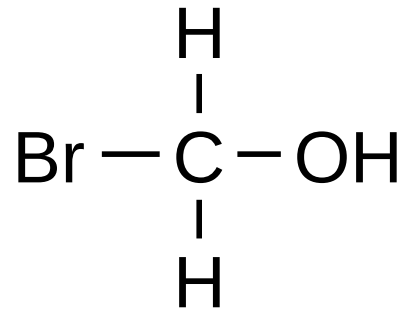


IUPAC NUMENCLATURE: Step 5

5. **Combine the different parts of the name**

Prefix(es) --------- Root or **Parent** -------- Ending or **Suffix**

e.g.



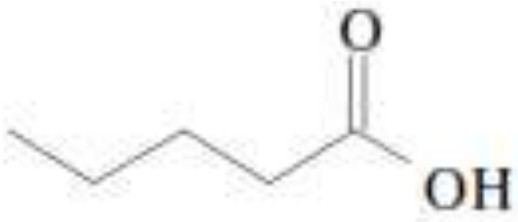
Bromo -------- methan --------- ol

OR Hydroxy -------- methane -------- bromide

IUPAC NUMENCLATURE: Punctuation Rules

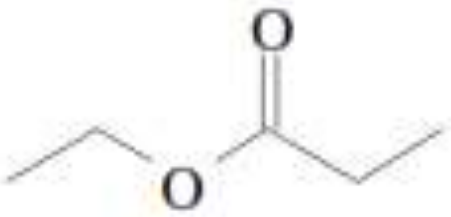
- Hyphens are placed between numbers and words
- Commas are used between numbers, ALWAYS!

IUPAC NUMENCLATURE: Examples



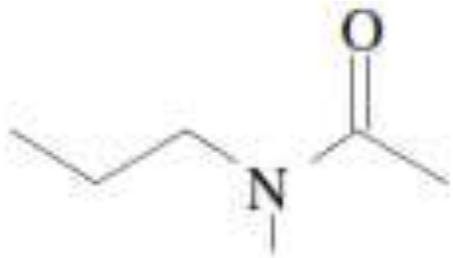
pentanoic acid

(carboxylic acid)



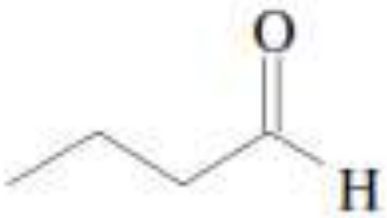
ethyl propanoate

(ester)



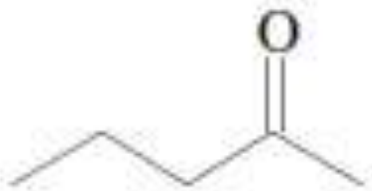
N-propyl ethanamide

(amide)



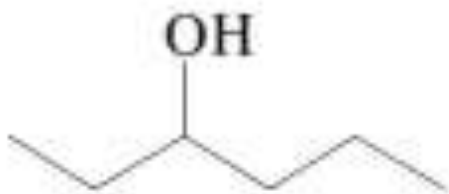
butanal

(aldehyde)



2-pentanone

(ketone)



3-hexanol

(alcohol)

IUPAC NUMENCLATURE: Examples

butylamine
or 1-butanamine

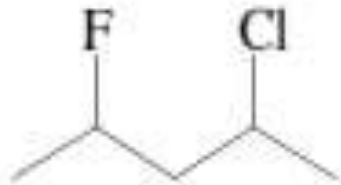
(amine)

1-pentene

(alkene)

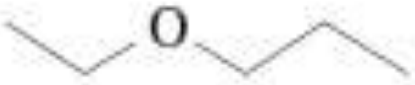
1-pentyne

(alkyne)



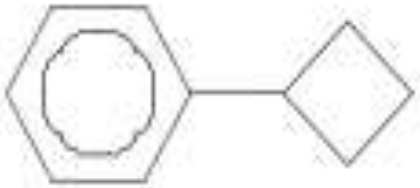
2-chloro-4-fluoropentane

(alkyl halide)



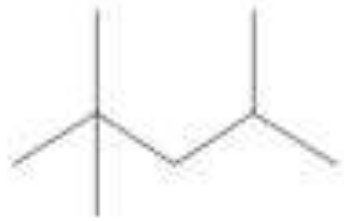
ethyl propyl ether
or 1-ethoxypropane

(ether)



cyclobutylbenzene
or phenylcyclobutane

(alkyl benzene)



2,2,4-trimethylpentane

(alkane)

IUPAC NUMENCLATURE: Tutorials

Try your hands on as many of the ‘Numenclature’ questions in this link as you can:

https://www.chem.tamu.edu/class/fyp/mcquest/ch27.html

Please DO NOT SKIP


Question