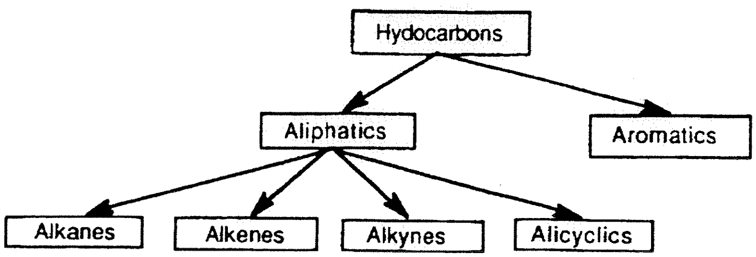
UNIT C

ORGANIC CHEMISTRY

Classification of Organic Chemistry



Prefixes used for science 10:

mono	1 of	hexa	6 of
di	2 of	hepta	7 of
tri	3 of	octa	8 of
tetra	4 of	nona	9 of
penta	5 of	deca	10of

Prefixes used in organic chemistry that are used to indicate the number of carbon atoms present in a molecule

meth	**1-C**	**hex**	**6-C**
eth	**2-C**	**hept**	**7-C**
prop	**3-C**	**oct**	**8-C**
but	**4-C**	**non**	**9-C**
pent	**5-C**	**dec**	**10-C**

Memorize

For your own benefit

Cyclo – indicates carbons are joined in a ring like structure

Suffixes that are used to indicate the type of bonding between carbon atoms

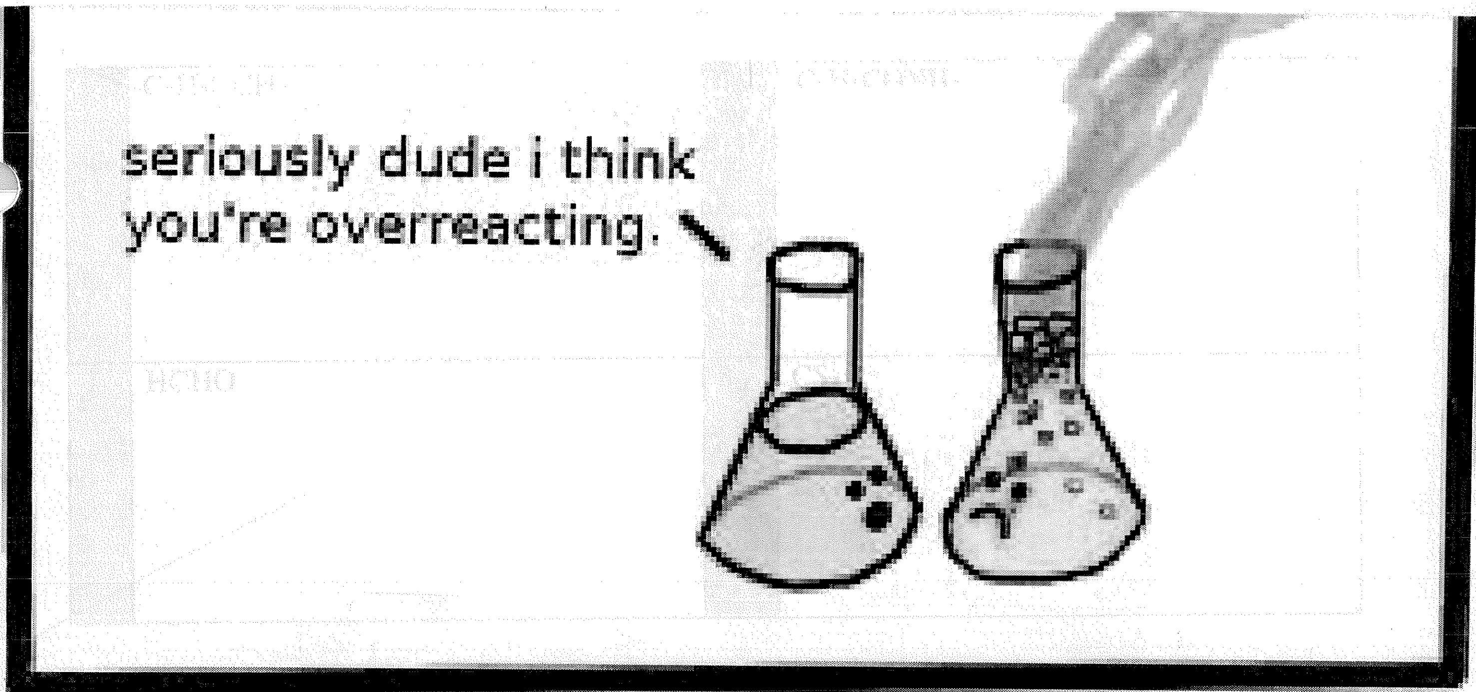
-ane single bonds are present between all the carbon atoms in a molecule
-ene one double bond is present in the molecule between two of the atoms
-yne one triple bond is present in the molecule between two of the carbons

other suffixes that are used

-diene two double bonds are present in the molecule
-diyne two triple bonds are present in the molecule
-ol compound is an alcohol
-oic compound id a carboxylic acid
-oate compound is an ester

General formula for hydrocarbons

Alkanes	Alkenes	Alkynes
C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}



Organic Chemistry

- Defined as the study of the molecular compounds of carbon

-Compounds of carbon that **are not molecular and therefore not organic** include

1) Oxides of carbon	i.e. CO_2, CO	
2) Carbonates	i.e. Na_2CO_3	(CO_3^{2-})
3). Bicarbonates	i.e. $NaHCO_3$	(HCO_3^-)
4) Carbides	i.e. Fe_2C	
5) Cyanides	i.e. NaCN	(CN^-)
6) Thiocyanate	i.e. NaSCN	(SCN^-)

- more than 4 million organic substances known
- derived from living organisms and numerous synthetic substances

Inorganic – all substances formed by the remaining elements
-Greater than 50,000 known

Carbon → many uses

- carbon compounds originally are extracted from living systems
- many are synthetically contracted
- has the amazing ability to possess:
  - single, double, or triple bonds, ring structures, chains, sheets, tubes
  - Carbon sources includes fossil fuels such as coal, oilsands, crude oil and natural gas

Hydrocarbons- compounds containing only hydrogen and carbon
- starting point for the synthesis for thousands of products such as plastics, specific fuels and synthetic fibres.

Refining - the technology that includes physical and chemical processes for separating complex mixtures into simpler mixtures or neat pure components.

Alkanes From Natural Gas

Natural gas

- Found trapped between a non-porous rock layer above and water below the natural gas layer.
- Varies in composition but is mainly methane ($CH_4(g)$)
- Methane is the smallest of a group of hydrocarbons called **alkanes**. (*a group of compounds containing only single bonds between the carbon atoms*)

Naming Alkanes

- Simplest class of organic compounds
- Each carbon has 4 single covalent bonds
- Called **saturated hydrocarbons** since they hold the maximum number of hydrogens possible
- Uses prefixes meth, eth, prop, etc. to indicate # of C (See 1st page of booklet)
- Suffix "**ane**" means all single bonds
- General formula $\mathbf{C_nH_{2n+2}}$ where n- # of C atom

Draw the following:

n=1	CH_4 – methane	n = __	**butane** ( )
n= 8	C_8H_{18} – octane **or** CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2- CH_3 **or** CH_3- $(CH_2)_6$-CH_3	n = __	**hexane** ( )

- alkanes are an example of a **homologous series** which are a sequence of molecules with similar structure and differing only in the number of repeating units; e.g. CH_2.
- we have worked with only a straight chained alkanes so far
- ***Alkanes may be branched – taken later***

ALKENES

- contain 2 less hydrogen than alkanes due to the presence of a double bond between 2 carbon atoms
- general formula $\mathbf{C_nH_{2n}}$
- ending "**ene**" – indicates a double bond
- The chain is numbered to show the position of the C = C using the lowest possible number and follows the prefix of the name of the compound parent chain.

n =2 C_2H_4 – ethene

n =3 C_3H_6 - propene

n =4 C_4H_8 – butene

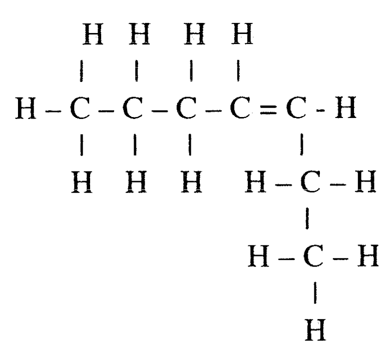
but-1-ene	but-2-ene	pent-1-ene	pent-2-ene

Note – both(C_4H_8) have the same chemical formula but different structural formulas called ISOMERS.

Draw the structural formulas and give the chemical formula of **hex-3-ene**

Name the following chemical structures

$CH_3 – CH_2 – CH_2 – CH = CH – CH_3$



ALKYNES

- hydrocarbons which contain one triple bond between 1 pair of carbons
- contain 4 less hydrogen's than alkanes
- naming is identical to alkenes except "**yne**" ending is used
- general formula $\mathbf{C_nH_{2n-2}}$

i.e. $H - C \equiv C - H$ ethyne (C_2H_2) $CH_3 - C \equiv C - CH_3$ but-2-yne (C_4H_6)

Name the following

1. $HC \equiv C - CH_3$
2. $CH_3 - C \equiv C - CH_2 - CH_3$
3. $CH_3 - CH_2 - CH_2 - C \equiv C$
|
CH_2
|
CH_3

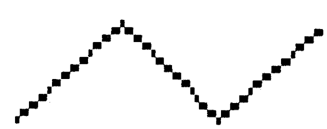
Draw the following

4. hept-2-yne
5. pent-1-yne

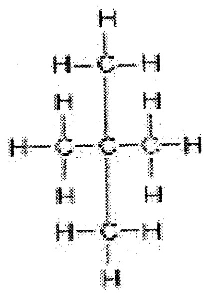
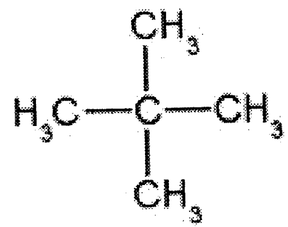
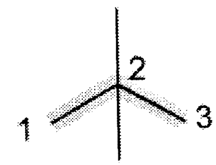
There are three different ways to represent or draw a hydrocarbon:

- **structural formula**
- **condensed structural formula**
- **line structural formula:**
    - Line structural formulas show the position of the carbon atoms as the intersections and ends of bonding lines; they do not show hydrogen atoms.
    - Line structural formulas will also indicate multiple bonds and branches.

Example: butane

Structural formula	**Condensed Structural Formula**	**Line Structural Formula**
H H H H | | | | H—C—C—C—C—H | | | | H H H H	CH_3-CH_2-CH_2-CH_3	

Example: 2,2-dimethylpropane

Structural Formula	Condensed Structural Formula	Line Structural Formula
		 2,2-dimethylpropane (neopentane)

General Formula For Hydrocarbons

Alkanes	Alkenes	Alkynes
________	________	________

1. Name the **hydrocarbon group** that the following belong to:

   a. C_6H_{10} ____________________ b. C_2H_4 ____________________

   c. C_8H_{18} ____________________ d. C_9H_{18} ____________________

2. Write the name of the following:

   a. C_5H_{12} ____________________ b. $C_{10}H_{18}$ ____________________

   c. C_7H_{14} ____________________ d. C_4H_8 ____________________

   e. C_3H_6 ____________________ f. C_9H_{16} ____________________

3. Write the chemical formula for the following:

   a. pentane ____________________ e. hexane ____________________

   b. nonene ____________________ f. decane ____________________

   c. ethyne ____________________ g. butene ____________________

4. Draw the ***structural*** OR ***condensed*** structural formula for each of the following:

a. butane	b. propene

c. pentane	d. propyne
e. but-2-yne	f. hex-3-ene
g. pent-2-yne	h. but-1-ene

CYCLOALKANES

- ring of saturated hydrocarbons
- from simple geometric shapes i.e. 3-C – triangle
  4-C – square
  5-C - pentagon
- have two less H than straight chained counter parts

Draw: cycloheptane cyclohexane cyclopentane

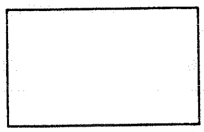
CYCLOALKENES AND CYCLO ALKYNES

- alkenes and alkynes in a closed ring structure
- contain 2 less hydrogen's than straight chain counterparts
- no number necessary to indicate C=C OR C≡C

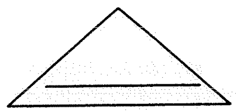
draw- 1) cyclohexene 2) cyclopropene 3) cyclopentyne

Name the following diagram:

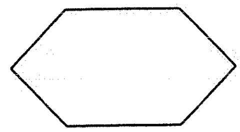
a.



b.



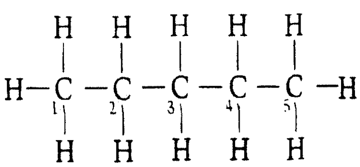
c.



Nomenclature of branched alkanes

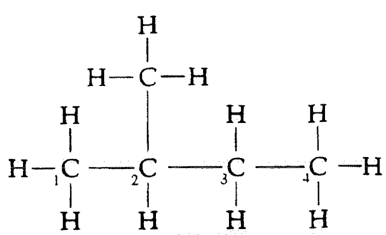
Not all alkanes are the straight chain
i.e. pentane C_5H_{12}

Pentane



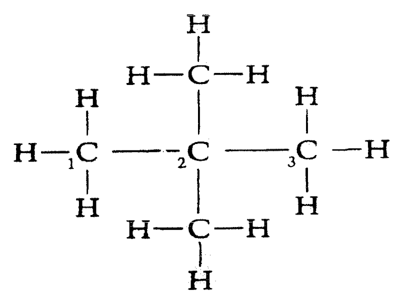
pentane

2- Methyl Butane



2-methylbutane

2,2 – Dimethyl Propane



2,2-dimethylpropane

The above, all have the same chemical formula, but different structural formulas. They are called ***isomers***. A method of nomenclature has been developed to give each isomer its own distinct chemical name.

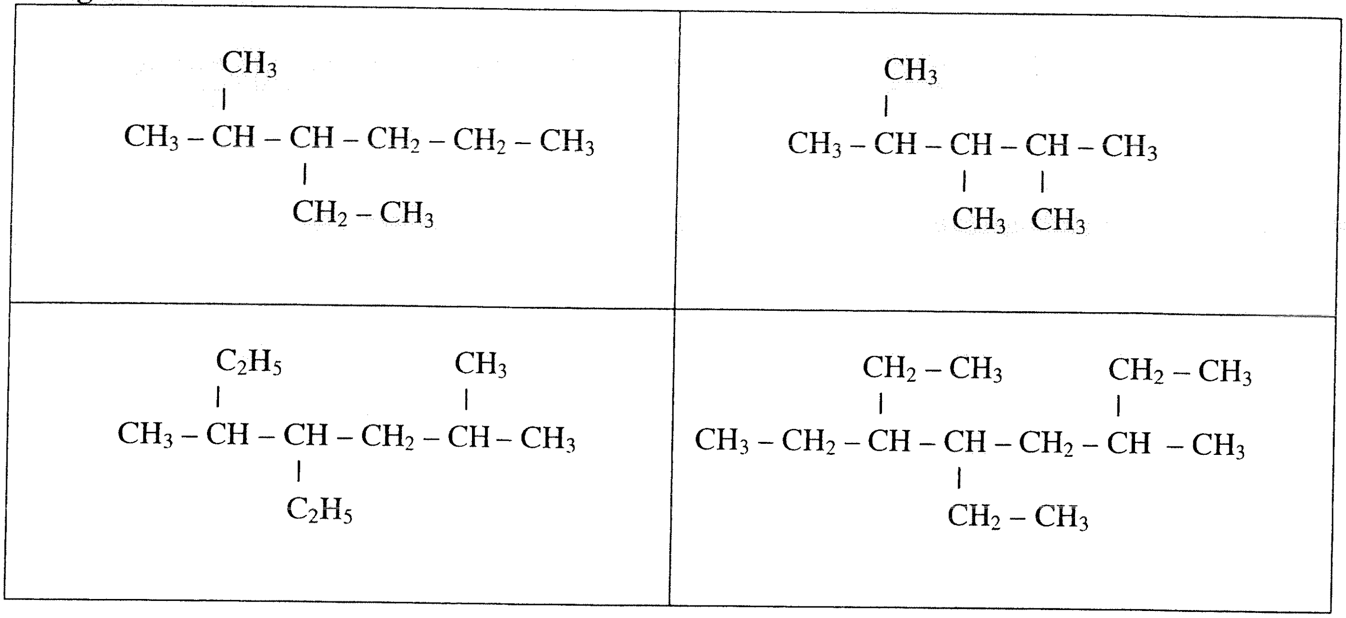
Nomenclature (IUPAC)

1) Determine the longest continuous carbon chain (parent chain).
2) Number the carbons in the chain beginning at the end of the chain closest to the branch.
3) Identify any branches and their location number on the parent chain.
4) Name branches called (**ALKYL GROUPS**) by using alkane parent name plus "yl" using the following format *(number of location, if necessary) – (branch name)(parent chain)*

List branches in alphabetical order

Examples of Alkyl Branches	
Branch	**Name**
- CH_3	methyl
- C_2H_5 (– CH_2CH_3)	ethyl
- C_3H_7 (- $CH_2CH_2CH_3$)	propyl
- C_4H_9 (- $CH_2CH_2CH_2CH_3$)	butyl

e.g. Write the IUPAC name corresponding to the following structural formula or diagram.



Drawing Structural Formulas of Branched Alkanes

e.g. 4 – ethyl – 2,3 – dimethylheptane

- Draw a straight chain containing the number of carbon atoms represented by the name of the parent chain.
- Number the carbon atoms from left to right.
- Attach all branches to their numbered locations on the parent chain.
- Add enough hydrogen atoms to show that each carbon has four single bonds

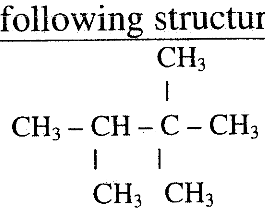
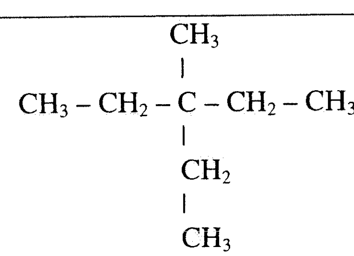
e.g.. #1) 2,3,4 – trimethyl hexane

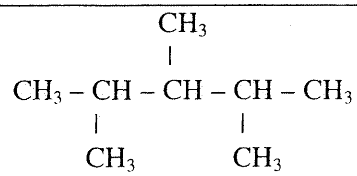
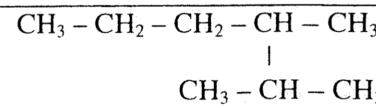
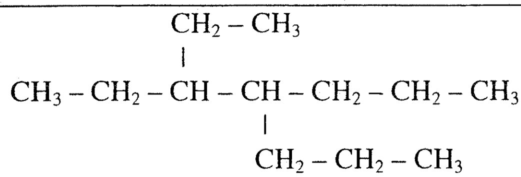
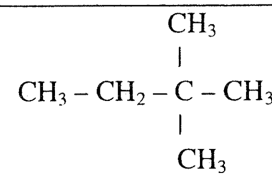
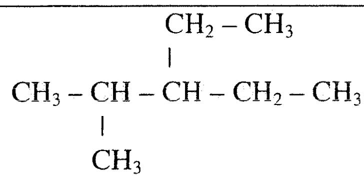
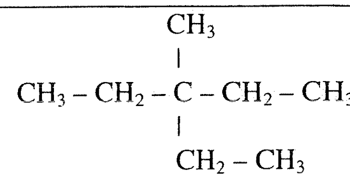
#2) 3- ethyl – 2 – methyl pentane

Draw a condensed structural formula or a line formula for each of the following compounds:

1. 2,2,4-trimethylhexane	**2.** 3-ethylhexane
3. 2-methyl-4-propyloctane	**4.** 2,4-dimethylhexane
5. 3-ethyl-2,2,5-trimethylheptane	**6.** 3,4-diethyl-3-methylhexane
7. 3-ethyl-3-methylpentane	**8.** 3-ethyl-2,3-dimethylhexane

Name the following structures

1. 	**2.** 

3.		4.	
5.		6.	
7.		8.	

9.3 Branched Alkenes and Alkynes

IUPAC Rules for the naming of alkenes and alkynes:

The rules for naming alkenes and alkynes are similar to those for naming alkanes, with the following modifications:

a) The longest continuous chain of carbons that contains the double bond or triple bond is the parent structure. The longest continuous chain must be chose to contain both carbon atoms of the double bond or the triple bond, even if a longer carbon chain could be found by choosing a different path.

b) The carbon chain must be numbered from the end closest to the double-bonded carbon atom OR the triple-bonded carbon atom (i.e. number the carbon atoms in this chain so as to give the lowest possible number to the double bond or triple bond regardless of the groups attached to the parent structure). If there is no difference, then it is numbered from the end closest to an alkyl group.

Name the following condensed structures. Also draw a line structural formula for each of the following

e.g. #1

```
CH3 – C = CH – CH – CH3
      |        |
      CH3      CH3
```

e.g. #2

```
CH2 =CH – CH2 – CH – CH3
      |         |
      CH3       CH3
```

e.g.#3

```
CH3 – CH2 – C ≡ C – CH – CH2 – CH3
                    |
                    CH3
```

e.g. #4

```
                CH2 - CH3
                |
CH3 – CH2 – CH –CH – C ≡ C – CH3
            |
            CH3
```

The number is omitted if there is only one possible location for the double or triple bond.

1. Name the following alkene and alkynes

a.

```
CH3 – C = CH – CH3
      |
      CH3
```

b.

```
               CH3
               |
CH ≡ C –  CH – CH3
```

c.

```
      CH3
      |
CH3 – CH – CH – CH = CH2
           |
           CH3
```

d.

```
                CH2 – CH3
                |
CH3 – CH = C – CH  – CH2– CH3
               |
               CH3
```

e.

```
                           CH3
                           |
C ≡ C – CH – CH2 – CH  –  CH3
|       |
CH3     CH3
```

f.

```
CH3 – CH2 – C = CH – CH2  – CH2– CH3
            |
            CH2– CH3
```

g.

```
                                CH3
                                |
CH3 – CH2 – CH – CH2 – CH = C
            |                   |
            CH2– CH3            CH2
                                |
                                CH2– CH2– CH3
```

h.

```
1.  CH3 – C = CH – CH – CH2 – CH3
          |        |
          CH3      CH2
                   |
                   CH3
```

2. Draw condensed OR structural formulas for the following

1.	2-methylhex-3-ene	2.	2,4-dimethylpent-2-ene
3.	3,4-dimethylhept-2-ene	4.	4-ethylpent-2-ene (what is wrong with this name?)
5.	2,3-dimethylhept-3-ene	6.	2,2-dimethylhex-3-yne

1. Draw the condensed structural formulas for and name all the non-cyclic isomers of C_4H_8.

2. Draw the condensed structural formula for and name the five non-cyclic isomers of C_5H_{10}.

BRANCHED CYCLOALKANES

- nomenclature is done similar to branched alkanes using the lowest number to name the position of the branches
- no number is necessary if only one branch is present

Draw the following

methyl cyclobutane 1- ethyl- 3- methyl cyclohexane 1,1,2 – trimethyl cyclopropane

Branched Cycloalkenes and Branched Cycloalkynes

- similar nomenclature to straight chain alkenes and alkynes with the C- atoms with the multiple bond receiving the lowest number.

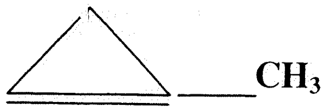
Draw the following

1) 4-ethyl 3-methylcyclohexene 2. 1-methylcyclopropene

3) 3-propylcyclobutyne

Name the following:

a.



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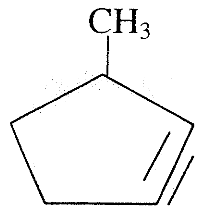

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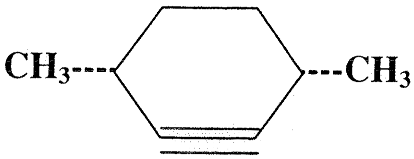
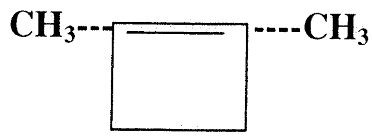


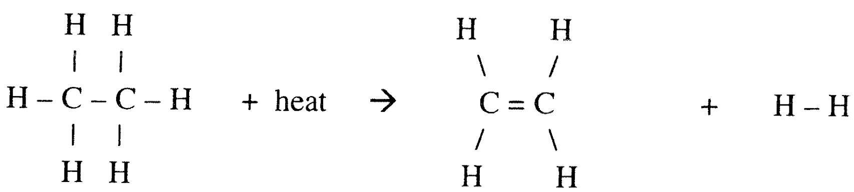
d.



Ethane Cracking

Cracking – is an industrial process in which larger hydrocarbon molecules are broken down at high temperatures, with or without catalysts to produce smaller hydrocarbon molecules.

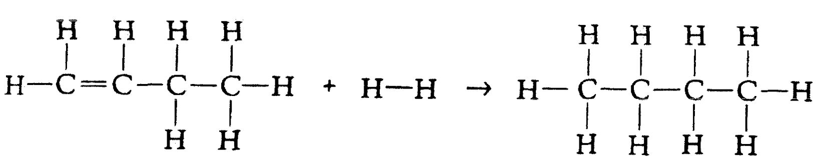
- is used to convert large hydrocarbons naptha (a mixture of $C_5 - C_7$ molecules to ethane.
- is a common process to convert ethane which Alberta has an abundance of to ethene (ethylene) which is the main component to produce plastics.



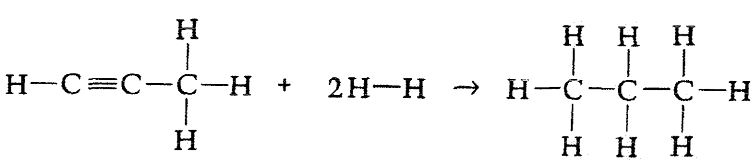
ethane ethene

CONVERSION OF ALKANES FROM ALKENES AND ALKYNES

- If hydrogen gas is added to an alkene or alkyne it will react at the double bonds to form single bonds
- this type of **addition** reactions is called **hydrogenation.**



1- butene + hydrogen → butane



propyne + hydrogen → propane

Draw out the structures of the following reaction

e.g. 4- methylhex-2-yne + hydrogen → 3- methyl hexane

REFORMING REACTIONS

- Reforming reactions are opposite to cracking
- production of larger chain hydrocarbons from smaller chain hydrocarbons

i.e. $C_4H_{10\,(g)} + C_5H_{12\,(l)} \rightarrow C_9H_{20\,(l)} + H_{2\,(g)}$

Summary of organic reactions taken so far

1. **Cracking:** large hydrocarbon molecule $\xrightarrow[\text{heat}]{\text{catalyst}}$ smaller molecules

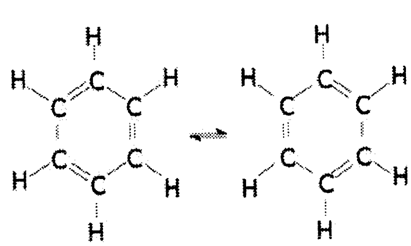
2. **Reforming:** small molecules of hydrocarbons $\xrightarrow[\text{heat}]{\text{catalyst}}$ larger molecules with branches

3. **Complete Combustion:**
   Hydrocarbon compound + oxygen → carbon dioxide + water

4. **Hydrogenation (addition of hydrogens)**
   Alkenes or alkynes + hydrogen → alkanes

9.4 Aromatics

- Historically, organic compounds with an aroma or odor were called aromatic compounds.
- Today, chemists define aromatics as benzene and all other carbon compounds that have benzene like structures and properties.



- alternating double bonds
- the double bond does not just exist between the same 2-C atoms but is distributed so that valence e^- are evenly shared by all carbons therefore benzene is represented like the following to the left
- those substances that do not have benzene rings are called **aliphatic compounds**

Naming aromatics compounds:

1) <u>one substitution</u>

Name branch first followed by benzene (no number required)

i.e. methyl benzene (toluene) ethyl benzene propyl benzene butyl benzene

2) <u>2- Substitution – two methods</u>

a) use numbers to show position of groups or branches

b) use of prefixes (ortho, meta, para)

ortho – symbol "**o**" – branches on adjacent C

meta – symbol "**m**" – branches with 1-C in between

para – symbol "**p**" – branches with 2-C in between

Draw the following

e.g.#1 1,2 – dimethyl benzene

e.g. #2 1 – ethyl -3 - methyl benzene

e.g. #3 o –dimethyl benzene

List branches Alphabetically – use lowest numbers going clockwise or counter clockwise

3) <u>Poly substituted</u>

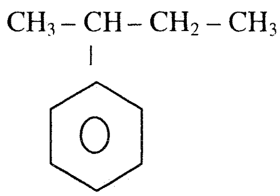
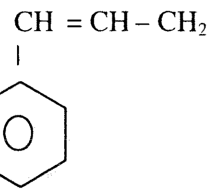
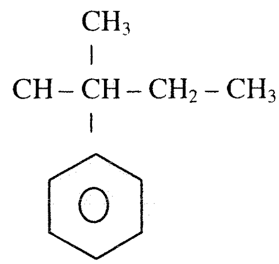
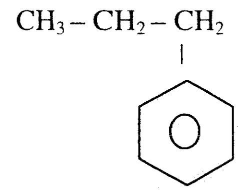
- name branches alphabetically using lowest numbers going clockwise or counter clockwise

e.g. #4 1– ethyl– 2,5, dimethyl – 3 – propyl benzene

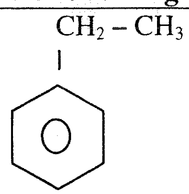
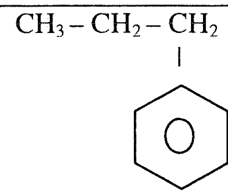
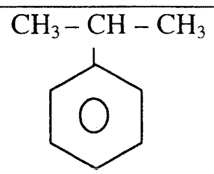
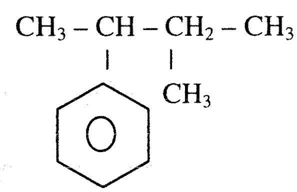
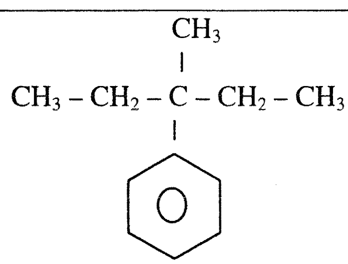
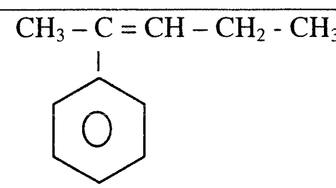
4) In some situations the benzene ring is treated as a branch, **not the main chain** and is given the name **phenyl.**

This happens when the phenyl is joined to

a) a branch by a central carbon
b) a branch that possesses a branch of it's own
c) a branch that possesses a multiple bond

Name the following

1.		**2.**	
3.		**4.**	
5.		**6.**	

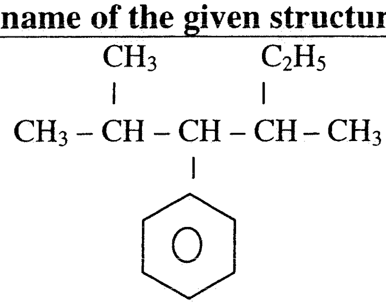
In such molecules, the benzene ring is called a **phenyl group**, $-C_6H_5$.

Draw the structural formulas of the following aromatics:

1.	p-ethylmethylbenzene	**2.**	1,2,4-triethylbenzene
3.	1,3-dimethyl-5-propylbenzene	**4.**	m-ethylmethylbenzene
5.	2-phenylpropene	**6.**	2-ethyl-1-phenylhex-3-yne
7.	toluene (**methyl benzene**)	**8.**	2,2-dimethyl-1-phenylbutane

Fill in the name of the given structure

1.



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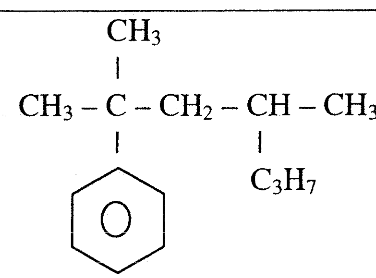

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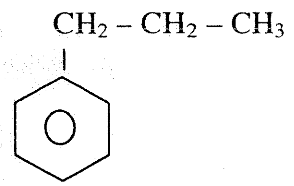
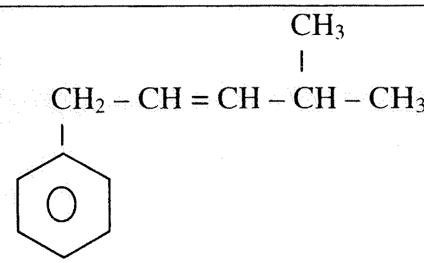


4.

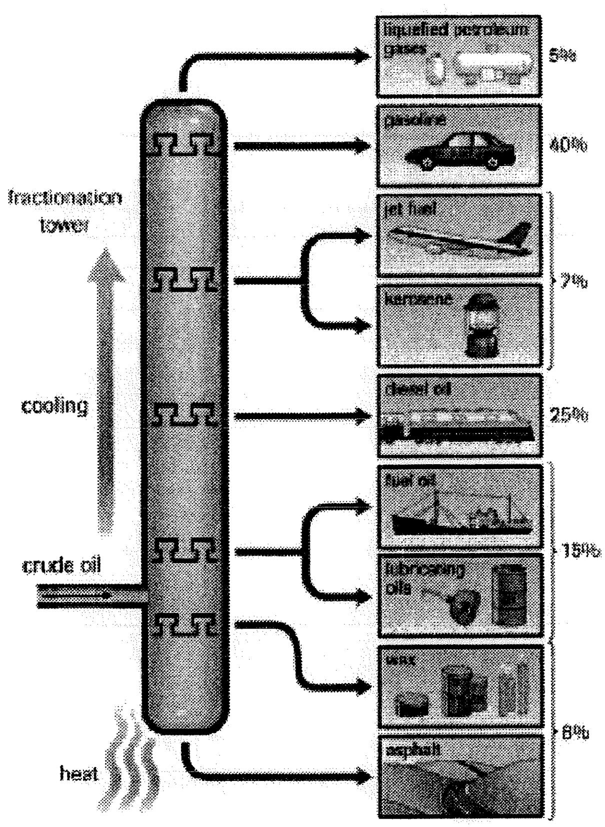


Crude Oil Refining

Crude Oil

- pumped from the ground
- transported by pipeline to a refinery
- classified based upon
  - viscosity
  - sulfur content
  - hydrocarbon composition
- crude oil is a mixture of hundreds of thousands of compounds.
- Crude oil is seperated into a variety of compounds by physical or chemical means.

Fractional Distillation



A fractional distillation (fractionation) tower contains trays positioned at various levels. Heated crude oil enters near the bottom of the tower. The bottom of the tower is kept hot, and the temperature gradually decreases toward the top of the tower. The concentration of components with lower boiling points increases from the bottom to the top of the tower.

The percentage distributions shown vary with the type of crude oil and with seasonal demands.

Physical Proceses in Oil Refining

- **Fractional distillation –** seperating components from each other by their differences in boiling point.
- The boiling points of the components that make up crude oil vary between 20°C – 400°C.
- The crude oil is heated to around 500°C and the vapours are allowed to rise.
- Each component will condense when it reaches a tray that is at it's boiling point
- **Fractions** with the lowest b.p. are the smallest molecules while the larger molecules have a higher b.p. and condense closer to the bottom of the tower due to the size of the London forces.

Chemical Processes in Oil Refining

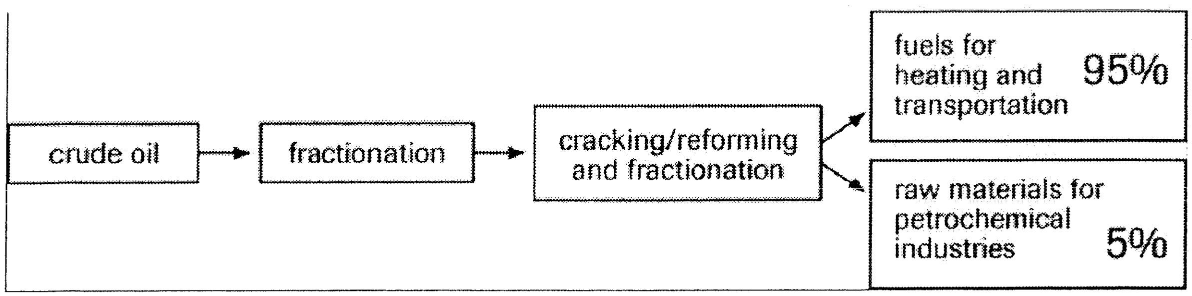


Figure 4

Only 5% of the original mass of crude oil is used as starting chemicals (called feedstock) in the manufacture of solvents, greases, plastics, synthetic fibres, and pharmaceuticals.

Cracking

Catalytic cracking: breaking down a large molecule into smaller molecule using a catalyst

$$\text{large hydrocarbon molecule} \xrightarrow[\text{heat}]{\text{catalyst}} \text{smaller molecules}$$

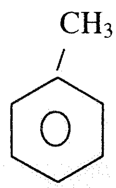
$$C_{17}H_{36}(l) \rightarrow C_9H_{20}(l) + C_7H_{16}(l) + C(s)$$

Thermal cracking: breaking down large molecules using only high temperatures

Catalytic Reforming and Alkylation

1. Catalytic Reforming:

- chemical process involved in converting molecules in gasoline fraction into aromatic gasoline molecules.
- usually produces a gasoline with better burning properties
- conversion of low grade gasoline (low octane rating to a higher grade gasoline (higher octane rating)

e.g. $CH_3 - (CH_2)_5 - CH_3$ →  $+ 4\ H_2$

heptane → methylbenzene

2. **Alkylation:**

- process used to increase the quality of gasoline by increasing the branching (isomerization) of the molecule.

e.g. $CH_3 - (CH_2)_5 - CH_3$ → $CH_3 - CH(CH_3) - CH_2 - CH(CH_3) - CH_3$

heptane → 2,4 - dimethylpentane

Combustion and Incomplete Combustion Reactions

Complete combustion

- More likely to occur when an excess of oxygen is available
- Will give produts that are predominantly water vapour ($H_2O(g)$) and carbon dioxide($CO_2(g)$)

e.g. $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

octane(gasoline) + oxygen → carbon dioxide + water vapour

Incomplete Combustion

- Generally occurs when a insufficient amount of oxygen is available
- Two possible reactions depending on the amount of oxygen available
- Will give products that may include carbon monoxide ($CO(g)$, soot ($C(s)$) and water vapour ($H_2O(g)$)

e.g. $2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$

octane(gasoline) + oxygen → carbon monoxide + water vapour **OR**

$2C_8H_{18}(l) + 9O_2(g) \rightarrow 16C(s) + 18H_2O(g)$

octane(gasoline) + oxygen → carbon (soot) + water vapour

- When an organic substance burns evidence indicates that all three types of reactions occur simultaneously but not in equal proportions. The proportion of each reaction depends on the amount of oxygen that is available.

Hydrocarbon Derivatives, Organic Reactions, and Petrochemicals

Chemicals produced from petroleum are called ***petrochemicals***. These include:

- plastics, asphalt shingles, paints and dyes
- antifreezes, lubricants, adhesives, carpets,
- cosmetics, pesticides, fertilizers and pharmaceuticals

95 % of refined crude oil and natural gas is burned.

5 % goes to form ***petroleum feedstock*** which is used to form higher order petrochemicals.

These include:

1. from natural gas - methane, ethane, butane and propane

2. from crude oil - naphtha and gas oil

Results in many jobs in the petrochemical industry

Organic Halides and Addition and Substitution Reactions

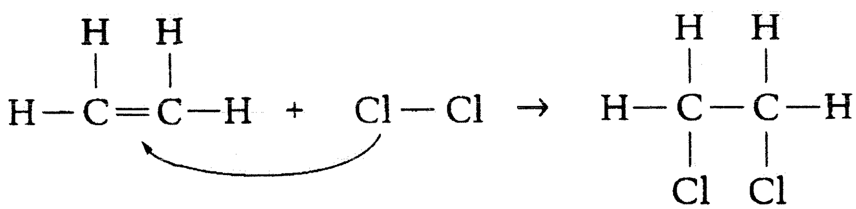
Hydrocarbon derivatives

- hydrocarbons containing at least one other element that is not carbon or hydrogen
- Include organic halides, alcohols, carboxylic acid, esters, polymers etc.
- Organic halides - contain a halogen
- not found in living systems therefore are artificial, many are toxic
- used to make freons (refrigerant), Teflon, DDT (insecticide) and PCB's
- some are polar (dissolve into water) or nonpolar or they may have a polar end and a nonpolar end meaning they can dissolve polar or nonpolar substances.
- They have a higher boiling point than similar hydrocarbons

5.	1,3-difluorobenzene	6.	1-chloro-2-phenylbutane

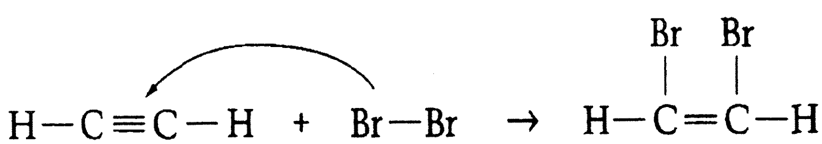
1) **Addition reaction**

- An addition reaction occurs when unsaturated hydrocarbons react with small diatomic molecules such as bromine and hydrogen, producing an organic halide.



ethene + chlorine → 1,2-dichloroethane

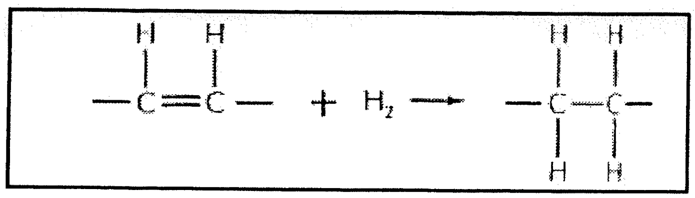
2)



ethyne + bromine → 1,2-dibromoethene

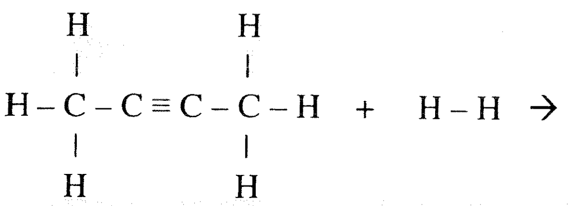
- This is called an **<u>addition reaction</u>** because the **halogen** or **hydrogen halogen is added to the original hydrocarbon and does not break up the hydrocarbon**. Alkynes can have 2 possible addition reactions occur since they have a triple bond that can go to a double bond and then to a single bond.
- The addition of a halogen to an alkene results in an alkane, and the addition of a halogen to an alkyne results in either an alkene or alkane.
- When a sufficient amount of hydrogen is added to an unsaturated hydrocarbon, making the hydrocarbon saturated, a **hydrogenation** reaction has occurred.

- Example:



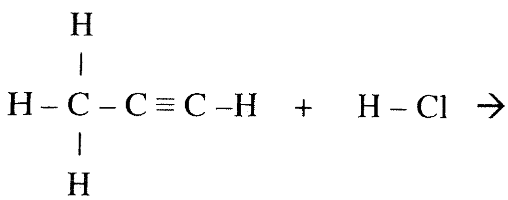
- The double bond of the alkene is broken by the addition of hydrogen, producing an alkane.

Eg.#1



But-3-yne + excess hydrogen →

Eg.#2

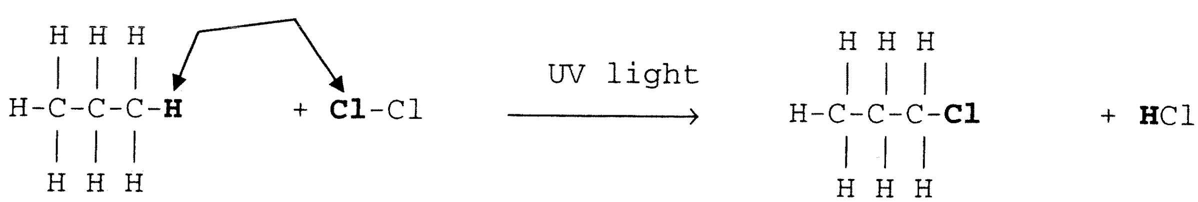


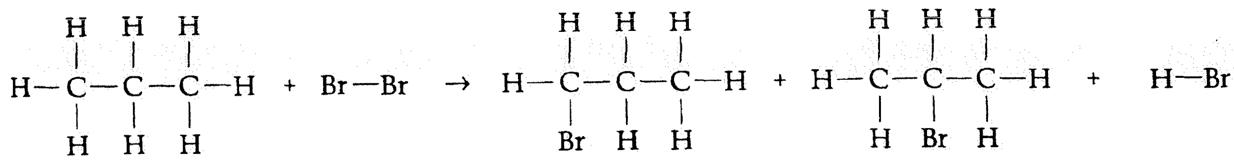
2) SUBSTITUTE REACTION

Alkane + halogen $\xrightarrow[\text{Energy}]{\text{light}}$ organic halide + hydrogen halogen

- A substitution reaction involves breaking a carbon-hydrogen bond in an alkane or aromatic ring and replacing the hydrogen atom with another atom or group or atoms
- Light is often required for these reactions to occur

Example:





propane + bromine → 1-bromopropane (b.p. 71°C) + 2-bromopropane (b.p. 59°C) + hydrogen bromide

i.e. $C_3H_{8(g)}$ + $Br_{2(l)}$ → $C_3H_7Br_{(l)}$ + $HBr_{(g)}$

- In the above reaction the hydrogen atom in the propane is substituted with the bromine atom.
- Notice that there are two possible locations for the bromine to attach to the propane. All possibilities MUST be given.

Organic Reactions

Draw the structural formulas and give names for the reactants and predict the products of the following reactions. Assume that the reaction will go to completion if an excess amount of reactant is used. Give ALL possible products.

Addition Reactions

a. 2-butene + hydrogen gas →

b. 2-butene + bromine →

Substitution Reaction

c. ethane + chlorine gas→

Classify and write balanced full structural formula equations for each of the following organic reactions. Assume light is present in all cases and catalysts are used as required.

a. propane + chlorine → 1-chloropropane + 2-chloropropane + hydrogen chloride

b. propene + bromine → 1,2-dibromopropane

c. benzene + iodine → iodobenzene + hydrogen iodide

d. 2-butene + hydrogen chloride → 2-chlorobutane

Alcohols and Elimination Reactions

Alcohols

- General formula

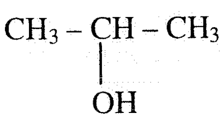
R – OH where R is an alkyl group

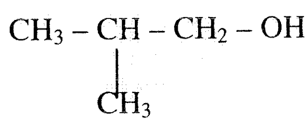
- The hydroxyl group is a functional group (i.e. a group of atoms that gives organic compounds bearing them characteristic chemical and physical properties).
    - Relatively high boiling points and high water solubility of alcohols are the result of intermolecular hydrogen bonding.
    - Due to hydrogen bonding, the melting points and boiling points of the alcohols are higher than those of alkanes of corresponding molar mass.
    - Short-chain alcohols are miscible in water in all proportions because of intermolecular hydrogen bonding – long-chain alcohols are only slightly soluble in water.

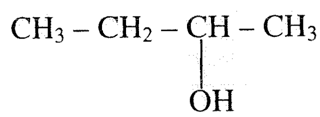
Naming Alcohols

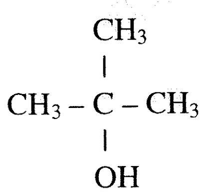
To name continuous-chain and substituted alcohols by the IUPAC system, drop 'e' ending of the parent alkane name and add ending **'ol'**. The parent alkane is the longest continuous chain of carbons that includes the carbon which has the hydroxyl group attached to it. When numbering the longest continuous chain, **the position of the hydroxyl group is given the lowest possible number.**

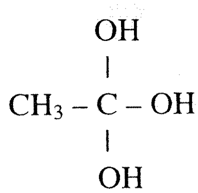
- Identify the longest chain of carbon atoms containing the –OH group.
- Number the chain such that the carbon with the –OH group gets the lowest possible number.
- Obtain the root name from the name of parent hydrocarbon chain by replacing the final 'e' with 'ol'. (i.e. drop the –e on the corresponding alkane and add –ol)
- Assigned a number to the carbon that has the –OH attached to it
- Name and number any other groups(branches) that are attached
- Alcohols containing two, three, or four –OH substitutents are named as diols, triols, and tetrols. (Retain the final 'e' on the parent name)



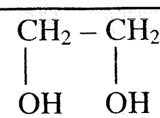








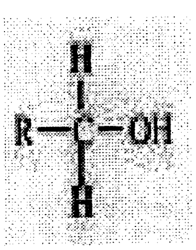
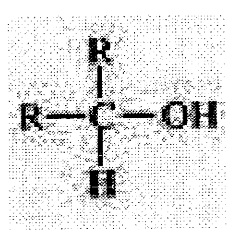
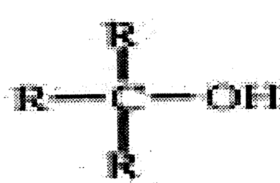
Ethane-1,2-diol



- ethylene glycol
- used in antifreeze/coolant
- starting material for polyester

Primary, Secondary and Tertiary Alcohols:

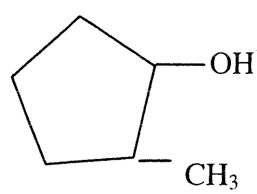
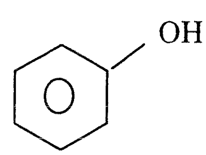
There are three different types of structural models of alcohols:

Primary Alcohols	**Secondary Alcohols**	**Tertiary Alcohols**
the carbon atom carrying the –OH group is bonded to **one** other carbon atom	the carbon atoms carrying the –OH group is bonded to two other carbon atoms	the carbon atoms carrying the –OH group is bonded to three other carbon atoms
$CH_3CH_2CH_2OH$ 	$CH_3CHOHCH_2CH_3$ 	$(CH_3)_3COH$ 

Draw the structural formula of the following alcohols and indicate if the alcohol is a primary, secondary or tertiary alcohol.

a.	propan-1-ol	**b.**	4-methylcyclohexanol
c.	propan-2-ol	**d.**	pentan-1-ol
e.	propane-1,2-diol (propan-1,2-diol)	**f.**	5-chlorohexan-3-ol

Name the following Compounds

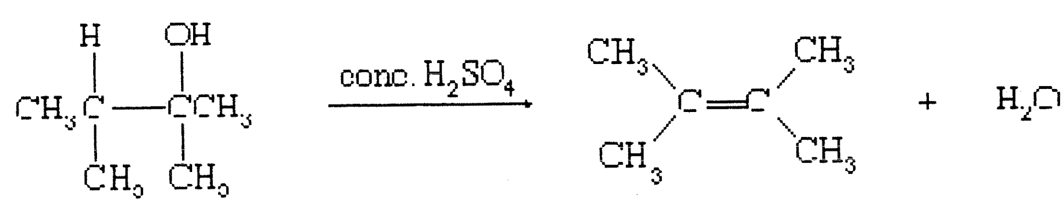
<table>
<tr><td>a.</td><td>$CH_3 - CH_2 - CH - CH_2 - CH_3$
|
OH</td><td>b.</td><td></td></tr>
<tr><td>c.</td><td>OH
|
$HO - C - CH_2 - CH_3$
|
OH</td><td>d.</td><td>OH CH$_3$ OH
| | |
$CH_3 - CH - CH - CH - CH_3$</td></tr>
<tr><td>e.</td><td>$CH_3 - CH_2 - CH_2 - CH - OH$
|
C_3H_7</td><td>f.</td><td></td></tr>
</table>

1. Use your knowledge of intermolecular forces to predict, with reasoning,
   a. the relative boiling points of ethane, chloroethane, and ethanol.

   b. the relative solubility in water of ethane, chlorethane, and ethanol.

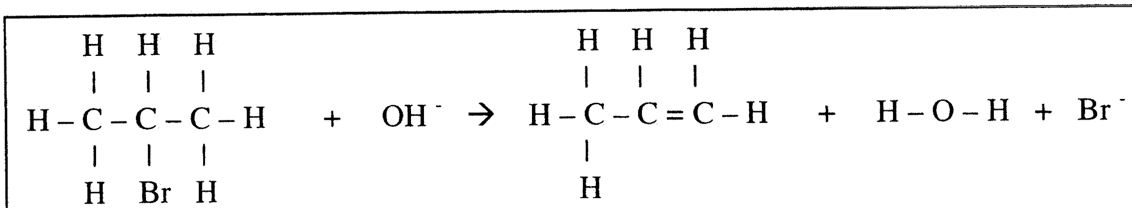
Elimination Reactions

- Are a primary source for alkenes, produced from either alcohols or alkyl halides
  - Molecules of hydrogen are "eliminated" from the organic molecule
- E.g



1,2-dimethyl-2-butanol 2,3-dimethyl-2-butene

- In **elimination reactions involving an alcohol**, atoms or groups of atoms are eliminated from adjacent carbon atoms in an organic molecule.
  - In this example, where 2,3-dimethyl-2-butene is synthesized from 1,2-dimethyl-2-butanol, a hydrogen atom and a hydroxyl group on adjacent carbon atoms are eliminated, forming water as a bi-product.
    - This specific type of elimination reaction is called a ***dehydration*** reaction because water is removed from the alcohol.
- example:



2-bromopropane + hydroxide ion → prop-1-ene + water + bromide ion

- In **elimination reactions involving an alkyl halide**, hydrogen atom(s) and halogen atom(s) are eliminated (in the presence of a strong base), to produce an alkene plus a halide ion and a water molecule.
    - This specific type of elimination reaction is called a ***dehydohalogenation*** reaction because both water and a halogen is removed from the alcohol.

3. Write a structural formula equation to represent the synthesis of ethene by reacting bromoethane with a strong base

4. Draw condensed structural diagrams for all reactants and products, and name all products. (You do not need to balance the equations.)
    a. Butan-1-ol reacts in the presence of concentrated sulfuric acid.

    b. In the presence of a strong base, 2-chlorobutane forms releases water and another small entity as it is transformed to an unsaturated compound.

Carboxylic Acids, Esters, and Esterification Reactions

Structure:

$$\begin{array}{c} O \\ \| \\ R - \underline{C - O - \textit{H}} \end{array}$$

Functional group: carboxyl group (-COOH); oxygen atom double bonded to a carbon, which is also bonded to a hydroxyl group and the hydrocarbon part of the molecule

Properties:

- acidic, usually water-soluble, strong unpleasant odors, form metal salts in acid-base reactions
- occur naturally in citrus fruits, crabapples, rhubarb; give the tangy taste of acids.
- polar therefore soluble in water (only those with 4 carbons or less)

Naming of Carboxylic Acids

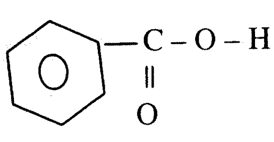
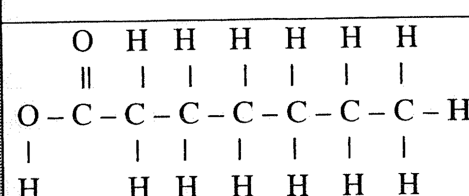
- Carboxylic acids are named by replacing the –e ending of the corresponding alkane name with –oic followed by the word "acid"

1. Draw a line and a condensed structural formula for each of the following compounds:
   (a) octanoic acid (b) butanoic acid

2. Give the IUPAC name for the following molecules:

   (a) $HOOC—CH_2—CH_2—CH_2—CH_3$ (b) $CH_3—CH_2—CH_2—CH_2—CH_2\text{-}COOH$

Provide the missing structural formula or chemical name for the following

a.	Propanoic acid	**b.**	Methanoic acid
c.	$CH_3 – CH_2 – CH_2 – CH_2 – COOH$	**d.**	Butanoic acid
g.		**h.**	

Esters

- Derived from carboxylic acids in which the –OH of the carboxyl group has been replaced with an – OR from an alcohol.
- Properties: strong aromas, volatile
- Uses: artificial flavorings and fragrances, polyester fabric
- Biological functions: fat storage in cells, DNA phosphate-sugar backbone, natural flavors and fragrances, beewax
- Examples: banana oil, oil of wintergreen, triglycerides (fats)

An ester has the following general formula:

```
  O     [From the alcohol]
  ||
R – C – O – R'
[From the acid]
```

general formula is RCOOR′

Esters are derivatives of carboxylic acids – they are produced through the reaction of carboxylic acids and alcohols. The process is know as **esterification.**

```
  O                            O              O
  ||            +       →      ||         +  / \
R – C – O – H     H – O – R′  R – C – O – R′   H   H
```

Carboxylic acid + alcohol → ester + water

- The ester functional group, -COOR, is similar to that of an acid, except that the hydrogen atom of the carboxyl group has been replaced by a hydrocarbon branch.

example:

$$CH_3\overset{O}{\overset{\|}{C}}OH + HOCH_2CH_3 \rightleftarrows CH_3\overset{O}{\overset{\|}{C}}OCH_2CH_3 + H_2O$$

ethanoic acid + ethanol react to form ______________________ + __________

Naming Esters:

The name of an ester is made up of two parts:

- The first part is the name of the alkyl group from the alcohol used in the esterification process
- The second part comes from the carboxylic acid. The ending of the acid name is changed from *–oic* acid to *–oate*

- Ester names are confusing because the name is written backwards from the way the structure is drawn. There's no way round this - you just have to get used to it!
- Draw the following

eg.#1 butylmethanoate

eg.#2 ethylmethanoate

1. **Complete the chart below**

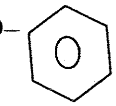
Name and structural formula of carboxylic acid used	Name and structural formula of alcohol used	Name of ester	Odor	Structural formula of ester
		ethyl butanoate	pineapple	
		Ethyl methanoate	rum	

2. Write a structural formula equation to illustrate the synthesis of each of the following esters from an alcohol and an acid.

(a) ethyl methanoate

(b) methyl butanoate

3. Name the following esters

a.	O ‖ $CH_3-CH_2-CH_2-C-O-C_2H_5$	b.	O ‖ $H-C-O-C_2H_5$
c.	O ‖ $CH_3-C-O-C_3H_7$		O ‖ CH_3-CH_2-C-O- 

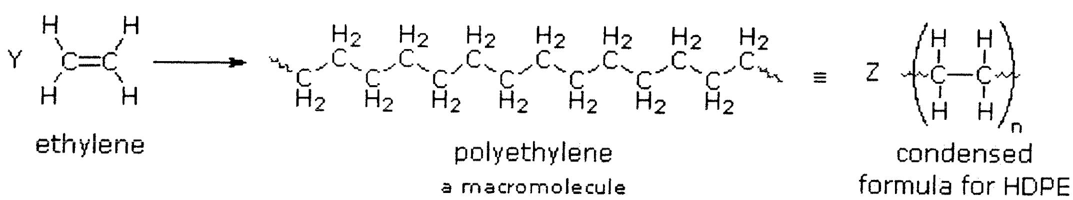
Polymerization Reactions – Monomers and Polymers

Polymers

- Large molecules formed by linking together many smaller molecules called **monomers**
- Process is called **polymerization**
- Links are formed by condensation or addition reactions depending on the monomer
- Monomer unit can be manipulated to give the polymer different characteristics such as strength flexibility, chemical stability, density, temperature resistance etc.
- Include plastics which are synthetic polymers
- Natural occurring polymers include amber, silk, rubber, cotton, proteins and carbohydrates.

Addition Polymerization

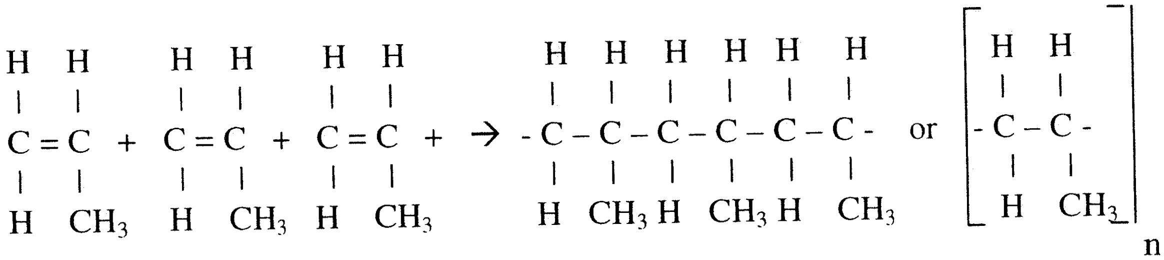
- The repeating structural unit of most simple polymers not only reflects the monomer(s) from which the polymers are constructed, but also provides a concise means for drawing structures to represent these macromolecules.
- For polyethylene, arguably the simplest polymer, this is demonstrated by the following equation.
- Here ethylene (ethane) is the monomer, and the corresponding linear polymer is called high-density polyethylene (HDPE).



- Used to make insulation for wire, plastic refrigerator dishes, plastic milk container

Polypropene (polyproplylene)

- Formed by the addition polymerization of propene

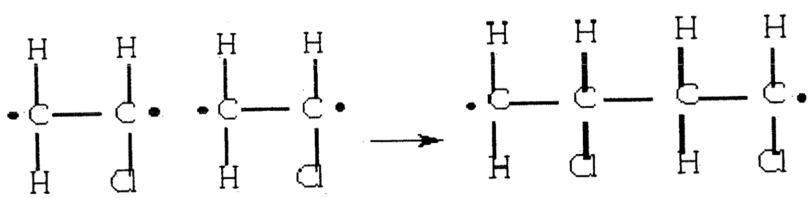


propene monomers polypropene (polypropylene)

- Used to make ropes and carpets
-

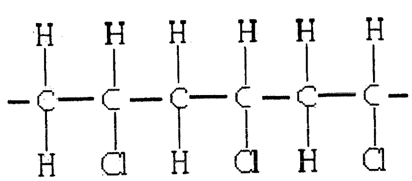
Polyvinyl Chloride (PVC)

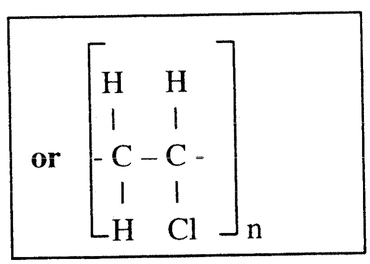
- Addition polymer of chloroethene (common name is vinyl chloride)
- Used for insulating electrical wires, raincoats, upholstery materials



vinyl chloride monomers

This dimer can react with another vinyl chloride to form a trimer:



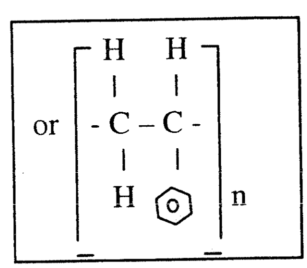


polyvinyl chloride (PVC)

By repeating this process many times, a long polymer, hundreds or even thousands of monomer units long, can be formed. This polymer is then called **polyvinyl chloride** or simply, **PVC**.

Polystyrene

- A polymer used to make cups and containers
- Uses the monomer vinyl benzene (phenyl ethane)

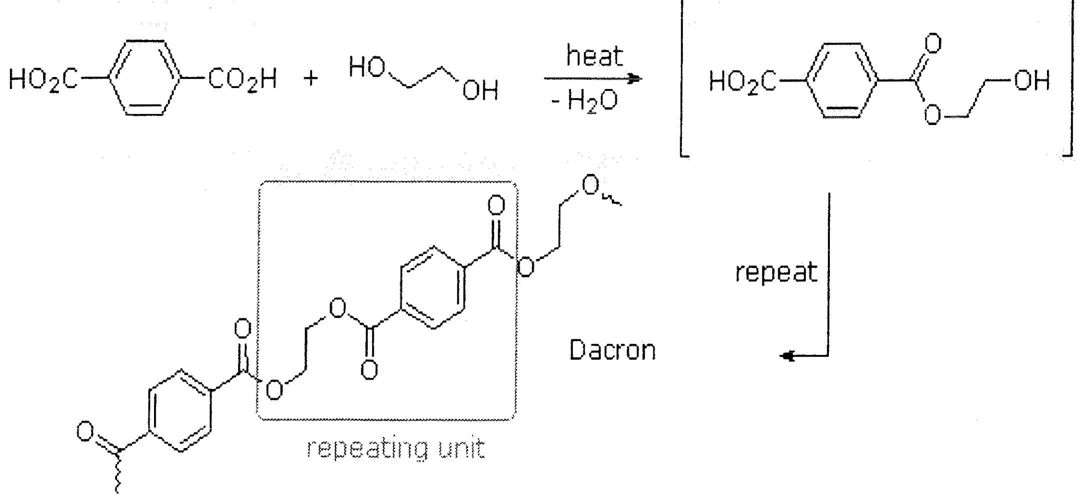


Condensation Polymerization

- Reaction involves the formation of a small molecule such as H_2O, NH_3, or HCl when two different monomer groups react.
- For condensation polymerization to work, each monomer **must possess two functional groups** eg. – OH or – COOH
- When a carboxylic acid reacts with a molecule in an esterification reaction, a water molecule is eliminated and a single ester is formed. This reaction can be repeated joining many esters together to form a polyester.

Examples of Condensation Polymers

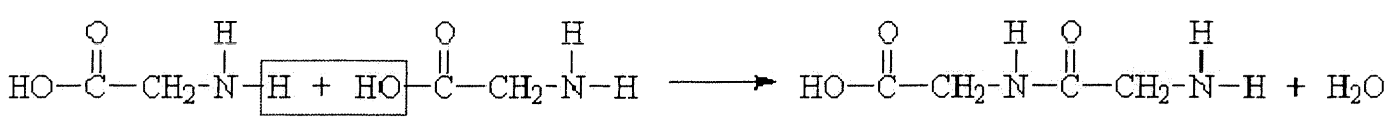
Polyester



Protein

- Proteins which are estimated to number over a billion types is made from about 20 different amino acids
- Condensation reaction occurs through the reaction of a carboxyl functional group (-COOH) on one monomer with the amine functional group (- NH_2) of the second monomer.
- Can produce proteins with a molar mass tens of thousands to millions of grams per mole.

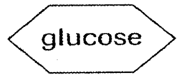
A condensation polymerization occurs when a polymer is formed from a reaction that leaves behind a small molecule, often water. The formation of peptide bonds in proteins is an example of a condensation polymerization. In this case, an amine reacts with a carboxcylic acid to form an amide bond. Glycine is the simplest amino acid: the reaction below shows the reaction between two glycine molecules to form a glycine dimer.



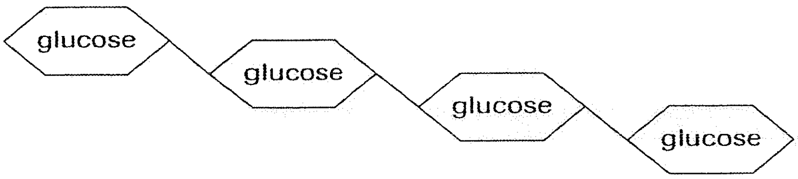
Carbohydrates and Cellulose Acetate

Carbohydrates—Starch and Cellulose

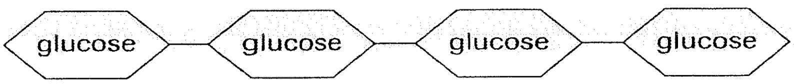
Monomer: glucose, $C_6H_{12}O_6$
6 carbons, usually in a ring;
an aldehyde with 5 OH groups



Starch: linkage produces coiled polymer



Cellulose: linkage produces linear polymer



- Starches include foods such as rice, corn, potatoes.
- Enzymes in intestinal tract can break down starch but not cellulose.
- Both cellulose and starch are formed from a glucose monomer except cellulose is a straight-chain to provide support for plants
- In starch the glucose monomers are joined at angles that lead to a helical structure.

Multiple Choice – Organic Chemistry

1. Esters are formed by reaction of

   A. an alkane and an alkene
   B. an organic acid and an inorganic acid
   C. an organic acid and an alcohol
   D. an alcohol and water

2. Which of the following is likely to have the highest boiling point?

   A. CH_4 C. CH_3CH_3
   B. C_4H_{10} D. C_7H_{16}

3. Which of the following is likely to be most soluble in water?

   A. CH_4 C. $C_{14}H_{30}$
   B. CH_3OH D. C_6H_6

4. The carbon-carbon bonds in benzene are

   A. identical to the carbon-carbon bonds in cyclohexane
   B. identical to the carbon-carbon bonds in cyclohexene
   C. a hybrid between a double and single bond
   D. easily broken in chemical reactions

5. Which of the following is NOT a property of alkanes?

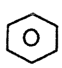
   A. They are soluble in water.
   B. They have weak intermolecular attraction.
   C. The boiling point increases as the number of carbons increase.
   D. They are unreactive at room temperature.

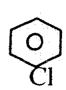
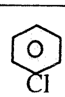
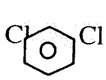
6. The coefficients for the balance equation for the reaction

   $$\_\_\_ C_5H_{12} + \_\_\_ O_2 \rightarrow \_\_\_ CO_2 + \_\_\_ H_2O$$

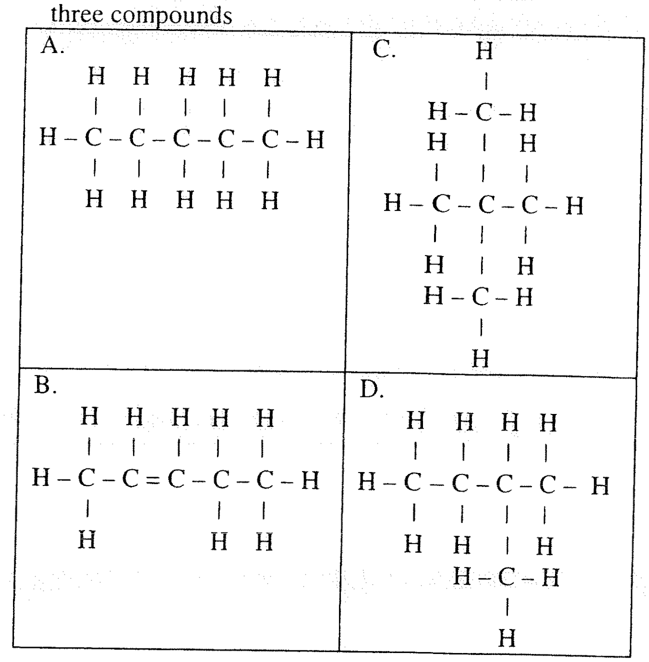
   A. 1, 8, 5, 6   C. 1, 16, 5, 6
   B. 0, 8, 5, 6   D. 2, 16, 10, 12

7. The product(s) of the reaction

    + $Cl_2 \rightarrow$

A. 	C.  + HCl
B. 	D. No reaction occurs

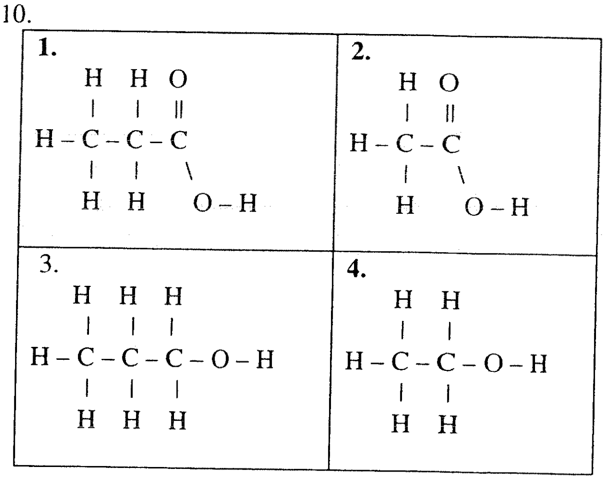
8. Which compound is not an isomer of the other three compounds



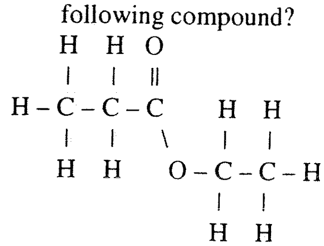
9. Which of the following is a homologous series?

   A. C_2H_6, C_2H_4, C_2H_2
   B. C_2H_6, C_3H_5, C_4H_8
   C. C_2H_6, C_3H_8, C_4H_{10}
   D. C_2H_2, $C_2H_2O_2$, $C_2H_2O_2N_2$

10.



Which of the above two reactants will form the following compound?

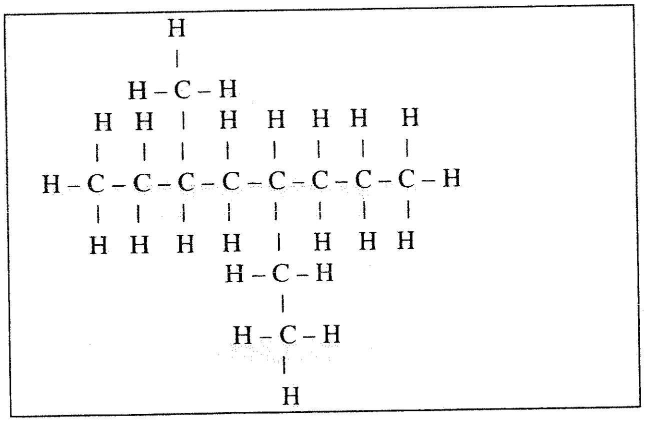


A. 1 and 3   C. 2 and 4
B. 1 and 4   D. 2 and 3

11. The name of the compound formed in question 10 is:

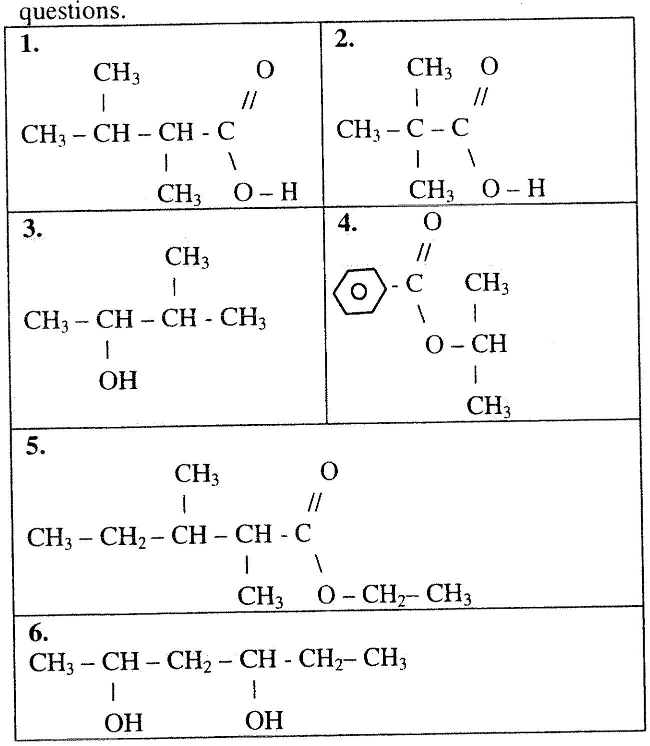
A. ethyl propanoate
B. 3,3- dioxypentane
C. propyl ethanoate
D. proplyethylester

12. The name of the following compound is



A. 5 – methyl - 6 – methyloctane
B. 3 – methyl - 4 – ethyloctane
C. 4 – ethyl - 3 – methyloctane
D. 3 – methyl - 5 – butylhexane

Use the following compounds to answer the next two questions.



13. A compound(s) which is an alcohol is(are)

A. 1 and 2
B. 2 only
C. 3 and 6
D. 4 and 5

14. A compound(s) which is an ester is(are)

A. 1 and 2
B. 2 only
C. 3 and 6
D. 4 and 5

15. A compound(s) which is a carboxylic acid is(are)

A. 1 and 2
B. 2 only
C. 3 and 6
D. 4 and 5

16. The saturated compound is

A. propene
B. octane
C. hept-3-yne
D. bur-2-ene

17. When $Cl_2(g)$ is mixed with propane, what type of reaction will occur?

A. a combustion reaction
B. a substitution reaction
C. an addition reaction
D. no reaction

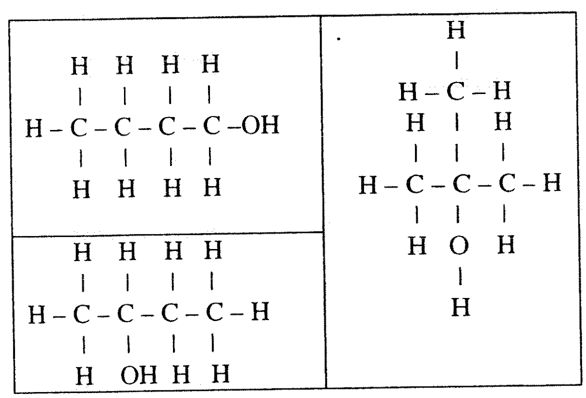
18. When $Cl_2(g)$ is mixed with propene, what type of reaction will occur?

A. a combustion reaction
B. a substitution reaction
C. an addition reaction
D. no reaction

19. The formula that represents an alkyne is

A. C_5H_8
B. C_5H_{12}
C. C_5H_{10}
D. C_5H_6

20.



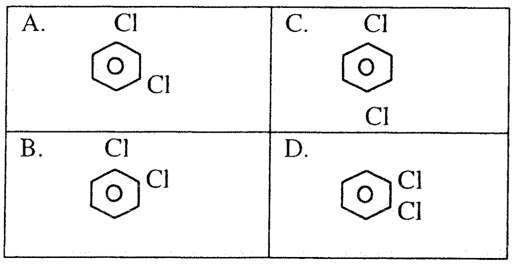
Which is the UNTRUE statement about the above three alcohols?

A. They are isomers of each other.
B. they all have the same chemical and physical properties.
C. They are examples of primary, secondary and tertiary alcohols.
D. They all have the same molar mass.

21. An artificial rum flavouring is ethylmethanoate. Ethylmethanoate is

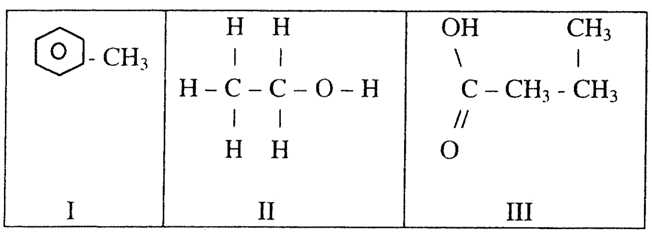
A. an acid
B. an alcohol
C. an ester
D. a ketone

22. The structural formula for 1,3-dichlorobenzene is



Use the following information to answer the next three questions.

Gasoline must meet more stringent requirements as more and more government restrictions are placed on automobiles to increase fuel economy and reduce emissions. Catalytic converters, which oxidize unburned hydrocarbons and carbon monoxide and reduce nitrogen oxides, require compounds, like the following, to work more efficiency.



23. Compound I is

A. phenol
B. benzene
C. methylbenzene
D. cyclohexene

24. Compound II is

A. isoethane
B. ethane
C. ethanol
D. ethene

25. Comound III is

A. an alcohol
B. an ester
C. a carboxylic acid
D. an aldehyde

Use the following to answer the next question.

Ethanol, used in the manufacture of poly(ethane), the plastic in grocery bags, is produced by the elimination of hydrogen from ethane (a common component of natural gas in Alberta)

26. An elimination reaction can be characterized by

A. Two reactant changing parts to give two products
B. one reactant reacts so as to lose atoms, usually as a small molecule
C. two reactants combining to form a single product
D. a reorganization of bonds and atoms to give a different product with the same chemical formula.

27. Propane can undergo a substitution reaction with chlorine gas. The expected balanced equation for this reaction is

A. $C_3H_8(g) + Cl(g) \rightarrow C_3H_7Cl(g) + H_2(g)$
B. $C_3H_8(g) + Cl_2(g) \rightarrow C_3H_7Cl(g) + HCl(g)$
C. $C_3H_8(g) + Cl_2(g) \rightarrow C_3H_6Cl_2(g) + H_2(g)$
D. $C_3H_8(g) + 2Cl(g) \rightarrow C_3H_6Cl_2(g) + H_2(g)$

Use the following to answer the next question.

Long chains of starch and cellulose are made up of many molecules of glucose. Starch is the main form of food storage in plants and cellulose is the main component of the cell wall in plants

28. Which chemical entity would be considered the monomer of starch and cellulose?

A. starch
B. cellulose
C. glucose
D. single chain

Answers

1. C	8. B	15. A	22. A
2. D	9. C	16. B	23. B
3. B	10. B	17. B	24. C
4. C	11. A	18. C	25. C
5. A	12. B	19. A	26. B
6. A	13. C	20. B	27. B
7. C	14. D	21. C	28. C