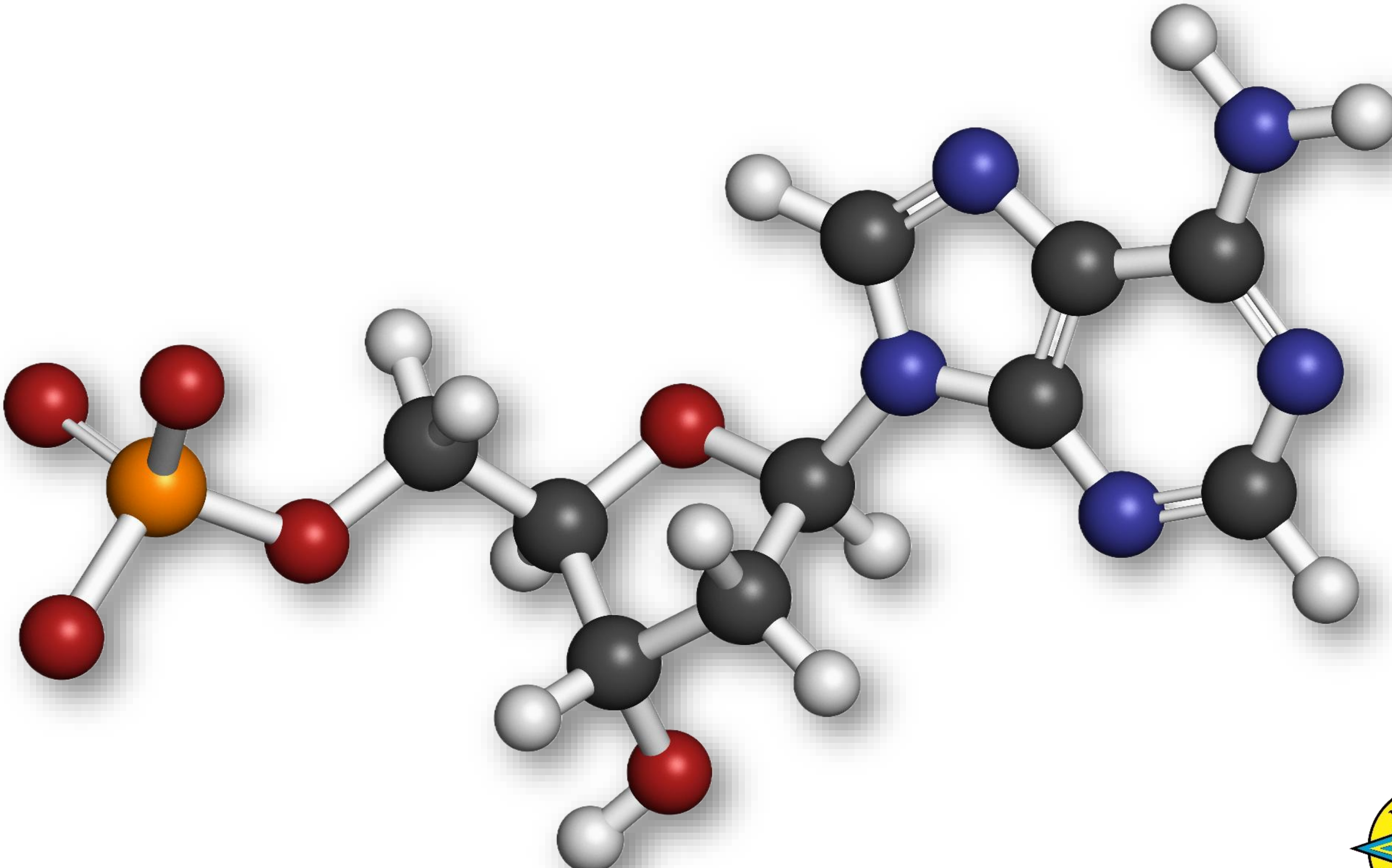
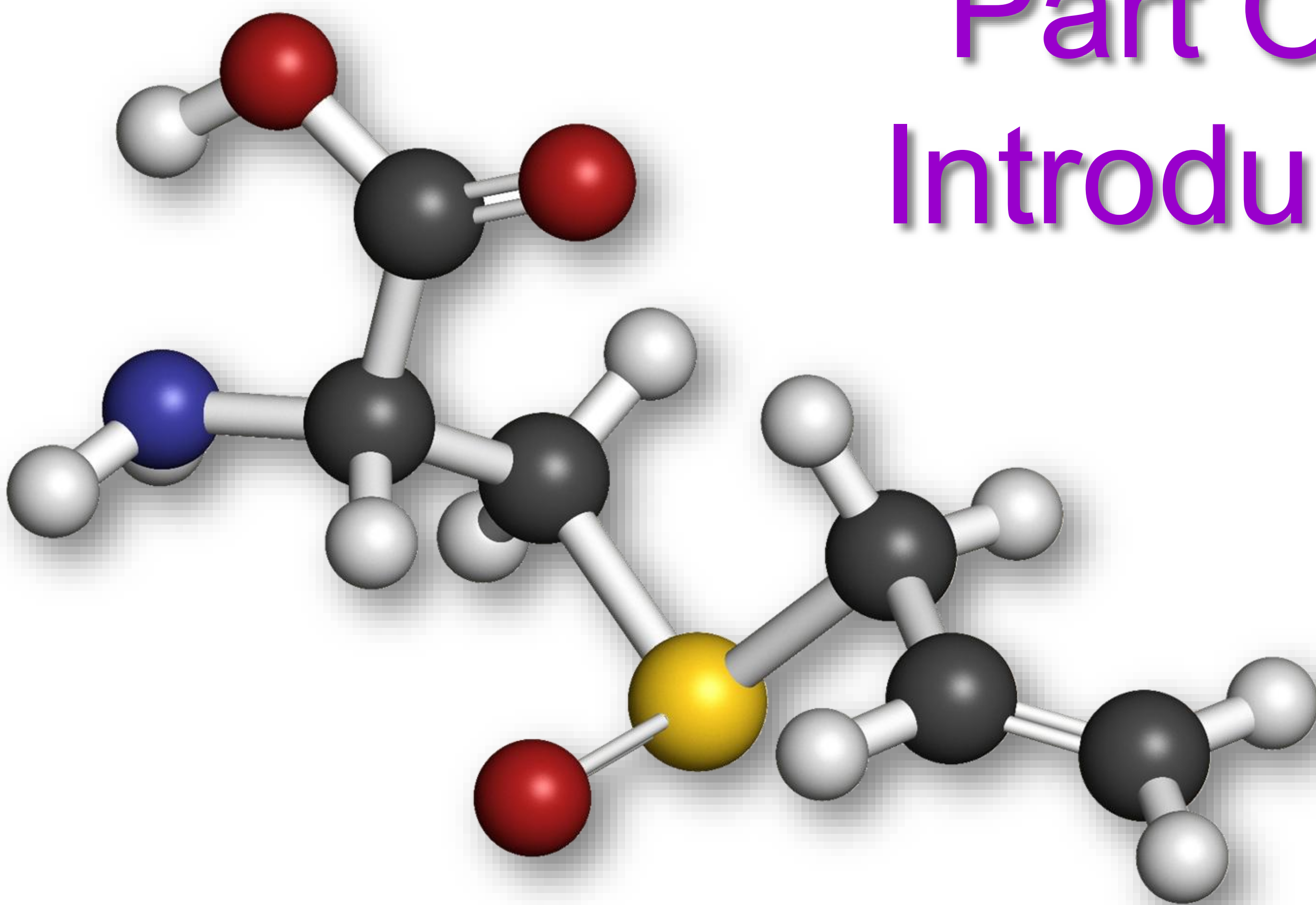
Organic Chemistry



Organic Chemistry

Part One: Introduction



Organic Chemistry

What do I need to know about *organic chemistry*?

Organic Chemistry

Overview

In the nineteenth century, chemists believed that all organic chemicals originated in tissues of living organisms. Friedrich Wohler, in 1828, challenged this belief and synthesised the organic compound urea, a compound found in urine, under laboratory conditions. His work led other chemists to attempt the synthesis of other organic compounds. In this section, students examine the sources of fuels, some basic concepts of organic chemistry such as homologous series, functional group, general formula and structural formula, and polymers. Students should be able to identify and name unbranched alkanes, alkenes, alcohols and carboxylic acids. They should recognise that materials such as plastics, detergents and medicines, and even the food that we eat are examples of organic compounds. Students should be able to value the need for assessing the impacts of the use of synthetic materials and the environmental issues related to the use of plastics.

- Singapore Examinations and Assessment
- Board University of Cambridge International Examinations
- Ministry of Education Singapore

Organic Chemistry

Learning Outcomes:

Candidates should be able to:

Fuels and Crude Oil

a) Name natural gas, mainly methane, and petroleum as sources of energy.
b) Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation.
c) Name the following fractions and state their uses:
- **i)** Petrol (gasoline) as a fuel in cars.
- **ii)** Naphtha as feedstock for the chemical industry.
- **iii)** Paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines.
- **iv)** Diesel as a fuel for diesel engines.
- **v)** Lubricating oils as lubricants and as a sources of polishes and waxes.
- **vi)** Bitumen for making road surfaces.

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d) State that the naphtha fraction from crude oil is the main source of hydrocarbons used as the feedstock for the production of a wide range of organic compounds.

e) Describe the issues relating to the competing uses of oil as an energy source and as a chemical feedstock.

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Alkanes

a) Describe an homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, *e.g.* melting and boiling points; viscosity; flammability.

b) Describe the alkanes as an homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}.

c) Draw the structures of branched and unbranched alkanes, C1 to C4, and name the unbranched alkanes, methane to butane.

d) Define isomerism and identify isomers.

e) Describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of burning and substitution by chlorine.

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Alkenes

a) Describe the alkenes as an homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}.
b) Draw the structures of branched and unbranched alkenes, C2 to C4, and name the unbranched alkenes, ethene to butene.
c) Describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process.
d) Describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine.
e) Describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerisation and the addition reactions with bromine, steam and hydrogen.
f) State the meaning of polyunsaturated when applied to food products.
g) Describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product.

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Alcohols

a) Describe the alcohols as an homologous series containing the –OH group.
b) Draw the structures of alcohols, C1 to C4, and name the unbranched alcohols, methanol to butanol.
c) Describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids.
d) Describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose.
e) State some uses of ethanol, *e.g.* as a solvent; as a fuel; as a constituent of alcoholic beverages.

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Carboxylic Acids

a) Describe the carboxylic acids as an homologous series containing the –CO_2H group.

b) Draw the structures of carboxylic acids, methanoic acid to butanoic acid and name the unbranched acids, methanoic to butanoic acids.

c) Describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals.

d) Describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium dichromate(VI).

e) Describe the reaction of a carboxylic acid with an alcohol to form an ester, *e.g.* ethyl ethanoate.

f) State some commercial uses of esters, *e.g.* perfumes; flavourings; solvents.

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Macromolecules

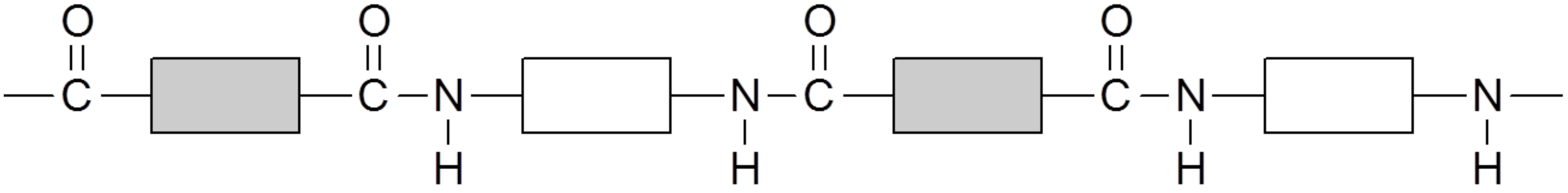
a) Describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages.

b) Describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer.

c) State some uses of poly(ethene) as a typical plastic, *e.g.* plastic bags; clingfilm.

d) Deduce the structure of the polymer product from a given monomer and vice versa.

e) Describe nylon, a polyamide, and *Terylene*, a polyester, as condensation polymers, the partial structure of nylon being represented as:



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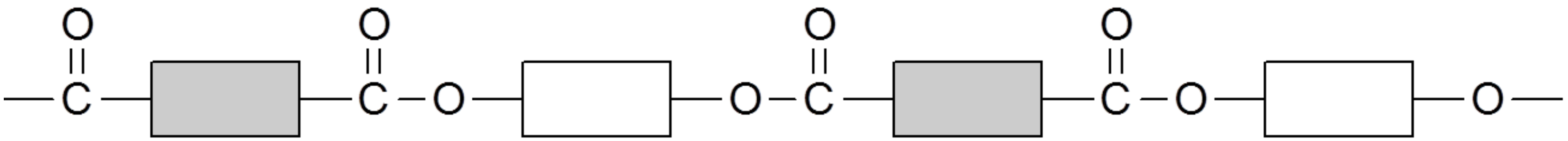
And the partial structure of *Terylene* as:



(Details of manufacture and mechanisms of these polymerisations are not required).

f) State some typical uses of man-made fibres such as nylon and *Terylene*, *e.g.* clothing; curtain materials; fishing line; parachutes; sleeping bags.

g) Describe the pollution problems caused by the disposal of non-biodegradable plastics.

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What is an *organic compound*?

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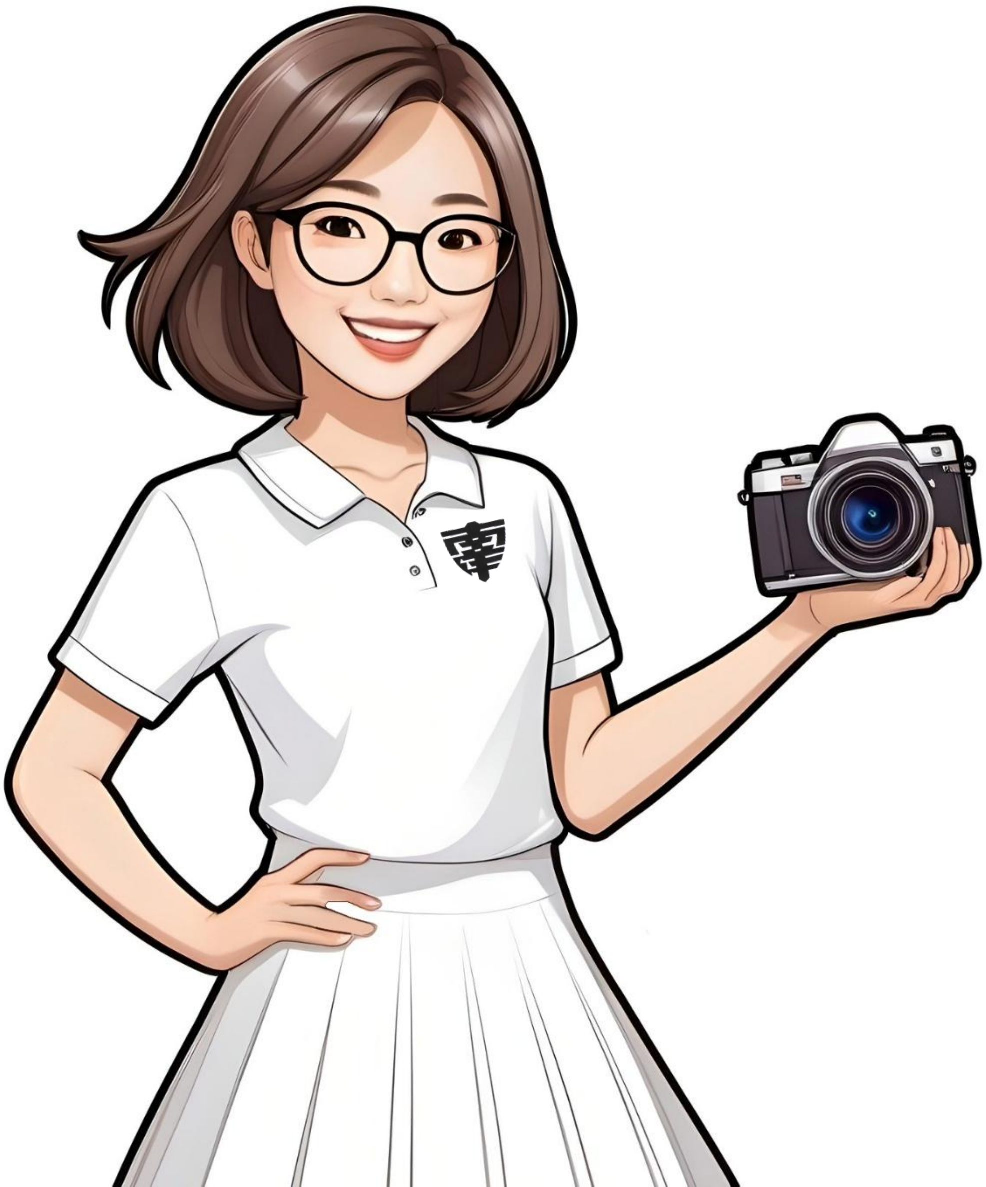

- Walk around Nanyang Girls’ High School and take photographs of different materials that you consider to be:

  → Organic × 6.

  → Inorganic × 6.

- Upload the photographs into the shared document, clearly stating whether you consider the material to be *organic* or *inorganic*.

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- What in this picture is *organic*?
- What in this picture is *inorganic*?

- The Tiger That Came to Tea – Judith Kerr – 1968

Organic Chemistry

Organic	Inorganic
Citric Acid – $C_6H_8O_7$	Aluminium Oxide – Al_2O_3
Ethanoic Acid – CH_3COOH	Calcium Carbonate – $CaCO_3$
Ethanol – CH_3CH_2OH	Carbon Dioxide – CO_2
Glucose – $C_6H_{12}O_6$	Copper(II) Sulfate – $CuSO_4$
Methane – CH_4	Sodium Chloride – $NaCl$
Poly(ethene) – $(CH_2CH_2)_n$	Sulfuric Acid – H_2SO_4
Propane – C_3H_8	Water – H_2O

- Compare the organic compounds with the inorganic compounds. What are the differences?

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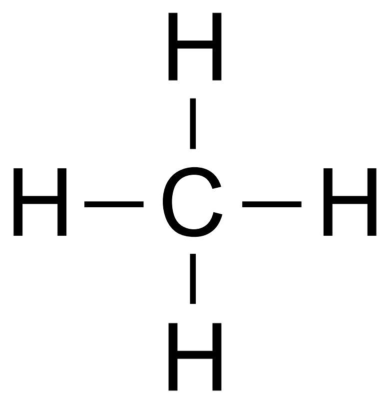
- An organic compound is a compound that contains *carbon covalently bonded to hydrogen*.

- Methane (formula CH_4) is *organic*.



- Carbon dioxide (formula CO_2) is *inorganic*.

$$O=C=O$$

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What is the nature of the *bonding* in organic compounds?

- Because only atoms of *non-metallic elements* are present, the bonding in organic compounds is *covalent*.

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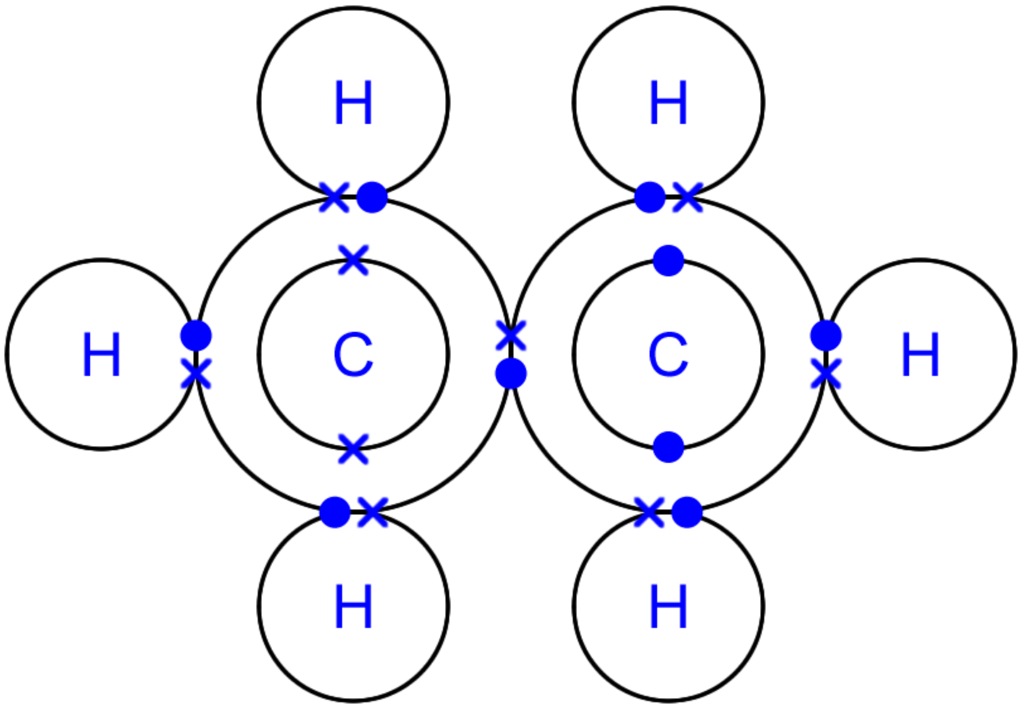
Bonding in Organic Compounds

Ethane – C_2H_6



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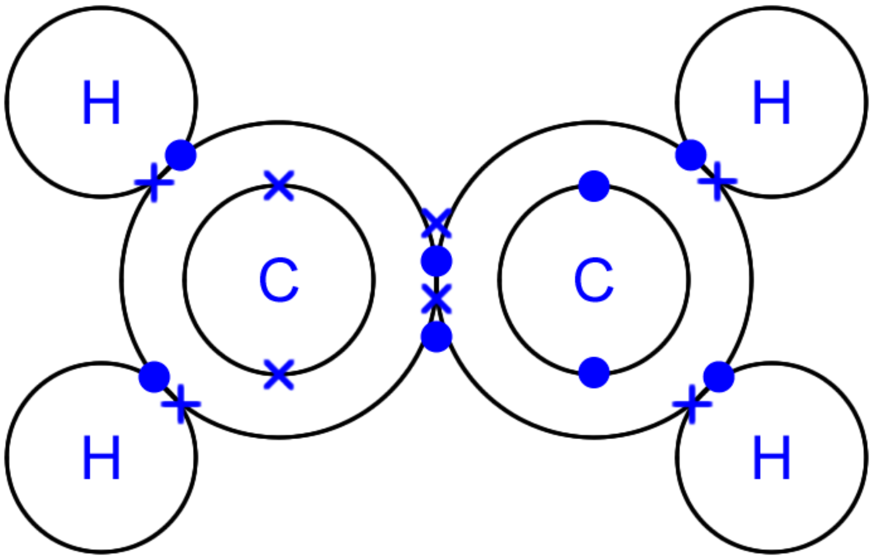
Bonding in Organic Compounds

Ethene – C_2H_4



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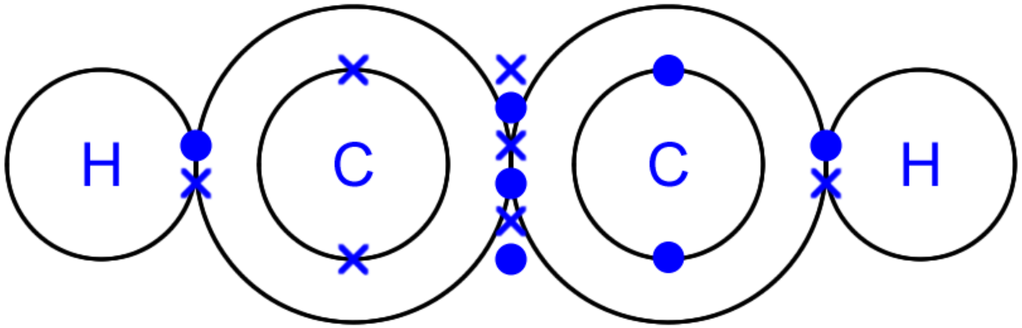
Bonding in Organic Compounds

Ethyne – C_2H_2



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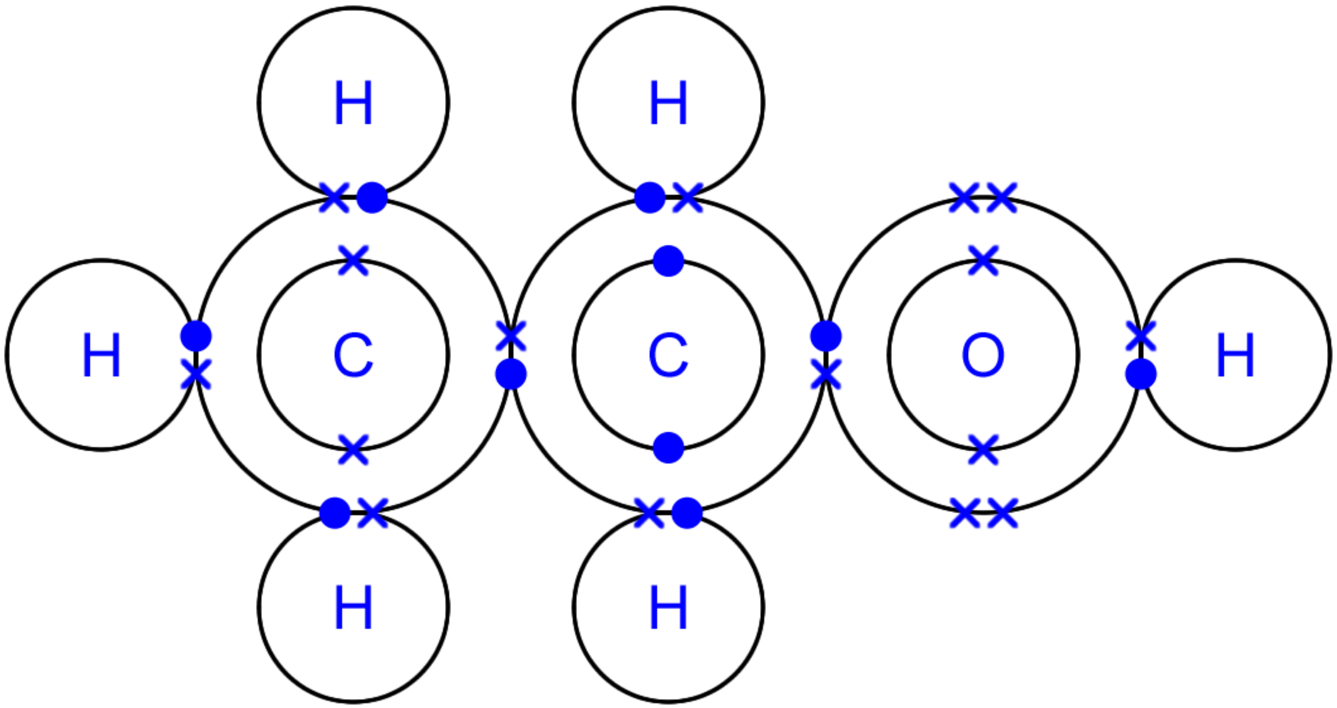
Bonding in Organic Compounds

Ethanol – CH_3CH_2OH



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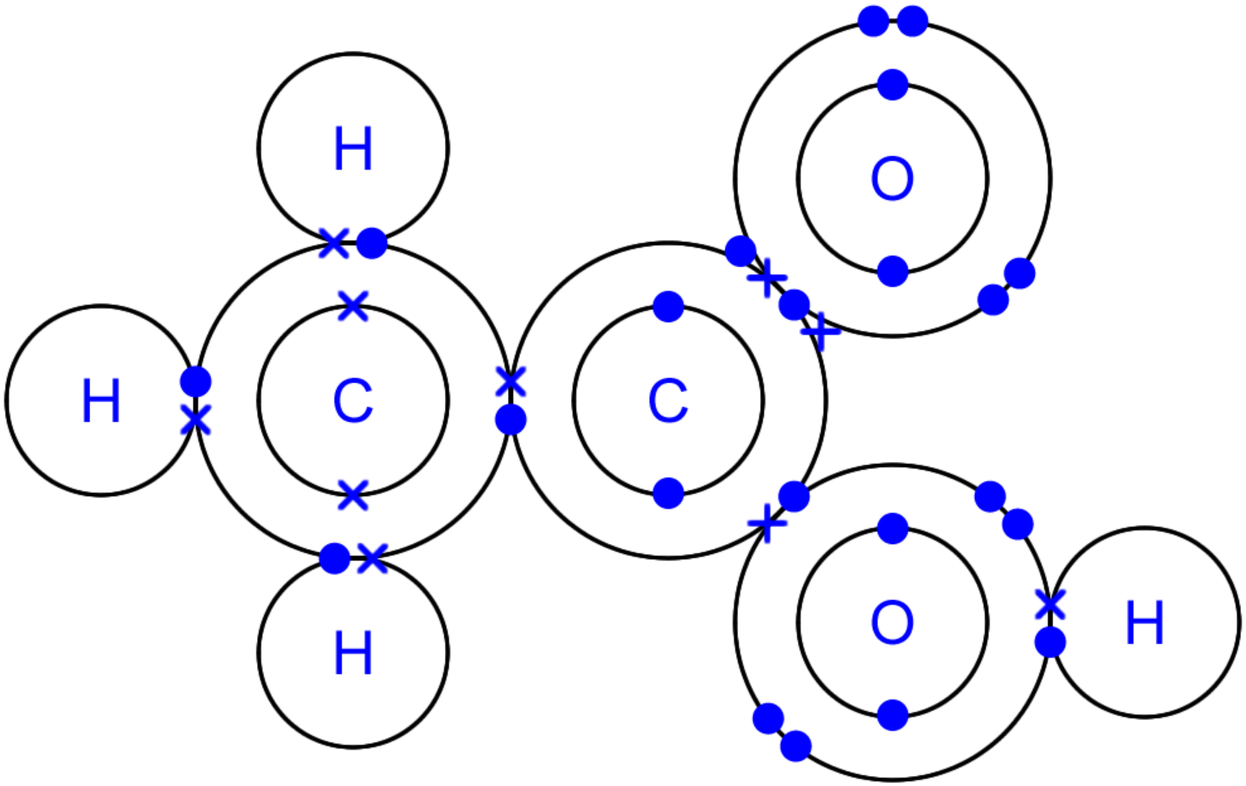
Bonding in Organic Compounds

Ethanoic Acid – CH_3COOH



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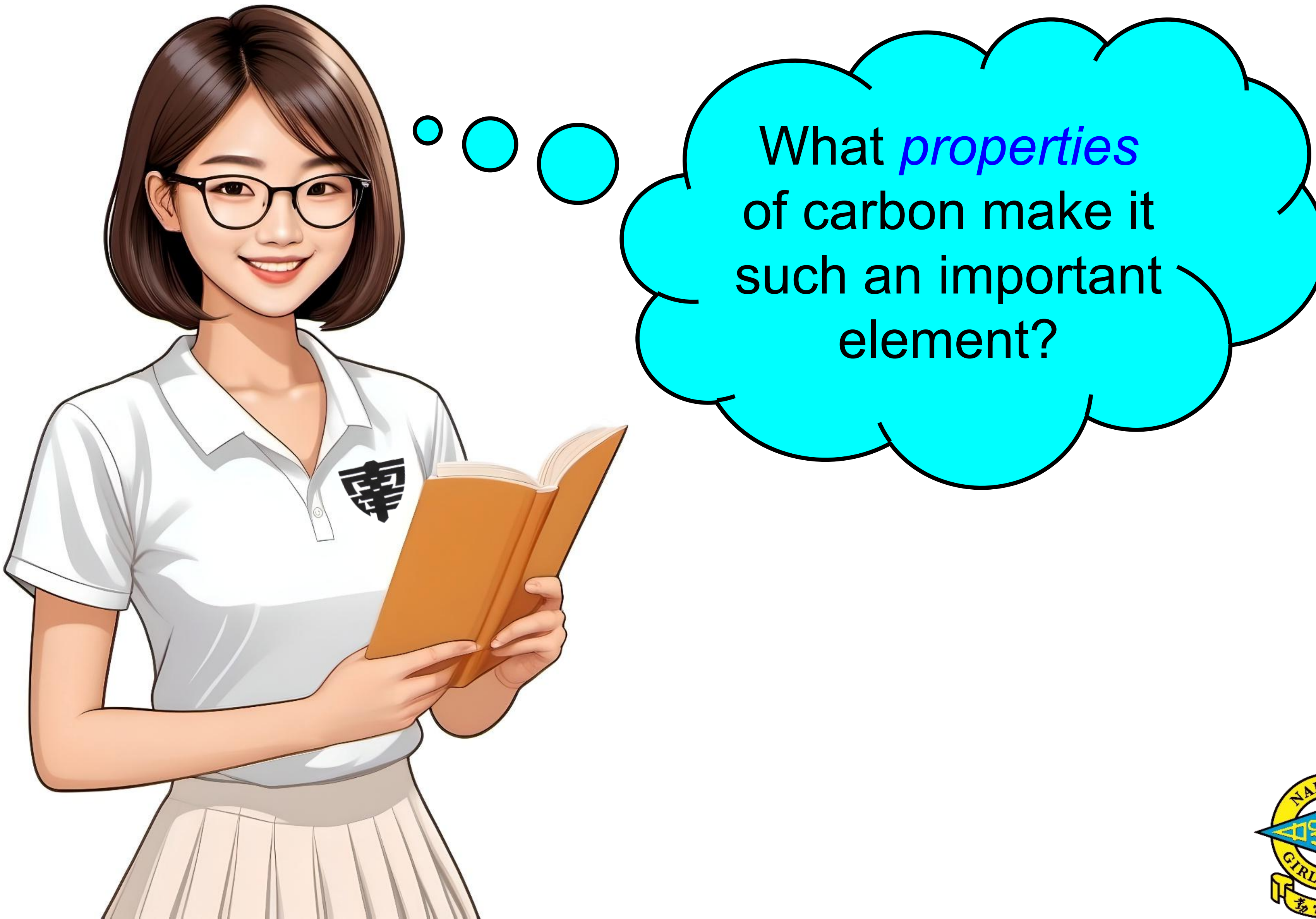

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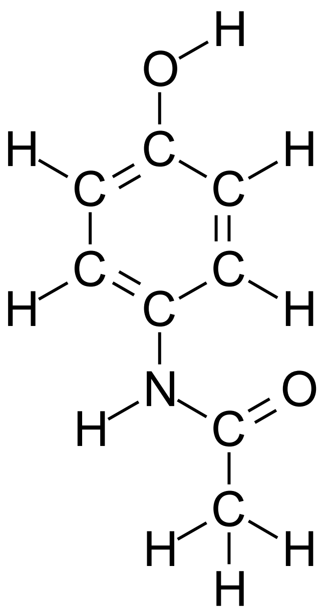
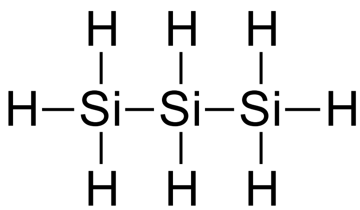
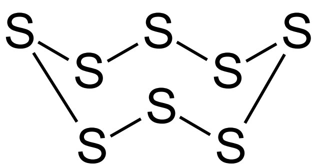
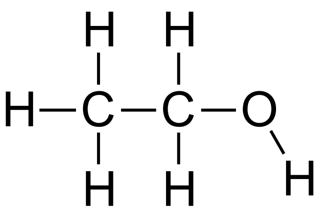
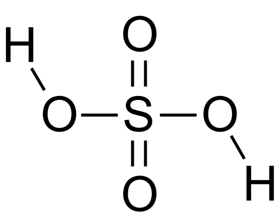
- Compare the bonding in the organic compounds with the bonding in the inorganic elements and compounds. What similarities and differences do you notice?

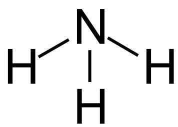


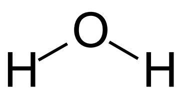


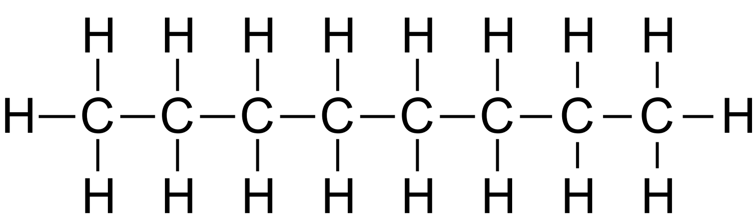


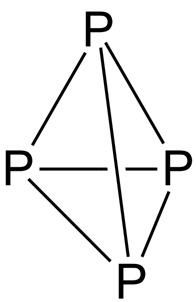












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- Compare the bond strengths between **i)** carbon atoms, **ii)** carbon atoms and other elements **iii)** other elements (excluding carbon). What similarities and differences do you notice?

Bond	ΔH kJ/mol
C – C	348
Si – Si	176
N – N	163
O – O	146
P – P	172
S – S	264
C*l* – C*l*	242

Bond	ΔH kJ/mol
C – H	412
Si – H	318
N – H	388
O – H	463
P – H	322
S – H	338
C*l* – H	431

Bond	ΔH kJ/mol
C = C	612
C ≡ C	837
C – N	305
C = N	613
C ≡ N	890
C – O	360
C – C*l*	338

Organic Chemistry

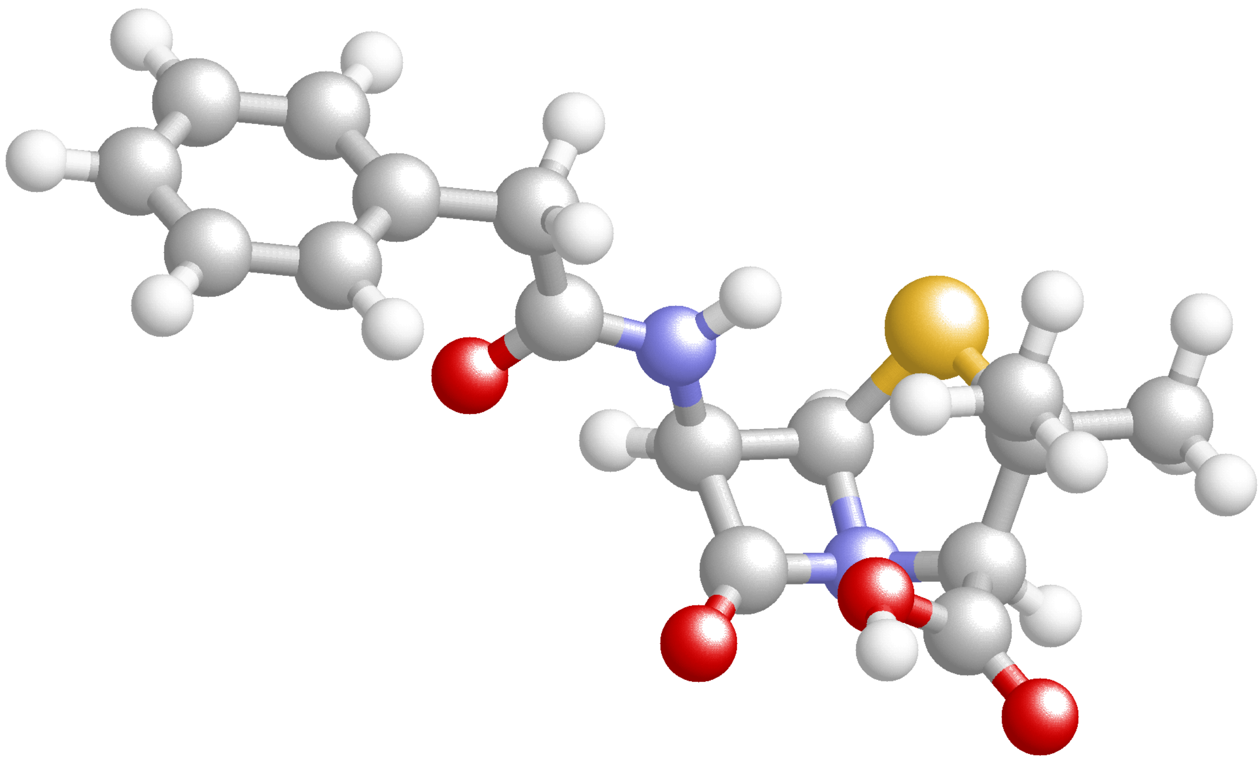
The Special Properties of carbon

- Carbon is in Group 14 of the Periodic Table. It has four electrons in its valence shell and therefore makes four covalent bonds with atoms of other non-metallic elements.
Carbon is described as being *tetravalent*.

- The covalent bond between two carbon atoms is very strong. This allows carbon atoms to join together in large numbers to form long-chains and complex rings.
Carbon is said to *catenate*.

Organic Chemistry

The Special Properties of carbon



- The complex structure of the antibiotic *penicillin*.

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Organic Chemistry

Homologous Series

- A *homologous series* of organic compounds is a group of molecules that possess the same *functional group*, share the same *general formula* and have similar names.

- A *functional group* is a group of atoms that are bonded together in a way that is unique to that particular homologous series. The functional group is responsible for a compound's characteristic *chemical properties*.

- Because they all possess the same functional group, members of the same homologous series will all *react in a similar way* to each other.

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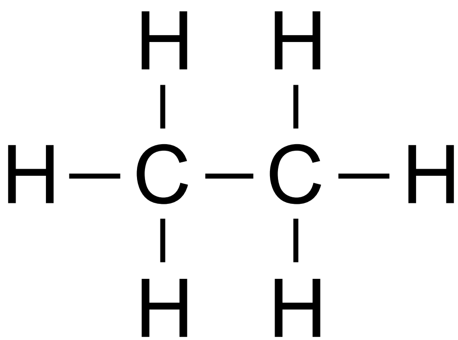
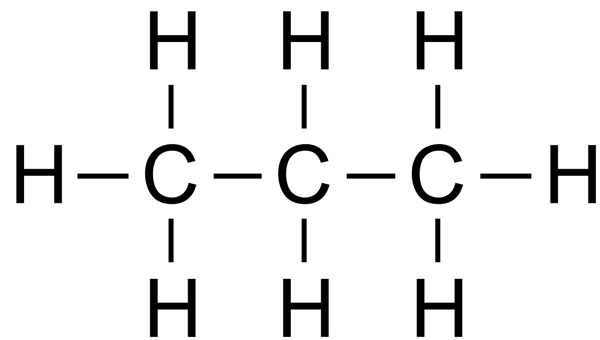
Homologous Series – Alkanes



- Ethane



- Propane

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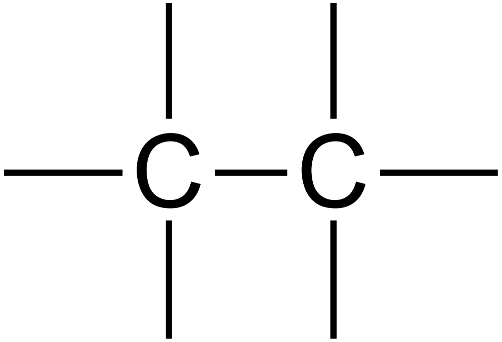
Homologous Series – Alkanes

Functional Group



General Formula

C_nH_{2n+2}

Name

-ane

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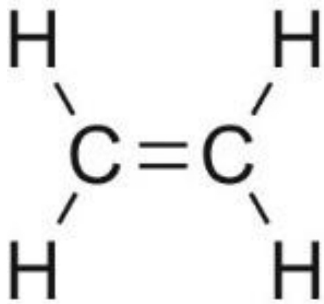
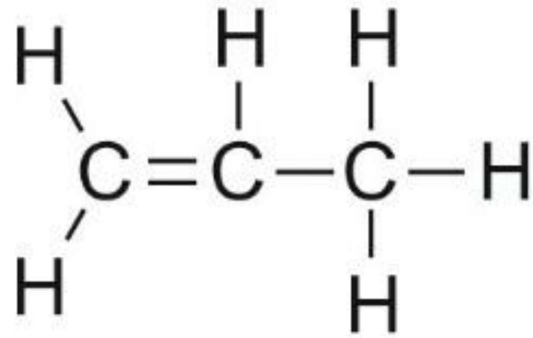
Homologous Series – Alkenes



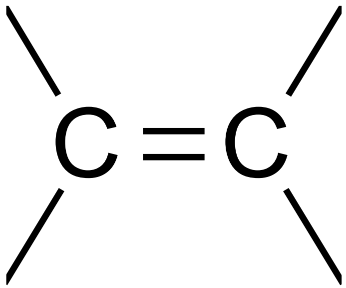


- Ethene
- Propene

Organic Chemistry

Homologous Series – Alkenes

Functional Group

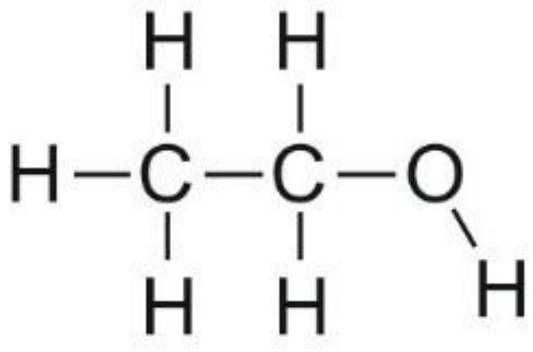


General Formula C_nH_{2n}

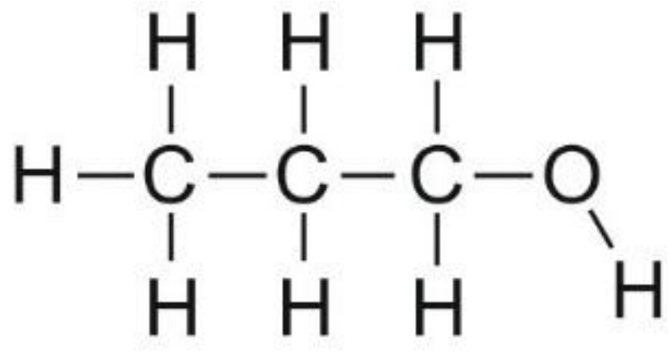
Name -ene

Organic Chemistry

Homologous Series – Alcohols



- Ethanol

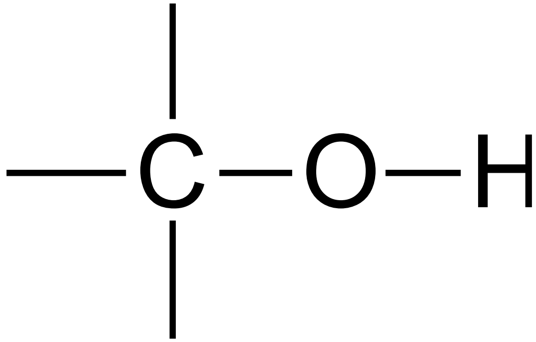


- Propan-1-ol

Organic Chemistry

Homologous Series – Alcohols

Functional Group
hydroxyl

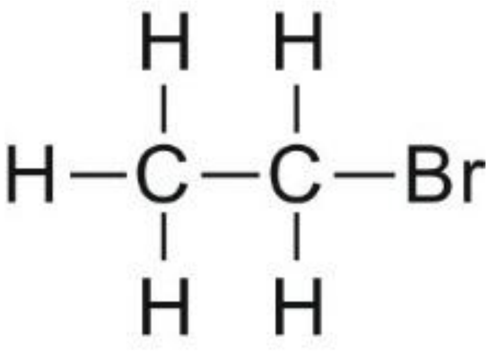


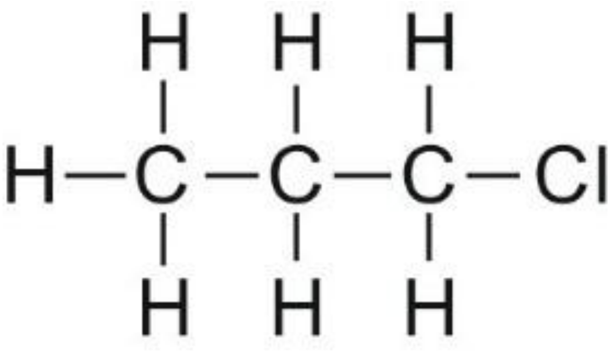
General Formula $C_nH_{2n+1}OH$

Name -ol

Organic Chemistry

Homologous Series – Halogenoalkanes



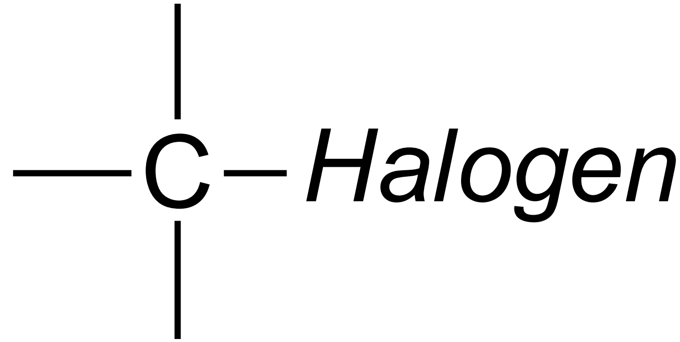


- Bromoethane
- 1-Chloropropane

Organic Chemistry

Homologous Series – Halogenoalkanes

Functional Group



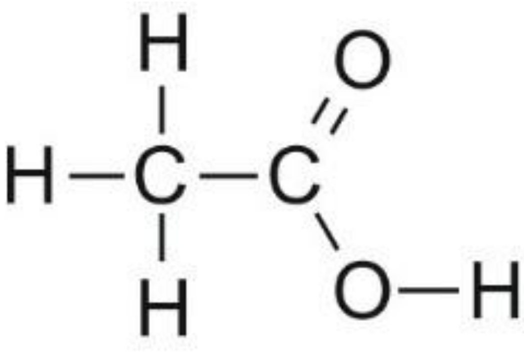
General Formula $C_nH_{2n+1}\mathit{Hal}$

Name

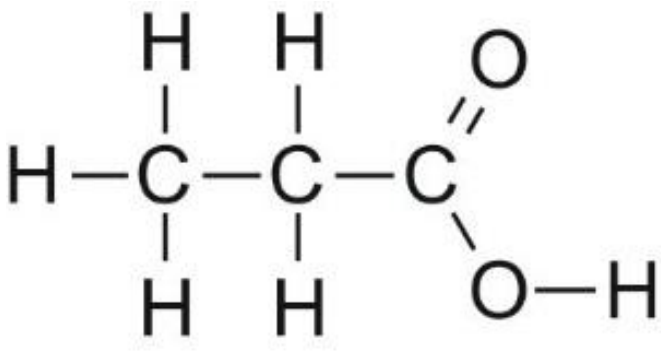
Bromo-
Chloro-

Organic Chemistry

Homologous Series – Carboxylic Acids



- Ethanoic Acid



- Propanoic Acid

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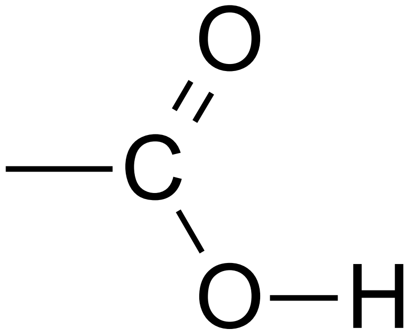
Homologous Series – Carboxylic Acids

Functional Group

carboxyl



General Formula $C_nH_{2n}O_2$

Name -oic acid

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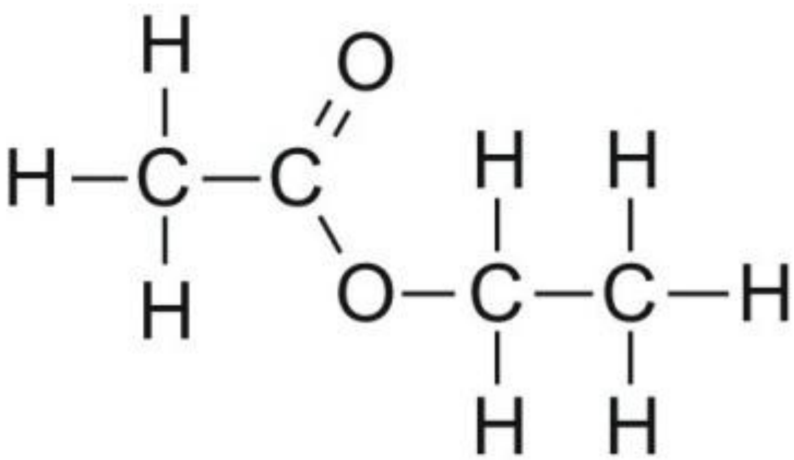
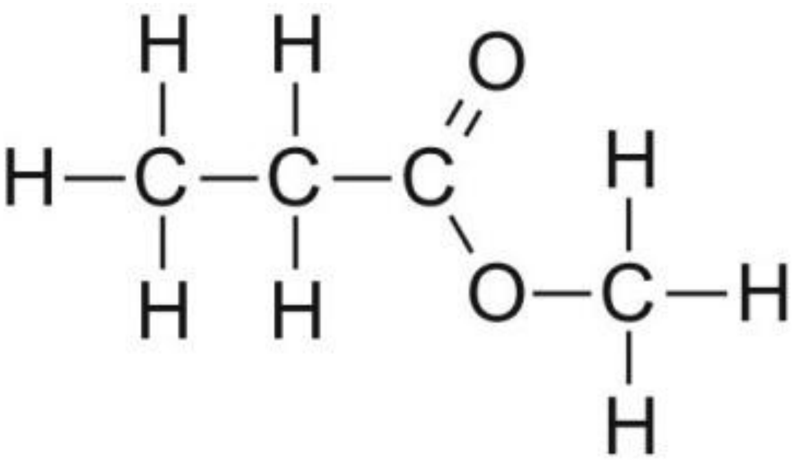
Homologous Series – Esters



- Ethyl Ethanoate

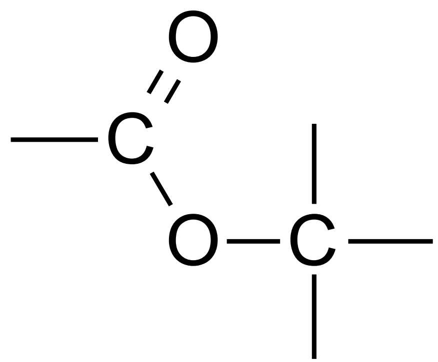


- Methyl Propanoate

Organic Chemistry

Homologous Series – Esters

Functional Group



General Formula $C_nH_{2n}O_2$

Name -yl -anoate

Organic Chemistry

What are the names and formulae of the *first 10 straight chain alkanes*?

Organic Chemistry

Naming Straight Chain Alkanes

- The alkanes are *saturated hydrocarbons* with the general formula C_nH_{2n+2}.

- *Saturated* means that the bonds between the carbon atoms are all *single covalent bonds*, there are no double or triple covalent bonds.

- *Hydrocarbon* means that the alkanes are composed only of the two elements *hydrogen* and *carbon*.

- General formula of C_nH_{2n+2}. For example, if n = 2, then $(2 \times 2) + 2 = 6$, so the formula of the alkane that contains two carbon atoms will be C_2H_6.

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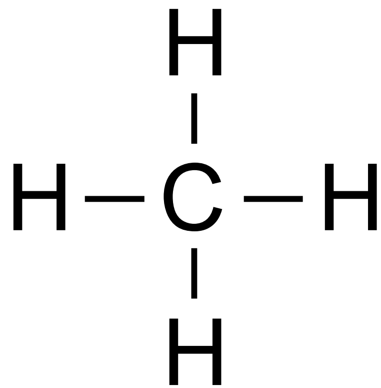
Naming Straight Chain Alkanes

Methane

Prefix:
Denotes the number of carbon atoms in the molecule.



Suffix:
Denotes the homologous series that the compound belongs to.

CH_4

Melting Point = −182.5°C
Boiling Point = −161.6°C

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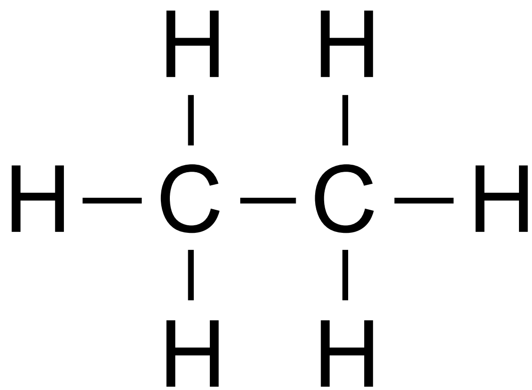
Naming Straight Chain Alkanes

Ethane



C_2H_6

Melting Point = −181.8°C

Boiling Point = −89.0°C

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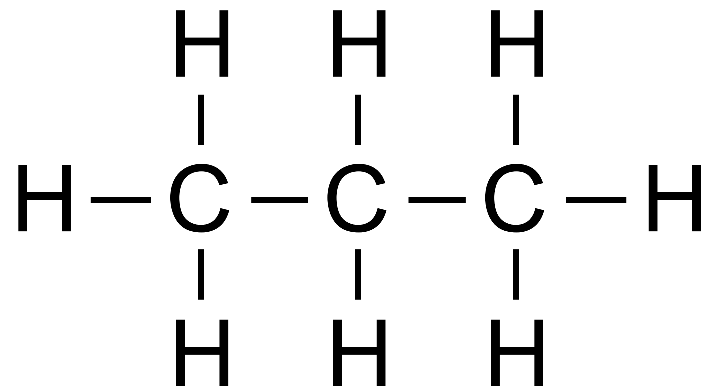
Naming Straight Chain Alkanes

Propane



$$C_3H_8$$

Melting Point = −187.7°C

Boiling Point = −42.1°C

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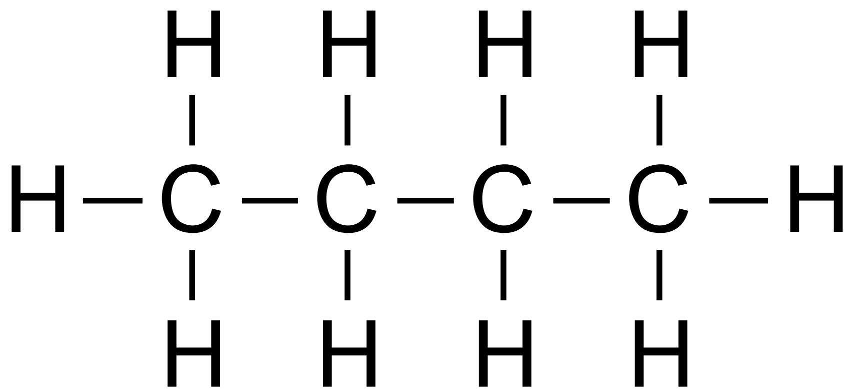
Naming Straight Chain Alkanes

Butane



$$C_4H_{10}$$

Melting Point = −138.4°C

Boiling Point = −0.5°C

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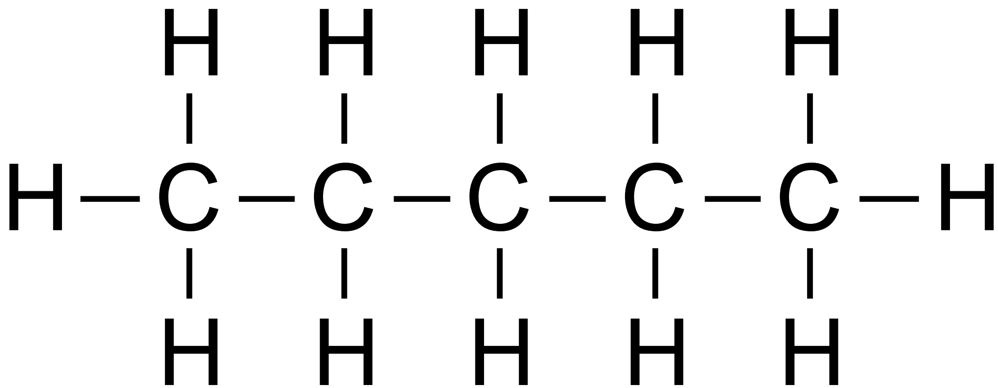
Naming Straight Chain Alkanes

Pentane



$$C_5H_{12}$$

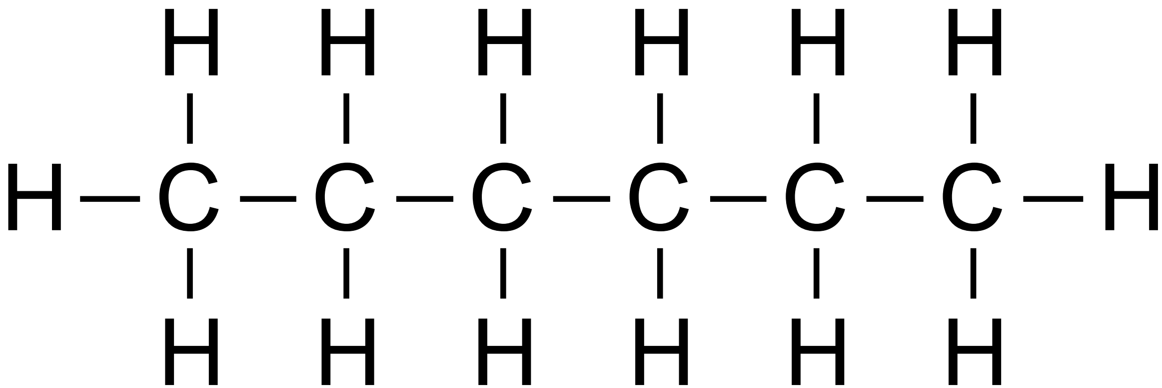
Melting Point = −129.8°C

Boiling Point = 36.1°C

Organic Chemistry

Naming Straight Chain Alkanes

Hexane



$$C_6H_{14}$$

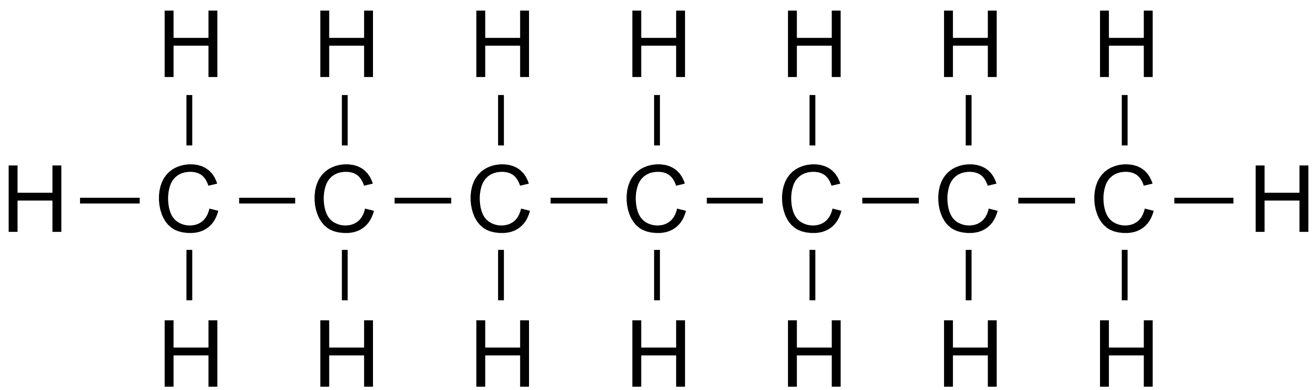
Melting Point = −95.3°C

Boiling Point = 68.7°C

Organic Chemistry

Naming Straight Chain Alkanes

Heptane



$$C_7H_{16}$$

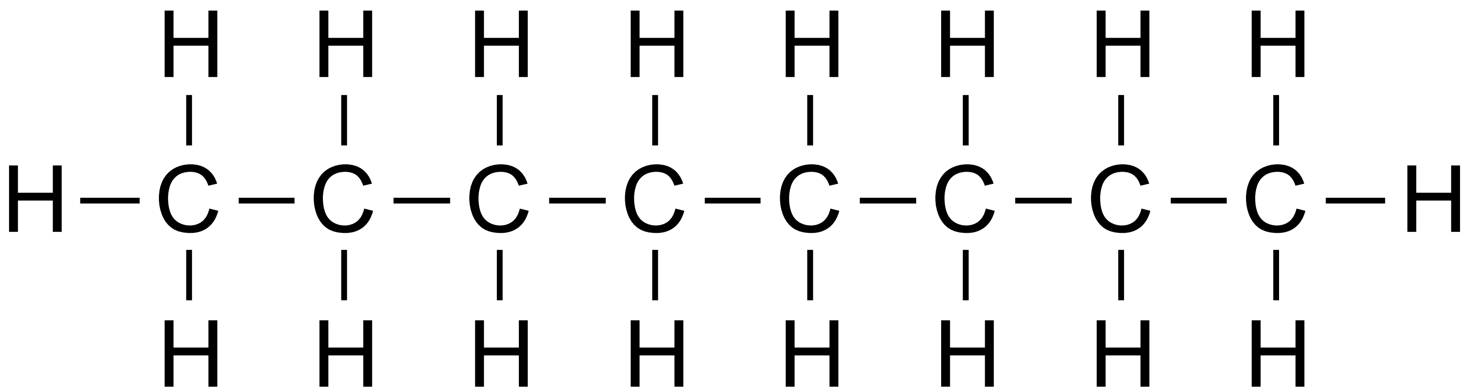
Melting Point = −90.6°C

Boiling Point = 98.4°C

Organic Chemistry

Naming Straight Chain Alkanes

Octane



C_8H_{18}

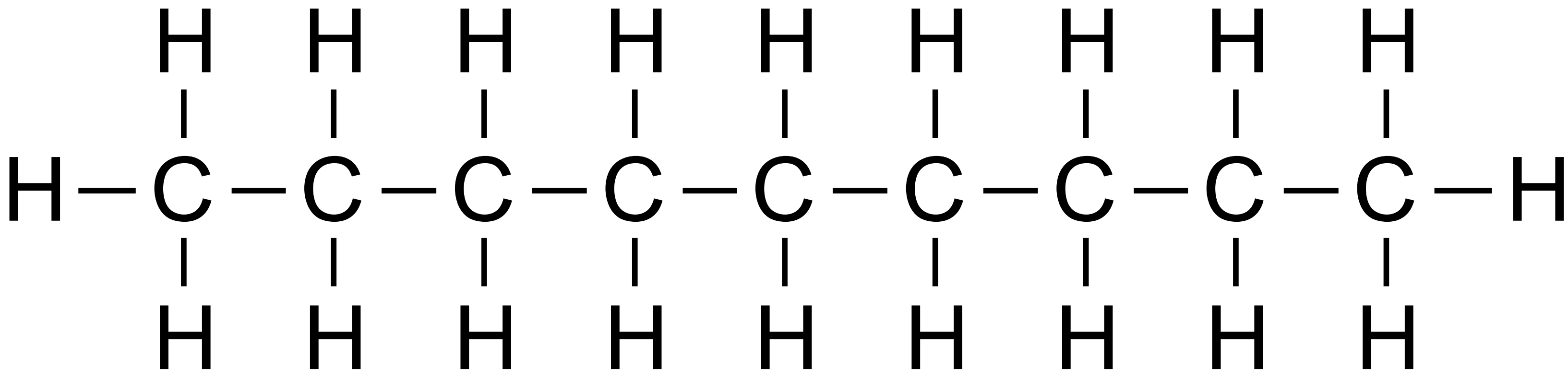
Melting Point = −57.0°C

Boiling Point = 125.5°C

Organic Chemistry

Naming Straight Chain Alkanes

Nonane



$$C_9H_{20}$$

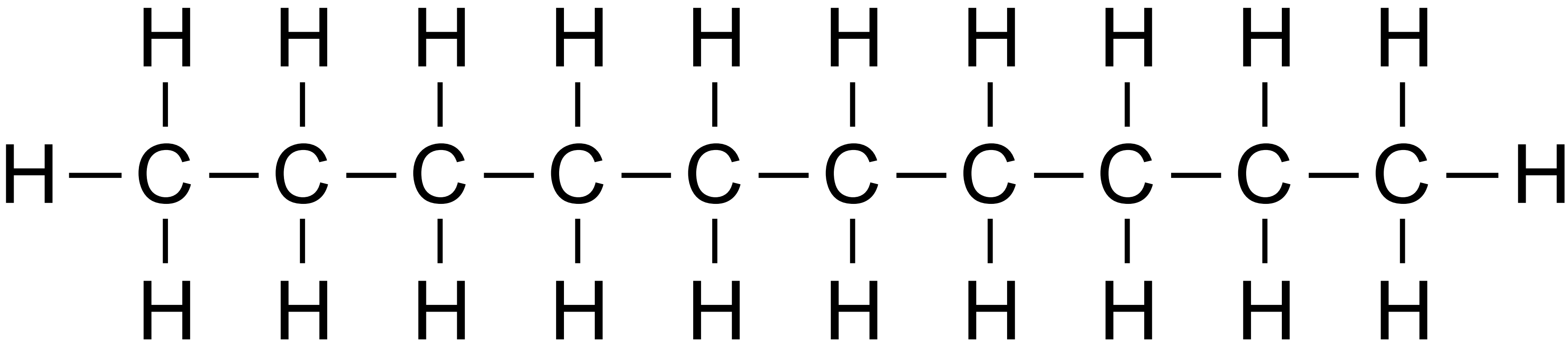
Melting Point = −53.0°C

Boiling Point = 151.0°C

Organic Chemistry

Naming Straight Chain Alkanes

Decane



$C_{10}H_{22}$

Melting Point = −27.9°C

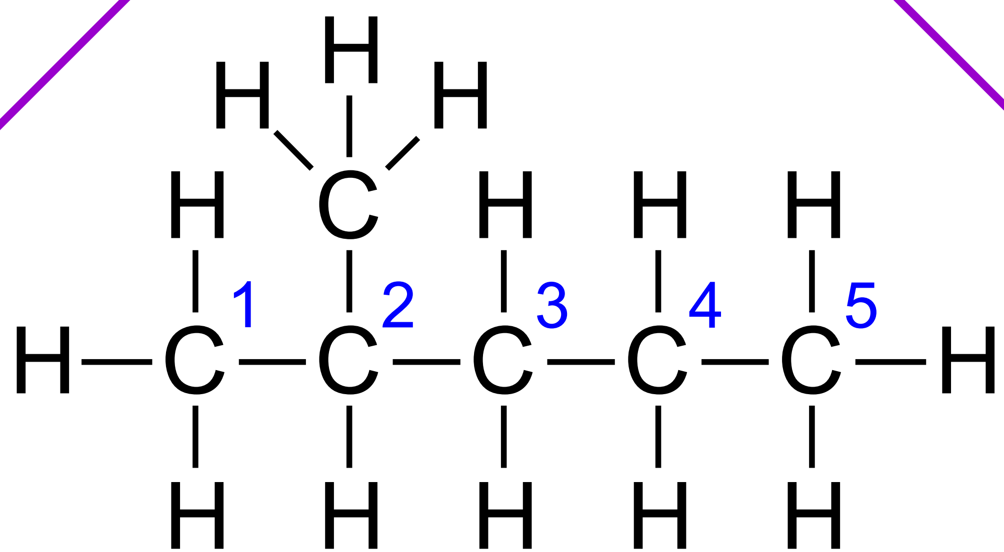
Boiling Point = 174.1°C

Organic Chemistry

Naming Branched Chain Alkanes

2-Methylpentane

Methyl group ($-CH_3$) bonded to carbon N°. 2 of the longest carbon chain.



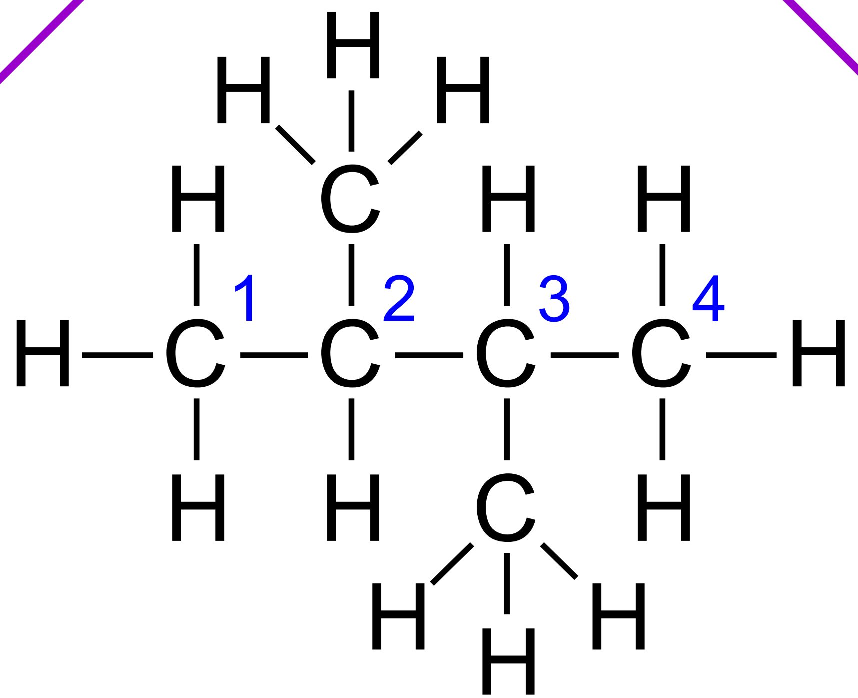
Indicates the longest carbon chain. Five carbon atoms = pentane.

Organic Chemistry

Naming Branched Chain Alkanes

2,3-Dimethylbutane

Two methyl groups ($-CH_3$), one bonded to carbon Nº. 2, and one bonded to carbon Nº. 3 of the longest carbon chain.



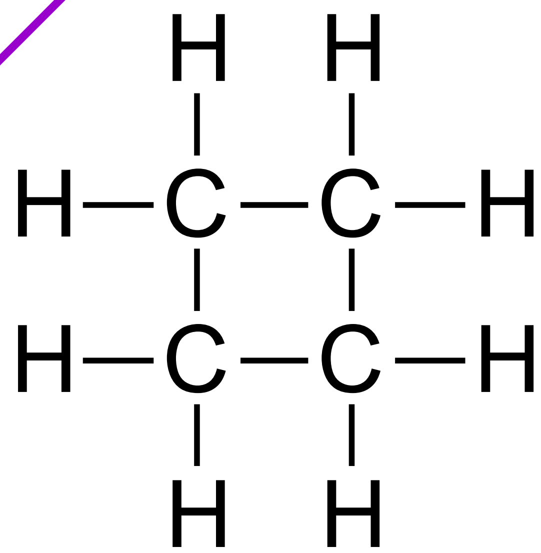
Indicates the longest carbon chain. Four carbon atoms = butane.

Organic Chemistry

Naming Cyclic Alkanes

Cyclobutane

The prefix *cyclo*– indicates that the carbon atoms are arranged in a *ring*.



Indicates the longest carbon chain. Four carbon atoms = butane.

Organic Chemistry

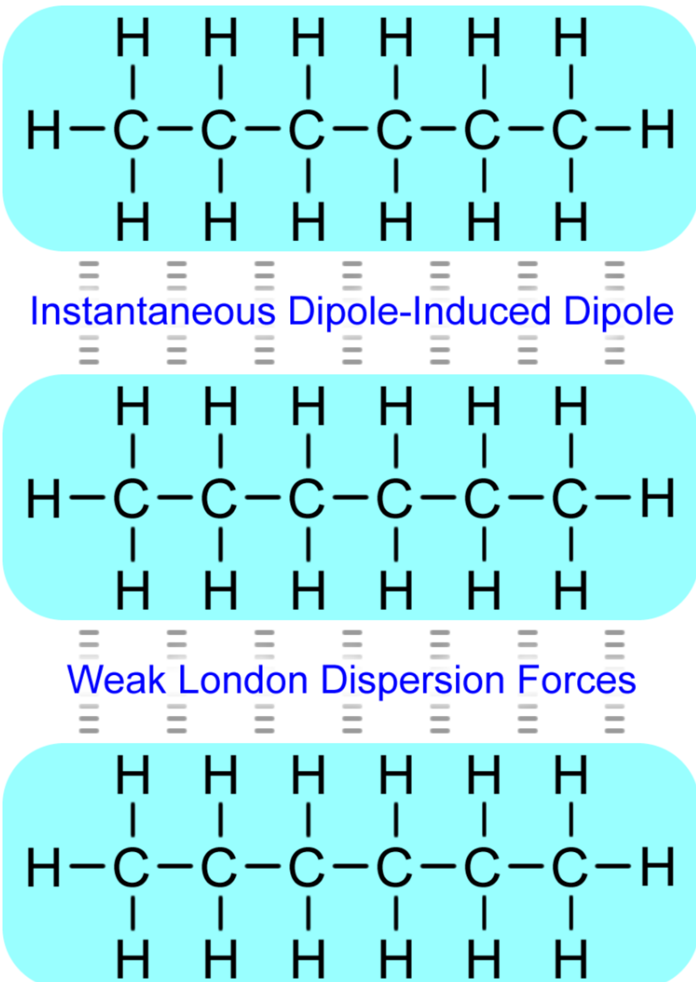
Physical Properties of Straight Chain Alkanes

Name	Formula	M_r	m.p. / °C	b.p. / °C	density / g cm^{-3}	solubility
Methane	CH_4	16.0	–182.5	–161.6	–	The alkanes are insoluble in polar solvents such as water, but soluble in non-polar organic solvents.
Ethane	C_2H_6	30.0	–181.8	–89.0	–	
Propane	C_3H_8	44.0	–187.7	–42.1	–	
Butane	C_4H_{10}	58.0	–138.4	–0.5	–	
Pentane	C_5H_{12}	72.0	–129.8	36.1	0.626	
Hexane	C_6H_{14}	86.0	–95.3	68.7	0.661	
Heptane	C_7H_{16}	100.0	–90.6	98.4	0.680	
Octane	C_8H_{18}	114.0	–57.0	125.5	0.703	
Nonane	C_9H_{20}	128.0	–53.0	151.0	0.718	
Decane	$C_{10}H_{22}$	142.0	–27.9	174.1	0.730	

- Viscosity (resistance to flow) *increases* as M_r and carbon chain length increase.
- Flammability *decreases* as M_r and carbon chain-length increase.

Organic Chemistry

Physical Properties of Straight Chain Alkanes



- The alkanes are *non-polar* hydrocarbons. This means that their molecules do not contain any permanent regions of slight positive ($\delta+$) or slight negative ($\delta-$) charge.
- Alkanes are unable to form *hydrogen bonds* with polar water molecules.
- As a consequence, the alkanes are immiscible (insoluble) with water.

Organic Chemistry

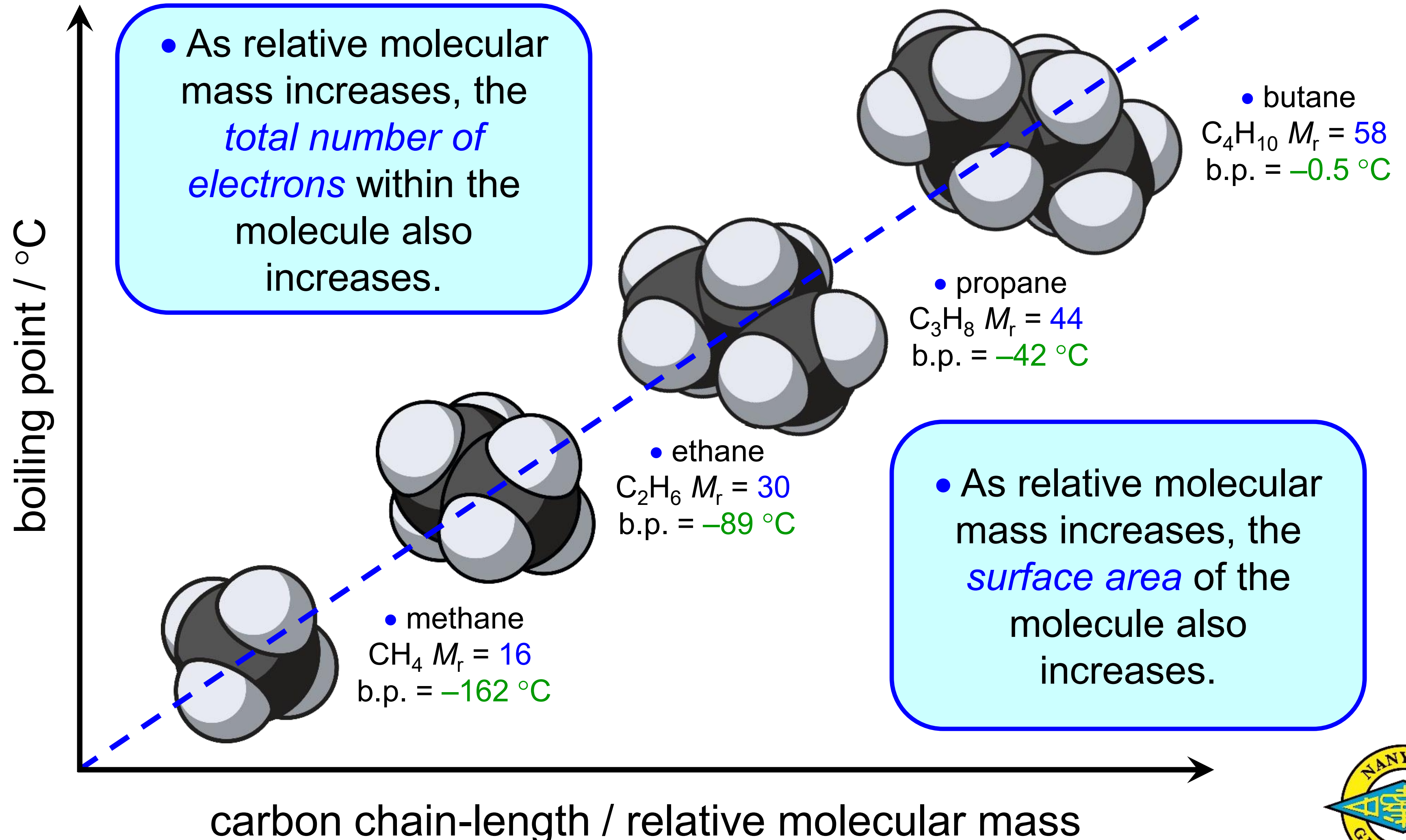
Physical Properties of Straight Chain Alkanes

- The melting points and boiling points of the alkanes increases as the *length of the carbon chain* increases.
- The melting points and boiling points of the alkanes increases as *relative molecular mass* increases.
- A complex mixture of alkanes can be separated by *fractional distillation* due to differences in their boiling points.
- On an industrial scale, the complex mixture of alkanes in crude oil is separated by fractional distillation in an *oil refinery*.

Organic Chemistry

Physical Properties of Straight Chain Alkanes

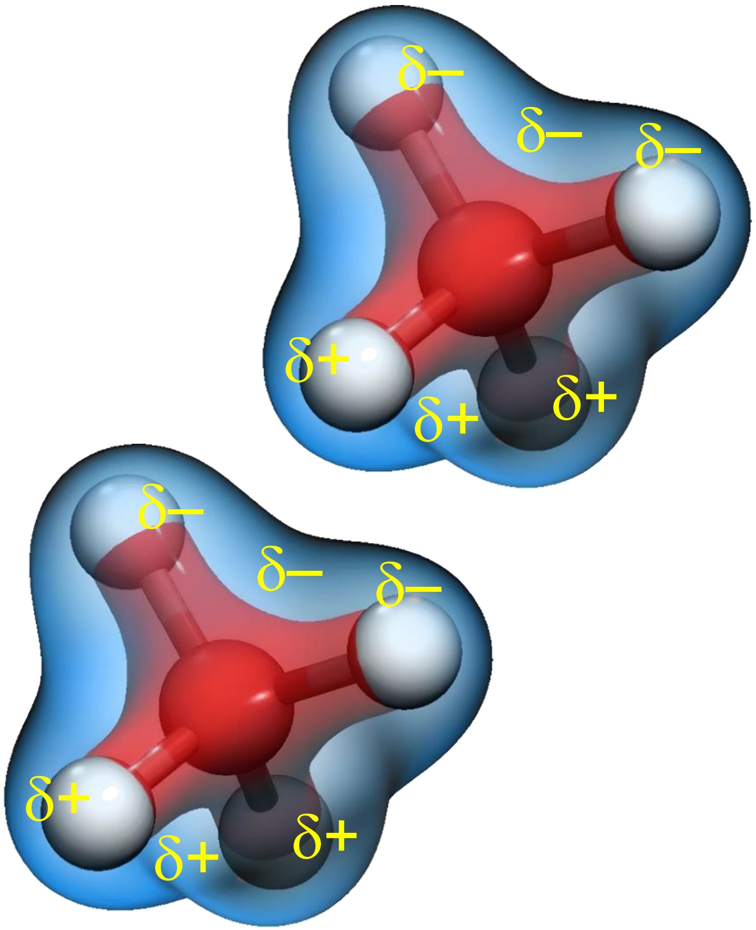
- As relative molecular mass increases, the *total number of electrons* within the molecule also increases.



- As relative molecular mass increases, the *surface area* of the molecule also increases.

Organic Chemistry

Physical Properties of Straight Chain Alkanes

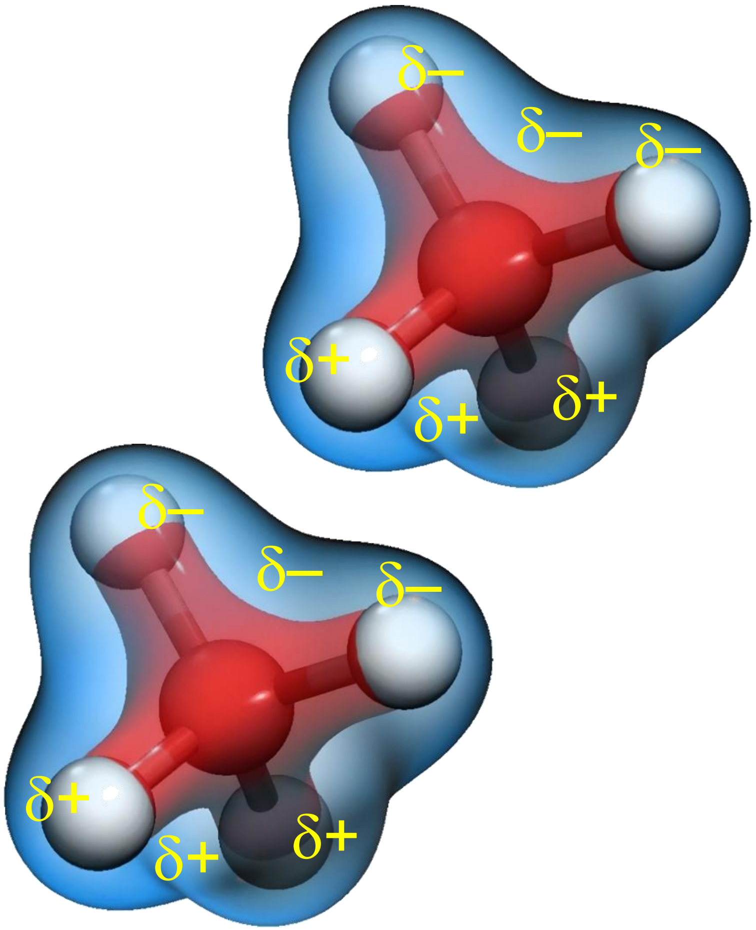


- The *melting points* and *boiling points* of the alkanes *increase* as the molecule's carbon chain-length and relative molecular mass increase.

- The larger the molecule, the more electrons it contains, which increases the probability of the molecule becoming *spontaneously polarized* (regions of δ+ and δ–) due to the random movement of electrons within its larger electron cloud.

Organic Chemistry

Physical Properties of Straight Chain Alkanes

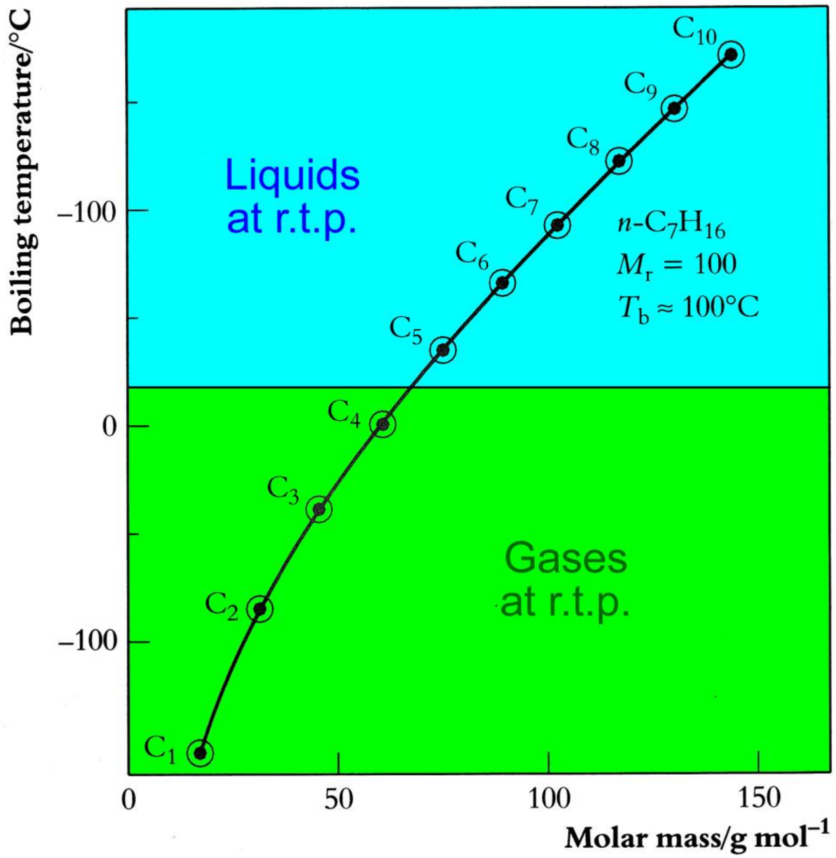


- A molecule that becomes spontaneously polarized for a short time induces polarity into its neighboring molecules.

- These short-lived regions of opposite charge attract individual molecules together. These weak intermolecular forces of attraction that exist between non-polar molecules are called *London dispersion forces*.

Organic Chemistry

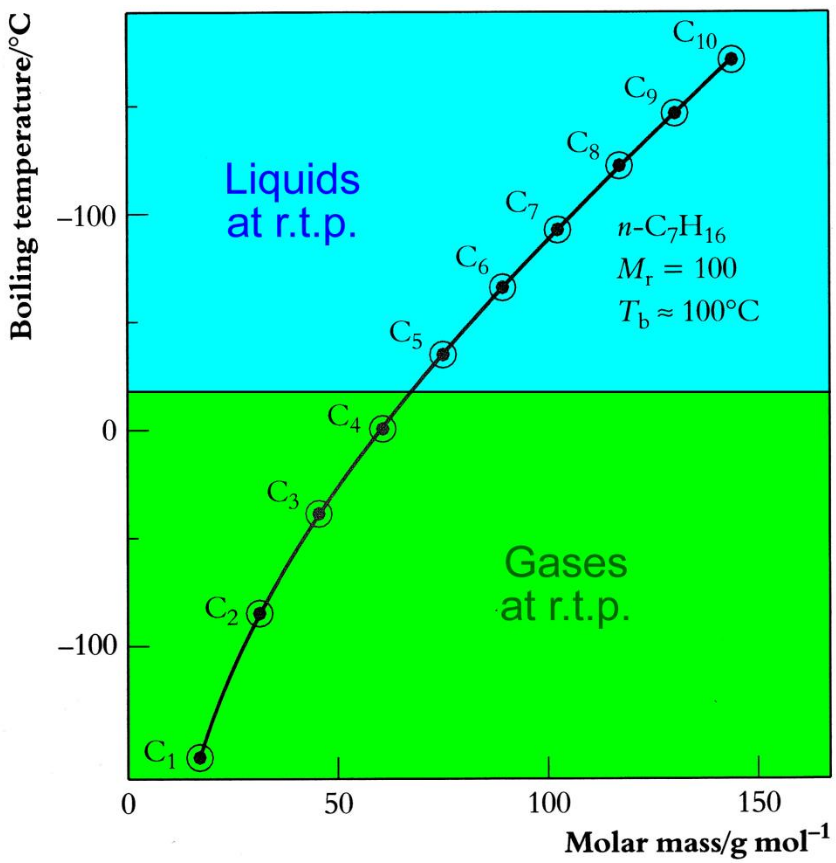
Physical Properties of Straight Chain Alkanes



- In addition to the electron cloud, the longer an alkane's carbon chain-length, *the larger its surface area*. This means that there is a larger surface in contact with neighboring molecules and hence there is a larger surface area over which intermolecular forces of attraction (*London dispersion forces*) can operate.

Organic Chemistry

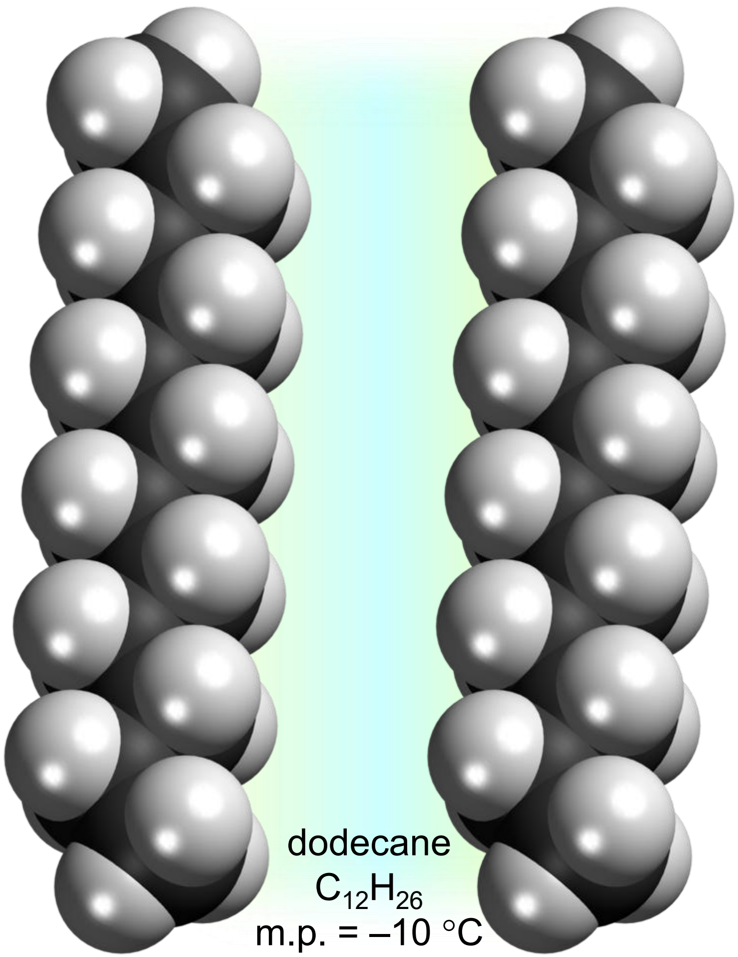
Physical Properties of Straight Chain Alkanes



- A larger amount of thermal energy is required to overcome the stronger intermolecular force of attraction, hence melting points and boiling points increase as carbon chain-length and relative molecular mass increase.

Organic Chemistry

Physical Properties of Straight Chain Alkanes



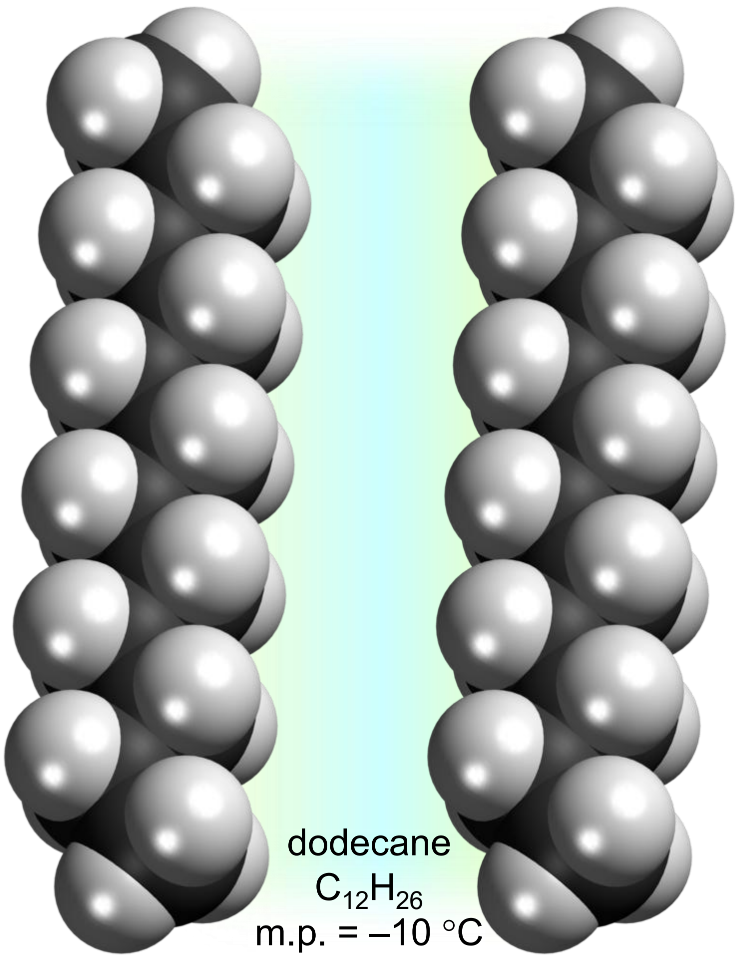
dodecane
$C_{12}H_{26}$
m.p. = –10 °C
b.p. = +216 °C

- As carbon chain-length increases, the liquid alkanes become *more viscous* (flows less easily).

- Molecules with longer carbon chains and higher relative molecular mass contain more electrons and become spontaneously polarized more easily. This increases the strength of the *London dispersion forces* between them.

Organic Chemistry

Physical Properties of Straight Chain Alkanes



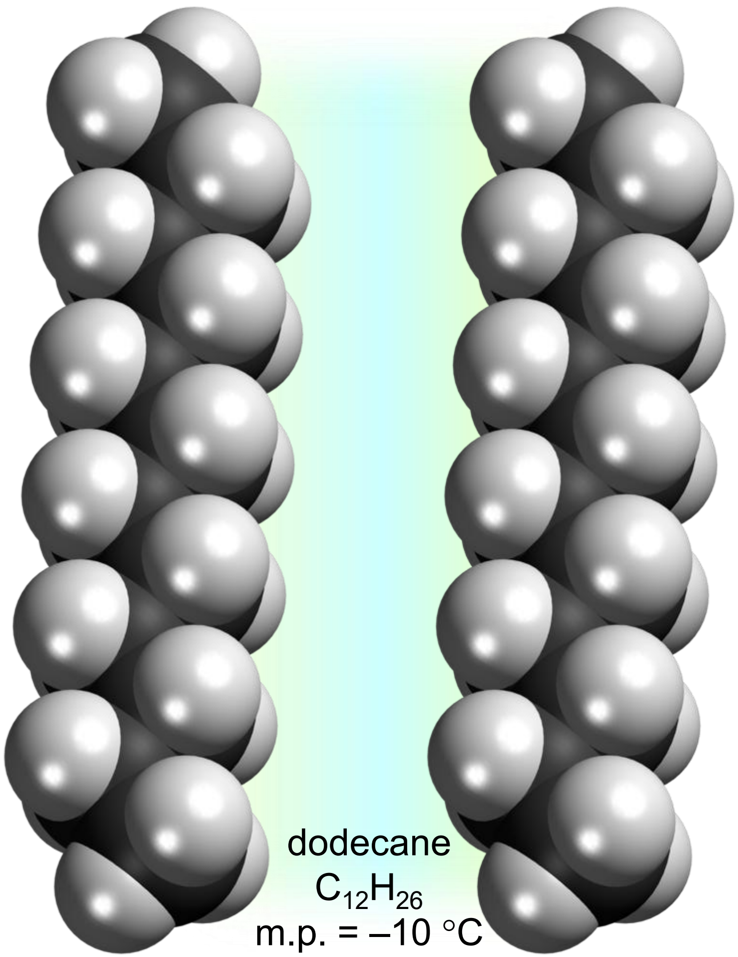
dodecane
$C_{12}H_{26}$
m.p. = –10 °C
b.p. = +216 °C

- In addition to the increased number of electrons, which increase the polarizability of the molecule, there is also an increase in the molecule's *surface area*.

- Intermolecular forces of attraction (*London dispersion forces*) become stronger, and the molecules are unable to slip-and-slide over each other as easily.

Organic Chemistry

Physical Properties of Straight Chain Alkanes

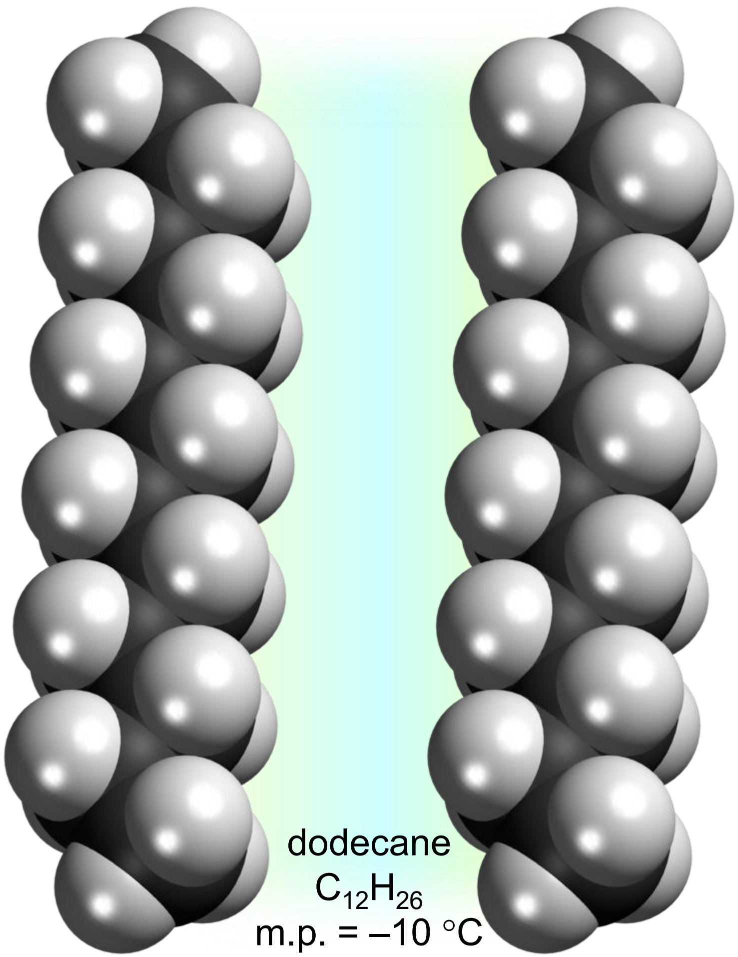


dodecane
$C_{12}H_{26}$
m.p. = –10 °C
b.p. = +216 °C

- The alkanes become *less flammable* as the molecule's carbon chain-length and relative molecular mass increase.
- As the number of electrons in the molecule increases, and the surface area of the molecule increases, so the intermolecular forces of attraction (*London dispersion forces*) become stronger.

Organic Chemistry

Physical Properties of Straight Chain Alkanes



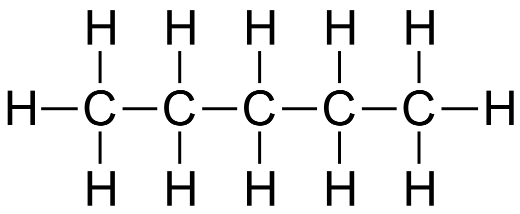
dodecane
$C_{12}H_{26}$
m.p. = –10 °C
b.p. = +216 °C

- As the *London dispersion forces* become stronger, this causes the boiling points of the alkanes to increase, and they become *less volatile*, meaning that they turn from liquid to gas less readily.

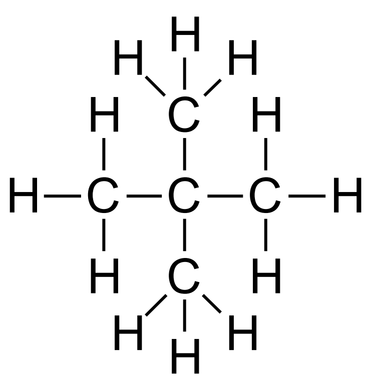
- Alkanes only burn in the gaseous state. The higher the boiling point of an alkane, the less likely it is to vaporise, ignite and burn.

Organic Chemistry

Physical Properties of Straight Chain Alkanes



pentane



2,2-dimethylpropane
(or just dimethylpropane)

- Pentane and 2,2-dimethylpropane are *isomers*, *i.e.* they share the same molecular formula (C_5H_{12}), but have different structural formulae. Pentane boils at *31.6 °C*, while 2,2-dimethylpropane boils at *9.50 °C*. The difference in boiling points is due to the difference in their surface areas. The larger surface area of pentane results in stronger intermolecular forces of attraction (*London dispersion forces*) between the molecules, which require more energy to overcome, hence increasing the boiling point.

Organic Chemistry

Organic Chemistry

Naming Alkenes

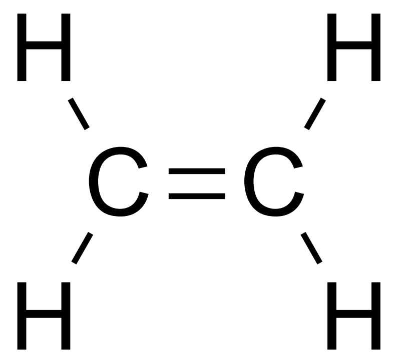
- The alkenes are *unsaturated hydrocarbons* with the general formula C_nH_{2n}.
- *Unsaturated* means that the molecule contains at least one *carbon-to-carbon double covalent bond*.
- *Hydrocarbon* means that the alkenes are composed only of the two elements *hydrogen* and *carbon*.
- General formula of C_nH_{2n}. For example, if n = 3, then $2 \times 3 = 6$, so the formula of the alkene that contains three carbon atoms will be C_3H_6.

Organic Chemistry

Naming Alkenes

Ethene

Prefix:
Denotes the number of carbon atoms in the molecule.



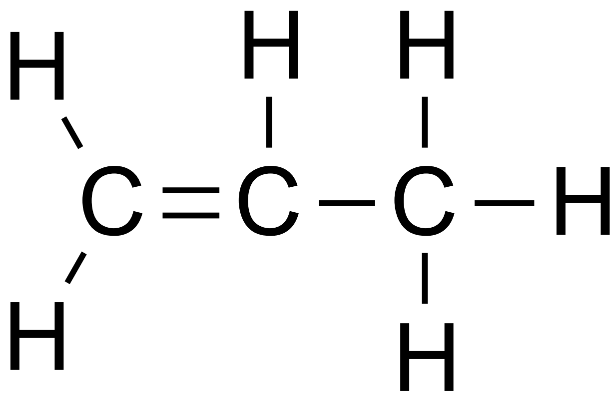
Suffix:
Denotes the homologous series that the compound belongs to.

C_2H_4

Organic Chemistry

Naming Alkenes

Propene

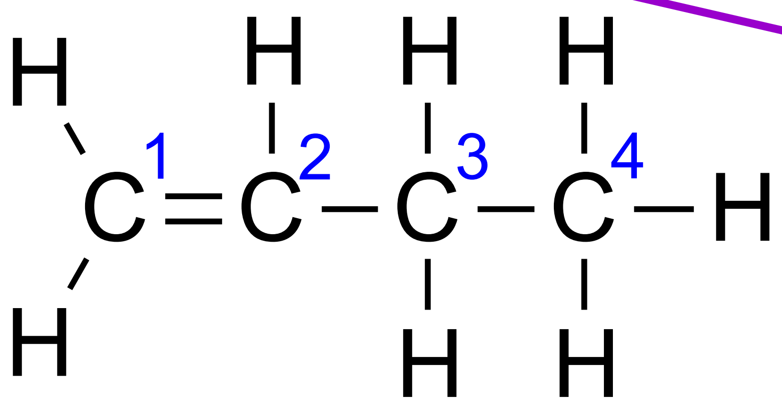


$$C_3H_6$$

Organic Chemistry

Naming Alkenes

But-1-ene



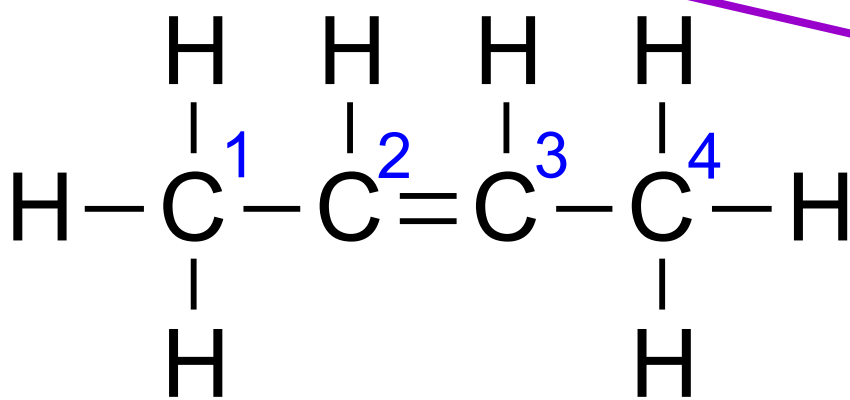
Number: Indicates the location of the C=C bond within the molecule.

C_4H_8

Organic Chemistry

Naming Alkenes

But-2-ene



Number: Indicates the location of the C=C bond within the molecule.

C_4H_8

Organic Chemistry

Naming Halogenoalkanes

- The halogenoalkanes are alkanes in which at least one of the hydrogen atoms has been substituted by a *halogen* (*Group 17 element*).

- The general formula of the halogenoalkanes is $C_nH_{2n+1}Hal$, where *Hal* is the symbol of a Group 17 element (*i.e.* F, Cl, Br, I). For example, if n = 4, then $(2 \times 4) + 1 = 9$, so the formula of the halogenoalkane that contains four carbon atoms and chlorine will be C_4H_9Cl.

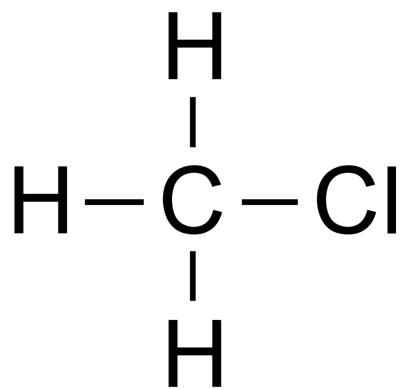
Organic Chemistry

Naming Halogenoalkanes

Chloromethane

Prefix:
Indicates the Group 17 element that is present in the compound,

F = fluoro-
C*l* = chloro-
Br = bromo-
I = Iodo-



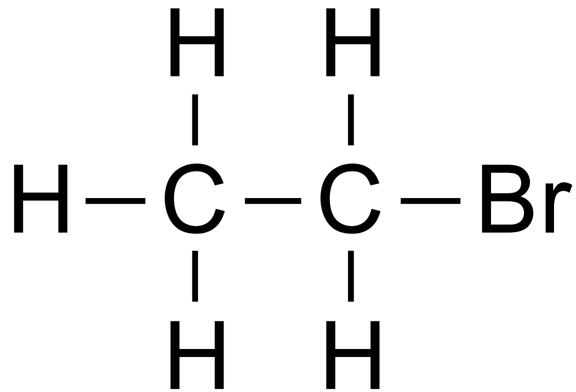
CH_3Cl

Suffix:
Denotes the number of carbon atoms in the molecule.

Organic Chemistry

Naming Halogenoalkanes

Bromoethane



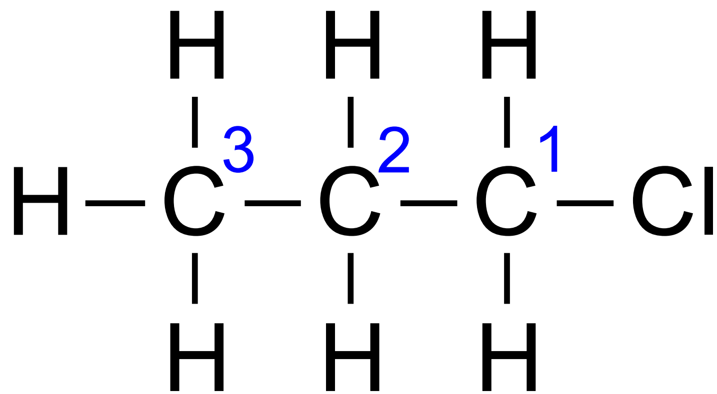
C_2H_5Br

Organic Chemistry

Naming Halogenoalkanes

1-Chloropropane

Number: Indicates the location of the chlorine atom within the molecule.



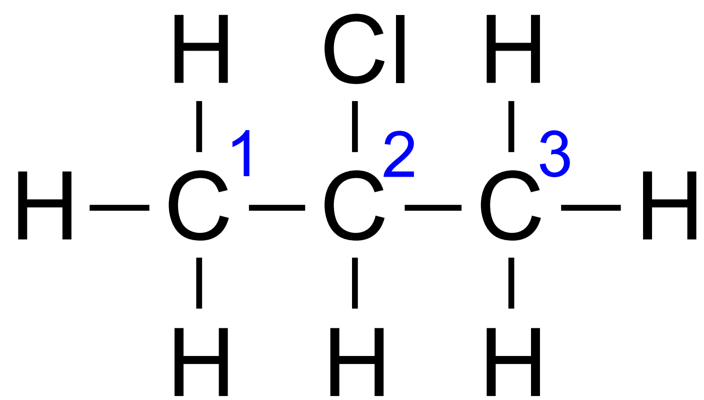
C_3H_7Cl

Organic Chemistry

Naming Halogenoalkanes

2-Chloropropane

Number: Indicates the location of the chlorine atom within the molecule.



$$C_3H_7Cl$$

Organic Chemistry

Naming Alcohols

- The alcohols are alkanes in which at least one of the hydrogen atoms has been substituted by a *hydroxyl group*, O–H.

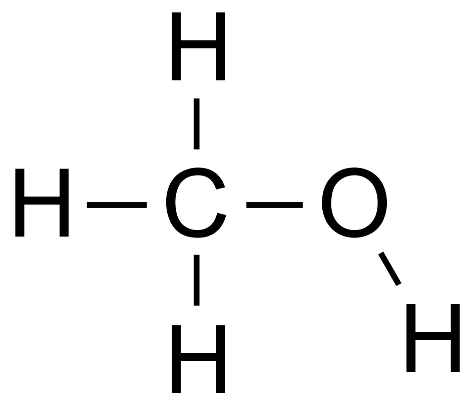
- The general formula of the alcohols is $C_nH_{2n+1}OH$. For example, if n = 5, then (2 × 5) + 1 = 11, so the formula of the alcohol that contains five carbon atoms will be $C_5H_{11}OH$.

Organic Chemistry

Naming Alcohols

Methanol

Prefix:
Denotes the number of carbon atoms in the molecule.



Suffix:
Denotes the homologous series that the compound belongs to.

CH_3OH

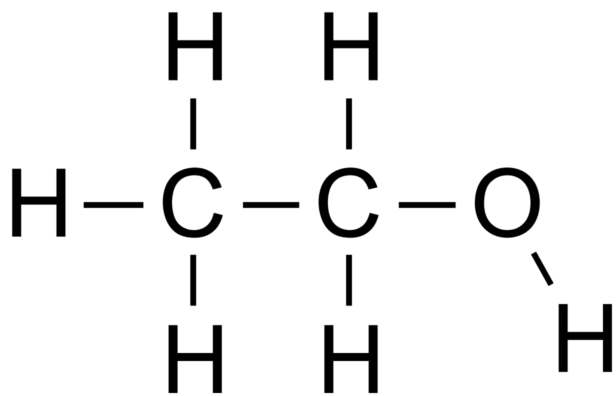
Melting Point = –97.6 °C

Boiling Point = 64.7 °C

Organic Chemistry

Naming Alcohols

Ethanol



C_2H_5OH

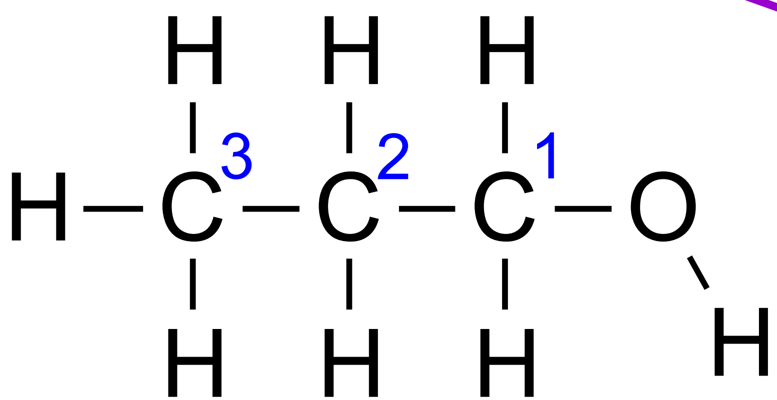
Melting Point = –114 °C

Boiling Point = 78.2 °C

Organic Chemistry

Naming Alcohols

Propan-1-ol



Number: Indicates the location of the O–H group within the molecule.

C_3H_7OH

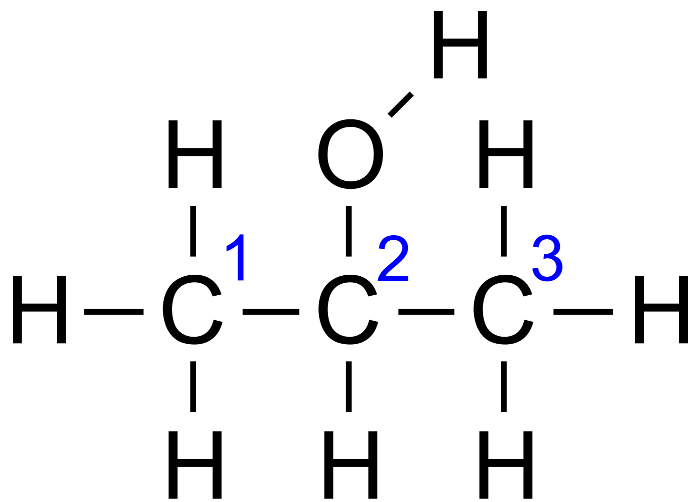
Melting Point = –126 °C

Boiling Point = 97.5 °C

Organic Chemistry

Naming Alcohols

Propan-2-ol

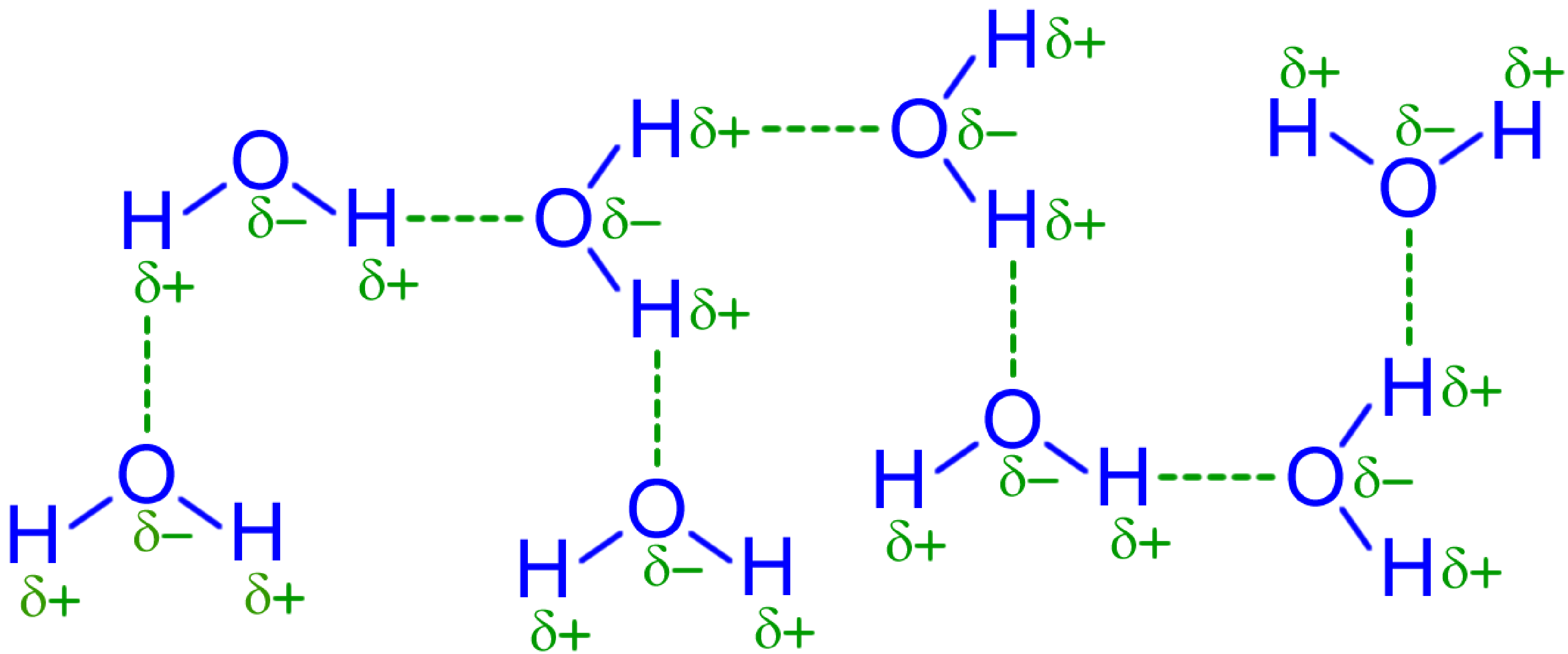


Number: Indicates the location of the O–H group within the molecule.

$$C_3H_7OH$$

Organic Chemistry

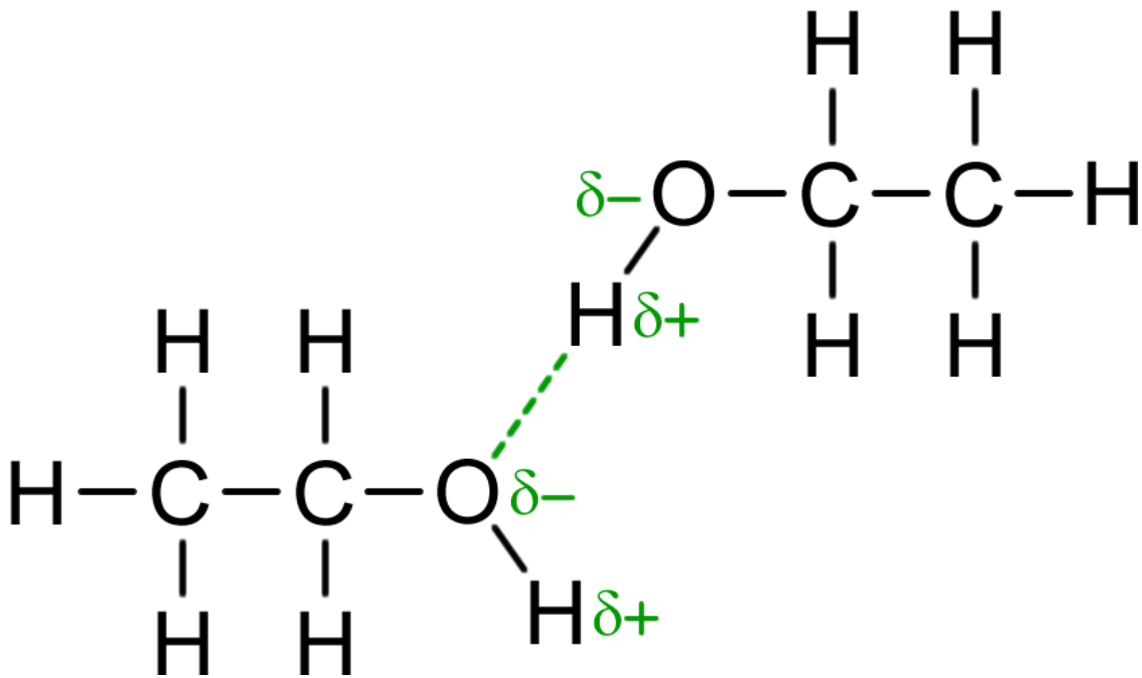
Physical Properties of Alcohols



- Hydrogen bonding between polar water molecules.

Organic Chemistry

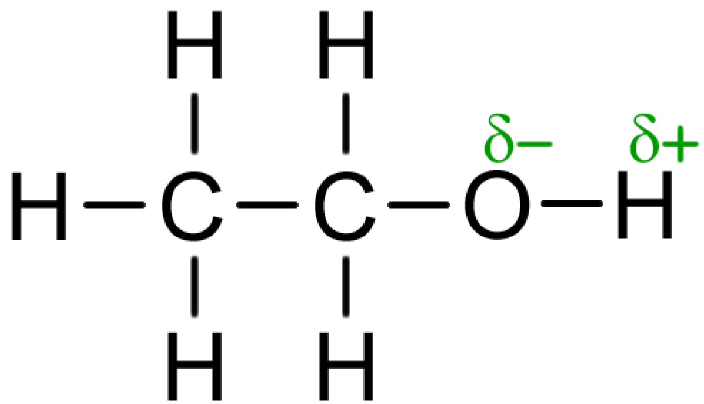
Physical Properties of Alcohols



- Hydrogen bonding between the polar regions of ethanol molecules causes short-chain alcohols to be liquids at room temperature and pressure (recall that short chain alkanes and alkenes of a similar relative molecular mass are gases).

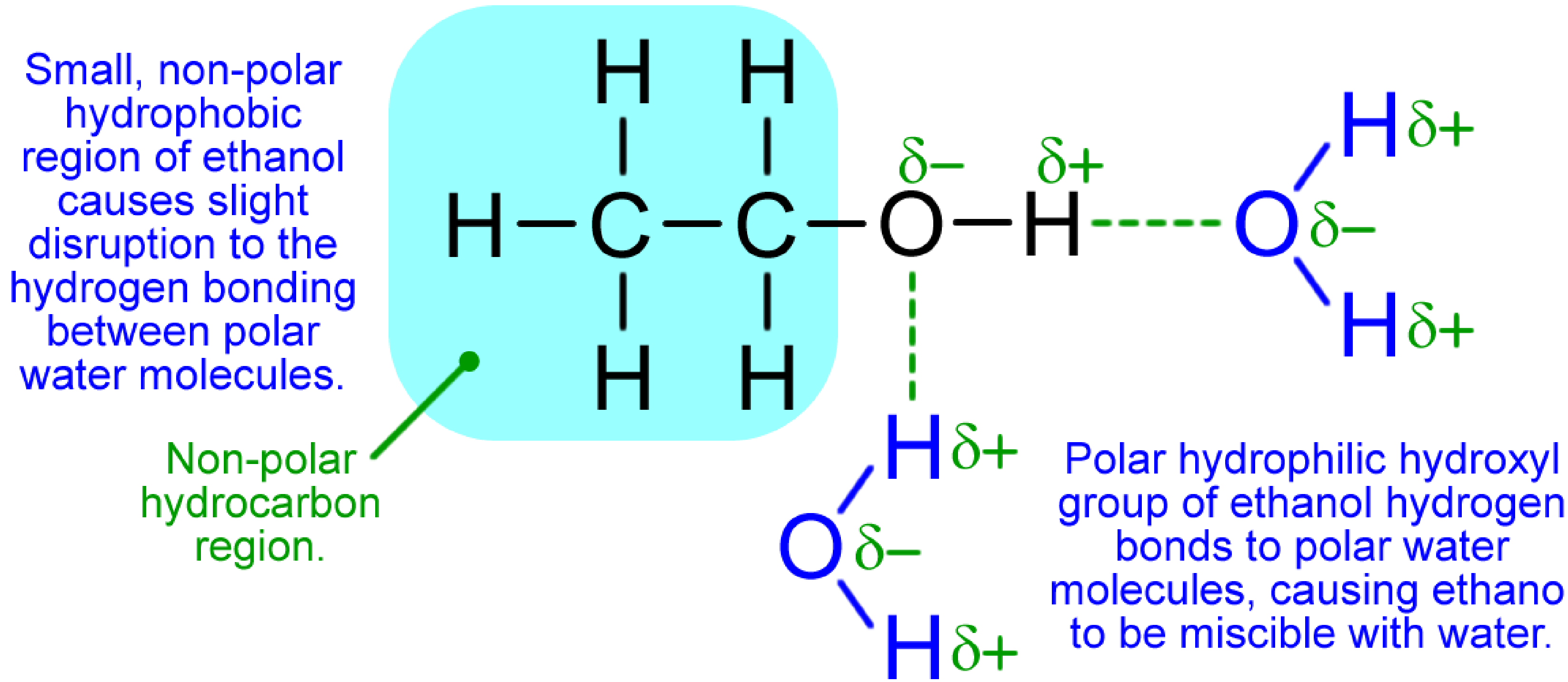
Organic Chemistry

Physical Properties of Alcohols



Organic Chemistry

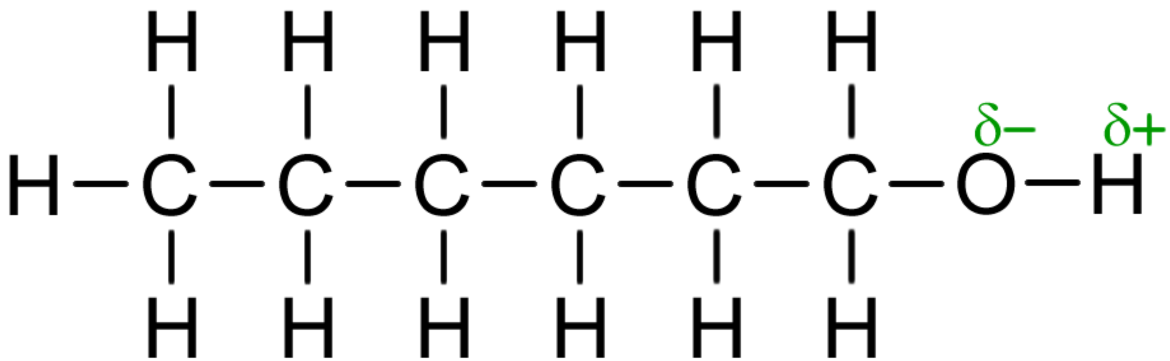
Physical Properties of Alcohols



- The polar *hydrophilic* region of ethanol is more significant than the small non-polar *hydrophobic* region, and dominates the properties of the molecule, causing it to be *miscible* (soluble) with water (ethanol is infinitely soluble in water).

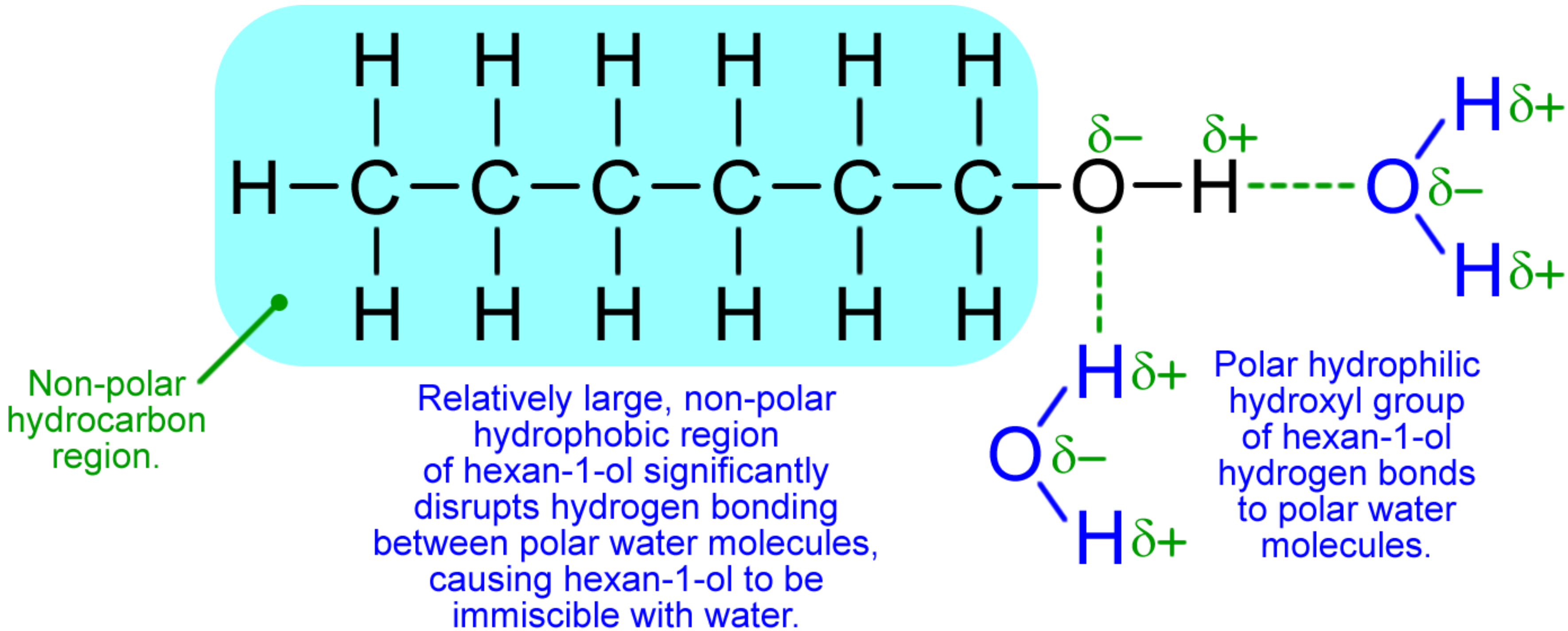
Organic Chemistry

Physical Properties of Alcohols



Organic Chemistry

Physical Properties of Alcohols



- The large non-polar *hydrophobic* region of hexan-1-ol is more significant than the polar *hydrophilic* region, and dominates the properties of the molecule, causing it to be *immiscible* (insoluble) with water.

Organic Chemistry

Physical Properties of Alcohols

Name	Formula	Melting point / °C	Boiling point / °C	*Solubility in water
methanol	CH_3OH	–97.6	64.7	miscible / ∞ soluble
ethanol	C_2H_5OH	–114	78.2	miscible / ∞ soluble
propan-1-ol	C_3H_7OH	–126	97.5	miscible / ∞ soluble
butan-1-ol	C_4H_9OH	–89.8	117.7	73
pentan-1-ol	$C_5H_{11}OH$	–78	137	22
hexan-1-ol	$C_6H_{13}OH$	–45	157	5.9

*Solubility measured in grams of alcohol per 1000 cm^3 of water at 20°C.

- The first six straight-chain alcohols are *colourless liquids* at room temp. and pressure.
- Melting points and boiling points *increase* as carbon chain-length *increases*.
- Solubility in water *decreases* as carbon chain-length *increases*.

Organic Chemistry

Naming Carboxylic Acids

- The general formula of the carboxylic acids is $C_nH_{2n}O_2$. For example, if n = 6, then 2 × 6 = 12, so the formula of the carboxylic acid that contains six carbon atoms will be $C_6H_{12}O_2$.

Note: The carboxylic acid functional group is COOH (*carboxyl*). This is normally written separately in the formula, so $C_6H_{12}O_2$ is re-written as $C_5H_{11}COOH$.

- Remember, the carboxylic acids are *weak acids*, *i.e.* they only partially ionise when dissolved in water.

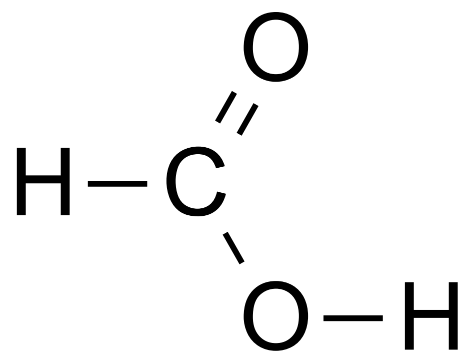
$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

Organic Chemistry

Naming Carboxylic Acids

Methanoic Acid

Prefix:
Denotes the number of carbon atoms in the molecule.



Suffix:
Denotes the homologous series that the compound belongs to.

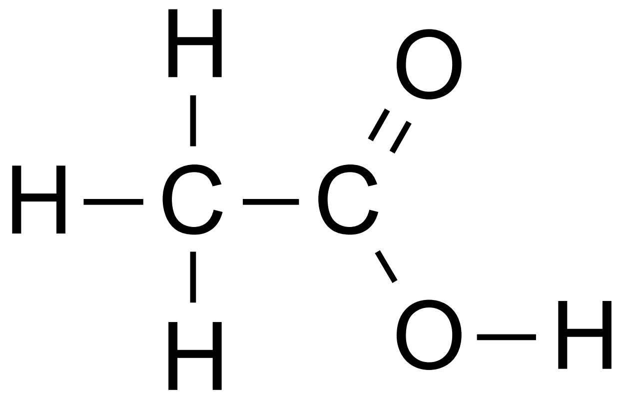
$HCOOH$

By default, the **C** of **C**OOH is always number **1**.

Organic Chemistry

Naming Carboxylic Acids

Ethanoic Acid



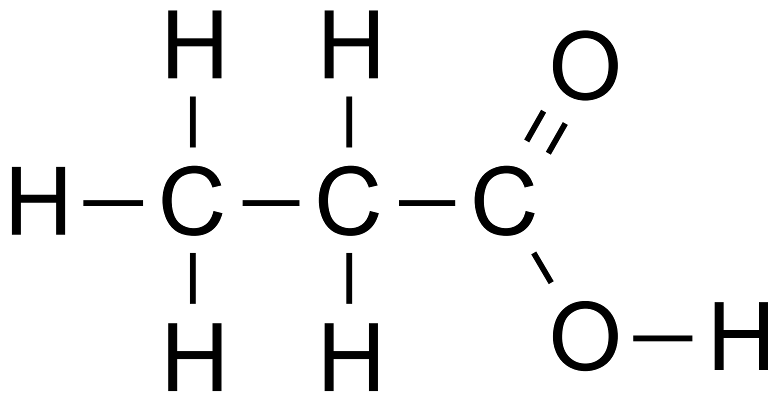
CH_3COOH

By default, the **C** of **C**OOH is always number **1**.

Organic Chemistry

Naming Carboxylic Acids

Propanoic Acid



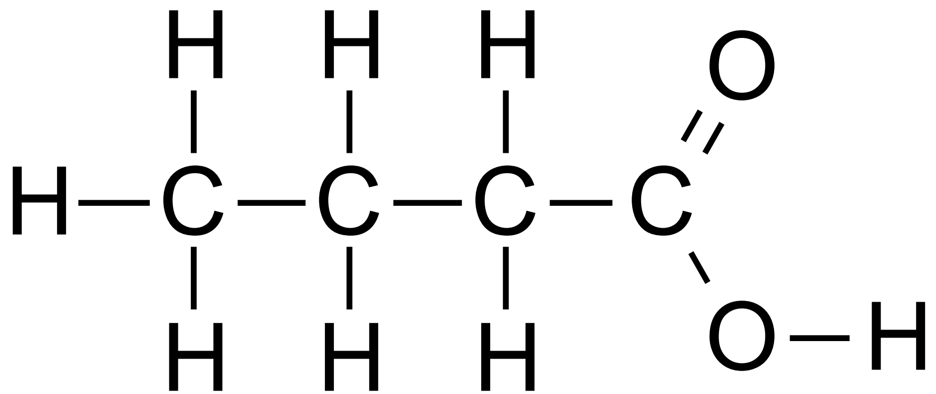
$$C_2H_5COOH$$

By default, the **C** of **C**OOH is always number 1.

Organic Chemistry

Naming Carboxylic Acids

Butanoic Acid

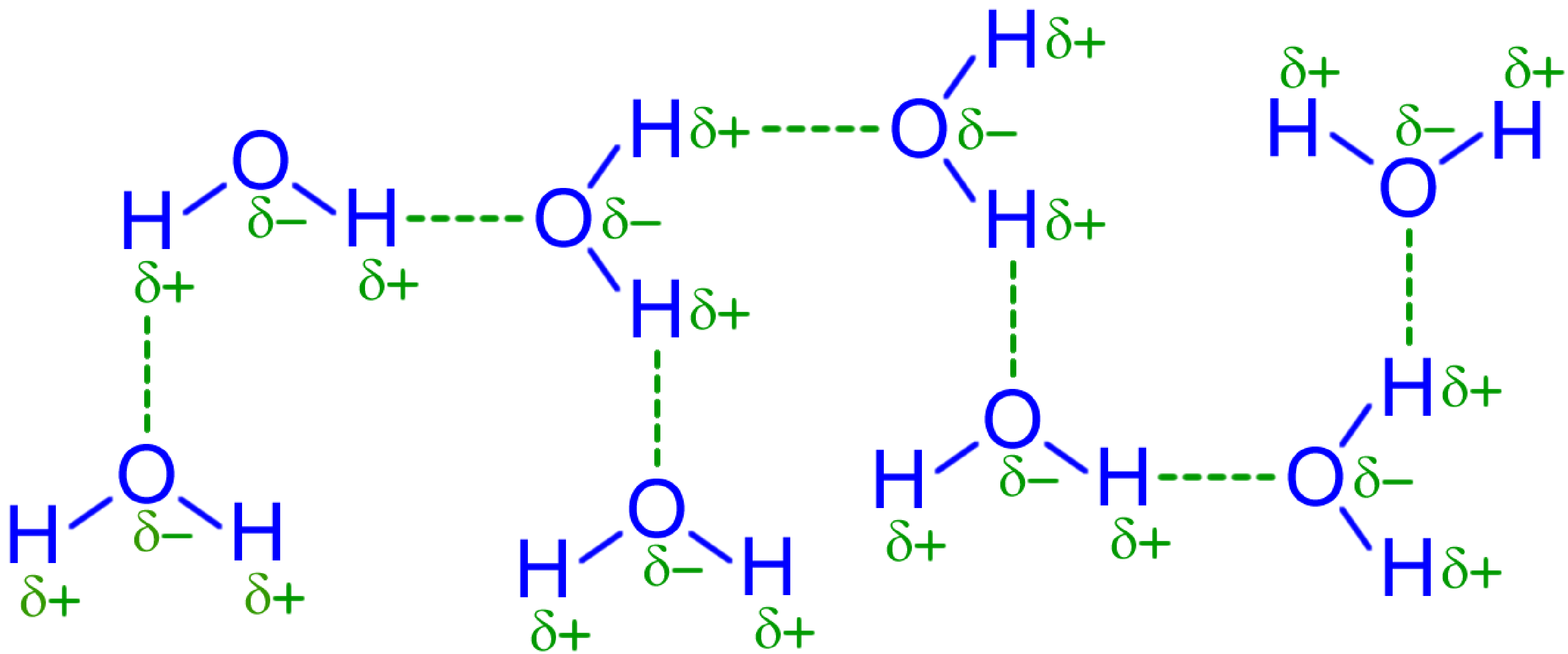


$$C_3H_7COOH$$

By default, the **C** of **C**OOH is always number 1.

Organic Chemistry

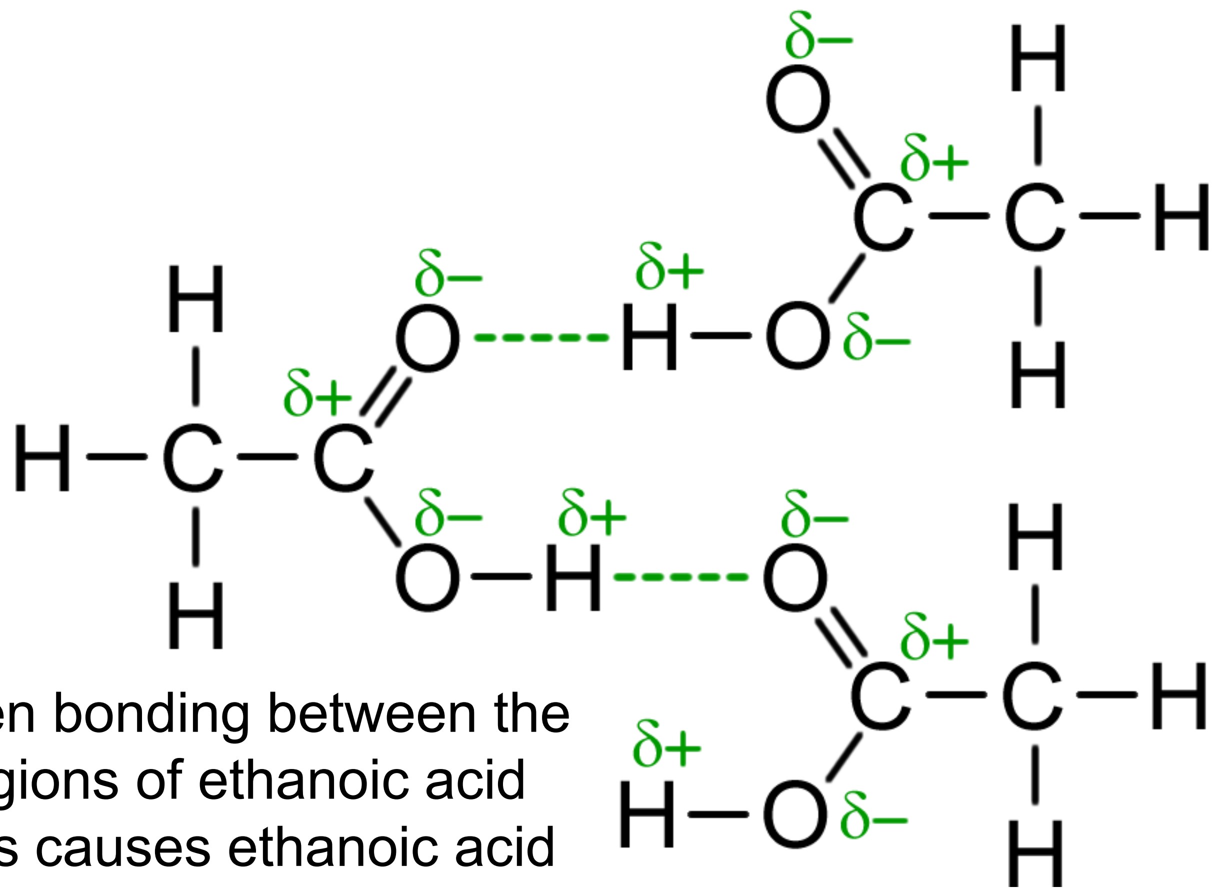
Physical Properties of Carboxylic Acids



- Hydrogen bonding between polar water molecules.

Organic Chemistry

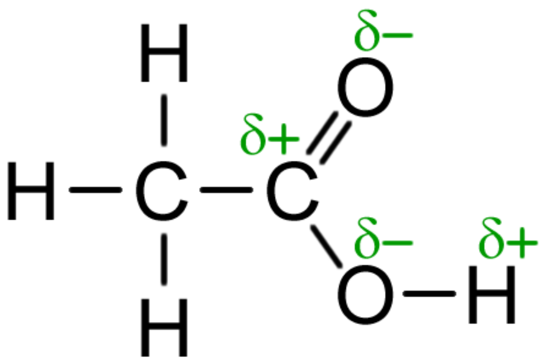
Physical Properties of Carboxylic Acids



- Hydrogen bonding between the polar regions of ethanoic acid molecules causes ethanoic acid to be a *liquid* at room temperature and pressure.

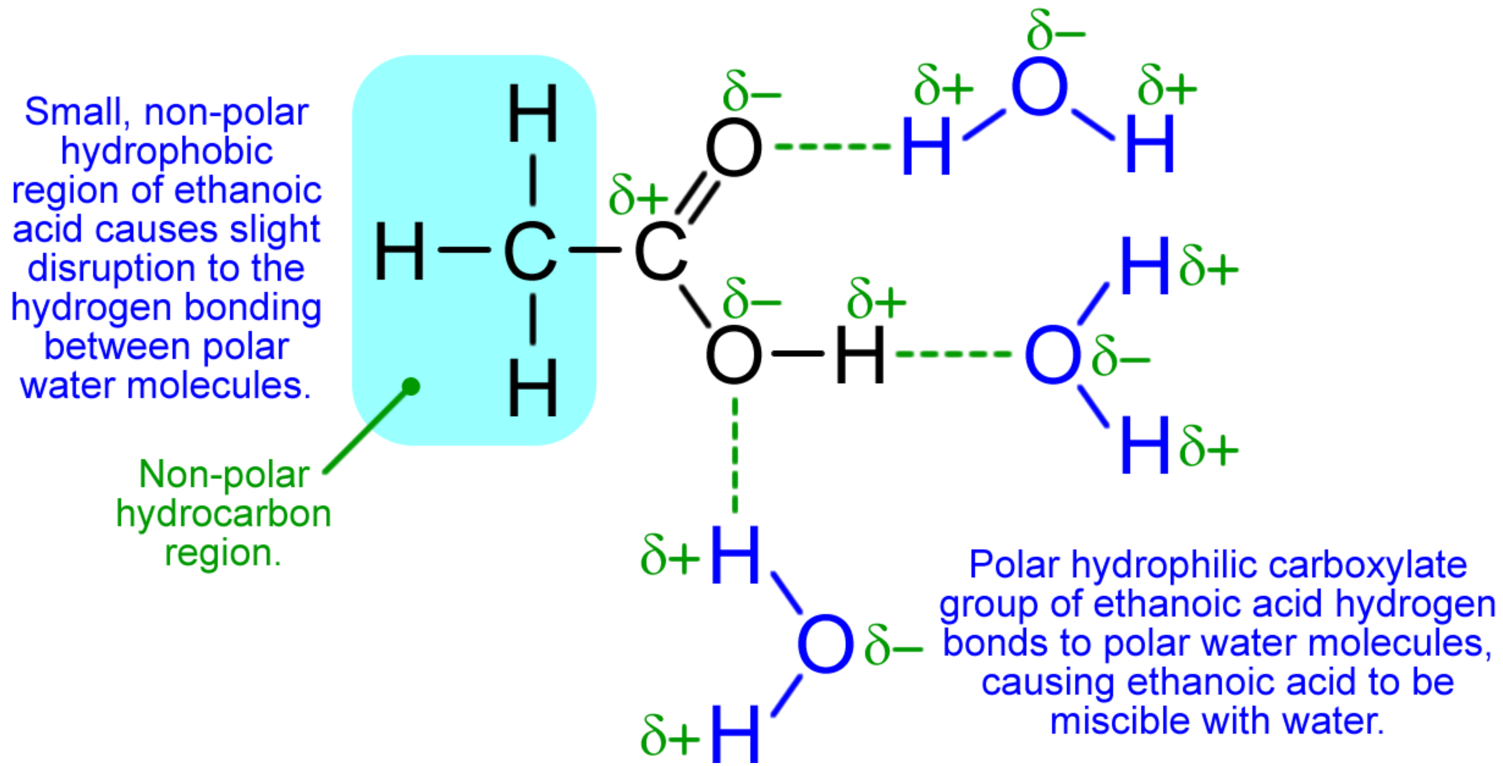
Organic Chemistry

Physical Properties of Carboxylic Acids



Organic Chemistry

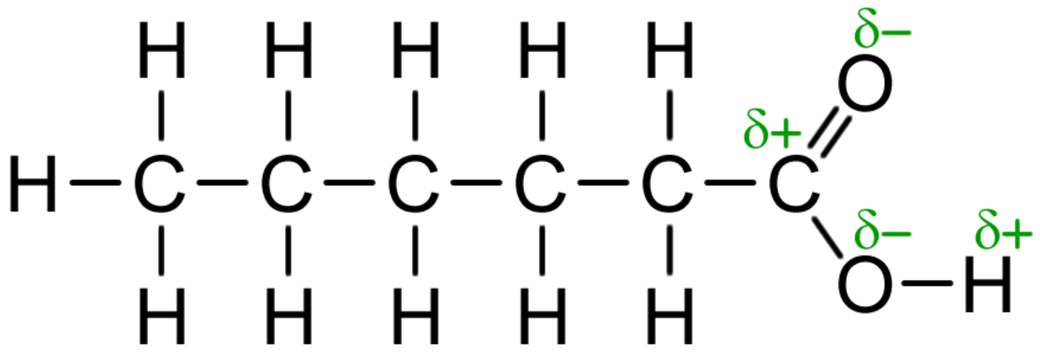
Physical Properties of Carboxylic Acids



- The polar *hydrophilic* region of ethanoic acid is more significant than the small non-polar *hydrophobic* region, and dominates the properties of the molecule, causing it to be *miscible* (soluble) with water (ethanoic acid is infinitely soluble in water).

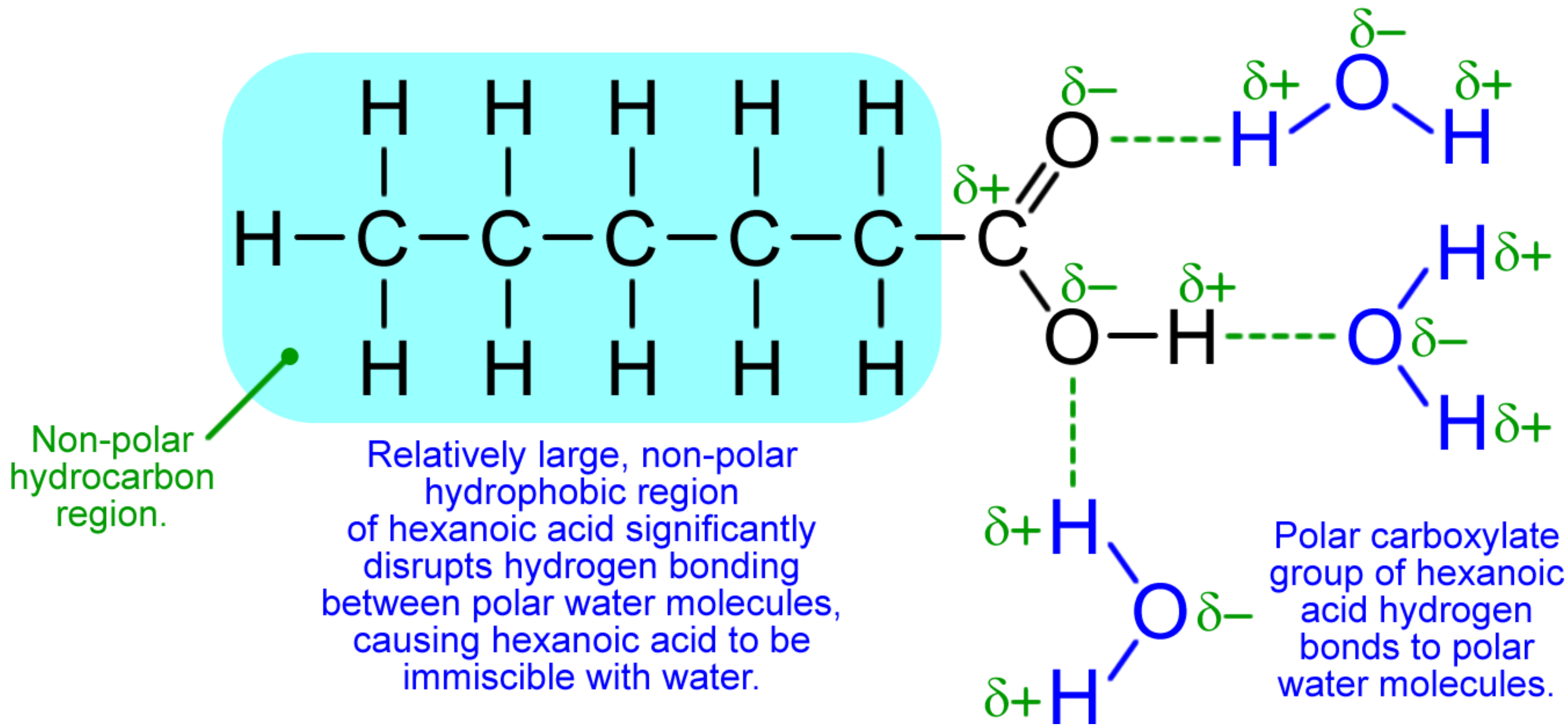
Organic Chemistry

Physical Properties of Carboxylic Acids



Organic Chemistry

Physical Properties of Carboxylic Acids



- The larger, non-polar, *hydrophobic* region of hexanoic acid is more significant than the polar *hydrophilic* region, and dominates the properties of the molecule, causing it to be *immiscible* (insoluble) with water.

Organic Chemistry

Physical Properties of Carboxylic Acids

Name	Formula	Melting point / °C	Boiling point / °C	*Solubility in water
methanoic acid	$HCOOH$	8.4	101	miscible / ∞ soluble
ethanoic acid	CH_3COOH	16.5	118.5	miscible / ∞ soluble
propanoic acid	C_2H_5COOH	–20.5	141	miscible / ∞ soluble
butanoic acid	C_3H_7COOH	–5.1	163.8	miscible / ∞ soluble
pentanoic acid	C_4H_9COOH	–34.5	185	49.7
hexanoic acid	$C_5H_{11}COOH$	–3.4	205.8	10.8

*Solubility measured in grams of carboxylic acid per 1000 cm^3 of water at 20°C.

- The first six carboxylic acids are *colourless liquids* at room temperature and pressure.
- Boiling points *increase* as carbon chain-length *increases*.
- Solubility in water *decreases* as carbon chain-length *increases*.

Organic Chemistry

How do I name organic compounds that have *more than one functional group*?

Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

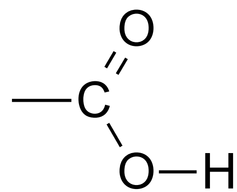
- Chemical nomenclature is a set of rules used to generate systematic names for chemical compounds. The nomenclature used most frequently worldwide is the one created and developed by the International Union of Pure and Applied Chemistry (IUPAC).

- Ideally, every possible organic compound should have a name from which an unambiguous structural formula can be created. IUPAC Nomenclature ensures that each organic compound (and its various isomers) has only one formally accepted name known as the systematic IUPAC name.

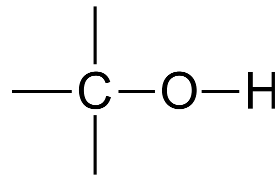
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

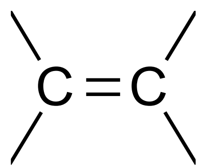
- Higher Priority



- Carboxylic Acid

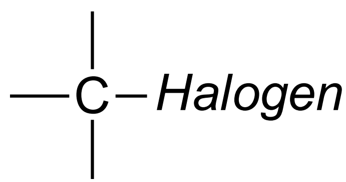


- Alcohol



- Alkene

- Lower Priority

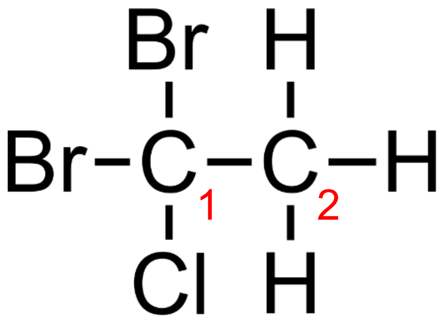


- Halogenoalkane

- Higher priority groups have lower numbers assigned to them when naming.

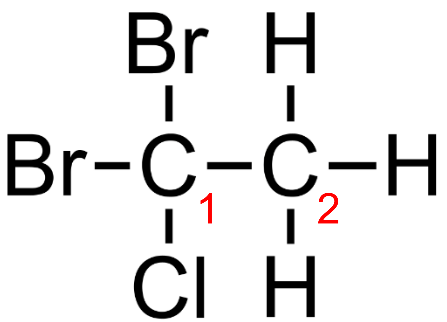
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

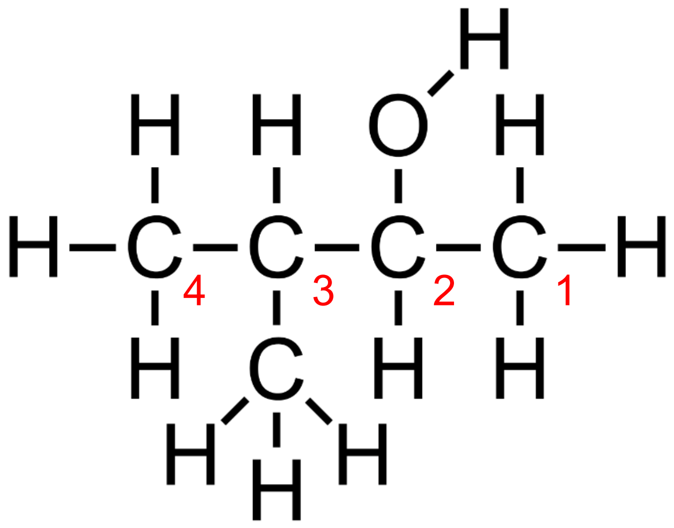


1,1-dibromo-1-chloroethane

- Longest carbon chain = 2, hence the name *eth*ane.
- Bromo- and chloro- are arranged in alphabetical order.
- Di- means ‘2’, hence dibromo means ‘2 atoms of bromine’ (tri- means ‘3’).
- Numbers are used to identify the locations of –Br and –C*l* in the molecule to avoid any ambiguity.

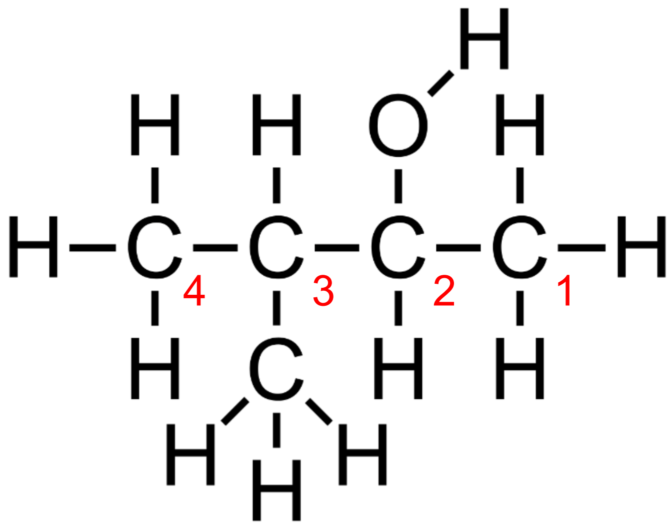
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

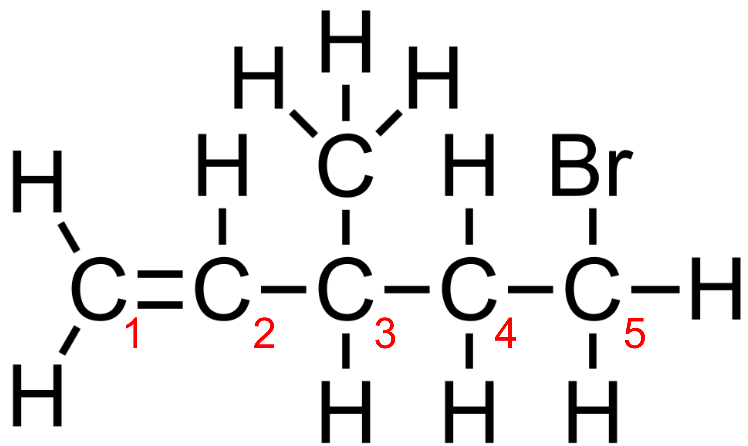


3-methylbutan-2-ol (*not* 2-methylbutan-3-ol)

- Longest carbon chain = 4, hence the name *butanol*.
- The hydroxyl group takes priority and is assigned the smallest number.
- Numbers are used to identify the locations of $-CH_3$ and $-OH$ in the molecule to avoid any ambiguity.

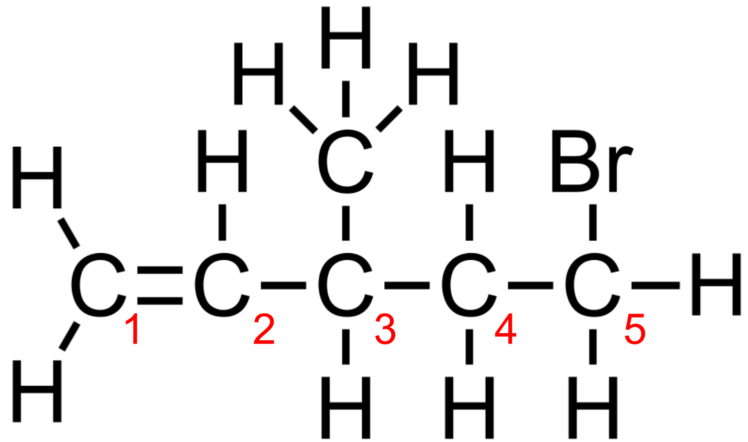
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

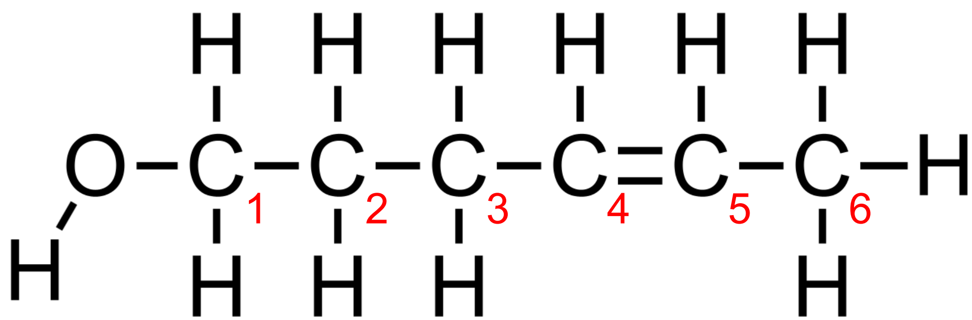


5-bromo-3-methylpent-1-ene

- The longest carbon chain = 5, hence the name <u>*pent*</u>*ene*.
- The alkene group takes priority and is assigned the smallest number.
- Bromo- and methyl- are arranged in alphabetical order.
- Numbers are used to identify the locations of $–Br$, $–CH_3$ and $C=C$ in the molecule to avoid any ambiguity.

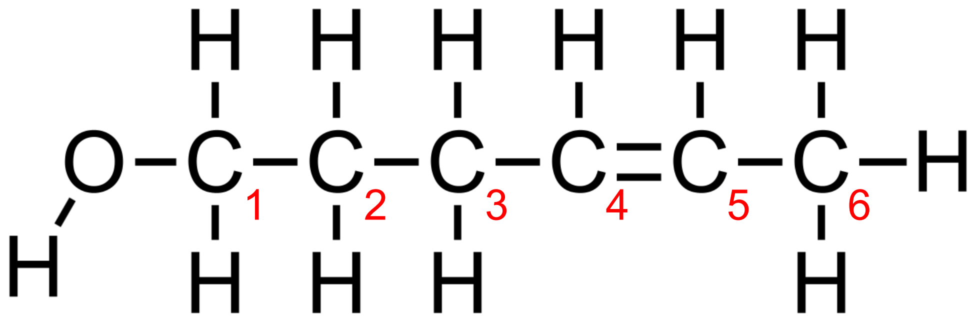
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

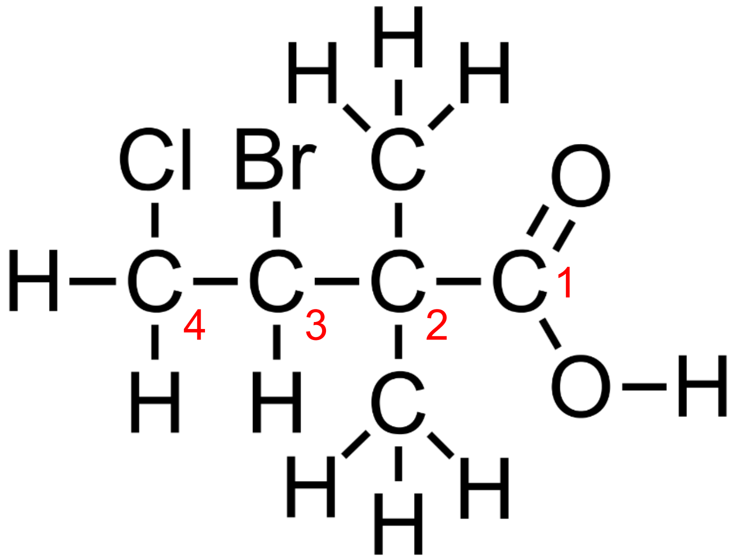


Hex-4-en-1-ol (*not* hex-2-en-6-ol)

- The longest carbon chain = 6, hence the name *hexenol*.
- The hydroxyl group takes priority and is assigned the smallest number.
- Numbers are used to identify the locations of C=C and –OH in the molecule to avoid any ambiguity.

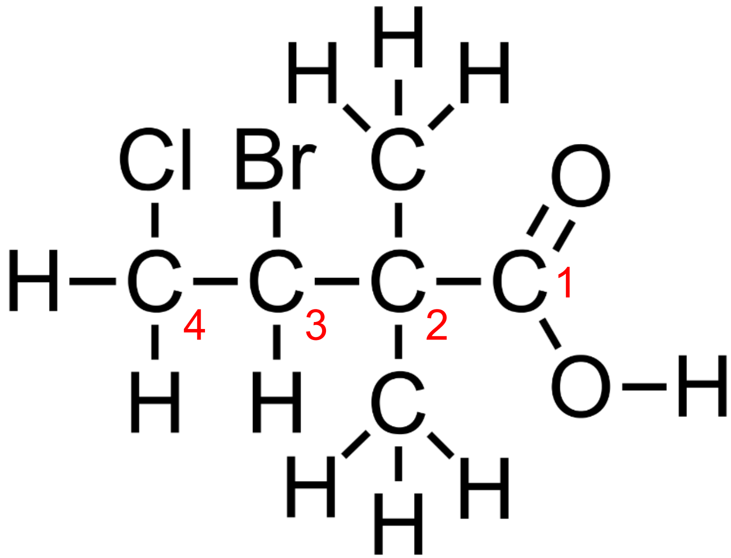
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds

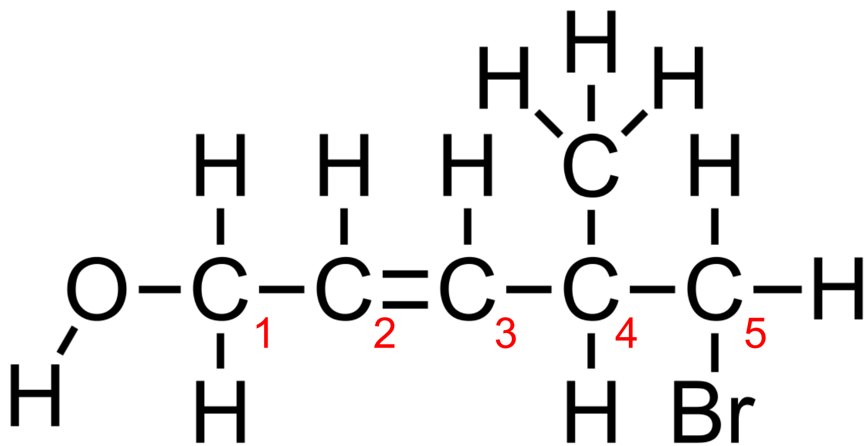


3-bromo-4-chloro-2,2-dimethylbutanoic acid

- The longest carbon chain = 4, hence the name *butanoic acid*.
- The carboxylic acid group takes priority and is assigned the value of 1.
- Bromo-, chloro- and methyl are arranged in alphabetical order.
- Di- means ‘2’, hence dimethyl means ‘2 methyl groups’ (tri- means ‘3’).
- Numbers are used to identify the locations of –Br, –C*l* and $–CH_3$ in the molecule to avoid any ambiguity.

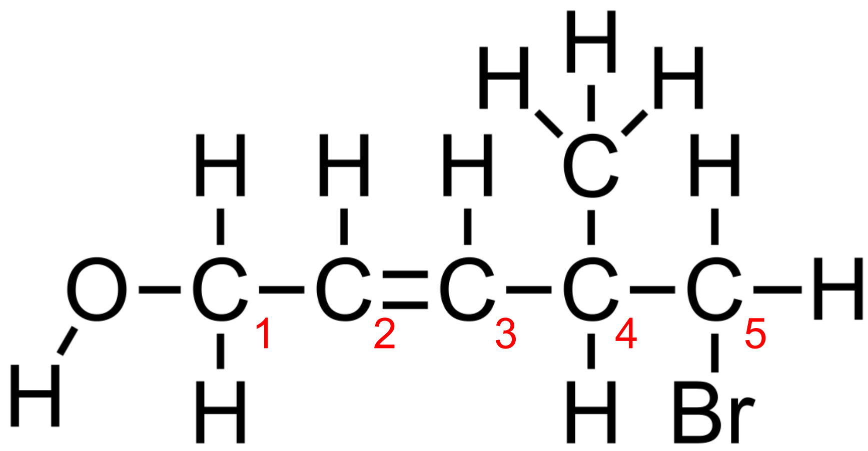
Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



Organic Chemistry

Hierarchy of Functional Groups in Naming Compounds



5-bromo-4-methylpent-2-en-1-ol

- The longest carbon chain = 5, hence the name *pentenol*.
- The hydroxyl group takes priority and is assigned the smallest number.
- Bromo- and methyl- are arranged in alphabetical order.
- Numbers are used to identify the locations of –Br, $–CH_3$, C=C and –OH in the molecule to avoid any ambiguity.

Organic Chemistry

What is the *origin* of the organic compounds that are used by chemists?

Organic Chemistry

Organic Chemistry

Origin of Crude Oil (Petroleum)

- Millions of years ago, prehistoric plankton and algae died and sank to the seabed. Over time, the dead organisms were slowly covered by layers of silt and sand.

- Heat from the Earth and pressure from the silt and sand acted on these organisms over millions of years. In the absence of oxygen (anaerobic conditions), complex organic compounds in the organisms transformed into *crude oil* (*petroleum*) and *natural gas*.

- Petroleum and natural gas are often found in underground deposits hundreds, or thousands, of metres below the surface of the Earth. Deep wells must be drilled to extract them.

Organic Chemistry

Origin of Crude Oil (Petroleum)

NANYANG GIRLS' HIGH

Organic Chemistry

Origin of Crude Oil (Petroleum)

- Crude oil (petroleum) is a very *complex mixture* of organic compounds.

- Crude oil is a dark brown, toxic, foul smelling and viscous liquid.

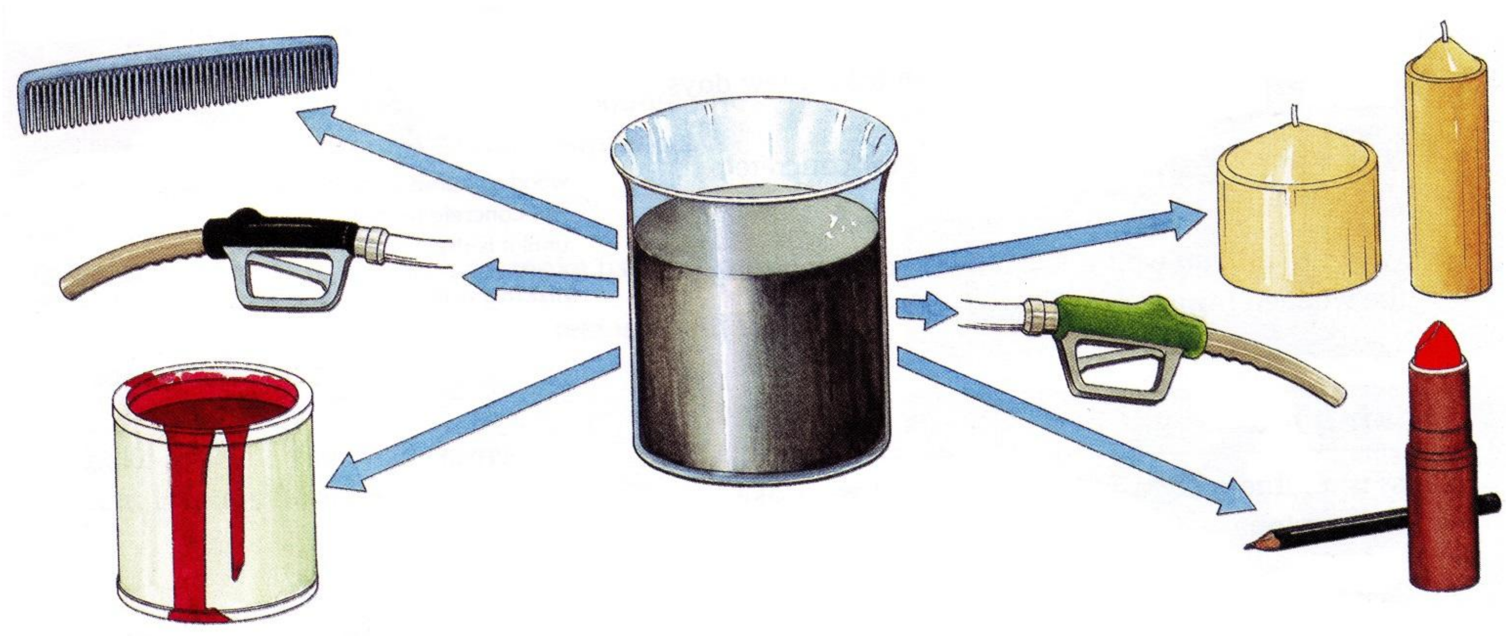
- Crude oil can be separated into useful fractions by *fractional distillation* in an oil refinery.

- Each crude oil fraction is a mixture of hydrocarbons that boils over a certain range of temperatures.

→ Lighter fractions (low b.p.) consist of smaller hydrocarbons.
→ Heavier fractions (high b.p.) consist of larger hydrocarbons.

Organic Chemistry

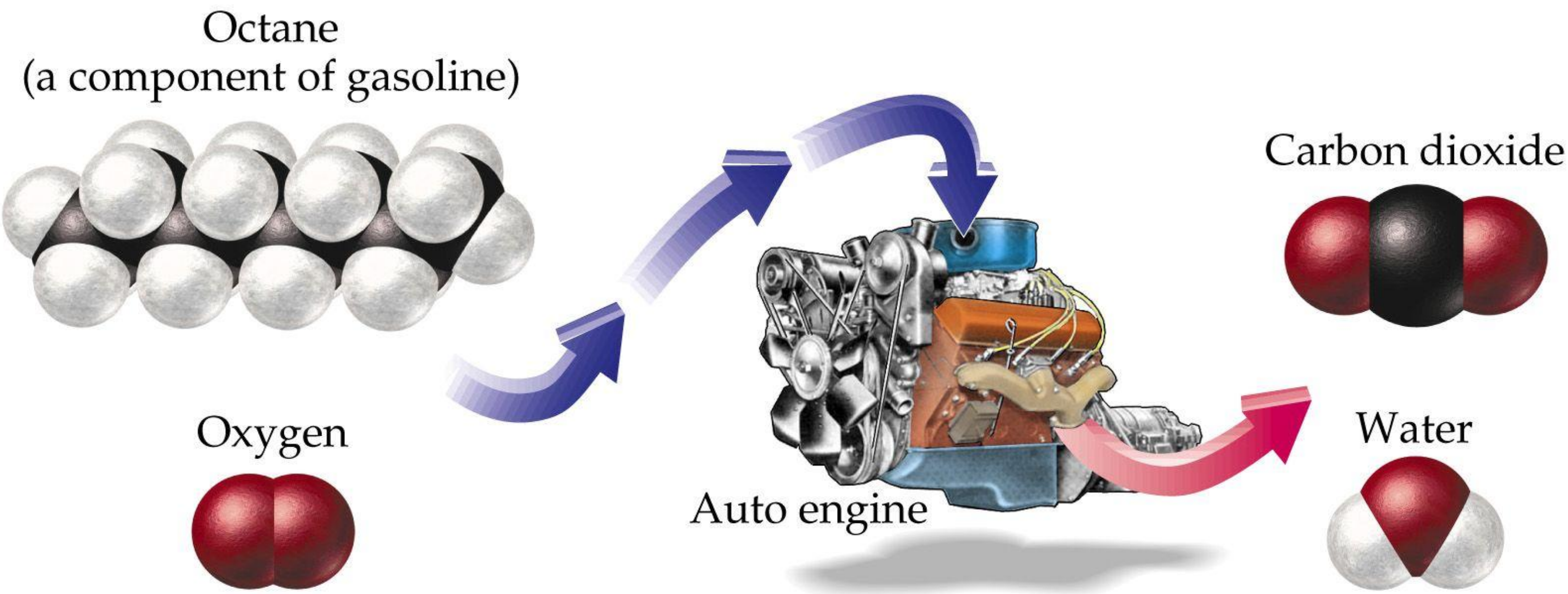
Fractional Distillation of Crude Oil (Petroleum)



- Diagram to illustrate some uses of the different fractions that are separated from crude oil.

Organic Chemistry

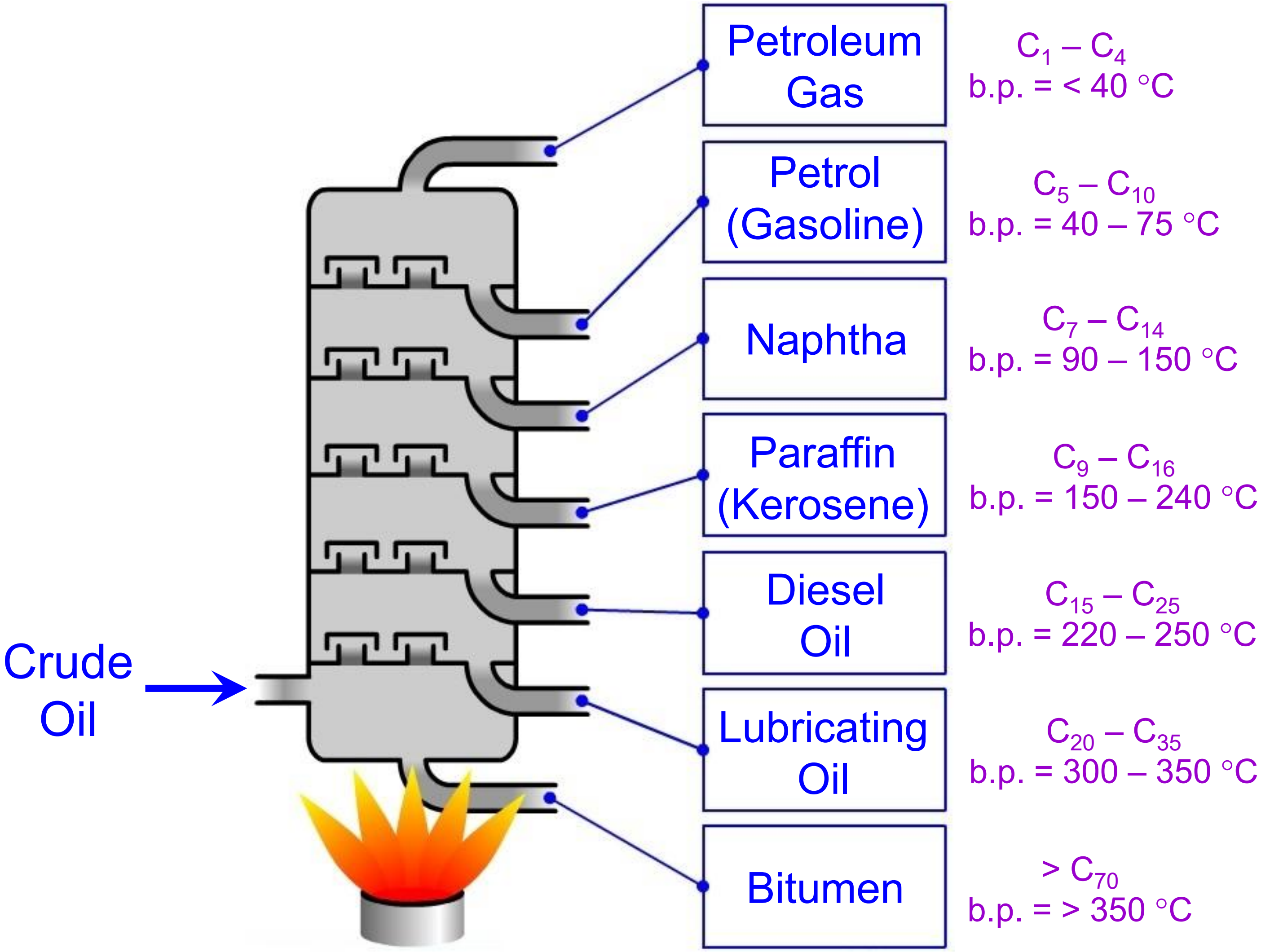
Fractional Distillation of Crude Oil (Petroleum)



- Petrol – C_5H_{12} to $C_{10}H_{22}$ – is an important fraction that is separated from crude oil by *fractional distillation*.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)



Organic Chemistry

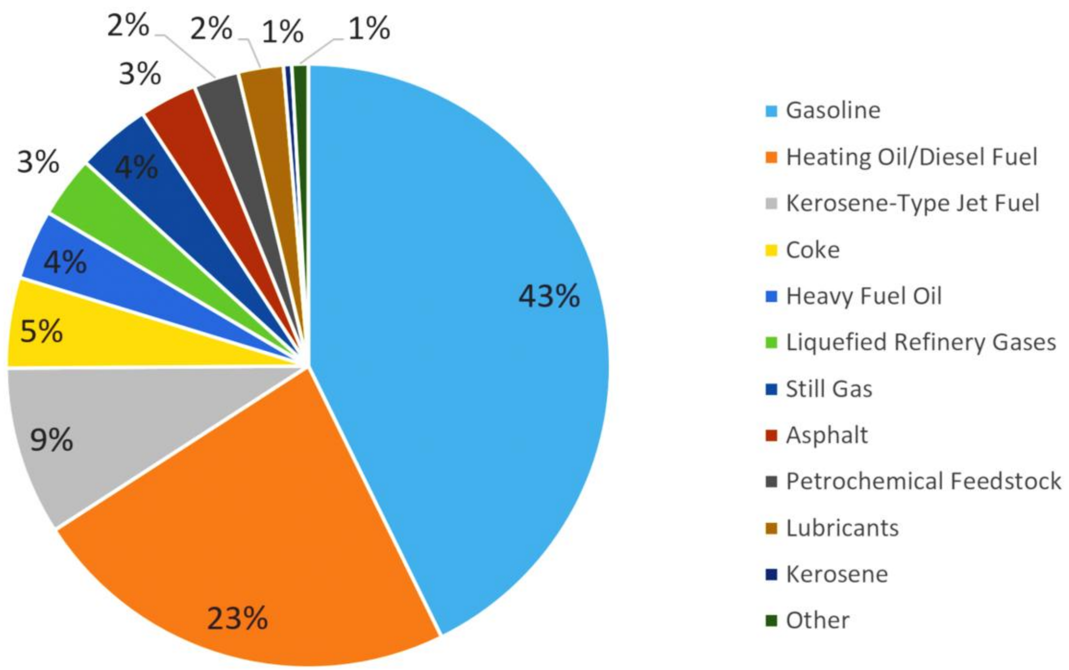
Fractional Distillation of Crude Oil (Petroleum)

Name of Fraction	Number of Carbon Atoms	Boiling Point / °C	Use of Fraction
Petroleum Gas	$C_1 – C_4$	< 40	Fuel for cooking and heating.
Petrol (Gasoline)	$C_5 – C_{10}$	40 – 75	Fuel for motorcars.
Naphtha	$C_7 – C_{14}$	90 – 150	Feedstock for the chemical industry.
Paraffin (Kerosene)	$C_9 – C_{16}$	150 – 240	Fuel for aircraft, cooking and heating.
Diesel Oil	$C_{15} – C_{25}$	220 – 250	Fuel for buses, lorries and trains.
Lubricating Oil	$C_{20} – C_{35}$	300 – 350	For lubricating machines.
Bitumen	$> C_{70}$	> 350	For making road surfaces and roofing.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- A single barrel of crude oil – once it has been refined – can yield a large number of different, useful petroleum products. The refining process separates these different hydrocarbons by virtue of their different boiling points in a fractional distillation tower. Note that a very large proportion of the crude oil is used as fuel, and only a relatively small proportion is used for manufacturing.



https://energyeducation.ca/encyclopedia/in_a_barrel_of_oil

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- As the relative molecular mass of the hydrocarbons in a fraction increases, so the colour of the fractions gradually become darker.

- This is because, as the relative molecular masses of the molecules in the fractions increases, so the bonding within the molecules becomes more complex, *e.g.* –CH=CH–CH=CH–. Electrons within these molecules are able to absorb light in the visible spectrum, and hence the fractions become coloured.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- As the relative molecular mass of the hydrocarbons in a fraction increases, so the colour of the fractions gradually become darker.

Low Relative Molecular Mass

- Short carbon chains
- Low melting point
- Low boiling point
- Low viscosity
- High flammability
- Pale colour

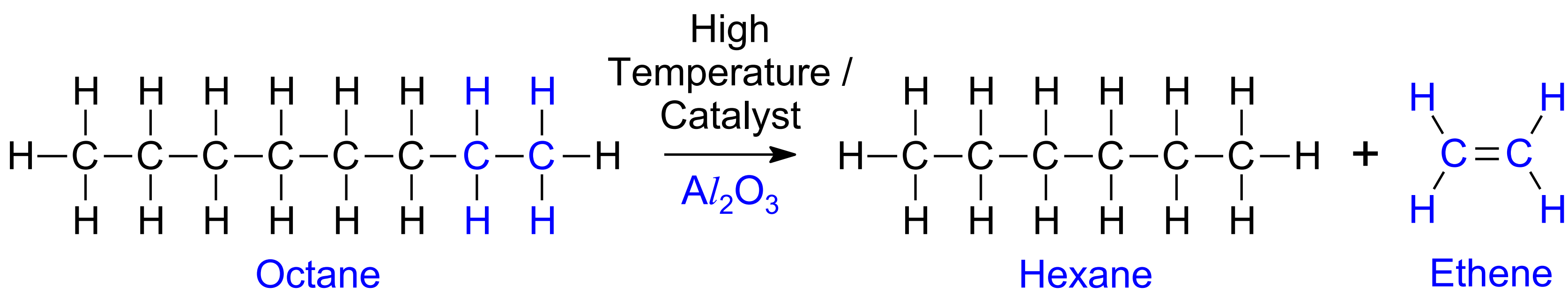
High Relative Molecular Mass

- Long carbon chains
- High melting point
- High boiling point
- High viscosity
- Low flammability
- Dark colour

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

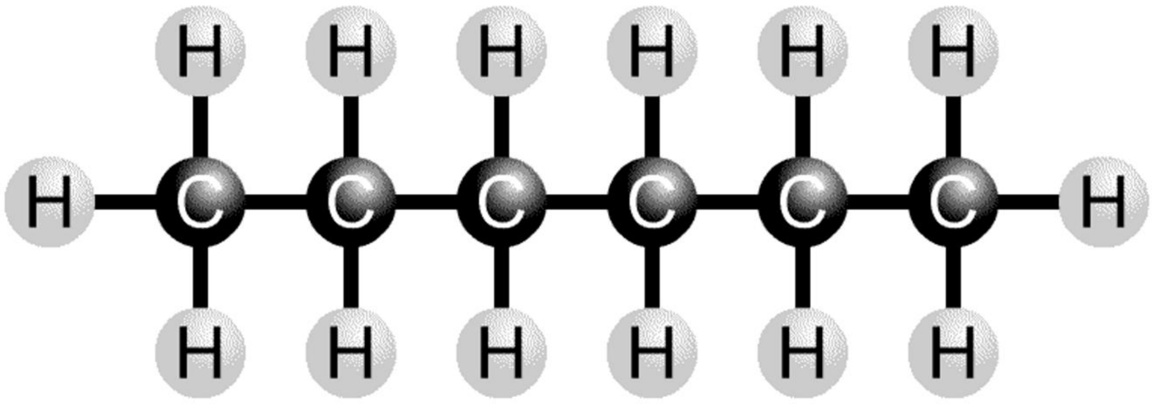
The catalytic cracking of long-chain alkanes produces short-chain alkanes and alkenes as reaction products. Short-chain alkanes tend to be more useful than long-chain alkanes, and alkenes can be used in organic synthesis.



Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

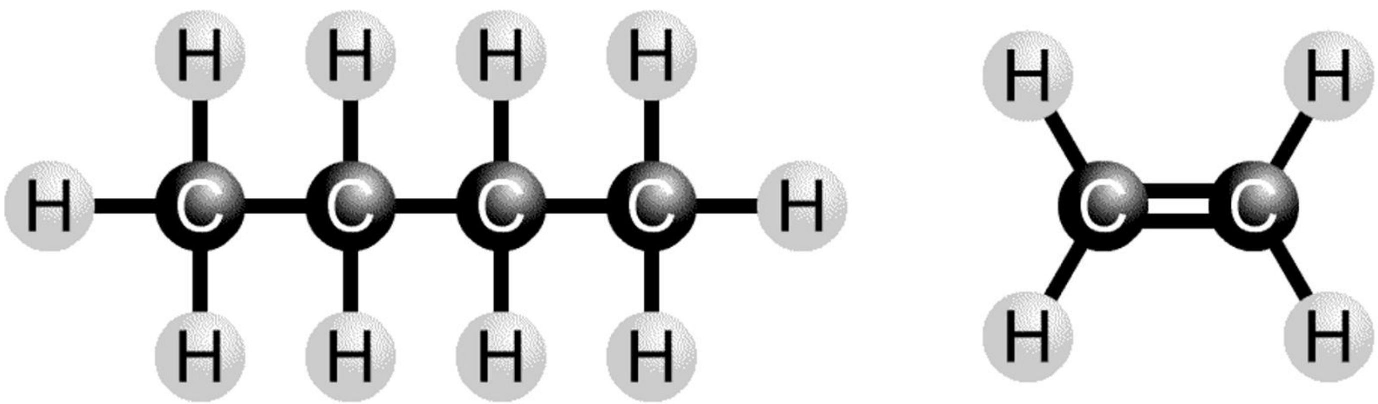
The catalytic cracking of long-chain alkanes produces short-chain alkanes and alkenes as reaction products. Short-chain alkanes tend to be more useful than long-chain alkanes, and alkenes can be used in organic synthesis.



Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

The catalytic cracking of long-chain alkanes produces short-chain alkanes and alkenes as reaction products. Short-chain alkanes tend to be more useful than long-chain alkanes, and alkenes can be used in organic synthesis.



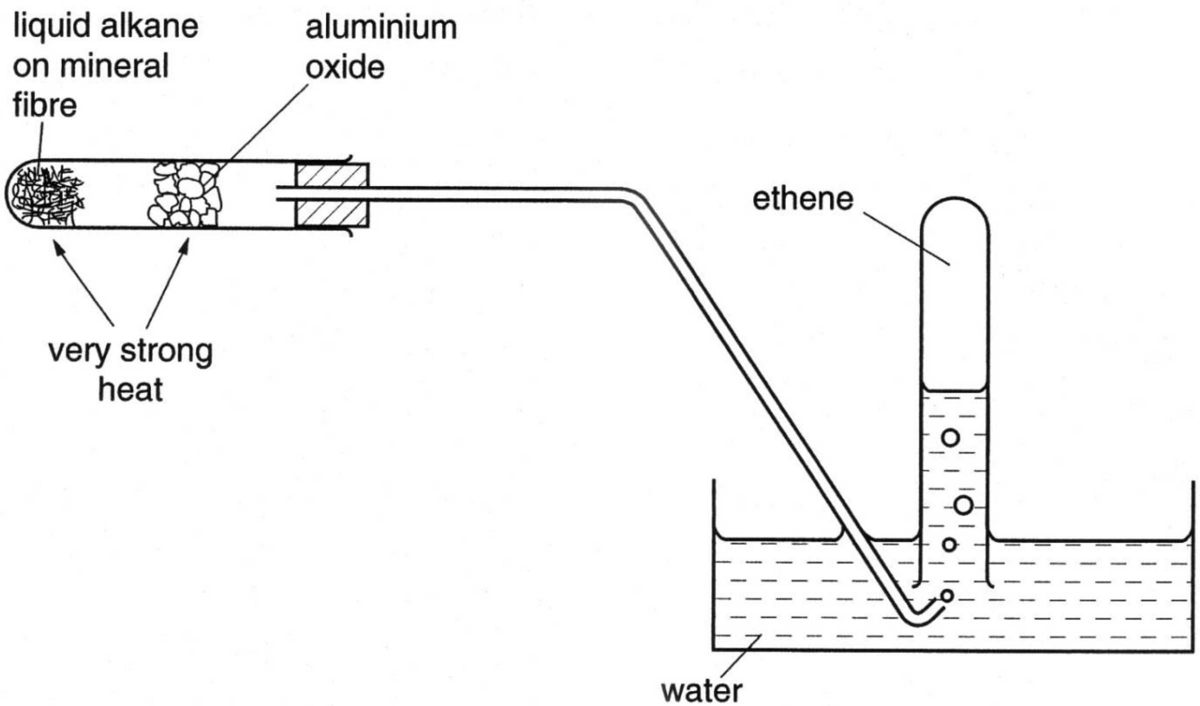
long chain alk*ane* → short chain alk*ane* + short chain alk*ene*

hexane → butane + ethene

$C_6H_{14} \rightarrow C_4H_{10} + C_2H_4$

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)



- An experiment to *crack* a long-chain hydrocarbon in the lab. Note that the insoluble ethene gas is collected by the *downward displacement of water*.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

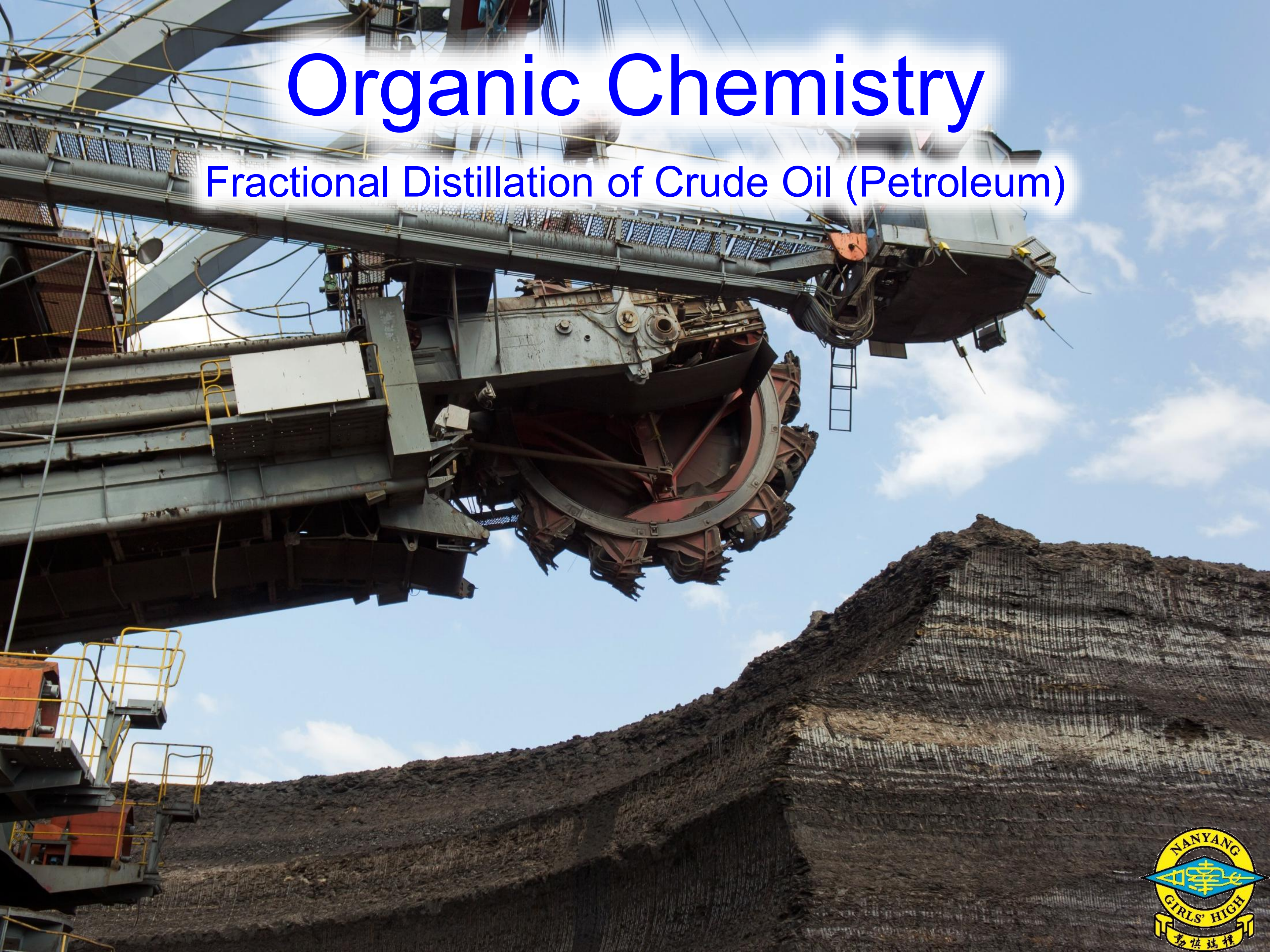
Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- Accidents during the transport of crude oil can lead to environmental disasters.
- The non-polar hydrocarbon molecules in crude oil are immiscible with the polar solvent water.
- Crude oil is less dense than water.
- The crude oil coats plants and animals with a thick, viscous layer of toxic chemicals which will eventually kill them if not removed.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)



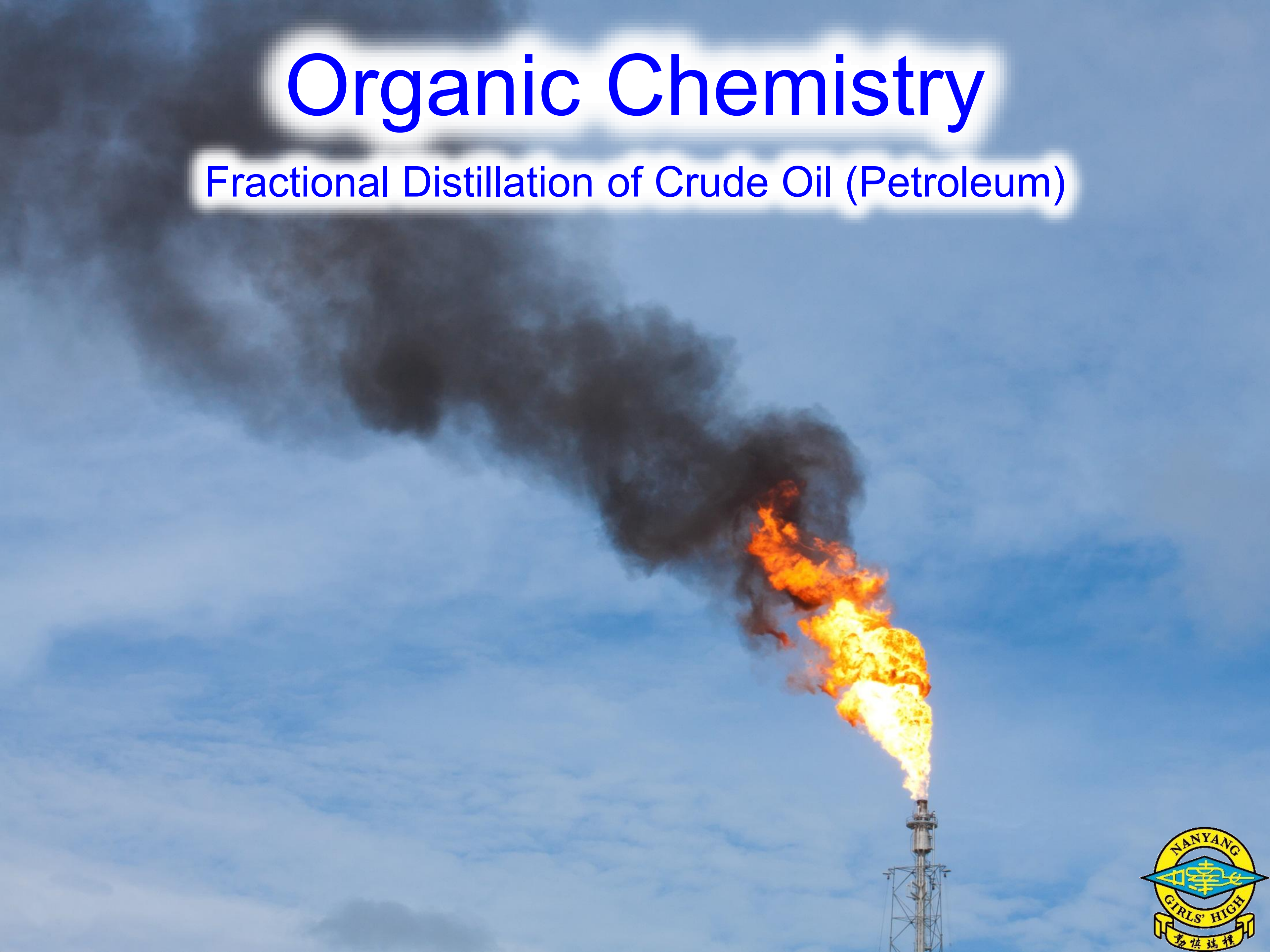
Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- Crude oil, coal and natural gas are *fossil fuels*. They are *non-renewable* sources of energy, and will eventually run out.
- It is important to develop alternative sources of *clean* and *renewable energy*.

Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)



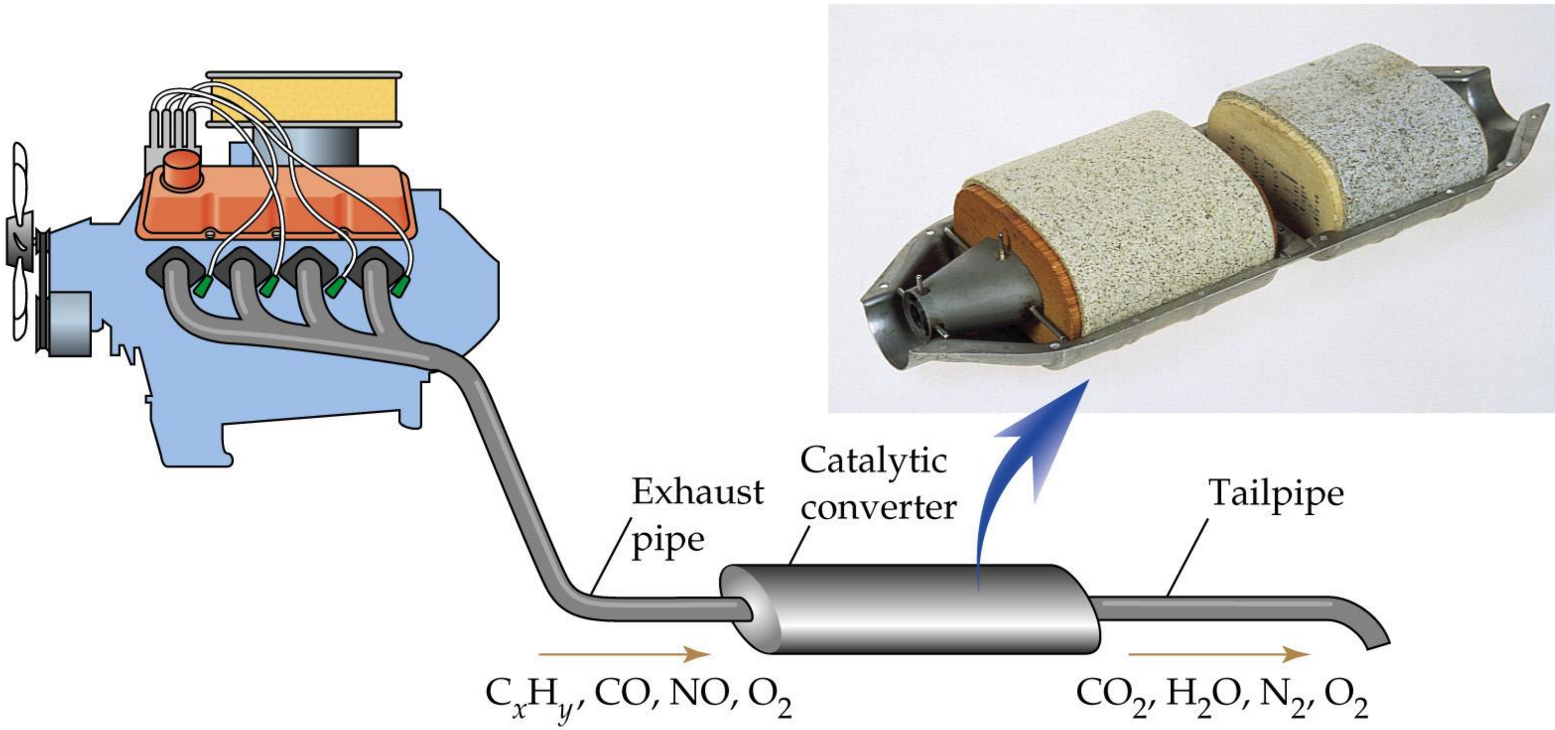
Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)

- The combustion of fossil fuels produce pollutants such as:
- Carbon dioxide → causes global warming.
- Carbon monoxide → toxic.
- Oxides of nitrogen → irritant, causes acid rain.
- Sulfur dioxide → irritant, causes acid rain.
- Unburned hydrocarbons → cause cancer.

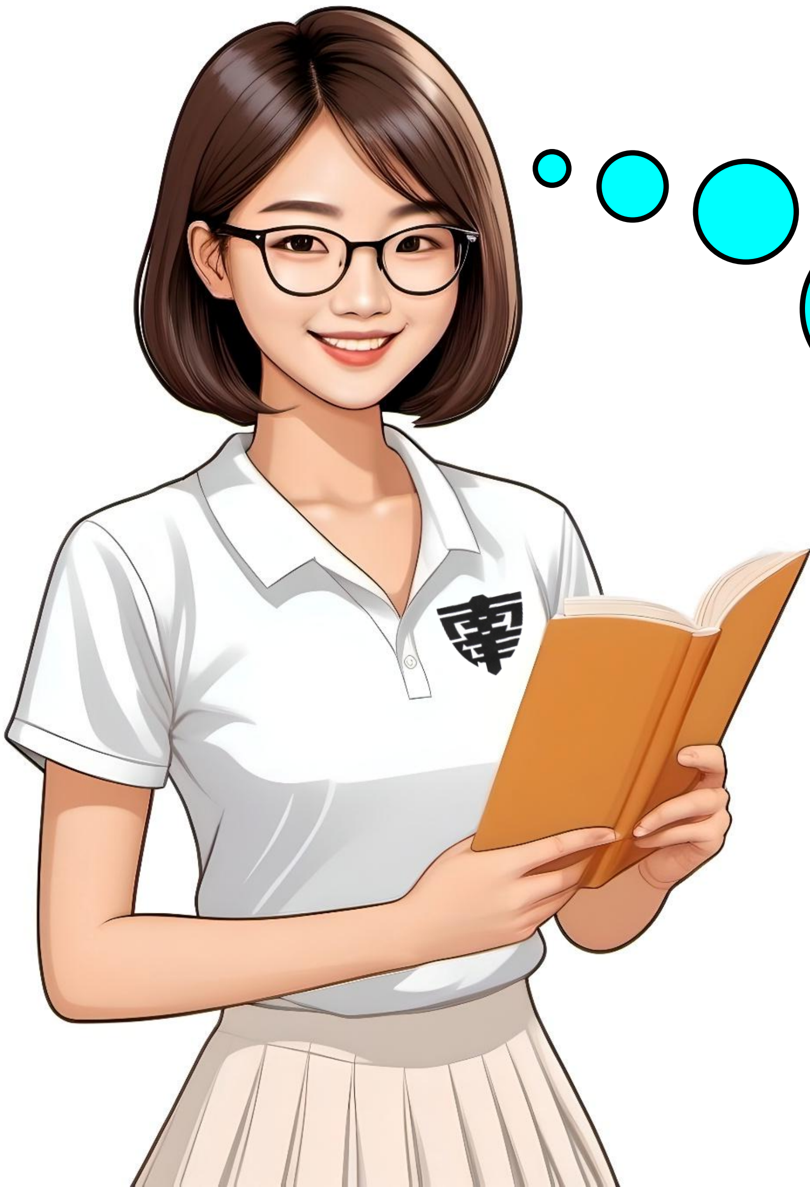
Organic Chemistry

Fractional Distillation of Crude Oil (Petroleum)



- Pollutants can be removed from car exhaust fumes using *catalytic converters*. For example:
  $2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$

Organic Chemistry



What are *isomers*?

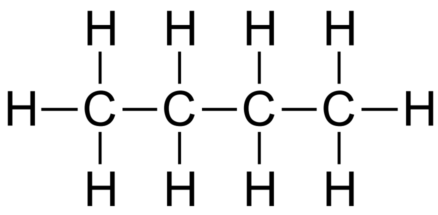
Organic Chemistry

Structural Isomerism

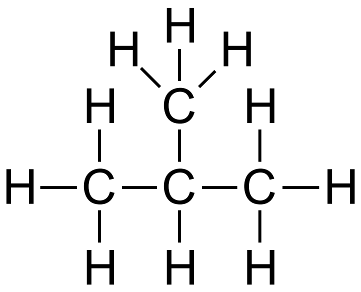
- Structural isomers are compounds that share the same molecular formula, but have different structural formulas (arrangement of atoms).
- Isomers may or may not belong to the same homologous series.
- Isomers have different names.

Organic Chemistry

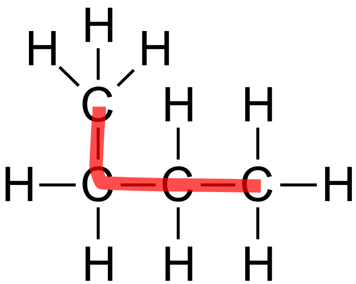
There are Two Isomers of C_4H_{10}:



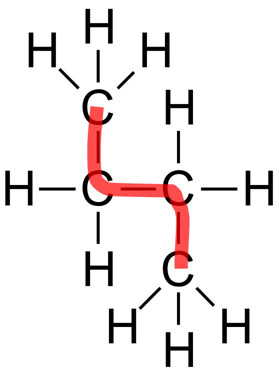
butane



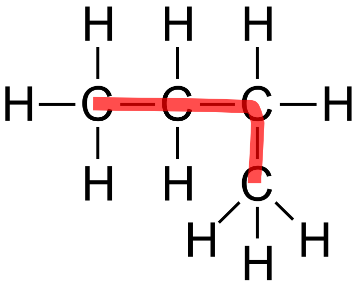
2-methylpropane
(or just methylpropane)



This is butane *not* 1-methylpropane



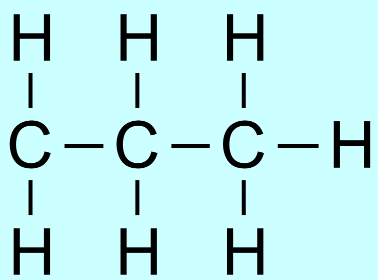
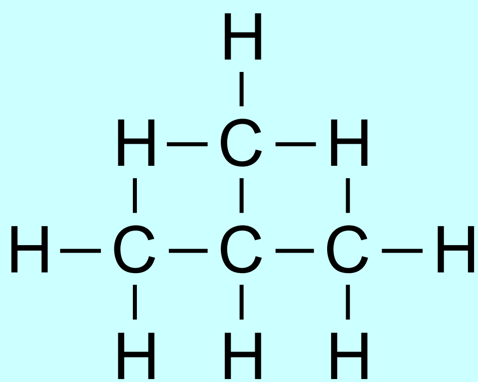
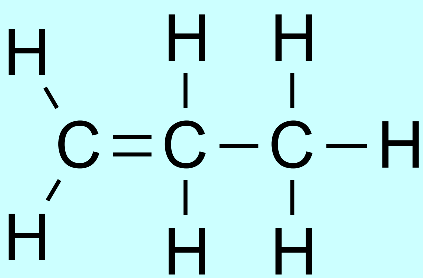
This is butane *not* 1,2-dimethylethane



This is butane *not* 1-methylpropane

Organic Chemistry

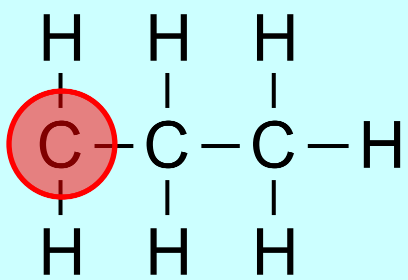
- Take care when drawing the structural formulae of organic compounds.

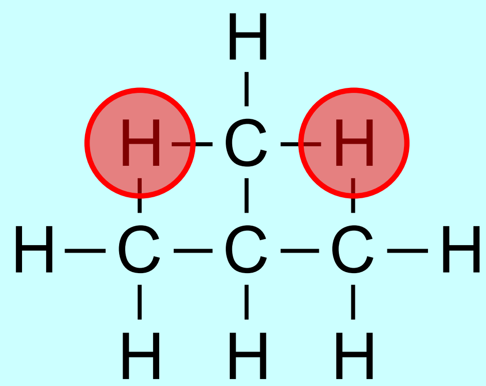
- What is wrong with the structural formulae of these three organic compounds?

Organic Chemistry

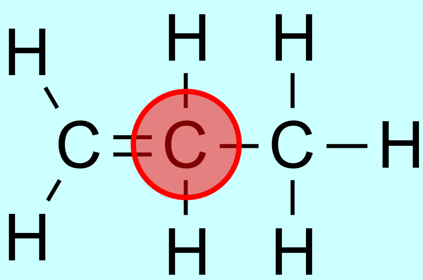
- Take care when drawing the structural formulae of organic compounds.



Carbon making 3 bonds instead of 4 bonds.



Hydrogen making 2 bonds instead of only 1 bond.



Carbon making 5 bonds instead of only 4 bonds.

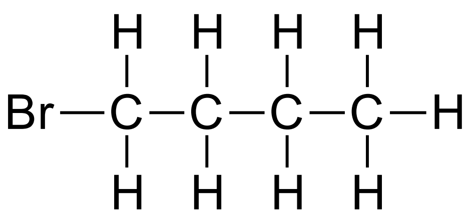
- What is wrong with the structural formulae of these three organic compounds?

Organic Chemistry

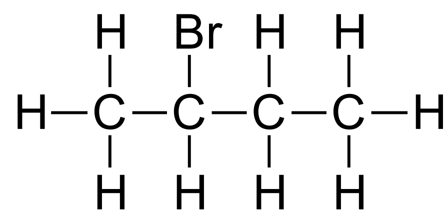
What are the Isomers of C_4H_9Br?

Organic Chemistry

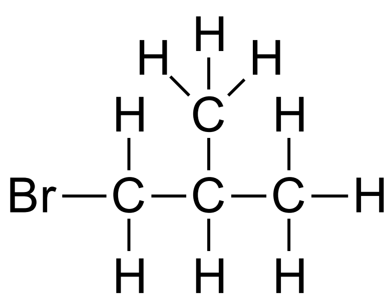
What are the Isomers of C_4H_9Br?



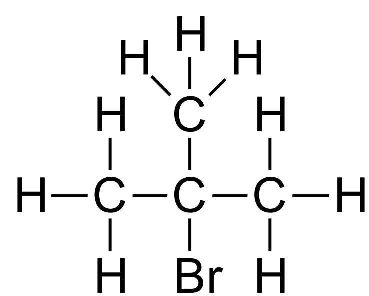
1-bromobutane



2-bromobutane



1-bromo-2-methylpropane
(or just 1-bromomethylpropane)



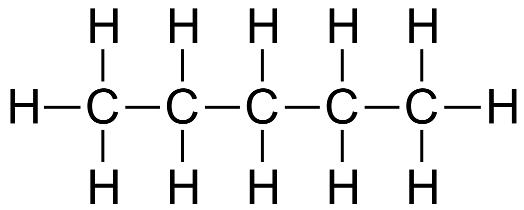
2-bromo-2-methylpropane
(or just 2-bromomethylpropane)

Organic Chemistry

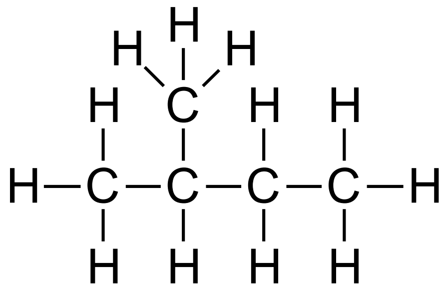
What are the Isomers of C_5H_{12}?

Organic Chemistry

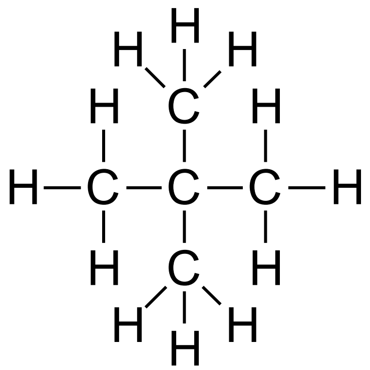
What are the Isomers of C_5H_{12}?



pentane



2-methylbutane
(or just methylbutane)



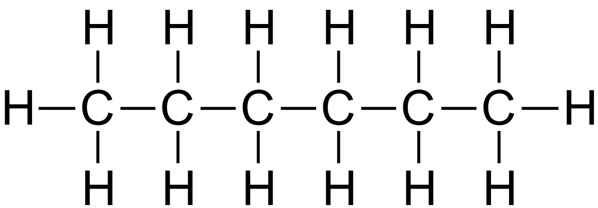
2,2-dimethylpropane
(or just dimethylpropane)

Organic Chemistry

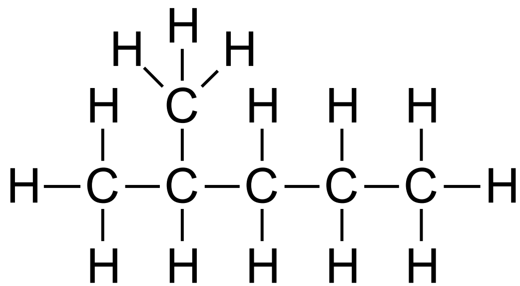
What are the Isomers of C_6H_{14}?

Organic Chemistry

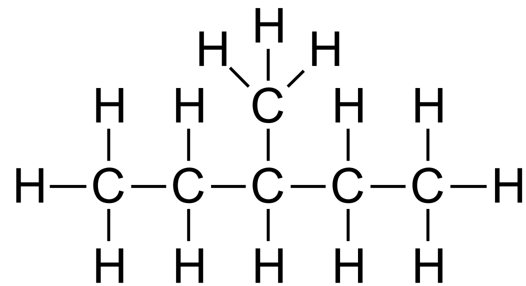
What are the Isomers of C_6H_{14}?



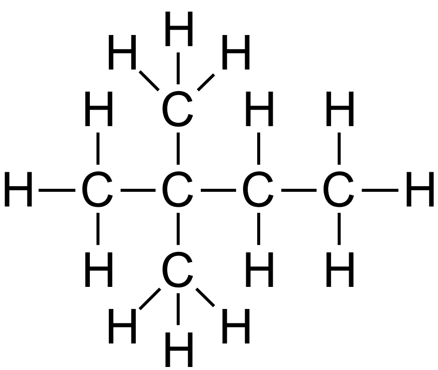
hexane



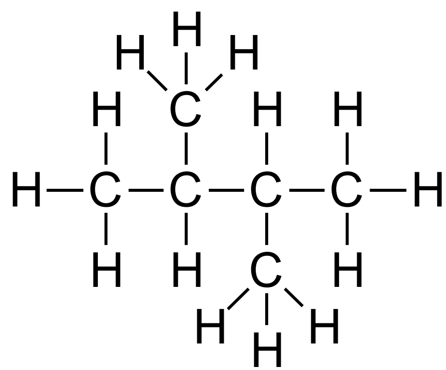
2-methylpentane



3-methylpentane



2,2-dimethylbutane



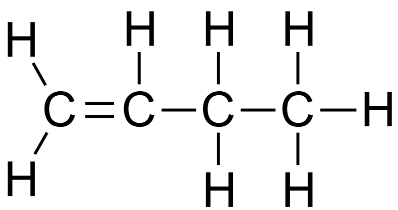
2,3-dimethylbutane

Organic Chemistry

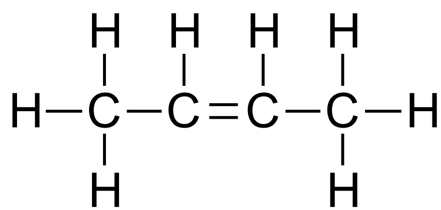
What are the Isomers of C_4H_8?

Organic Chemistry

What are the Isomers of C_4H_8?

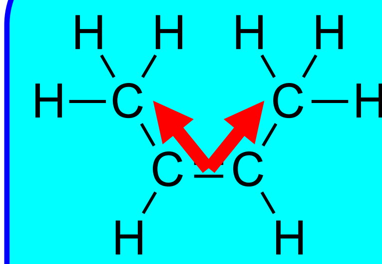


but-1-ene

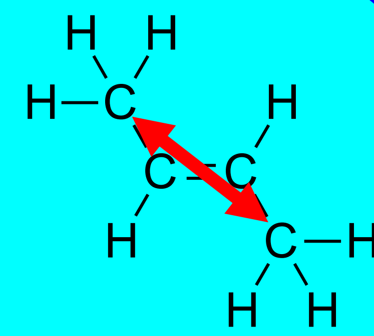


but-2-ene

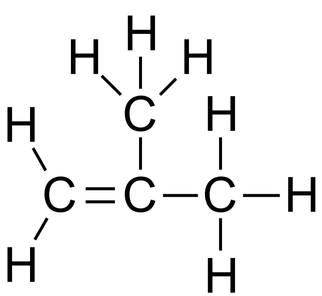
Geometric Isomers!



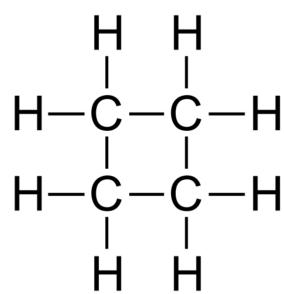
cis-but-2-ene



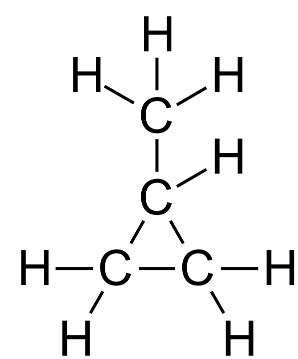
trans-but-2-ene



2-methylprop-1-ene
(or just methylpropene)



cyclobutane



methylcyclopropane

Organic Chemistry

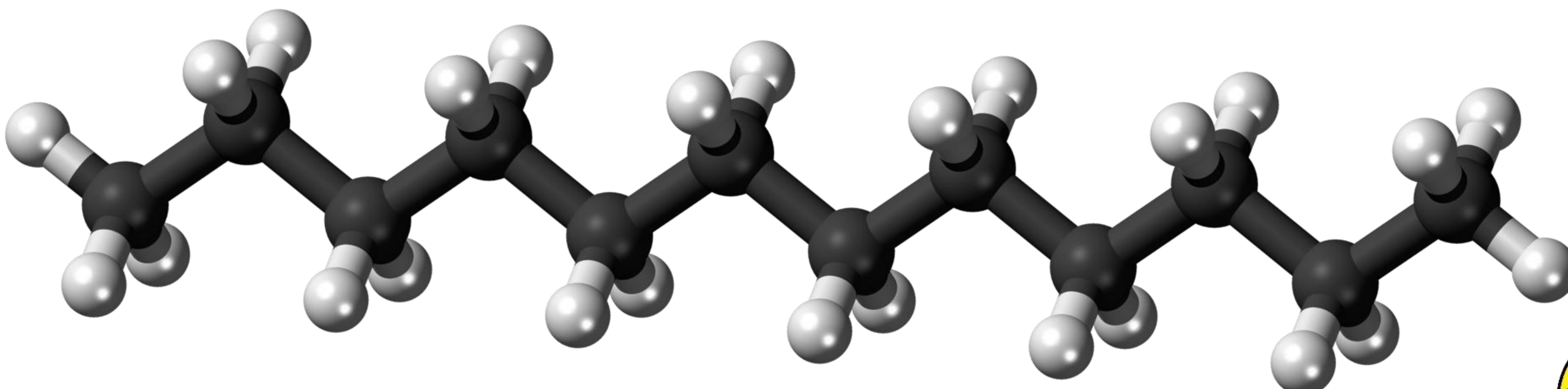
Structural Isomerism

- As the number of carbon atoms and hydrogen atoms in an alkane gradually increases, so the number of structural isomers increases *very rapidly*.

→ Octane, C_8H_{18}, has **18** isomers

→ Decane, $C_{10}H_{22}$, has **75** isomers

→ Dodecane, $C_{12}H_{26}$, has **355** isomers



Organic Chemistry

How do I *calculate the formula* of an organic compound from its percentage composition?

Organic Chemistry

Calculation of Formula from Percentage Composition

- Calculate the empirical formula of the hydrocarbon that has the following percentage composition:

C = 85.7%   H = 14.3 %

- Given that the relative molecular mass of the hydrocarbon is 42.0, calculate the molecular formula of the hydrocarbon.

- This hydrocarbon has two isomers. Give the structural formulae and names of the two isomers.

Organic Chemistry

Calculation of Formula from Percentage Composition

Step 1: Divide each element's percentage by the element's relative atomic mass.

- For carbon: 85.7 ÷ 12.0 = 7.14
- For hydrogen: 14.3 ÷ 1.0 = 14.3

How does this calculation work? Imagine that you had 100 g of the hydrocarbon. 85.7 g of the compound would be carbon, and 14.3 g would be hydrogen. Remember, mass in grams divided by relative atomic mass gives number of moles as the answer. So, 85.7 ÷ 12.0 = 7.14 moles of carbon and 14.3 ÷ 1.0 = 14.3 moles of hydrogen. The simple mole ratio of elements in a compound gives us the empirical formula of the compound.

Organic Chemistry

Calculation of Formula from Percentage Composition

Step 2: Divide each one of the answers by the smallest answer.

- For carbon: $7.14 \div 7.14 = 1.00$
- For hydrogen: $14.3 \div 7.14 = 2.00$

Organic Chemistry

Calculation of Formula from Percentage Composition

Step 3: This gives the compound's empirical formula which is the most simple ratio of elements in the compound.

$$CH_2$$

Organic Chemistry

Calculation of Formula from Percentage Composition

Step 4: Calculate the relative molecular mass of the compound's empirical formula.

$$= C + (2 \times H)$$

$$= 12.0 + (2 \times 1.0)$$

$$= 14.0$$

Organic Chemistry

Calculation of Formula from Percentage Composition

Step 5: Divide the relative molecular mass of the compound's molecular formula by the relative molecular mass of the compound's empirical formula.

$$= 42.0 \div 14.0$$

$$= 3.00$$

Organic Chemistry

Calculation of Formula from Percentage Composition

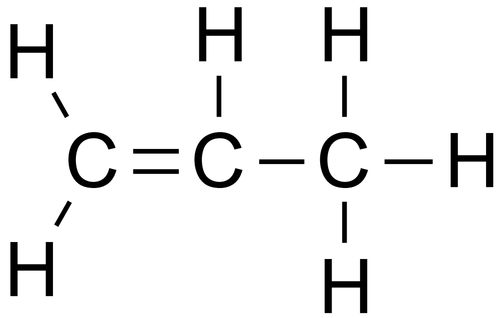
Step 6: Multiply the empirical formula by the answer to Step 5 to determine the compound's molecular formula.

$= CH_2 \times 3.00$

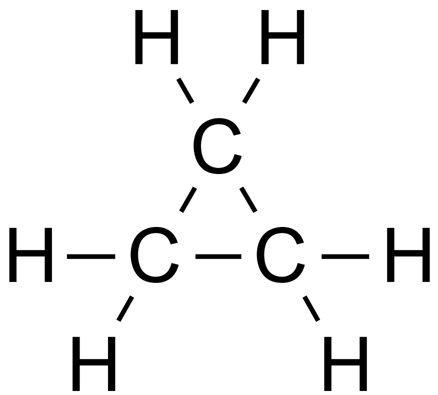
C_3H_6

Organic Chemistry

Calculation of Formula from Percentage Composition



Propene



Cyclopropane

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- The complete combustion of a hydrocarbon will produce carbon dioxide gas and water – in the form of steam – as the reaction products.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- Remember, the formula of a compound is an expression of how many moles of each constituent element are present in one mole of the compound.

- The number of moles of hydrocarbon **X**, moles of hydrogen and moles of carbon can each be determined from the volumes of gases that are given in the question:

moles of gas = volume of gas in cm^3 $\div$ 24 000

Recall: 1 mol of gas occupies 24 000 cm^3 at room temperature & pressure.

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

a) Calculate moles of gaseous hydrocarbon **X** that were burned:

= volume of hydrocarbon **X** in $cm^3 \div$ 24 000

= 20 $\div$ 24 000

= 0.0008333 mol

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- On cooling, the volume of gaseous product decreased by 100 cm^3 because the steam condensed.

b) Calculate moles of steam – $H_2O(g)$ – that were produced:

= volume of steam in $cm^3 \div 24\,000$

= $100 \div 24\,000$

= 0.004167 mol of steam

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- 1 mol of steam – $H_2O(g)$ – contains 2 mol of hydrogen atoms – H.

c) Calculate moles of hydrogen atoms present in 0.0008333 mol of hydrocarbon **X**:

$= 0.004167 \times 2$

$=$ 0.008334 mol of hydrogen atoms

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

d) Calculate moles of hydrogen atoms present in 1 mol of hydrocarbon **X**:

0.0008333 mol of hydrocarbon **X** contains 0.008334 mol of hydrogen atoms

$\therefore$ 0.0008333 $\div$ 0.0008333 mol of hydrocarbon **X** contains 0.008334 $\div$ 0.0008333 mol of hydrogen atoms

$\therefore$ 1 mol of hydrocarbon **X** contains 10.0 mol of hydrogen atoms

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- The volume decreased by 80 cm^3 because carbon dioxide (acid) was absorbed by sodium hydroxide (alkali).

e) Calculate moles of carbon dioxide – $CO_2(g)$ – that were produced:

= volume of carbon dioxide in $cm^3 \div 24\ 000$

= $80 \div 24\ 000$

= 0.003333 mol of carbon dioxide

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

- 1 mol of carbon dioxide – $CO_2(g)$ – contains 1 mol of carbon atoms – C.

f) Calculate moles of carbon atoms present in 0.0008333 mol of hydrocarbon **X**:

$= 0.003333 \times 1$

$= 0.003333$ mol of carbon atoms

Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

g) Calculate moles of carbon atoms present in 1 mol of hydrocarbon **X**:

0.0008333 mol of hydrocarbon **X** contains 0.003333 mol of carbon atoms

$\therefore$ 0.0008333 $\div$ 0.0008333 mol of hydrocarbon **X** contains 0.003333 $\div$ 0.0008333 mol of carbon atoms

$\therefore$ 1 mol of hydrocarbon **X** contains 4.00 mol of carbon atoms

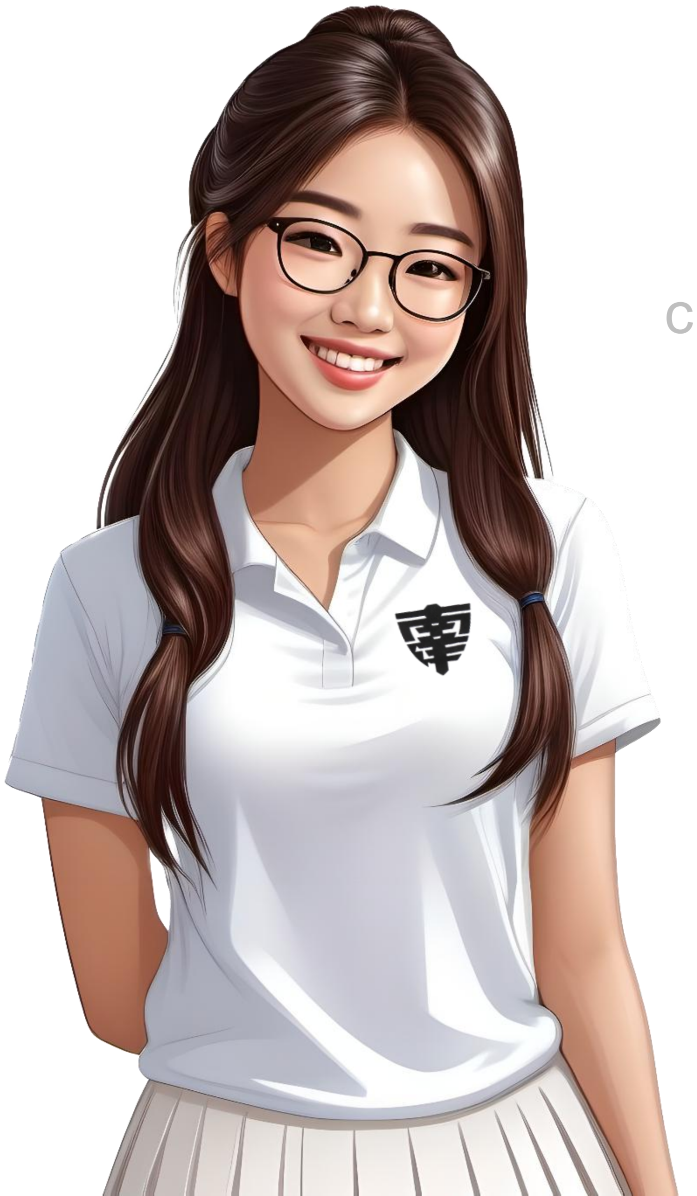
Organic Chemistry

Question: 20 cm^3 of gaseous hydrocarbon **X** was completely burned in oxygen. On cooling, the gaseous product contracted in volume by 100 cm^3. After bubbling through concentrated aqueous sodium hydroxide, the volume contracted again by another 80 cm^3. Calculate the molecular formula of hydrocarbon **X**.

h) State the molecular formula of hydrocarbon **X**:

- 1 mol of hydrocarbon **X** contains 4 mol of carbon atoms.
- 1 mol of hydrocarbon **X** contains 10 mol of hydrogen atoms.
- The molecular formula of hydrocarbon **X** is C_4H_{10}.

Organic Chemistry



Presentation on
Organic Chemistry
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