Stage 2 Chemistry

**Organic and Biological Chemistry:** Introduction

**Science Understanding**

* Organic compounds can be represented by molecular and structural formulae.
	+ Determine the molecular formula of an organic compound given its extended, condensed, or skeletal structural formula.
* Organic compounds are named systematically to provide unambiguous identification.
* Condensation reactions occur when two organic molecules combine to form a larger molecule, also releasing another small molecule, such as water.
* The physical properties of organic compounds are influenced by the molar masses of the molecules, and the number and polarity of functional groups.
	+ Predict, explain, and compare the melting points, boiling points, and solubilities in water and in non-polar solvents of organic compounds, given their structural formulae.

|  |  |  |
| --- | --- | --- |
| **Term** | **Definition** | **Example** |
| homologous series | A grouping of organic compounds based on their composition and properties.A series has:* a general formula,
* the same functional group,
* similar chemical properties,
* changing physical properties as molecular size changes.
 |  |
| functional group | Is the reactive site on a molecule.It’s the group of atoms on the molecule responsible for its chemical properties. |  |
| saturated hydrocarbons | They are compounds of carbon and hydrogen only.These compounds that contain only single C – C bonds.They are relatively unreactive.They do not have a functional group.Non polar |  |
| unsaturated hydrocarbons | They are compounds of carbon and hydrogen only.These compounds have multiple carbon – carbon bonds, eg double or triple carbon bonds.Homologous series are the alkenes alkynes and the aromatic compounds. |  |
| molecular formula | Shows the actual number of atoms present in the molecule. |  |
| structural formula | Shows the arrangement of atoms in the molecule – the way the atoms are bonded together in the compound |  |
| isomers | Compounds with the same molecular formula but different structural formula. |  |

***Determine the molecular formula of an organic compound given its extended, condensed, or skeletal structural formula.***

1. Determine the molecular formula of the following compounds
	1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



* 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	2. CH3CH2COOH \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



* 1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Systematically Naming Organic Compounds**

There are three aspects of a compound that should be considered when naming. These are:

1. The number of carbon atoms in the primary chain, the longest continuous chain.
2. The functional group(s) in the compound.
3. The branches, side-chains, off the primary chain.



**The Primary Carbon Chain**

If the compound contains any functional groups, the primary chain is the longest carbon chain containing the functional group.

The length of the primary carbon chain has a corresponding name:

|  |  |
| --- | --- |
| **Number of carbons in the Primary Chain** | **Prefix** |
| 1 | Meth- |
| 2 | Eth- |
| 3 | Prop- |
| 4 | But- |
| 5 | Pent- |
| 6 | Hex- |
| 7 | Hept- |
| 8 | Oct- |

**The Functional Group**

If a functional group is present, a suffix is added to the name of the molecule.

|  |  |  |
| --- | --- | --- |
| **Functional group** | **General Formula** | **Suffix added** |
| Alkane |  | -ane |
| Alkene |  | -ene |
| Alkyne |  | -yne |
| Hydroxyl (alcohol) |  | -ol |
| Aldehyde |  | -al |
| Ketone |  | -one |
| Carboxyl (Carboxylic acid) |  | -oic acid |
| Amino (amine) |  | -amine |

**Side Chain Carbons**

If a branch (side chain) is present, a prefix is added to the name of the molecule, with the suffix **yl**. It consists of two parts:

1. a number indicating the position of the branch,
2. and the name of the branch.

|  |  |
| --- | --- |
| **Number of carbons in the side chain** | **Name of side chain** |
| 1 | Methyl |
| 2 | Ethyl |
| 3 | Propyl  |

**Name the following molecules**



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**Draw the following molecules**

1. pentane
2. 2-methyl-butane
3. 2,3-dimethyl-3-ethyl-pentane
4. 2,3dimethyl-but-2-ene
5. 2,3-dimethyl-4-ethyl-hexan-2,3-diol

***The physical properties of organic compounds are influenced by the molar masses of the molecules, and the number and polarity of functional groups.***

***Predict, explain, and compare the melting points, boiling points, and solubilities in water and in non-polar solvents of organic compounds, given their structural formulae.***

**Melting and Boiling Points**

Melting and boiling points are determined by the strength of the intermolecular bonds.

Intermolecular bonds or secondary interactions can be broken down into two main categories, **polar** and **non-polar**.

The strength of the secondary interactions is the **sum of both** of these.

**Boiling points of alkanes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Molecular Formula** | **Condensed structural formula (of straight-chained isomers)** | **Molar mass** | **Boiling Point (0C)** |
| methane | CH4 | CH4 | 16.04 | -164 |
| ethane |  | CH3CH3 | 30.07 | -87 |
| propane |  | CH3CH2CH3 | 44.09 | -42 |
| butane | C4H10 |  | 58.12 | 0 |
| pentane |  | CH3(CH2)3CH3 | 72.15 | 36 |
| hexane |  | CH3(CH2)4CH3 | 86.17 | 69 |
| heptane | C7H16 | CH3(CH2)5CH3 | 100.20 | 98 |
| octane |  | CH3(CH2)6CH3 | 114.22 | 126 |
| nonane | C9H20 |  | 128.25 | 151 |
| decane |  | CH3(CH2)8CH3 | 142.28 | 174 |

1. Complete the above table
2. Describe the trend between molar mass and boiling point

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Alkanes are non-polar molecules, so the only secondary interactions are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Boiling points of alcohols**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Structural Formula** | **Molar mass** | **Boiling point (0C)** |
| methanol | CH3OH | 32.04 | 65 |
| ethanol | CH3CH2OH | 46.07 | 78 |
| propanol | CH3CH2CH2OH | 60.09 | 97 |
| butanol |  | 74.12 | 117 |

1. Is there a similar trend in boiling points observed here? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Compare methanol with ethane, which has a similar molecular mass. What do you notice about the boiling points?

**Boiling Points of carboxylic acids**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Structural Formula** | **Molar mass** | **Boiling point (0C)** |
| ethanoic acid | CH3COOH | 60.05 | 117.9 |
| propanoic acid | CH3CH2COOH | 74.08 | 141.1 |
| butanoic acid | CH3CH2CH2COOH | 88.10 | 163.7 |
| pentanoic acid |  | 102.13 | 186.1 |

1. Is there a similar trend in boiling points observed here? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Compare propanol with ethanoic acid, which has a similar molecular mass. What do you notice about the boiling points?

|  |  |
| --- | --- |
| **Aldehydes** | **Ketones** |
| **Name** | **Structural Formula** | **Boiling point (0C)** | **Name** | **Structural Formula** | **Boiling point (0C)** |
| methanal | HCHO | -19.1 |  |  |  |
| ethanal | CH3CHO | 20.1 |  |  |  |
| propanal | CH3CH2CHO | 48 | propanone |  | 56 |
| butanal | CH3CH2CH2CHO | 74.8 | butanone |  | 79 |

1. Why are methanone and ethanone not included in the table?
2. Given that, for the same size carbon chain, the molar masses of the aldehydes and ketones are very much the same as their alcohol equivalent, describe how the boiling points/melting points of alcohols compare with the aldehydes and ketones.

**Summary**

The boiling point of an organic compound depends on the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

These can be broken down into two categories, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Non polar interactions are present between \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compounds.

They can be increased by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Polar interactions are present between \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compounds.

They can be increased by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Functional Group Polarity**

|  |  |  |
| --- | --- | --- |
| Non-polar | Polar | Hydrogen bonds |
|  |  |  |

Fill in the above table with all the functional groups listed on page four plus **esters**.

1. State the two main chemical factors that will determine the melting and boiling point of an organic compound.

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Explain which of the following compounds will have the highest boiling point:

 C2H4, C3H6, C4H8, C5H10.

1. Propanoic acid has the molecular formula C3H6O2
	1. Draw the structural formula for propanoic acid
	2. On your diagram indicate the polarity of the functional group by indicating the dipoles.
	3. Is propanoic acid able to display hydrogen bonding? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	4. Draw the structural formula of an ester with the same molecular formula as propanoic acid.
	5. Would you expect this ester to have a higher or lower boiling point than propanoic acid? Explain your answer

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1. For each group of compounds circle the one with the highest boiling point.
	1. butanol, butanal, butanone
	2. ethyl ethanoate and butanoic acid
	3. pentane, butane, hexane and octane
	4. propanol, butanol, hexanol, and ethanol
	5. propanol, ethanoic acid, propanone and propanal
2. An organic compound has the molecular formula C4H8O2.
	1. Name and draw the structural formula of the straight-chained carboxylic acid with this molecular formula.
	2. Name and draw the two esters with this molecular formula.
	3. State the chemical term used to describe these three compounds.
	4. Predict and explain which compound, the carboxylic acid or one of the two esters, would have the highest boiling point.
3. Carefully examine the data in the table below:

|  |  |  |
| --- | --- | --- |
|  | **Molar mass** | **Boiling point (0C)** |
| ethanol | 46.02 | 78 |
| ethanal | 44.05 | 20.1 |

 Explain the difference in boiling points of these two compounds

1. Predict with reasons, which of the following pairs of organic compounds would have the highest boiling point
	1. CH3(CH2)7CH=CH(CH2)7COOH and CH3(CH2)13CH=CH(CH2)13COOH

CH3CH2

CH3

O

CH3CH2

CH3

 OH

* 1. and

***The physical properties of organic compounds are influenced by the molar masses of the molecules, and the number and polarity of functional groups.***

***Predict, explain, and compare the melting points, boiling points, and solubilities in water and in non-polar solvents of organic compounds, given their structural formulae.***

******For a substance to dissolve there must be a force of attraction between the solvent and solute that is strong enough to disturb the intermolecular forces in both the solvent **and** solute

The closer in strength that the intermolecular forces are between solute and solvent, the more likely they are to be soluble.

Like boiling point, the solubility of compounds is affected by two variables:

******\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Solubility in water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as chain length increases

Solubility in water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as polarity increases

Solubility in non-polar solvents will have the opposite relationship with polarity

1. State the two characteristics of an organic compound that would contribute to it being insoluble in water.

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. Petrol is a complex mixture of hydrocarbons with the main constituent being octane, C8H18.
	1. Is octane a non-polar or a polar molecule? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	2. Would you expect octane to be soluble in water? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	3. What type of solvent will dissolve octane? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	4. Describe why octane is able to dissolve in these types of solvents.

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1. 1. Draw the structural formula for a molecule of pentan-2-ol.
	2. On your diagram indicate the polarity of the functional group by drawing the dipoles.
	3. Is pentan-2-ol able to display hydrogen bonding? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	4. Add a water molecule to your diagram and show the hydrogen bonding between water and pentan-2-ol.
	5. Explain whether you would expect hexan-2-ol to be soluble in water?

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1. The following diagram shows the structural formulae for ibuprofen and acetaminophen, two pain-relieving drugs, similar to aspirin.



Briefly explain which of these two drugs would be more soluble in water. *[Assume the molar masses of both molecules are similar.]*

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. Large organic molecules are usually insoluble in water. However glucose, whose structure is shown opposite, is very soluble in water.
	1. Write the molecular formula for glucose.

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* 1. Explain why glucose has such a high solubility in water.

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