**Materials Science** is a [Division C](https://scioly.org/wiki/index.php/Division_C) event which tests knowledge of the properties and characteristics of various materials. For the [2018](https://scioly.org/wiki/index.php/2018) season, the event will focus on polymers and plastics.

**Organic Nomeclature**

The most common system of naming organic compounds (hydrocarbons and derivative molecules) is the IUPAC system. You could also be tested on traditional names of some common compounds (such as styrene, vs. the IUPAC designation of ethenylbenzene), though this is less likely.

**Parent Chain**

|  |  |
| --- | --- |
| Parent chain | |
| **Length** | **Stem** |
| 1 | meth- |
| 2 | eth- |
| 3 | prop- |
| 4 | but- |
| 5 | pent- |
| 6 | hex- |
| 7 | hept- |
| 8 | oct- |
| 9 | non- |
| 10 | dec- |

The first step in naming an organic molecule is identifying the parent chain - a single continuous chain that forms the basis of the systematic IUPAC name. This typically also involves noting any functional groups and determining their precedence. The parent chain is determined by three characteristics, in order of precedence:

1) the chain that contains the largest number of the highest precedence [functional group](https://scioly.org/wiki/index.php/Materials_Science/Polymers#Functional_Groups).

2) the chain that contains the most double/triple bonds.

3) the longest chain.

Once the parent chain is determined, it is named based on its length. This forms the stem of the molecule's name.

Only the most common names are listed above.

For an alkane (an organic molecule with no double or triple bonds), "-ane" is appended to the end of the stem (if there is a suffix, append "-an"). Hence, a three-carbon chain (with the requisite hydrogen atoms attached) would be "propane".

The parent chain is numbered by assigning location numbers along the chain in both directions, and choosing a direction based on which one minimizes the lowest location number of:

1) suffix functional groups (i.e. whichever attached functional group type has the highest precedence)

2) multiple bonds

3) prefixes (i.e. both functional groups and side chains)

Substituents are attached to the stem as either prefixes or a suffix, and with associated location numbers. Most functional groups can be attached as either prefixes or suffixes - the highest-precedence of these will be the suffix, and the rest will be prefixes. Side chains and halogens are attached as suffixes.

**Multiple Bonds**

Double and triple bonds are identified by their first location when counting along the direction of numbering. For example, a 4-carbon chain with a double bond joining the second and third carbons would have a double bond at position 2. Double and triple bonds are denoted by adding "-ene" or "-yne" to the stem instead of "-ane", with the position number. For example, the previously described molecule would be "buta-2-ene", with the "a" after the stem for pronunciation purposes.

Although double and triple bonds are used as suffixes, they do not count as such suffix when evaluating functional groups. A stem can have both a multiple bond suffix and a functional group suffix (with the latter being attached after the former).

**Side chains**

Side chains are hydrocarbons that branch off of the parent chain. They are named similarly to the parent chain except with -yl: methyl, ethyl, propyl, etc.

They are identified by their location. For example, a propyl at position 3 would be "3-propyl", with a dash used to separate the components. If there are multiple side chains of the same length, use commas, and pre-prefixes (di-, tri-, tetra-, etc.). For example, if there are two ethyls at position 3 and one ethyl at position four, they would be collectively identified as "3,3,4-triethyl".

**Functional Groups**

Functional groups are parts of a molecule (moeities) that typically have unique chemical properties and affect the way an organic molecule behaves. They are attached to the parent carbon chain, or inserted in between the parent chain and a side chain, and are identified by their number (they can be attached to side chains as well, but the nomenclature for that is complicated and unlikely to show up in competitions). Functional groups also have an order of precedence. The type of functional group in a molecule with the highest precedence will be used in suffix form, while the rest will be used in prefix form.

Functional groups allowed under the [2018](https://scioly.org/wiki/index.php/2018) [rules](https://scioly.org/wiki/index.php/Rules_Manual) are listed below, in order of precedence. "R" refers to an arbitrary section of the molecule (in the usage below, excluding a single hydrogen). The prefixes for most higher-precedence groups are rarely used, since test questions are unlikely to include many different types of functional groups.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Simpler Functional Groups | | | | | | |
| **Precedence** | **Name** | **Formula** | **Description** | **Prefix form** | **Suffix form** | **Notes** |
| **1** | Carboxylic acids | R-COH=O | An aldehyde and alcohol attached to the same carbon (which must be an end carbon, since carbon can form a maximum of four covalent bonds). | carboxy-1 | -oic acid | The end carbon is typically considered part of the R-chain, and numbered accordingly - hence, the number used to identify the position of the carboxylic acid is the position number of that carbon. There are other prefixes/suffixes used if the end carbon is considered separately from the attached chain. |
| **2** | Esters Amides | R-CO-O-RB R-CO-N-RB,RC | An ester is just a carboxylic acid with the hydrogen on the alcohol replaced by another chain. An amide is similar, except the alcohol is instead a nitrogen attached to two other chains. | RB-oxycarbonyl- ?2 | RB...-oate RB RC...-amide | When used in suffix form, treat the R-groups as side chains and place them before the stem, separated by spaces. Typically, a test question asking about esters or amides will not include any additional functional groups or side chains. |
| **3** | Aldehydes | R-CH=O R=C=O | Essentially a ketone (see below) attached to the end of a chain. Doesn't need a position number, since the presence/absence of "di-" is sufficient to unambiguously identify the molecule. | formyl- | -al | The end carbon is typically considered part of the R-chain, and numbered accordingly - hence, the number used to identify the position of the carboxylic acid is the position number of that carbon. There are other prefixes/suffixes used if the end carbon is considered separately from the attached chain. |
| **4** | Ketones | R-CO-RB | An oxygen double-bonded to a carbon. If it is attached to an end carbon, it is an aldehyde. | oxo- | -one |  |
| **5** | Alcohols | R-COH-RB | An oxygen single-bonded to a carbon, and also bonded to a hydrogen. | hydroxy- | -ol |  |

1 This is unlikely to be used, since the rules don't include any functional groups with higher precedence.

2 can't find general form including R-groups

**Putting it Together**

<how to combine into a single IUPAC systematic name>

|  |  |  |
| --- | --- | --- |
| Examples | | |
| **Image** | **Description and Process** | **IUPAC name** |
|  |  |  |
|  |  |  |
|  |  |  |

**Aromatics**

An aromatic is a derivative of benzene. Nomenclature for aromatics quickly becomes complicated, so you will likely only see simpler aromatics on tests.

**Polymer Structure**

**Linear vs. Branched**

Linear polymer chains are continuously attached monomers in a line. A branched polymer contains chains that attach to the side of existing chains via replacement of a hydrogen. When side chains attach on both ends, this is cross-linking, which is what produces thermoset polymers.

**Entanglement**

Entanglement is the process by which a polymer transfers stress from one part of the chain to the entire object. It is less of a physical entanglement and more a chemical process of attractive forces between different parts of the chain.

**Network Polymers**

Network polymers typically have three or four connections per monomer, and are arranged in two or three dimensions without much linear structure.

**Polymer Types**

**Thermoplastics and Thermosets**

Thermoplastic polymers are those which become pliable at higher temperatures (often above the glass transition point). In contrast, thermoset polymers are formed by cross-linking at high temperatures, and once cured the hardening process is irreversible.

**Elastomers**

Elastomers are polymers with [viscoelasticity](https://scioly.org/wiki/index.php/Materials_Science/Polymers#Viscoelasticity) and typically weak intermolecular forces, which stretch easily in response to tension. This includes some natural polymers such as rubber.

**Natural Polymers**

Historically the most important natural polymer was rubber - polyisoprene - extracted as latex from trees and processed to be more useful (e.g. vulcanization). Other natural polymers include proteins (polypeptides), carbohydrates (polymers of various sugars), and DNA (polymers of nucleic acids).

**Characteristics and Properties**

**Crystal Structure**

**Phases and Glass Transition**

**Optical Properties**

**Young's Modulus**

Young's modulus describes a materials resistance to linear strain, like pulling a wire or placing a weight on a column.

*E*=*σϵ*=*FL*0*A*0Δ*L*E=σϵ=FL0A0ΔL

*E*E

is the Young's modulus (modulus of elasticity)

* *F*F

is the force exerted on an object under tension (a compressive force is represented by a negative value)

* *A*0A0

is the original cross-sectional area through which the force is applied;

* Δ*L*ΔL

is the amount by which the length of the object changes;

* *L*0L0

is the original length of the object.

The force may be found using Hooke's Law,

*F*=−*kx*F=−kx

where

* *x*x

is the displacement of the spring's end from its equilibrium position.

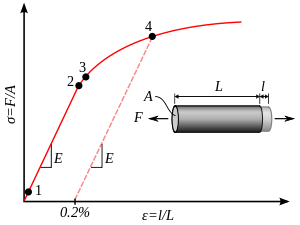
* *k*k

is a constant called the rate or spring constant.

* *F*F

is the restoring force exerted by the spring on that end.

**Yield Strength**

[](https://scioly.org/wiki/index.php/File:Metal_yield.svg.png)

A stress-strain curve

The yield strength of a material is the force at which the material begins to deform plastically, or the force at which changes are not fully reversible.It is determined through a stress-strain curve, such as the one at right.

1. True elastic limit
2. Proportionality limit
3. Elastic limit (yield strength)
4. Offset yield strength

For some materials (e.g., metals and plastics), change from elastic to plastic cannot be easily identified. Therefore, an offset method to determine the yield strength of the material tested is used. An offset is specified as a % of strain (for metals, usually 0.2%, for plastics, usually a value of 2%). The stress that is determined from the intersection point when the line of the linear elastic region (with slope equal to the Young's Modulus) is drawn from the offset becomes the Yield Strength by the offset method. For example, in the above image, an offset of 0.2% is used for the yield strength.

**Viscosity**

Viscosity is "the resistance to flow."

Viscosity is caused by friction between molecules that move at different velocities. When in a tube, for example, the adhesion to the walls causes the outer material to move slower, while the material in the center moves faster. This means that some stress is required for the liquid to move. The more viscous the material, the more stress is needed.

A simple test of viscosity is to simply fill a graduated cylinder with the test liquid, and time how long a steel ball(or some other heavy object) takes to reach the bottom. While not giving an "accurate" measure of viscosity, or a number in terms of viscosity's actual units(which is in Pascals times seconds,

*Pa*Pa

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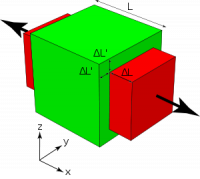
*s*s

), it does provide a good comparison between liquids, and is a test you may find in the lab portion of the event.

**Viscoelasticity**

Viscoelasticity refers to a property of some materials that have both viscosity (time-dependent changes in strain) and elasticity. Viscoelastic materials produce energy (typically as heat) during a loading cycle. When stress is applied and removed, a viscoelastic material show both the ability to return to its original shape (elasticity) and creep (viscosity).

**Poisson's Ratio**

[](https://scioly.org/wiki/index.php/File:PoissonRatio.png)

A visual depiction of an object exhibiting positive axial strain and positive transverse strain, and the associated length changes.

Poisson's Ratio is the measure of how much a material expands(or contracts) when stretched or squeezed. Most objects have a positive Poisson's ratio, meaning they expand when squeezed and contract when stretched. However, some materials do exist with a negative ratio. The value of the ratio is

−1.0<*ν*<0.5−1.0<ν<0.5

due to the requirement for the Young's, shear, and bulk modulus to be positive.

*ν*=−*dϵydϵx*ν=−dϵydϵx

* Where

*ν*ν

is Poisson's ratio,

* *dϵy*dϵy

is transverse or lateral strain (negative for tension, positive for compression)

* *dϵx*dϵx

is axial strain (positive for tension, negative for compression).

**Processing and Production**

**Extrusion**

**Molding**

**Casting**

**Catalysts**

**Additives**

**Common Polymers**

|  |  |  |  |
| --- | --- | --- | --- |
| **Abbreviation** | **Name** | **Description** | **Images** |
| HDPE | High-Density Polyethylene |  |  |
| LDPE | Low-Density Polyethylene |  |  |
| PC | Polycarbonate |  |  |
| PETE | Polyethylene Terephthalate |  |  |
| PMMA | Poly(methyl methacrylate) |  |  |
| PP | Polypropylene |  |  |
| PS | Polystyrene |  |  |
| PVC | Polyvinyl Chloride |  |  |

Bottom of Form