



Principles of Chemistry

Optometry Technology Department

First Level First Program

Prepared by

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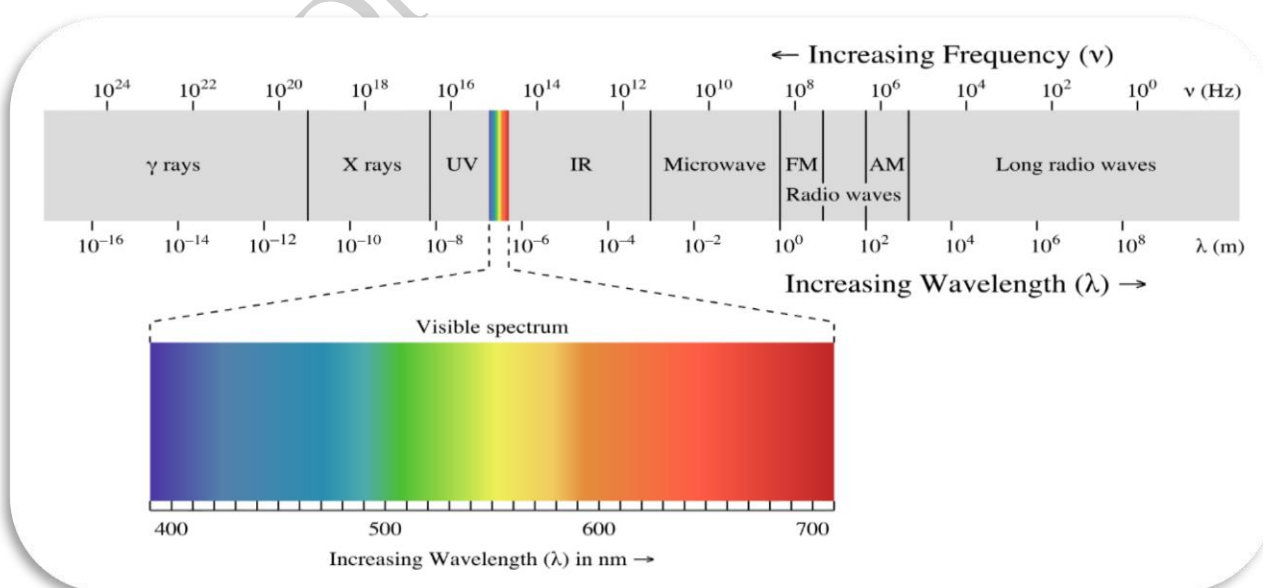


Chemistry of vision

Vision is such an everyday occurrence that we seldom stop to think and wonder how we are able to see the objects that surround us. Yet the vision process is a fascinating example of how light can produce molecular changes. The retina contain the molecules that undergo a chemical change upon absorbing light, but it is the brain that actually makes sense of the visual information to create an image.

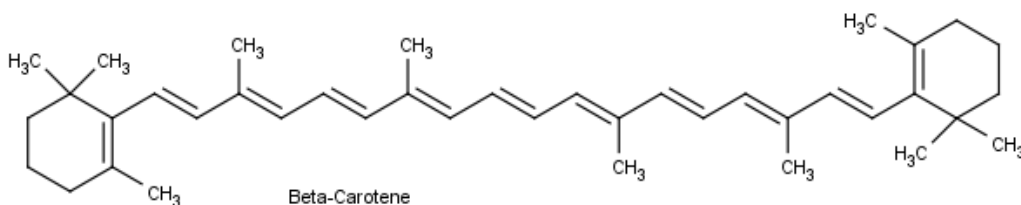
Introduction

Light is one of the most important resources for civilization, it provides energy as it pass along by the sun. Light influence our everyday live. Living organisms sense light from the environment by photoreceptors. Light, as waves carry energy, contains energy by different wavelength. In vision, light is the stimulus input. Light energy goes into eyes stimulate photoreceptor in eyes. However, as an energy wave, energy is passed on through light at different wavelength.



Light, as waves carry energy, contains energy by different wavelength. From long wavelength to short wavelength, energy increase. 400 nm to 700 nm is visible spectrum.

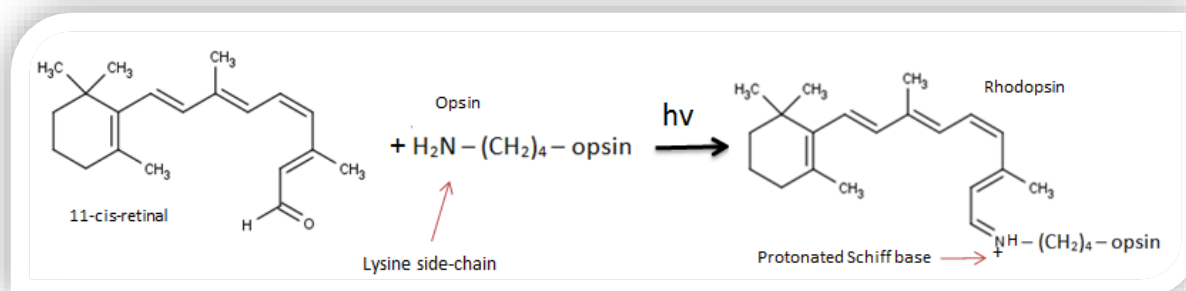
Light energy can convert chemical to other forms. **Vitamin A**, also known as **retinol**, anti-dry eye vitamins, is a required nutrition for human health. The predecessor of vitamin A is present in the variety of plant carotene. **Vitamin A is critical for vision because it is needed by the retina of eye.** Retinol can be convert to retinal, and retinal is a chemical necessary for rhodopsin. As light enters the eye, the 11-cis-retinal is isomerized to the all-"trans" form.



Biochemistry of the eyes

Mechanism of Vision

The molecule cis-retinal can absorb light at a specific wavelength. When visible light hits the cis-retinal, the cis-retinal undergoes an isomerization, or change in molecular arrangement, to all-trans-retinal. The new form of trans-retinal does not fit as well into the protein, and so a series of geometry changes in the protein begins. The resulting complex is referred to a bathrhodopsin



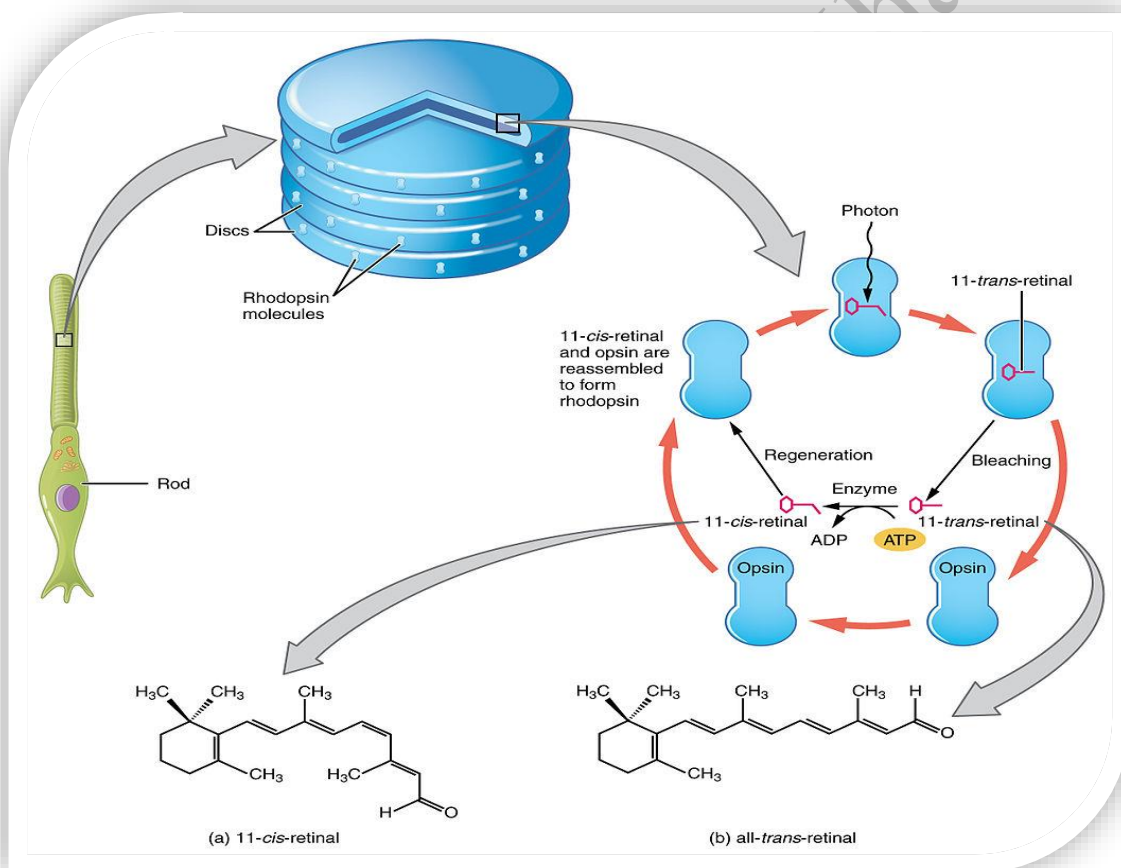
The reaction above shows Lysine side-chain from the opsin react with 11-cis-retinal when stimulated. By removing the oxygen atom from the retinal and two hydrogen atom from the free amino group of the lysine, the linkage shown on the picture above is formed, and it is called Schiff base.

Signal Transduction Pathway

As the protein changes its geometry, it initiates a cascade of biochemical reactions that results in changes in charge so that a large potential difference builds up across the plasma membrane. This potential difference is passed along to an adjoining nerve cell as an electrical impulse. The nerve cell carries this impulse to the brain, where the visual information is interpreted.

The light image is mapped on the surface of the retina by activating a series of light-sensitive cells known as rods and cones or photoreceptors. The rods and cones convert the light into electrical impulses which are transmitted to the brain via nerve fibers. The brain then determines, which nerve fibers carried the electrical impulse activate by light at certain photoreceptors, and then creates an image.

The retina is lined with many millions of photoreceptor cells that consist of two types: 7 million **cones** provide color information and sharpness of images, and 120 million **rods** are extremely sensitive detectors of white light to provide night vision. The tops of the rods and cones contain a region filled with membrane-bound discs, which contain the molecule cis-retinal bound to a protein called opsin. The resulting complex is called rhodopsin or "visual purple".



In human eyes, rod and cones react to light stimulation, and a series of chemical reactions happen in cells. These cells receive light, and pass on signals to other receiver cells. This chain of process is class signal transduction pathway. Signal transduction pathway is a mechanism that describe the ways cells react and response to stimulation.

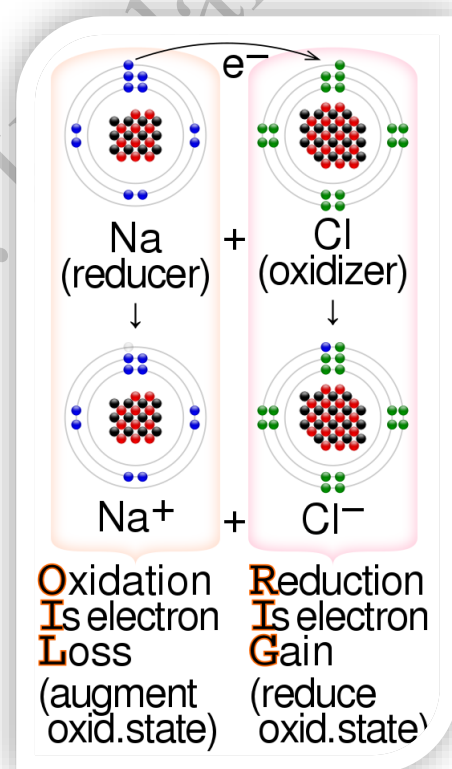


Redox reaction (Oxidation-Reduction)

Redox is a type of chemical reaction in which the oxidation states of a substrate change. Oxidation is the loss of electrons or an increase in the oxidation state, while reduction is the gain of electrons or a decrease in the oxidation state.

There are two classes of redox reactions:

- Electron-transfer – Only one (usually) electron flows from the atom being oxidized to the atom that is reduced. This type of redox reaction is often discussed in terms of redox couples and electrode potentials.
- Atom transfer – An atom transfers from one substrate to another. For example, in the rusting of iron, the oxidation state of iron atoms increases as the iron converts to an oxide, and simultaneously the oxidation state of oxygen decreases as it accepts electrons released by the iron. Although oxidation reactions are commonly associated with the formation of oxides, other chemical species can serve the same function. In hydrogenation, C=C (and other) bonds are reduced by transfer of hydrogen atoms.

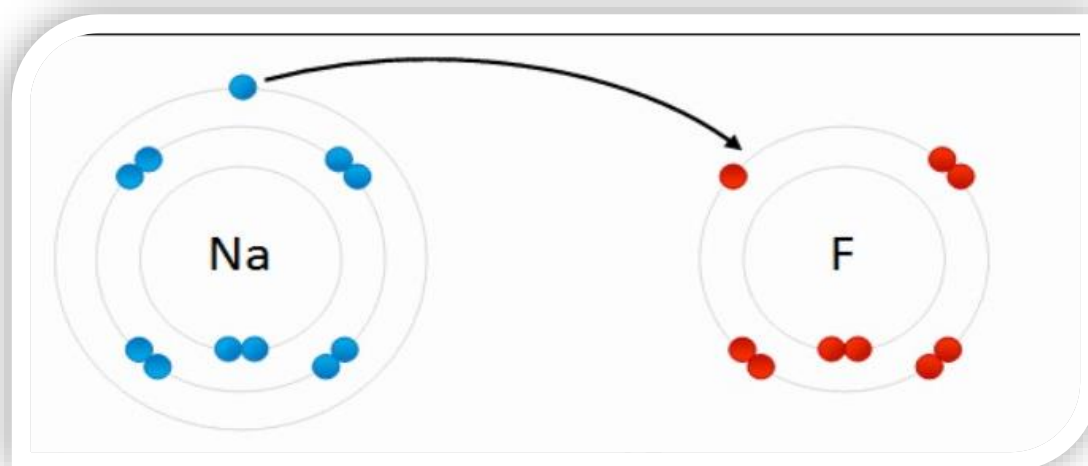


Terminology

"Redox" is a portmanteau of the words "reduction" and "oxidation". The term "redox" was first used in 1928. The processes of oxidation and reduction occur simultaneously and cannot occur independently. In redox processes, the reductant transfers electrons to the oxidant. Thus, in the reaction, the reductant or reducing agent loses electrons and is oxidized, and the oxidant or oxidizing agent gains electrons and is reduced. The



pair of an oxidizing and reducing agent that is involved in a particular reaction is called a redox pair. A redox couple is a reducing species and its corresponding oxidizing form, e.g., Fe^{+2} / Fe^{+3} . The oxidation alone and the reduction alone are each called a half-reaction because two half-reactions always occur together to form a whole reaction.



Oxidants

Oxidation originally implied a reaction with oxygen to form an oxide. Later, the term was expanded to encompass substances that accomplished chemical reactions similar to those of oxygen. Ultimately, the meaning was generalized to include all processes involving the loss of electrons or the increase in the oxidation state of a chemical species. Substances that have the ability to oxidize other substances (cause them to lose electrons) are said to be oxidative or oxidizing, and are known as oxidizing agents, oxidants, or oxidizers. The oxidant (oxidizing agent) removes electrons from another substance, and is thus itself reduced. And, because it "accepts" electrons, the oxidizing agent is also called an electron acceptor. Oxidants are usually chemical substances with elements in high oxidation states (e.g. H_2O_2 , MnO_4^- , $\text{Cr}_2\text{O}_7^{2-}$), or else highly electronegative elements (e.g. O_2 , F_2 , Cl_2 , Br_2 , I_2) that can gain extra electrons by oxidizing another substance.



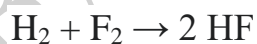
Reducers

Substances that have the ability to reduce other substances (cause them to gain electrons) are said to be reductive or reducing and are known as reducing agents, reductants, or reducers. The reductant (reducing agent) transfers electrons to another substance and is thus itself oxidized. And, because it donates electrons, the reducing agent is also called an electron donor. Electron donors can also form charge transfer complexes with electron acceptors. The word reduction originally referred to the loss in weight upon heating a metallic ore such as a metal oxide to extract the metal. In other words, ore was "reduced" to metal. Antoine Lavoisier demonstrated that this loss of weight was due to the loss of oxygen as a gas. Later, scientists realized that the metal atom gains electrons in this process. The meaning of reduction then became generalized to include all processes involving a gain of electrons. Reducing equivalent refers to chemical species which transfer the equivalent of one electron in redox reactions. The term is common in biochemistry. A reducing equivalent can be an electron, a hydrogen atom, as a hydride ion.

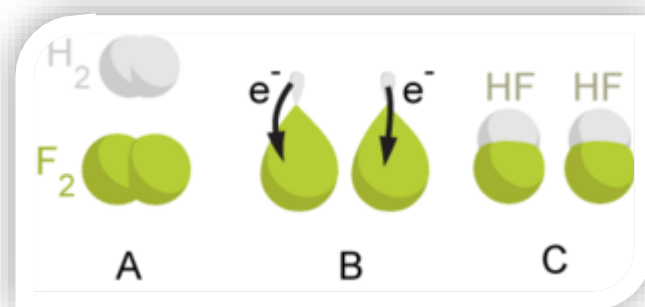


Examples of redox reactions

In the reaction between [hydrogen](#) and [fluorine](#), hydrogen is being oxidized and fluorine is being reduced:



This reaction is spontaneous and releases 542 kJ per 2 g of hydrogen because the H-F bond is much stronger than the F-F bond. This reaction can be analyzed as two [half-reactions](#). The oxidation reaction converts hydrogen

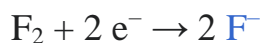




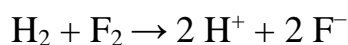
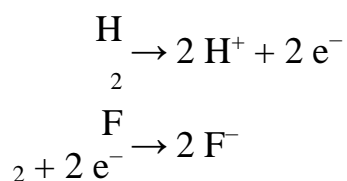
to protons:



The reduction reaction converts fluorine to the fluoride anion:



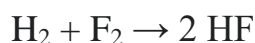
The half reactions are combined so that the electrons cancel:



The protons and fluoride combine to form [hydrogen fluoride](#) in a non-redox reaction:



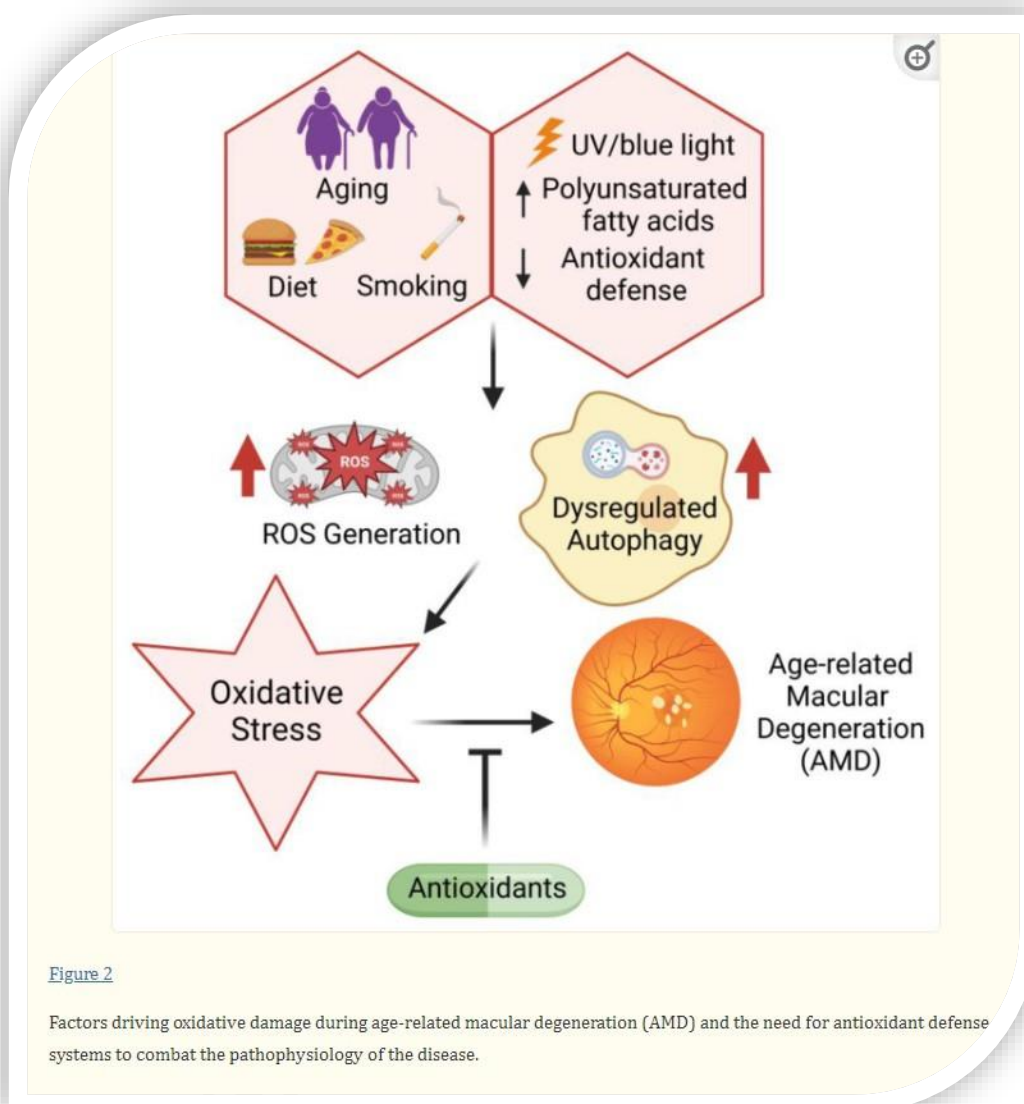
The overall reaction is:



Oxidation stress in the eye

Introduction

The human eye is not resistant to processes associated with aging. At the front of the eye, the cornea and lens are particularly susceptible to oxidative stress that can be attributed to direct exposure to ultraviolet (UV) light emitted by the sun. As a highly metabolic tissue, the retina is also at increased risk of age-associated processes that contribute to increased oxidative stress and neurodegeneration. Damage to these cell layers may cause deficits in visual acuity or progressive vision loss and significantly affect mobility and quality of life.



Oxidative Stress

Reactive Oxygen Species (ROS)

Oxidative stress is caused by an imbalance between the antioxidant defense system and the production of reactive oxygen species (ROS), including superoxide anion ($O_2^{\cdot-}$), hydroxyl radical ($\cdot OH$), hydrogen peroxide (H_2O_2), and singlet oxygen (1O_2). In particular, the superoxide anion ($O_2^{\cdot-}$) and hydroxyl radical ($\cdot OH$) with an unpaired electron are also known as free radicals. Hydrogen peroxide exhibits a low reactivity,



but it can penetrate cell membranes, including the inner and outer membranes of mitochondria. Therefore, hydrogen peroxide (H₂O₂) can react with cellular iron and generate hydroxyl radicals, the most reactive form of oxygen, via the Fenton reaction: $\text{H}_2\text{O}_2 + \text{Fe}^{2+} \rightarrow \cdot\text{OH} + \text{OH}^- + \text{Fe}^{3+}$

Cigarette Smoking

Cigarette smoke is known as one of the exogenous sources of ROS and contains multiple ROS producers, such as nicotine and cadmium. Nicotine promotes nitric oxide (NO) production and increases proangiogenic factors and cadmium accumulates preferentially in the RPE and choroid and increases ROS production. Moreover, hydroquinone (HQ) is also included in cigarette smoke.

Light Exposure

Light exposure reduces lipofuscin autofluorescence

Autofluorescence photobleaching is an indication of lipofuscin photooxidation. At a higher level of light exposure, such as after prolonged exposure or being subjected to blue light, RPE disruption occurs in a manner which permanently alters the autofluorescence pattern



Summary of the major chemical species associated with oxidative stress in the eye.

Chemical Species	Source(s)	Downstream Reaction(s)
Superoxide ($O_2^{\cdot-}$)	The reaction of O_2 with enzymes in the electron transport chain in the mitochondria generated via a single-electron transfer; enzymatic and non-enzymatic biosynthetic pathways; produced by neutrophils	Reacts with $O_2^{\cdot-}$ and H_2O to generate H_2O_2 and O_2
Hydroxyl radical ($\cdot OH$)	The reaction of H_2O_2 with iron or copper (Fenton reaction); may also be generated as a byproduct of the exposure of water molecules to ionizing radiation	Reacts with deoxyguanosine residues of DNA to form 8-hydroxy-2-deoxyguanosine; also reacts with deoxycytidine and deoxyadenosine, among others
Hydrogen peroxide (H_2O_2)	The reaction of $O_2^{\cdot-}$ molecules mediated via superoxide dismutase and non-enzymatically; may also be generated as a byproduct of normal catalytic oxidative processes mediated via oxidases	May be converted by myeloperoxidase or other enzymes containing Fe^{2+} or react with UV light to form hydroxyl radical ($\cdot OH$); involved in downstream signaling pathways, such as platelet-derived growth factor signaling



<p>Malondialdehyde (MDA) (CH₂(CHO)₂)</p>	<p>Produced by lipid peroxidation of polyunsaturated fatty acids</p>	<p>Reacts with deoxyguanosine of DNA to form 8-hydroxy-2-deoxyguanosine; also reacts with deoxyadenosine residues; may also react with lysine residues on proteins to form secondary oxidation products</p>
<p>4-Hydroxynonenal (4-HNE) (CH₃(CH₂)₄CH(OH)CH=CH(CHO))</p>	<p>Produced by lipid peroxidation of polyunsaturated fatty acids or linoleic or arachidonic side chains</p>	<p>Reacts with lysine on proteins to form carbonylated side chains, increasing the hydrophobicity of modified proteins; also involved in downstream signaling pathways, including activation of glutamate-cysteine ligase expression</p>



➤ Oxygen in the Eye

Oxygen is crucial to your body, including your eyes. It may not seem obvious, but your eyes need enough oxygen in order to be healthy and functional.

Did you know that the cornea (the transparent front surface of the eye) is one of the few parts of the body (along with tooth enamel, hair and nails) **that doesn't have a supply of oxygen**? It doesn't contain any blood vessels as it must remain transparent for light to pass through it.

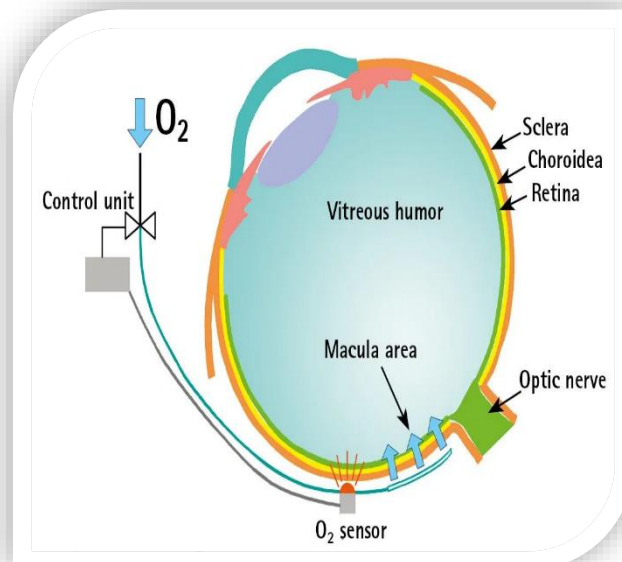
Without the presence of blood vessels, the eye must get its oxygen directly from the atmosphere. And here's the incredible thing - the oxygen from the air dissolves into the tears that naturally coat the eye, and then diffuses through the cornea.

The Importance of Oxygen to the Eye

It's a well-known fact that oxygen is crucial to the human body. However, it's a less common fact that oxygen is also important to the human eye. That said, you should be more conscious about your eyes getting the right amount of oxygen, especially if you are wearing contact lenses more than eyeglasses for vision correction.

Why Your Eyes Need Oxygen

Contact lenses can restrict the amount of oxygen that your eyes receive, particularly if the lenses are worn incorrectly. Over time, this incorrect use of contacts could lead to eye problems and potentially optical damage.



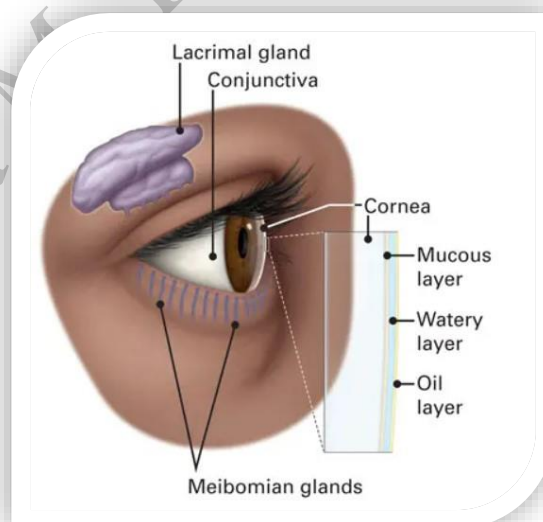


Keep in mind that the cornea does not have any blood vessels, so it does not have its own blood supply. It relies on getting oxygen from the environment and from the tears that coat the eye.

If your eyes are not getting enough oxygen, you may experience symptoms such as **hazy vision**, **redness of the eye** and **eye discomfort**. Furthermore, if the lack of oxygen to the cornea is not addressed, the condition could result in the structural warpage of the cornea and possibly corneal ulceration.

➤ THE TEAR FILM AND HOW IT PROTECTS OUR TEARS

Tears are important to the overall health of our eyes and our vision. Each time we blink, a protective coating of tears is spread like a film over the front of our eye. If we don't blink often enough, **dry spots can develop on the surface of the eye and can cause our vision to decrease**. Thus, our tear film serves four important purposes:



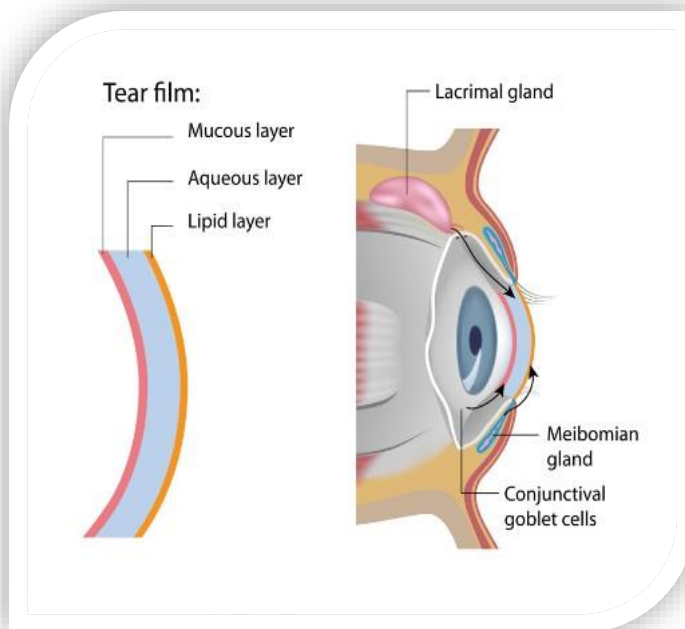
1. Protects and lubricates the eyes
2. Reduces the risk of eye infection
3. Washes away foreign particles
4. Keeps the surface of the eyes smooth and clear

When our tear film becomes unstable, symptoms of **Dry Eye** can occur.

➤ TEAR FILM LAYERS

Our tear film is made up of three layers – an oil (**lipid**) layer, a water (**aqueous**) layer and a (**mucin**) layer. These three layers work together to help maintain the health of our eyes and ward off infection.

When any part of the tear film isn't functioning properly, you may start to experience one or more Dry Eye symptoms.



- **OIL (LIPID) LAYER:**

The outer layer of our tear film is an oil or lipid-based layer. Its main purpose is to seal the tear film which helps reduce evaporation of our natural tears.

- **WATER (AQUEOUS) LAYER:**

The middle layer is mostly comprised of water. Its job is to lubricate the eye, wash away particles and prevent infection.

- **MUCIN LAYER:**

The inner layer is the mucin layer. The mucin layer allows the watery layer to spread evenly over the surface of the eye and helps the eye remain moist and lubricated. It also provides the underlying cornea with nourishment. This layer helps the tears stick to the surface of the eye.



➤ Watery of Eyes (Tears of Eyes)

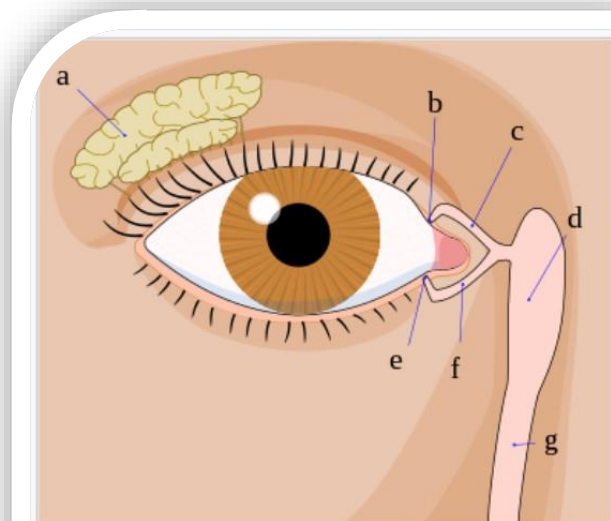
Tears are a clear liquid secreted by the lacrimal glands (tear gland) found in the eyes of all land mammals. Tears are made up of **water**, **electrolytes**, **proteins**, **lipids**, and **mucins** that form layers on the surface of eyes. The different types of tears—basal, reflex, and emotional—vary significantly in composition.

The **functions of tears** include **lubricating the eyes** (basal tears), **removing irritants** (reflex tears), and also **aiding the immune system**. Tears also occur as a part of the body's natural pain response. Emotional secretion of tears may serve a biological function by excreting stress-inducing hormones built up through times of emotional distress

Chemical composition

Tears are made up of three layers: **lipid**, **aqueous**, and **mucous**. Tears are composed of water, salts, antibodies, and lysozymes (antibacterial enzymes); though composition varies among different tear types.

The composition of tears caused by an emotional reaction differs from that of tears as a reaction to irritants, such as onion fumes, dust, or allergens. Emotional tears contain higher concentrations of stress hormones such as adrenocorticotrophic hormone and leucine enkephalin (a natural pain killer), which suggests that emotional tears play a biological role in balancing stress hormone levels.



Anatomy of lachrymation, showing

- a) Lacrimal gland
- b) Superior lacrimal punctum
- c) Superior lacrimal canal
- d) Lacrimal sac
- e) Inferior lacrimal punctum
- f) Inferior lacrimal canal
- g) Nasolacrimal canal

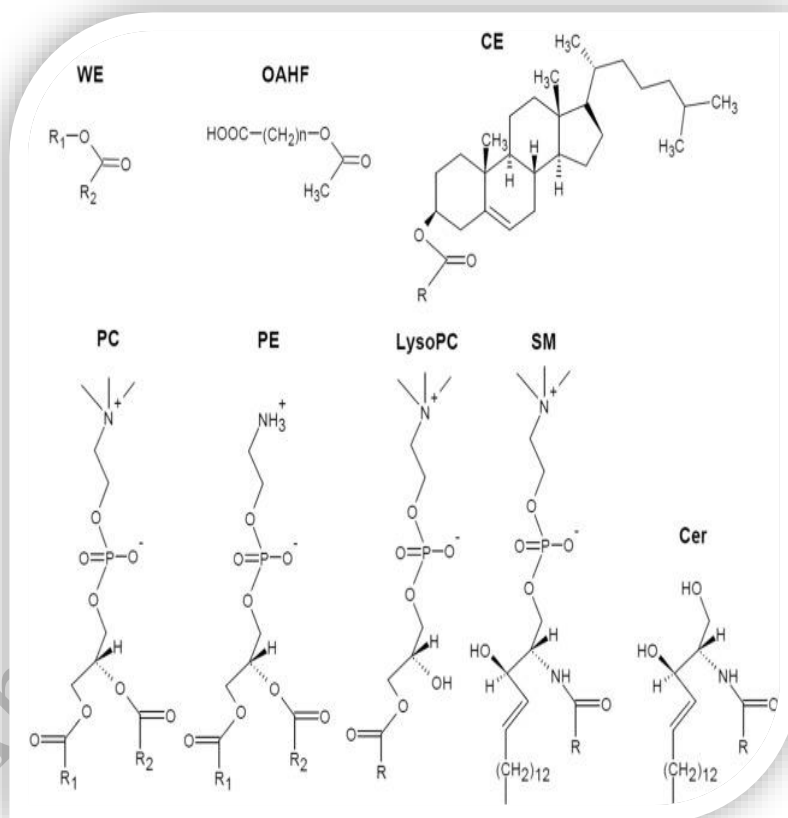


Types of Watery (Tears)

There are three basic types of tears: **basal**, **reflex** and **emotional**.

• Basal tears

the cornea is continually kept wet and nourished by basal tears. They lubricate the eye and help keep it clear of dust. Tear fluid **contains** water, mucin, lipids, lysozyme, lactoferrin, lipocalin, lacritin, immunoglobulins, glucose, urea, sodium, and potassium. Some of the substances in lacrimal fluid (such as lysozyme) fight against bacterial infection as a part of the immune system.



• Reflex tears

The second type of tears results from irritation of the eye by foreign particles, or from the presence of irritant substances such as onion vapors, perfumes and other fragrances, tear gas, or pepper spray in the eye's environment, including the cornea, conjunctiva, or nasal mucosa, which trigger TRP channels in the ophthalmic nerve. It can also occur with bright light and hot or peppery stimuli to the tongue and mouth. It is also linked with vomiting, coughing, and yawning. These reflex tears attempt to wash out irritants that may have come into contact with the eye.



- **Emotional tears (psychic tears)**

The third category, in general, referred to as crying or weeping, is increased tearing due to strong emotional stress, pleasure, anger, suffering, mourning, or physical pain. This practice is not restricted to negative emotions; many people cry when extremely happy, such as times of intense humor and laughter.

Tears brought about by emotions have a different chemical makeup than those for lubrication; emotional tears contain more of the protein-based hormones prolactin, adrenocorticotrophic hormone, and Leu-enkephalin (a natural painkiller) than basal or reflex tears. The limbic system is involved in the production of basic emotional drives, such as anger, fear, etc. The limbic system, or, more specifically the hypothalamus, also has a degree of control over the autonomic system. The parasympathetic branch of the autonomic nervous system controls the lacrimal glands via the neurotransmitter acetylcholine through both the nicotinic and muscarinic receptors. When these receptors are activated, the lacrimal gland is stimulated to produce tears.

Physiology

- Bogorad's syndrome "Crocodile Tears Syndrome"
- Keratoconjunctivitis sicca (dry eye)
- Familial dysautonomia
- Pseudobulbar affect

Causes of watery eyes

There are many reasons our eyes can water. Often it isn't serious, but it can be a sign of an infection.

Watery eyes can be caused by bright sunlight, strong winds and smoky environments.

Your eyes can also water if you get something in them, like an eyelash or a piece of dust, sand, or grit. If you just have one watery eye it's quite likely you've got something in it. Stinging watery eyes can also be caused



by chemicals, such as the chlorine in swimming pools, or household cleaning products. Allergies such as hay fever can also cause itchy, watery eyes.

Blocked tear ducts can stop our tears from draining away properly, resulting in watery eyes.

you can actually get watery eyes as a consequence of having dry eyes. Dry eyes can be caused by:

- wearing contact lenses
- looking at screens for a long time
- being out in strong winds
- being indoors in air-conditioned or heated rooms
- smoking
- drinking alcohol
- side effects of certain medications
- certain long-term medical conditions such as Sjögren's syndrome



Mechanism of the Food Metabolism related to the eyes vision

Introduction

Vision loss is a pervasive health impairment affecting over 400 million people worldwide. Aging is a significant risk factor for several loss-of-vision eye diseases. As the global elderly population is growing, it is incumbent upon researchers to uncover mechanisms of ocular disease progression and identify strategies to prevent or slow these diseases.

The four major age-related eye diseases are age-related macular degeneration (AMD), cataracts, diabetic retinopathy (DR), and glaucoma.

Nutritional epidemiology has provided insights into the major age-related eye diseases, largely through observational studies, as well as some seminal randomized clinical trials (RCTs), most notably the Age Related Eye Disease Study (AREDS)1 and AREDS2 studies. Multiple reviews indicate effects of individual food components through supplementation with whole foods, micronutrients, or macronutrients. AMD onset and progression are associated with low levels of **carotenoids**, **antioxidant vitamins**, and **omega-3 fatty acids**, and reduced intake of **fruit**, **vegetables**, and **fish**. The AREDS studies demonstrated that high intake of **vitamin A**, **vitamin C**, **zinc**, **copper**, and **carotenoids** could reduce the progression of AMD by approximately 25%. Age-related cataract has also been associated with vitamin and carotenoid status. Although nutrients such as vitamins A, C, and E, lutein, zeaxanthin, and β -carotene were associated with reduced cataract risk in cohort studies, inconsistent results are reported in RCTs. Observational cohort studies suggest that regular consumption of nitrate-rich leafy green vegetables is associated with reduced risk of glaucoma development. There is also evidence that vitamins A and C are protective against glaucoma.



Dietary Patterns and Eye Disease

Traditionally, dietary patterns have been divided into **prudent dietary patterns** and **western dietary patterns**. These can be defined based on a food factor analysis from dietary survey data, using techniques like principal component analysis to determine correlations between foods that are eaten together, or can be based on scores of adherences to pre-specified dietary patterns.

For example, defined food intake patterns including prudent dietary patterns, the healthy eating index, and the Mediterranean diet have been related to risk for prevalence or progression of eye diseases in multiple cohorts. However, small differences in methodology likely contribute to some variation in findings using these metrics.

Important Titles on the role of Nutrition in Eye health

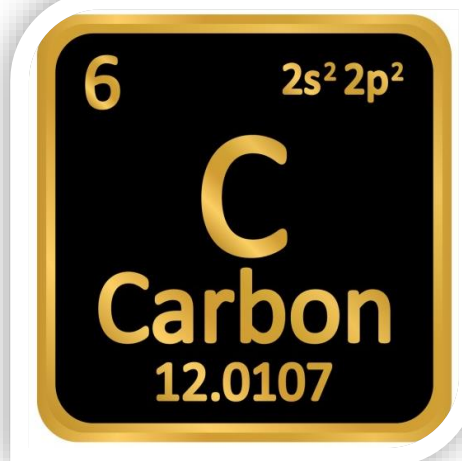
- Prudent Dietary Patterns and AMD
- Healthy Eating Index and AMD
- Cataract and Dietary Patterns
- Glaucoma and Dietary Patterns
- Diabetic Retinopathy and Dietary Patterns
- Physiological Effects of Dietary Carbohydrates
- Physiological Effects of Hyperglycemia
- High Glycemic Diet and Age-Related Eye Diseases
- Calorie Restriction and Ocular Diseases
- Intermittent Fasting and Eye Diseases
- Future Directions for Nutrition and Age-Related Eye Diseases

	AMD	Cataract	DR	Glaucoma
Prudent Dietary Patterns	<ul style="list-style-type: none"> •Across several studies, lower incident AMD and late-stage AMD •Variability in "prudent" dietary designations 			
Mediterranean Dietary Pattern	<ul style="list-style-type: none"> •Associated with decreased late-stage AMD •Mixed results on incident AMD 	<ul style="list-style-type: none"> •No association between MeDi and cataract surgery as surrogate for cataract •Further analysis needed looking at cataractogenesis 	<ul style="list-style-type: none"> •MeDi prevents diabetes and shown to be associated with reduced incident DR 	<ul style="list-style-type: none"> •To date, no reports of dietary pattern effects on glaucoma
Healthy Eating Index	<ul style="list-style-type: none"> •Protective against early and late AMD 	<ul style="list-style-type: none"> •Mixed results, some evidence of protection against nuclear cataract 		<ul style="list-style-type: none"> •Specific micronutrients have been shown to be associated with both increased and decreased risk of glaucoma
Western Dietary Patterns	<ul style="list-style-type: none"> •Associated with increased risk for late AMD 			
High Glycemic Diet	<ul style="list-style-type: none"> • Associated with increased risk for AMD in humans • Increased AMD-like features in WT and Nrf2^{-/-} mice compared to low glycemic diet 	<ul style="list-style-type: none"> •Associated with increased risk for cataract in humans 	<ul style="list-style-type: none"> •Presumptive association, but not experimentally demonstrated yet 	
Calorie Restriction	<ul style="list-style-type: none"> •Resulted in decreased risk for AMD-like features (lipofuscin accumulation) in rats 	<ul style="list-style-type: none"> •Delayed age-related cataract in animal model 		<ul style="list-style-type: none"> •In rats, CR prevented retinal ischemia and ganglion cell death
Intermittent Fasting			<ul style="list-style-type: none"> •Gut microbiome changes by IF prevented development of DR in db/db mice 	<ul style="list-style-type: none"> •Improved intraocular pressure in animal model for glaucoma



Organic chemistry

Organic chemistry is the chemistry subdiscipline for the scientific study of structure, properties, and reactions of organic compounds and organic materials (**materials that contain carbon atoms**). Study of structure determines their chemical composition and formula. Study of properties includes physical and chemical properties, and evaluation of chemical reactivity to understand their behavior. The study of organic reactions includes the chemical synthesis of natural products, drugs, and polymers, and study of individual organic molecules in the laboratory.

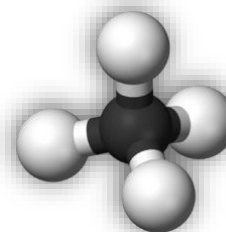


Hydrocarbon

In organic chemistry, a hydrocarbon is an organic compound consisting entirely of hydrogen and carbon. Hydrocarbons are examples of group 14 hydrides. Hydrocarbons from which one hydrogen atom has been removed are functional groups called hydrocarbyls. Because carbon has 4 electrons in its outermost shell (and because each covalent bond requires a donation of 1 electron, per atom, to the bond) carbon has exactly four bonds to make, and is only stable if all 4 of these bonds are used.

Aromatic hydrocarbons (arenes), alkanes, cycloalkanes and alkyne-based compounds are different types of hydrocarbons.

Most hydrocarbons found on Earth naturally occur in crude oil, where decomposed organic matter provides an abundance of carbon and hydrogen which, when bonded, can catenate to form seemingly limitless chains.



Alkane

In organic chemistry, an alkane, or paraffin, is an acyclic saturated hydrocarbon. In other words, an alkane consists of hydrogen and carbon atoms arranged in a tree structure in which all the carbon-carbon bonds are single. Alkanes have the general chemical formula C_nH_{2n+2} . The alkanes range in complexity from the simplest case of methane (CH_4), where $n = 1$ (sometimes



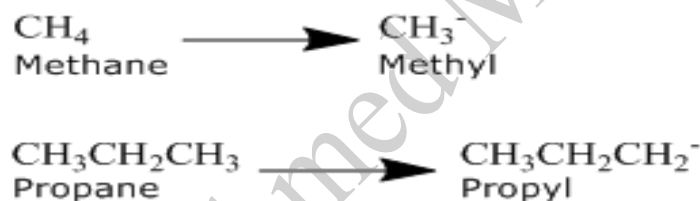
called the parent molecule), to arbitrarily large and complex molecules, like pentacontane ($C_{50}H_{102}$) or 6-ethyl-2-methyl-5-(1-methylethyl) octane, an isomer of tetradecane ($C_{14}H_{30}$).

Alkanes are not very reactive and have little biological activity. They can be viewed as molecular trees upon which can be hung the more active/reactive functional groups of biological molecules.

The alkanes have two main commercial sources: petroleum (crude oil) and natural gas.

Alkyl Groups (R)

Alkanes can be described by the general formula C_nH_{2n+2} . An alkyl group is formed by removing one hydrogen from the alkane chain and is described by the formula C_nH_{2n+1} . The removal of this hydrogen results in a stem change from **-ane** to **-yl**. Take a look at the following examples.



IUPAC Rules for Alkane Nomenclature

1. Find and name the longest continuous carbon chain.
2. Identify and name groups attached to this chain.
3. Number the chain consecutively, starting at the end nearest a substituent group.
4. Designate the location of each substituent group by an appropriate number and name.
5. Assemble the name, listing groups in alphabetical order.
6. The prefixes di, tri, tetra etc., used to designate several groups of the same kind, are not considered when alphabetizing.

No. of C atoms	Name of alkene	Molecular formula
2	Ethene	C_2H_4
3	Propene	C_3H_6
4	Butene	C_4H_8
5	Pentene	C_5H_{10}
6	Hexene	C_6H_{12}
7	Heptene	C_7H_{14}
8	Octene	C_8H_{16}
9	Nonene	C_9H_{18}
10	Decene	$C_{10}H_{20}$

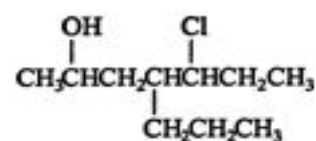


Halogen substituents are easily accommodated, using the names: fluoro (F-), chloro (Cl-), bromo (Br-) and iodo (I-).

Applying the IUPAC nomenclature rules to a more complex alkane molecule

ethane	C_2H_6	CH_3CH_3
propane	C_3H_8	$CH_3CH_2CH_3$
decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

5-chloro-2-hydroxy-4-propylheptane. Notice that the names of the substituent groups are in alphabetical order.



. This compound is called 2,4-dichlorohexane



Other EX.

3-bromo-2-hydroxypentane

2, 3-dimethylpentane

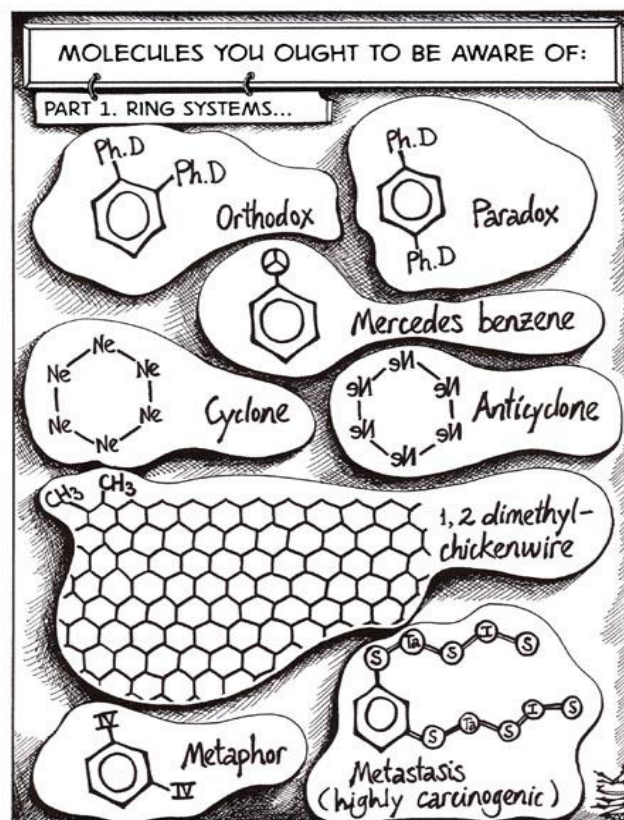
3,4-Dimethyl hexane

2-methyl pentane

2,2,4-trimethyl pentane

Cycloalkanes

Cycloalkanes have one or more rings of carbon atoms. The simplest examples of this class consist of a single, unsubstituted carbon ring, and these form a homologous series similar to the unbranched alkanes. The IUPAC names of the first five members of this series are given in the following table. The last (yellow shaded) column gives the general formula for a cycloalkane of any size. If a simple unbranched alkane is converted to a cycloalkane two hydrogen atoms, one from each end of the chain, must be lost. Hence the general formula for a cycloalkane composed of n carbons is C_nH_{2n} .

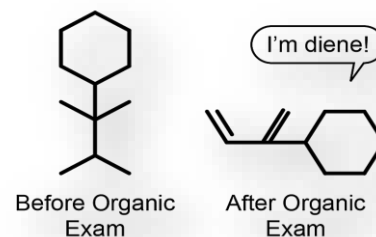




Examples of Simple Cycloalkanes

Name	Cyclopropane	Cyclobutane	Cyclopentane	Cyclohexane	Cycloheptane	Cycloalkane
Molecular Formula	C_3H_6	C_4H_8	C_5H_{10}	C_6H_{12}	C_7H_{14}	C_nH_{2n}
Structural Formula						$(CH_2)_n$
Line Formula						

Substituted cycloalkanes are named in a fashion very similar to that used for naming branched alkanes. The chief difference in the rules and procedures occurs in the numbering system. Since all the carbons of a ring are equivalent (a ring has no ends like a chain does), the numbering starts at a substituted ring atom.



Physical Properties of Alkanes:

- Alkanes are colourless.
- Alkanes are less dense than water (alkanes float on top of water).
- Alkanes are non-polar molecules so they are more soluble in non-polar solvents than they are in polar solvents. Alkanes are insoluble in water.
- The melting and boiling points of the shorter chain alkanes is low, but the melting and boilings of alkanes increase as the number of carbon atoms in the carbon chain increases.

Chemical Properties of Alkanes:

- Alkanes are relatively unreactive. Alkanes do not react with strong acids, bases, oxidising agents (oxidants) or reducing agents (reductants).
- Alkanes combust (react rapidly with oxygen) releasing energy, which makes alkanes useful as fuels. (see combustion of hydrocarbons and heat of combustion)



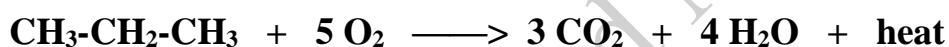
- Alkanes will react with halogens such chlorine gas and bromine water in the presence of ultraviolet light.
(see halogenation of hydrocarbons)

Alkane Reactions

The alkanes and cycloalkanes, with the exception of cyclopropane, are probably the least chemically reactive class of organic compounds. Despite their relative inertness, alkanes undergo several important reactions that are discussed in the following section.

1- Combustion

The combustion of carbon compounds, especially hydrocarbons, has been the most important source of heat energy for human civilizations throughout recorded history. The practical importance of this reaction cannot be denied, but the massive and uncontrolled chemical changes that take place in combustion make it difficult to deduce mechanistic paths. Using the combustion of propane as an example



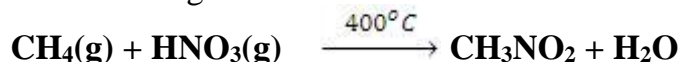
2- Halogenation

Halogenation is the replacement of one or more hydrogen atoms in an organic compound by a halogen (fluorine, chlorine, bromine or iodine). Unlike the complex transformations of combustion, the halogenation of an alkane appears to be a simple substitution reaction in which a C-H bond is broken and a new C-X bond is formed. The chlorination of methane, shown below, provides a simple example of this reaction.



3- Nitration

Replacement of H atom of alkane by $-\text{NO}_2$ group is known as nitration. Nitration of alkane is made by heating vapours of alkanes and HNO_3 at about 400°C to give nitroalkanes. This is also known as vapour phase nitration.

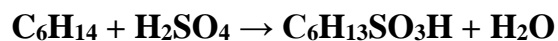


4- Sulphonation

Replacement of H atom of alkane by $-\text{SO}_3\text{H}$ is known as **sulphonation**. Lower

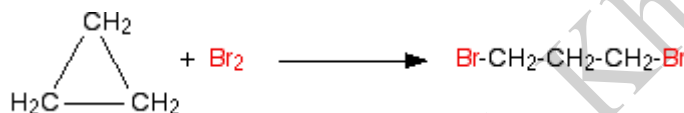


normal alkanes are not sulphated, but higher normal alkanes show sulphation (hexane onwards) when heated with oleum (i.e., conc. H_2SO_4) at 400°C .



5- Cycloalkanes

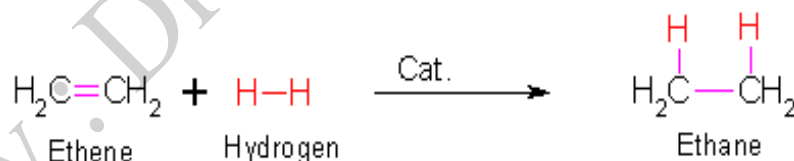
The reactions of the cycloalkanes are generally just the same as the alkanes, with the exception of the very small ones - particularly cyclopropane. In the presence of UV light, cyclopropane will undergo substitution reactions with chlorine or bromine just like a non-cyclic alkane. However, it also has the ability to react in the dark. In the absence of UV light.



General methods of preparation of alkanes

1- From Alkenes. Hydrogenation (“reduction”) of alkenes.

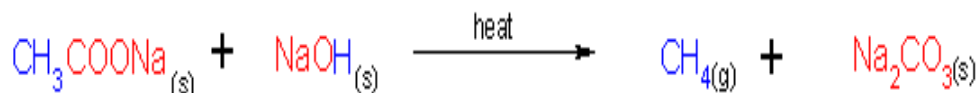
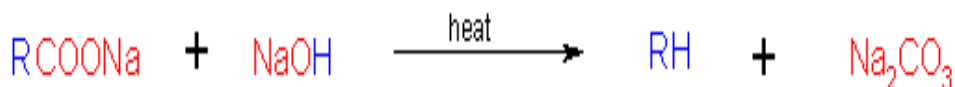
The addition of hydrogen to alkenes is known as a “hydrogenation” or “reduction”. In this reaction a molecule of hydrogen is added to the alkene molecule at the site of unsaturation i.e. where the double bond is. This is achieved under mild conditions when a catalyst is used to bring about this change.



Suitable catalysts for this reaction are : 1- Raney Nickel, 2- Pd on C 3- Pt on C

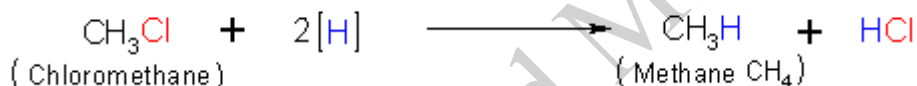
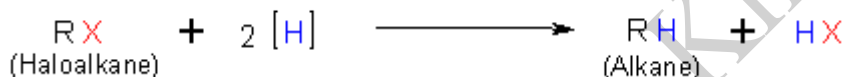
2- From Carboxylic Acids and their salts

by decarboxylation reactions , removal of CO_2 When a carboxylic acid, or its salt (sodium, potassium or calcium salts are commonly used) is heated strongly with sodalime , the carboxylic acid loses CO_2 and gives the alkane :



3- From Haloalkanes.

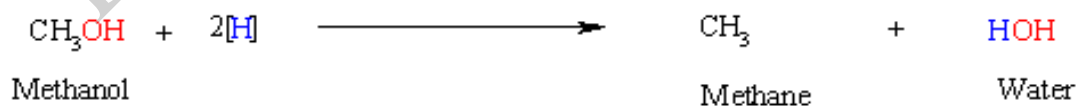
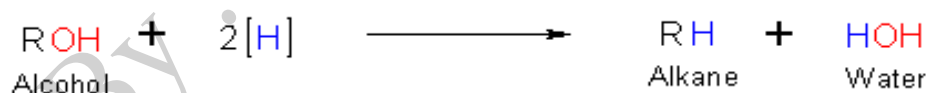
By reduction of haloalkanes - using an “active” form of hydrogen. Haloalkanes can easily be made to give the alkanes if these are exposed to an environment where hydrogen atoms are generated.



Sources of H : Na/Hg + C₂H₅OH ; Al/Hg + C₂H₅OH; Cu/Zn + C₂H₅OH
Ni/Al + NaOH; Zn/Hg + HCl.

4- From Alcohols.

Aggressive reduction of alcohols by very strong reducing agents, will remove the alcohol functionality (i.e. the OH group) replacing it with an H atom.



Reagents for [H] : red P + conc. HI(aq) (P + H₂O + I₂ regenerates HI)



5- From Carbonyl compounds

i.e. aldehydes and ketones – By strong reducing agents.



e.g. Aldehyde R and/or R' = H or
Ketone R and R' = alkyl (but not H)

Alkene

In organic chemistry, an alkene is an unsaturated hydrocarbon that contains at least one carbon–carbon double bond. The words alkene and olefin are often used interchangeably. Acyclic alkenes, with only one double bond and no other functional groups, known as mono-enes, form a homologous series of hydrocarbons with the general formula C_nH_{2n} . Alkenes have two hydrogen atoms fewer than the corresponding alkane (with the same number of carbon atoms). The simplest alkene, ethylene (C_2H_4).

IUPAC Names

To form the root of the IUPAC names for alkenes, simply change the -an- infix of the parent to -en-. For example, $\text{CH}_3\text{-CH}_3$ is the alkane ethANE. The name of $\text{CH}_2=\text{CH}_2$ is therefore ethENE.

In higher alkenes, where isomers exist that differ in location of the double bond, the following numbering system is used:

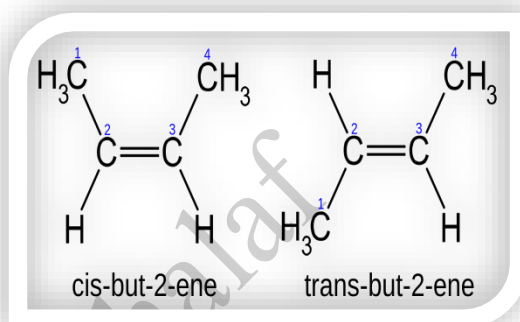
1. Number the longest carbon chain that contains the double bond in the direction that gives the carbon atoms of the double bond the lowest possible numbers.
2. Indicate the location of the double bond by the location of its first carbon.
3. Name branched or substituted alkenes in a manner similar to alkanes.



4. Number the carbon atoms, locate and name substituent groups, locate the double bond, and name the main chain.

Cis–trans notation

In the specific case of disubstituted alkenes where the two carbons have one substituent each, cis–trans notation may be used. If both substituents are on the same side of the bond, it is defined as cis-. If the substituents are on either side of the bond, it is defined as trans-.



Physical Properties of Alkenes

- 1- Physical properties of alkenes are quite similar to those of alkanes.
- 2- Alkenes exist naturally in all three states. The first three alkenes are gases, and the next fourteen are liquids. Alkenes higher than these are all solids.
- 3- All alkenes are insoluble in water, due to the weak van der Waal forces. But alkenes are soluble in organic solvents like benzene or acetone because here the van der Waal forces will be replaced by new ones, making alkenes fully soluble.
- 4- The boiling points of alkenes depend on their molecular structure. The bigger their molecular chain the higher the boiling points. So the higher alkenes have very high boiling points
- 5- The polarity of alkenes will depend on their functional groups

Chemical Properties of Alkenes

Alkenes are unsaturated compounds, which makes them highly reactive. Most of these chemical reactions occur at the Carbon-Carbon double bonds. This makes alkenes far more reactive than alkanes. Alkenes undergo three types of main reactions, (1-Addition Reactions, 2-Oxidation Reactions).

Reactions

Alkenes are relatively stable compounds, but are more reactive than alkanes, either because of the reactivity of the carbon–carbon pi-bond or the presence of allylic CH centers. Most reactions of alkenes involve



additions to this pi bond, forming new single bonds. Alkenes serve as a feedstock for the petrochemical industry because they can participate in a wide variety of reactions, prominently polymerization and alkylation.

a- Addition reactions

Alkenes react in many addition reactions, which occur by opening up the double-bond. Most of these addition reactions follow the mechanism of electrophilic addition. Examples are hydrohalogenation, halogenation, halohydrin formation, oxymercuration, hydroboration, dichlorocarbene addition, Simmons–Smith reaction, catalytic hydrogenation, epoxidation, radical polymerization and hydroxylation.

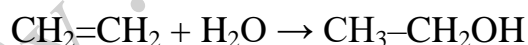
1- Hydrogenation

Hydrogenation of alkenes produces the corresponding alkanes. The reaction is carried out under pressure at a temperature of 200 °C in the presence of a metallic catalyst. Common industrial catalysts are based on platinum, nickel or palladium. For laboratory syntheses, Raney nickel (an alloy of nickel and aluminium) is often employed. The simplest example of this reaction is the catalytic hydrogenation of ethylene to yield ethane:



2- Hydration

Hydration, the addition of water across the double bond of alkenes, yields alcohols. The reaction is catalyzed by strong acids such as sulfuric acid. This reaction is carried out on an industrial scale to produce ethanol.



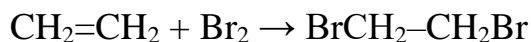
Alkenes can also be converted into alcohols via the oxymercuration–demercuration reaction, the hydroboration–oxidation reaction.

3- Halogenation

In electrophilic halogenation the addition of elemental bromine or chlorine to alkenes yields vicinal dibromo- and dichloroalkanes (1,2-dihalides or ethylene dihalides), respectively. The decoloration of a



solution of bromine in water is an analytical test for the presence of alkenes:



Related reactions are also used as quantitative measures of unsaturation, expressed as the bromine number and iodine number of a compound or mixture.

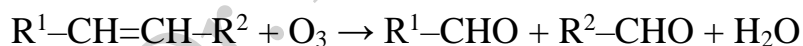
4- Hydrohalogenation

Hydrohalogenation is the addition of hydrogen halides such as HCl or HI to alkenes to yield the corresponding haloalkanes:



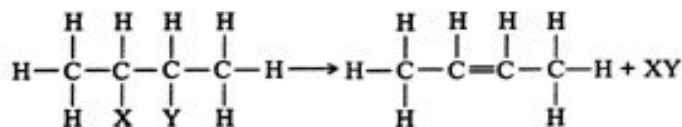
b- Oxidation

Alkenes are oxidized with a large number of oxidizing agents. In the presence of oxygen, alkenes burn with a bright flame to produce carbon dioxide and water. Catalytic oxidation with oxygen or the reaction with percarboxylic acids yields epoxides. Reaction with ozone in ozonolysis leads to the breaking of the double bond, yielding two aldehydes or ketones. Reaction with concentrated, hot KMnO_4 (or other oxidizing salts) in an acidic solution will yield ketones or carboxylic acids.



Preparations

Alkenes are generally prepared through β elimination reactions, in which two atoms on adjacent carbon atoms are removed, resulting in the formation of a double bond.



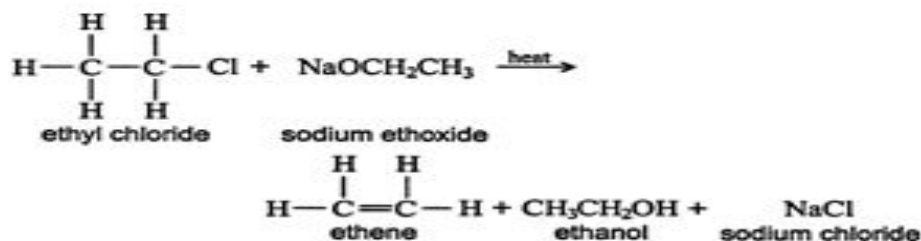


Preparations include the dehydration of alcohols, the dehydrohalogenation of alkyl halides, and the dehalogenation of alkanes.

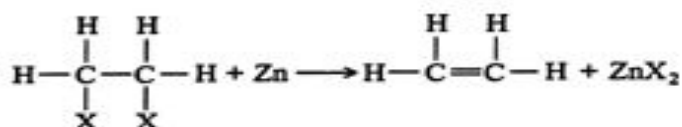
1- Dehydration of alcohols. In dehydration reactions, a molecule of water is eliminated from an alcohol molecule by heating the alcohol in the presence of a strong mineral acid. A double bond forms between the adjacent carbon atoms that lost the hydrogen ion and hydroxide group.



2- Dehydrohalogenation of alkyl halides. The dehydrohalogenation of alkyl halides, another β elimination reaction, involves the loss of a hydrogen and a halide from an alkyl halide (RX). Dehydrohalogenation is normally accomplished by reacting the alkyl halide with a strong base, such as sodium ethoxide.



3- Dehalogenation. Vicinal dihalides, which are alkane molecules that contain two halogen atoms on adjacent carbon atoms, can form alkenes upon reaction with zinc.



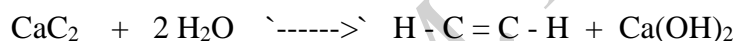


Alkynes (Acetylene or Ethyne)

an alkyne is an unsaturated hydrocarbon containing at least one carbon—carbon triple bond.[1] The simplest acyclic alkynes with only one triple bond and no other functional groups form a homologous series with the general chemical formula C_nH_{2n-2} . Alkynes are traditionally known as acetylenes, although the name acetylene also refers specifically to C_2H_2 , known formally as ethyne using IUPAC nomenclature. Like other hydrocarbons, alkynes are generally hydrophobic but tend to be more reactive.

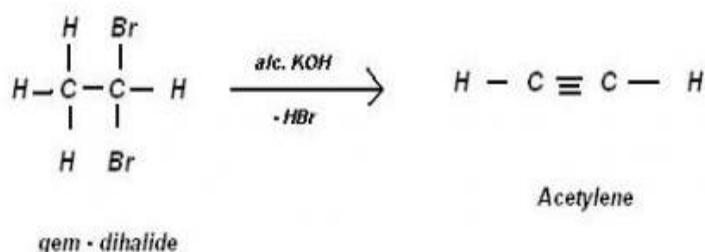
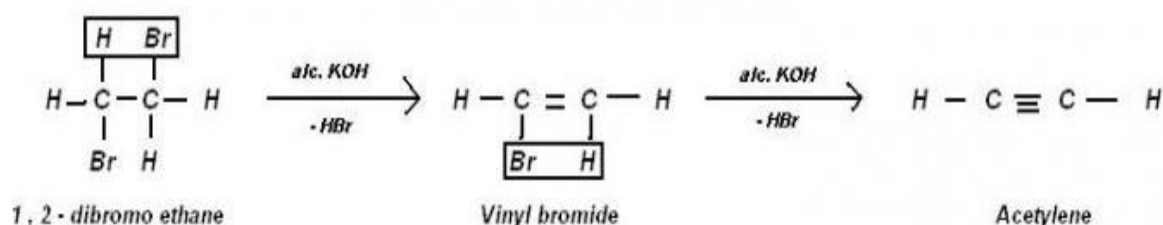
Methods of Preparation of alkynes

a- Industrial method : It is prepared by the hydrolysis of calcium carbide .



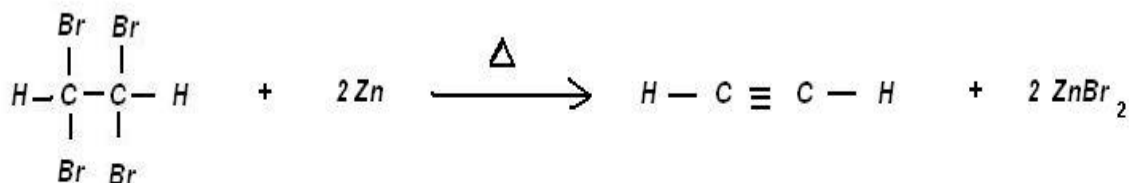
b- Laboratory methods of preparation

1. Dehydrohalogenation : Acetylene is obtained when 1, 2 or 1, 1-dihaloethane is treated with alcoholic KOH .





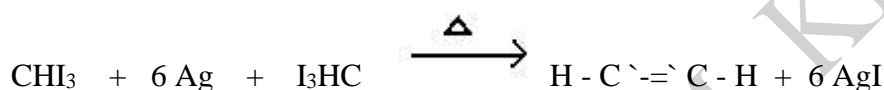
2. **Dehalogenation** of 1, 1, 2, 2 - tetrahaloethane : 1, 1, 2, 2 - tetrabromoethane on heating with Zn dust gives acetylene .



1, 1, 2, 2 - tetrabromoethane

Acetylene

3. **From haloform** : Acetylene is obtained by heating iodoform , CHI₃ with silver powder .



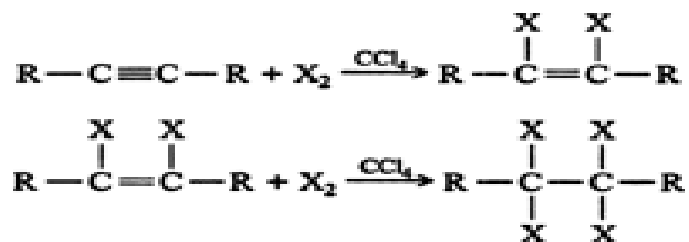
Alkynes: Addition Reactions

The principal reaction of the alkynes is addition across the triple bond to form alkanes. These addition reactions are analogous to those of the alkenes.

1- Hydrogenation. Alkynes undergo catalytic hydrogenation with the same catalysts used in alkene hydrogenation: platinum, palladium, nickel, and rhodium. Hydrogenation proceeds in a stepwise fashion, forming an alkene first, which undergoes further hydrogenation to an alkane.



2- Halogenation. The addition of halogens to an alkyne proceeds in the same manner as halogen addition to alkenes. The halogen atoms add to an alkyne molecule in a stepwise fashion, leading to the formation of the corresponding alkene, which undergoes further reaction to a tetrahaloalkane.



Unlike most hydrogenation reactions, it is possible to stop this reaction at the alkene stage by running it at temperatures slightly below 0°C.

3- Hydrohalogenation. Hydrogen halides react with alkynes in the same manner as they do with alkenes.

