Limonene

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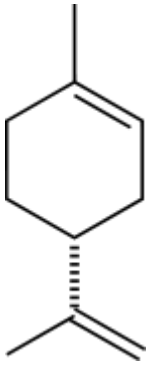
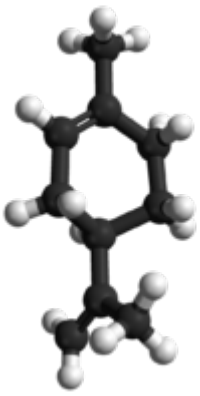
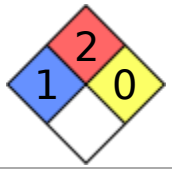
Limonene is a colourless liquid hydrocarbon classified as a cyclic terpene. The more common D-isomer possesses a strong smell of oranges.[1] It is used in chemical synthesis as a precursor to carvone and as a renewably based solvent in cleaning products.

Limonene takes its name from the lemon, as the rind of the lemon, like other citrus fruits, contains considerable amounts of this compound, which contributes to their odor. Limonene is a chiral molecule, and biological sources produce one enantiomer: the principal industrial source, citrus fruit, contains D-limonene ((+)-limonene), which is the (*R*)-enantiomer (CAS number 5989-27-5, EINECS number 227-813-5). Racemic limonene is known as dipentene.[2] D-Limonene is obtained commercially from citrus fruits through two primary methods:

Limonene	
	
IUPAC name	
1-Methyl-4-(1-methylethenyl)-cyclohexene	
Other names	
4-Isopropenyl-1-methylcyclohexene p-Menth-1,8-diene Racemic: DL-limonene; Dipentene	
Identifiers	
CAS number	138-86-3 ✗
PubChem	22311, 439250 (*S*)
ChemSpider	20939 (*R*/*S*) ✓, 388386 (*S*), 389747 (*R*)
UNII	GFD7C86Q1W ✓
KEGG	D00194 ✓
ChEBI	CHEBI:15384 ✓
ChEMBL	CHEMBL449062 ✗
Jmol-3D images	Image 1 (http://chemapps.stolaf.edu/jmol/jmol.php?model=CC1%3DCCC%28CC1%29C%28%3DC%29C)
SMILES	
InChI	
Properties	

centrifugal separation or steam distillation.

Contents

Molecular formula	$C_{10}H_{16}$
Molar mass	136.23 g mol^{-1}
Density	0.8411 g/cm³
Melting point	−74.35 °C (−101.83 °F; 198.80 K)
Boiling point	176 °C (349 °F; 449 K)
Chiral rotation $[\alpha]_D$	87° - 102°
Hazards	
R-phrases	R10 R38 R43 R50/53
S-phrases	(S2) S24 S37 S60 S61
NFPA 704	
Flash point	50 °C (122 °F; 323 K)
Except where noted otherwise, data are given for materials in their standard state (at 25 °C (77 °F), 100 kPa)	
✗ (verify) (what is: ✓/✗?)	
Infobox references	

Chemical reactions

Limonene is a relatively stable terpene and can be distilled without decomposition, although at elevated temperatures it cracks to form isoprene.[3] It oxidizes easily in moist air to produce carveol, carvone, and limonene oxide.[4] With sulfur, it undergoes dehydrogenation to *p*-cymene.[5]

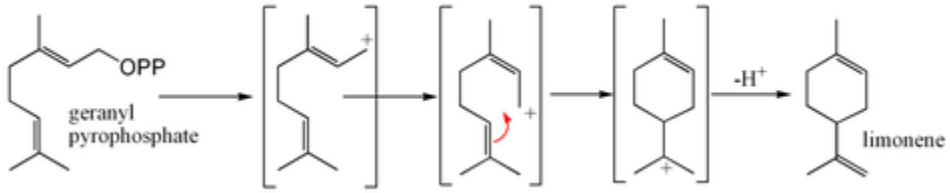
Limonene occurs naturally as the (*R*)-enantiomer, but racemizes to dipentene at 300 °C. When warmed with mineral acid, limonene isomerizes to the conjugated diene α-terpinene (which can also easily be converted to *p*-cymene). Evidence for this isomerization includes the formation of Diels-Alder adducts between α-terpinene adducts and maleic anhydride.

It is possible to effect reaction at one of the double bonds selectively. Anhydrous hydrogen chloride reacts preferentially at the disubstituted alkene, whereas epoxidation with MCPBA occurs at the trisubstituted alkene.

In another synthetic method Markovnikov addition of trifluoroacetic acid followed by hydrolysis of the acetate gives terpineol.

Biosynthesis

Limonene is formed from geranyl pyrophosphate, via cyclization of a neryl carbocation or its equivalent as shown.[6] The final step involves loss of a proton from the cation to form the alkene.



The most widely practiced conversion of limonene is to carvone. The three step reaction begins with the regioselective addition of nitrosyl chloride across the trisubstituted double bond. This species is then converted to the oxime with base, and the hydroxylamine is removed to give the ketone-containing carvone.[1]

Uses

Limonene is common in cosmetic products. As the main odor constituent of citrus (plant family Rutaceae), D-limonene is used in food manufacturing and some medicines, e.g. as a flavoring to mask the bitter taste of alkaloids, and as a fragrant in perfumery; it is also used as botanical insecticide,[7] particularly the (*R*)-(+)-enantiomer is most active as an insecticide. It is added to cleaning products such as hand cleansers to give a lemon-orange fragrance (see orange oil) and because of its ability to dissolve oils. In contrast, L-limonene has a piney, turpentine-like odor.

In natural and alternative medicine, D-limonene is marketed to relieve gastroesophageal reflux disease and heartburn.[8]

Limonene is increasingly being used as a solvent for cleaning purposes, such as the removal of oil from machine parts, as it is produced from a renewable source (citrus oil, as a byproduct of orange juice manufacture). It is used as a paint stripper and is also useful as a fragrant alternative to turpentine. Limonene is also used as a solvent in some model airplane glues and as a constituent in some paints. All-natural commercial air fresheners, with air propellants, containing limonene are used by philatelists to remove self-adhesive postage stamps from envelope paper.[9]

Limonene is also finding increased use as a solvent for filament-fused 3D printing. Printers can print the plastic of choice for the model, but erect supports, and binders from HIPS, a polystyrene plastic, that are easily solvable in Limonene.

As it is combustible, limonene has also been considered as a biofuel.[10]

In preparing tissues for histology or histopathology, D-limonene is often used as a less toxic substitute for xylene when clearing dehydrated specimens. Clearing agents are liquids miscible with alcohols (such as ethanol or isopropanol) and with melted paraffin wax, in which specimens are embedded to facilitate cutting of thin sections for microscopy.[11][12][13]

Limonene is adenosine agonist which may explain its anti-stress and sedative properties.[14][15][16]

Safety

Limonene and its oxidation products are skin and respiratory irritants, and limonene-1,2-oxide (formed by aerial oxidation) is a known skin sensitizer. Most reported cases of irritation have involved long-term industrial exposure to the pure compound, *e.g.* during degreasing or the preparation of paints. However, a study of patients presenting dermatitis showed that 3% were sensitized to limonene.[17]

Although high doses have been shown to cause renal cancer in male rats,[18] limonene is considered by some researchers to be a potential chemopreventive agent [19] with value as a dietary anti-cancer tool in humans.[20] There is no evidence for carcinogenicity or genotoxicity in humans. The IARC classifies D-limonene as a Group 3 carcinogen: *not classifiable as to its carcinogenicity to humans*.[17][21]

No information is available on the health effects of inhalation exposure to D-limonene in humans, and no long-term inhalation studies have been conducted in laboratory animals.[*citation needed*]

D-Limonene is biodegradable, but due to its low flash point, it must be treated as hazardous waste for disposal.[*citation needed*]

Compendial status

- British Pharmacopoeia [22]

See also

- Citral
- Perfume allergy

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External links

- Limonene MS Spectrum (http://gmd.mpimp-golm.mpg.de/Spectrums/69d65d67-cef8-4af7-8d38-43a63ba43249.aspx)
- Detailed description of d-limonene from Biochem Corp. (http://www.biochemcorp.com/dlimonene2.htm)
- d-limonene information from the United States Environmental Protection Agency (http://www.epa.gov/iris/subst/0682.htm#refinhal)

Categories: Hydrocarbon solvents | Insecticides | Flavors | Histotechnology | Monoterpenes | IARC Group 3 carcinogens

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