

Chemistry I (Organic)

Stereochemistry

LECTURE 2

Stereogenic elements & enantiomers

Alan C. Spivey
a.c.spivey@imperial.ac.uk

**Imperial College
London**

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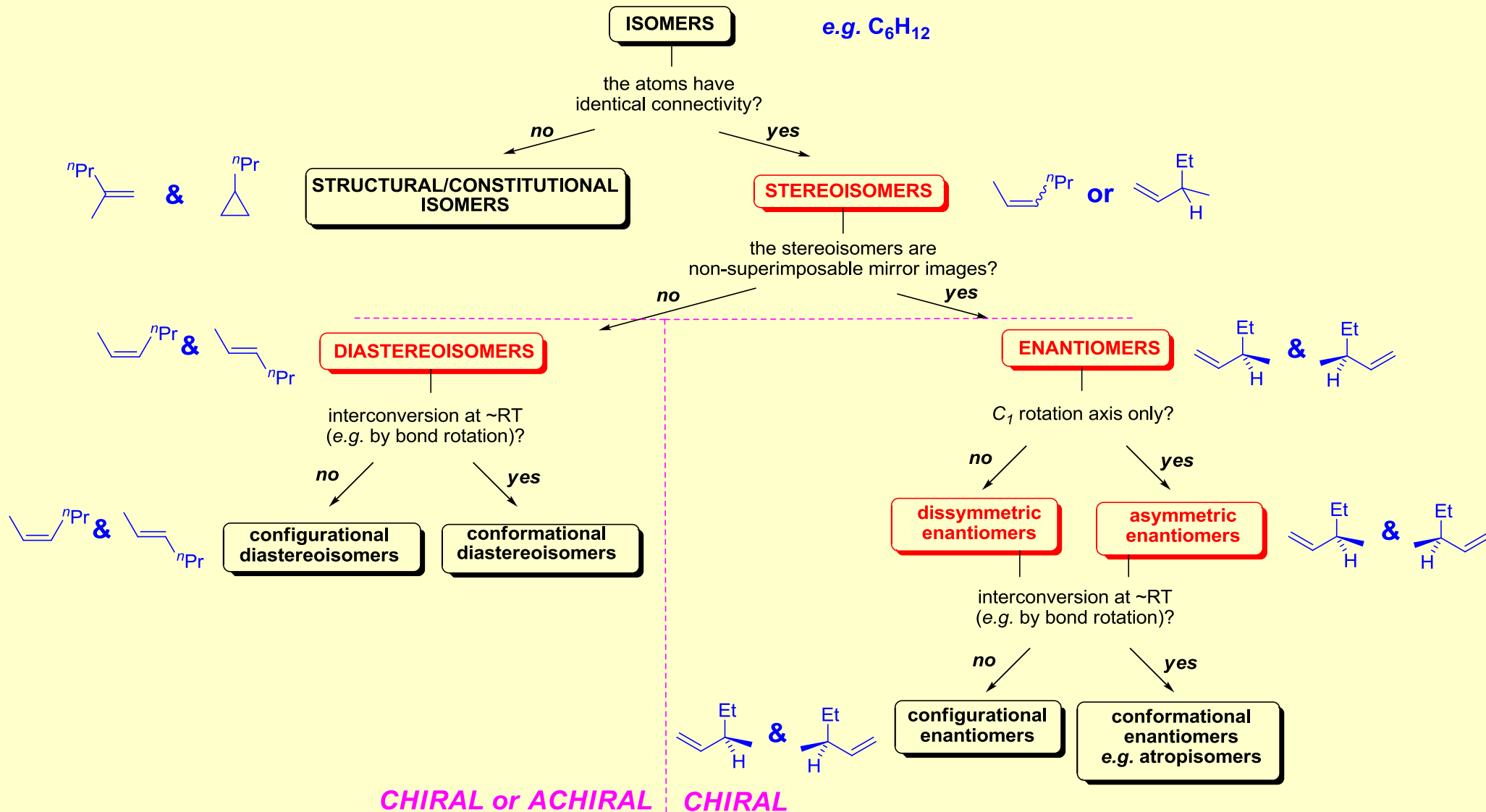
Format & scope of lecture

- ***Isomers & stereoisomers***
 - some definitions
- ***Enantiomers***
 - asymmetric enantiomers
 - dissymmetric enantiomers
 - physical and optical properties

NB. For 3D Jmol models of molecules **A-X** see link @ <http://www.ch.ic.ac.uk/spivey/?q=firstyear>

Isomers & stereoisomers - *definitions*

- Isomers** are compounds with the same molecular formula; they are further classified as follows:



Enantiomers

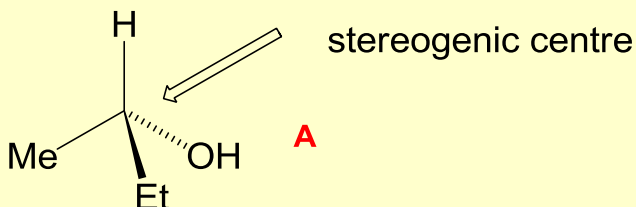
- **There are two equivalent definitions of enantiomers:**
 - They are stereoisomers that are ***non-superimposable mirror images***
 - They are stereoisomers ***lacking any improper rotation axes***
 - The most common improper rotation axes are: S_1 = plane of symmetry, S_2 = centre of symmetry*
- **Enantiomers are referred to as being chiral (from the Greek word for 'hand')**
- **A chiral molecule is therefore one that can exist in two enantiomeric forms**



A sample of a chiral compound can be:

- a **racemic** mixture = 50:50 mix of enantiomers
- a **scalemic** mixture = non-50:50 mix of enantiomers
- **homochiral** or **enantiomerically pure** = single enantiomer

- **A common, but not obligatory, feature of enantiomers is that they contain one (or more) stereogenic centres. Stereogenic centres are tetrahedral (sp^3) centres having 4 different substituents attached (also referred to as *chiral centres*)**

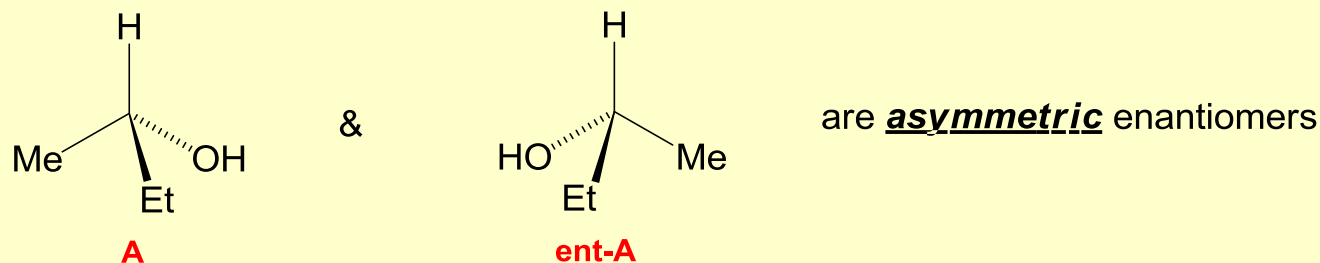


- **Enantiomers can be further subdivided into asymmetric- and dissymmetric enantiomers**

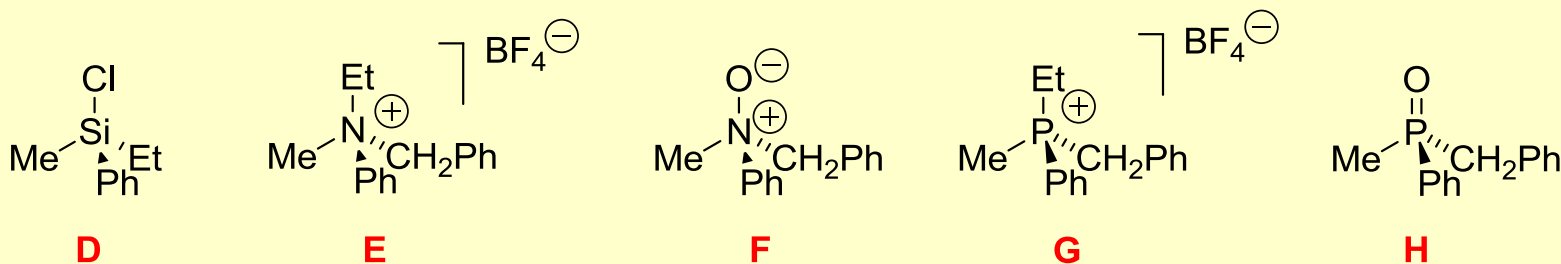
*For a useful review of symmetry see: <http://www.cem.msu.edu/~reusch/VirtTxtJml/symmetry/symmtry.htm>

Asymmetric enantiomers (C_1)

- **Asymmetric enantiomers** have a C_1 **proper rotation axis** (i.e. rotation through 360°) as the **ONLY** symmetry operation that restores self.* They have **NO** higher rotation axes.
- e.g. a molecule containing a carbon atom with four different groups attached as the **only stereogenic centre**



- **The centre does not need to be a carbon atom**
 - these compounds also have enantiomeric forms:

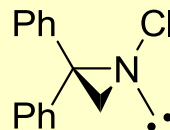
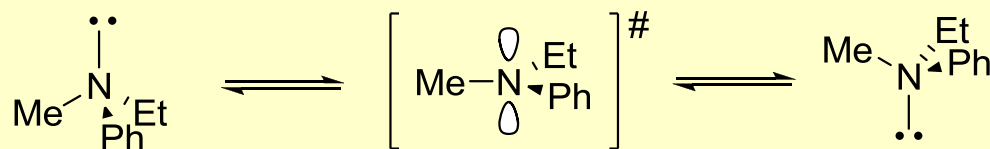


*For a useful review of chirality see:

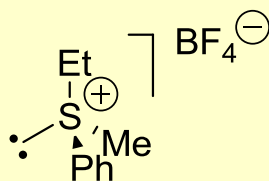
<http://csi.chemie.tu-darmstadt.de/ak/immel/script/redirect.cgi?filename=http://csi.chemie.tu-darmstadt.de/ak/immel/tutorials/chirality/index.html>

Conformational asymmetric enantiomers (C_1)

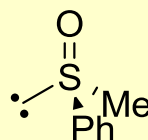
- Enantiomers having an atom other than carbon as the stereogenic atom, particularly those for which one 'substituent' is a lone pair, may not be configurationally stable at all temperatures:



I



J

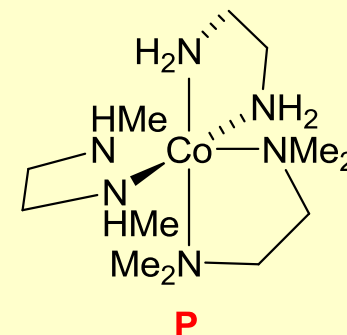
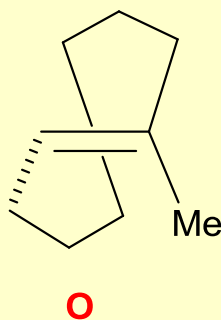
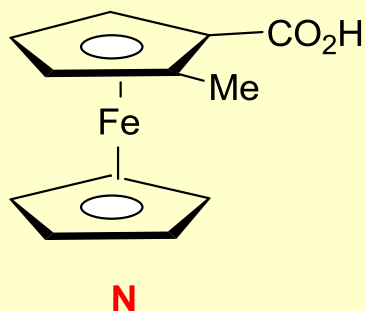
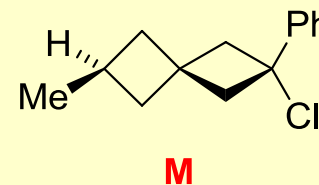
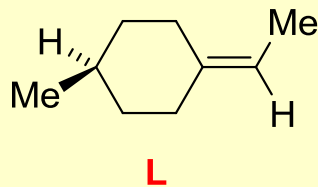
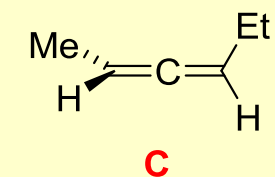


K

- Lone pairs are able to 'tunnel' through the central atom; this results in an inversion of configuration of the molecule (i.e. the enantiomers can interconvert, as shown explicitly for the tert-amine case above)
 - The temperature/rate at which this happens depends on the central atom and the other substituents present. For example, most *tert*-amines rapidly interconvert their configuration at room temperature but the aziridine shown can be separated into its enantiomers at this temperature

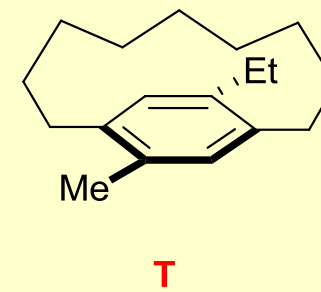
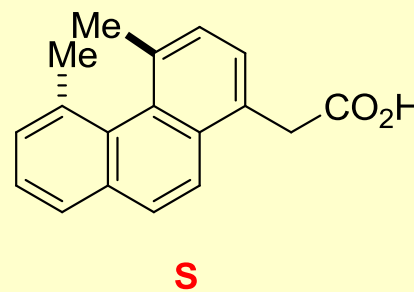
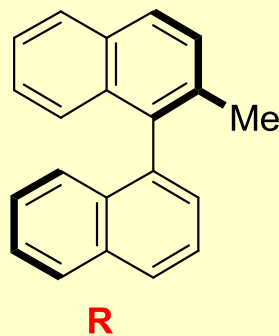
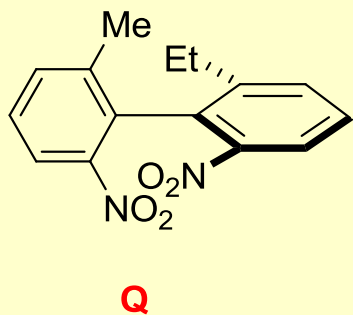
Asymmetric enantiomers (C_1)

- Enantiomers do not have to contain stereogenic centres. All the following have enantiomers:



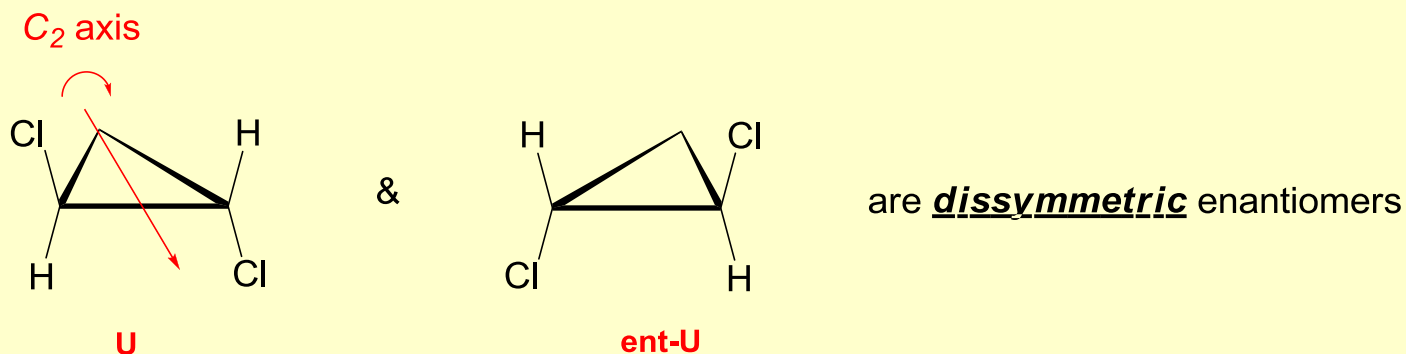
*For a useful review of tris-metal chelate chirality see: <http://www.ch.ic.ac.uk/local/inorganic/>

- Again, some enantiomers lacking stereogenic centres are also not configurationally stable at all temperatures = **conformational asymmetric enantiomers**:

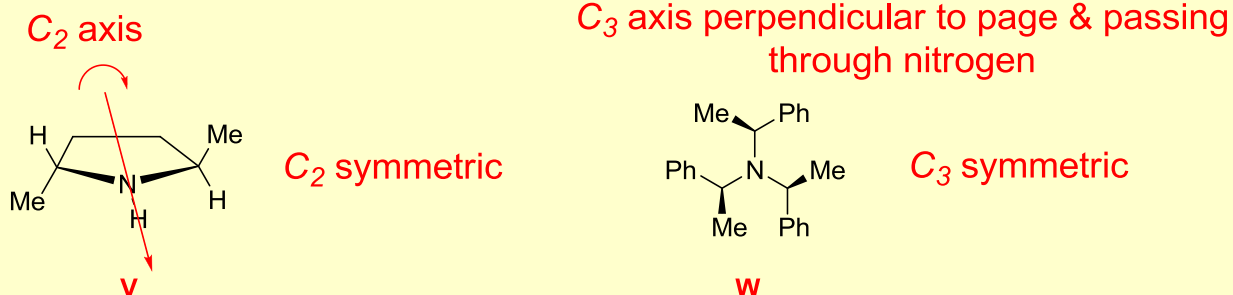


Dissymmetric enantiomers (C_n)

- **Dissymmetric enantiomers** have one or more C_n ($n = \text{integer} > 1$) **proper rotation axes** (i.e. rotation through $360/n^\circ$), **in addition to a C_1 axis**, as the **ONLY** symmetry operations that restore self
- e.g. **C_2 -symmetric 1,2-trans-disubstituted cyclopropanes** (containing two stereogenic centres)



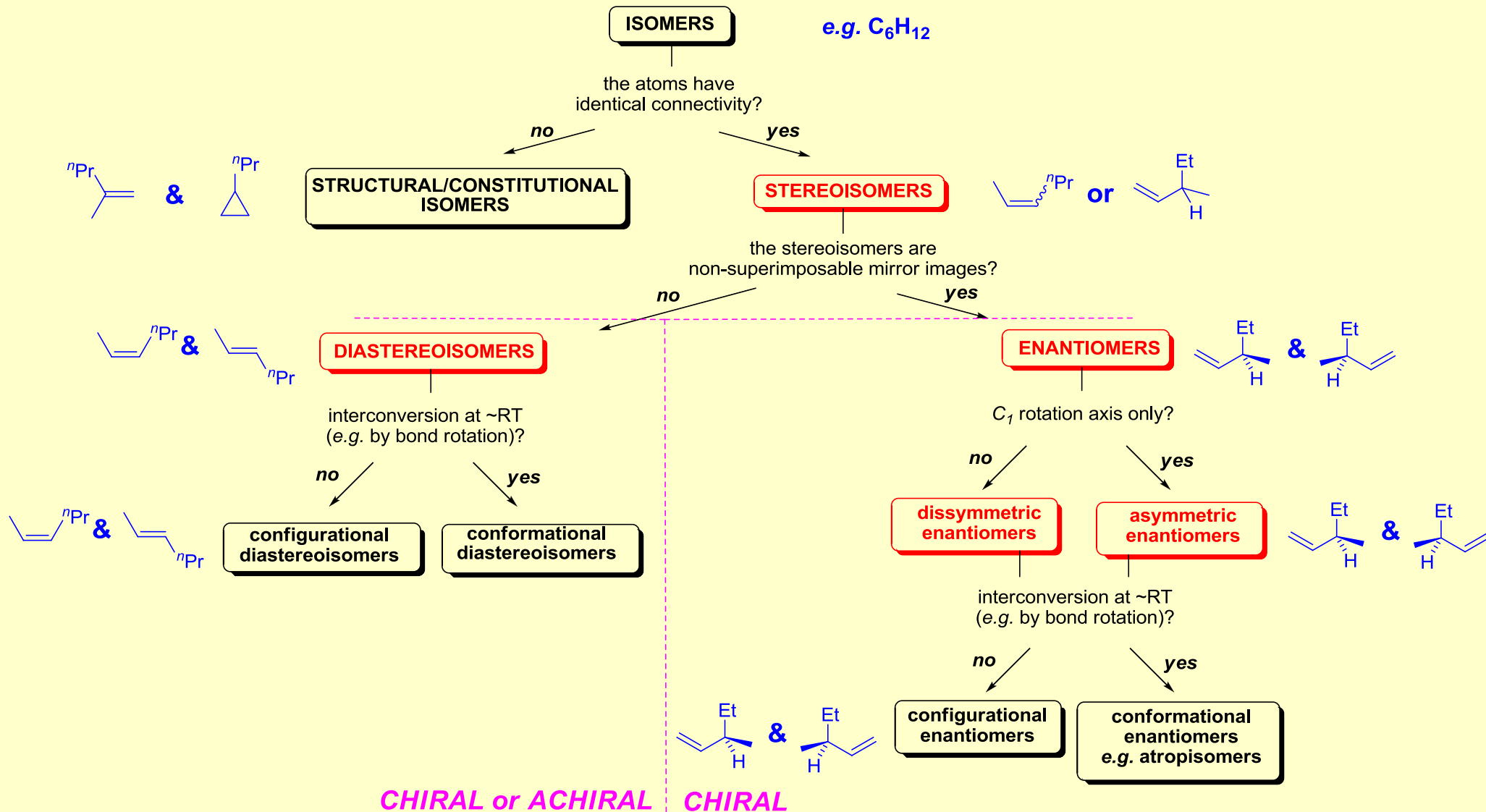
- **Additional examples are:**



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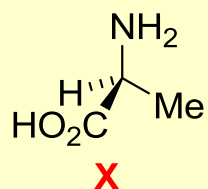
Isomers & stereoisomers - *definitions*

- Isomers** are compounds with the same molecular formula; they are further classified as follows:

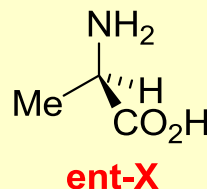


Physical & optical properties of all enantiomers

- Enantiomers** have identical chemical and physical properties, except insofar as they rotate the plane of polarised light equally, but in the opposite directions, e.g.



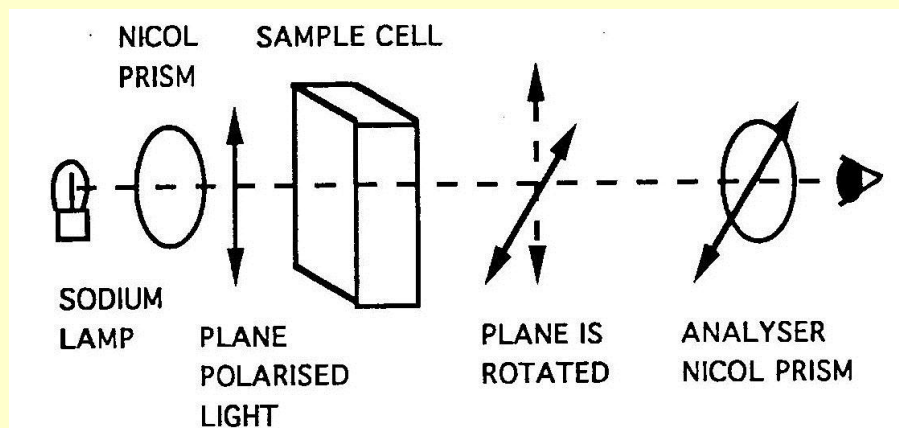
(+)-alanine
 $[\alpha]_D = + 8.5$



(-)-alanine
 $[\alpha]_D = - 8.5$

[units: $10^{-1} \text{degcm}^2\text{g}^{-1}$]

- The rotation of the plane of polarised light is measured using a polarimeter:

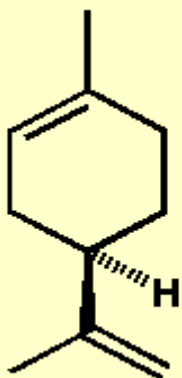


- Compounds which rotate the plane of polarised light clockwise are called **(+)-isomers**, or **dextrorotatory (d)**
- Those that rotate the plane anticlockwise are called **(-)-isomers** or **laevorotatory (l)**
 - The separation of enantiomers is called resolution. Because enantiomers have the same chemical and physical properties, resolution can be difficult. The first recorded resolution is that of Louis Pasteur in 1848

Limonene & Carvone



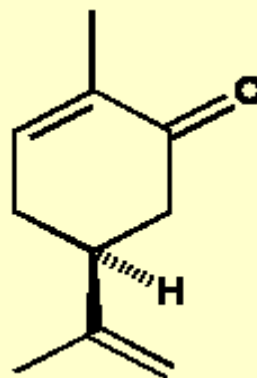
Chiroscience plc. (now Dow Inc.)



1. *S*-(-)-limonene (lemon)

2. *R*-(+)-limonene (orange)

3. *RS*-(±)-limonene (pleasant)



4. *R*-(-)-carvone (spearmint)

5. *S*-(+)-carvone (caraway)

6. *RS*-(±)-carvone (disgusting)