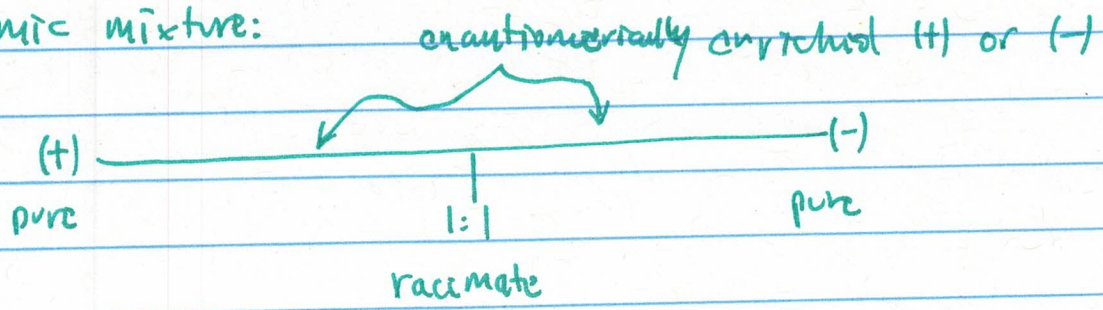


Physical

Lecture XII: Properties of Enantiomers

02-10-2020

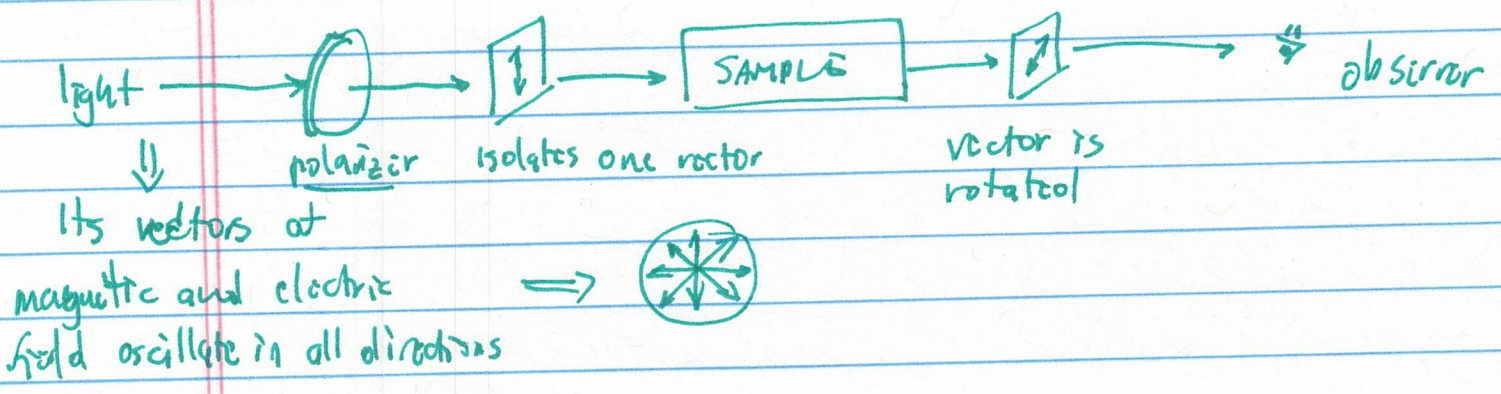
The two enantiomers can exist completely separately of each other, but they are also often formed together with one another in a 1:1 ratio. Such a mixture is called racemate or racemic mixture:



What are the properties of these enantiomers relative to each other and to the racemate?

In general, the two enantiomers have identical properties unless they are interacting with a chiral chemical or are exposed to a chiral environment.

Optical activity is a very common method of assessing enantiomers and a pure enantiomer is often said to be "optically pure". How does this work?



The two enantiomers—everything else being equal—will turn the plane of polarized light by the same amount, but in the opposite directions. One is called (+) isomer and the other (-) isomer, but this has nothing to do with their R/S-designators.

The rotation of this vector (α) is dependent on the substance, path length (l) and concentration ($g\ cm^{-3}$):

$$\alpha = [\alpha] \times c \times l$$

↳ specific rotation depends on the wavelength and temperature $[\alpha]_{25}^D$ —sodium's D line

$$\phi\text{-molar specific rotation: } [\phi] = \frac{[\alpha]}{M} \times 100$$

Optical purity is the ratio of measured $[\alpha]$ to the literature value for the same compound:

$$op = \frac{[\alpha]}{[\alpha]_{max}}$$

$op = 0$ racemate
 $op = 1$ pure enantiomer

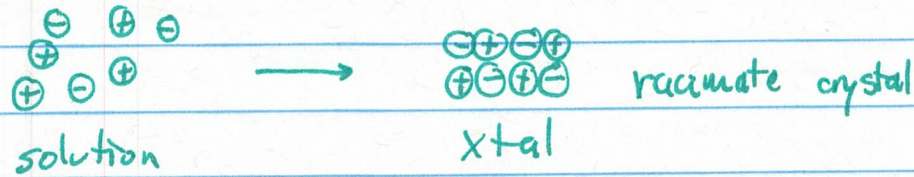
Enantiomeric excess (ee) is the % surplus of the major enantiomer:

$$ee = \frac{\%_{major} - \%_{minor}}{100\%} \quad \text{or} \quad \frac{n_{major} - n_{minor}}{n_{major} + n_{minor}}$$

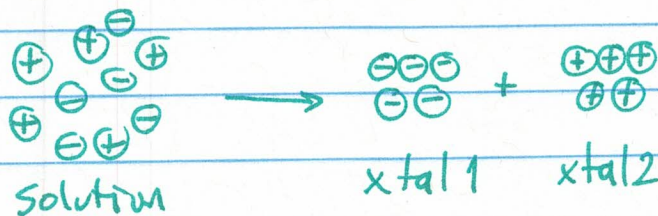
98/2 mixture is 96% enantiomeric excess.

Crystallization

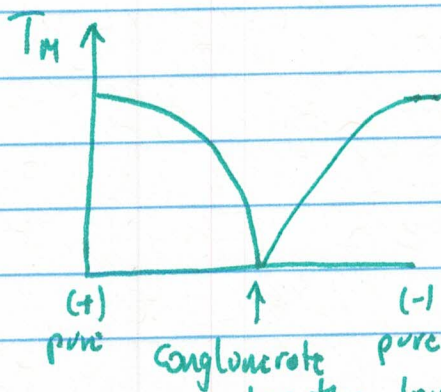
Some racemates crystallize as such:



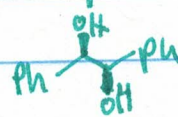
Others crystallize as 1:1 mixtures of crystals of pure enantiomers; such a mixture is called a conglomerate.



How do you tell the difference? Melting point dependence:



Examples include:



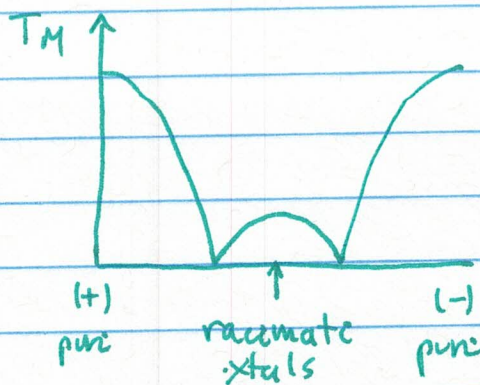
mp (pure) = 147.5 °C

mp (racemate) = 121 °C

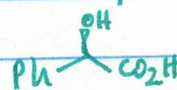
[6]Thelone

mp (pure) = 265-267 °C

mp (racemate) = 231-233 °C



Examples include:



mp (pure) = 132.8 °C

mp (racemate) = 118 °C

addition of small amount of either enantiomer will decrease the melting point

In case of conglomerates, the two crystals could in principle be macroscopic mirror images of each other, allowing their separation using Pasteur's tweezers method. However, things are not so simple. For this phenomenon, called hemihedrism to be observable, molecules should crystallize in a chiral space group $P2_1$. However, only about 40% of all conglomerates do. Another 40% crystallize in $P2_12_12_1$, where such an observation is very difficult. In fact, Pasteur was very lucky:

Sodium ammonium tartrate $\cdot 4H_2O$ is conglomerate

$\downarrow > 28^\circ C$

" " "

$\cdot H_2O$, is a racemic compound

slightly
different
crystallization

conditions
would have
led to failure

Racemic crystals tend to have higher solubility and slightly higher density than those of pure enantiomers. This phenomenon can be used to amplify the chirality of low α mixtures through preferential crystallization:

(+) 51% & (-) 49%

→ crystallize →

(+) crystallizes alone first
M enantiopure crystals

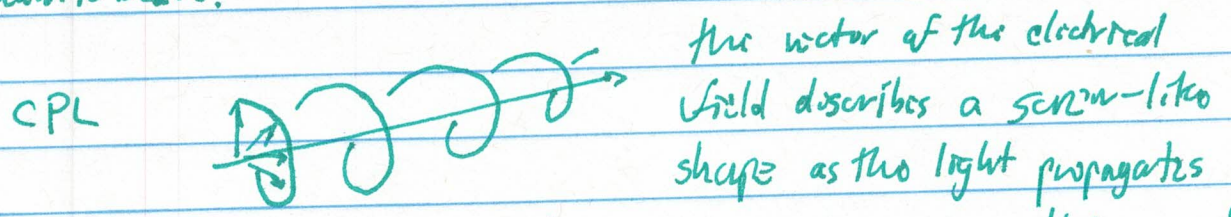
↓

more on this later
in separations of enantiomers

they act as seeds to pull
out all of (+) out of the mix

Circular Dichroism (CD)

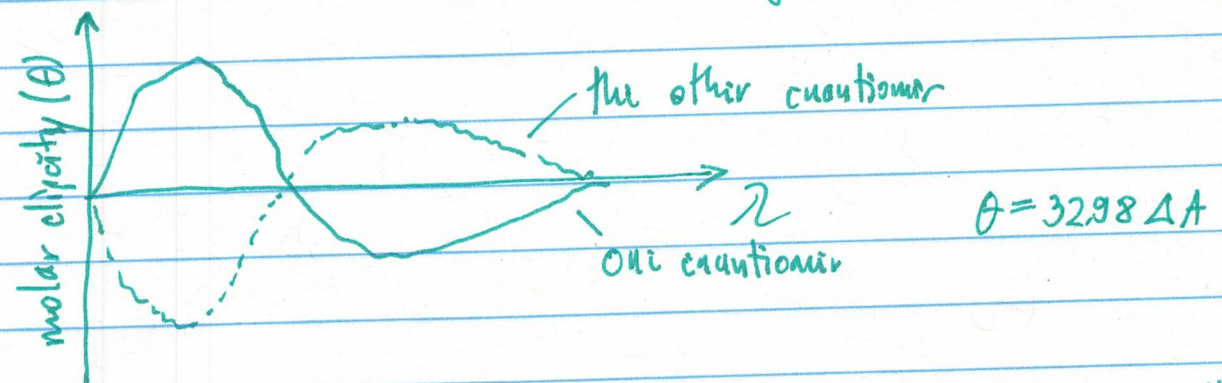
This is a technique which can detect chirality. It is based on the different absorption of circularly polarized light (CPL) by the two enantiomers.



CD can be done in a UV, VIS, OR NIR region. It is sensitive to various secondary effects ~~not~~ on the structure, e.g. in proteins. CPL can be left- or right-handed. The chiral substrate will absorb the two kinds differently

$$\Delta \epsilon = \epsilon_L - \epsilon_R \quad \text{circular dichroism}$$

↳ this is wavelength-dependent



Racemate or an achiral molecule shows no CD signal - a small amount of a chiral impurity can be detected.

Limitations are in the fact that - like UV/VIS spectroscopy - it does not give nearly as much structural information as e.g. NMR or X-ray.

NEXT TIME: interactions of enantiomers with other chiral chemicals: DIASTEREOMERS