So far...

- We have covered a lot of material...
- You should have an understanding of the structure of molecules
- You should be familiar with IR spectroscopy
- Understand how the structure of compounds relates to their chemistry

- Have a vague comprehension of 'curly arrows'

- Now before we use that to look at reactions you need to understand a little more about structure...
Isomerism

- **Isomers** - compounds that have the same numbers & same kind of atoms, but they differ in the way they are arranged
- **Constitutional isomers** - same molecular formula but atoms joined in different ways
- As a result can be very different compounds...

**Examples**

- **pentane**
  - bp 36.2°C

- **2-methylbutane**
  - bp 28°C

- **2,2-dimethylpropane**
  - bp 9.6°C

- **2-methylpropan-2-ol**
  - C₄H₁₀O
  - mp 26°C

- **diethyl ether**
  - C₄H₁₀O
  - mp –116°C

- Presence of hydroxyl group (alcohol) makes a huge difference!

- Only attractive forces in alkanes are **van der Waals** forces
- These are proportional to surface area
- Smaller the surface area smaller the attractive forces & lower the bp
**Conformational isomerism**

- Different shapes of the **same molecule**
- Differ by **rotation** around a single bond
- Two extremes: eclipsed (below) & staggered (next slide)

**Eclipsed conformation**

- Substituents of each atom overlap
- Less stable (more energy) than staggered

**Diagram**:

- Conventional representation
- Sawhorse projection
- Newman projection (view along C–C bond, small dot = front carbon, large circle = back carbon)
Conformational isomerism II

Staggered conformation

- Staggered conformation more stable (lower energy)
- Reason for stability is **NOT** due to sterics (size); H too small to interact
- Reason is electronics - electrons of bond repel (so don't like overlap)
- Possible that a stabilising overlap of C-H $\sigma$ and C-H $\sigma^*$ exists
Conformational isomerism III

- Substituted ethanes more complex
- Staggered conformations have different energies
- **Anti-periplanar** most stable
- Hence most stable alkanes are zig-zag (as we draw!)
- Barrier to rotation can be steric now (depends on R)
- Each conformation can have effect the behaviour of the compound (reactivity / mechanism / nmr spectroscopy)
Conformational isomerism IV

Cyclohexane can adopt two (extreme) conformations

- The chair is the more stable conformation than the boat
- Reason: boat has steric interactions between C1 & C4 hydrogens
- Interconversion occurs via ring flipping
Substituted cyclohexanes

- Substituent prefers to be **equatorial** as this reduces **1,3-diaxial interactions** (steric hindrance)
- The bigger $R$ the more equatorial conformer

- In disubstituted cyclohexanes both substituents will try to be equatorial
- If not possible the largest will adopt equatorial position

\[ \text{bulky group equatorial favoured} \]

\[ \text{tert-butyl group rarely is axial} \]

- **cis-disubstituted cyclohexane**
- Both substituents up (equatorial preferred)

- **trans-disubstituted cyclohexane**
- One substituent up & one down
Configurational isomerism

- The spatial arrangement of atoms / groups in a molecule is its configuration.
- Configurational isomers have the same formula & same bonds.
- Configurational isomers can only be interconverted by breaking a bond.

**Alkenes**
- Alkenes with two different substituents at each end can exist as configurational isomers.
- Reason - no rotation around double bond.

\[
\begin{align*}
\text{A} & \equiv \text{C} \\
\text{B} & \equiv \text{D}
\end{align*}
\]

- *E*-alkenes are more stable than *Z*-alkenes.
- Reason - substituents further apart so no steric hindrance.

\[
\begin{align*}
\text{R} & \equiv \text{R} \\
\text{H} & \equiv \text{H}
\end{align*}
\]

*E* or *trans* 

\[
\begin{align*}
\text{less stable} \\
\text{steric crowding}
\end{align*}
\]

*Z* or *cis*
**E and Z nomenclature**

- *E*-alkenes have the groups of highest priority on the **opposite** sides
- *Z*-alkenes have the groups of highest priority on the **same** side

**Priority rules**

1. Rank atoms directly attached to alkene in order of decreasing atomic number
2. If atoms are the same, then move along substituent until a difference is found
3. Multiple bonds are assumed to count as the same number of single bonds

\[
\begin{align*}
\text{atom} &= \text{Br} > \text{Cl} > \text{O} > \text{N} > \text{C} > \text{H} \\
\text{Atomic number} &= 35, 17, 8, 7, 6, 1
\end{align*}
\]

Examples:

- (Z)-2-chloro-3-methylpent-2-ene
- (Z)-3-hydroxymethyl-4-oxo-2-phenylbut-2-enoic acid
- (E)-2-bromo-3-(hydroxymethyl)pent-2-enenitrile
- (E)-3-methyl-4-phenylpent-3-en-2-one
Optical isomerism - stereoisomers

- **Optical isomers** - configurational isomers with the same chemical & physical properties, which rotate plane-polarised light
- One isomer rotates light clockwise
- Other isomer rotates light anti-clockwise

- The two compounds are mirror images
- They are **asymmetric** & can not be superimposed
- They are called **CHIRAL** molecules
- If two molecules can be superimposed they are **ACHIRAL**

- The tetrahedral asymmetric carbon is known as a **chiral** or **stereogenic** centre
- The two isomers are called **enantiomers**
- They rotate light in opposite directions

- **lactic acid**
  
  \[
  \begin{align*}
  H & \quad C \quad \text{CH}_3 \\
  \text{HO}_2C & \quad \text{CH}_3 \quad \text{OH} \\
  \text{(+)-enantiomer} & \quad [\alpha]_D^{25} = +3.82
  \end{align*}
  \]

- **mirror plane**

- **(-)-enantiomer**
  
  \[
  \begin{align*}
  H & \quad C \quad \text{CO}_2H \\
  \text{HO} & \quad \text{CO}_2H \\
  \text{(-)-enantiomer} & \quad [\alpha]_D^{25} = -3.82
  \end{align*}
  \]
Chiral & achiral compounds

- Molecule is **CHIRAL** if it has **ONE** carbon with **FOUR** different groups on it
- **ANY** molecule with a plane of symmetry is **ACHIRAL**
Nomenclature (groan): \((R)\) or \((S)\)

- Need to be able to define enantiomers
- Assign priorities to each substituent of chiral centre
- Highest atomic number = highest priority (move along chain until difference)

Next, point lowest priority away from you...

- Draw line pointing from 1 to 3
- If line is clockwise (to the Right) then \((R)\)
- If line is anti-clockwise then \((S)\)

\((S)\)-alanine

\((S)\)-2-aminopropanoic acid
Example of nomenclature

- First prioritise substituents
- H is easy!
- Keep moving along chain until a difference

\[ a = \text{CH}_3 = 3 \]
\[ b = \text{CH}_2 = c \]
\[ c = \text{CH}_2 = b \]

- Point lowest priority away from you
- Draw line from 1 to 3
- Line is clockwise so...

\( (R)\)-3,6-dimethylhept-5-enal