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Amazing shapes: chirality

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Abstract

The use of songs to help learning of content is consistent with multi-sensory models of learning. Here, a song to the tune of "Amazing Grace" can be used in the classroom to enhance the learning of chirality and the Cahn-Ingold-Prelog priority rules.

(Sung to the tune of Amazing Grace)

Amazing shapes: chiral-i-ty,
That makes both left and right!
Carvone does have e-nan-tio-mers
Diff’rent tastes do delight.

One will be dill and caraway,
Spear-mint is the mir-ror!
Tetrahe-dral stereo-cen-tres,
Four groups: no less, or more.

Pri-or-i-tise from 1 to 4,
By “Z”, the high-est led!
I-so-topes have same Z number
So use the mass instead.

Put lowest group away a-far
Which way it turns, to see
Turn left is “S”, turn right is “R”,
Carbon chir-al-i-ty.

Amazing shapes: chiral-i-ty,
That makes both R and S!
Tetrahe-dral stereo-cen-tres,
Four groups: no more, or less.

Notes and Discussion

The fact that molecules have 3-dimensional shapes is a key concept in chemistry, giving rise to differences in physical and chemical properties when interacting when molecules interact with each other or with light. Chirality refers to that property where some molecules are different from their mirror images. For example, the enantiomers of carvone (Figure 1) have different smells and tastes.

Chirality can arise from particular combinations of stereocentres, or in some cases from the overall molecular shape in the absence of stereocentres (Figure 2). In another example, poly-glycine has no stereocentres, but can form left- and right-handed helices. The possibility of chirality without stereocentres is usually not emphasised in introductory chemistry.

Five and 6-coordinate atoms cannot be simple stereocentres as shown in Figures 3 and 4. For 5-coordinate trigonal bipyramidal geometry, Berry pseudo-rotation interchanges the axial positions with racemises the positions for 5-coordinate trigonal bipyramidal geometry, which therefore cannot have simple enantiomeric isomerisation.
two of the equatorial positions (1). Hence 5-coordinate atoms cannot have simple enantiomeric isomerisation since a series of Berry pseudo-rotations will scramble and racemise all positions. Six-coordinate atoms in an octahedral geometry, do not have simple enantiomeric isomerisation since there are several types of isomerisation, some of which are shown in Figure 6. As a result, simple stereocentres are 4-coordinate atoms with four different substituents in a tetrahedral (sp$^3$) arrangement.

**Figure 4** Six-coordinate trigonal planar geometry does not have simple enantiomeric isomerisation because there are several types of isomerisation, some of which are shown here.

Stereocentres are classified as $R$ and $S$ configurations, through use of the Cahn-Ingold-Prelog priority rules (2-4) as indicated in Table 1 and Figure 5.

**Table 1** Cahn-Ingold-Prelog priority rules (2-4).

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>Atoms directly attached to the double bond or stereocentre are ranked according to the atomic number (Z), with the highest atomic number having highest ranking;</td>
</tr>
<tr>
<td>2</td>
<td>If two atoms differ only by being isotopes, then the atomic mass is used for the ranking;</td>
</tr>
<tr>
<td>3</td>
<td>If two or more groups have the same ranking, then rank the atoms in those groups, that are two bonds from the double bond or stereocentre (see Refs (2–4) for more details);</td>
</tr>
<tr>
<td>4</td>
<td>If groups still have equal ranking, then atoms that are three bonds from the double bond or stereocentre are ranked; then atoms four bonds distant, etc, until the groups are either ranked or determined to have identical ranking.</td>
</tr>
</tbody>
</table>

The use of songs in chemistry is not new, but it is also not common. The use of mnemonics can help the memorisation, learning and recall (5) of chemical information, which are necessary first steps before the ultimate goal of chemical education, for students to learn, understand and apply chemical principles, can be achieved. Songs use rhyme, rhythm, text, melody and fun to engage learners, using multiple modes of learning. Here, information about chirality, stereocentres, the Cahn-Ingold-Prelog priority rules (2-4), and $R$ and $S$ configurations, have been encoded in the form of song as a learning aid.

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**References**

Figure 1 Enantiomers of carvone. Left: $S$-$(+)$-carvone, smells like caraway; it is found in caraway and dill. Right: $R$-$(–)$-carvone smells like spearmint; it is found in spearmint and peppermint.
Figure 2 Examples of chiral molecules (enantiomers) that have no stereocentres.
Figure 3 Berry pseudo-rotation ($\tau$) scrambles and racemises the positions for 5-coordinate trigonal bipyramidal geometry, which therefore cannot have simple enantiomeric isomerisation.
Figure 4 Six-coordinate trigonal planar geometry does not have simple enantiomeric isomerisation because there are several types of isomerisation, some of which are shown here.
Figure 5 Assigning $R$ and $S$ enantiomers. When the lowest priority group faces away from the reader, (right) turning clockwise from priority groups 1-3 is $R$, and (left) turning anticlockwise from priority groups 1-3 is $S$. 
Chinese name for Kieran Lim (author)