

## Introduction to optical isomerism & chirality

### Introduction

Hello! I am Sanziana Foia from the CCDC and today we'll explore together optical isomerism and chirality, starting from something you know as well as the back of your hands.

We will see everyday examples of chiral objects and how that affects their properties and behaviours. Then, we'll step into the microscopic world and learn about chirality and optical isomerism in molecules and visualise it in 3D. Let's get started!

In chemistry, we often hear about the term isomerism referring to molecules that have the same formula but are arranged differently in space.

There are multiple types of isomerism, such as position, functional and geometric isomerism to name a few. But perhaps one of the trickiest to get our heads around is optical isomerism along with the notion of chirality.

### Chiral Objects

Let's take a quick break from chemistry and take a look at our hands. What do you think? Are they really the same?

They're both made of the same "stuff": a palm, a thumb and four other fingers; and they both have the same bones, muscles and skin.

And that's not everything!

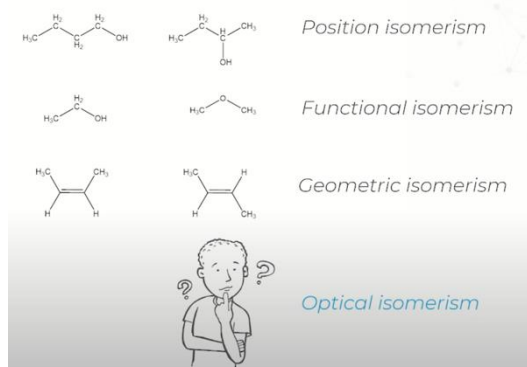
Not only are they made of the same "stuff", but the shapes, sizes and distances between all the stuff that makes them up are the same!

Now try superimposing your hands – that's... just a fancy way of saying to lay one over the other. No matter how hard you try, you can't perfectly fit them one over the other say... in the same way you could do with two left hands from two different people.

So there must be something special that makes your hands different despite the appearance of them being identical. And that special something is called... *chirality*.

Chirality, or handedness, is a spatial property of some objects, such as your hands. Put your hands together and notice how your left hand looks like it's looking in a mirror at your right. Your hands are mirror images of each other!

## ISOMERISM



## CHIRALITY

Objects that are mirror images of each other behave differently in space. Take screws – another example of everyday chiral objects. By screwing a left-handed screw to the left it inserts into a wooden board but if we twist left a right-handed screw it will come out. The same action can have opposite effects on objects that are mirror images of each other.

Another example is kitchen – or boxing – gloves! The left glove won't fit your right hand no matter how hard you try. Chiral objects have different spatial properties and often behave differently.

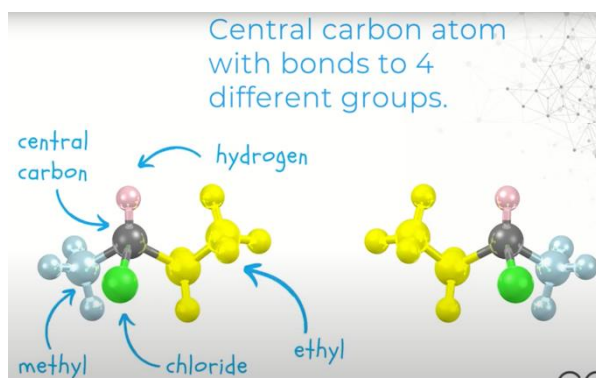
## Chiral Molecules

But how does all this apply to chemistry?

Take a look at the two molecules you see here.

Each one has a central carbon atom bound to four different groups: a hydrogen, a methyl, ethyl and a chloride.

Just by looking at what they're made of and which bonds they form, they appear to be the same.



However, if we try to overlay the two molecules by rotating and translating them as we wish, we'll see that no matter how we move them we can never perfectly superimpose them. Try and build a 3D model of this molecule to convince yourself – feel free to use materials you have around the house. You can even try toothpicks for bonds and various fruit for the atoms!

Just as screws or your hands, some molecules which appear identical at a first glance are also chiral.

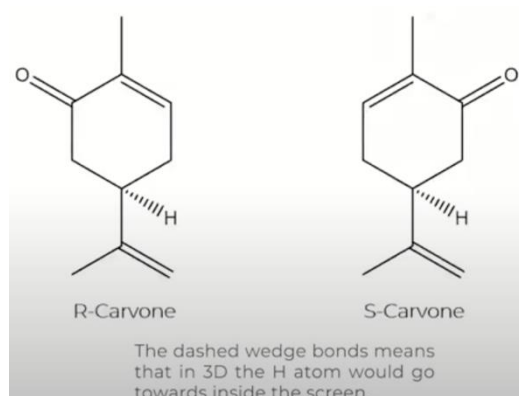
They have the same components and the same internal distances between these components. However, on closer inspection, we will notice they are, in fact, mirror images of each other.

Stereoisomers don't only differ through their arrangement in space. They often have different properties and behaviours, as we've seen with hands and screws. Take carvone, a molecule found in cumin, toothpaste and spearmint.

This is the chiral carbon in carvone. Don't get confused by this six-membered ring – the chiral carbon is attached to four different groups, even if two of them are joined in a ring.

As you can see, carvone has two non-superimposable stereoisomers which have different chemical properties.

One has a strong spearmint smell and is used for flavouring mint sweets and toothpaste and can also be used as a mosquito repellent.



The other stereoisomer is present in cumin and other spices and smells of caraway. It can be used to prevent potatoes sprouting during storage.

## Test your understanding

We've seen how chiral molecules behave and learned their importance in chemistry. Now let's see if we can recognise which of the following carbons are chiral.

## YOUR TURN!

### Question 1

This molecule is alanine, an amino acid. Can you guess which of alanine's carbons is chiral? Remember! A chiral carbon has four different groups attached to it. Feel free to pause the video if you need more time to think!

1.

Which carbon atom is a stereocenter of alanine?

A. Carbon A
B. Carbon B
C. Carbon C
D. None!

CSD Entry LALNIN03

The right answer is B! This carbon is attached to four different groups: a hydrogen, a methyl, a carboxylic acid and an amine.

### Question 2

What about this molecule of citric acid? Can you identify a chiral carbon?

2.

Which carbon atom is a stereocenter of citric acid?

A. Carbon A
B. Carbon B
C. Carbon C
D. None!


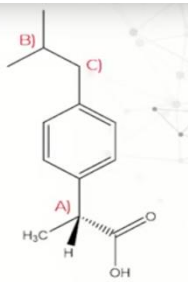
CSD Entry CITRAC10

That was a tricky one! Citric acid has no stereocenters. Look carefully at the structure: there are no carbon atoms that are bonded to four different groups.

## Question 3

Did you know that the molecule of Ibuprofen is chiral? Which carbon do you think is a stereocenter?

3.

Which carbon atom is a stereocenter of Ibuprofen?

A.	Carbon A
B.	Carbon B
C.	Carbon C
D.	None!

CSD Entry JEKNOC10

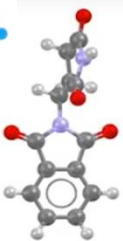
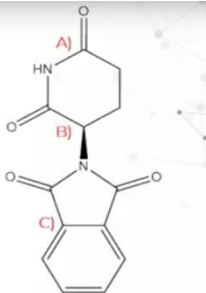
That's right! The correct answer is Carbon A, which is attached to four different groups.

## Question 4

Now, take a look at these stereoisomers of thalidomide. Thalidomide is a drug that was given to pregnant women to reduce the effects of morning sickness in the 1960's. The drug was sold as a mixture of the two stereoisomers – only one of which had the desired effect against morning sickness while the other led to many disabilities and deaths in babies.

This shows how important it is that we can correctly distinguish the isomers of chiral compounds. Can you identify which carbon atom is a stereocenter? Give it a thought before I reveal the answer and feel free to pause the video if you need more time!

4.

Which carbon atom is a stereocenter of Thalidomide?

A.	Carbon A
B.	Carbon B
C.	Carbon C
D.	None!

CSD Entry THALID03

Great job! Thalidomide's chiral centre is this carbon with four different groups attached to it. Don't worry if you didn't get it right this time – it takes more practice to rapidly identify tricky stereocenters such as this one.

## Summary

Congratulations - you made it to the end of this video!

Today we learnt about optical isomerism and chirality, starting from something as simple as our hands and all the way to the fascinating world of chemistry! We saw how some objects – be they gloves, screws or complicated molecules – can be different from each other despite being made of the same components which are connected in the exact same ways to each other. If such objects can't be superimposed it means they are far from being identical: they're mirror images of each other!

We then saw how chirality can have a major impact on the behaviour of molecules such as carvone or thalidomide. And finally, we challenged ourselves with identifying chiral centres in various molecules!

If you enjoyed learning with us about optical isomerism and chirality, give this video a thumbs up and subscribe to our channel for more educational content! Don't forget to check out the teaching modules linked in the description.

Thank you for watching!



## Quiz

### Questions

1. Which carbon atom is a stereocenter of alanine?
2. Which carbon atom is a stereocenter of citric acid?
3. Which carbon atom is a stereocenter of Ibuprofen?
4. Which carbon atom is a stereocenter of Thalidomide?

### Quiz Answers

1. B. Carbon B
2. D. None!
3. A. Carbon A
4. B. Carbon B

## Resources

The molecules used to demonstrate these concepts are available in the Cambridge Structural Database (CSD). In particular we used CSD Entries: OGUSIV, RERXIV, KOSNIS, LALNIN03, CITRAC10, JEKNOC10, THALID03.

You can visualise and download the structures for free from CCDC's Access Structures service: <https://www.ccdc.cam.ac.uk/structures/>



The images and animation frames of these molecules are prepared using Mercury. Mercury visualisation software is available to download for free <https://www.ccdc.cam.ac.uk/Community/csd-community/FreeMercury/>

More advanced functionality from the CCDC enables you explore molecules and structures in more detail, for example Molecule Overlay, which you could use to superimpose chiral molecules. To find out how to access more advanced functionality with a CSD-Core license see <https://www.ccdc.cam.ac.uk/solutions/csd-core/>