CCDC
advancing structural science

Crystals Showcase.

At the Cambridge Crystallographic Data Centre (CCDC), crystals are celebrities! We collect information on new crystals that scientists discover, we share them with the world, and we study new ways to understand more and more about crystals, supporting the advance of research. Did you know that understanding and learning from crystals helps scientists to develop new medicines?

But what are crystals? Before getting into our favourite subject, let's review the states of matter together!

! Before starting: This activity should be easy and safe to follow but it is carried out at your own risk. Please read the health and safety guidelines on the **activity webpage** to reduce risks.

This activity will take approximately from one to two hours to complete.

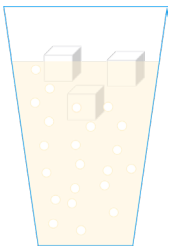
States of matter

1 To begin with, we ask you to be aware of what is around you. Take time to use your **senses**: what can you see, taste (if you know it is safe to eat!), feel, and smell?
Make a list here. Your list might include what your desk, drink holder, drink or snack are made of or other things you can find around you.

Tip: Search for the words in **bold** in the glossary at page 10 of this document.

With all probability, some of the substances you identified are in a solid state, while others are in a liquid state, and others are in a gas state. Solid, liquid and gas are three different states of matter, which means that you can find the substances in these different forms.

We drew some examples here, and you can add your own drawings!



2 You are able to recognise and distinguish these three states with your naked eye and your senses: this is called a **macroscopic** observation.

Can you think of any macroscopic characteristic (something you can observe with your senses) that distinguishes gas, liquid and solid?
List them here.

3 These three states are different also in the behaviour of the **molecules** that make the substance. This is called a **microscopic** observation, as it is too small to see with the naked eye.

Read forward to learn the differences.

Solid

Macroscopic: A solid has a specific shape and size, which you can measure by its volume. Solids do not take the shape of the container you put them in and they keep their shape unless a force is applied to them.

Microscopic: The **molecules** or **atoms** that compose the material are in specific places. And they do not change position! They are very close to each other, and they create connections with the molecules around them. When a molecule is part of a solid, this network of connections does not change over time: they always see the same neighbours!

Liquid

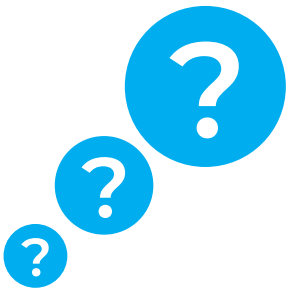
Macroscopic: Liquids do not have their own shape but take the shape of the container that hosts them. You can notice this every time you pour water from a bottle into a glass. The volume of the liquid does not change during this process.

Microscopic: In liquids, molecules do not have a fixed place or a defined organisation. They still create connections with the molecules around them, but these are weaker than in a solid. This allows them to travel around and meet new friends every time!

Gas

Macroscopic: Gases do not have any shape, so they easily and quickly adapt to the container you put them in, or sometimes they escape from it! Can you think of a container full of gas? Any room: we are always surrounded by air. Even empty boxes you find in the kitchen are actually full... of air! It might be hard to catch a gas, but you can sometimes feel it moving around you, if it is hot or cold, and you can sometimes smell a gas.

Microscopic: Molecules in a gas are completely free to travel around. They are very far from other molecules (well, from their point of view!) and do not create significant connections.



Substances can also change their state! When this happens, the transformation between one state to the new one is called a **phase transition**.

Another fantastic fact is that some things can contain a molecule in more than one state. Have you ever thought of a cloud? This can contain gas, liquid (ready to rain on you) and solid (ice ready to snow or hail on you).

As science and technology advance, more new and unusual states of matter are identified. Isn't it fantastic?

4 Can you identify the state?

Here is a list of molecules and substances. Do you know any of these? In which state do you encounter them in everyday life?

For this activity, match each substance from the following list and from your own list in question 1 to the appropriate state or states.

As an example, we completed the row for water.

substance	*solid*	*liquid*	*gas*
H_2O, water	x (*ice*)	x	x
CO_2, carbon dioxide			
N_2, nitrogen			
$C_{57}H_{108}O_6$, cocoa butter			
$C_{12}H_{22}O_{11}$, sugar			
$C_8H_9NO_2$, paracetamol			
He, helium			
C, diamond			
SiO_2, quartz			
C_8H_8, styrene			
H_2S, hydrogen sulfide			

Tip: At the end of this activity, you can compare your answers with the discussion in the ***Discussion handout***, where you can also find an extra table for your entries.

Crystals!

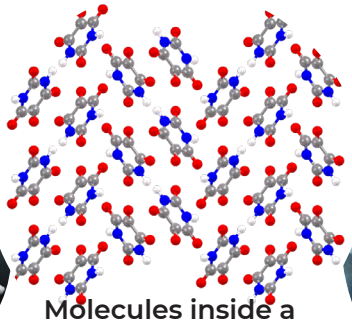
5 What are crystals?

Crystals are one of our favourite things!

Crystals are a type of solid where the atoms or molecules are positioned in a specific (and often beautiful) geometric organisation. This geometric pattern repeats identically throughout the crystal. So, you could say crystals are a bit like wallpaper but they have repeating molecules rather than a repeating picture, they are in 3D and they are much, much smaller.

Commonly when we think of crystals we think of beautiful rocks, mineral formations, and gems. But, there are many more crystals with very different sizes and uses! You can find some crystals in the kitchen, like table salt, sugar, and even **chocolate** has a crystal structure. Drugs are also often found in crystal form, especially in tablet or granulated powders .


C atoms in diamond


Molecules inside a crystal - CSD Entry ALOXAN


A beautiful crystal!


Sugar crystals

6 How many crystals exist?

You are asking us a very difficult question! We do not know how many crystals there are, but we can keep track of how many different crystal structures have been identified by scientists. Different databases exist that contain this information, and they specialise in different types of molecules. Here at the CCDC we curate the **Cambridge Structural Database** (CSD), which has more than one million different crystal structures! The number of crystal structures that exist must be much bigger than that, and do not forget the ones that still have to be discovered.

To help you learn about some of the different crystal structures that exist we have collected together some of the most interesting, recognisable and our favourite structures to use in education. We call this collection our **teaching subset**, which we consider would be very useful in helping you to learn about different aspects of science.

Don't forget to have a look at some of these magnificent structures later!

Crystals Crosswords

7 Now that we have learnt more about the states of matter and crystals, let's see if we can fill in this puzzle. Complete the crosswords using words related to crystals and the states of matter.

Hint: the words in bold and in blue that you found along the text are a good place to look for answers.

For the youngest learners: If you are finding our crossword a bit challenging, then see if you can find the same words on our **Words Search** at page 8, instead. Across and down still apply, but the order may vary.

Definitions - Across

2. An observation of this type is one you can do with your naked eye.

4. The science that studies crystals.

7. Groups of atoms held together by bonds.

8. The acronym (initials) for an organisation full of people who love crystals and love talking about them!

11. A transformation of a substance that changes its state. (Two words)

16. A place that contains lots of data. *Hint*: in our case the data are about crystal structures.

17. The acronym (initials) for a database where you can find more than one million crystal structures.

Definitions - Down

1. A solid material, with molecules organised in a pattern.

2. Something too small to be seen with a naked eye.

3. The state of matter where molecules are very far from the others.

5. The smallest building block of matter.

6. A very important ingredient for the CCDC Home Learning.

9. Strong connections that hold atoms together in a molecule.

10. When molecules form weak connections with their neighbours and are free to travel around, they are in this state of matter.

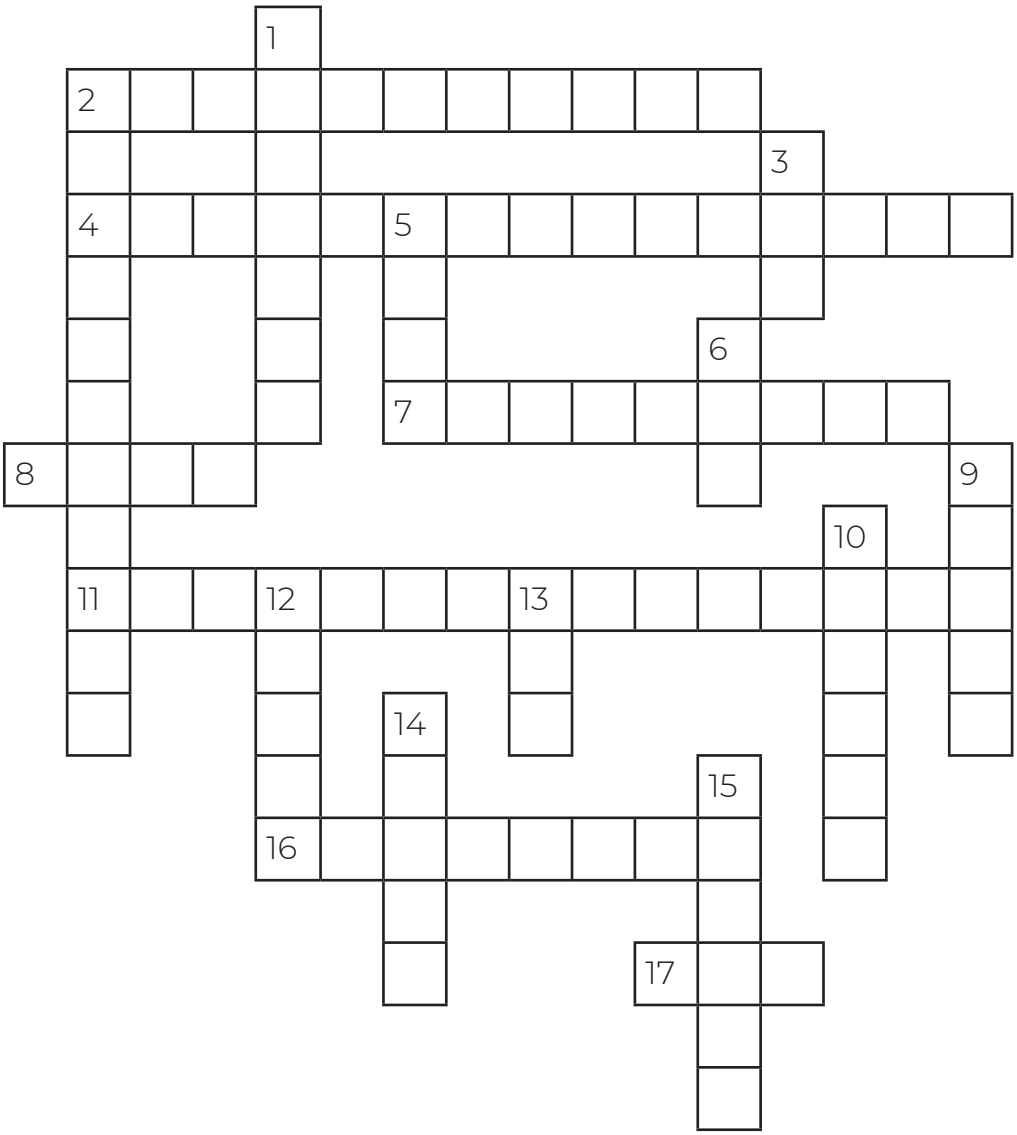
12. The state of matter that does not change its shape to fit a container.

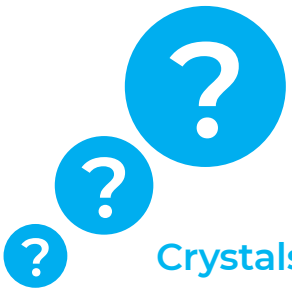
13. Empty things in the house are full of it.

14. A molecule that we drink every day.

15. We used these a lot in this activity to learn more about our surroundings.

Crystals Crosswords





Crystals Words Search

M	A	C	R	O	S	C	O	P	I	C	A	C	S	D
I	C	R	E	S	T	R	U	I	L	H	G	I	E	R
C	R	Y	S	T	A	L	L	O	G	R	A	P	H	Y
R	W	S	I	D	T	I	C	R	I	S	S	A	L	S
O	A	T	E	S	O	L	U	D	S	F	R	U	C	T
S	T	A	H	E	M	O	L	E	C	U	L	E	S	N
C	E	L	T	N	T	A	E	R	O	N	E	T	A	B
O	R	W	A	S	A	C	C	D	C	N	N	L	E	O
P	H	A	S	E	T	R	A	N	S	I	T	I	O	N
I	R	C	O	S	L	O	I	D	B	E	A	Q	U	D
C	A	E	L	T	W	S	R	O	U	R	D	U	I	S
S	O	Z	I	D	A	R	H	T	I	A	M	I	M	K
B	S	E	D	A	T	A	B	A	S	E	C	D	C	D

8 Crystals Gallery

We have learnt so much about what makes crystals *crystals* and distinguishes them from less ordered solids and different states of matter, that we almost forgot to admire how beautiful they are.
It is time to head to our gallery on the activity webpage and admire the showcase! You can also observe the 3D structures of some crystal structures from the CSD.

Do you have any picture or drawing of crystals that you would like to show us? Did you draw something inspired to this activity?
We would like to see it! You can post it on social media and tag us (Twitter @ccdc_cambridge, Facebook @ccdc.cambridge, Instagram @ccdc_cambridge). We are looking forward to seeing more crystals!

9 Congratulations on completing the activity!

It is time for the learners to collect their badge. You can find a downloadable copy of the virtual badge following the directions in the activity webpage.

This activity is just a taste to introduce you to the wonderful world of crystals. If you want to learn more about crystals, a more comprehensive handout is available in our **teaching resources space** for learners aged 16+.

If you enjoyed observing the world around you and discovering molecules from the everyday life, then you cannot miss the **Identikit of Common Substances** where you will learn more about substances like sugar, chocolate, lemons and mint (age 8+).

The solutions of the Crystals Crosswords and Crystals Words Search are available on the activity page from the 12th August 2020.

Glossary

Atoms are the basic building-block of all matter and are the smallest unit of a chemical element. Did you know the word atom comes from Greek and it means "*that cannot be cut*"?

Bonds are strong chemical connections formed between atoms.

A **molecule** is a group of two or more atoms that are held together by bonds.

A **crystal** is a solid material where molecules or atoms are packed in an ordered way. Crystals have specific geometries and shapes.

A **phase transition** is the transformation that a substance undergoes to change its state. Phase transitions between specific states have specific names. For example, the transformation from liquid to solid is called *freezing*, while from solid to liquid is called *melting*.

The term **macroscopic** refers to things you can observe with a naked eye. **Microscopic**, instead, is for things too small to be seen with a naked eye, for example molecules.

CSD is the acronym for Cambridge Structural Database. This is the database curated by the CCDC that contains the data of over one million crystal structures!

In this activity we used our **senses** to investigate our surroundings. The five senses are sight, smell, touch, hearing and taste.