CCDC
advancing structural science

Lego, Chocolate, and Polymorphs.

What is a crystal?

A **crystal** is a solid made of different **atoms** or **molecules** repeating over and over in a regular pattern. A bit like tiling, but in 3D!
You could think of the atoms or molecules inside a crystal as a lego brick. A crystal would be the block of lego bricks joined together. The properties and stability of the crystal depend on how these atoms and molecules, or in our case the lego bricks, are arranged.

What is a polymorph?

If the same molecules can be arranged together in different ways, these are called **polymorphs**. Different crystal polymorphs will have different stabilities and different properties. For example, a less stable polymorph might melt at a lower temperature, while different polymorphs might have different capabilities to dissolve in a solvent (i.e., different **solubilities**).

Why do we study polymorphs?

Scientists research polymorphic forms to ensure that the crystals produced show specific properties for the correct functionality of the product. This is very important! For example, drugs might be required to be absorbed by the patient's body over a specific time: the presence of a polymorph with non-suitable properties might compromise the functionality of the drug.

Tip: Look up the words in **bold** in the glossary at the end of the activity sheet!

Before starting: This activities are carried out at your own risk. Please read the health and safety guidelines on our **webpage** to reduce risks.

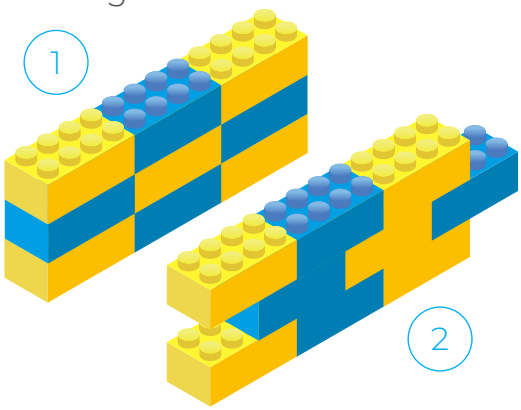
Activity 1 - Can you identify the most stable crystal structure?

The crystal contains two different molecules:

MOLECULE A

MOLECULE B

1 Using lego build two different walls containing both molecules on a lego base:



2 Which wall is easier to knock over and break?

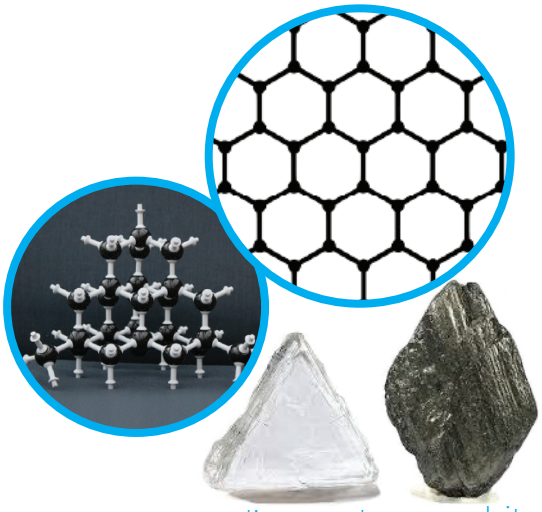
3 If these were crystal structures which one do you think is the most stable?

4 Can you build more lego polymorphs with different repeating patterns?
Like in polymorphic crystals, you will notice that only some constructions are stable.

5 In the world there are lots of different crystals. Can you think of any crystals you know?

6 Do you know any crystals that contain the same chemicals but in a different arrangement like our lego brick walls? *Hints: one is in the activity title, and another is in your pencil.*

7 Diamond and graphite are both solid materials containing carbon. What different properties do you observe between the two forms?



diamond graphite

Tip: You can find a discussion of questions 2, 3, 5, and 7 in the last page of this handout.

Did you know: Cocoa butter, one of the ingredients of chocolate has different polymorphs?

The molecules in cocoa butter have at least 6 different ways that they can arrange themselves in a crystal. As we have learnt, each polymorph might show very different properties. Polymorph number 5 is the desired form in **chocolate** bars, as it snaps when you break it, it melts in the mouth, and has a glossy, smooth appearance. If you have ever accidentally left one of your chocolate bars somewhere warm and it has melted, when you cool it down again the chocolate bar turns slightly white (this is called *blooming*). This is because 4 other forms of cocoa butter have a lower melting point and you need to go through some extra steps, called *tempering*, to turn melted chocolate into a nice glossy polymorph 5 chocolate bar.

Activity 2 – Chocolate polymorphs (optional)

If you want to see this for yourself, you will need two squares of chocolate, preferably dark. Take one square of chocolate and leave it somewhere warm to melt. You could do this by leaving it on a plate in the sunshine or near a radiator. Once it has melted place it somewhere cold, like in the fridge, so the chocolate turns back into a solid. Now compare this square of chocolate with the un-melted one. Let's use our senses. First, break the squares and listen to the sound they make. You might hear a sharper snap from the un-melted square. Then, what differences can you observe in their appearance? Examine the colour and the texture. The square that we melted and solidified will be lighter outside, as it presents blooming, and more grainy inside. For the best part of the activity, taste each of them: although they taste the same, the texture will feel different.

Tip: You can find more information about the structure of chocolate in the dedicated handout.

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 means "*that cannot be cut*"?

Molecules are a group of two or more atoms that are held together by a bond.

A **crystal** is a solid material where molecules or atoms are arranged in a well-defined order. Crystals have specific geometries and shapes.

Polymorphs are crystals made of the same molecules, but that differ in how they pack together.

Solubility is, in this context, the capability of a solid to dissolve into a liquid.

Chocolate is tasty and polymorphic!

Answers to Activity 1

Questions 2 and 3: Wall number 1 is easier to knock over and break. If walls 1 and 2 were polymorphic crystals, this would mean that polymorph/wall 1 is less stable than polymorph/wall number 2.

Question 5: Table salt and sugar are examples of crystals you meet on the dining table. You will find more common crystals in the activity "Identikit of common substances".

Question 7: Different properties observed for diamond and graphite include colour, hardness, density.

Diamond is a less stable polymorph than graphite, even though it appears to be stronger. What does it mean practically? The less stable polymorph will eventually transform into the most stable form. So, did the James Bond movie lie to us with the title "Diamonds are forever"? Fear not: this process is extremely slow, it could take billions of years! So, James Bond told us a partial truth, and we guess the title "Diamonds are less stable than graphite but will still last for an extraordinary long time" was not as catchy.

Congratulations on completing the activity!

You can download your collectable virtual badge following the instructions on our webpage.

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