Crystals

At a glance

	Content summary	National Curriculum links	Activities
Lesson 1	What are crystals? Growing crystals	Particle theory; pure / impure substances; scientific terminology; working scientifically	**Activity A:** What is a crystal? How do we use crystals? **Activity B:** Growing crystals
Lesson 2	Growing crystals, continued Current and historical properties attributed to crystals	Working scientifically; scientific knowledge explains natural phenomena	**Activity C:** Claims about crystals

Background and National Curriculum links

These activities are intended for two lessons for Year 7-9 students, focusing on crystals. In the first lesson, students consider substances they think are crystals, compare these with substances that are crystalline, and set up crystal growing experiments. In the second lesson, they examine the results of the crystal growing. They discuss people's beliefs about crystals and consider how scientific knowledge explains natural phenomena.

Lesson 1

Students inspect crystals, finding out that these have regular structures (Activity A). They set up crystal growing experiments using saturated solutions and 'seed' crystals (Activity B).

National Curriculum

- Students work scientifically. They use an appropriate technique and materials to grow crystals. They record observations. They can measure the crystals at the start and end of the growing period.
- Crystals reinforce learning about the particulate nature of matter; the difference between pure and impure substances; and understanding of the terms 'dissolving', 'solution' and 'crystallisation'.

Lesson 2

Plan Lesson 2 to take place a minimum of two days after Lesson 1. Inspect the crystal growing experiments started in Lesson 1 (Activity B, continued). In 'Claims about Crystals' (Activity C) students find out about crystal pseudoscience. Some people believe crystals have 'energy', 'healing powers' and can store or amplify emotions. Encourage students to challenge these claims using scientific evidence. This will help students understand that science is about working objectively.

National Curriculum

- Science offers rational, evidence-based explanations for phenomena. Science involves working objectively.
- Scientific ideas that we know are true today are often different from those that have developed through history. Scientists modify ideas using evidence. Pseudoscience is not science.

Teacher subject knowledge

- The lessons can be taught by science teachers of any subject background.
- A history specialist may help maximise potential from the cross-curricular links in Lesson 2.

Cross-curricular links: ancient history and social uses of crystals

Many civilisations have adopted crystals as a source of healing, to provide protection, or aid recovery from difficult situations. Lesson 2 gives an opportunity to investigate ancient history. About 6000 years ago, the Sumerians formed what is regarded as the first civilisation, living in Mesopotamia, which is now part of modern Iraq. Sumerians were familiar with crystals such as lapis lazuli, alabaster and carnelian. Egyptians made scarabs from semi-precious stones such as lapis lazuli and amethyst. Scarabs were supposed to have protective and healing properties. The use of crystals to foresee events was first recorded in the first century AD by Pliny the Elder. He describes soothsayers using crystal balls later called *orbuculi*. The tradition of making decisions about the future based on 'scrying' or what could be seen in a crystal ball remained popular into the Victorian era. Today, crystal healing is an example of alternative medicine. Specific crystals are associated with healing certain types of illness, or provide emotional support. Some people believe crystals carry energy. There is no scientific evidence for any of these claims. Meanwhile, many cultures use precious stones such as diamonds, emeralds, sapphires and rubies (among others) in jewellery to symbolise personal commitment, wealth and prosperity.

Student background knowledge

Students may hold prior knowledge about crystals in everyday life, such as precious and semi-precious stones in jewellery; soda crystals for washing and reducing lime scale; salt crystals added to food; snowflakes each being a uniquely structured water crystal; and some may be aware of 'crystal energy'. The usage of liquid crystals in display screens (mobile phones, plasma screens, etc.) may also be well known.

Resources and timing

Two 50 – 60 minute lessons are required. There are three activities for students labelled A, B and C. Before Lesson 1, saturated solutions of one or more salts for growing crystals should be prepared for Activity B.

Technical requirements

Lesson 1

Activity A: What is a crystal?

- Hand lens;
- Samples of solid substances for example:
  - Non-crystalline (amorphous) – rubber, jelly cube, paper, leaf, wood, fabric, glass, butter, chocolate, sponge, ceramic
  - Crystalline – metals, e.g. paper clip, copper wire, zinc granules, magnesium ribbon; rocks and minerals, e.g. granite, basalt, calcite, sand, fluorite, diamond, quartz, amethyst; salts, e.g. copper(II) sulfate, sodium chloride; compounds, e.g. sugar, ice; non-metallic elements, e.g. sulfur, iodine (HARMFUL), graphite
  - Mixed / composite – e.g. soil, clay, coal, plastics

Label samples with names only. Do not indicate if samples are metals, composites, etc. When laying out the samples, ensure that the collection is placed randomly, not grouped by type of substance. Make sure a wide variety is provided.

Activity B: Growing crystals

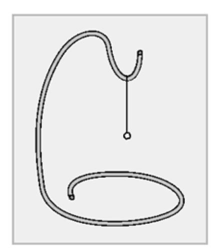
Making seed crystals: To be completed by technical support about 48 hours prior to the lesson:

- 250 cm^3 beaker
- Access to a balance
- Glass rod
- 100 cm^3 water
- Eye protection
- Bunsen burner and heatproof mat
- Tripod and gauze
- 20 g alum (aluminium potassium sulfate, $AlK(SO_4)_2.12H_2O$) plus a few extra grains
- Watch glass
- Clingfilm to seal the beaker, or a screwtop container such as a jam jar
- Spatula
- 100 cm^3 measuring cylinder

1. Measure 100 cm^3 water into the beaker.
2. Add 20 g alum.
3. Sit the beaker on the gauze over the Bunsen burner.
4. Heat the water and alum gently, stirring with the glass rod.
5. Stop heating when the solid has dissolved. This occurs when the water is at about 50°C.
6. Remove the beaker from the gauze.
7. Cover with the watch glass. Leave to cool.
8. When the contents of the beaker are at room temperature, add a few extra grains of alum. Stir.
9. Cover the beaker again and leave for about 48 hours. If possible, stir the solution occasionally. The solution is saturated and ready when no change occurs to the amount of solid at the bottom of the beaker.
10. Pour a small amount of the solution into a watch glass. Leave this undisturbed to crystallize.
11. Cover the remaining solution in the beaker with clingfilm.
    Save for growing large crystals.
12. When crystals have formed in the watch glass, these can be removed to a clean dry container for use in Lesson 1.

Growing large crystals: To be started by students in Lesson 1

- 100 cm^3 beaker
- Wire 'cobra' to sit inside the 100 cm^3 beaker - see diagram
- Saturated solution saved from stage 1
- Hand lens
- Sewing thread
- Porous cloth and rubber band to cover the beaker
- Access to tweezers
- Bunsen burner and heatproof mat
- Tripod and gauze



'Cobra' for hanging the crystal

Alternative substances for Activity B: Growing crystals

Table 1 shows alternatives to alum, with details of mass values and temperatures needed to make saturated solutions.

Table 1: Alternative substances for growing crystals.

Substance	Mass / g 100 cm^{-3} water	Temperature /°C
Sodium chloride	40.0	50
Sucrose	248.8	45
Potassium sodium tartrate, 'Rochelle salt'	130.0	50
Hydrated magnesium sulfate, 'Epsom salts'	31.3	40
Disodium tetraborate, 'Borax'	10.0	100
Copper(II) sulfate (HARMFUL)	30.0	50

Lesson 2

Activity B: Growing crystals (continued)

Provide the solutions set up by students in the crystal growing experiment in Lesson 1. To examine the crystals students need:

- Paper towels to dry the crystals
- Ruler
- Hand lens

Activity C: Claims about crystals

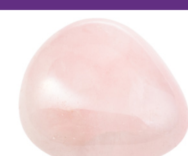
Name and non-scientific claim	Image Photos: iStock.com
Rose quartz This stone is the centre of universal love. It restores trust and harmony in relationships. The stone harnesses the rays of commitment, caring and determination.	
Citrine Citrine carries the power of the Sun. It provides warmth and energy. It can raise self-esteem and motivate and revitalise the mind.	
Aventurine Aventurine helps mental healing and calms irritation and anger. It protects against electromagnetic pollution created from everyday electronic devices.	
Amethyst Amethyst is a powerful and protective stone. It has a high vibration. It helps to protect against psychic attacks and enhances the memory.	

Table 2a: Names, claims and images of four crystals.

Table 2b: Names, claims, images and scientific information about four crystals

Name and non-scientific claim	Image	Scientific name, formula and information
Rose quartz This stone is the centre of universal love. It restores trust and harmony in relationships. The stone harnesses the rays of commitment, caring and determination.		**Rose quartz** is a form of silicon dioxide, formula SiO_2. Silicon dioxide is the 2nd most abundant mineral on Earth. The colour in rose quartz comes from titanium, iron and manganese impurities.
Citrine Citrine carries the power of the Sun. It provides warmth and energy. It can raise self-esteem and motivate and revitalise the mind.		**Citrine** is a form of silicon dioxide, formula SiO_2. Silicon dioxide is the 2nd most abundant mineral on Earth. The colour in citrine comes from iron impurities.
Aventurine Aventurine helps mental healing and calms irritation and anger. It protects against electromagnetic pollution created from everyday electronic devices.		**Aventurine** is a form of silicon dioxide, formula SiO_2. Silicon dioxide is the 2nd most abundant mineral on Earth. Aventurine is often green but can be brown, grey or yellow. The green colour comes from chromium impurities.
Amethyst Amethyst is a powerful and protective stone. It has a high vibration. It helps to protect against psychic attacks and enhances the memory.		**Amethyst** is a form of silicon dioxide, formula SiO_2. Silicon dioxide is the 2nd most abundant mineral on Earth. The violet colour of amethyst comes from irradiation as the stone formed, and iron impurities. It may turn yellow like citrine if heated.

Activities

Lesson 1

Activity A: What is a crystal? How do we use crystals?

Terminology to introduce / explain:

- Crystal – from Greek 'krustallos'.
- Lattice – a crystal is made from particles arranged in a regular structure called a lattice.
- Crystalline – the adjective to describe a substance that is a crystal.
- Igneous rocks – formed when molten magma from a volcano solidifies. Slow solidification results in large crystals of rocks, for example, granite and basalt.

What is a crystal?

1. Ask students to name substances they think are crystals. For each named substance, ask for a reason why they think this is a crystal or 'is crystalline'.
2. Build up a list of substances and reasons. Ask students to identify any patterns.
3. Note any difficulties and challenges in classifying a substance as a crystal. Point out that scientists devise classification systems to help with these.
4. Set this discussion aside for later.
5. Ask students to examine the range of substances with hand lenses. Ask them to develop a classification for the substances, each with criteria, starting with two straightforward classes:
    a. Crystalline
    b. Non-crystalline
6. Next, once these are agreed, ask students to investigate sub-classes of each type, again with reasons. This could lead to:
    a. Crystalline – metals, salts, minerals
    b. Non-crystalline – no structure ('amorphous'), mixtures / 'composites'
7. Now focus on the properties crystals share. For example:
    a. Regular structure, or evidence of a regular internal structure
    b. Shiny – surfaces are smooth, reflect light
    c. Hard – rigid structures, solids
    d. Transparent or opaque – contrast diamond, graphite
8. Revisit the substances students listed earlier – how would they classify these now?
    a. Note that students may be surprised that metals are crystals, also everyday substances such as sugar.

How do we use crystals?

9. Discuss uses of crystals – where and why do we use crystals?
    a. Expensive jewellery
    b. Metallic coating, e.g. zinc plating, or galvanizing
    c. Liquid crystal displays
    d. Diamond cutters
    e. Watches

Activity B: Growing large crystals (instructions given for alum)

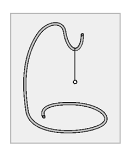
The time required can be minimised by pre-preparing the wire cobra hooks, making the seed crystals and providing the saturated solutions (see Requirements). Note that 48 hours are needed for seed crystals to develop.

Students need to identify a good seed crystal. Suggested criteria are: regular shape, large enough to tie on a thread and with no obvious flaws, e.g. rough corners. This is tied to a thread and hung from the cobra.

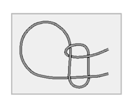
If possible, provide a range of saturated solutions and seed crystals so that students can grow a variety of crystals (see Table 1, above). Some are easier to grow in school laboratory conditions than others.

Activity B: Growing large crystals from seed crystals

1. Make a cobra from the wire using the diagram as a guide. Make sure that the cobra will sit so that the curved hook will allow a crystal to dangle into a 100 cm^3 beaker.
2. Choose a seed crystal. Examine the crystal with a hand lens. Measure, describe and draw or photograph the crystal.
3. Tie thread around the crystal using a slip knot (see diagram).
4. Tie the other end of the thread to the cobra hook.



'Cobra' for hanging the crystal



Slip knot for tying the crystal with thread

5. Remove the cover from the beaker of saturated solution.
6. Heat the solution gently until all solid particles at the bottom of the beaker are dissolved.
7. Pour the solution into a 100 cm^3 beaker.
8. Cool the solution to about 25°C.
9. Sit the beaker under the cobra so that the crystal hangs in the solution.
10. Carefully cover the set-up with a porous cloth, or a 'tent' made from filter paper or similar.
11. Leave the beaker undisturbed for about 48 hours. This should allow enough time for a reasonably-sized crystal to form.

Troubleshooting crystal-growing

Crystals may not grow. This could be because:

1. The solution was not super-saturated. Heat the solution to a higher temperature and add more solid. Then repeat from step 7 onwards.
2. The temperature changed while waiting for crystals to form. Re-heat the solution, add more solid, then repeat from step 7 onwards. Try to keep saturated solutions at a constant temperature.
3. The humidity changed while waiting for crystals to form. If this is a problem, grow the crystals in a jar that can be sealed, e.g. a jam jar. Add 2-5 g of the substance to the saturated solution. Stir to dissolve. Tie the seed crystal to thread wrapped around a cardboard disc that fits under the lid of the jar. Stick the cardboard disc in place. Fix the lid to the jar. Keep the jar at a constant temperature.

Extensions

An imitation snowflake

Rather than a seed crystal, shape a pipe cleaner into a six-pointed star and hang this from the cobra to make a 'snowflake'.

Making snow crystals

Each snowflake is a unique crystal of water ice. See some images taken by William 'Snowflake' Bentley at:
https://www.rsc.org/education/teachers/resources/contemporary/student/pop_snow.html.

Snow crystals can be grown in a plastic bottle. See:
https://www.youtube.com/watch?v=ExvA5V6CUq0.

Diamonds

Investigate the origin of diamonds, the world's most well-known and loved precious gemstones. The story of the biggest diamond ever found, the Cullinan, is available at:
https://www.rct.uk/collection/themes/trails/the-crown-jewels/the-cullinan-diamond

This website explains how diamonds form:
https://science.howstuffworks.com/environmental/earth/geology/diamond1.htm

Discuss with students why diamonds are regarded as so precious.

Lesson 2

Activity B, continued

Examine crystals grown from Lesson 1. Some large crystals should be available to observe. Discuss crystals formation using scientific terminology, including:

- Saturated solution, Super-saturated solution, Evaporation, Dissolving

Compare and contrast the crystals. Measure, describe, draw / photograph the crystals. Compare the grown crystals with the seed crystals they started with. Explain how the seed crystals 'grew':

- The large crystals and seed crystals should have the same shapes. The seed crystals provide a surface for particles of the substance in solution to attach to. In a saturated solution, a lot of substance is dissolved. When water evaporates slowly from a saturated solution, and the solution cools, solid substance crystallises.

Discuss questions such as:

1. Why are crystals different shapes?

   The shapes are different because the substances in solution are different. They comprise chemical elements that have atoms of different sizes. These pack together tightly in solid crystals. The sizes mean that crystals are different shapes. Water molecules are also packed into crystals. These affect crystal shape.

   Why are the solutions kept covered and glassware perfectly clean?

2. This prevents impurities such as dust particles getting into the crystals. If glassware is not clean, other substances could be present as impurities.

3. What is a 'saturated' solution?

   A saturated solution is prepared by adding solute to a solvent until the solute starts to appear as solid substance in the solution. This is usually at the base of the beaker / vessel.

4. What is a 'super-saturated' solution?

   A super-saturated solution holds more solid than it normally would as a saturated solution. To make a super-saturated solution, a saturated solution is heated gently and more solute is added. The solution is cooled slowly. Excess solid crystallizes out when a seed crystal is added.

5. What is happening as the solutions cool?

   When the solutions cool, excess solute crystallises out. Some water evaporates.

Activity C: Claims about crystals

For steps 1 – 3, provide Table 2a.

1. Examples of non-scientific claims about crystals are provided. Ask students to discuss if they think these non-scientific claims are:

   TRUE FALSE MAY BE TRUE

   Invite students to give reasons for their answers.

2. Why do people think these non-scientific claims are true?

   Many people do not think scientifically; crystals offer easy ways of possibly solving difficult problems; there is a long history of crystals being an 'alternative' therapy or a way of 'seeing' the future (see Cross-curricular links); people can be persuaded by stories of 'positive' results; claims can be persuasive and made to sound scientific.

3. Discuss what evidence would be needed to prove / disprove the claims.

   Prove: We could design an experiment to test claims (without a need to carry it out) made about a crystal. This could include the crystal in a 'test' situation as an independent variable, comparing with a 'control' situation without a crystal.

   Disprove: We could find out what the crystals are made from. Are they really different substances that could be like medicines we take for different illnesses? Or are they all the same substance?

After this discussion, give students Table 2b.

4. What do they notice about the 'Scientific name, formula and information' for these crystals?

   From Table 2b we learn that scientific evidence shows that the four crystals are the same substance, silicon dioxide. Silicon dioxide is sand, which is found in many places around the world. Scientists think that these minerals formed in igneous rocks, in gas cavities in volcanic lava. Lava cools and solidifies around the gas cavity creating special conditions inside. When the rock is cold, the cavity still exists as a 'geode'. The minerals crystallised in the conditions in the cooling cavity. The cavities contained silicon dioxide and small amounts of metal impurities.

5. What is 'good scientific evidence'? How can we make sure that facts we accept as 'true' are based on good scientific evidence?

   Scientific evidence is: objective, not biased; based on repeatable results; reviewed by scientists who agree with the results; unchanged over time.

   Using the scientific information in Table 2b, discuss if the non-scientific claims about these crystals could be true – they are all the same substance, but with very different 'properties'!

6. Remind students that crystal healing is a pseudoscience and that none of the non-scientific claims have any evidence to show that they are true.

Extension: An imitation geode

A geode is a piece of rock inside which crystals form. Make an imitation geode by pouring some saturated solution into the two halves of a walnut shell. Support the shell, for example in an egg box. When crystallisation occurs, the result is like a geode.

Claims about crystals

A wide range of crystals are used in crystal healing. Table 2a shows some non-scientific claims about some crystals.

Table 2a: Names, claims and images of four crystals.

Name and non-scientific claim	Image Photos: iStock.com
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Citrine Citrine carries the power of the Sun. It provides warmth and energy. It can raise self-esteem and motivate and revitalise the mind.	
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Amethyst Amethyst is a powerful and protective stone. It has a high vibration. It helps to protect against psychic attacks and enhances the memory.	

Image sources: iStock.com

Table 2b: Names, claims, images and scientific information about four crystals.

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