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Chemical Institute of Canada | ***For Our Future***

The 2023 National Crystal Growing Competition Handbook

Including:

- Information on the competition
- A guide to crystal growth

Special thanks to our sponsors :

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Mineralogical Association of Canada
Association Minéralogique du Canada

CCDC advancing structural science

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Table of Content

A word about our sponsors

These scientific companies, and this association, have generously accepted to sponsor this competition. Without them, this competition would not be possible! They all share a common passion for science, and in most cases, specifically for crystals. Here are, in their words, their main interets. Perhaps some of our participants will, one day, be part of these organizations?

SolidStatePharma®	Solid State Pharma is a Halifax based pharmaceutical research company with speciality in crystallization engineering and solid-state science. As a partner to global pharmaceutical companies, SSPI combines rigorous experimentation with insightful analysis to generate knowledge, not just data.
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CCDC advancing structural science	The Cambridge Crystallographic Data Centre (CCDC) are world-leading experts in structural chemistry data, software and knowledge for materials and life sciences research and development.
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Information on the National Crystal Growing Competition

What is the Chemical Institute of Canada?

The Chemical Institute of Canada (CIC) is a Canadian, not-for-profit association of professionals involved in the field of chemistry, chemical engineering and chemical technology. The CIC association organizes outreach activities promoting chemistry to students and the public. The National Crystal Growing Competition, which has been going on for more than thirty years, is one of these.

How does this competition work?

The competition aims at growing the largest and highest quality crystal possible. It takes place in Canadian high schools during the fall semester. Winning crystals from each school are sent for evaluation, first to a regional coordinator, and regionally winning crystals are sent for judging at the national level.

Competition schedule

The 2022 competition schedule appears below. In case of abnormal delivery delay of the substance to be crystallized, please contact your regional coordinator, who will adjust dates if required.

August 28 to September 1st	Competition announcement sent to high schools by regional coordinators
September 1st to October 2nd	Schools register with their regional coordinator
September 1st to October 2nd	Schools order/purchase their chemicals
October 10 to November 13	Crystal growth
November 13 to 20	Schools choose their representing crystals
November 20	Deadline to send your two best crystals to regional coordinator
December 4	Deadline for coordinators to send their winning crystals to the national coordinator
Early January	National judging: results are sent to regional coordinators

What can I win?

Students and their teachers can win cash prizes for their school and will receive individual certificates for the national prizes. Prizes will be posted on the Competition web site.

Who can participate?

All Canadian high school students or homeschooled youth between the ages of 13 and 18 (included) can participate. Students can participate individually or as teams. There are no fixed limits to the number of participants per school.

The competition is also open, although in a separate division, to high school teachers and lab technicians.

Whom am I up against?

Participants are assigned to the following four divisions:

- Division 1: High school students within regions that have coordinators. Crystals are submitted to the regional coordinator for regional judging.

- Division 2: "Outlier" high school students are those living outside regions that have coordinators. These crystals will be submitted to the national coordinator for "regional" judging.

- Division 3: Home-schooled students. Please see coordinator list on the web site.

- Division 4: High school teachers. High school teacher crystals are judged for overall quality on a national basis only, separate from crystals submitted by students. These are submitted directly to the national coordinator for judging.

Winning crystals in each regional section of Division 1, and in Divisions 2 to 3 are pooled against one another for the final, national judging.

How do I sign up?

All you need to do is contact your regional coordinator to let him/her know that you are participating. If you are unsure of who your coordinator is, contact Josée Brisson, national coordinator at josee.brisson@chm.ulaval.ca . Please do not overlook this step, as it allows regional coordinators to organize their event and contact participants if their crystals do not arrive.

Parents of home-schooled students should register directly with the national coordinator, at josee.brisson@chm.ulaval.ca, or with Gale Hanlon at info@learnfree.ca.

If you cannot find your regional coordinator in the list posed on the competition web site, please contact Josée Brisson, national coordinator, at josee.brisson@chm.ulaval.ca.

Important contacts

National coordinator
Josée Brisson, MCIC
Department of chemistry
Université Laval
1045 Avenue de la Médecine
Quebec (Quebec) G1V 0A6

Tel.: 418-656-2131, ext. 403536
josee.brisson@chm.ulaval.ca

CIC Office
Philip Glowacki
Member engagement coordinator
Chemical Institute of Canada
Ottawa (Ontario) K1P 5V9

Tel. : 613-232-6252 ext. 234
pglowacki@cheminst.ca

To order your material:

In 2023, the crystals will be grown from **aluminum potassium sulfate 12-hydrate.**

Contact Boreal Science by phone at 1-800-387-9393, by fax at 1-800-668-9106 or by e-mail at scied_boreal_main@avantorsciences.com, between September 1st and October 2nd.

When ordering use **quote number 8602779435–item No. 470300-154,** aluminum potassium sulfate 12-hydrate. The company will ship one 500 g bottle of the material directly to you with a 15% discount. The discount price is $15.18 for 500 g, plus a hazardous goods cherge of $17.50, plus shipping charges why vary according to your location, and plus taxes. Schools which already have a contract with Boreal will of course be charged the lowest cost possible. Payment must be made by credit card (a personal credit card can be used if requested), and the **shipping address must be that of the school.** Please allow 7 to 10 business days for delivery once the order has been processed. It is therefore important to order early.

- If you need more material, you can order one extra bottle at the same time. Quantity is limited due to the supply available. Of course, you may purchase supplies from alternative sources.
- Home schooled students must ask their parents to contact a school for ordering the chemical, as shipping can only be made to a school. Alternatively, parents can buy the chemical from a different supplier. Please contact the national coordinator for more information.

How does the competition work?

Crystal growing must occur between October 10 and November 13. Two main rules apply

- RULE 1: Participating crystals must weigh between 0,5 g to 100,0 g. This corresponds to the use of a maximum of 100 g chemicals per student or team.
- RULE 2: So that all students across the country have an equal preparation time, crystal production must conclude within five weeks after the receipt of starting material.

As soon as the growth period is finished, teachers should select the two best crystals that will represent the school at the regional level and send these to the regional coordinator:

1) The best quality crystal, notwithstanding size (minimum mass must nevertheless be 0,5000 g)
2) The best overall crystal, which combines a large size to a good quality (single crystal, well-formed, sharp edges, faces, good transparency, etc.), which must not have a mass higher than 100, 0 g.

Each of these two crystals should be well dried and placed in a small plastic bag (Ziploc or similar) labelled with the **name of students having grown the crystal, the name of the participating school and the email of the teacher.**

We know that several crystals from a school may be of roughly equivalent overall quality, and it is sometimes difficult for the teacher to make a choice. In such a case, it may be necessary to submit several crystals. Of these crystals from a given school, only two will be the “official” crystals to be considered for all prize(s) awarded.

How and when are the crystals judged?

The best crystal from each region will be sent for judging at the national level. Prizes will be attributed to the students having submitted the best crystals. Results will be announced in January.

Judging Criteria

One single crystal will be judged based only on quality, as outlined below. The other single crystal will be judged on mass and quality criteria, as also outlined below.

Experts will rank crystals on a scale of 0 to 10. A score of 10 will be given to a perfect gem quality, unique single crystal (no crystal cluster or 'twinned' crystals) that fits the ideal crystal form known for the chemical.

The crystal is weighed, and the mass M_o recorded. **Crystals must weigh between 0,5000 and 100,0 g.**

The **quality of the crystal** is judged on a scale of 1 to 10, with 10 representing a perfect crystal. The following factors will be considered in judging quality:

- match/mismatch with crystal type (out of 2)
- presence/absence of occlusions (out of 2)
- intact, clean and well-defined/broken, rounded edges (out of 2)
- well-formed/misformed faces (out of 2)
- clarity/muddiness (out of 2)

Total Observed Quality Qo = x,xx (out of 10)

The **Total Score** is then determined as follows:

$$\text{Total Score} = [\log (Mo+1)] \times Qo$$

The logarithm of the mass is chosen so that large poor quality crystals do not swamp out smaller good quality crystals.

The value 1 is added to the mass so that crystals weighing less than 1,0000 g get a positive score.

A 100 per cent yield crystal made from 100 g (M_{MAX}) that scores a perfect 10 on quality (Q_{MAX}) would get a theoretical maximum of:

$$[\log (100+1)] \times 10 = 20{,}01$$

The actual score is expressed as a percentage of the maximum. The crystal with the highest Overall Score is the winning crystal.

$$100 \times \{[\log (Mo+1)] \times Qo\} / \{[\log (M_{MAX}+1)] \times Q_{MAX}\} = \text{Overall Score } \%$$

A perfect crystal weighing 100 g would get a score if 100%.

Example: The best overall crystal in the 2001 competition with 150 g starting material (M_{MAX} = 150 g) weighed 46,53 g and had a quality of 8,65. Its overall score was:

$$100 \times \{[\log (46{,}53+1)] \times 8{,}65\} / \{[\log (150+1)] \times 10\} = 66{,}6\%.$$

Guide to crystal growth

What is a crystal?

A crystal is a solid that consists of the various atoms, ions, or molecules organized in a uniform repeating pattern. This results in the material having a specific shape and colour, and having other characteristic properties. Diamond (used in jewelry and cutting tools) is an example of a crystal. It is made of pure carbon. Graphite (used in pencils and lubricants) is also a crystal made from carbon. Salt and sugar are also examples of substances that can form crystals.

The recrystallization is a process that has been used to purify solid material by dissolving the solid (called a solute) in an appropriate liquid (called a solvent), and then having the material come out of solution in crystalline form. Depending upon conditions, one may obtain a mass of many small crystals or one large crystal. Click on these links for more detailed information:

Buffalo University videos used for the American crystal growing competition:

1) https://www.youtube.com/watch?v=gsC039jpOT0

2) https://www.youtube.com/watch?v=_0F0I3XKiOY

University of Otago, NZ : https://www.otago.ac.nz/chemistry/outreach/crystals/growing/index.html

Web site of the international Union of Crystallography competition held in 2014:

https://www.iycr2014.org/participate/crystal-growing-competition-2014/info-for-newcomers/how-to-grow

Instructables workshop: https://www.instructables.com/How-to-grow-great-crystals/

Which substances crystallize well?

Many substances crystallize. At home, table salt (sodium chloride) is often used to grow crystals. For the competition, we change the chemical used each year. Thus far, the National Crystal Growing Competition has used three different substances:

- Cupric sulfate pentahydrate (copper (II) sulfate pentahydrate, or “bluestone”), which was used in 2022;
- Aluminum potassium sulfate (or “alum”). This substance seems to be a popular one with which to experiment, was used in 2021 and will be used again in 2023;
- Potassium sodium tartrate (or “Rochelle Salt”).

Choice was made based on relative safety, availability, and good crystal growth. The first two chemicals are available from most laboratory chemical supply houses. The third may be bought at a grocery store, but make sure to use real cream of tartar to do your experiment, as some sellers substitute a blend of two different chemicals.

Other chemicals that give good crystals include:

- Potassium ferricyanide,
- Copper acetate monohydrate, and
- Calcium copper acetate hexahydrate.

Precautions when manipulating chemical substances

Substances chosen for the competition are not very dangerous. Precautions are nevertheless needed. In high schools, crystal growth will probably be undertaken in a laboratory, and wearing a lab coat and safety glasses will be mandatory, as will be washing your hands after manipulating these substances.

If growing crystals at home, wearing an overall or an apron is advised, and wearing safety glasses, which are readily available in hardware shops, is strongly suggested. Again, you should wash your hands after using the substance.

In all cases, if you get some solid or solution in your eyes, thoroughly wash your eyes with room temperature tap water for 5 to 15 minutes. If your eye remains irritated, consult your doctor or local hospital immediately. In such an event, it is strongly advised to bring the Safety Datasheet supplied by Boreal.

Chemicals used in this contest are listed in the Workplace Hazardous Materials Information System WHIMS-1985 system. Safety information is given in the Safety Data Sheet that the chemical supplier normally includes with the product. According to the Répertoire toxicologique of the CNESST (https://reptox.cnesst.gouv.qc.ca/en/Pages/to-english-users.aspx), the following safety information for these follows in Table 1.

Table 1 : Safety information for most commonly used crystal growing substances.

Chemical substance	Pictogram	Classification	Signal word	Hazard statements	Precautionary statements
$CuSO_4 \cdot 5H_20$		▪ Acute toxicity – oral - cat. 4 ▪ Serious eye damage/eye irritation cat. 2	Warning	▪ Harmful if swallowed ▪ Causes serious eye irritation	▪ Wash hands thoroughly after handling ▪ Do not eat, drink or smoke when using this product. ▪ IF SWALLOWED: Call a POISON CENTER or a doctor if you feel unwell ▪ Rinse mouth ▪ Dispose of contents/containers in accordance with local regulations ▪ Wear eye protection ▪ IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing ▪ If eye irritation persists: Get medical advice/attention.
alum		▪ Serious eye damage/eye irritation cat. 2	Warning	▪ Causes serious eye irritation	▪ Wash hands thoroughly after handling ▪ Wear eye protection ▪ IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing ▪ If eye irritation persists: Get medical attention.

How to grow crystals

To obtain large single crystals, three steps are usually followed:

1) A small seed crystal is obtained
2) A supersaturated solution is prepared
3) Increasing the size of the seed crystal is performed by suspending this seed crystal into the supersaturated solution (more details later).

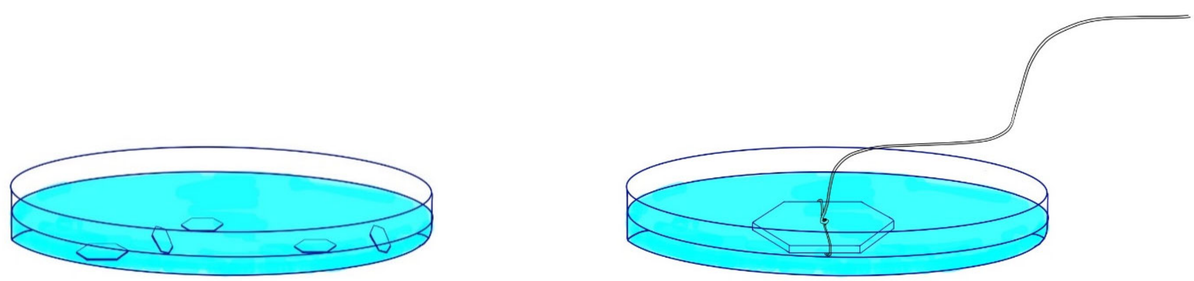
It is relatively easy to obtain nice small crystals. Obtaining larger, almost perfect crystals is almost an art, and requires constant attention to details. The rest of this guide will teach you the basics of this art.

What you need to know before starting

- The solubility of the substance in water at room temperature, which you can obtain from a chemistry reference book.
- It would also be useful to know the solubility of the substance at elevated temperatures, which is information that may also be available in a reference book such as the *Handbook of Chemistry and Physics*, section *Aqueous Solubility of Inorganic Compounds in Mass % as a Function of Temperature*.

First step: growing a seed crystal

The aim of the competition is to obtain a single crystal and not a bunch of crystals all stuck together and intergrown, no matter how nice this may look. In order to do this, you will need a small, well-formed crystal, which will serve a "seed" to start crystal growth. You will then let this small crystal slowly grow bigger, as a rapid crystallization often leads to multiple crystals instead of a single, well-formed crystal.



What you will need

- Substance to be crystallized;
- Distilled or demineralized water;
- A shallow dish (e.g., Petri);
- Heating plate or stove;
- Beaker or other small container, 100 to 250 mL capacity
- Fishing line (1 to 2 kg strength);
- Small stick (popsicle sticks work fine)
- A magnifying glass (optional).

What you should do

- Warm about 50 mL (1/4 cup) of water in a glass container.
- Dissolve enough of the substance to produce a saturated solution at elevated temperature.
- Pour the warm solution into a shallow dish.
- Allow the solution to cool to room temperature.
- After a day or so, small crystals should begin to form.
- Remove some of the crystals.
- With a magnifying glass, select a regular, small transparent crystal. This will be your seed crystal.
- Tie the seed crystal with the fishing line by using a simple overhand knot. Make sure the line is long enough (approximately half of the height of the beaker used in Step 3).
- Suspend the seed crystal in a shallow dish (1 to 2 mm deep) containing a small amount of supersaturated solution (a few milliliters, see next section for how to prepare the solution) in a shallow container, for example a Petri dish for some time (1 to 2 days).
- Check with the magnifier that the seedling crystal is well attached to the line, and that the crystal grows over the line. This step is very important because one can lose several days of growth if the "beginning growth" is not regular or not along the structure of the seedling crystal. It is worth checking properly before going on with the regular crystal growth.

Second step: Preparation of a supersaturated solution

To grow a large crystal, you will need to suspend it in a supersaturated solution. This solution is not in an equilibrium state: you want it to contain more of the crystallizing substance (the solute) than normally presented. In order to do this; you will first prepare a saturated solution, which is at equilibrium and which contains the maximum of the substance that can dissolve in water. Afterwards, you will change the conditions in order for the substance to be too concentration as compared to equilibrium conditions and the solute will need to crystallize out. This, however, takes time, and meanwhile, your solution is supersaturated!

Many methods exist to obtain a supersaturated solution. We have given below three different methods.

Please note: Quantities of the growing substance and of water depend on solubility at room temperature and at a slightly higher temperature. Handbook data will guide you, but you may also need to proceed by trial and error to determine the exact proportions, just like any scientist would do when beginning a new experiment.

What you will need

- Substance to be crystallized;
- Distilled or demineralized water;
- Thermometer;
- Scale;
- Heat-resistant glass or stainless steel container (1 L or more);
- Heating plate;

Method One

- Place about double the amount of substance that would normally dissolve in a certain volume of water at room temperature into that volume of water. (e.g. If 30 g (about 1 oz.) of X dissolves in 100 g (mL) of water at room temperature, place 60 g of X in 100 mL of water.) Adjust the proportions depending upon how much material you have. Use clean glassware.
- Stir the mixture until it appears that no more will go into solution.
- Continue gently stirring the mixture while slowly heating it.
- Once all of the substance has gone into the solution, remove the container from the heat.
- Allow the solution to cool to room temperature.

You now have a supersaturated solution.

Note: The supersaturation method, as well as the second one, works when the solute is more soluble in hot solvent than cold. This is usually the case, but there are exceptions. For example, the solubility of table salt (sodium chloride) is about the same whether the water is hot or cold. Some substances are even more soluble at low than at high temperatures.

Method Two

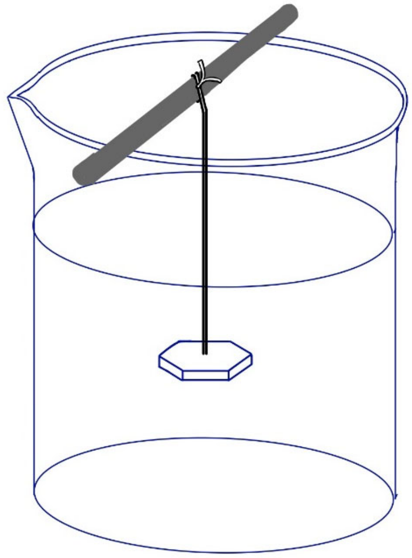
- Select an appropriate volume of water.
- Warm this water to about 15–20° above room temperature.
- Add some of your substance to the warm water and stir the mixture to dissolve completely.
- Continue adding the substance and stirring until there is a slight amount of material that won't dissolve (the solution will be slightly cloudy).
- Warm the mixture a bit more until the remaining material goes into solution. The solution must be entirely transparent, with no haziness whatsoever.
- Once all of the substance has gone into the solution, remove the container from the heat.
- Allow the solution to cool to room temperature.
- You now have a supersaturated solution, one which is clear and limpid. If slightly cloudy, **add a bit of water, reheat and let the solution cool again.** .

Method Three

- Prepare a saturated solution, using the solubility value (mass of substance / volume of water) found in a chemistry handbook.
- Let the water evaporate (this can take a few hours up to a few days, depending on how well saturated the initial solution is).

This procedure is simple, but slower, and also works with substances which are more soluble at lower temperatures, contrary to the two previous methods.

Third step: Growth of a large crystal



You are now ready for the final growing step. You will suspend your seed crystal in the supersaturated solution prepared in Step 2. This solution contains more than the maximum solubility of the solute, it is not at equilibrium, and the solute will "want" to get out of the solution. It will crystallize onto any surface that can serve as a seed, including your seed crystal (and this is what you want) or any dust particle or solid impurity present (which you want to avoid, as it will give irregular, badly shaped crystals).

The speed at which crystallization occurs will greatly influence final crystal quality. The more supersaturated the solution (the higher the excess in solute as compared to equilibrium conditions), the faster the crystal will grow. However, the best crystals are always obtained with a slow growing speed.

One word of warning: as solubility varies with temperature, it is of utmost importance to avoid temperature fluctuations during crystal growth. Further, your solution must always remain saturated at the chosen growth temperature (usually room temperature), or else your crystal could dissolve partially or entirely.

A more symmetrical crystal can be obtained by slowly rotating the crystal in the supersaturated solution. Having such a setup can improve your crystal shape, but is not essential.

Unfortunately, many schools have had the disappointment of admiring a big crystal on a Friday, only to come back on Monday to an empty fishing line. The reason? A rise in room temperature in the school over the weekend, which caused the crystal to dissolve completely. The worst period for this is around October when schools turn on the heating systems. For this reason, if available, growing the crystals in a thermostated bath set to a few degrees above room temperature is highly recommended. If unavailable, placing the growth set up inside a cooler (Styrofoam or other) will limit temperature fluctuations, and can also save the day.

What you will need

- Substance to be crystallized;
- Seed crystal of the substance to be crystallized, tied to a fishing line;
- Small wood stick (e.g., Popsicle stick);
- Distilled or demineralized water;
- Thermometer;
- Scale;
- Heating plate or other heating device;
- Beaker of 2 to 4 liters volume;
- Styrofoam picnic cooler (optional);
- Magnifying glass or microscope (optional);
- Thermostated bath (optional);
- Slow revolution motor (1 to 4 rotations per day) (optional).

What you should do

1. Take the fishing line on which you have tied your seeding crystal. Attach to a wooden stick (popsicle stick) at the other end, making sure the crystal will be immersed approximately in the middle of your supersaturated solution in the growing vessel.

2. Carefully suspend your seed crystal from the stick into the supersaturated solution, taking care not to let the crystal touch the bottom of the container.

3. Cover the container in which the crystal is growing. This is to:
   - keep out dust, and
   - reduce temperature fluctuations.

   This can be done using plastic wrap or aluminum foil. If you want to allow the solvent (typically water) to evaporate (see step #4 below), then use porous paper (e.g., filter paper).

4. Observe the crystal growth. Depending upon the substance, the degree of supersaturation, and the temperature, it may take several days before the growth slows down and stops.

   - WHY DOES THE CRYSTAL STOP GROWING?

     A crystal will only grow when the surrounding solution is supersaturated with the solute. When the solution is exactly saturated, no more material will be deposited on the crystal. (This may not be entirely true. Some may be deposited. However, an equal amount will leave the crystal surface to go back into the solution. We call this an equilibrium condition.)
   - WHY DID MY CRYSTAL SHRINK/DISAPPEAR?

     If your crystal shrank or disappeared, it was because the surrounding solution became unsaturated and the crystal material went back into the solution. Unsaturation may occur when the temperature of a saturated solution increases, even by only a few degrees, depending upon the solute. (This is why temperature control is so important.)
   - HOW DO I GET CRYSTAL GROWTH RESTARTED?

     You must re-supersaturate your solution. Step 6 will give you the details.

5. Re-supersaturate the solution. This may need to be done on a daily basis, especially when the crystal gets larger. But first, remove the crystal.

   One way to re-supersaturate the solution is to reduce the amount of solvent. This may be done by heating the solution for a while and then cool it to the original temperature. Alternatively, you can just let the solvent evaporate from the solution (this may be a slow process, but has the advantage of getting a better quality crystal.) You can also supersaturate the solution by warming it somewhat, then adding and dissolving more solute, and finally cooling it.

Each time the solution is saturated, it is a good idea to “clean” the monocrystal surface, by

- making sure the crystal is dry;
- not touching the crystal with your fingers (hold only by the suspending line if possible);
- removing any “bumps” on the surface due to extra growth;
- removing any small crystals from the line.

6. Resuspend the crystal back into the newly supersaturated solution.
7. Repeat steps 5 and 6 as needed.
8. To get improved symmetry and size, especially if the crystal gets very big, better results will be obtained if you slowly rotate the growing monocrystal (1 to 4 rotations per day) while it is immersed in the supersaturated solution. An electric motor with 1 to 4 daily rotations might be difficult to find (reusing one from an old humidity drum register or a similar apparatus is suggested).
9. Remove your crystal from the bath once the growth period is finished, and wipe it thoroughly with absorbent paper. Do not touch your crystal with your fingers! Once well dried, put your crystal in a small plastic bag (such as a Ziploc bag), close it, and put a label on the bag sating your name and school name, and give the crystal to your teacher or lab technician. He or she will choose the best two crystals and will send them to the regional coordinator for judging. It is important to verify, before sending any crystal, if their mass falls between the 0,5 to 100 g thresholds for acceptable crystals: if not, the crystals are automatically disqualified.

   The teacher or technician should consult sections “Competition schedule”, “How the competition works” and “Judging criteria” for more information on how the crystal are judged, and when and how to send your two selected crystals to the regional coordinator. Before sending your crystals, please do not forget to check that they weigh between 0,5 and 100,0 g. Crystals outside this range will be automatically disqualified.

   At this stage, some people varnish their crystals. This ensures that the crystals do not dry out, and maintains their general shape longer. This may hide some defects present on the crystal faces, but on the other hand, edges appear rounder, less well-defined. Although we have decided not to disqualify these varnished crystals, these will invariably lose many points due to loss in perfection of the edges, and will invariably fall down the ranking. We do not recommend that you varnish the crystals that will be submitted to the competition.
10. Finally, when manipulating chemicals, is it essential to always thoroughly wash your hands with soap and water afterwards.

Once you have mastered this step, you may be interested in trying to grow single crystals in the presence of introduced “impurities” that may give different crystal colours or shapes. These will, however, not be accepted for the Competition.

Last revision: June 15, 2023.