U.S. CRYSTAL GROWING COMPETITION

The 2021 United States Crystal Growing Competition Handbook

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www.USCrystalGrowingCompetition.org

Official Sponsors of the #2021USCGC:

Special Thanks to Denis Bussières and the Candian Institute of Canada for providing the written materials upon which our contest is based:

http://www.cheminst.ca/outreach/crystal-growing-competition

What's new for 2021:

- The crystal growing period is: **October 18 to November 22, 2021**
- Bottles of alum will be a flat rate of $8/bottle which includes shipping (no tax); Bottles will be shipped on/around October 10.
- Some changes to prizes! This contest is about having fun **and learning**! To that end we're offering winner the choice of awesome educational tools/toys/models *or* the cash prize.
    - Best Overall Crystal (K-8)
        - 1st prize (4x4 3D crystal model (approx. value $215) **or** $200 cash)
        - 2nd prize (3x3 3D crystal model (approx. value $100) **or** $100)
        - 3rd prize ('Cup of water kit' (approx. value $50) **or** $50 cash)
    - Best Quality Crystal (K-8)
        - 1st prize ('Cup of water kit' (approx. value $50) **or** $50 cash)

    - Best Overall Crystal (9-12)
        - 1st prize (4x4 3D crystal model (approx. value $215) **or** $200 cash)
        - 2nd prize (3x3 3D crystal model (approx. value $100) **or** $100)
        - 3rd prize ('Cup of water kit' (approx. value $50) **or** $50 cash)
    - Best Quality Crystal (9-12)
        - 1st prize ('Cup of water kit' (approx. value $50) **or** $50 cash)

    - Coolest Crystal (K-12)
        - 1st prize (3x3 3D crystal model (approx. value $100) **or** $100)
        - 2nd prize ('Cup of water kit' (approx. value $50) **or** $50 cash)

    - Best Overall Teacher's Crystal
        - (3x3 3D crystal model (approx. value $100) **or** $100)

More info about the prize models:

https://www.3dmoleculardesigns.com/Education-Products/NaCl-Lattice.htm
https://www.3dmoleculardesigns.com/Education-Products/Water-Kit.htm

- Judging will be held at the Texas A&M University!
    - Crystals for the #2021USCGC will go on permanent display at TAMU!
    - Submission shipping info will be provided at a later date!
- A BIG USCGC Welcome to our newest USCGC Crystallite – Jeffrey Rack from the University of New Mexico!
- Contest registration via MailChimp
    - Participants will now be able to manage their own account/subscription info!
    - New team name? New address? Change it using the email used to sign up!
    - Choose to receive html (fancy) or plain text (less fancy) emails!

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Contents

Definition

The United States Crystal Growing Competition is an important scientific outreach activity designed to provide K-12 grade students and teachers a fun, hands-on STEM experience as well as an exciting competition. Materials for crystal growth will be provided on a first come, first served basis. The objective is to grow the biggest and highest quality single crystal.

National Prizes

Students win cash prizes for their school and will receive individual certificates for the national prizes.

- Best Overall Crystal (K-8)
  - 1st prize (4x4 3D crystal model (approx. value $215) **or** $200 cash)
  - 2nd prize (3x3 3D crystal model (approx. value $100) **or** $100)
  - 3rd prize ('Cup of water kit' (approx. value $50) **or** $50 cash)
- Best Quality Crystal (K-8)
  - 1st prize ('Cup of water kit' (approx. value $50) **or** $50 cash)

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- Coolest Crystal (K-12)
  - 1st prize (3x3 3D crystal model (approx. value $100) **or** $100)
  - 2nd prize ('Cup of water kit' (approx. value $50) **or** $50 cash)

- Best Overall Teacher's Crystal
  - (3x3 3D crystal model (approx. value $100) **or** $100)

More info about the prize models:

https://www.3dmoleculardesigns.com/Education-Products/NaCl-Lattice.htm
https://www.3dmoleculardesigns.com/Education-Products/Water-Kit.htm

The submitted crystals will become part of a permanent display at the Department of Chemistry at the University at Buffalo.

If you are in Buffalo, the display is located on the 7th floor of the Natural Sciences Complex on the University at Buffalo's North Campus (in Amherst). Stop on by to see the collection!

Who can participate?

- All US students or homeschooled youths ages 5-18.
- Individuals, small teams (often around four students), or classrooms! There is no limit on the number of teams per school.
- K-12 school teachers.

Should you have questions don't hesitate to contact any of the coordinators listed on page 3 and at the end of this handbook!

We look forward to receiving your crystals!!!!

How do I sign up?

All participants must register online using the entry form on our website at:

https://www.uscrystalgrowingcompetition.org/entry-form

If you have trouble accessing the form, please contact Dr. Jason Benedict by e-mail (jbb6@buffalo.edu).

What is the crystallization material and how to get it?

For 2021 the material is aluminum potassium sulfate dodecahydrate ('alum'), $AlK(SO_4)_2 \cdot 12H_2O$.

Bottles are available for a flat rate charge of $8/bottle including shipping (and no tax!).

This material is chosen on the basis of relative safety, availability, and because it produces large beautiful colorless crystals.

To order your material:

- Complete the online entry form at https://www.uscrystalgrowingcompetition.org/entry-form
- Order bottles via secure UBF checkout at
    - https://www.uscrystalgrowingcompetition.org/order-bottles
    - Most forms of electronic payments are accepted
    - Bottle orders must be completed by October 1.

Safety

The Safety Data Sheet for alum has been included at the end of this handbook and is available at the Ward's Science (one of our sponsors) web site at

https://www.wardsci.com/store/product/8866176/aluminum-potassium-sulfate-12-hydrate
https://www.wardsci.com/assetsvc/asset/en_US/id/16977346/contents

Aluminum potassium sulfate dodecahydrate is considered non-hazardous and is relatively safe, but the usual safety precautions should be exercised including:

1. Wear eye protection
2. Do not smoke, drink, or eat while handling the chemical
3. Wash hands after handling chemical

Disposal

What to do with the alum once the contest is complete? Because alum is a stable chemical, you may store any unused or leftover alum in a cool, dry, well-ventilated area. If you wish to dispose of the alum, please consider the following recommendation from the supplier, Ward's Science:

This disposal method is published for your convenience. You MUST have checked with your federal, state, and local regulations before using this method and these methods are only applicable for small laboratory sized quantities.

The disposal of this chemical does not need pretreatment and it is not necessary for any chemical reaction to be conducted before it is disposed into a landfill or down the school drain. HOWEVER, there are numerous conditions that should be met which are outlined below before this can be discharged.

If the material is in the solid form, it can be buried in a landfill if:

a. Local regulations have been confirmed that this material can be disposed of in a landfill.
b. Chemical is packed into a cardboard box with an appropriate amount of packing material.
c. Cardboard box is sealed with durable tape.

If the material is in an aqueous form, it can be poured down the drain with excess water if:

a. Local and State regulations have been checked and you have verified that this material is suitable for this type of disposal
b. The school drain is connected to the sanitary sewer system.
c. The quantity that you are disposing of is minimal. A good rule of thumb is less than 250 mL.
d. Combinations of chemicals are not going down the drain at the same time.
e. A twenty-fold excess of water is used when washing the chemical down the drain.

A good resource to contact is the local wastewater treatment facility as they can give you guidance and be a resource on drain disposal.

What is a crystal?

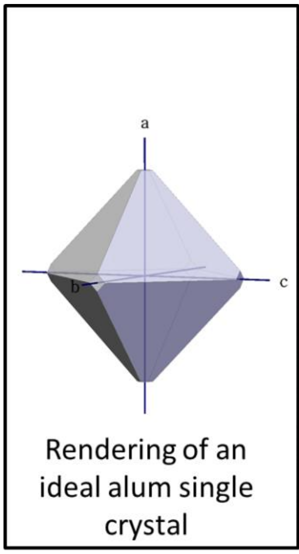
A crystal is a solid that consists of the various atoms, ions, or molecules being arranged in a uniform three-dimensional repeating pattern. This results in the material having a specific shape and color, and having other characteristic properties. Diamond (used in jewelry and cutting tools) is an example of a crystal. It is made of pure carbon. Salt and sugar are also examples of crystals.

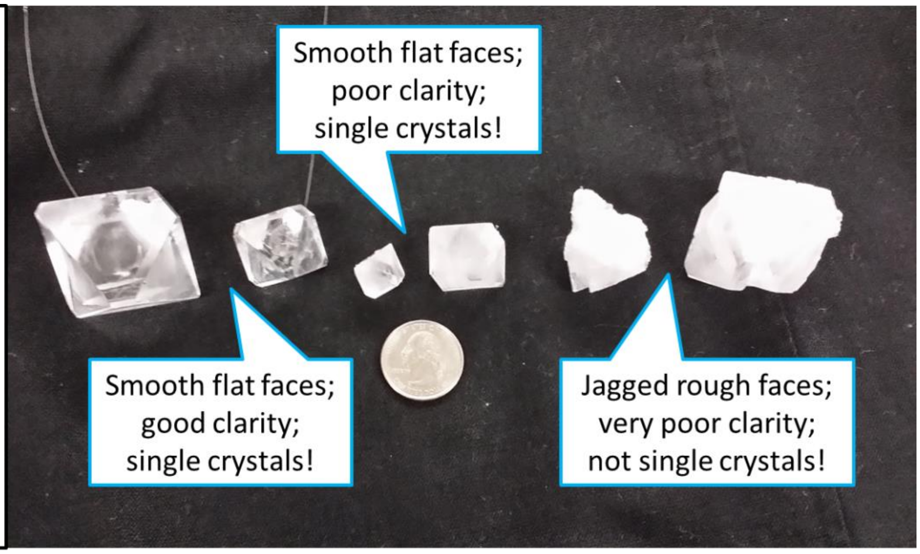
Recrystallization is a process that has been used to purify solid material by dissolving the solid (called a solute) in an appropriate liquid (called a solvent) and then having the material come out of solution in crystalline form. Depending upon conditions, one may obtain a mass of many small crystals or one large crystal.

Crystals are characterized by type, shape, form, clarity, and color.

What is a *single* crystal?

A single crystal is an object in which there is only *one crystal!* Sometimes crystals like to stick to each other or grow together in clumps. These clumps are **not** a single crystal, rather they are collections of hundreds, thousands, or perhaps millions of single crystals. For this contest, you want to grow one large single crystal. Good single crystals have smooth flat faces (outer surface of the crystal) and good optical clarity (you should be able to see through them!) For some examples, see the illustration below!





Rendering was done using WinXMorph by Werner Kaminsky. Download a free copy today!
http://cad4.cpac.washington.edu/WinXMorphHome/WinXMorph.htm

Contest Rules:

The crystal growing period is from October 18 to November 22, 2021. The judging will take place in January, 2022 by a panel of judges.

RULE 1: The maximum amount of starting material that may be used for each given crystal is limited to 100 g.
RULE 2: So that all participants have an equal preparation time, crystal production must conclude within the time period specified above (five weeks).

How to grow single crystals

Helpful advice on growing a crystal can be found at the following:

Step-by-step video tutorial by Dr. Jason Benedict on the Benedict Research Labs YouTube Channel:
https://www.youtube.com/channel/UC73kcJKC3BxY2r3k5iSaSdw

The official United States Crystal Growing Competition website:
http://www.uscrystalgrowingcompetition.org/

Wisconsin Crystal Growing Contest run by Dr. Ilia Guzei
http://xray.chem.wisc.edu/WICGC.html

Great examples of alum single crystals – Winners of the Canadian Crystal Growing Contest!
http://www.cheminst.ca/outreach/crystal-growing-competition

First Stage: Grow a Seed Crystal

The idea is to grow a single crystal, not a bunch of crystals. You will first need to grow a small perfect crystal that will become your seed crystal, around which you will later grow a large crystal. It is therefore essential to avoid excessively rapid growth, which encourages the formation of multiple crystals instead of a single crystal.

What You Need

- Substance to be crystallized;
- Distilled or demineralised water;
- A shallow dish (e.g., Petri);
- Heating plate or stove;
- Fishing line (1 to 2 kg strength);
- A small wood rod (e.g., popsicle stick);
- A magnifying glass (optional).

Important Things to Know

- How much substance you have to work with, which you can determine by weighing it on a balance.
- 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 Handbook of Chemistry and Physics, 45th Ed (1964-5).

What to Do

- Warm about 50 mL (1/4 cup) of water in a glass container.
- Dissolve a quantity of the substance to produce a saturated solution at the 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 magnifier select a beautiful and transparent small crystal. This will be your seed crystal.
- Tie the seed crystal with the fishing line by using a simple overhand knot.
- Suspend the seed crystal in a shallow (1 to 2 mm deep) small volume (about 1 to 2 mL) saturated solution (for example, in a cover or a Petri dish) for some time (1 to 2 days).
- Check with the magnifier that the seedling crystal is well-fixed to the line by its beginning growth. 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 Stage: Grow a Large, Single Crystal

Now you are ready to proceed with the preparation of a large single crystal.

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 colors or shapes. In recrystallization, one tries to prepare a solution that is supersaturated with respect to the solute (the material you want to crystallize).

There are several ways to do this. One is to heat the solvent, dissolve as much solute as you can (said to be a "saturated" solution at that temperature), and then let it cool. At this point, all the solute remains in solution, which now contains more solute at that temperature than it normally would (and is said to be "supersaturated"). This situation is somewhat unstable. If you now suspend a solid material in the solution, the "extra" solute will tend to come out of solution and grow around the solid. Particles of dust can cause this to occur. However, this growth will be uncontrolled and should be avoided (thus the recrystallization beaker should be covered). To get controlled growth, a "seed crystal", prepared from the solute should be suspended into the solution. The supersaturation method 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. The rate at which crystallization occurs will affect crystal quality. The more supersaturated a solution is, the faster growth may be. Usually, the best crystals are the ones that grow SLOWLY.

Thus, if you heated the solvent to near the boiling point to get a highly supersaturated solution on cooling back to room temperature, crystals may start to form before the solution had completely cooled.
This is where the "art" of science comes into play. One has to experiment a bit to get the right conditions.
A second way to get supersaturation is to start with a saturated solution and let the solvent evaporate.
This will be a slower process.

The above will apply to most situations. It is necessary to match the proper solvent with a given solute.

WARNING: the solubility of some salts is quite sensitive to temperature, so the temperature of recrystallization should be controlled as best you can. There have been reports in the past of students having a nice big crystal growing in a beaker on a Friday, the room temperature rising in a school over the weekend, and by Monday morning the crystal had totally gone back into solution. Consider insulating your crystallization vessel inside a Styrofoam box.

What You Need

- Substance to be crystallized;
- A seed crystal of the substance to be crystallized on a fishing line;
- Distilled or demineralized water;
- A small wood rod or popsicle stick;
- Thermometer;
- Balance;
- Plastic or glass container;
- Heating plate;
- Beaker of 2 to 4 liters volume;
- Temperature control bath (optional);
- Slow revolution motor (1 to 4 rotations per day) (optional).

Important Things to Know

- How much substance you have to work with, which you can determine by weighing it on a balance.
- 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.

How to Prepare a Supersaturated Solution

To grow your large, single crystal, you will need a supersaturated solution.
The amounts of substance and water to be used will depend upon the solubility at room and elevated temperatures. You may have to determine the proper proportions by trial and error (just like professional scientists!!!).

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 stirring the mixture while gently warming the solution.
- Once all of the substance has gone into solution, remove the container from the heat.
- Allow the solution to cool to room temperature.
- You now have a supersaturated solution.

Method two
- Select an appropriate volume of water.
- Warm this water to about 15–20˚C above room temperature.
- Add some of your substance to the warm water and stir the mixture to dissolve completely.
- Continue adding substance and stirring until there is a little material that won't dissolve.
- Warm the mixture a bit more until the remaining material goes into solution.
- Once all of the substance has gone into solution, remove the container from the heat.
- Allow the solution to cool to room temperature.
- You now have a supersaturated solution.

Now you can grow your wonderful crystal
Since the solubility of a substance varies a lot with temperature, it is very important to control the temperature carefully.

If the room temperature is stable then you might be able to leave your apparatus out in the open. If it can vary by even only a degree or two, then it may be necessary to place the apparatus into a temperature control bath set to a few degrees above room temperature (if available, but this is not mandatory). You could also place the growing apparatus inside any well insulated but not airtight container.

Also, for the seed crystal to grow, it is absolutely necessary that the solution never be unsaturated at the temperature of the experiment (usually the room temperature).

Getting Started
1. Carefully suspend your seed crystal from the stick into the supersaturated solution, being careful not to let the crystal touch the bottom of the container.

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

This can be done with plastic wrap or aluminum foil. If you want to allow the solvent (typically water) to evaporate, then use porous paper (e.g., filter paper) or poke a few holes in the cover.

3. Observe the crystal growth. Depending upon the substance, the degree of supersaturation and the temperature, this may take several days before the growth slows down and stops. A couple of different things can happen at this stage.

The questions and answers below can help you.

Q: Why does the crystal stop growing?

A: A crystal will only grow when the surrounding solution is supersaturated with 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 solution. We call this an equilibrium condition.)

Q: Why did my crystal shrink/disappear?

A: If your crystal shrank or disappeared, it was because the surrounding solution became unsaturated and the crystal material went back into 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.)

Q: How do I get crystal growth restarted?

A: Step 4 below will give you the details.

4. Resupersaturate 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 resupersaturate 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. Or, 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.) One can also supersaturate the solution by warming it somewhat, then adding and dissolving more solute, and finally cooling it.

5. 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.

It is a good habit to clean your hands after each manipulation.

6. Resuspend the crystal back into the newly supersaturated solution.

7. Repeat steps 4-6 as needed.

8. To get improved symmetry and size, slowly rotate the growing monocrystal (1 to 4 rotations per day). An electric motor with 1 to 4 daily rotations might be difficult to find (consider one from an old humidity drum-register or other apparatus). This option becomes useful only when a monocrystal gets rather big.

How Are the Crystals Judged?

The United States Crystal Growing Competition judging will take place in January, 2021.
- **The number of submissions is limited to 3 per classroom or household (2 for Overall and Quality categories and 1 cool crystal).** It is recognized that where several crystals from a school or household may be of roughly equivalent overall quality, and it is difficult to make a choice, it may be necessary to submit several crystals. If more than two crystals are submitted by a classroom/household, we reserve the right to preselect two crystals for judging.
- Each submission will receive a Quality and Overall score.
- Prize winners in the Overall category will be determined based upon their overall score. All remaining crystals will be re-ranked and judged according to their quality score.
- Each classroom/household is limited one prize winning crystal per category.
- The minimum size for any submission is 0.5 g.

Judging Criteria

The quality is judged by experts who will rank the crystals on a scale of 0 to 10. A score of 10 will be given to a perfect gem-quality crystal that fits the ideal crystal structure known for the chemical.

1. The crystal is weighed, and the mass (m) is recorded. The crystal must be a minimum of 0.5 g to be eligible for judging.

2. 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/broken edges (out of 2)
- well-formed/misformed faces (out of 2)
- clarity/muddiness (out of 2)

Total Observed Quality (Q) = x.xx (out of 10)

3. The Total Score is then determined as follows:

Total Score = [log (m+1)] x Q

The logarithm of the mass is chosen so that large poor quality crystals don't swamp out smaller good quality crystals. The value 1 is added to the mass so that crystals weighing less than 1 g get a positive score. A 100 per cent yield crystal made from 100 g (m_{max}=100 g) that scores a perfect 10 on quality (Q_{max}=10) would get a theoretical maximum of:

[log (100+1)] x 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 x {[log (m+1)] x Q} / {[log (m_{max}+1)] x Q_{max}} = Overall Score %

For example, the best overall crystal (grades 9-12) in the 2016 contest with 100 g starting material weighed 32.8349 g and had a quality of 8.24. Its overall score was:

100 x {[log (32.8349+1)] x 8.24} / {[log (100+1)] x 10} = 62.88%

This score is nearly an absolute score that could be used to judge different types of crystals grown from differing amounts of starting material.

Cool Crystal Contest

Time to let your imaginations run wild! Only two rules:

1. The crystallization must use alum
2. We don't return the crystals!

Things you might consider trying:

- Growing a funky shaped crystal
- Trapping an object (Note: crystals will not be returned, so only use materials you don't want back!)
- Coloring the crystals using dye or metal salts (please take appropriate precautions)
- Anything else! (Just be safe and only use materials you don't want back!)

Judges will consider originality, aesthetics, and difficulty when determining the Coolest Crystal!

Acknowledgements

Many thanks go to our generous sponsors and to the enthusiastic contest contributors. We are grateful to our Canadian and Australian colleagues for sharing their expertise and contest-related materials.

Contact

With questions of any type regarding this United States Crystal Growing Competition contact

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