Using 3D Printing Technology to Recreate Historically Accurate Teaching Models from the 1800s

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Introduction

- 3-D printing provides endless possibilities to innovate, create, and modify how learning can take place in a classroom.
- 3-D models are easy to produce and edit, and allow room for initial error.
- It is an effective way of allowing students to transform their ideas into actions.
- Learning about crystal structures are often too abstract for introductory chemistry students to grasp.
- Our goal is to grow crystals and 3-D print to model the complex equations that create major crystalline lattice structures.
- These particular models can be used by introductory or higher chemistry courses for visual and hands-on learning.
- The seven major crystal lattice systems include cubic, tetragonal, orthorhombic, hexagonal, trigonal, triclinic, and monoclinic

Crystal Growing Process

- First, a saturated mother liquor is made based on the solubility of the ionic compound.

Seed Crystals

From left to right: Potassium Dichromate, Nickel Sulfate, Potassium Chromic Sulfate, Potassium Chromium Sulfate, Ferric Ammonium Sulfate, Cobalt (II) Chloride, Sodium Ferrocyanide, Copper (II) Sulfate, Monoammonium Phosphate, and Cobalt Nitrate

Saturated Mother Liquors

From top left to bottom right: Ferrous sulfate, Potassium Dichromate, Sodium Ferrocyanide, Copper (II) Sulfate, Ferric Ammonium Sulfate, and Potassium Chromium Sulfate

- Once the mother liquor is super saturated, seed crystals will begin to deposit on the bottom and sides of the beaker.

Seed Crystals Suspended in Solution

From left to right: Copper (II) Sulfate, Nickel Sulfate, and Monoammonium Phosphate

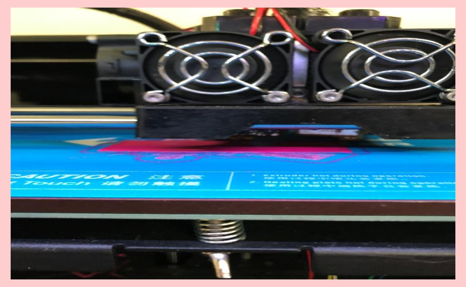
- Next, a seed crystal is suspended in the saturated solution using fishing line. Saturation of the solution and rate of evaporation both need to be monitored throughout this step.
- Finally, the crystals are sealed in resin to prevent dehydration and prepare them to be handled by students.

Design Process

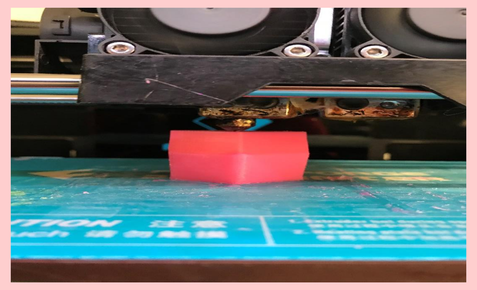
- Models were based off of sample models from the 1800s era
- Tinkercad files were used for the design and replication of each crystal structure
- Each structure was labelled for easy recognition and comparison
- Once the design is finalized, it can be sent directly to the printer or uploaded via a micro SD card

3-D Printing

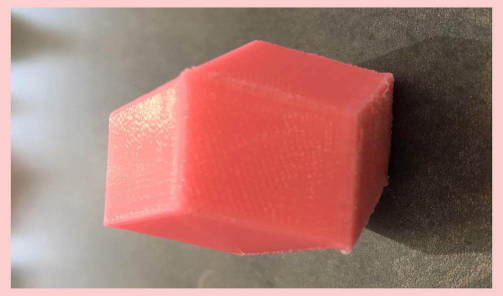
- 3-D printing allows for the rapid design and manufacture of prototypes at a relatively low cost
- Depending on the size, a model can take ten minutes to two hours to be completely printed. For these models, the longest print was over four hours!
- This process works by heating thin plastic to 230°C and extruding filament onto a 90°C platform.
- There are many different types of 3-D printers and they can vary in cost, but once the initial costs are paid, the cost of printing is relatively low.



First step of Rhombic Dodecahedron print



Midway point of the print

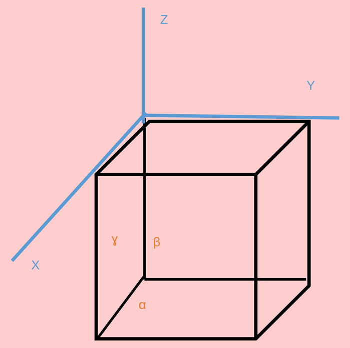


Completed Rhombic Dodecahedron printed design

A 3-D printer making replications of a structure

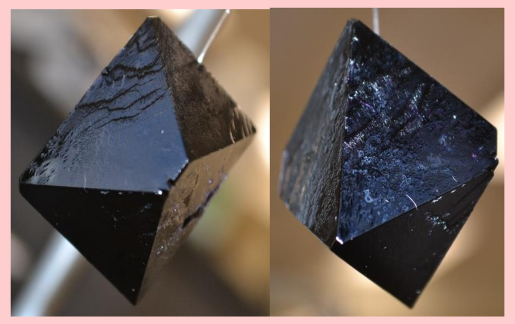
Cubic

$\alpha, \beta, \& \gamma = 90°$
$X = Y = Z$



3-D Printed Model

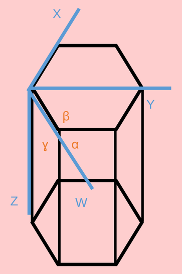
Ferric Ammonium Sulfate



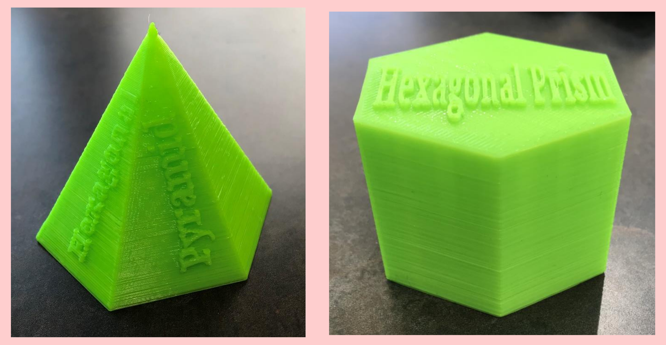
Potassium Chromium Sulfate

Hexagonal

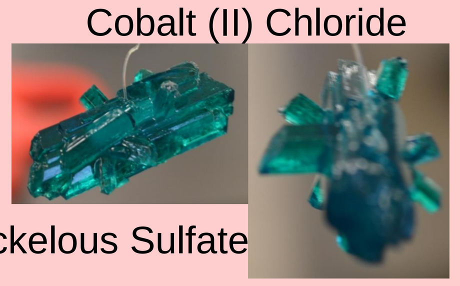
$\alpha = \beta = \gamma$
ϙ = 90°
$X = Y = Z$
$W \neq X, Y, Z$



3-D Printed Models



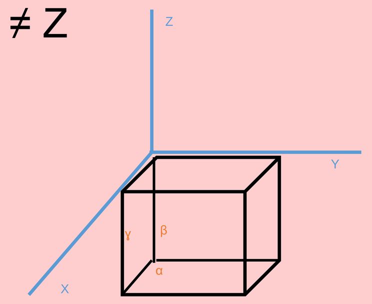
Cobalt (II) Chloride



Nickelous Sulfate

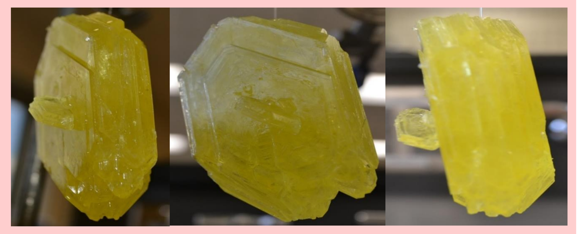
Monoclinic

$\alpha \& \beta$
OR $\alpha \& \gamma$
OR $\beta \& \gamma = 90°$
$X \neq Y \neq Z$



3-D Printed Model

Cobalt (II) Nitrate

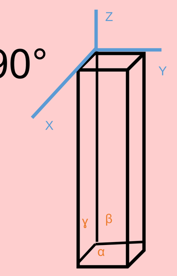


Sodium Ferrous Cyanide

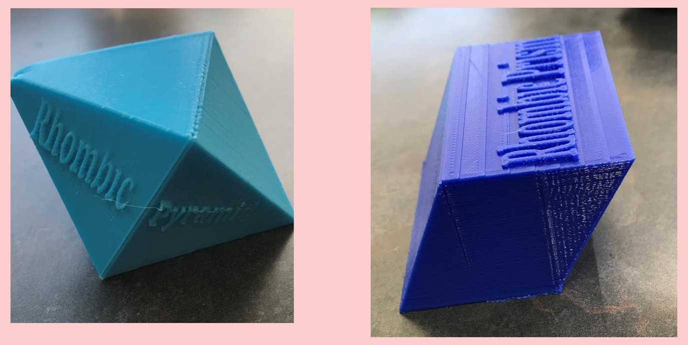
Ferrous Sulfate

Orthorhombic

$\alpha, \beta, \& \gamma = 90°$
$X \neq Y \neq Z$



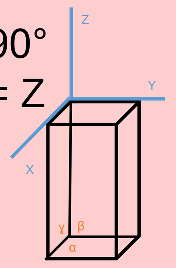
3-D Printed Models



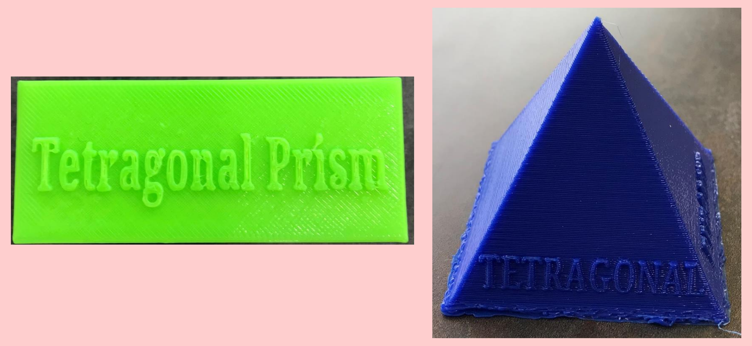
We are working to crystallize Potassium Permanganate but struggling to work with its oxidative properties. An easier future possibility is potassium sodium tartrate

Tetragonal

$\alpha, \beta, \& \gamma = 90°$
$X = Y$ or $X = Z$
or $Y = Z$



3-D Printed Models

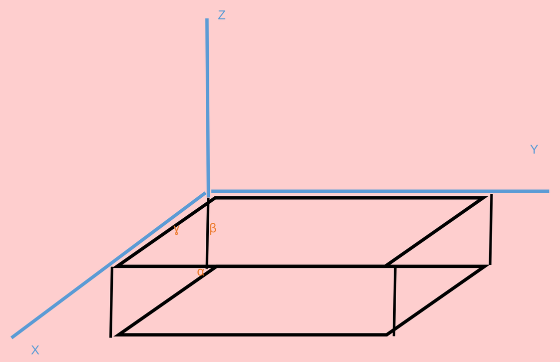


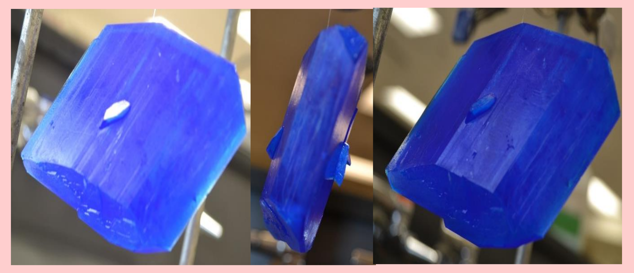
Calcium Copper Acetate

Monoammonium Phosphate

Triclinic

$\alpha, \beta, \& \gamma \neq 90°$
$X \neq Y \neq Z$



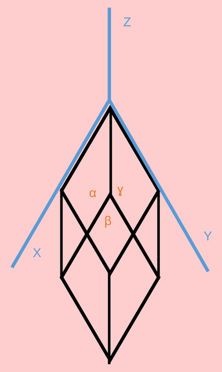


Copper (II) Sulfate

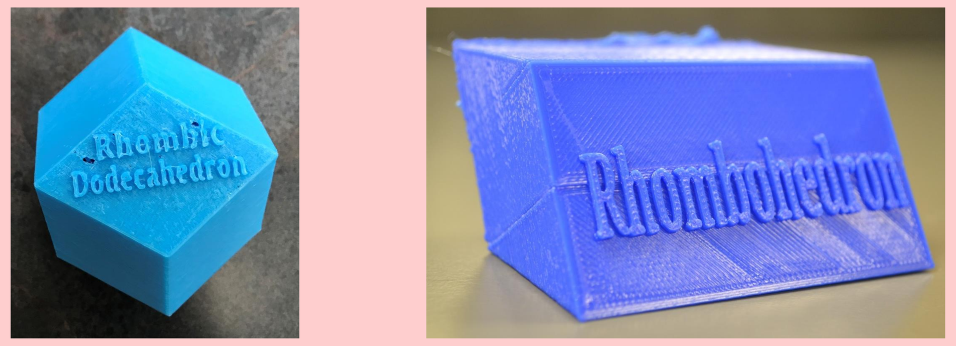
Potassium Dichromate

Trigonal

$\alpha, \beta, \& \gamma \neq 90°$
$X = Y = Z$



3-D Printed Models

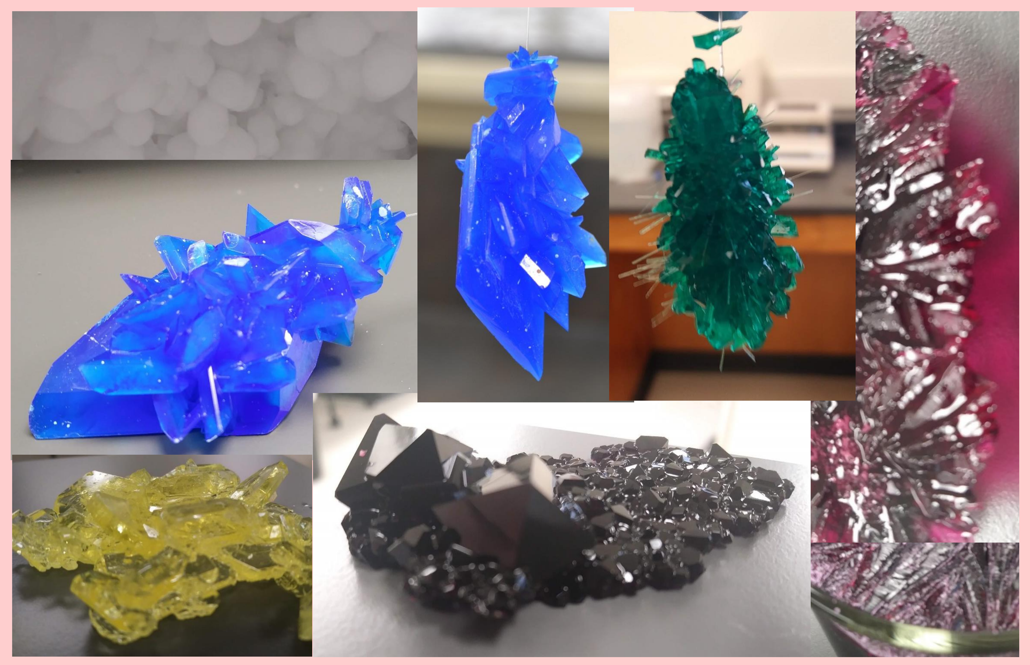


Finished Models

- Print time for each ranged from one hour to anywhere upwards of three hours depending on the design's complexity
- Extruder heated to 210℃
- Printed with the Creator Pro and XYZ printers and accompanying software
- Included structures such as:
  - Octahedron
  - Rhombic Pyramid
  - Hexagonal Prism
  - Pentagonal Dodecahedron

Happy Little Accidents

Things don't always go as planned. Although these specimens are not useful as teaching tools, they are still interesting and demonstrate variates of crystal structures.



Future Work

- Preserve the crystals, that are currently growing, in resin so that they will not dehydrate and can be handled as teaching tools.
- Grow different point systems within each crystalline family.
- Find better examples of tetragonal and trigonal crystals.
- Modify the shape of the designs of the 3-D replications if need be to enhance the structures
- Create more 3-D representations of different crystal structures to add more tangible tools
- Incorporate the structures into chemistry courses to be used as visual tools

Selected References

1. Holden, Alan and Morrison Phylis. *Crystals and Crystal Growing.* MIT Press, 1982.
2. Mendez, J. D., An Inexpensive 3D Printed Colorimeter. The Chemical Educator 2015, 20, 224-226

Acknowledgements

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