The IMI On-line Glass Learning Library

William R. Heffner

Int. Materials Inst. for New Functionality In Glass
Lehigh University, Bethlehem, PA

A. Technical Lectures for the Professional

B. Outreach Activity for Students
(Pre-College and College Students)
- Low-cost Learning Curriculum from the Kitchen Lab

http://www.lehigh.edu/imi/

NSF

LEHIGH UNIVERSITY

IMI NFG International Materials Institute for New Functionality in Glass

http://www.lehigh.edu/imi/library.html

On-line Glass Learning Library

An important goal of the IMI-NFG is to provide learning resources for the glass community. Here we present a large (and growing) collection of glass learning materials including on-line video lectures on a number of interesting and important glass topics, most by world leading glass experts. The categories include:

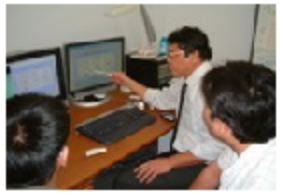
Glass Education for Students, Teachers & General Public

Glass-related information and activities to help the novice understand and appreciate the contribution and excitement of glass. Includes information, presentations, video clips, hands-on activities and ideas for exciting student projects for the home or school lab - all collected to compliment the glass learning experience. More >

Technical Learning Library

More than 200 technical video lectures in glass

This section is aimed for the science and engineering students and professionals. For most of the material in this category, you will need to be logged in as a Member to view. Membership is free.
Log in or register here.



The video lectures and material in the technical learning library include:

Semester Length Glass Courses

- Properties of Glass
- Characterization and Structure of Glasses
- US-Japan Winter School

Navigation Links

Learning Library:

Glass Education for Students, Teachers & General Public

Technical Learning Library

Quick Links:

Become a member

Plus many others – see actual page

Technical Learning Library

Materials in this section are aimed at the science and engineering students and professionals. For most of the material in this listing, you will need to be logged in as a Member to view. There is no charge for membership, just an interest in glass science. **Log in or register here**:

The material in the technical learning library includes:

A. Semester Length Glass Courses and Glass Schools (member log-in required to view)

Optical and Photonic Glasses by Prof. Rui Almeida - There are 39 forty-five minute lectures delivered at Lehigh University in Spring 2005. To see the complete listing of all lectures, please click the link above. You can view a Sample Lecture #1 without the member log-in.

Characterization and Structure of Glasses - A more advanced series of 26 ninety minute lectures by glass experts from six different universities. Course was delivered Spring 2007 semester.

US Japan Winter School - Thirteen international experts from Japan, US, Brazil and France lecture on application focused glass science topics. The lectures include 35 separate videos.

Properties of Glass - New Item - This series of 27 ninety minute lectures covers the properties of glass by glass experts from nine different universities. Course was delivered Fall 2008

B. Tutorial & Advanced Topic Lectures (member log-in required to view)

Tutorial and Advanced Lectures & Small Series

Most of these are half to one hour lectures on a variety of topics from

Navigation Links

Learning Library:

Glass Education for Students, Teachers & General Public

Technical Learning Library

Quick Links:

Education Outreach

Access the online library

Become a member

US-China Winter School will be here

Local Page – TLL US/Japan WS

Some Details for Viewing Streaming Videos

Several Types of Video Format

Real Media – requires Real Player (free download)
Adobe Connect – flash player – just browser
Windows (wmv) video – comes with MS operating system

All work fine from the Yuguan Hotel in Hangzhao

Please try some of our videos and let mu know
if they work from Zhejiang University and
if your like them.

B. Outreach Activity for Students (Pre-College and College Students)

Low Cost, Hands-on Activities for Learning Glass Science with Candy Glass

A Learning Curriculum from the Kitchen Lab

LEHIGH UNIVERSITY

IMI NFG International Materials Institute for New Functionality in Glass

Objectives of Student Outreach Program

Primary Goal:
To connect young students with glass & material science through hands-on learning

Approach:
Develop series of experiments around candy glass
- material students can make and use to explore many aspects of glass science.

- low cost (most activities below $20 (140Y) yet
- capture real glass science principles and issues
- inter-related to provide accumulated learning and prolonged engagement
- developed and tested with students
- available free to all on our website:

http://www.lehigh.edu/imi/

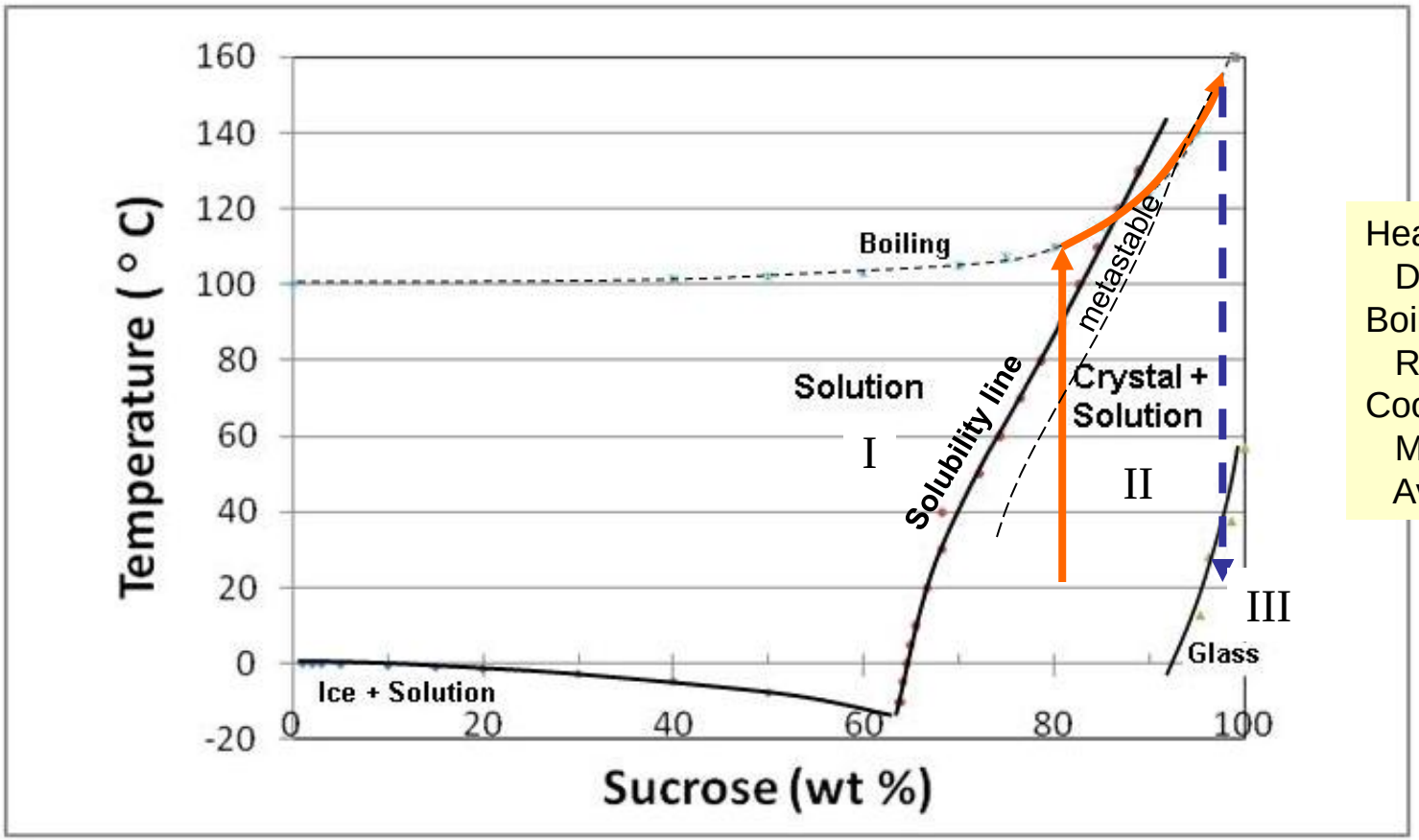
Some Outreach Experiments to Discuss

- Overview of Sugar Glass System
- Making of candy glass
- Fiber drawing experiments
- Refractive Index (2 methods)
- Crystal growth mechanisms (2)
- Thermal analysis for Glass Transition

Many others with more detail provided on the glass learning website. And I would like to hear about any that you have to share.

http://www.lehigh.edu/imi/

Material Science – The Sucrose Water Phase Diagram

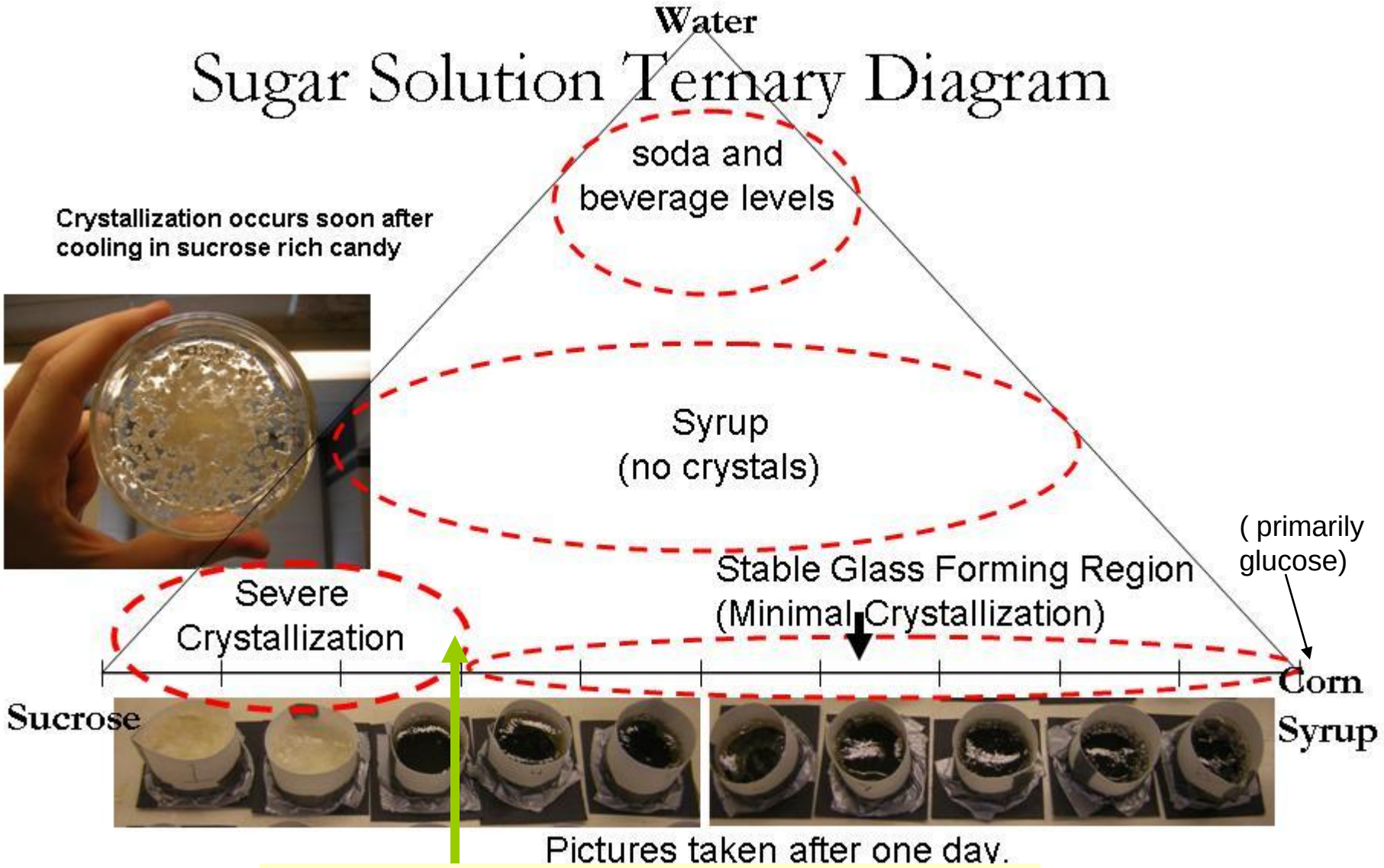


Heat to:
Dissolve
Boil to:
Reduce H_2O
Cool quickly to
Make Glass
Avoid Xtals

Data from **Mathlouthi and Reiser** (ed.), **Sucrose Properties and Applications (1995).**

Problem with Sucrose: **Very prone to crystallization at low water**

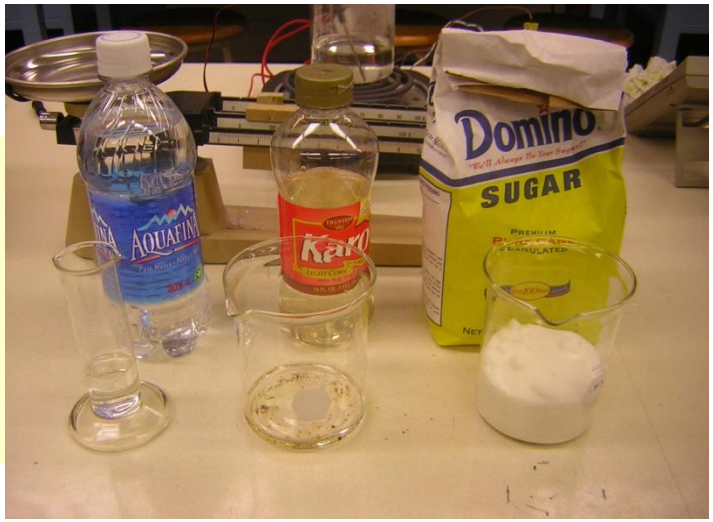
Sugar Solution Ternary Diagram



Recommend:

2:1 sucrose to corn syrup (by wt.)
for good glass with some crystal tendency

The Making of Hard Candy (Glass) – Material Synthesis Phenomenological approach

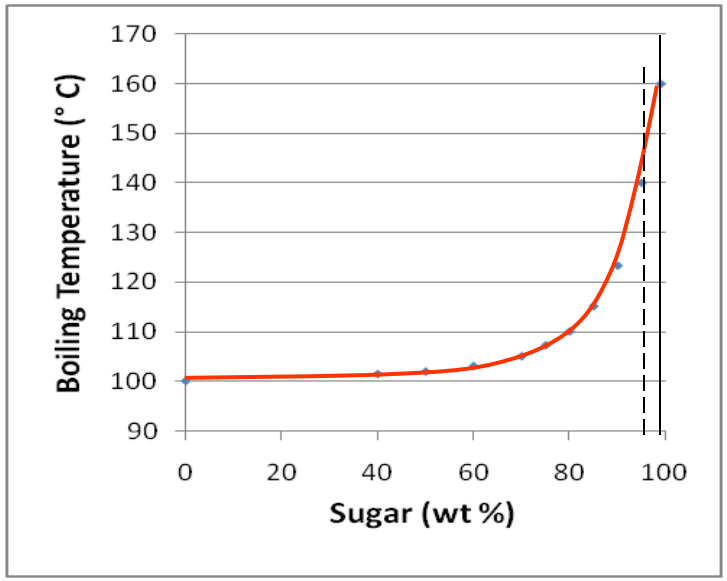


Sucrose, Corn Syrup and Water are combined and cooked-

- first to dissolve into a single liquid phase &
- then to remove most of the water.

Boiling temp provides measure of the water content.
Boil to ~ 150 C.

Cost ~ $5 in materials for many batches

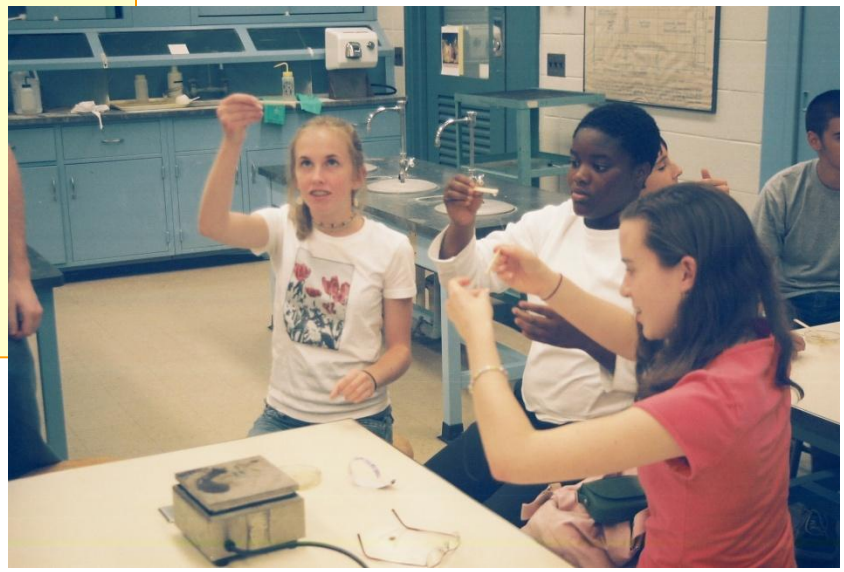


Data from Food Industries Manual, 24th ed, (1997).

A Favorite for the Science Camp

Typical Science Camp Activity or Teacher Workshop

- **examples, properties and structure of glass**
- **applications e.g. optics and fiber optics**
- **making of candy glass**
- **fiber drawing**

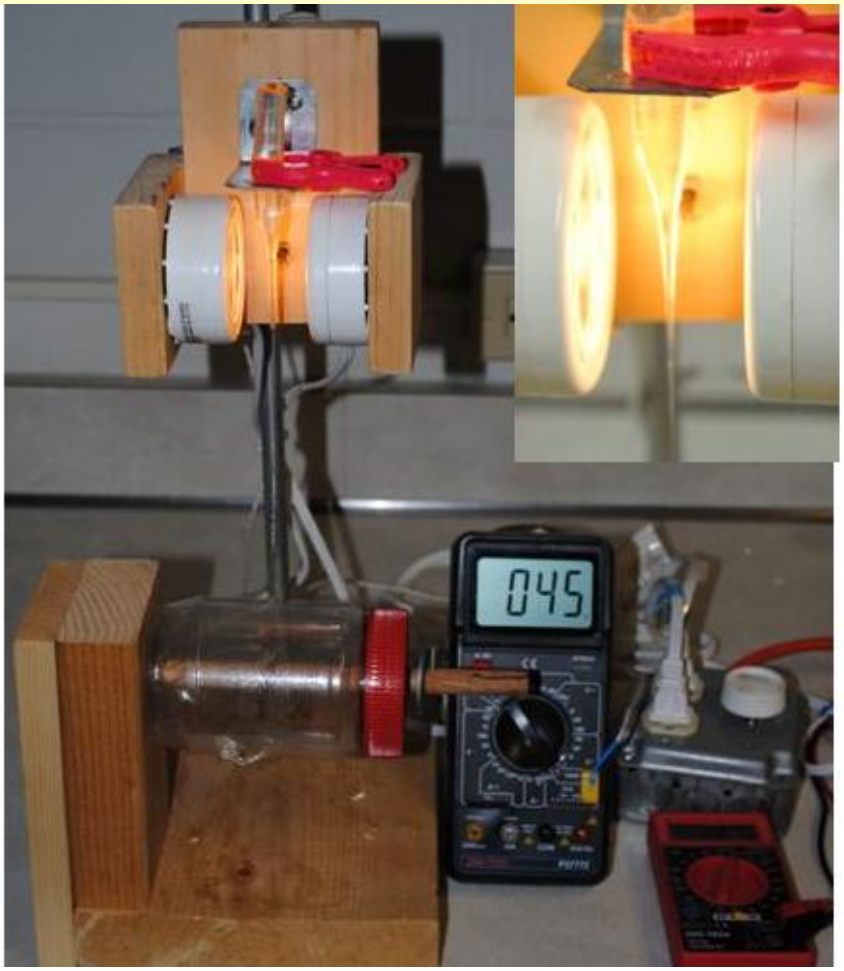


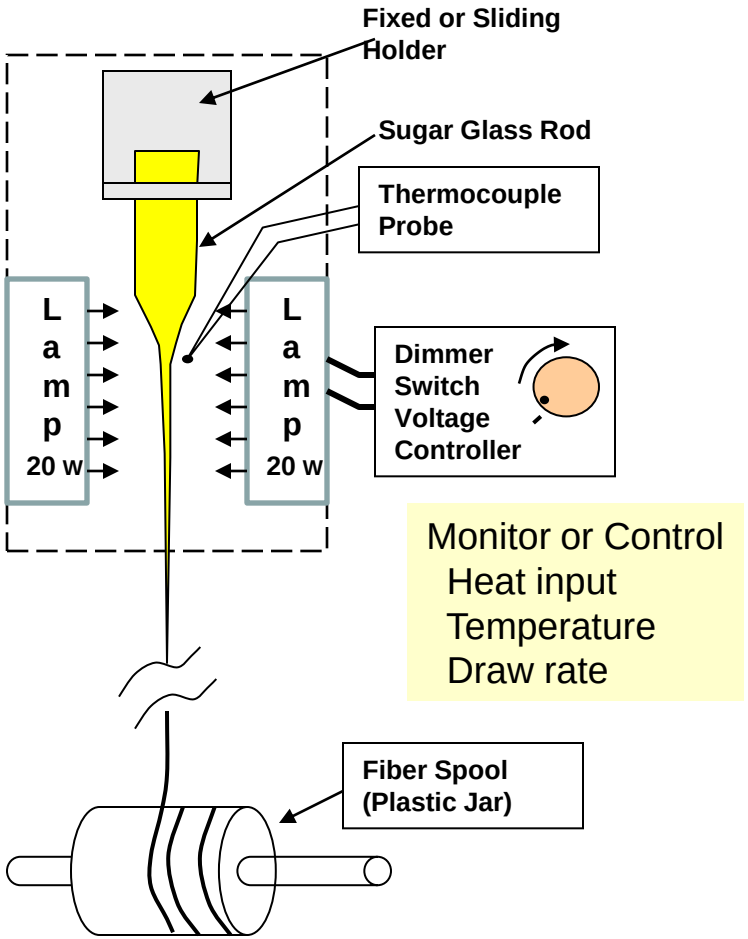
Fiber drawing never fails to excite and captivate – both young and old!

Multiple camps and workshops have provided a wonderful testing ground for what works!

Fiber Drawing Tower

Mimics the optical fiber manufacture process





Monitor or Control
- Heat input
- Temperature
- Draw rate

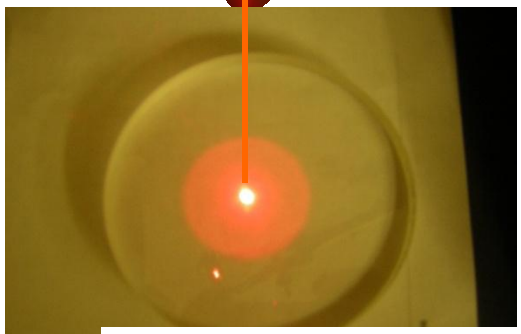
Opportunity to explore –
glass melting, visco-elasticity, heat transfer by radiation, and much more

Estimated cost - $20 for Tower and lamps, $10 for dimmer switch control

Refractive Index – 2 Methods

Pfund's Method

$n=\sqrt{(d^2+16h^2)}/d$



Requires:

- Slab of candy glass ~ 1 cm thick
- laser pointer ($5.00)
- caliper ($10.00)
- ring stand and clamp to hold laser

Accuracy: **std dev ~ 0.015 (~1%)**
sufficient for index increase with boiling

Min. Deviation Method

with Student Spectrometer

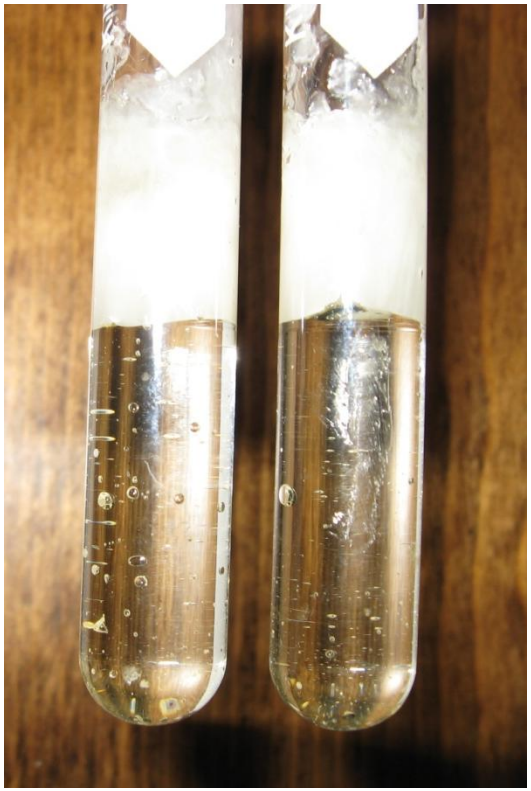
sugar glass prisms in microscope slide molds

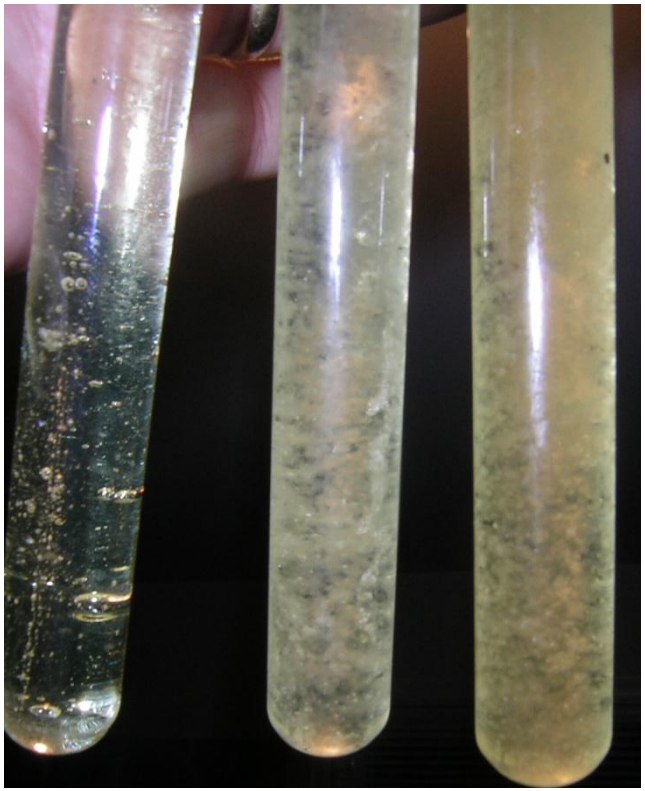
Requires:
Student spectrometer (from school lab)
box of microscope slides ($20)
and epoxy ($3).

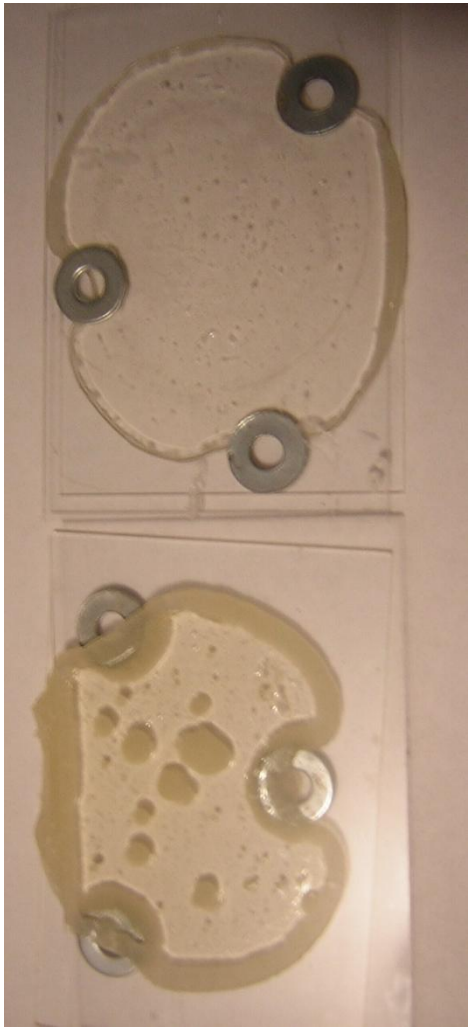
Accuracy: σ ~ 0.0015 (0.1%)

Excellent for Crystal Growth Studies

Two Distinct Mechanisms







Surface Crystal Growth
At room temperature
with moisture (humidity)

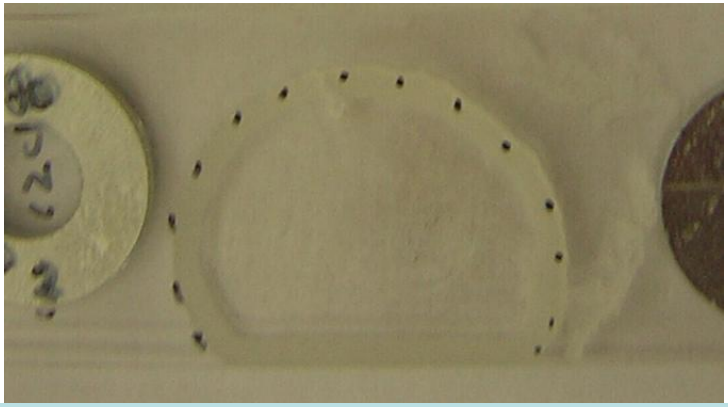
Interior Crystal Growth
From melt at elevated
temperatures

microscope slides provide convenient observation

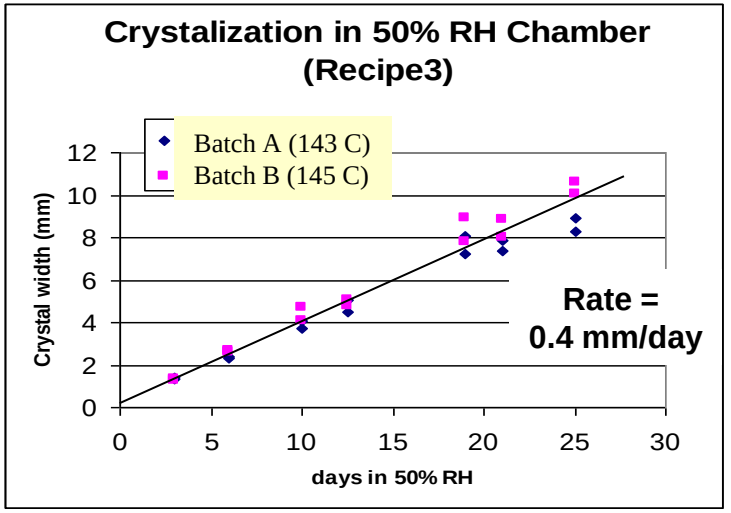
Have quantitative experiments for both

Quantitative Crystal Growth Experiments

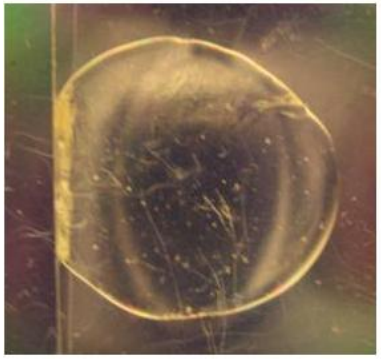
A. Moisture mediated surface crystallization at Room Temp



Growth of outer ring after 6 days at 50% RH



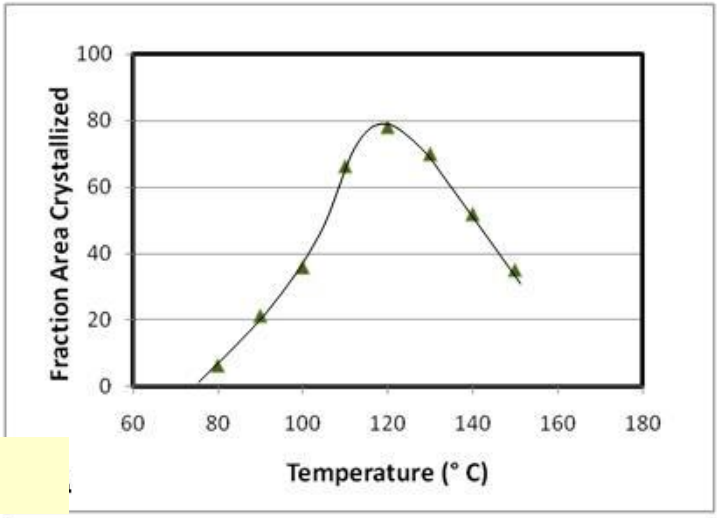
B. Finding the maximum crystal growth temperature in molten solutions



before anneal

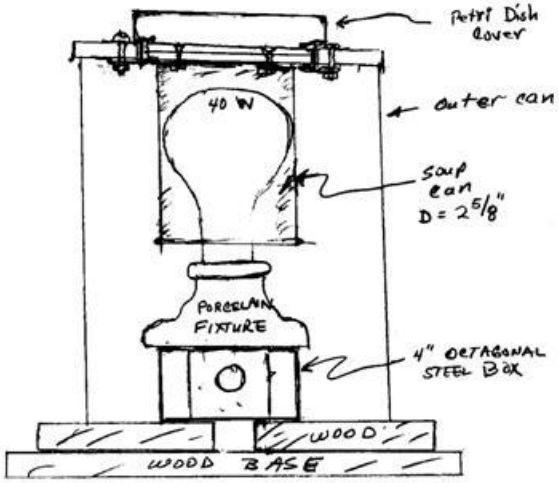
after one hour at 100 C

Heated in student-built oven (cost ~ $20)

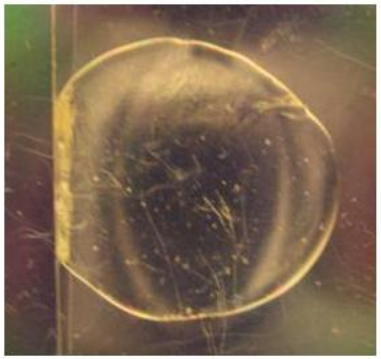


Devitrification in Molten Solutions

Finding the maximum crystal growth temperature

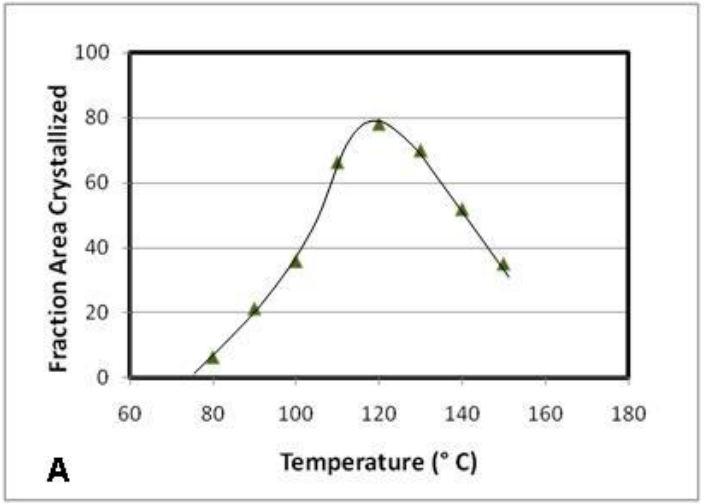


T uniformity
± 1°C typical



before anneal

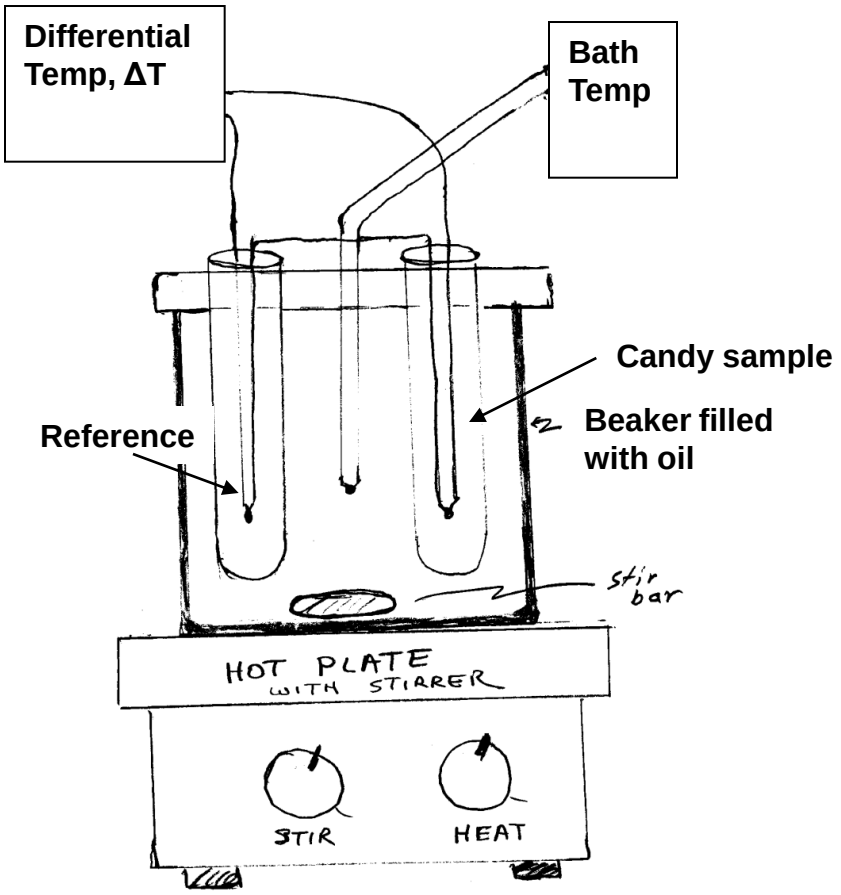
after one hour at 100 C

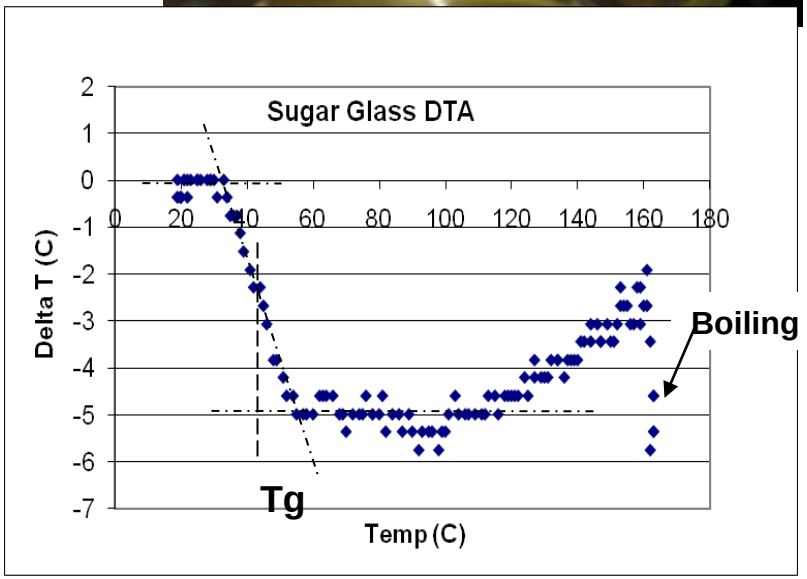


Oven cost ~ $20 with temp probe

Student used Image J freeware and calculate crystal area.
From NIH at: http://rsbweb.nih.gov/ij/

Thermal Analysis (DTA) for the Glass Transition





Quantitative Tg and Melting Expts

Enabling many interesting experiments on effect of thermal history and composition .

Summary

- **Collection of Hands-On Learning Activities in Glass Science (middle school through college)**
- **Inter-related around candy glass**
  - **materials synthesis**
  - **physical property measurements**
  - **crystal growth – both surface and from melts**
  - **thermal analysis and Tg**
- **Website accessible for wide distribution**
- **Regular updates**
- **Consider Candy glass in your undergraduate materials lab and share your experience and thoughts with us**

http://www.lehigh.edu/imi/

Acknowledgements:

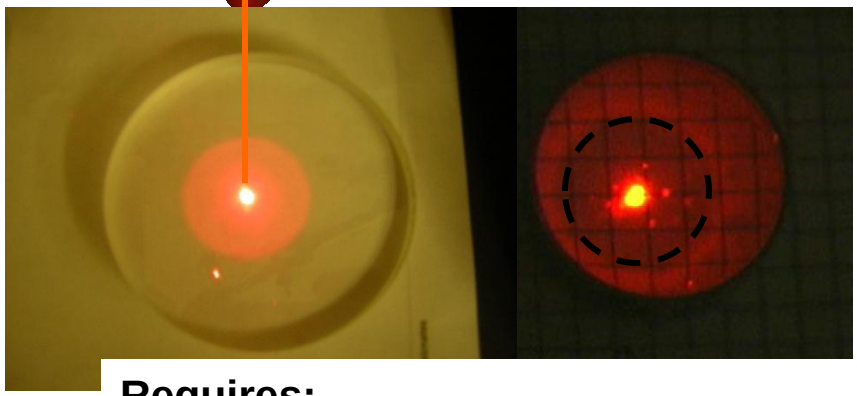
High school students (science projects):
Jung Hyun (Gloria) Noh (2007, 2008)
Isha Jain (2001)
REU students:
Tara Schneider (2006),
Sean Kelly (2007) and
Sarah Horst (2009).

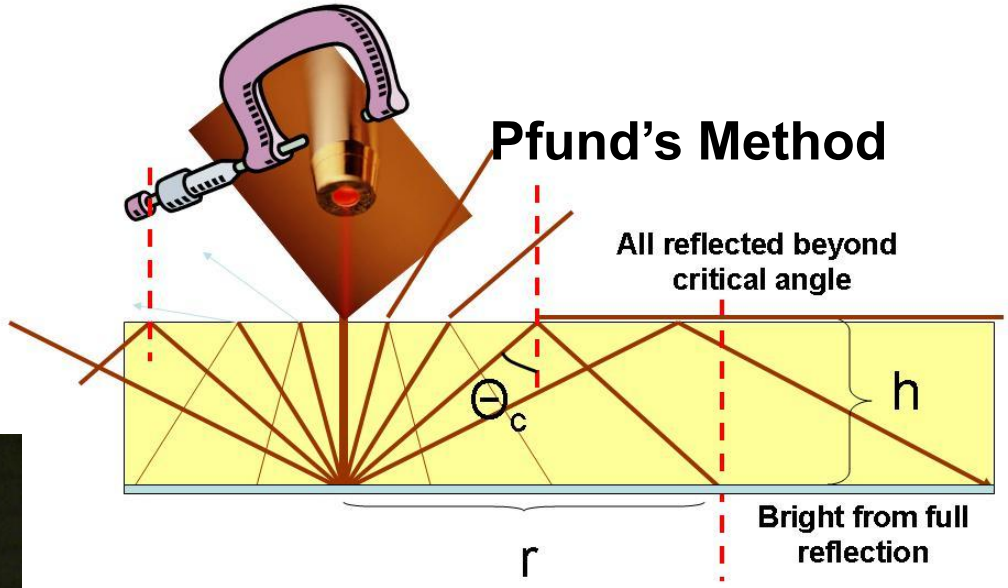
NSF for funding through the International Materials Institute for New Functionality in Glass (IMI-NFG): DMR-0409588 and DMR-0844014.

http://www.lehigh.edu/imi/

Refractive Index of Candy Glass via Pfund's Method

$n=\sqrt{(d^2+16h^2)}/d$



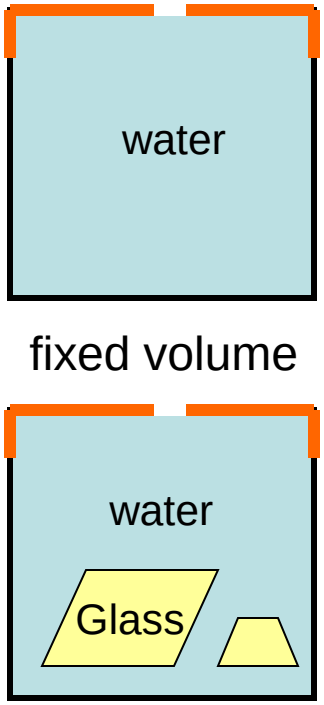


Requires:

- Slab of candy glass ~ 1 cm thick
- laser pointer ($5.00)
- metric ruler or caliper ($10.00)
- ring stand and clamp to hold laser

With practice Tara was able to achieve a **std dev of ~ 0.015 (~1%)** , sufficient to see the index increase with boiling temperature.

Student-built Pycnometer for Density Determination

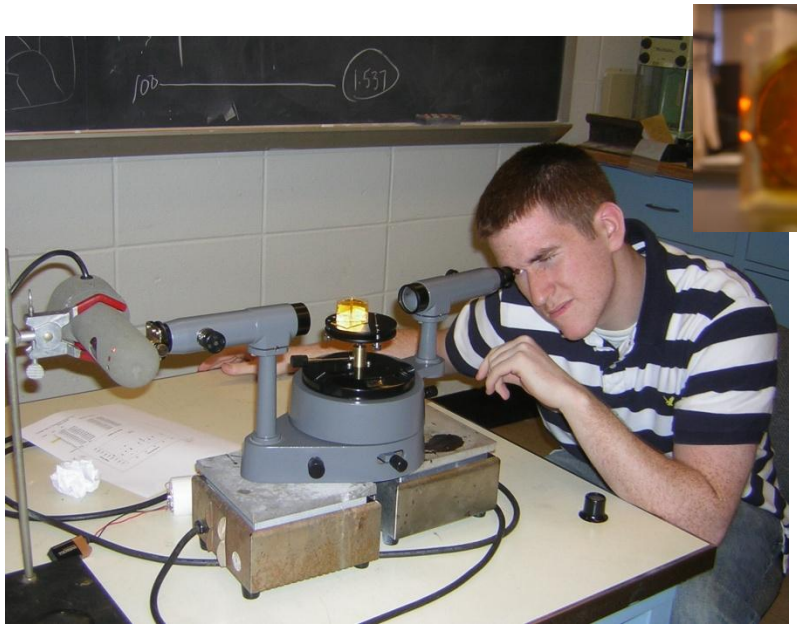


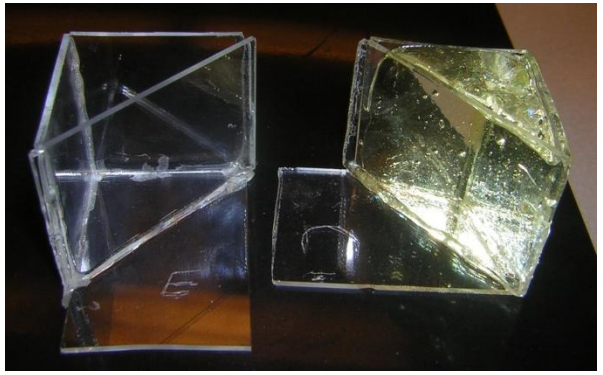
Specific Gravity = (wt of glass) / (wt of displaced water)
= (wt of glass) / {(wt of glass) – (wt of water displaced)} ,

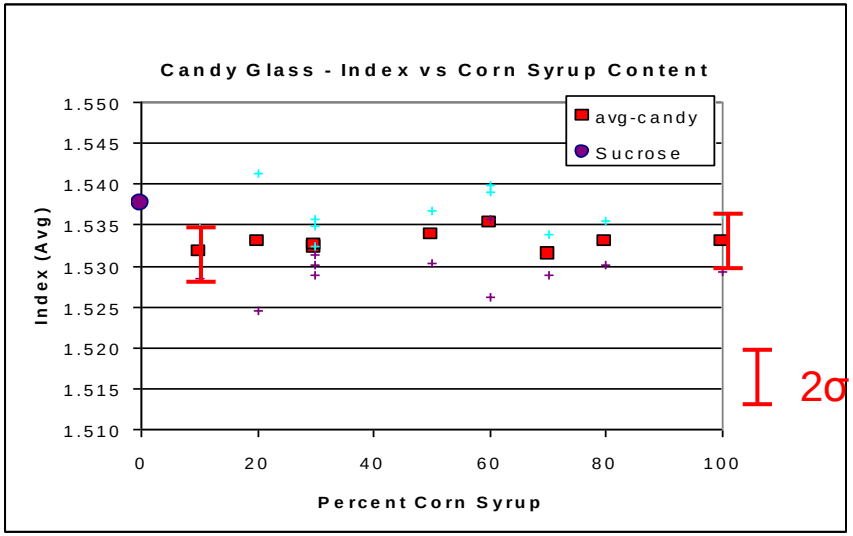
Utilizes Centigram Balance – available in most high school labs and salsa jar with hole in lid - **no other costs**

Results for insoluble oxide glass as test sample –
avg. specific gravity of 1.674 with std. dev. = 0.0032 (**0.2%**)

Student Spectrometer for more accurate Refractive Index Using the Min. Deviation Method







REU student Sean Kelley (2006) develops method for making sugar glass prisms from microscope slide molds and determining index of refraction to four place precision.

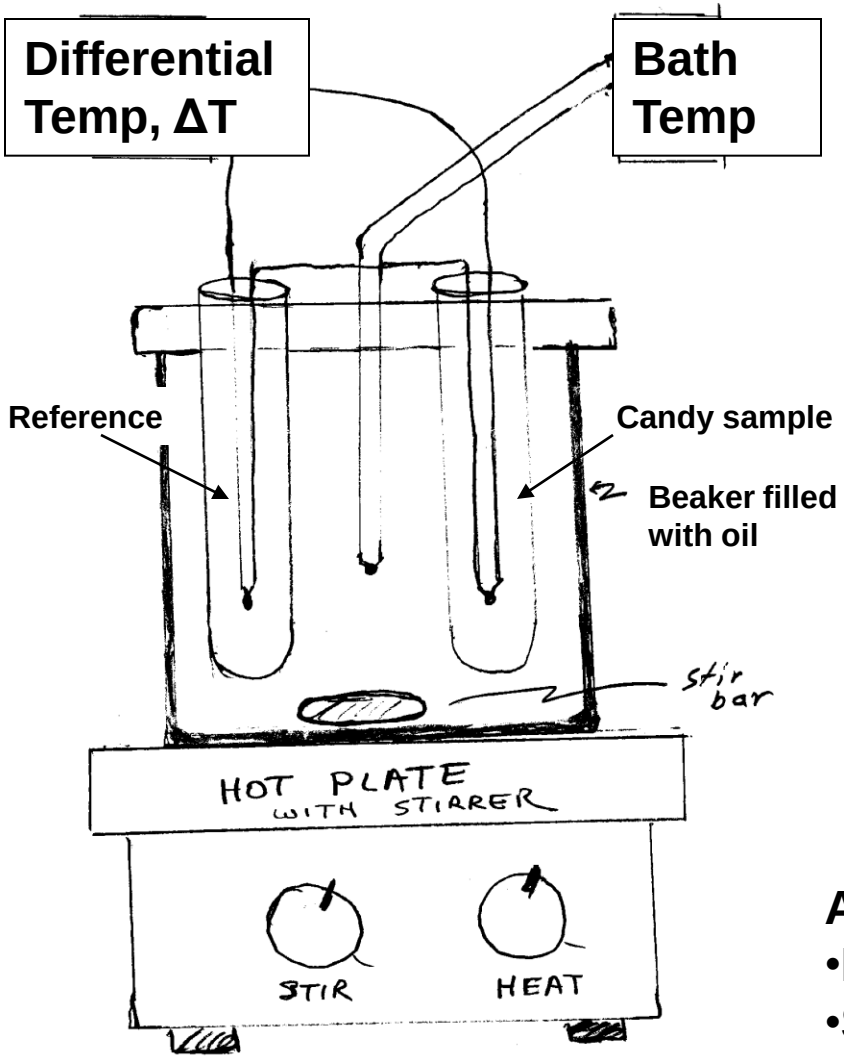
Having spectrometer, **cost is** a box of microscope slides ($20) and epoxy ($3).

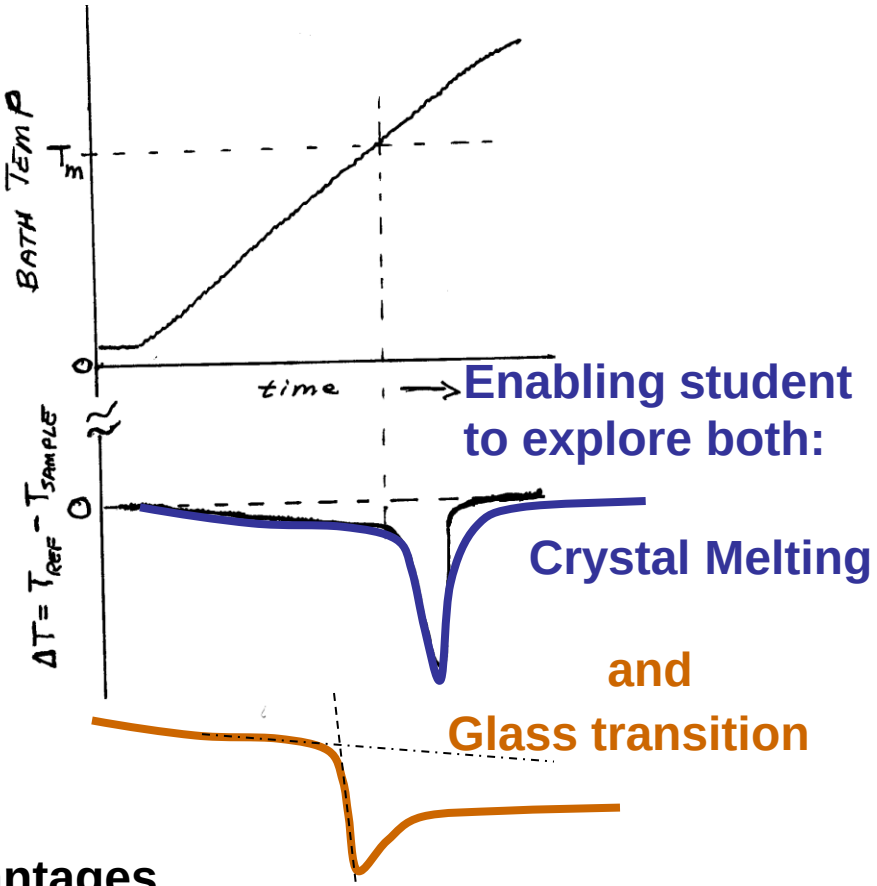
index method provides σ ~ 0.0015 (0.1%)

No significant dependence of index on sucrose/ corn syrup ratio.

Thermal Analysis for the Home Experimenter

Getting a handle on Glass Transition





Advantages

- Low Cost
- Student Assembled
- Can see (and poke) what's happening