Lessons learned from 30 Years
……at the front of the class room

If I have ever made any valuable discoveries,
it has been owing more to patient attention,
than to any other talent.
Isaac Newton (1642 - 1727)

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First things first… Good teachers… Care…

- First and foremost you must **care** deeply about your students…
  - A lot of the extra work needed…
  - A lot of the extra time required….
  - A lot of the extra patience necessary…
  - A lot of the extra perseverance that is essential…
  - A lot of the extra everything that is important…

- Comes from your heart when you care…

2… Know their subjects well…

- Technical competence is expected…
- Technical depth is needed…
- Technical knowledge is essential…
- Technical experience is really appreciated…
- So…continue to study your subject thoroughly…
- **To…**
- Convey your subject in a deep and meaningful way…
- Enable your students to reach the technical competence you expect…
- Establish your confidence and leadership in the classroom….

3…Interact with their students….

- A good teacher encourages contact with their students…
  - Frequent student-faculty contact helps motivate students and keep them engaged….
  - Faculty concern helps students get through tough assignments and keep on working.
  - Close interactions with faculty members enhances students' intellectual commitment…
  - Faculty connection and concern shows that you care about your students…
- ***They will go the extra mile for you if you go the extra mile for them…***

"Implementing the Seven Principles: Technology as Lever" by Arthur W. Chickering and Stephen C. Ehmann

4. … Create quality experiences that emphasize time on task….

- Engineering subjects are demanding…
- Well planned assignments encourage self-learning…
- Time plus energy spent on the subject deepens learning…
- Time well spent is critical for students...
- Allocate realistic amounts of time to increase effective learning for students and effective teaching for you…
  - ***Too little is too little…***
  - ***But***
  - ***Too much is too much…***

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5…..Communicate High Expectations

- Expect more and your students will strive to deliver it…
- High expectations challenge the poorly prepared to achieve more….
- High expectations foster further excellence for bright and well motivated students….
- High expectations are habit forming…

- ***The quality standards you set by how you conduct yourself…***

  ….. are the quality standards that your students rise to…

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6…. Give Prompt Feedback

- Prompt feedback enables students to assess what they know and don't know…
- …..Gives students frequent opportunities to perform and receive feedback on their performance…
- …..Enables students to reflect on what they have learned, what they still need to know, and how they assess themselves…

If you expect your students to be prompt with their work,

…you must be prompt with yours…

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7….. .Use active learning techniques

- Learning requires active engagement…
- Students learn best when they....
  - Talk about what they are learning…
  - Write reflectively about their learning…
  - Relate their learning to past experiences…
  - Apply their learning to their daily lives…

Students learn best when what they learn in your class, …becomes part of themselves.

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8…Develop reciprocity and cooperation among students…

- Learning requires both team and individual focus…
- Students benefit from collaborative and social learning environments…
- Collaborative work often increases involvement in learning…
- Students sharing ideas and responding to others' improves thinking and deepens understanding…
- Focus on a balance of team and individual work, both are important..

No one glass engineer made a strong touch screen….

….but each engineer had an important individual contribution….

…..they were individually responsible for….

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9….Respect diverse talents and ways of learning

- All students are different and learn differently…
- Visual vs. textural vs. auditory…
- Different students bring different talents and styles to your classroom…
- “Theory” students might be all thumbs in a lab…
- “Hands-on” students may not do so well with theory…

Students need opportunities to learn in ways that work for them…

…then they can be pushed to learn…

...in new ways that do not come so easily….

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Good teachers….

... are caring guides along the lifelong path of learning…

All truths are easy to understand. . .

once they are discovered. . . .

the point is to (help your students)

discover them. . .

Galileo Galilei (1564 - 1642)

- **Fundamentals of Glass Science and Engineering**
- Introduction to and general features of glass
- Compositions of Inorganic Glasses
- Fundamentals of the glassy (vitreous) state
- Conditions for glass formation
- Survey of glass structure and composition relations
- Survey of glass structure and composition relations

- **Physical Properties of Glass**
- Density
- Thermal properties of glass
  - Viscosity
  - Glass transition temperature
  - Thermal expansion
- Electrical properties
  - Dielectric properties of Glass
  - Conductive properties of Glass
- Optical properties
  - Passive optical properties of glass
  - Active optical properties of glass
- Mechanical properties
  - Elastic Properties of Glass
  - Strength of Glass

- **Glass Engineering and Manufacturing - I**
- Raw materials
  - Sources, mining, and costs
  - Handling, and mixing
- Compositions and batching
  - Soda-lime-silicate, window glass
  - Bottle glass, bulb glass, and specialty glasses
- Glass melting
  - Melting Processes; mixing, homogenization, and fining
  - Furnaces and fuels
  - Furnace design, types, and operation
  - Air and combustion
  - Fuels and their sources, costs
  - Refractories and thermal properties

- **Glass Engineering and Manufacturing- II**
- Glass forming
  - Float glass, bottles and containers
  - Fibers, tubing, and rods
- Enamels and glazes
- Glass Ceramics
- Annealing and toughening
  - Annealing for strain relief
  - Strengthening by rapid cooling (thermal tempering)
  - Strengthening by ion exchange

So….let's give a short example lecture….

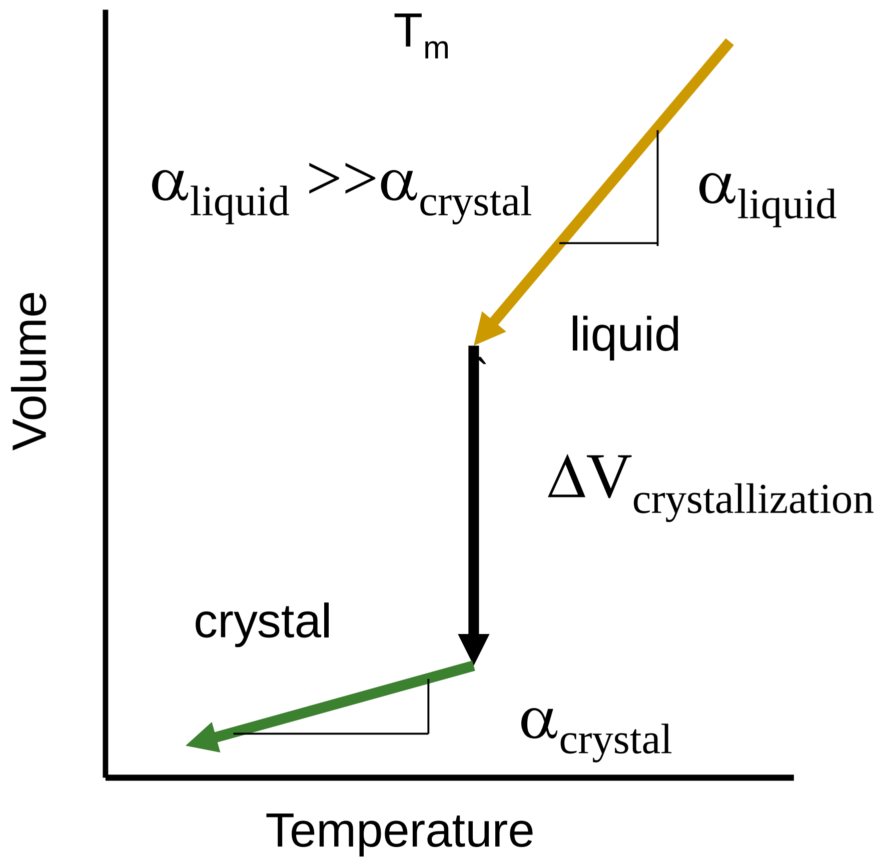
- Suppose you wanted to teach the kinetic aspects of the glass transition….
- Assume…
  - This is a 3rd or 4th year university course in glass science and engineering
  - The students have had….
    - Calculus, Freshman chemistry, sophomore physics, introduction to materials science, introduction to ceramics, and a first course in thermodynamics…
  - You must know what your students know coming into your class…
    - How well are they prepared? How well did they do in previous courses? What classes have they taken to prepare for your course? Talk to professors who have already had your students in previous courses….

The kinetic aspects of the glass transition…

- Turn to your partner….(TTYP)…this is a partner exercise…
- Discuss and Draw a sketch...
  - Of the temperature dependence of a normal liquid…
  - As it is cooled…
  - From well above its equilibrium freezing point…
  - Through the crystallization of the liquid at its freezing point…
  - To the smaller volume crystal…
  - Down to room temperature…
- Make this sketch assuming that the freezing (melting) point is 1000 ^{o}C and that thermodynamic equilibrium is achieved at each temperature along the path…

How did you do?....Crystallization is a Thermodynamic Transition

- Volume is *high as a* hot liquid
- Volume shrinks as the liquid is cooled
- At the melting point, T_m, the liquid crystallizes to the thermodynamically stable crystalline phase
- More compact (generally) crystalline phase has a smaller volume
- The crystal then shrinks as it is further cooled to room temperature
- OK, so this is the equilibrium path…

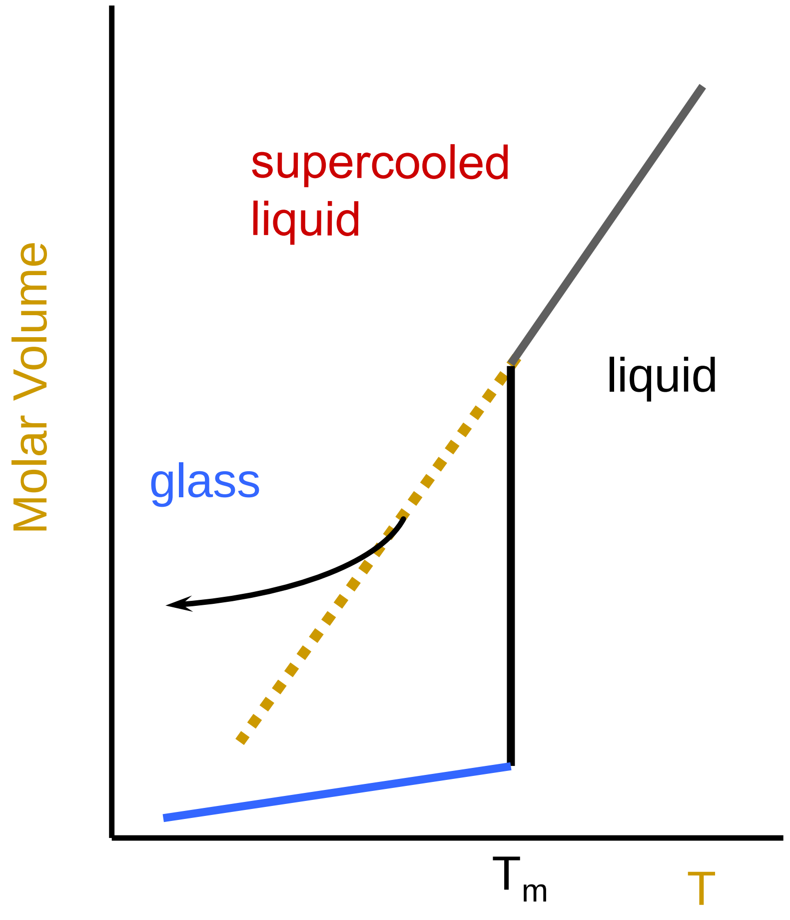


Now what happens if Equilibrium is not maintained?

- Use your same diagram and sketch
- What happens to the same liquid…
- Cooled from the same temperature…
- But now it doesn't crystallize at its melting point…
- It supercools below the melting point without crystallizing…
- This time, work on this yourself…

How did you do?.....Glass Formation is Controlled by Kinetics…

- Glass forming liquids are those that are able to "by-pass" the melting point, T_m, without crystallization
- Liquid may have a high viscosity that makes it difficult for atoms of the liquid to diffuse (rearrange) into the crystalline structure
- Liquid maybe cooled so fast that it does not have enough time to crystallize
- Two time scales are present
  - **"Internal"** time scale controlled by the viscosity (bonding) of the liquid
  - $\mathbf{t_{internal}}$
  - **"External"** timescale controlled by the cooling rate of the liquid
  - $\mathbf{t_{external}}$

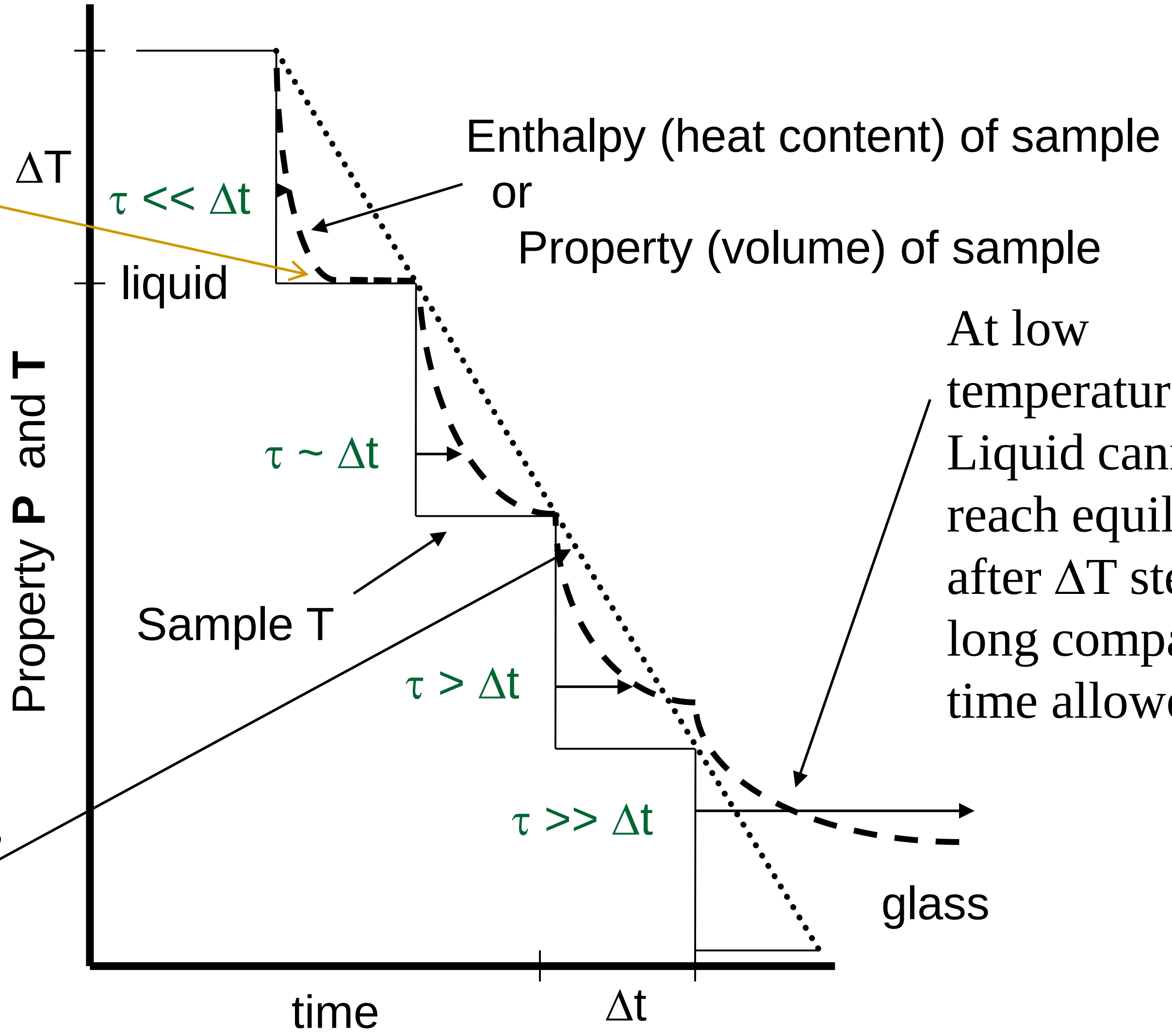


Glass Transition is a kinetic transition….

At high temperatures, Liquid can reach equilibrium after ΔT step, relaxation time τ is short compared to time allowed

$t_{external} \equiv$ Δt external timescale

$t_{internal} \equiv$ τ internal timescale



At low temperatures, Liquid cannot reach equilibrium after ΔT step, τ is long compared to time allowed

Average cooling rate,

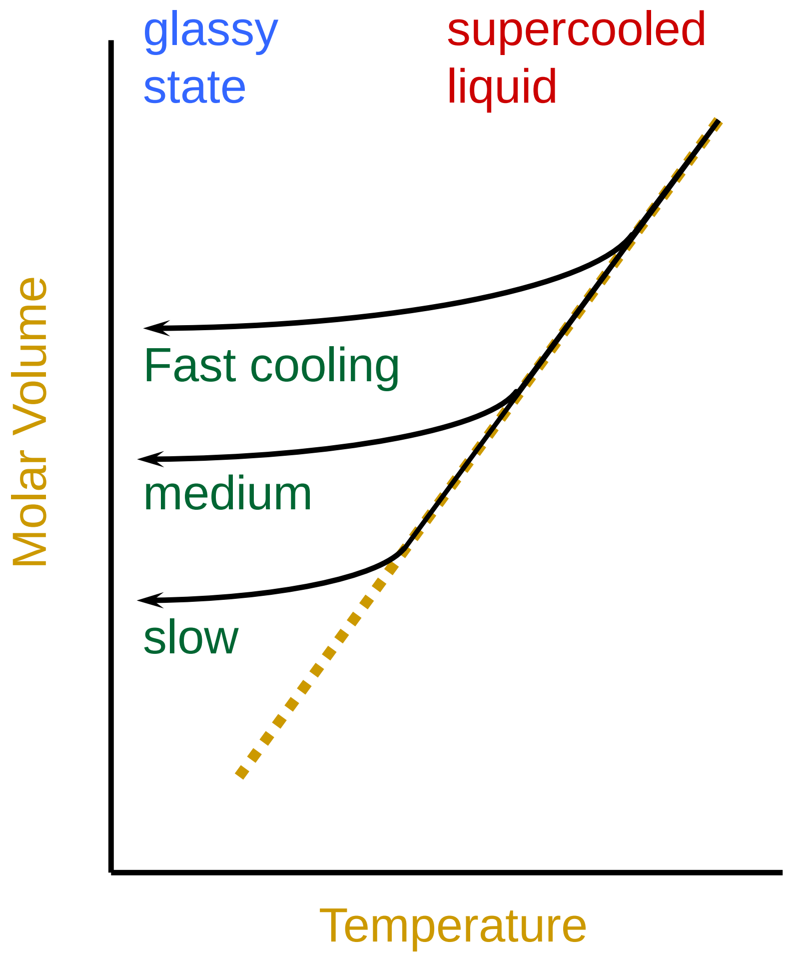
$\dot{T} = \Delta T / \Delta t$

Glass Transition is a kinetic transition….

- Cooling rate, the external time scale, affects the properties of glass
  - Faster cooling rates decrease the time the liquid has to "relax", the time to readjust to the temperature change, to the properties at the new (lower) temperature
  - Slower cooling rates increase the time the liquid has to relax to the properties at the new temperature
  - Fast cooling freezes the structure of the liquid (glass) at a higher temperature, therefore it has properties corresponding to these high temperatures
  - Slower cooling enables the structure to freeze at a lower temperature and therefore the glass has properties corresponding to these lower temperatures

The Cooling Rate Affects the Properties of Glass

- Faster cooling freezes in the glass at a higher temperature
- …the liquid does not have time to relax to the properties at the next lower temperature, glass is formed at a high temperature
- Slower cooling freezes in the glass at a lower temperature
- …the liquid can relax to properties at lower and lower temperatures, glass is eventually formed at a lower temperature



So let's wrap up….how did you do?

- What did you learn today….?
- Was anything confusing to you….?