Thermal Shock Demo

Soda-lime glass rod (flint glass)
Borosilicate glass rod (Pyrex glass)
Fused silica glass rod (list source here)
Propane torch and lighter or Bunsen burner
Beaker of ice water

Have students journal observations during the demonstration.

Show the students the difference in color (looking at the ends) of the 3 glass rods. The soda-lime glass will have a definite green color (think Coke bottle green). The fused silica will be white if unpolished. Borosilicate will be in-between. The higher the percentage of silica content, the less color the glass will have. The greenish tint is due to iron oxide impurities in the silica.

Heat one end of the soda-lime glass rod in the flame.
Point out the "sodium flare" that occurs as the glass heats up.
Allow the glass to sag or slump to show softening.
Remove from flame and quench in ice water.
Thermal shock will occur and pieces of glass will break off onto the bottom of the beaker.

Heat one end of the borosilicate glass rod in the flame.
There should be less sodium flare.
Sagging or slumping should be harder to achieve but the end should fire polish.
Remove from the flame and quench.
Some thermal shock will occur. There should be fewer overall cracks than with the soda-lime glass.

Heat one end of the fused silica glass rod in the flame.
There should not be a sodium flare
No sagging, slumping, or fire-polishing will occur.
Remove from the flame and quench.
The rod will not thermal shock. No cracks should occur.

Glass is a poor conductor of heat. The outside will cool and contract much more rapidly when quenched. A lot of stress is put on the glass and it causes failure. The greater the coefficient of thermal expansion, the more likely the glass will break.

The two most important properties that determine resistance to thermal shock in glass are thermal conductivity and coefficient of thermal expansion.
Thermal conductivity - how well heat is conducted.
- hard to measure
- doesn't vary much in glass
- the better the conductivity - the more rapidly and evenly heat is distributed
- better conductivity = less chance of thermal shock  (inversely proportional)

Coefficient of Thermal Expansion - amount of expansion per unit of length per °C.
- easy to measure
- varies greatly in glass
- the lower the coefficient - the less stress caused by sudden temperature changes
- lower coefficient = less chance of thermal shock  (directly proportional)

General guideline for determining thermal shock probability in glass:

\[
\text{Coefficient of thermal expansion} \quad \frac{\text{Thermal conductivity}}{\quad}
\]

Larger the value of the ratio, more likely damage will occur due to thermal shock.

The value for thermal conductivity stays pretty much the same for all glass. Thus the coefficient of thermal expansion has the most effect.

Show the overhead of “materials and coefficient of thermal expansion”.
Show overhead of “properties of silica in glass”.
- soft glass = higher modifier rate
- hard glass = lower modifier rate

<table>
<thead>
<tr>
<th>Material</th>
<th>Coefficient of Thermal Expansion (cm/cm x °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fused Silica Glass</td>
<td>6 x 10^{-7}</td>
</tr>
<tr>
<td>Borosilicate Glass</td>
<td>33 x 10^{-7}</td>
</tr>
<tr>
<td>Aluminosilicate Glass</td>
<td>44 x 10^{-7}</td>
</tr>
<tr>
<td>Porcelain</td>
<td>60 x 10^{-7}</td>
</tr>
<tr>
<td>Soda-Lime Glass</td>
<td>85 x 10^{-7}</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>110 x 10^{-7}</td>
</tr>
<tr>
<td>Aluminum</td>
<td>250 x 10^{-7}</td>
</tr>
</tbody>
</table>
Properties of Silica in Glass

<table>
<thead>
<tr>
<th>Lower</th>
<th>% of Silica in Glass</th>
<th>Higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>Type of Glass</td>
<td>Hard</td>
</tr>
<tr>
<td>Lower</td>
<td>Melting Temperature</td>
<td>Higher</td>
</tr>
<tr>
<td>Higher</td>
<td>Coefficient of Expansion</td>
<td>Lower</td>
</tr>
</tbody>
</table>

Soda-lime glass has a high percentage of modifier. Fused silica glass has no modifier, it is pure silica. Borosilicate glass has an intermediate amount of modifier. A modifier is used to lower the melt temperature of the glass and increases the workability of the glass.

Another demonstration using the three different glass rods involves the index of refraction. Borosilicate glass has about the same index of refraction as vegetable oil. Immerse the three rods in a beaker or clear plastic cup containing an inch or two of vegetable oil. Only two rods should be visible in the oil. The third one, the borosilicate rod “disappears”.

Sources of glass rods:
Soda-lime and borosilicate: Frey Scientific and Flinn Scientific
Fused silica glass rod: National Scientific Company - www.quartz.com