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The Wasberg Effect

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Working on demonstrations that were considered useful and graphic teaching tools received considerable energy from the participants at the NorthWest Workshop for Teachers of Chemistry (NWW) under the direction of Dr. Glenn Crosby at Washington State University in 1987. Some new demonstrations were developed, but most of the effort was spent dealing with traditional and published successful teaching aids to make the directions uniform and clear, even to teachers without extensive chemistry training, and to perfect directions that would work every time.

One of the participants, George Palo of Gig Harbor, Washington, presented the "Conductivity of Glass" showing that an ordinary glass rod, usually considered a superior insulator, will conduct electricity quite well when heated to a softening temperature. The presentation is useful to explain why salt water conducts electricity but pure water does not and why sodium chloride salt will conduct quite well in the molten state but not as a solid. It is a reliable procedure and much easier, quicker and more spectacular than trying to melt sodium chloride. An element of surprise as the glass becomes a conductor helps make the lesson memorable.

Dennis Wasberg, a chemistry teacher from South Bend, Washington, was intrigued by this demonstration and wanted to find out how well it would work using ordinary soft glass tubing instead of a glass rod. The borosilicate glass commonly used in lab stirring rods requires very high temperatures to reach the required softening point, but nearly every chemistry laboratory has soda-lime glass tubing that is easily bent and fire-polished with an ordinary gas burner.

In the laboratory, Wasberg set up the usual apparatus for the glass conductivity experiment demonstrated by Palo, but instead of the solid glass rod he used 6 mm O.D. glass tubing about 2 cm in length. (The exact size is not critical to the integrity of the experiment, but the entire length of the tube between the wire electrodes must be capable of melting with the bunsen burner used.) Rather than laying the glass across the electrodes, Wasberg inserted the wires a short distance into the tube (Figure 1). When it was heated briefly with a burner flame, the light bulb began to glow and became brighter as the glass softened, indicating conductivity as did the glass rod experiment.

When the burner was removed to allow the glass to cool, Wasberg noticed an unexpected glow. Light was being emitted from the glass tube that appeared not to be a result of the glass being heated "red hot." Much interest was shown by nearby participants and, when no one could explain the phenomenon, it was suspected to be one of those strange quirks that could never be repeated except by accident. To the surprise of the group, the light could be made to recur in the same glass tube and in fresh replacements. Dr. Glenn Crosby of the Washington State University Chemistry Department was summoned, and he expressed surprise at never having seen this arrangement effect a light such as the one Wasberg produced. The new discovery therefore was named the *Wasberg Effect*.

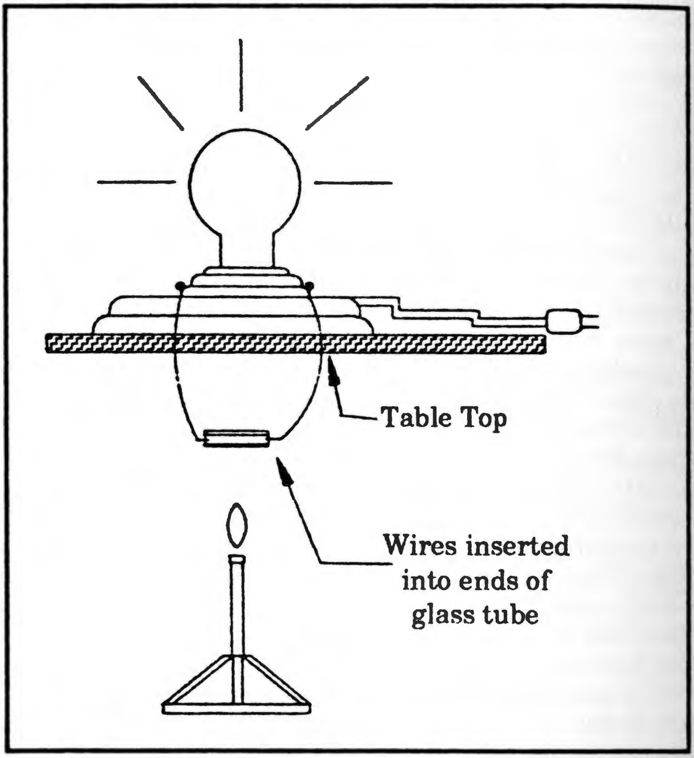

Figure 1
Conductivity Apparatus

Dr. Crosby spotted a plasma inside the glass tube, and the color of the light emitted by the plasma appeared to be the same shade of yellow as the bright, fluffy sodium flame that came from the glass as it neared and reached softening temperatures. From the first, it was strongly suspected that the plasma contained sodium ions from the glass, but no one expected the volitization of the sodium at the temperatures at which the effect occured to be high enough. Household voltage and room pressure sustained the plasma until the temperature seemed to have dropped quite below usual softening and conduction.

Constraints of time available in a busy schedule prevented research in any depth of the phenomenon until the summer of 1991. As a Teacher Research Associate (TRAC) participant in a DOE funded program at Battelle Pacific Northwest Laboratory (PNL) in Richland, Washington, the author had the opportunity to find out more about this effect. Scientists in the glass and ceramics labs at PNL who were familiar with the readiness of glass to conduct when softened but not at all familiar with the light production at the electrodes, cooperated in the investigations.

The first attempt to demonstrate the Wasberg Effect nearly failed because the tubing used was borosilicate glass and the burner heat source would not heat the glass enough to conduct sufficient current to light the bulb. Because no soda-lime glass tubing was handy, a piece of a broken glass microscope slide was placed across the copper wire electrodes. When this glass was heated, the lamp began glowing, and light was emitted from the electrode-glass junction. The Wasberg Effect worked without a tube.

With the electrode wires about 5 mm apart and bridged by the glass, the bright light at the electrode continued, and conduction occurred without additional heating with the burner for more than an hour. The power from the household electrical circuit was keeping the glass hot and sustaining the effect. During this performance and the next day, when soda-lime glass tubing was used, a lot of bright sparking was noted at the junction between the glass and the copper electrode. Furthermore, the copper wire was considerably degraded following the long demonstration. An oxide coat naturally formed on the wire where it was exposed to the air and heated by the flame, but corrosion was severe at the points of contact with the glass. To check on the interaction of the glass with the metal, Mike Schweiger, a PNL glass scientist provided some platinum wire to use as electrodes. Short lengths of platinum wire were connected to the copper wire with alligator clips and the procedure was run as before. Bright sparks still occurred at the glass-metal interface as the glass began conducting. Light was emitted and the glass became hot enough to melt to a viscosity low enough so that it would no longer support itself. As the glass stretched and became thinner, the narrow place become hotter and glowed nearly white hot before breaking. This bright light was most certainly black body radiation. The high temperature was due to the expected ohmic resistance of the glass and the electrical power.

Inspection of the cooled glass revealed fine bubbles at one electrode and streaks of dark grey or black discoloration in the glass around the platinum electrodes. Red discoloration and black copper oxide had previously been seen around the copper wires. This prompted the question as to whether this discoloration would occur at both platinum electrodes if a D.C. circuit were used. Ron Stevens, a Battelle technician, supplied a rectified power source for the circuit. With it in place, the effect appeared as usual. Small sparks were seen initially and a bright light was emitted at one electrode. Fine foamy bubbles appeared at this electrode and the glass remained hot with the burner removed as happened before.

Soon, the light went out and evidence of a current stopped. Reheating the glass with a gas burner had no effect. Following a suggestion that we see if the bright light changed electrodes when the polarity was reversed, the plug was turned over, polarity switched and immediately current flowed. Bright Wasberg Effect light was emitted from the same electrode as before, and arcing was noted at the opposite electrode along with foamy bubble formation. The effect continued for a short time and stopped again. Without adding heat, the polarity was reversed and current flow was again evident. This was repeated five or six times before the glass cooled enough to stop conduction.

This is a good demonstration to show that the conduction of glass is from ion migration, not electron conduction as in metals. In glass, the ions pile up and polarize the electrodes, halting the current flow. Polarization is not seen, of course, when a normal alternating current (A.C.) is used. The ions can be reversed to allow conduction in the opposite direction, but polarization again occurs. Ion migration offers quite a bit of resistance and results in the electric current heating the glass to glowing temperature. Black body radiation accounts for some of the light but not the brightest. The really bright light was recognized at discovery as coming from a plasma. The plasma appears to be always between the electrode metal and the conducting glass or ceramic. It appears that the formation of the gas causing the fine foam around the platinum electrode reduces contacting surfaces, promoting arcing and its plasma glow of bright light. Gas bubbles do not appear when the copper wires are in contact with the glass, but the copper corrodes excessively. This suggests that the gas involved is oxygen, which reacts with the copper readily at the high temperatures produced in the experiment.

That the bubbles produced in the direct current demonstration are oxygen is supported by another procedure. Following this demonstration, a black substance was observed in the molten glass. The presence of this material along with the fine bubbles suggested that the silica, SiO_2, in the molten glass was undergoing electrolysis. X-ray diffraction by Gary Maupin, one of the ceramics scientists at Battelle, confirmed this suspicion when the "black stuff" produced a positive pattern for silicon crystals (Figures 2 and 3). Not too surprisingly, platinum was

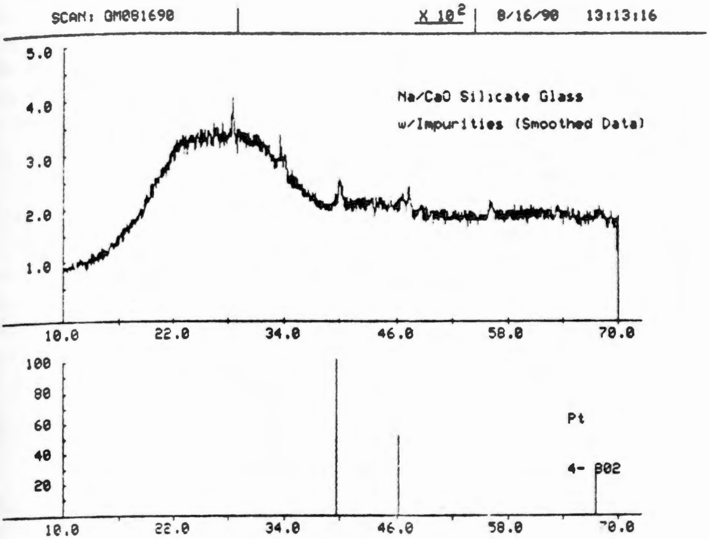

Figure 2
X-ray diffraction scan showing presence of platinum metal imbedded in glass from conductivity experiment

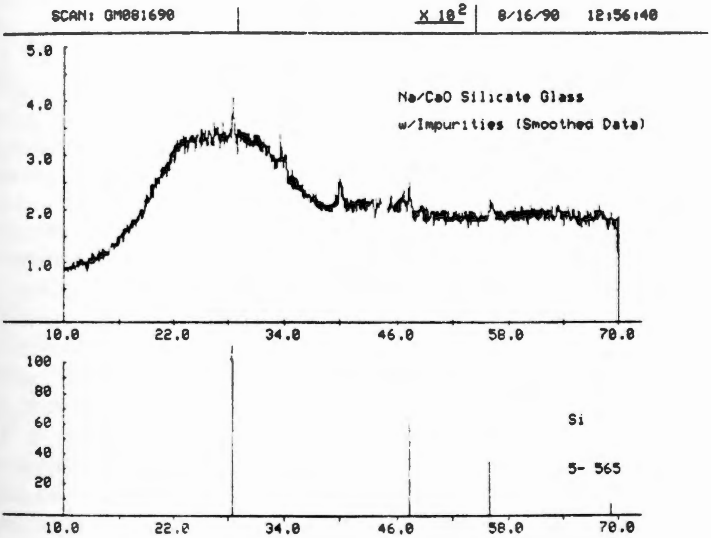

Figure 3
X-ray diffraction scan showing presence of silicon metal imbedded in glass from conductivity experiment

found in the glass as well. Some of the silicon metal alloys with the platinum wire making it extremely brittle. As a result, it breaks easily leaving pieces in the solidified glass.

Maupin suggested replacing the glass with a short length of stabilized zirconia, ZrO_2. No immediate conduction was observed, but when the zirconia was heated red hot, sparking occurred at the electrode interface as in the glass and the zirconia began glowing along a path between the electrodes. As it heated, conductivity increased, typical of ceramic conductors, and no additional heat from the burner was necessary to continue the demonstration. Bright Wasberg Effect light was emitted at the junction between the metal and the ceramic, and the path of conduction through the zirconia glowed with black body radiation. Zirconia is most often used as a refractory, and because it does not melt like the glass, the effect could be sustained almost indefinitely. The extremely high temperatures that accompany the Wasberg Effect plasma were evidenced as small droplets of melted platinum were seen spattering from the arc at the bright light. Platinum melts at 1773°C, so temperatures had to approach 2000°C in at least tiny local areas. Temperatures this high at the interface would account for the red discoloration in the glass at the copper electrode and black at the platinum electrode as finely divided or molten metal is incorporated in the softened glass.

Like glass, zirconia conducts by ion migration. Oxygen ions migrate through the stabilized or "doped" zirconia. Using the D.C. electrodes, polarization did not occur since interaction with oxygen in the air kept the ion supply moving, preventing polarization of the electrodes. Depletion of oxygen from the zirconia, especially at the positive electrode junction at that high temperature is indicated by grooves the electrodes seem to have "eaten" into the zirconia as it became brittle and was degraded by the electric arc into a non-stoichiometric form. Zirconia is an excellent refractory material resisting damage from high temperatures alone.

The Wasberg Effect plasma could be shown not to be dependent on volatilized ions from the glass. With the electrodes less than one millimeter apart in air, no plasma could be generated or arc induced even with the wires enveloped in the thick, fluffy yellow of a sodium flame from glass or salts. Quartz tubing was tried to enclose the electrodes, and with glass or salts inside the tube but not making contact with the wires, no arc would form and no current would flow. Lithium glass, containing no sodium, was supplied by Guy Whittaker, a TRAC participant, and the conduction was even more easily demonstrated than with soda-lime glass. The bright Wasberg Effect light was present and not significantly different to the naked eye from earlier experiments. There may have been a pinkish tinge to the light, but not the bright pink expected if lithium ions were significantly responsible.

The Wasberg Effect light seems to be from an air plasma in the electric arc between the metal electrodes and the ceramic conductor. Elements from both materials may be present in the plasma as the high temperatures and electric energy create a sputtering of matter into the space. Spectroscopy on this light should confirm this. Larry Pederson of Batelle and the author tried capturing the light from the Wasberg arc in a spectrophotometer, but were unsuccessful. The light was not the right brightness and too unsteady, therefore a lot of "noise" and no conclusive evidence was registered.

A good spectroscopic study of the Wasberg Effect light remains to be done. Even so, this work should contribute to the understanding of this phenomenon. The demonstration is easy to perform and recommended for chemistry, physics and materials science classes.

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