# Live Wire

**Properties of Solids** 

## Introduction

See a "live" wire snap back into its remembered shape when it is put into hot or cold water.

## Concepts

• Metal alloys

Crystal structures

## Materials

"Live" Wire (nitinol wire, pronounced "night 'n all" )Bunsen burner (or candle)Beaker of ice waterMatchesBeaker of near-boiling waterPliers or tongs

## Procedure

#### Part A. See the wire remember its straight shape

- 1. Start with the Live Wire in a "straight" form.
- 2. Hold one end of the wire and place it into the beaker of ice water until it is thoroughly chilled.
- 3. Remove the wire and quickly use your hands to bend it into crazy shapes (or better yet, if you can, bend it while it is still in the ice water).
- 4. While holding one end of the bent Live Wire, carefully dip it into the near-boiling water. The wire should instantaneously pop back straight again. Amazing that a piece of wire can "remember" and return to its original straight shape!



#### Part B. "Train" the wire to remember a new shape

- 1. Starting with the straight wire, use your hands or pliers to bend the wire at room temperature into a desired shape.
- 2. While firmly holding the wire in this shape with pliers or tongs (you may need 2 pairs), heat it in a Bunsen burner flame (or candle flame) until it is just slightly red. The wire will at first "fight" and want to straighten out. (You must "train" it.) *Note:* Overheating will not help in this procedure and may actually damage the wire.
- 3. Allow the wire to cool to room temperature, still holding it in its "trained" shape.
- 4. Chill the wire by dipping it into ice water. Remove the wire from the ice water and immediately straighten it out.
- 5. Using tongs, dip the wire into a near-boiling water bath.
- 6. The wire should "remember" the bent shape in which you "trained" it and form back into that shape.
- 7. Both Parts A and B may be repeated millions of times if the wire's unique crystal structure is not damaged by overextending or overheating.

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## Disposal

If not overheated or overextended (which may damage the wire's unique crystal structure), the nitinol wire can perform for over 20 million cycles.

## Discussion

The Live Wire is actually part of a class of metals known as Shape Memory Alloys (SMAs). These alloys have crystal structures that can form different shapes at distinct temperatures. The crystal structure is easily deformed at cool temperatures (see A), and then when heated, the crystal structure returns to its original shape with great speed and force (see B).

The Live Wire is a nickel-titanium alloy and thus is given the acronym Nitinol. Nitinol consists of nearly equal percentages of the two metals and is specially alloyed and annealed to produce a small grained, extremely uniform crystal structure. A difference of less than 1% in composition will change its transition temperature by 150 °C. Therefore, the materials require very careful formulation and processing.

The Shape Memory Effect (SME) of the nickel-titanium alloy was accidentally noticed by William Beuhler and his research team at the U.S. Naval Ordnance Laboratory in 1961. However, the first SME was discovered in 1932 by Arne Ölander, a Swedish researcher, who observed the Shape Memory Effect of a gold–cadmium alloy. During the 1960s and 1970s, other Shape Memory Alloys were found. Researchers around the world studied alloys of titanium, copper, iron and gold that had this newly found property.

The most successful applications have come more recently. Raychem Corporation came out with Shape Memory Alloy pipe connectors that will shrink, thus producing a better seal in jet engines and hydraulic systems. Toki Corporation of Tokyo, Japan, improved nitinol for specific use by electrical activation. At the 1986 International Symposium on SMAs, papers were presented on possible applications including basic alloy research and development, crystal structures, medical applications (such as using SMA wires like electric muscles in robotic or prosthetic devices), product designs, and manufacturing studies. Since not all areas of Shape Memory Alloys have been explored, the research and interest is still growing today.

## Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12

Evidence, models, and explanation
Constancy, change, and measurement
Form and function

Content Standards: Grades 9–12

Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter and chemical reactions

## Flinn Scientific—Teaching Chemistry<sup>TM</sup> eLearning Video Series

A video of the *Live Wire* activity, presented by Jeff Hepburn, is available in *Properties of Solids*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

### Materials for Live Wire are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1937	Nitinol "Live Wire"
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Consult your Flinn Scientific Catalog/Reference Manual for current prices.