INVESTIGATION 3
Notes for the Instructor

PURPOSE

To allow students to reshape a piece of memory metal and to further stimulate them to think about the changes taking place at the atomic level that allow this to happen.

METHOD

Questions may arise as to how the memory was imparted to the metal in the first place or whether or not the memory may be altered. It should first be noted that if the transition between phases were represented by the thermochemical equation below:

$$\text{Martensite} \quad + \quad \text{energy} \quad \rightarrow \quad \text{Austenite}$$

the energy required would be in the neighborhood of only a few kJ/mol. The Ni and Ti atoms within one of the many crystalline regions (called grains) within a sample of memory metal in the austenite phase are almost perfectly arranged with a few imperfections here and there. (A piece of galvanized metal clearly shows such crystals, and the BB board discussed earlier shows defects within the crystal) These defects in the austenite phase along with the grain boundaries, another kind of defect, are responsible for giving the austenite its "remembered" shape. To give the metal a new shape it is necessary to create a new set of defects that will in turn force the metal to return to this new shape upon mild heating through the martensite-to-austenite phase change. This new set of defects can only be obtained by heating the metal sample to approximately 500^{o}C while it is secured in the new shape. This large amount of thermal energy allows atoms to relax into lower energy positions, thus creating a new set of defects.

The procedure simply involves having the students bend the wire into a new shape: they hold it at its ends and heat the center in the flame of a candle. The wire resists bending until it reaches the temperature of the flame at which point it yields and can be bent into a V-shape.

MATERIALS

NiTi wire from kit or supplier listed in the Appendix (3 inches of wire per group)

Candle and matches

Hot water bath like the one used in Investigation 1

PROCEDURE

a. Holding the wire at its ends (CAUTION, the ends may be sharp!), bend it into a V-shape and place the middle of the V into the center of a candle flame.
b. After cooling by blowing on the wire, Investigation 1 may be repeated with the deformed wire.
c. Holding the wire at its ends (CAUTION, the ends may be sharp!), try straightening it back into its original, linear shape as you place the middle of the wire into the center of a candle flame.

ANSWERS TO FOLLOW-UP QUESTONS

1. Why can't you use hot water to retrain the wire to "remember" a new shape?

    The energy required for the martensite-to-austenite transition is far lower than that required to "move" defects in the structure.

2. Describe any similarities or differences in the wire from its original condition after heating it in the flame.

    Student responses will vary. They may notice slightly slower response times after annealing several times. Discoloration may also be observed.

EXTENSIONS

If a metal frame of some type is available, it is possible to produce more complicated shapes (even your name) with the memory metal. This would require that you have access to some sort of metal rack or basket capable of withstanding the annealing temperatures and a heat source capable of providing those temperatures. The kiln in the art department would certainly be adequate; or perhaps the physics department has a muffle furnace that would work as well. The wire would have to be secured to the template and the entire assembly placed in the heat source for a period of about 15 minutes, removed, and allowed to cool. Longer heating may destroy the memory feature of the wire. Annealing produces the "remembered" shape by creating a new set of defects. Prolonged heating, however, will destroy the shape memory feature that relies on these defects. When the atoms surrounding the defects are supplied with sufficient energy, they relax into an almost defect-free structure.