Name:______________________________Date:______________Class:_______________

Student Worksheet

Nanotechnology Invention and Design: Phase Changes, Energy, and Crystals

Safety

Safety glasses are required when using glassware and the Nitinol wire. Hot plates, wires, and beakers placed on them may be very hot so use caution and proper equipment such as beaker tongs or forceps. Do not throw matches/candles into the trash. Use the solid waste containers.

(answers in red)

Materials per group

1. goggles (one per student)
2. hot plate (shared by 2 groups)
3. 250 ml beaker
4. water
5. ring stand
6. test tube clamp
7. thermometer or temperature probe
8. tape
9. pen/pencil
10. stir rod
11. ~ 8 cm Nitinol wire
12. 2 forceps, beaker tongs, or hot gloves
13. needle nose pliers or crucible tongs
14. candle
15. matches

Introduction

Congratulations! You earned an A in chemistry. Your dad decided you are responsible enough to borrow his brand new bright yellow Corvette. Now you are cruising down the highway, when suddenly a whale breaches up from the nearby ocean and leaps out of the air. WOW! You were so awestruck that you failed to notice that the car in front of you had stopped. Oh no! Who or what can help? Nanotechnology to the rescue. What if Dad's Corvette was made of a special alloy? What if, with a simple blow dryer, you could allow the alloy to "remember" its shape before the crash?

This is just one possible application for a class of nanomaterials called shape memory alloys (SMA). From reducing the impacts of surgery to mimicking the smooth motion of muscles for prosthetics, these materials can and will affect your everyday life! In this lab you will investigate how and why an SMA, called Nitinol, responds to energy changes by determining the transition temperature, predicting its crystal structure, and becoming Nanotechnology inventors by creating, designing, and then testing a potential use for the smart material.

Question: Using the temperature chart on the following page, what do you think the transition temperature of the shape memory alloy will be? Explain your choice.

Make a Prediction

*I think over 100°C because metals are harder to change than water OR a certain amount of energy is needed to cause a change or move the atoms around.*______________________

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Temperature of Common Objects

Temperature		Description
Celsius (°C)	Fahrenheit (°F)	
0 °C	32 °F	Ice cubes
3 °C	37 °F	The inside of your refrigerator
22 °C	72 °F	Room temperature
37 °C	99 °F	Normal body temperature
39 °C	102°F	A hot tub
49 °C	120 °F	Hot water from the tap
59 °C	138 °F	Swiss cheese melts
75 °C	167 °F	Roast chicken coming out of the oven
100°C	212 °F	Boiling water

(Figure from Catherine Jordan at http://www.ccmr.cornell.edu/education/modules/documents/Nitinol.pdf)

Procedure

1. Gather materials and safety equipment (i.e., goggles).
2. Turn the hot plate on low.
3. Fill a 250 ml beaker halfway with water and place it on the hot plate. Prepare setup as seen in the picture to the right using a ring stand, test tube clamp, thermometer, and tape.
4. Obtain an 8 cm length of Nitinol and coil it around a pen or pencil. Slide the wire off the pen/pencil. Describe 2 initial qualitative observations.
5. Place the wire into the beaker.
6. Use a thermometer or probe to continually monitor the temperature of the water near the wire. Make sure the thermometer is near the wire.
7. Slowly warm the water and record the temperature at which the wire begins to change shape. Draw the new shape and describe 2 other final qualitative observations.
8. Turn the hot plate to the lowest setting and remove the wire carefully using forceps since the water and the wire may be very hot.
9. Record your temperature on the class data sheet.
10. Once the wire cools, hold the wire at its ends and bend it into a V-shape.
11. Light a candle and make sure it is stable. Do not throw matches into the trash. Use the solid waste container.

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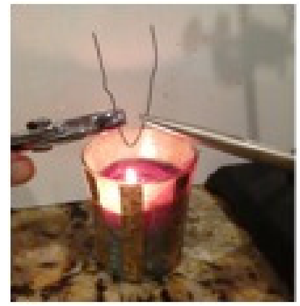
12. Using forceps at each end, place the middle of the V into the center of the flame and hold it there tightly (because the wire will try to bend outwards) until you feel a release in the wire. Immediately remove it from the flame.
13. Set the wire aside to cool, and blow out the candle.
14. After a few minutes, use the backside of your hand to see if the wire has cooled enough to touch.



15. Change the shape however you like, and record 2 initial observations.
16. Record the temperature of the water in the beaker (it should be at or above the temperature you previously recorded). If not, adjust it.
17. Place the wire into the water and record 2 final observations along with a drawing.

Cleanup
Return goggles and materials clean and dry to the designated area(s).
Turn hotplates to low and refill beakers with water for the next class.
If it is the last class of the day, unplug hotplates and empty beakers using beaker tongs or hot gloves.

Record Your Observations

Measurements of Nitinol

	Coiled Nitinol	**Flame Treated Nitinol**
Initial Observations	*Drawing of coil shape, dark gray in color* *shiny/smooth* *easy to bend* *bumpy*	*Drawing of any shape* *dark gray in color* *shiny/ smooth* *easy to bend*
Transition Temp. (°C)	*50*	*50*
Drawing	*Drawing of linear shape*	*Drawing of V shape*
Final Observations	*dark gray in color* *shiny/smooth* *rigid* *warm*	*dark gray in color* *shiny/ smooth* *easy to bend* *bump*

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Class Transition Temperature Measurements of Nitinol

Group #	1	2	3	4	5	6	7	8	9	10	11	Avg.
Transition Temp. of Nitinol (°C)												

Analyze the Results

1. Calculate the average transition temperature for the Nitinol and enter it into the chart on the previous page.

   Answers will vary

2. Describe how you calculated the average. Include an explanation for any data that was left out of the calculation.

   Add up all the values and divide by the total number of groups. Data may be left out if the group had extreme errors in their experimental procedure.

3. The actual value for the transition temperature of Nitinol is 50.0°C.

   1. Calculate your group's percent error below.

      $$\% \text{ error} = \frac{|\text{accepted value} - \text{experimental value}|}{\text{accepted value}}$$

   2. State your percent error and then provide meaningful sources of error to explain your value.

      Answers will vary. The percent error was 15% because the temperature probe wasn't close enough to the metal.

4. If the 0.21 g Nitinol metal sample was originally at room temperature, 21.0°C, and the specific heat capacity of Nitinol is 0.46 J/g°C, how much energy must be absorbed by the metal before it can change phase? Show all work below

   q = heat energy *m = mass*
   c = specific heat *ΔT = change in temperature*

   $q = (0.21\ g)x(0.46\ J/g{\cdot}°C)[(50.0\ °C - 21.0\ °C)]$
   $q = (0.21\ g)x(0.46\ J/g{\cdot}°C)x(29.0\ °C)$
   $q = 2.8\ J$

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Draw Conclusions

1. Why is a specific temperature needed to cause the Nitinol to change phase?

   I think a certain amount of energy is needed to cause the phase change OR move the atoms around. Atomic level changes require energy based on the amount of change required.

2. How can a phase change be happening in the Nitinol if there is no visible change of state?

   I think the phase change is too small to see OR atoms are moving around but we can't see the change.

3. How do you think the energy being absorbed by the Nitinol is used at the nanoscale (atoms)?

   The energy is absorbed by the atoms which increases their kinetic energy and temperature. Then the increase in potential energy changes the atom arrangement or crystal structure.

4. In this investigation you measured temperature change. Could this value be used to calculate the latent heat of the solid-to-solid phase change? Explain.

   Latent heat is the energy exchanged when there is no temperature change during a phase change, so we could not calculate it since we had a temperature change. We were on the slope not the plateau.

5. The energy required to cause a solid-to-solid phase change in the Nitinol is only a few kJ/mol. Water requires 40.7 kJ/mol to undergo a liquid-to-gas phase change. What do you think is happening at the nanoscale to cause liquid-to-gas phase changes to require so much more latent energy than solid-to-solid phase changes?

   Boiling water requires greater amounts of energy to break intermolecular forces between water molecules to cause the molecules to become more disordered as a gas, while solid state changes need much less energy so they must be causing less change—slight shifts in the atom arrangements.

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