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.

Materials per group
- goggles (one per student)
- hot plate (shared by 2 groups)
- 250 ml beaker
- water
- ring stand
- test tube clamp
- thermometer or temperature probe
- tape
- pen/pencil
- stir rod
- ~ 8 cm Nitinol wire
- 2 forceps, beaker tongs, or hot gloves
- needle nose pliers or crucible tongs
- candle
- 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

____

____

Development and distribution partially funded by the National Science Foundation
NNIN Document: NNIN-1357
Rev: 08/2013

Temperature of Common Objects

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

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

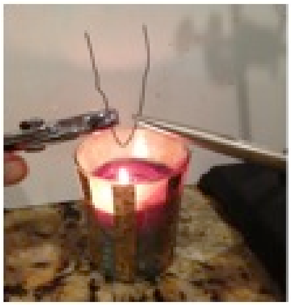
Procedure

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.

Development and distribution partially funded by the ***National Science Foundation***

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		
Transition Temp. (°C)		
Drawing		
Final Observations		

*Development and distribution partially funded by the **National Science Foundation***

NNIN Document: NNIN-1357
Rev: 08/2013

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.

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

____

____

____

____

3. The actual value for the transition temperature of Nitinol is 50.0°C.
   a. Calculate your group's percent error below.

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

   ____

   ____

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

*Development and distribution partially funded by the **National Science Foundation***

NNIN Document: NNIN-1357

Rev: 08/2013

Draw Conclusions

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

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

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

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.

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?

Development and distribution partially funded by the ***National Science Foundation***