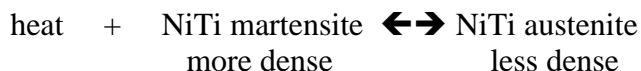


Memory Metal Review Questions

1. One of the problems with syringes used in some chemistry experiments is that the metal plunger can bend, making the expensive syringe useless. To eliminate this problem, a company has recently produced a syringe whose plunger is made from memory metal, NiTi. Recall the equilibrium for this material:

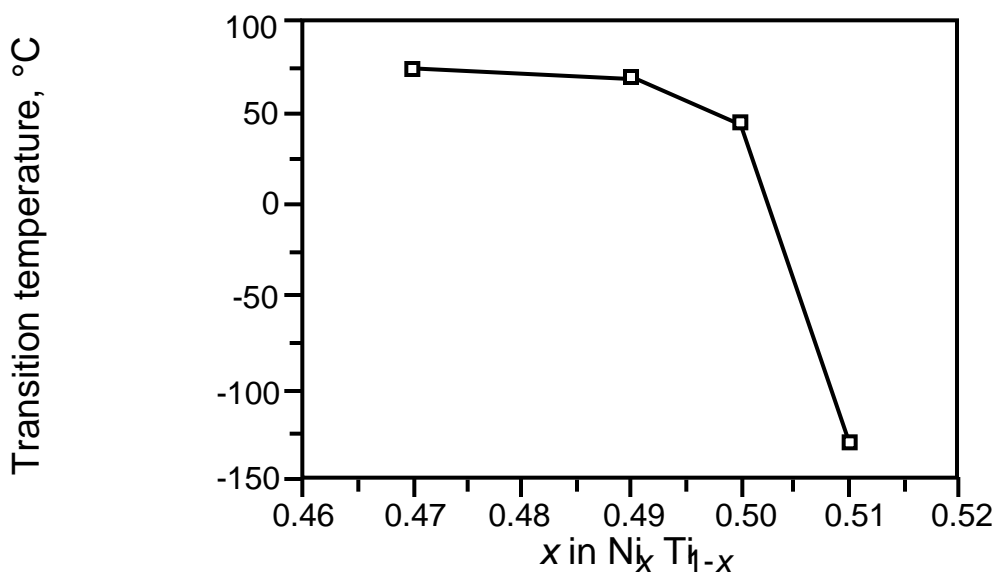


Based on temperature and/or pressure effects associated with this equilibrium, design such a plunger: Specifically, how is its operation connected to the equilibrium, and what instructions, if any, would you need to give the purchaser?

The plunger should be in the high temperature phase (austenite) because you want the plunger to be rigid and hard so that it doesn't bend when pressure is applied to it. As you apply pressure the equilibrium may shift towards the denser martensite phase. If it does bend under applied pressure, you can straighten it out by heating it up.

2. Sarah Mason's recently published mystery thriller, "Dying Breath," describes a knife that could be fashioned from memory metal. The following graph shows the transition temperature of the phase change of memory metal as a function of its composition, i.e., x in the formula $\text{Ni}_x\text{Ti}_{1-x}$.

The Effect of Ni Concentration on the Transition Temperature



This figure was adapted from *Teaching General Chemistry: A Material Science Companion*. It is a compilation of data by several researchers, who measured the composition and transition temperatures by different methods.

a. If the villain desires the knife to be in the low-temperature phase at room temperature (about 25°C), select a value of x that will produce this result and explain your choice.

Any x value that corresponds to a transition temperature above 25°C. If you want the knife to be in the low-temperature, more flexible phase at 25°C, then the transition temperature must be above room temperature. A value for x less than or equal to 0.50 would work.

b. The villain has designed the knife's initial shape to leave an unusual imprint when it is used for the crime. The knife is subsequently to be bent into a different shape at room temperature, so that it appears that the knife could not have caused the imprint. Would hot water (50°C) or candle flame temperature (500°C) have been required to give the knife its initial, unusual shape and does this temperature correspond to a phase change of the Ni and Ti atoms; or to movement of defects in the alloy and why?

Candle flame temperature (500°C) is required to give the knife its initial, unusual shape, because it needs to be at a temperature high enough to move the defects in the alloy. If the defects are not changed, the knife will not remember its new shape.

c. If you were the investigator assigned to the case, how would you change the temperature to cause the knife to recover its initial, unusual shape, and does this temperature correspond to a phase change of the Ni and Ti atoms; or to movement of defects in the alloy and why?

The investigator would use hot water or a heat gun (hair dryer) to cause the knife to recover its unusual shape. This temperature corresponds to a phase change of the Ni and Ti atoms. If the defects are changed, the knife will not return to its original shape, and it would not match up

with the wound.

3. When a NiTi rod is heated into its symmetric high temperature phase from the less

symmetric structure of its low temperature phase which of the following is true?

- a. it becomes more flexible and thuds when dropped
- b. it becomes more flexible and rings when dropped
- c. it becomes more rigid and thuds when dropped
- d. it becomes more rigid and rings when dropped**

4. A sculpture made of memory metal is found to change its shape when electricity is

passed through it because

- a. it is cooled into the low-temperature martensite phase
- b. it is heated into the high-temperature austenite phase**
- c. passing electricity through the structure changes its atomic composition
- d. passing electricity through the structure removes electrons from the structure

5. Which of the following phase changes will release heat?

- a. melting an alloy
- b. transforming NiTi memory metal from the phase that thuds to the phase that rings when dropped
- c. subliming dry ice into the gas phase
- d. condensing gaseous water into liquid water**