Memory Metal Assessment

Name _____

Teacher's Guide

Date _____ Hour _____

Matching

Match the word with the best definition.

G	1. austenite	a. a pattern that can be shifted repeatedly to create the entire structure of atoms in a crystal
H	2. martensite	b. a solid solution composed of two or more metals
I	3. transition temperature	c. alloy containing nearly equal amounts of nickel and titanium
C	4. Nitinol	d. a physical state of matter
B	5. alloy	e. a type of unit cell
F	6. smart material	f. a substance that can respond to stimuli in its environment
J	7. density	g. high temperature phase
A	8. unit cell	h. low temperature phase
K	9. coordination number	i. the temperature at which a phase transformation occurs
E	10. body-centered cubic	j. mass per unit volume
D	11. phase	k. number of nearest neighbors
L	12. LeChatelier's Principle	l. when a system at equilibrium experiences a stress, the equilibrium shifts partially to relieve that stress partially
		m. the temperature at which martensite melts

Multiple Choice

Choose the best answer.

__D__ 13. In the high-temperature phase of NiTi, the coordination numbers of the Ni and Ti are
a. 6 for Ni and 6 for Ti
b. 6 for Ni and 8 for Ti
c. 8 for Ni and 6 for Ti
d. 8 for Ni and 8 for Ti

__D__ 14. What technique lets us determine the atomic positions in NiTi memory metal both before and after the solid has undergone its phase change?
a. spectroscopy with visible light
b. measurement of specific heat
c. electrical resistivity
d. x-ray diffraction

__B__ 15. Austenite exhibits which characteristic?
a. less symmetrical than martensite
b. more rigid than martensite
c. more flexible than martensite
d. both a and c

__B__ 16. At room temperature Nitinol can exist in either of two structures, which are dependent upon
a. the mass of the sample.
b. the exact ratio of Ni to Ti.
c. the length of the sample.
d. the diameter of the rod.

__A__ 17. In some phase changes like that of ice and water, there is a noticeable change; however, there is no visible phase change between austenite and martensite because
a. it only occurs at the atomic level.
b. only two atoms exchange places.
c. the structures are the same
d. the temperature is too high
e. no phase change occurs.

Problems

18. Using figure 9.10, what compositions of Ni_xTi_{1-x} would you choose so as to have two samples, one of which is in the low-temperature phase at 0 °C, with the other in the high temperature phase at this same temperature. How could you tell them apart without chemical analysis?

From the figure, at 0 °C, a sample of Ni_xTi_{1-x} with x = 0.51 would be in the high-temperature phase, whereas a sample with x = 0.49 would be in the low-temperature phase. They could be distinguished by their flexibility, sound, etc.

19. Design a sculpture made of memory metal that will change its shape using electricity. Why can this be done?

Any drawing of a sculpture that has moved will do; show both pictures.

Electricity can be used to heat the sculpture resistively, thereby transforming the memory metal from its low-temperature to its high-temperature shape.

20. When a thin straight wire of NiTi memory metal in the low-temperature phase is bent and placed in a concentrated solution of bromine in wet methanol, it straightens out as it dissolves. Why?

This must be an exothermic reaction, the heat from which can be used to drive the martensite-to-austenite conversion of the unreacted NiTi.

Depending upon when you add this material to your curriculum, you may want to ask students to speculate on the products. Using redox chemistry and knowing that Ni likes to be divalent, Ti tetravalent, and Br diatomic, the formula and balanced reaction is

$$NiTi + 3\,Br_2 \longrightarrow NiBr_2 + TiBr_4$$

The $TiBr_4$ is an assumed product.

21. Since NiTi memory metal is biocompatible, it has been proposed that it could be inserted into arteries to help unclog them. Given that the metal is to be coiled like a spring in one phase and straight in the other, how is the experiment carried out?

A sample could be prepared that is coiled or spring-shaped in the high-temperature form and linear in the low-temperature form. Insert the cold linear sample into the artery, and when it warms to body temperature, it assumes the coiled shape that can help keep the artery open.

22. Why do purely solid-state phase changes like that exhibited by NiTi memory metal often involve enthalpies of only a few kilojoules of energy per mole compared to values like 40 kJ to vaporize a mole of water?

Vaporization of water requires the disruption of strong intermolecular forces (hydrogen bonding) and therefore requires a great deal of energy in order to convert the condensed, liquid phase to the disordered gaseaous phase. A solid-state phase change like that exhibited by NiTi involves only slight shifts in atomic positions and thus much less energy.