Next Generation Science Standards

Students who demonstrate understanding can:

2-PS1-1. Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

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AP Chemistry Standards

LO 2.3 The student is able to use aspects of particulate models (i.e., particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases and among solid and liquid materials.

LO 2.20 The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom.

LO 2.25 The student is able to compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning.

LO 2.26 Students can use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys.

LO 2.27 The student can create a representation of a metallic solid that shows essential characteristics of the structure and interactions present in the substance.

LO 2.28 The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level.

T E A C H E R S G U I D E

GRADE LEVEL 2+

NITINOL MEMORY WIRE
ITEM # 1001-SERIES

ENERGY - HEAT

Nitinol (pronounced “night-in-all”) is an alloy metal that stands for Nickel (Ni), Titanium (Ti), and the “NOL” stands for the Naval Ordnance Laboratory where it was discovered. Bend it, then drop it into hot water and watch it return to its original shape! This crystalline metal changes phase around 75C. You can also retrain this wire by annealing it. First bend it into the desired shape, heat it to a dull red glow along the entire length then cool it by immersing it in water. After cooling, the wire can be deformed but will instantly return to its newly trained shape by dunking it into hot water!

Materials

- Nitinol wire
- brass wire
- copper wire
- zinc wire
- steel wire
- platinum wire
- nickel wire
- carbon rods
- iron wire
- stainless steel wire
- chromium wire
- hotplate or Bunsen burner
- hammer
- voltmeter

Optional:
- liquid nitrogen

Goals & Objectives

see page 8 for National Next Generation Science Standards

Assessment

1 ***Glossary/Vocabulary***
- interstitial alloy
- substitutional alloy
- malleability
- ductility
- elasticity
- plasticity
- shape memory
- crystal lattice
- electron sea
- brittleness
- hardness
- nanoscale

2 ***Use for assessment:***
- Participation
- Vocabulary
- Charts and Diagrams drawn during activities and discussion

Discussion

Additional Discussion and Real Life Applications

1 Ask students to research the uses of shape memory alloys.
- Results should include eye glass frames and implantable medical devices.

2 Ask them to find other examples of shape memory alloys.
Are these alloys substitutional or interstitial?
- A possible assessment includes asking them to draw particle diagrams of their alloy.

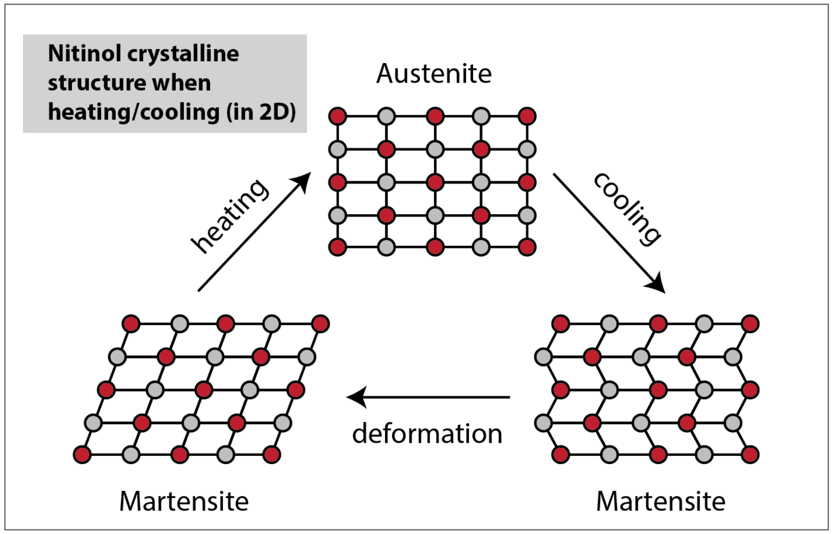
3 Does their alloy oxidize? (the iron in steel alloys oxidizes and makes rust – iron oxide)

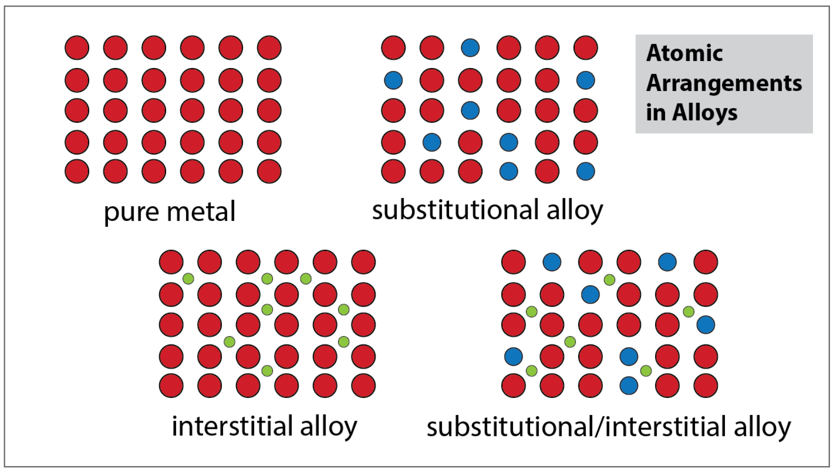
4 How would oxidation make their particle diagram look different? (they should draw a new particle attached to their diagram only on the outside of the diagram to represent the oxidized metal)

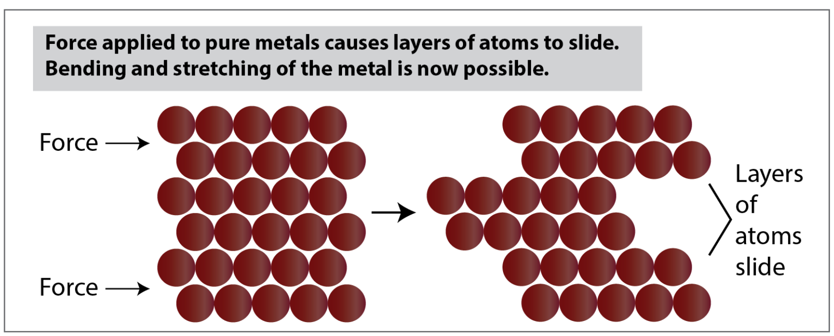
5 Investigate careers in materials science.

6 What is nanochemistry?

Charts and Diagrams







Introduction

Nitinol (a nickel-titanium substitutional alloy in a nearly 50-50 ratio) demonstrates properties that seem almost magical! It is possible to change its shape and then have it “spring back” to its original shape by adding energy.

It is also possible to permanently change the shape of “memory” and then stress by bending it, but recover the new shape again. There are many possibilities to stress and test this alloy.
Are their certain environments where this alloy would be most beneficial? What about environments in which the alloy would fail?
Failing alloys can mean exploding spaceships, satellites, bridges falling, and medical devices failing.

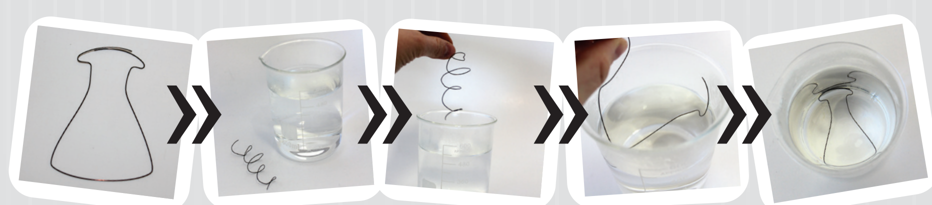
Use nitinol to discuss the particulate nature of matter – specifically metals.

How is an alloy a solution if it is a solid too?

Draw particle diagrams of the alloy at rest and stressed. Draw particle diagrams of the metals that make up the alloy - include atoms, protons, neutrons, and electrons.

How do the electrons behave differently in metals versus nonmetals?
Do the electrons behave differently in alloys?
Do other alloys display the same behavior as nitinol?
What does the particle diagram of those alloys look like?

Contrast the substitutional structure of nitinol with the interstitial structure of steel. Investigate all these questions and others your students generate to develop models of the particulate nature of matter.



Activities

1 Be sure to have already taught the classification of matter – pure substances versus mixtures with students.

Alloys are solutions of metals and commonly students have a difficult time understanding how the application of solute versus solvent can apply with a solid-solid solution. In addition, students have a difficult time describing and representing how particles in a substance are arranged.

a Train your students how to test the nitinol alloy and then apply it by testing the brass and steel alloys. Have the different types of wires on your desk.

b Draw particle diagrams (*see page 6*) together and discuss the particle arrangements in nitinol at rest and after stressed and then at rest again. Repeat the process with the steel which is an interstitial alloy.

c Demonstrate the shape memory of the nitinol. Ask your students to test the shape memory of the other three alloys:
brass (substitution alloy of copper and zinc), steel (iron-carbon interstitial alloy), and stainless steel (iron, carbon, and chromium alloy that is BOTH substitutional and interstitial)).

d Ask your students to test the electrical conductivity of the pure metals that the alloy is made of and the alloy using the voltmeter.

e Ask them to test the hardness of the pure substances versus the alloy. Is there one pure substance that is different from the others? (the carbon will conduct but it is brittle, not ductile, or malleable)

The pure metals and carbon should be more conductive than the alloy of them combined, but the alloys are harder.

f Ask them to draw particle diagrams of the brass and stainless steel (be sure to tell them that the stainless steel is both types with chromium substituted for some of the iron atoms).

How do the particle diagrams of the pure substances compare?

***Note**
It is always best to DO an experiment ahead of time to be able to best present it to the class.

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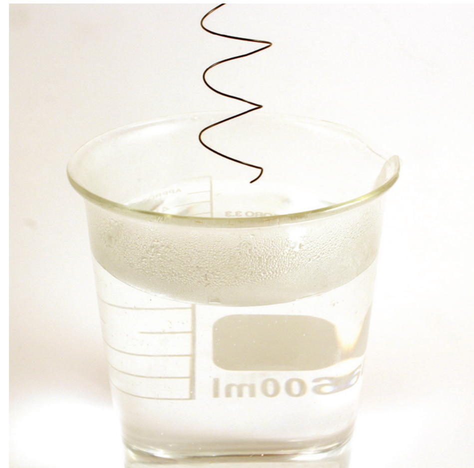
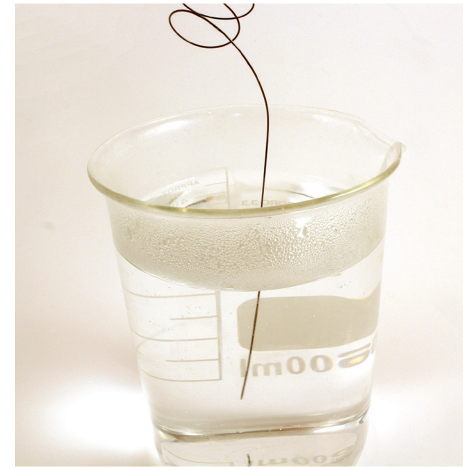
Activities





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a After you have taught the different classifications for solids (metallic, covalent, ionic, network covalent and atomic), ask students to draw particle diagrams for each type.

b How do each of these substance differ in electrical conductivity?
If you hit a block of each of these solids and change the crystal lattice how do the particles align?

What characteristic of matter will this display (brittleness versus malleability – see particle diagrams below for comparing brittle ionic solids versus malleable metallic solids).

c If you strike an alloy; why are they stronger?
Use a particle diagram to support your discussion.

d Will extreme temperatures affect that strength?
Use the liquid nitrogen to test the nitinol and steel wires. Use a bunsen burner to test a different piece of wire.
Do the steel and nitinol retain their strength or do they become brittle like ionic solids?
Again support your observations with a particle diagram.

e Does the nitinol still display shape memory after being exposed to extreme cold or extreme heat? Ask students to write a procedure to test this.

