The Periodic Table & Superconductors

Teaching Objective: Introduce Superconductivity in the context of reviewing the properties of the Periodic Table of the Elements in preparation for *FCAT Science*.

Learning Objectives:

Students will review the basic organization of the Periodic Table of the Elements.

Students will apply recently learned concepts concerning the organization of the periodic table of the elements to the development of the initial high critical temperature ($T_c > 77$ K) superconducting materials.

Students will work cooperatively in groups to create three-dimensional models of a superconducting material, clearly labeling elemental components, bonds, and general plane of electron flow.

Students will answer an *FCAT Writing-like* prompt related to content addressed in this unit.

Method of Instruction:

The Pre/Post Test instruments are intended to provide a means of documenting knowledge gained by students AND for a "down and dirty" method for the teacher to use as an evaluation instrument for his/her Individualized Professional Development Plan on a unit dealing with new and emergent science and technology.

Students should have access to a Periodic Table, such as the one included here, throughout all the activities. This includes the Pre- and PostTests.

The first lesson that deals with the periodic table can be done as either a worksheet and class discussion lesson or be used as a suggested script for small group or entire class discussions.

The second lesson is designed for small groups of students to collaboratively construct a unit cell of the YBCO material. Teachers should consider student group composition and the amount of materials for model building that is available before assigning groups.

The Levitation Demonstration that is commonly referred to as the Meissner Effect would be appropriate to do with either the periodic table lesson or the model building lesson. Appropriate planning by the teacher should include transitions between topics to applications of superconductors and the acquisition of liquid nitrogen necessary for the demonstration. The company/supplier-supplied instructions and safety guidelines for the specific kit that is available should be followed.

The writing activity can be done either in immediate association with these lessons or as part of a cumulative evaluation.

State of Florida's Sunshine State Standards
Addressed by *The Periodic Table & Superconductors*

Science

SC.A.1.4.1 The student knows that the electron configuration in atoms determines how a substance reacts and how much energy is involved in its reactions.

SC.A.1.4.2 The student knows that the vast diversity of the properties of materials is primarily due to variations in the forces that hold molecules together

SC.A.2.4.1 The student knows that the number and configuration of electrons will equal the number of protons in an electrically neutral atom and when an atom gains or loses electrons, the charge is unbalanced.

SC.A.2.4.2 The student knows the difference between an element, a molecule, and a compound.

SC.A.2.4.5 The student knows that elements are arranged into groups and families based on similarities in electron structure and that their physical and chemical properties can be predicted.

SC.E.2.4.6 The student knows the various ways in which scientists collect and generate data about our universe.

SC.H.1.4.2 The student knows from time to time, major shifts occur in the scientific view of how the world works, but that more often the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.

SC.H.3.4.2 The student knows that technological problems often create a demand for new scientific knowledge and that new technologies make it possible for scientists to extend their research in a way that advances science.

SC.H.2.4.1 The student knows that scientists assume that the universe is a vast system in which basic rules exist that may range from very simple to extremely complex, but that scientists operate on the belief that the rules can be discovered by careful, systematic study.

Mathematics

MA.D.1.4.1 The student describes, analyzes, and generalizes relationships, patterns, and functions using words, symbols, variables, tables, and graphs.

MA.E.1.4.1 The student interprets data that has been collected, organized, and displayed in charts, tables, and plots.

Language Arts/Writing

LA.A.1.4.3 The student refines vocabulary for interpersonal, academic, and workplace situations, including figurative, idiomatic, and technical meanings.

LA.B.1.4.1 The student selects and uses appropriate prewriting strategies, such as brainstorming, graphic organizers, and outlines.

LA.B.1.4.2 The student drafts and revises writing that: is focused, purposeful, and reflects insight into the writing situation … .

Teaching Materials

Periodic Table(s): either individual photocopies of the FCAT Science Periodic Table, a textbook figure, and/or a large, classroom displayed periodic table.

Effective "Spotlighting" technique to ensure effective whole-class discussions of primary points (i.e., laser pointer, overhead transparency of the same representation of the periodic table that the students will use).

Optional: Samples of specific elements or native minerals for introductory purposes. These may include the starting compounds for the manufacturing of the YBCO superconducting material.

Optional: Meissner Effect (Levitation) Demonstration Kit

Model making supplies. These can be traditional and conventional kits as used in standard chemistry activities or more nontraditional and unconventional materials that possibly may be consumed at the end of the activity (marshmallows, candies, toothpicks, pipe cleaners, styrofoam balls, etc.)

> Quantities for one unit cell of YBCO: 16 copper, 20 oxygen, 2 barium, 1 yttrium, 8 long bonds, 32 medium bonds, 8 short bonds.

Assessments of knowledge of the organization of the periodic table of the elements: pre and post.

Rubrics for evaluating: model construction, writing responses.

Background Material for Teachers

Consult one or more of the following web sites that have excellent materials to read to increase your level of comfort in discussing superconductors. Remember, though, that this activity is designed primarily to be used to teach and review the principles associated with the periodic table of elements.

http://superconductors.org/

http://www.ill.fr/dif/3D-crystals/superconductors.html

http://www.asc.wisc.edu/

http://www.lanl.gov/orgs/mst/stc/welcome.html

http://www.nobel.se/physics/laureates/index.html (click on 1987 & 1913 Awards)

Student Reading

PART ONE: Review of Periodic Table of Elements

The Periodic Table of Elements is a tremendously useful instrument to use in science to understand, predict, and explain how matter behaves. Remember:

- an element is the simplest substance that cannot be broken down by chemical or physical means without losing its properties;
- an atom is the smallest unit of an element; and
- that elements of the periodic table are arranged into columns and rows.

The columns are frequently called families. Elements in the same column or family will generally have the same arrangement of electrons in their outermost orbitals.

Understanding the Basics

The calcium atoms that you need for strong bones have an atomic number of 20.

What is calcium's atomic symbol?

Is calcium a metal, nonmetal, or semimetal?

Fluorine is a very reactive element. Acids that have fluorine atoms can eat through glass. Fluorine has an atomic number of 9.

What is fluorine's atomic symbol?

Is fluorine a metal, nonmetal, or semimetal?

If the arrangement of outermost orbital electrons is similar, what do you predict about the chemical activity of elements that are in the same family on the periodic table?

List three elements that are in the same family:

The rows on the periodic table are frequently called periods. Elements in the same row or period may share some general properties, but changes occur as one goes across the table within a row.

Why do you think the chemical properties of elements in the same period change as one goes through a period?

List five consecutive elements that are in the same period:

One of the properties that change is the atomic radius. This is the distance from the center of an atom to its outermost electron.

In the space provided, properly graph the atomic radius versus the Period or Group Member Number (this is the number within the parentheses) for these elements. Draw one line for elements in the same Period and a second line for elements in the same Group.

Element (*)	**Atomic Radius (picometers, 10^{-12} m)**
Lithium (1)	155
Beryllium (2)	112
Boron (3)	98
Carbon (4)	91
Nitrogen (5)	92
Oxygen (6)	73
Fluorine (7)	72
Neon (8)	71
Sodium (2)	190
Potassium (3)	235
Rubidium (4)	248
Cesium (5)	267

***** Period or Group Member Number

Using your graph, describe the change in atomic radius in a period.

Using your graph, describe the change in atomic radius in a family.

Compare the changes in atomic radius of atoms of elements in a period versus the changes in the atomic radius of atoms of elements in a family.

Major Sections of the Periodic Table

In general, elements that are found in the middle and on the left side of the periodic table are metals and those on the right side are nonmetals. A staircase-like line can separate the metals from the nonmetals, beginning with the left side and bottom of the Boron box, then between Aluminum and Silicon, and so forth.

Does your Periodic Table have this line?

The elements that border this line (except aluminum) are called semimetals.

List the semimetal elements:

The family of elements called the Noble gases is in the right most column.

List all the Noble gases:

Which element do you predict has the same outermost electron arrangement as Carbon (C)?

Sodium atoms react with chlorine atoms to form molecules of table salt. One molecule of the compound we call table salt is shown by the formula NaCl. What do you predict is the formula of a molecule of the compound that results when potassium atoms react with chlorine atoms?

PART TWO: Superconductivity and the Periodic Table

What is superconductivity?

Superconductivity can be defined as the ability of a material to allow an electrical current to pass through it without any (that means ZERO!) resistance. Remember how you can hook up copper wires to a battery and try to light up a bulb. What happened to the wire when you had it all connected? Yes, the wire got hot. This is a result of the resistance of the copper wire to allowing a current to pass through.

What does that heat mean for the efficiency of that copper wire for conducting electricity?

What would it mean if a wire could conduct electricity and NOT generate any heat?

In January 1986, two scientists named Georg Bednorz and Alex Müller, who were working for IBM in Zurich, Switzerland, came upon an interesting phenomenon. They used observations made by others that chemicals known as oxides (because they have oxygen in them) have some interesting electrical properties. Bednorz and Müller were working by themselves and without much encouragement from others when they started mixing various compounds together in carefully recorded amounts. Then on January 27, a specific combination of the compounds barium carbonate ($BaCO_3$), lanthanum oxide (La_2O_3), and copper oxide (CuO) showed superconductivity at 30 K. This was important because this new superconductive material was of a class of chemical compounds that was new to the field of superconductivity. Very quickly people started trying to find even better superconductors.

How does the Periodic Table come into play?

The central portion of the periodic table is made up of the Transition Metals. The transition metals are slightly different than the groupings we have discussed so far. Transition Metals are very similar within their period *as well as* within a given column.

Copper is a transition metal.

Which elements do you predict would act most similar to Copper (Cu)?

Explain the reasoning for your prediction that you just made.

In addition, two special sections that fit in the middle portion of the periodic table are the Lanthanides (from atomic number 58 – 71) and the Actinides (from atomic number 90 – 103). List the first three members of the Lanthanide series:

List the first three members of the Actinide series:

In November 1986, Bednorz and Müller published their research. A researcher in Houston, Texas named Paul Chu read this paper wherein the pair shared their discovery. Chu quickly realized the importance of this new class of materials that were shown to be superconductors.

Chu and his group of researchers in Houston worked with colleagues in Huntsville at the University of Alabama to quickly set out to reproduce the discovery by Bednorz and Müller. Chu's next step was to try and find new combinations of materials that would be superconductive at higher temperatures than Bednorz's and Müller's $La_{1.85}Ba_{0.15}CuO_4$.

Using the periodic table of the elements, which element would you predict to have properties most similar to Lanthanum?

Explain your reasoning for your selection to the previous question.

Name three other elements that may have similar properties to Lanthanum?

Using the periodic table of the elements, which element would you predict to have properties most similar to Barium?

Explain your reasoning for your selection to the previous question.

Name three other elements that may have similar properties to Barium?

Given the formula of barium carbonate is $BaCO_3$, what would you predict is the formula for the calcium carbonate that makes up most of the limestone in our sinks and springs?

Explain your answer.

Given the formula of lanthanum oxide is La_2O_3, what would you predict is the formula for yttrium oxide?

In early 1987, Paul Chu and his research group synthesized a new material represented by the formula $YBa_2Cu_3O_7$. This new material is superconductive at 90 K. The temperature of 90 K is of great importance because it is above the temperature of liquid nitrogen, which boils at 77 K. Thus a new class of matter was described that could be economically and efficiently cooled to its superconductive temperature. This breakthrough has resulted in many researchers and companies pursuing research for applying superconductor science in such areas as magnetic levitating (maglev) trains and magnetic resonance imaging (MRI).

Part of the problem in developing these materials is that they are ceramics. Think of how ceramics are different from copper wire.

What problems do you predict exist for using these new materials for conducting high amounts of electricity?

Going Further: Use the Google search engine on the internet to research and report back to the class on other applications of superconductor research. Create a poster with three illustrations and 250 words of text explaining your topic.