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Bite-size Information

- Model of an atom
- Where to get samples of pure substances
- A new material on the periodic table

Main features

Big Picture Science

The Science Newsletter for Montessori Teachers of 6-15 yr-olds #6 September 1998

Introducing Chemistry

Make a concept framework bridge from matter to atoms

Understanding the chemical elements is an important key to science literacy. The starting point is the concept of matter. There are several important ideas that bridge from matter to atomic structure. Students need to work with real substances before learning electron arrangements.

Chemistry is a key science for understanding life science, materials science, a great deal of our technology, and what happens around us. It is also a very abstract science, since it seeks to explain atoms and their interactions. Lower elementary students can begin their chemistry studies by learning the concept of matter, the concept of an element, and becoming familiar with elements, compounds, and their properties. They need to understand mixtures and pure substances. Upper elementary students are ready to learn about chemical properties, the periodic table, and be introduced to electron configurations.

Skipping straight to the periodic table leaves out several important concepts that allow students to see the reason for the arrangement of elements. While it is certainly within the lower elementary students' capabilities to reproduce the periodic table, the knowledge is much more meaningful if they have had experience with elements and are familiar with the elements in substances around them.

Upper elementary students are eager chemists. They need to explore chemical reactions as well as learn the characteristics of atoms. They can understand the groups of elements on the periodic table, and may be able to correlate the chemical characteristics with electron configuration. Middle school students can certainly master the latter task.

An outline of the framework concepts of chemistry starts on page 2. Within the square brackets, I have included questions to ask and activities to give your students. Each teacher must decide what in this outline her students have mastered and how they need to proceed. I urge you to make sure that students have had a good experiential basis before emphasizing the periodic table. Notice I said "emphasizing", not "introducing". If we follow the child, I think we will find lower elementary students are interested in exploring substances and basic atomic structure. Middle school and many upper elementary students are ready to appreciate why substances do what they do and to study details of electron configuration of atoms. In the next issue, I will continue with experiments for building chemistry concepts.

Welcome back!

I hope you had a great summer and are starting another fruitful year guiding students in their explorations of science.

Big Picture Science grew to over 100 subscribers last year. Thanks for your support and interest.

Special thanks to Pam Shand, Patty Schaible, and Dot Thompson for asking questions and stimulating my thinking on presenting chemistry.

Don't forget to ask your questions. I won't be able to answer them all, but hopefully we will both learn.

Big Picture Science now has a Web site! It has all of the learning materials that I offer and will be updated regularly. There is a printable order form and you can e-mail me from there. It is at http://www.denver.net/~pspears/

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A Concept Framework for Chemistry

- **Matter is anything that takes up space and can be weighted on Earth**. It has mass.
  [Ask students what senses they use to detect matter. Smell is one of them! Do we see matter or light?]
- **Matter has two kinds of properties, physical properties and chemical properties**.
  - Physical properties include the size, shape, color, odor, state of matter, boiling and melting point, conductivity of heat and electricity, the density, and hardness. Is it crystalline or not, transparent or opaque, magnetic or not, or does it have a metallic luster? You can describe most physical properties without mentioning any other substance. Solubility is also a physical property, but you have to say in what solvent the substance will dissolve.
    - Examples: Water is a transparent liquid at room temperature and a crystalline solid below 0°C. Pure water is not a good conductor of electricity. Water dissolves many salts. * Copper is a metallic solid that conducts electricity and heat very well. It has a reddish color and it is not magnetic. It does not dissolve in water.
    - [Present your students with substances to describe. Include air, water, sugar, and metals. Show them how to tell conductivity of heat by touching the object to see if it feels cold at first touch. If it does, it may be conducting heat away from their hands. Give them a simple apparatus to test electrical conductivity. Have students prepare descriptions and read them to classmates, who then guess the substance.]
  - Chemical properties tell how the substance reacts with another substance. Will it burn (combine with oxygen)? Will it tarnish (combine with oxygen, sulfur, or another substance in its surroundings)? Will it displace another metal from solution? Will it explode? Will it react with an acid solution to form a salt?
    - Examples: Iron rusts (combines with water and oxygen). Baking soda reacts with vinegar and releases carbon dioxide. Chlorine removes the color from dye (breaks down dye molecules). If we run an electrical current through a solution of water and salt, the water breaks down into hydrogen and oxygen. If we add a flame to a mixture of hydrogen in air, it burns quickly and produces water.
- **Matter can be divided into mixtures and pure substances**
  - Pure substances can be elements or compounds. **Pure substances always have the same composition**, whenever and wherever they are sampled. Water always consists of one part oxygen and two parts hydrogen. This is an example of the law of definite proportions for compounds.
    - Examples: water, copper, table salt, minerals
    - [Give the children a collection of pure substances to examine. See page 5 for suggestions. Label each with the common and chemical name. Make a second set of labels with the chemical name and symbol or formula, but save these to use after chemical symbols and formulas have been introduced.]
  - **Mixtures can vary in proportions**. They can be uniform (homogeneous) or non-uniform (heterogeneous).
    - **Homogeneous mixtures** have the same composition throughout but can be mixed in many different proportions. Solutions are homogeneous mixtures, and can be solid in liquid, liquid in liquid, gas in liquid, solid in solid, or a mixture of gases.
      - Examples: salt water, rubbing alcohol, carbonated water, alloys (solid solutions of metals), air.
    - **Heterogeneous mixtures** are different depending where they are sampled.
      - Examples: rocks, wood, butter, living things, dyed fabrics, raisin bread, and most matter around us.
  - You need a pure substance to describe physical and chemical properties. If you want to measure the melting point of water, it has to be pure, not mixed with salt. Mixtures often soften or decompose before melting. If you want to find out if iron is magnetic, you cannot use stainless steel, a mixture of iron and other metals.
    - [Have students check the magnetic properties of iron and stainless steel. They may be surprised to find that most stainless steels are not magnetic. Ask them if water has a definite melting point. What about butter?]
  - Many mixtures can be separated by physical means, including floating, dissolving, filtering, chromatography, evaporating, and distilling.
    - [Give students opportunities to separate mixtures. See the references on page 6 for experiments.]
- **Matter is made of basic building blocks called atoms.**
  - Ask your students to think of **things that are made of smaller units**. Examples are beaches made of sand, galaxies made of stars, buildings made of bricks, and our bodies made of cells. Tell them that the pattern of large structures made of basic building blocks is one they will see over and over in nature (and Legos). Ask them what the building blocks of matter are. Tell them that people have been thinking about this since the ancient Greeks. Review early thinking, including the earth, fire, water, and air theory. (See the references for information.) Now we know that atoms are the basic building blocks of matter as we experience it.

- Ask your students to consider these questions? **How many kinds of atoms are there?** Is there only one kind with many arrangements? Or are there as many kinds as there are substances? Or is the situation somewhere in between? Are there a number of different atoms that are combined in many different ways? After they have discussed this, let them know that there are 90 naturally occurring kinds of atoms (and about 20 more synthetic ones). <u>All the matter they see around them is made of those 90 kinds of atoms, bonded together in many ways</u>.

- **Chemical elements contain only one kind of atom.**
  - If a substance is made of only one kind of atom, it is called a chemical element. Chemical elements are pure substances. Each has a name, a symbol, and an atomic number, which tells the number of protons in it.
    - [Do "first knowledge" stories of elements. Tell the appearance, occurrence, and uses of the element.]
    - [Give your students samples of elements to observe and describe. See page 5 for suggestions.]
  - **Chemical elements react with one another to make chemical compounds, which have different properties than the elements in them**.
    - [Show two elements and a compound made from them. Copper, sulfur, and copper sulfide or sulfate are good examples. Iron, sulfur, and the mineral pyrite are another.]
  - [Give students the opportunity to explore and learn to identify the chemical elements in common objects. See the list on page 5. Give them element labels to place around the classroom on objects that contain the element.]

- **Chemical elements can be divided into groups based on their properties**.
  - **Metals and nonmetals**
    - [Give your students samples of each and have them explore the properties. Introduce the property of ductile vs. brittle. Brittle substances break if they are bent even a little. Ductile substances can be bent without breaking. Metals are shiny, ductile, good conductors, solids at room temperature. Nonmetal solids are brittle, powdery, poor conductors. Many nonmetals are gases at room temperature.]
  - Let your students know that there is a third group, but that samples of those elements are not easy to obtain for classroom use. These are the **metalloids (**also called **semimetals**), which have properties of both metals and nonmetals. The metalloids are shiny and metallic, but brittle and glassy. Metalloids conduct electricity better than nonmetals, but more poorly than metals and are called semiconductors. Remind them how important semiconductors are to our technological society.

- **Elements are arranged according to their chemical properties in the periodic table.**
  - ***<u>NOTE!</u>*** It is best to have the students go through the sequence of ideas above BEFORE introducing the periodic table. They can see why the periodic table exists and gain much more information from it if they have the proper background. Otherwise it becomes just something to memorize.
  - You can give your students an opportunity to discover the arrangement of the periodic table using a card set. Make a card for each element with its physical and chemical properties and its atomic number. Simplify the chemical properties. For instance, tell how the metals and metalloids react with chlorine and how the nonmetals react with hydrogen. Examples: one atom of sodium reacts with one atom of chlorine; one atom of oxygen reacts with two atoms of hydrogen; the noble gases do not react with any other element in nature. Lay the cards out in numerical order and ask the students to look for repeating patterns. (***Big Picture Science will have a card set for discovering the periodic chart available soon. See page 6.)***
  - After students have explored the chemical properties of elements and found the periodicity of those properties, help them explore the groups or families of elements. (Note: there are two designations for the groups of the periodic table and it is best for students to know about both.)
    - **Alkali metals** – group 1 or IA. These are soft, highly reactive, metals with low density and melting point that are always found combined in nature. One atom of these metals reacts with one atom of chlorine.
    - **Alkaline earth metals** – group 2 or IIA. These are very reactive, moderately hard metals that are always found combined in nature. One atom of these metals reacts with two atoms of chlorine.
    - **Transition metals** – groups 3-12 or IB-VIIIB. These are metals with moderate to very low reactivity. We are most familiar with these metals because we see them in the form of elements, not compounds. One atom of these metals often reacts with chlorine and other nonmetals in more than one ratio.
    - **Lanthanide series** of metals – These metals have very similar chemical properties, but are different enough to have different uses. They have moderate reactivity. Most commonly one atom of these metals reacts with three atoms of chlorine.
    - **Post-transition metals** – in groups 13-16 or IIIA-VIA. These metals are soft and have moderate to low reactivity. They often react with chlorine in two different ratios.

- **Metalloids** – in groups 13-17 or IIIA-VIIA. These elements have properties of metals and nonmetals. They often exist in several physical forms, including shiny, brittle crystals. They react with chlorine in several ratios.
- **Nonmetals** (other than halogens) – in groups 14-16 or IVA-VIA. The elements in this group often form molecules, atoms bound in a close arrangement. They commonly react with each other, as well as with metals. They are very reactive and combine with hydrogen in several ratios. They are the elements of life.
- **Halogens** – group 17 or VIIA. These are highly reactive elements. They react with all metals. One atom of these elements reacts with one atom of hydrogen. Their name means "salt makers."
- **Noble gases** – group 18 or VIIIA. These elements are gases that are highly inert. They do not react with any other elements in nature.
- **Hydrogen** is in a group by itself, since it has properties similar to those of several other groups.

➢ The groups of elements are arranged together on the periodic table.
- [Have students reassemble the periodic table by groups of elements. Color code the groups.]

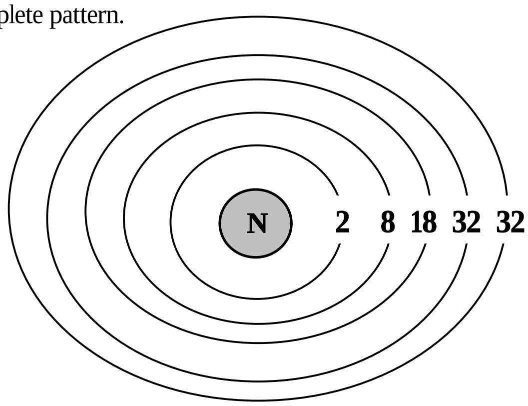
❖ **The arrangement of elements on the periodic table reflects the arrangement of electrons around the nucleus of the atom.**

➢ <u>NOTE</u>! If you save detailed study of the electron configuration of the atom until this point, the students can get the great "AHA!" of discovering the relationship of the electrons to the chemical properties of the atoms.

➢ [Use a model of an atom to explore electron configuration. It can be made of wood, felt, etc. It needs a central holder for marbles, pom-poms, etc. to symbolize the protons and neutrons. (If the students have not studied the parts of the atom and their functions, they should do so now. See p. 6). Concentric circles symbolize the main energy levels for the electrons. Mark places on them for the electrons. See the diagram below.]

➢ [Have the students assemble the model for an atom from groups 1, 2, 17, and 18. Ask them to think about the electron arrangement and the chemical properties of the atom. Discuss their findings.]
- The outer energy level of group 1 has one electron. Group 2 has two electrons in its outer energy level. Group 17 has seven electrons and group 18 has eight electrons in its outer energy level.
- Now you have come to a basic idea of chemistry. **Chemical properties depend on the arrangement of the outer electrons of an atom**. Chemistry itself is all about electrons and what they do.
- The secret of chemical reactions for "A" elements (groups 1,2,13-18) is in group 18. **Atoms are most stable when they have 8 electrons in the outer energy level.** Group 1 elements give up one electron when forming chemical bonds and they are left with 8 electrons in their outer energy level. Group 2 gives up two electrons. Group 17 needs one electron to have 8 electrons in its outer energy level, so it takes an electron from another element. Transition elements do not follow this rule.
- **When electrons are given away or taken up by atoms, they become ions and an ionic bond is formed**. **Atoms change properties when they form ions**. An ion has a different number of electrons than protons. This gives it a charge. It will move in an electric field. "Ion" means "mover" or "that which goes". Atoms are neutral and will not move in an electric field.
- **Atoms** do not always totally give up or take on electrons. Some elements, especially the nonmetals, **share electrons to fill their outer energy level**. When this happens, **a molecule is formed**. The atoms are held close together in a tight arrangement. The chemical bond is called a covalent bond, meaning, "of equal strength". The atoms have about the same pull on the electron, so they share it.
- The outer electrons of an element are called its **valence electrons**. The valence number of an element is tells how many electrons it gains, loses, or shares when it reacts chemically. A positive valence means the atom loses electrons. If the atom gains electrons, it has a negative valence. For example, all the alkali metals have a valence of +1.

The model of an atom – the main energy levels of electrons shown as concentric rings. Nucleus = N. Number = how many electrons will fit in the energy level. Note – levels 6 and 7 are partly filled in the largest elements, but are omitted from this model. <u>After element 18</u>, the electrons do not sequentially fill the main levels one after another. See a chemistry reference for the complete pattern.



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Samples of elements and other pure substances and where to get them

- **Metallic elements** – Carolina Science Supply item D8-75-7487 (electrodes set) is 10 metal strips. It includes iron, aluminum, copper, lead, nickel, and zinc, as well as carbon and costs about $13. If you also want to show how a battery works, get the student voltaic cell, item D8-75-7486, for $30. You can get samples of magnesium metal at a hobby store that carries chemicals (Caution: it is flammable). A less expensive option is to visit your local hardware store for iron nails, galvanized nails (coated with zinc), copper pipe fittings, and aluminum wire.
- **Nonmetals** – Use a charcoal briquette for carbon. For sulfur you can visit a garden store for the powder. A better form for class use is roll sulfur, which is compressed and looks like a large chalk. You can get it from a science supplier. Air is your sample of oxygen and nitrogen. You may want to get some iodine crystals from a science supply, but remember they must be kept in a tightly closed container because they are toxic and they sublime.
- **Compounds** (pure substances) for the classroom. **REMEMBER SAFE HANDLING AND STORAGE!**
  - From the household or grocery store: salt (sodium chloride – $NaCl$); baking soda (sodium bicarbonate – $NaHCO_3$); washing soda (sodium carbonate – Na_2CO_3); sugar (sucrose – $C_{12}H_{22}O_{11}$); cream of tartar (potassium tartrate – $KC_4H_4O_6$); pickling lime (calcium oxide – CaO)
  - From the pharmacy: Ask the pharmacist what s/he can order. Look for a generic chemicals section. It often includes saltpeter (potassium nitrate – KNO_3); Epsom salts (magnesium sulfate – $MgSO_4$); citric acid ($C_6H_8O_7$); and alum (aluminum ammonium sulfate – $AlNH_4(SO_4)_2$). Know the hazards of your materials!
- Get to know your local high school chemistry teacher. S/he can often give you small samples of chemicals.

Chemical elements in common substances

Here are the principal elements in some common substances. For further information, look in your library reference section for the ***Materials Handbook*** by George S. Brady and Henry R. Clauser. The ***Merck Index***, another reference book, lists commercially available substances and their formulas and properties, including toxicity. Rock and mineral field guides list the elements in those substances. Here's one way to use this information for lower elementary. Make two sets of cards, "A", with the name of the substance on one side and the elements in it on the other and "B", with the picture or sample of the material and its name. The child first matches the names on the A and B cards, then turns the A card over to find the elements. Later s/he can match the element list on the A cards to the picture and name on B cards and check the work by reading the name on the back of the A cards. After children are familiar with the names of the elements, it is a good time to introduce the chemical symbols for the elements.

Stainless steel – iron, chromium, nickel, carbon
Steel – iron, carbon
Silver jewelry, sterling silver – silver, copper
Gold jewelry – gold, silver, copper
Common clear glass – silicon, oxygen, sodium, calcium
Pyrex (borosilicate) glass – silicon, oxygen, boron, aluminum, sodium
Blue glass has cobalt added
Green glass has nickel, chromium, or copper added
Brown glass has sulfur and iron added
PVC plastic (polyvinyl chloride) – carbon, hydrogen, chlorine
#1 plastic (PETE – polyethylene terephthalate G copolymer)– carbon, hydrogen, oxygen
#2 plastic (HDPE – high density polyethylene), #3 plastic (vinyl), #4 plastic (LDPE – low density polyethylene), #5 plastic (PP – polypropylene), and #6 plastic (PS – polystyrene) – carbon, hydrogen
Teflon nonstick coating – carbon, fluorine
Cellulose, starch, sugar – carbon, hydrogen, oxygen
Bones and teeth – calcium, phosphorus, oxygen
Brass – copper, zinc
Bronze – copper, tin
White paint pigment – titanium, oxygen
Wood – Carbon, hydrogen, oxygen, with small amounts of potassium, nitrogen, sulfur, phosphorus
Water – hydrogen, oxygen
Table salt – sodium, chlorine
Living things – carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, with smaller amounts of calcium, iron, potassium, sodium, and many more
Cement – calcium, oxygen, silicon, aluminum, iron, sulfur
Ceramic tile – aluminum, silicon, oxygen
Pewter – tin, copper, antimony
Aluminum screen doors, ladders, etc. – aluminum, copper, manganese, magnesium
Light bulb filaments – tungsten
The gas in incandescent light bulbs – argon
The gas in fluorescent light bulbs – mercury, argon
Red in fireworks – strontium
Green in fireworks - barium
Gas in floating balloons – helium
Electrical solder – tin, lead

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Q: What are the parts of the atom and their functions?

A: Atoms are composed of protons and neutrons, which are in the nucleus of the atom, and electrons, which move around the nucleus at high speed. The number of protons determines the kind of atom. All carbon atoms have six protons. The neutrons help pack the protons into the nucleus and make it stable. The number of neutrons can vary in one kind of atom, but some numbers may be unstable. Carbon atoms can have 6, 7, or 8 neutrons, but only those with 6 or 7 are stable. Electrons change arrangements during chemical reactions and bond atoms into molecules.

Q: How can I order the card set, "Discovering the Periodic Table" from Big Picture Science?

A: Check the Big Picture Science Web site. As soon as it is printed, I'll post it there and in this newsletter. The set will include 92 element cards, 10 group cards, and a six-page guide booklet with research questions , a list of concepts introduced, and references. The element cards include physical and chemical properties, symbol, and additional facts.

Resources for teaching about chemistry - 540's in Dewey decimal cataloguing

General references and books on the chemical elements (LE = 6-9 yr., UE = 9-12 yr., MS = 12-15 yr.)

Asimov, Isaac. 1975. ***How Did We Find Out About Atoms?*** Walker and Co.: New York. 62p. ISBN 0-8027-6247-6. Out of print, but may be available in libraries. An excellent history of ideas and experiments. UE, MS.

Atkins, P. W. 1995. ***The Periodic Kingdom***. Basic Books: New York. 163p. ISBN 0-465-07266-6. A lively view of the elements, most easily understood by those with some background. It has its own terminology (elements as "regions"). MS and up. UE with assistance.

Chisholm, Jane and Mary Johnson. 1993. ***Usborne Introduction to Chemistry***. EDC Publishing: Tulsa, OK. 48p. ISBN 0-86020-709-9. Good background on properties, separating mixtures, general chemistry. LE, UE, MS.

Heiserman, David L. 1992. ***Exploring Chemical Elements and their Compounds***. TAB Books: Blue Ridge Summit, PA. 376p. ISBN 0-8306-3015-5. This book gives the pronunciation of the names for all the elements as well as good information on their discovery, sources, and chemical reactions. UE and up.

Knapp, Brian. 1996. ***Elements*** set. Grolier Educational: Danbury, CT. ISBN 0-7172-7572-8 (set) This well-illustrated 15-volume set shows the chemical reactions you DON'T want to see in person, such as the combustion of copper in chlorine gas. More importantly, it gives the history, uses, and reactions of the elements, and the electron configuration of each. UE and up. Read sections to interested LE.

Newmark, Ann. 1993. ***Chemistry*** (Eyewitness Science Series). DK Publishing: New York. 64p. ISBN 1-56458-231-0. This is a well-illustrated book that covers many basic concepts. UE, MS. Read the more basic sections to LE.

Stwertka, Albert. 1996. ***A Guide to the Elements***. Oxford University Press: New York. 238p. ISBN 0-19-508083-1. This book gives good information on the uses of the elements. UE, MS. Read to LE.

Experiment books

Cobb, Vicki. 1985. ***Chemically Active***. Harper Trophy: New York. 154p. ISBN 0-06-446101-7. Experiments and basic chemistry information for UE and MS.

Mebane, Robert C. and Thomas Rybolt. 1985. ***Adventures with Atoms and Molecules***. Enslow Publishers, Inc., PO Box 777, Hillside, N.J. 07205. 82p. ISBN 0-89490-120-6. This 5 volume series has very basic to more sophisticated experiments. Many are physics experiments instead of chemistry. LE, UE

VanCleave, Janice. ***Chemistry for Every Kid*** (ISBN 0-471-62085-8) offers simple instructions and explanations. Her ***A+ Projects in Chemistry*** (ISBN 0-471-58631-5) offers better background and more advanced activities.

Internet sites

Chem4Kids is a good place for beginners or those who wish to review the basics. http://www.chem4kids.com/chem4kids/index.html

Periodic table from Los Alamos Scientific Laboratory has good readable information for students and adults. It includes a list of links to other periodic table sites. http://cst.lanl.gov/CST/imagemap/periodic/periodic.html

WebElements allows you to hear the pronunciation of the names of elements. (Although you will get the British term, aluminium, instead of aluminum.) http://www.shef.ac.uk/chemistry/web-elements/

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Are electrons around an atom are in shells or energy levels? When do sublevels come in?

I have used the term “energy levels” because it is the current usage in texts and because it steers students away from the false idea of atoms as little solar systems. Both terms are used for the same thing. The sublevels or subshells are important for fully understanding the periodic table. Middle school students and interested upper elementary should investigate these. See a chemistry textbook for the details on the sublevels, *s*, *p*, *d*, and *f*.