Scope, Sequence & Coordination

A National Curriculum Development and Evaluation Project for High School Science Education

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National Science Education Standard—Physical Science
Structure and Properties of Matter

Atoms interact with one another by transferring or sharing electrons that are farthest from the nucleus. These outer electrons govern the chemical properties of the element.

Bonds between atoms are created when electrons are transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atms bind together chemically.

Teacher Materials

Learning Sequence Item:

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Chemical Formulas for Molecules

March 1996
**Adapted by: Jesse Jones and Dorothy Gabel*

Chemical Formulas and Chemical Bonds. Students should be able to interpret chemical formulas in terms of the kinds and numbers of particles (atoms) they contain. They should also be able to use ball and stick models to model a variety of structures produced by particles bonding with each other. (*Chemistry, A Framework for High School Science Education, p. 56.)*

Contents

This micro-unit was adapted by **Jesse Jones** (Rocky Mount, N.C.) and **Dorothy Gabel** (Indiana Univ., Bloomington, Ind.)

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Learning Sequence

Chemical Formulas and Chemical Bonds. Students should be able to interpret chemical formulas in terms of the kinds and numbers of particles (atoms) they contain. They should also be able to use ball and stick models to model a variety of structures produced by particles bonding with each other. (*Chemistry, A Framework for High School Science Education, p. 56.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Water + O **Activity 1** Formulas and Molecules **Activity 2** Accounting for Atoms **Activity 3** Isomers **Assessment 3** Two Compounds **Assessment 4** Atoms and Molecules **Assessment 5** Atoms and Elements **Assessment 6** More Atoms **Assessment 7** Ball & Stick **Assessment 8** Alcohol Uses **Assessment 9** Octane Forms **Assessment 10**	An Iron Story **Assessment 2**		A Gold Story **Assessment 1** Galileo's Atomism **Reading 1** Descartes on the Nature of Bodies **Reading 2**

Suggested Sequence of Events

Event #1

Lab Activity

1. Water + O (50 minutes)

Event #2*

Lab Activity

2. Formulas and Molecules (50 minutes)

Event #3

Lab Activity

3. Accounting for Atoms (50 minutes)

Event #4

Readings from Inquiry, Science and Technology, Personal and Social Perspectives, and History of Science. Students select two or three from list.

Reading 1 Galileo's Atomism
Reading 2 Descartes on the Nature of Bodies

The above readings can be found in the student version of this publication.

Assessment items can be found at the back of this volume.

***These events are very important to the sequential development of this microunit. Please complete them in this order and do not omit. Be careful of substitutions.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Water + O

How do the properties of water (H_2O) and hydrogen peroxide (H_2O_2) differ?

Overview:

Students examine the difference in the chemical properties of two compounds each containing hydrogen and oxygen, but whose formulas differ by only one oxygen atom. Do not attempt to include the balancing of equations. This will occur later and more appropriately in grade 10.

Materials:

Per lab group:
100 mL hydrogen peroxide (5% or higher)
3 large test tubes (20–30 mL)
potato cube (to fit test tube) or cooked liver
25-mL graduated cylinder
water
colored fabric—variety of fibers (small swatches)
fruit, ink and other materials for making stains on the fabric
1 g manganese dioxide
2 splints
matches
ball and stick model kits (or styrofoam balls of different colors and volume, pipe cleaners or toothpicks)

Procedure:

Students compare the chemical activity of water and hydrogen peroxide on potato, with manganese dioxide, and on colored cloth. They place 20 mL of water and hydrogen peroxide in two separate test tubes and add a small cube of potato to each. They note the release of a gas from the hydrogen peroxide and test it for oxygen and hydrogen with a glowing splint and burning splint. Once the gas bubbles have diminished, they add the same piece of potato to a new sample of hydrogen peroxide and note that the potato once again causes the release of gas bubbles, thus acting as a catalyst. They then repeat this activity substituting a pinch of manganese dioxide. Finally, they add several pieces of different kinds of fabric and to which they have added stains to test tubes containing hydrogen peroxide and water, and note the bleaching effect of hydrogen peroxide.

Students are then given the formulas for the two compounds, and construct models of each using balls and sticks.

Background:

Water and hydrogen peroxide differ by only one oxygen atom per molecule, yet very different chemical properties. Hydrogen peroxide is a powerful oxidizing agent which removes a lot of stains but does not generally affect color fast dyes. It is particularly effective when the material is left to soak, but requires a high washing temperature. Potatoes contain an enzyme that causes the decomposition of the hydrogen peroxide to water and oxygen. Manganese dioxide acts in a similar manner. The equation for the reaction is: $2H_2O_2 = 2H_2O + O_2$. The emission of the oxygen causes a glowing splint to burst into flames. Hydrogen peroxide is stored in brown bottles to help eliminate the decomposition into oxygen and water which occurs during storage.

Variations:

Substitute pieces of cooked potato for the raw potato and repeat the procedure. Heating usually destroys enzymes.

Science as Inquiry

Formulas and Molecules

How do the properties of substances with closely related formulas differ from one another?

Overview:

Students examine the differences in the properties of pairs of compounds each having similar formulas.

Materials:

Per lab group:

copper (I) chloride (small vial)
copper (II) chloride (small vial)
copper (II) sulfate pentahydrate (10 g)
cobalt (II) chloride hexahydrate (10 g)
water
burner
matches
tongs
hair dryer
20 mL test tube
test tube holder
evaporating dish, small
graduated cylinder, 25-mL
stirring rod
teaspoon
4 circular filter papers
4 pipe cleaners (optional)

Procedure:

Students compare the physical appearance of copper (I) chloride and copper (II) chloride. They make a water solution of the cobalt (II) chloride hexahydrate, and dip filter paper in it, to make a humidity indicator. They dry the filter paper with a hair dryer, and note the color change. Students could make the filter paper into a paper flower, that is attached to a pipe cleaner. The flower could be dipped in the solution of cobalt chloride, and dried with the hair dryer. Students could then take this home with them to use as a humidity indicator.

Students also heat hydrated copper (II) sulfate, note the difference in appearance of the anhydrous copper II sulfate, and test for the release of water.

Background:

The color of chemical compounds depends on their chemical composition. In the case of compounds containing the same elements, but different ratios of those elements, colors may vary considerably. The example given in this activity are copper (I) and copper (II) chloride. Copper (1) chloride is white whereas copper (II) chloride is yellowish-brown. Other chemicals could be used if these two chemicals are not available.

The color and crystalline appearance of a chemical are also dependent on whether water of hydration is included in its composition, and the quantity of that water. Cobalt chloride is blue in the anhydrous state but turns to red when it is hydrated as the hexahydrate. The is the basis for the activity in which students make a solution of cobalt chloride, dip filter paper into it, and dry it, thus turning it into the anhydrous form. This change is used as the test for water, and can be used to check for the humidity of the air.

Copper (II) sulfate hexahydrate is blue. When it is heated it become white and looses its crystalline appearance. Students can test for the presence of water being released from the hydrated copper sulfate as it is heated by using cobalt chloride paper which turns from blue in the anhydrous state to red when it is hydrated as the hexahydrate.

Variations:

Other families of chemicals could be used to see similar comparisons. In addition, using ores containing some of these chemicals (e.g., copper ore—malachite, azurite) to see naturally-occurring versions.

Created by:
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Science as Inquiry

Accounting for Atoms

What happens to atoms in chemical reactions?

Overview:

After observing several simple reactions, students will construct models of various substances involved in the reactions, making sufficient quantities of molecules to show that mass is conserved in chemical reactions.

Materials:

Per lab group:

set of ball and stick models (alternate: styrofoam balls of different colors/volumes with pipe cleaners or tooth picks

charcoal stick

butane lighter

bottle/can carbonated beverage (or sample in jar)

silver knife, fork, or spoon

egg

iron nail (new)

iron nail (rusted)

Bunsen burner

tongs

matches

100 mL limewater (saturated solution of calcium hydroxide)

5 strips cobalt chloride paper (can be made by dipping filter paper into a concentrated solution of cobalt chloride, and drying with a hair dryer)

Procedure:

Students will first observe a series of simple and familiar chemical reactions. With the help of the teacher, they will establish the reactants and products for each reaction. (The teacher might devise or have students devise ways that they can test the products with lime water to test for the presence of carbon dioxide or cobalt chloride paper that turns from pink to blue in the presence of water.) Then using the formulas and a model-building set, students will construct a model of each substance (reactants and products) involved in each reaction. They will then count the number of atoms of reactants and products involved in each reaction, and make models of additional molecules to account for conservation of mass.

Reactions.

Burning of carbon. Place a piece of charcoal in a flame. After it glows for a couple of minutes extinguish and note the product.

carbon plus oxygen yields carbon dioxide: $C + O_2 = CO_2$

Burning of methane. Light a Bunsen burner.
methane plus oxygen yields carbon dioxide and water: $CH_4 + 2O_2 = CO_2 + 2H_2O$

Burning of butane. Light a butane lighter.
butane plus oxygen yields carbon dioxide and water: $2C_4H_{10} + 3O_2 = 8CO_2 + 10H_2O$

Decomposition of carbonic acid. Open a can or bottle of a carbonated beverage.
carbonic acid decomposes to carbon dioxide and water: $H_2CO_3 = H_2O + CO_2$

Tarnishing of silver. Place egg yolk on a silver knife, fork or spoon.
silver plus sulfur yields silver sulfide: $2Ag + S = Ag_2S$

Rusting of iron. Place a nail in water (or bring in new and rusted nails).
iron plus oxygen yields iron oxide: $3Fe + 2O_2 = Fe_3O_4$

Background:

This activity develops students' understanding of conservation of atoms based on conservation of mass which was established in an earlier Learning Sequence microunit activity. Because balancing formula equations is taught at grade 10, students should not be expected to balance equations first, and then confirm the balanced equation with the models. They should begin with the reaction (either in lab or as a demonstration), write a word equation, make models of the formulas of the reactants and products given in the equation, and make additional models to account for conservation of mass, and hence atoms.

Once these additional models have been made, the models can be used to show how the number of models corresponds to the coefficients in the balanced equation. Students should then practice interpreting the meaning of balanced or unbalanced equations in terms of conservation of atoms.

Variations:

Have students devise ways that they can test products with lime water to test for the presence of carbon dioxide.

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History and Nature of Science

A Gold Story

Item:

In the early years of World War II while Germany was occupying Denmark, friends of Niels Bohr were concerned that the gold medal given to him when he received the Nobel Prize would be confiscated for the war effort. It was decided to dissolve the gold medal in aqua regia, the only solvent in which gold is soluble. The dark brown solution containing the gold was stored on a shelf in the lab, where it remained throughout the war. The friends were confident they could process the solution and remake the medal to look exactly as id did when Bohr initially received it. What property of gold did the scientists rely on? Explain your answer thoroughly.

Answer:

Conservation of atoms. It didn’t matter what chemical form the gold was in, it could be chemically changed back into gold metal at any time.

Science and Technology

An Iron Story

Item:

Railroad tracks often need to be connected to form a continuous rail. The thermite reaction between iron oxide and aluminum powder is used to produce molten iron which connects the rails together. The reaction can be thought of as two steps:

$2Fe_2O_3$ = 4Fe + 1600kJ = $3O_2$
800kJ = $3O_2$ = 4Al = $2Al_2O_3$

Net reaction: $2Fe_2O_3$ + 4Al = $2Al_2O_3$ + 4Fe = 800kJ

Examine the net reaction and count the number of all atoms on the left side of the equation and the right side of the equation.

A. (left side) Fe: O: Al: (right side) Fe: O: Al:

B. What do you notice about the number of atoms on each side of the equation? Why?

C. If a scientist proposes that there are different reactions involved, but that the net reaction remains the same, why does this not affect your answers to "A" and "B" above?

Answer:

A. (left side) Fe: 4 O: 12 Al: 4 (right side) Fe: 4 O: 12 Al: 4

B. The number of each atom on each side of the equation is the same. Atoms in a chemical reaction are conserved.

C. Since atoms are always conserved, it doesn't matter what steps they go through, or what other molecules are involved, the end result must have the same number of every type of element.

Science as Inquiry

Isomers

Item:

Draw three isomers of nonane, C_9H_{20}. Describe differences and similarities in chemical and physical properties that you might expect in these three compounds.

Answer:

Science as Inquiry

Two Compounds

Item:

Two different forms of tin chloride exist, $SnCl_2$ and $SnCl_4$. Describe differences and similarities in chemical and physical properties that you might expect in these two compounds.

Answer:

Science as Inquiry

Atoms and Molecules

Item:

How many atoms are present in three molecules of butanol, C_4H_9OH?

Answer:

Science as Inquiry

Atoms and Elements

Item:

How many atoms of each element are present in $Ca(SCN)_2 \cdot 3H_2O$?

Answer:

Science as Inquiry

More Atoms

Item:

Given the formulas of compounds commonly used by people, which compound listed below contains the most atoms? Which formula has the fewest atoms?

A. $C_{12}H_{22}O_{11}$ (sugar)
B. CH_4 (natural gas)
C. NaCl (table salt)
D. C_2H_5OH (ethyl alcohol)

Answer:

Science as Inquiry

Ball & Stick

Item:

Discuss how a ball and stick model would be useful to a researcher in developing a new compound. How useful will a ball and stick model be in developing a harder compound to be used in making a drill bit?

Answer:

Science as Inquiry

Alcohol Uses

Item:

Alcohols have many different uses. Of the two structures below, which alcohol is used for cleaning wounds?

A.
```
      H   H   H
H – C – C – C –OH
      H   H   H
```

B.
```
      H   H   H
H – C – C – C – H
      H  OH   H
```

C.
```
      H
H – C – O – H
      H
```

D.
```
      H   H
H – C – C –OH
     OH   H
```

Answer:

Science as Inquiry

Octane Forms

Item:

Octane is found in gasoline. However, there are many different forms of this compound. Given the formula C_8H_{18}, draw two different structures (isomers) for this compound.

Answer:

Consumables

Item	Quantity (per lab group)	Event
carbonated beverage	1	3
charcoal stick	1	3
cobalt (II) chloride hexaydrate	10 g	2
cobalt chloride paper	5 strips	3
copper (I) chloride	small vial	2
copper (II) chloride	small vial	2
copper (II) sulfate pentahydrate	10 g	2
egg	1	3
fabric, colored	2–3 varieties	1
filter papers	4 circular	2
fruit	2 small pieces	1
hydrogen peroxide, 5%	100 mL	1
ink	1 mL	1
lime water	100 mL	3
manganese dioxide	1 g	1
matches	2	1, 2, 3
pipe cleaners	4	2
potato, raw, cubed	1 cube	1
splint	2	1
water		1, 2

Non-Consumables

Item	Quantity (per lab group)	Event
ball and stick model kits	1	1, 3
Bunsen burner	1, 1	2, 3
cylinder, graduated, 25 mL	1	2
dish, evaporating, small	1	2
hair dryer	1 (per 2 groups)	2
lighter, butane	1	3
nail, new and rusted	1 each	3
rod, stirring	1	2
spoon, silver (knife, fork)	1	3
teaspoon	1	2
test tube holder	1	2
test tube, large, 20–30 mL	3, 1	1, 2
tongs	1	2

Activity Key
1. Water + O
2. Formulas and Molecules
3. Accounting for Atoms