SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

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> **National Science Education Standard—Physical Science**
> **Structure and Properties of Matter**
> Matter, as found in nature, consists primarily of mixtures, compounds, and elements in various proportions. The observable properties of mixtures depend upon the nature of the components. A mixture can be separated into pure substances using the characteristic properties of the substances contained in the mixture.

Teacher Materials

Learning Sequence Item:

928

Matter and Energy

March 1996
Adapted by George Miller and Dorothy Gabel

Mixtures, Elements, and Compounds. Students should distinguish matter from energy and determine that matter, as found in nature, consists primarily of mixtures of compounds or elements *(Chemistry, A Framework for High School Science Education, p. 51).*

Contents

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Lab Activities
1. Matter and Energy
2. Does the Energy Matter?
3. Chemicals: What's in a Name?
4. Pure Alchemy

Assessment
1. What's the Matter with Energy?
2. What's New?
3. The Chemistry of Lunch

This micro-unit was adapted by **George Miller** (University of California, Irvine) and **Dorothy Gabel** (Indiana University, Bloomington)

928
Learning Sequence

Mixtures, Elements, and Compounds. Students should distinguish matter from energy and determine that matter, as found in nature, consists primarily of mixtures of compounds or elements *(Chemistry, A Framework for High School Science Education, p. 51).*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Matter and Energy **Activity 1** Does the Energy Matter? **Activity 2** Chemicals: What's in a Name? **Activity 3** Pure Alchemy **Activity 4** What's the Matter with Energy? **Assessment 1** What's New? **Assessment 2**		Arsenic in Our Water: How Much Is Safe? **Reading 1** The Chemistry of Lunch **Assessment 3**	Matter and Its Transformations: The Increase in Weight of Tin and Lead on Calcination **Reading 2**

Suggested Sequence of Events

Event #1

Lab Activity

1. Matter and Energy

Additional Experiment

2. Does the Energy Matter?

Event #2

Lab Activity

3. Chemicals—What's in a Name?

Additional Experiment

4. Pure Alchemy

Event #3

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

The following readings are included in the student version of the unit:

Reading 1 Arsenic in Our Water: How Much Is Safe?
Reading 2 Matter and Its Transformations: The Increase in Weight of Tin and Lead on Calcination

Suggested additional readings:

Conant, James, "The Significance of Phlogiston." *Chemtech*, October 1991, pp. 592-596.

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

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.

Teacher Sheet

Science as Inquiry

Matter and Energy

Does the energy balance?

Overview:

This activity focuses on careful use of a balance as a major tool in science and mass as a fundamental unit of science. Students revisit, explore, and measure equal-mass samples of matter containing different amounts of energy, observing over time how masses may change and making an inference/explanation.

Materials:

Per lab group:

two-pan balance: can be a simple one constructed for this experiment (wood or plastic strip on a fulcrum support with equal-distance arms carefully marked, bottom of cup drawn, and adjusted to balance with known equal masses)
triple-beam or other centigram balance
cups, glasses, or beakers (polystyrene, glass, plastic, or china), 2 (identical)
liquids (water, salt solutions, rubbing alcohol, etc.)
thermometers, 2 (one could be used)
source of heat—burner or hot plate
graph paper
access to clock or watch for timing
small masses (pins, paper clips, washers, etc.) (additional)

Procedure:

Different groups should use different starting conditions (temperatures), apparatus (cups of different materials), and liquids. Have students place equal volumes of the same liquid in cups on a balance and obtain the mass of each. One cup is then heated to a reasonable temperature above room temperature, but not to the boiling point. If ice is available, one cup can contain ice water.

After measuring temperatures, students place the hot and cold cups on the equal-arm balance, after checking masses on the single-pan balance to see that they are the same. They should predict what may happen and observe the balance point as a function of time. If the beam becomes unbalanced, students obtain and record the new masses.

Students should write down their observations, not their inferences. All observations should be recorded in an organized manner so that someone else could easily reproduce the observations. Labeled drawings or diagrams should be included. Have students graph the data over time and explain what they observed and what they think is happening.

Background

You should be able to encourage a lively debate about whether "something happened" or not. Smart students may argue that nothing should happen—mass does not change with temperature. On the other hand, evaporation is going to occur at differing rates depending upon the starting circumstances. Students may be tempted to change what they observe to suit their model. All observations must be treated as real and explanations sought.

The question of whether the amount of energy affects the mass should be carefully discussed in terms of whether variables are well enough controlled to truly answer the question—*not* whether it has been "proven"! Students at this level probably will accept that temperature is a measure of energy, but you may need to discuss this.

See Activity 1 of micro-unit 931, "What You See Is What You Record," for a more detailed discussion of observations and communication of observations. Those ideas should be reinforced here.

Alternative Procedure:

Have a collection of small known masses available (e.g., pins, plastic paper clips, small nuts, washers). If and when the two-pan balance gets out of balance, students add these masses to the light side to bring it back to balance. The additions are then plotted as a function of time.

Adapted from *Fun with Physics and Chemistry*, Version 1.3. Thomas Kardos.

an alternative/extension activity for Event 1

Teacher Sheet

Science as Inquiry

Does the Energy Matter?

Overview:

Students revisit, explore, and measure an example of matter undergoing chemical change, observing over time how total mass remains unchanged but energy has been transferred/transformed.

Materials:

Per lab group:

triple-beam or other centigram balance
(an accurate top-loading balance would be best)
soft drink bottle, 2-liter with cap
thermometer
white vinegar, 25 mL
baking soda, 10 g
paper towel
graph paper
access to clock or watch for timing

Materials for Alternative Reaction:

Per lab group:

triple-beam or other centigram balance
zip-closure bag (quart size)
thermometer
sodium chloride (solid), 1 g
vermiculite, 1 tbsp
water, 3–4 mL
graph paper
access to clock or watch for timing

Procedure:

As in Activity 1, this experiment requires careful use of a balance to be convincing. Have students obtain the mass of a two-liter bottle containing about 25 mL of vinegar. They should also obtain the mass of about 10 g of baking soda (*not* baking powder) wrapped tightly in a paper towel, making a long twist that can be inserted through the neck of the bottle.

Carefully, without losing any powder, students then place the wrapped packet into the bottle and quickly screw the cap on tightly. The total mass can be checked on the balance as the reaction starts. Shaking the bottle to help the powder release and the liquid to soak through the towel, students continue to measure and record the total mass. Placing a thermometer on the base of the bottle, they can see if the temperature is changing.

Have students graph the data over time and explain what they observe and what they think is happening.

Procedure for Alternative Reaction:

Students place the iron powder and salt in the bag and mix well. They then add the vermiculite, mix again, and obtain the mass of the bag and the contents. They also obtain the mass of 3–4 mL of water. After measuring the temperature of the water and of the bag and contents, students add the water to the bag, close it quickly, and obtain the total mass of the bag and contents. They then squeeze and mix the contents (being careful that the bag does not pop open!).

Have students monitor temperature and mass as a function of time and treat the data as in the bottle experiment.

Background:

This may be a repeat experiment/demo for many students. But the focus is probably new: mass changes vs. energy changes. Students can do the experiment themselves, perhaps being more quantitative this time and writing more complete reports. The experiment could be done as a demonstration if balance equipment is limited, but it would be better done by students in small groups. This is an important experiment for students, as they can begin to discuss a system and what is included. In terms of matter, the system is closed because no matter enters or leaves. In terms of energy, it is open because heat can flow in or out.

Students should not do the bottle activity in a plastic bag because buoyancy changes as the bag inflate give an incorrect result. This doesn't happen with the alternate reaction because no gas is produced. Some class groups could do this and see if they can determine why mass (using a sensitive balance) does not seem to be conserved with the bag method but is with the bottle (the bottle doesn't change volume much).

It is important to identify where we (the observers) are in relation to systems. When something feels cold, this means heat (energy) has flowed from our hand into the object, lowering our surface temperature and thus making our temperature sensors feel cold (and vice versa for hot). Remember, by definition heat flows from hotter to cooler objects. It is a common misconception that we possess "heat" sensors. Heat sensors are really thermometers, or temperature sensors, although they can be conditioned or "fooled" because they are relative, not absolute, devices. The basis for comparison is the most recent "normal" adjustment.

The question "are energy and mass conserved?" should be carefully discussed in terms of whether variables are well enough controlled and the system well enough identified to truly answer the question—not in terms of whether it has been "proven." As in Activity 1, students probably will accept that temperature is a measure of energy, but you may need to discuss this. Here the T measurement is less certain because the thermometer is not immersed. If balances are sensitive enough, the bottle can be opened at the end of the experiment, and the mass checked again. Some carbon dioxide will escape and the mass will be reduced. No gas is produced in the bag experiment so it should not inflate.

Sodium acetate and iron oxide are the respective products. Neither is a waste disposal problem. See Activity 1 of unit 9.04 for a more detailed discussion of observations and communication of observations).

Adapted from experiments appearing in many texts. For bottle, latest reference is *Journal of Chemical Education*, May 1995. For bag: *Experiments in a Bag*, Institute for Chemical Education (ICE). The bag reaction is similar to that found in Hand Warmers sold in drug stores.

Science as Inquiry

Chemicals: What's in a Name?

Does a chemical name reveal its composition?

Overview:

Students explore home and store environments to seek out and become familiar with the names of elements and compounds. They look for similarities that provide information about elements contained in compounds.

Materials:

Per lab group:

supply of cards (3 × 5) or other means of routine recording of information
(if computers are available this can be good practice for spreadsheet use)
supply of labels from household products (ask students to supply these)

Procedure:

Have students set up a table using cards or a spreadsheet on which they record information from labels on foods, household cleaners, auto shop chemicals, hardware store chemicals, nursery chemicals, etc. Each card or listing will contain information regarding one chemical element from one product. They may find instances where one chemical substance will yield two listings. For example, if they found hydrochloric acid listed, they would indicate on one card that this name implies that the substance contains the element hydrogen and on another card they would indicate chlorine as the element. The information should include (add other information if you wish):

1. name of product
2. where the product is found
3. intended use for the product
4. chemical substance name listed
5. whether the chemical is an element, compound, or mixture (or ? if not sure)
6. chemical element name as listed or chemical element name as inferred in compound name
7. element symbol
8. location in periodic table (column and row and/or sequence number)

Student groups should discuss how to interpret unusual cases and whether an element, compound, or mixture is being listed. They may want to make a separate list of chemical substance names that do *not* seem to indicate any composition information.

Ask groups to seek out certain products or certain elements and share their results with the class.

In this activity the emphasis is not on memorizing names but in looking at the wide variety of substances with which we deal in everyday life and in observing ways in which science systematically provides ways to communicate about the chemical composition of substances. You should gradually build a database of suggestions for students to guide their search. This database can be tailored to the neighborhood experience of students at the school. An opportunity is used to familiarize students with the location of elements in the periodic table. However, this should not become the focus of this exercise.

Background:

Elements are often listed as such on labels, even when they do not occur in elemental form in the product (e.g., sodium or calcium in a food product, or phosphorus or nitrogen in a fertilizer). Students should become aware of these distinctions and the reasons for them. Such simplifications are often done because of the way the product has been analyzed or to make it easier for the customer to understand.

Element names show up with minor variations in compound names (e.g., sodium chloride). In this exercise, students should become aware of these variations but should not be expected to write formulas or to identify specific ions. However, they should understand that name variations imply distinctions about the way elements (atoms) are organized in compounds (e.g., chlorate vs. chloride), while also indicating that a certain element is involved (in this case, chlorine). Students may also discover that many names are relatively uninformative as to the elemental composition (e.g., aspirin or cholesterol or muriatic acid), either for historical reasons or because a whole different naming system must be learned (organic nomenclature).

Lab groups could be assigned certain projects, such as kinds of stores, types of products, particular elements, chemicals in use at home or in school, etc.

Students can also be made aware of handbooks that contain chemical information, including encyclopedias and standard science and medical handbooks. Companies may also provide information about their products on publicity leaflets or inserts on how to use the product.

Another important function of this exercise is to help convince students that all matter consists of chemicals, that matter cannot be "chemical free," and that use of the word "chemical" to imply either bad or good is really inappropriate.

In question 4, students are asked to classify the products as mixtures, solutions, compounds, or elements. Most of the products will be mixtures (all solutions fall in this category). Few, if any, will be elements.

an alternative/extension activity for Event 2

Teacher Sheet

Science as Inquiry

Pure Alchemy

Can a penny change to gold?

Overview:

In this activity, students observe an example of matter undergoing chemical change. They see how two elements, zinc and copper, can combine to form a substance with different properties.

Students need to be careful , as in all labs, not to touch solutions, splash them, or touch hot items. Warn them not to place hot pennies onto paper towels and to drench hot pennies in cold water before handling. Disposal of excess zinc solution requires care, especially as unreacted zinc may remain. It should be neutralized with hydrochloric or sulfuric acid, which will dissolve excess zinc, and then diluted and disposed of as zinc chloride or zinc sulfate. Finely powdered zinc may be pyrophoric and may start a fire with paper in a trash can.

Materials:

Per lab group:
clean copper penny
zinc dust, 5 g
sodium hydroxide solution (6 M: 240 g of NaOH per liter of solution), 20 mL
evaporating dish or small beaker
tongs or tweezers
burner
dish or beaker support (wire gauze) or hot plate

Procedure:

This activity can be done as a demonstration, but with proper precautions students will gain much more appreciation for the power of chemical synthesis from direct experience.

Students place about 5 g zinc dust in the dish or beaker, add sodium hydroxide solution to cover the zinc, and fill about one-third full. They then heat the dish and contents over a burner or hot plate to just below boiling to dissolve the zinc powder.

Advise students to be sure the copper penny is clean. After holding it in the hot solution with tongs for 3–4 minutes, they will notice a surface color change. When all the surface has changed, the penny is ready. Students then remove the penny, rinse it in water, and wave it in a burner flame. Only a few seconds are usually needed for another color change to occur. The penny is allowed to cool and is then washed and dried. Students should record their observations during the synthesis.

Background:

Zinc dissolves in sodium hydroxide to form sodium zincate (NA_2ZnO_2). The zincate ions are then reduced by the copper in the penny to metallic zinc, which coats the penny. Copper still remains underneath, protected from further reaction by the zinc coat. Heating the surface allows the metals to diffuse together to form an alloy—brass. Commercial brass varies from 60–80% copper, the rest is zinc.

Bronze may be a familiar substance to some students. This alloy forms in a manner similar to that of brass but is made of tin and copper. It has been known for thousands of years as a useful hard alloy for weapons, utensils, and art objects. Brass has been made only in modern times. Common objects made of brass (or brass plated today, since brass is more expensive than steel) include door knobs, door knockers, handles for furniture, etc. You may wish to have a few items on hand to show students if they are unfamiliar with brass objects.

Zinc is most commonly encountered as galvanizing on steel/iron objects intended for use outdoors, including nails, water cans, buckets, etc. It is also used as a protective coating on automobiles but is rarely observable, being covered by paint or rubberized coatings for further protection. Zinc used to be applied electrochemically (hence the term galvanize from galvanic cell). Today galvanizing often involves dipping the object into molten zinc and cooling it quickly (hot-dip galvanizing). This leaves crystalline patterns as the zinc solidifies, which can be seen on close observation. You may wish to have some galvanized objects for students to observe.

Copper and zinc are two of only a few elements that are observed directly as commercial products. As an extension of this activity, the class might be asked to list all known occurrences where elements can be directly observed in nature or commerce.

This experiment appears in many texts. Latest reference is *Journal of Chemical Education* (1995). This version is adapted from Summerline and Ealy, *Chemical Demonstrations*. American Chemical Society, 1985.

Science as Inquiry

What's the Matter with Energy?

Item:
A 10.0 g rock and a 10.0 g steel ball resting on a table have the same amount of energy. They are made of different elements. Under the given conditions, why do they have the same amount of energy?

Answer:
Same mass, same conditions, same potential energy.

Science as Inquiry

What's New?

Item:
When a chemical reaction occurs:

A. New atoms and new substances are formed.
B. New substances are formed.
C. New atoms are formed.
D. Energy is always given off.

Justification:
Sodium is a silvery gray metal and chlorine is a greenish-yellow gas. When sodium combines with chlorine, sodium chloride, a white crystalline solid, is formed. Why is it correct to agree that a new substance is formed?

Answer:
B.

Science in Personal
and Social Perspectives

The Chemistry of Lunch

Item:
For lunch today, your friend had a Coke, a hamburger on a bun with catsup and pickles, french-fried potatoes, and a candy bar. Were the items she ate single elements, single compounds, mixtures, or solutions?

Answer:
All of the items given in the luncheon menu are mixtures. The coke is a homogeneous mixture or a solution.

Consumables

Item	Quantity per lab group	Activity
3 × 5 cards	—	3
baking soda	10 g	2
clean copper penny	1	4
graph paper	1 piece	1, 2
liquid (water, salt solution, or alcohol, varied among lab groups)	—	1
paper towel	1	2
product labels (supplied by students)	—	3
sodium chloride (solid)	1 g	2*
sodium hydroxide solution (6 M:240 g of NaOH per liter of solution)	20 mL	4
vermiculite	1 tbsp	2*
water	3–4 mL	2*
white vinegar	25 mL	2
zinc dust	5 g	4
zip-closure bag	1	2*

Non-Consumables

Item	Quantity per lab group	Activity
balance, two-pan	1	1
balance, triple-beam or other centigram	1	1, 2
burner	1	4
burner or hot plate	1	1
clock/watch	1	1, 2
cups, glasses, or beakers (polystyrene, glass, plastic, or china)	2 identical	1
dish or beaker support	1	4
evaporating dish or small beaker	1	4
small masses (e.g., pins, paper clips)	—	1*
soft drink bottle, 2-liter with cap	1	2
thermometer	1-2	1
thermometer	1	2
tongs or tweezers	1	4

*alternative or additional activity

Key to activities:
1. Matter and Energy
2. Does the Energy Matter?
3. Chemicals: What's in a Name?
4. Pure Alchemy

References

Activiy Sources

Experiments in a Bag, Institute of Chemical Education (ICE). No other source information available.
Fun with Physics and Chemistry, Version 1.3. Thomas Kardos. No other source information available.
Journal of Chemical Education, May 1995. No other source information available.
Summerline and Ealy, *Chemical Demonstrations*, American Chemical Society, 1985. No other source information available.

Readings

"Arsenic in Our Water: How Much Is Safe?" Unpublished manuscript by N. Erwin, SS&C, National Science Teachers Association, Arlington, VA.
Essays of Jean Rey, Doctor of Medicine, On an Enquiry into the Cause Wherefore Tin and Lead Increase in Weight on Calcination, pp. 14–15, 36–37, 49–51. Edinburgh and London, 1895. From Guerlac, H. (Ed.), *Selected Readings in the History of Science, Volume 2.* Ithaca: Henry Guerlac, 1953.