SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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Student Materials

Learning Sequence Item:

928

Matter and Energy

March 1996
Adapted by George Miller and Dorothy Gabel

Contents

Lab Activities

Readings

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

Student Sheet

Science as Inquiry

Matter and Energy

Does the energy balance?

Overview:

In this activity, water or another liquid is heated and the mass is measured at different temperatures. Does the mass of the heated liquid change? What is the difference between mass and energy and how is energy related to temperature?

Procedure:

Place equal volumes of the same liquid in two cups and obtain the mass of each. Heat one cup to a reasonable temperature above room temperature, but not to the boiling point. Measure the temperature of each cup. Place the hot and cold cups on the equal-arm balance after checking masses on the single-pan balance. Be careful in handling the hot cup! Predict what may happen.

Observe the balance point as a function of time. If the beam becomes unbalanced, obtain and record the new masses. Record all your observations in an organized manner so someone else could easily reproduce your observations. Include labeled drawings or diagrams.

Graph the data over time. Explain to the class what you observe and what you think is happening.

Alternative Procedure:

Start with the two-cup system exactly balanced. If and when it goes out of balance, add small standard masses (e.g., pins or paper clips) to one side to bring it back to balance. Graph the number of items added, if any are needed, as a function of time.

Questions:

1. What does measuring the temperature tell you about the material in each cup?

2. What does measuring the mass tell you about the material in each cup?

3. What would happen if you did this experiment over a much longer time? Why?

4. What variables are controlled in this experiment? What variables are not controlled? Explain.

5. Are energy and mass directly connected? Why or why not? How does this experiment help or not help to answer this question?

Science as Inquiry

Does the Energy Matter?

Overview:

Making careful mass measurements in this activity will help you determine whether energy and/or mass changes occur when one chemical is added to another.

Procedure:

Obtain the mass of a two-liter bottle containing about 25 mL of vinegar. Also, obtain the mass of about 10 g of baking soda (not baking powder) wrapped tightly in a paper towel (sausage style) to make a long twist that can be inserted through the neck of the bottle.

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

Graph the data over time. Explain what you observe and what you think is happening.

Questions:

1. What does measuring the mass tell you about the substances in the bottle?

2. What does measuring the temperature tell you about the substances in the bottle?

3. What variables are controlled in this experiment? What variables are not controlled? Explain.

4. Did your hand on the bottle feel cold, hot, or unchanged? How did this relate to measurements with the thermometer? What does it mean if something cools or heats your hand?

5. Are energy and mass conserved in this experiment? Why or why not? Can one ever be conserved without the other?

Procedure for Alternative Reaction:

Place the iron powder and salt in the bag. Mix well. Add the vermiculite and mix again. Obtain the mass of the bag and contents. Obtain the mass of 3–4 mL of water. Add the water to the bag, closing it quickly, and obtain the mass of the total bag and contents. Squeeze and mix the contents (don't let the bag pop open!). Monitor temperature and mass as a function of time. Treat data as for the bottle experiment.

Science as Inquiry

Chemicals: What's in a Name?

Does a chemical name reveal its composition?

Overview:

An examination of product labels can tell you much about the contents. Can you tell from the chemical names of products or lists of ingredients which elements on Earth are most common?

Procedure:

Your teacher will provide you with cards or sheets of paper on which you will record information from labels on foods, household cleaners, auto shop chemicals, hardware store chemicals, nursery chemicals, etc. Each listing will contain information regarding one chemical element from one product. You may find instances where one chemical substance will yield two cards (listings). For example, if you found hydrochloric acid listed, you would indicate on one card that this name implies that the substance contains the element hydrogen and on another card you would indicate the element chlorine.

Set up a table on each card to include the following information:

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)

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

Your teacher may ask you to seek out certain products or certain elements and share your results with the class.

Questions:

1. There are approximately 100 elements known to exist. Are there any that are extremely unlikely to *ever* be listed on a food label? Why or why not?

2. What other sources of chemical information could be used to find out where elements and compounds exist?

3. Check with other groups to determine which elements are most common. What are the 10 most common?

4. Make a list of the original products whose labels (ingredients) you and your classmates examined. Identify each as mixture, solution, compound, or element. Give a reason for each item classified. Which class of materials is most common?

Student Sheet

Science as Inquiry

Pure Alchemy

Can a penny change to gold?

Overview:

Chemists for centuries have tried to change one element into another. Has this ever happened? Are there modern-day alchemists? How could you tell whether a new element has been formed? In this activity an ordinary penny undergoes change.

Procedure:

Caution: Do not touch chemical solutions or heated objects with your fingers. Be extremely careful about splashes. Wash with lots of water if you splash solutions on yourself or your clothes. Wear eye protection and be sure to follow your teacher's instructions for disposal of all chemicals.

Place about 5 g of zinc dust in the dish or beaker. Add sodium hydroxide solution to cover the zinc and fill about one-third full. Heat over burner or hot plate to just below boiling to dissolve the zinc powder.

Be sure your copper penny is clean. Use tongs to hold it in the hot solution for 3–4 minutes. You will notice a surface color change. When all the surface has changed, it's ready! 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. Allow the penny to cool and wash and dry it. Observe and record all your observations during the synthesis.

Questions:

1. What do you think the silver color is that formed on the penny at first? Have you seen other objects that look like this? What are some examples?

2. Do you think the shiny color formed in the flame is real gold? Why or why not? Have you seen objects that have this color? Do you know a name for this substance, assuming it isn't gold? What other objects are often made from this material?

3. How would you classify the product of the reaction you observed? Is it an element, a compound, a mixture, or a solution?

Science in Personal
and Social Perspectives

Arsenic in Our Water: How Much Is Safe?

Arsenic, a poisonous element found throughout the Earth's crust, is a common contaminant of groundwater. Just how safe is our water? According to limits set by the U.S. Environmental Protection Agency in 1976, the health risk associated with drinking water with levels of arsenic at 50 parts per billion (ppb) corresponds to a skin cancer risk of 2.5 in 1,000. Is this too high a risk?

Toxicologists with California's Environmental Protection Agency think so (*Science News*, 1992). Citing evidence from various studies, the California agency recommends a regulatory goal of 2 parts per trillion arsenic. The chief evidence supporting this recommendation stems from a Taiwanese study linking cancer mortality rates with consumption of well water. Wells in Taiwan typically have arsenic levels of 150-800 ppb. High levels of various internal cancers, such as lung, liver, and bladder, were associated with these arsenic levels.

The 2 parts per trillion regulatory limit recommended by the California EPA corresponds to an overall cancer risk of roughly one in 1 million.

References:

"Arsenic in Water: Bigger Cancer Threat." *Science News*, April 18, 1992, p. 253.

By N. Erwin, SS&C, National Science Teachers Association, Arlington, VA.

History and Nature of Science

XIII. Matter and Its Transformations

62. *Jean Rey on the Increase in Weight of Tin and Lead on Calcination*

Heaviness is so closely united to the primary matter of the elements, that when these are changed one into the other they always retain the same weight.

My chief care hitherto has been to impress on the minds of all the persuasion that air is heavy, inasmuch as from it I propose to derive the increase in weight of tin and lead when they are calcined. But before showing how that comes to pass, I must make this observation—that the weight of a thing may be examined in two ways, viz. by the aid of reason, or with the balance. It is reason which has led me to discover weight in all the elements, and it is reason which now leads me to give a flat denial to that erroneous maxim which has been current since the birth of Philosophy—that the elements mutually undergoing change, one into the other, lose or gain weight, according as in changing they become rarefied or condensed. With the arms of reason I boldly enter the lists to combat this error, and to sustain that weight is so closely united to the primary matter of the elements that they can never be deprived of it. The weight with which each portion of matter was endued at the cradle, will be carried by it to the grave. In whatever place, in whatever form, to whatever volume it my be reduced, the same weight always persists. But not presuming that my statements are on a parity with those of Pythagoras, so that it suffices to have advanced them, I support them with a demonstration which, as I conceive, all men of sense will accept. Let there be taken a portion of earth, which shall have in it the smallest possible weight, beyond which no weight can subsist: let this earth be converted into water by the means known and practised by nature: it is evident that this water will have weight, since all water must have it, and this weight will either be greater than that of the earth, or less than it, or else equal to it. My opponents will not say that it is greater, for they profess the contrary, and I also am of their opinion: smaller it cannot be, since we took the smallest weight that can exist: there remains then only the case that the two are equal, which I undertook to prove. What is shown of this particle may be shown of two, three, or

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Essays of Jean Rey, Doctor of Medicine, On an Enquiry Into the Cause Wherefore Tin and Lead Increase in Weight on Calcination. Edinburgh and London, 1895. From Guerlac, H. (Ed.), *Selected Readings in the History of Science, Volume 2*. Ithaca: Henry Guerlac, 1953.

a very great number—in short, of all the element, which is composed of nothing else. The same proof may be extended to the conversion of water into air, of air into fire; and, conversely, of the last of these into the first. . . .

Formal response to the question, why Tin and Lead increase in weight when they are calcined.

Now I have made the preparations, nay, laid the foundations for my answer to the question of the sieur Brun, which is, that having placed two pounds six ounces of fine English tin in an iron vessel and heated it strongly on an open furnace for the space of six hours with continual agitation and without adding anything to it, he recovered two pounds thirteen ounces of a white calx; which filled him at first with amazement, and with a desire to know whence the seven ounces of surplus had come. And to increase the difficulty, I say that it is necessary to enquire not only whence these seven ounces have come, but besides them what has replaced the loss of weight which occurred necessarily from the increase of volume of the tin on its conversion into calx, and from the loss of the vapours and exhalations which were given off. To this question, then, I respond and sustain proudly, resting on the foundations already laid, "That this increase in weight comes from the air, which in the vessel has been rendered denser, heavier, and in some measure adhesive, by the vehement and long-continued heat of the furnace: which air mixes with the calx (frequent agitation aiding) and becomes attached to its most minute particles: not otherwise than water makes heavier sand which you throw into it and agitate, by moistening it and adhering to the smallest of its grains." I fancy there are many who would have been alarmed by the sole mention of this response if I had given it at the beginning, who will now willingly receive it, being as it were tamed and rendered tractable by the evident truth of the preceding Essays. For those without doubt whose minds were preoccupied with the opinion that air was light, would have rushed to oppose it. Why (they would have said) does not one extract cold from heat, white from black, light from darkness, since so much heaviness is extracted from air, a thing inherently light? And those who chanced to have bestowed their credence on the heaviness of air, would not have been able to persuade themselves that it can every increase weight, being balanced in itself. On this account I was constrained to show that air had weight; which was recognisable by other means than the balance: and that even with the latter, a portion previously changed and made denser could manifest its weight. . . .

By a single experiment all opinions contrary to mine are entirely destroyed.

It is said of Hercules that no sooner had he cut off one of the heads of the Hydra which devastated the Lernaean marsh, than two others sprang forth. My condition is similar. The error that I combat teems with opinions, which are so many heads: if I cut off one, we see two appear. My labour is always on the increase: and I believe I should never have done if I only employed myself in cutting off one after the other. To give it the deathblow, I must gather my strength and make stiff my arm, in order that I may strike them all off at a single blow. Let him who will take heed: for now the fatal stroke will be dealt him. I have just read in Hamerus Poppius, in the third chapter of his book entitled *Basilica Antimonii* the new method which he practises to calcine antimony. He takes a certain quantity of it, weights it, and places it in the fashion of a cone on a slab of marble, then having a burning mirror, he opposes it to the Sun, and directs the pyramidal point of the reflected rays on the point of the cone of antimony, which straightway fumes abundantly, and in a little while, what the rays have touched is converted into a very white calx, which he separates with a knife, and conducts the rays on the remainder till all has become white: and then the calcination is ended. It is remarkable thing (he adds) that although in this calcination the antimony has lost much of its substance, by the vapours and fumes which are copiously exhaled, yet its weight augments instead of diminishing. Now if we seek the cause of this augmentation: will Cardan say that it is the vanishing of the celestial heat? It is even infused into it more largely by the solar beams. Will Scaliger say that it is the consumption of the aerated particles? But on being broken up into calx and increasing in volume, more of these are thrust into it. Will Caesalpinus allege soot? There is no fire to produce any. Would the vessel furnish something on its part? The rays are conducted so dextrously on the substance that they do not touch the marble. Will anyone suggest the vapours of charcoal? None is used in this affair. As to the volatile salts which have been so ingeniously brought forward, they here lose their savour and their charm. Peradventure someone will put humidity to the fore, as has quite lately been done. But whence would it come? from the marble? nay nay, that is not imaginable. From the air? still less, for this operation should succeed best in the hottest days of Summer, in the most violent ardours of the Dog-days, when everything below is so heated, that even in the shade and in the night-time the air dries soaked linen, and parches the moist earth. And, during the day, where the Sun strikes, he burns our complexions, withers the grass, scorches fruits, dessicates wood.

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