SCOPE, SEQUENCE, and COORDINATION

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SCOPE, SEQUENCE, and COORDINATION

Student Materials

Learning Sequence Item:

931

Physical vs. Chemical Change

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Adapted by George Miller

Contents

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Science as Inquiry

What You See Is What You Record

Overview:

In this activity you will observe and describe a *system* including a candle. You will make changes in that system and continue observations.

Science makes clear distinctions between observations and inferences, and so must you. For example, it is an observation that a clear substance in a tube transmits light readily, it is an inference that it is a liquid. When you try to transfer it, or place a rod in it, you may have more information that enables you to conclude whether it is a solid or a liquid.

Procedure:

Observe an unlit candle using both qualitative observations and quantitative measurements. Record all the observations in an organized manner, so someone else could easily reproduce your observations. Include labeled drawings or diagrams.

Light the candle, let a few drops of wax fall onto the can lid, and place the base of the candle on the molten wax drops. This will form a firm base for the lighted candle as the wax sets hard. This is the “candle system." Make additional observations and record these. When finished, compare your records to those in Reading 1, Michael Faraday’s 100 observations of a burning candle. Why do you think these differ from yours?

Blow out the candle (carefully, beware of flying hot wax!) and determine the mass of the system. Light the candle again and allow it to burn for three minutes. Blow it out and determine the mass again. Do this until you have obtained five massings. Prepare a table and graphs of your data to show how the mass of a burning candle changes with how long it burns. The graphs (see below) should have properly drawn and labeled axes, and include ***all*** of your data points.

Prepare two graphs:

a) As if you were trying to sell long lasting candles so that someone looking at the graph will conclude that the mass changes very little as it burns.

b) As if you were trying to show how quickly the mass of the candle was changing, so the person looking at the graph will conclude this is very fast.

Questions:

1. Does the candle mass change? If so, in which direction?

2. Can you draw a straight line through the data points? What does this mean if you can or cannot? Describe the change shown by the graph in words.

3. What is the average mass change in grams per minute of burning? Explain how you calculated this.

4. Predict the mass of the candle if it burned for (a) 20 minutes and (b) 30 minutes. Explain how you estimated this.

5. How long will it take for a new candle the same size as yours to change mass by 10.0 g? Explain how you make this estimate.

Student Sheet

Science as Inquiry

Now You See It, Now You Don't

Overview:

In this activity you will set up a series of small groups of materials, each called a *system*. You will observe and describe each of your systems. You are asked to make changes in that system and to continue observations. Record your observations and descriptions in writing and prepare a report to your classmates on your findings.

Science makes clear distinctions between observations and inferences, and so must you. For example, it is an observation that a clear substance in a tube transmits light readily, it is an inference that it is a liquid. When you try to transfer it, or place a rod in it, you may have more information that enables you to conclude whether it is a solid or a liquid.

Procedure:

Obtain your assigned system(s) from the teacher, and follow the directions provided. Be sure to follow good safety practices with all systems in the science classroom.

For ***each*** system your group is assigned to observe:

1. Make both qualitative (visual) and quantitative (measuring) observations. You will be deciding which observations can be made on which system.

2. Describe in writing the system at the start, during change, and at the end, based on your observations.

3. Conclude whether or not your system is undergoing physical or chemical change or both, and state the evidence on which this conclusion is based.

4. List physical and chemical properties of each substance involved. Clearly indicate the evidence on which your statements of these properties are based.

5. Answer any other questions on the individual system procedure card/sheet.

Student Sheet

Science as Inquiry

What Can Be Put Together Can Be Pulled Apart

Procedure:

1. Synthesis

Put small samples (about 0.25 g) of zinc powder and iodine powder onto clean watch glasses. Record measurements and observations of the properties of the two substances. Mix the two by stirring together with the glass rod. Record observations. Place the watch glass on a white paper in a well ventilated area. Add about 1 mL of water from a dropper, one drop at a time. Record observations. When all the water has been added, stir the mixture again. Record observations.

Pour the mixture into the filter paper, folded correctly in the funnel. Catch the filtrate (the liquid that comes from the funnel) in a clean beaker. Record observations. Discard the filter paper and its contents into the approved waste container. Carefully pour the filtrate onto a clean, previously massed watch glass. Place this in a clean area where the water can evaporate. If your lab has a heat lamp, this can be used to speed up the process. Observe the material left after the water evaporates. Record observations and mass measurements. Note whether the material is different from the starting substances, zinc and iodine.

2. Decomposition.

Use the dropper to add small amounts of water to the white residue formed in the procedure above. Stir with a glass rod to dissolve completely. Attach short copper wires to two alligator clips, connecting wires and battery clips as shown in Figures 1 and 2.

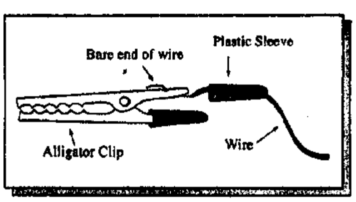

FIGURE 1

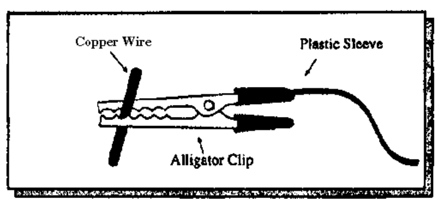

FIGURE 2

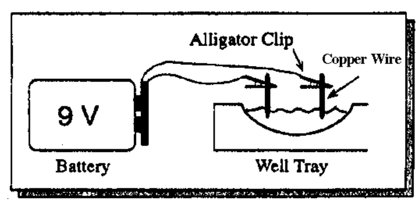

FIGURE 3

Place the battery behind the well. Hold the wires in the solution on opposite sides of the well as shown in Figure 3. Be sure the rods do not touch each other.

Observe the wires (electrodes) for a few minutes and note any changes that occur.

Questions:

1. At the end of the synthesis, is all the mass that you started out with present? If not, why not?

2. Can you identify any physical changes taking place in the entire experiment? Which steps, and why?

3. Can you identify chemical changes? Which steps, and what is your evidence?

4. Show ways in which you could prove that the final products on the copper wires are the same as the original zinc and iodine.

5. Suggest other examples from your experience, where substances or objects are supposed to come back to their original state but somehow do not quite look quite the same as when they started. Are the changes involved physical or chemical? Why?

Student Sheet

Science as Inquiry

Is it Physical or Chemical?

Overview:

Physical and chemical changes are generally distinguished by several characteristics, including color changes, evolution or absorption of heat (or other form of energy), evolution of gases, appearance or disappearance of matter, or difficulty in reversing a change.

Many physical changes exhibit at least one of these characteristics, and most chemical changes exhibit more than one of these characteristics. In this activity, you will examine a system and decide whether the change is physical or chemical or both based on its characteristics.

Procedure:

Obtain your assigned system from the teacher. Individually, or with your group, think about the change that is occurring. Write notes so you can answer the following questions when called upon.

Questions:

1. Is the change a single step or more than one step? If more than one, describe each step.
2. For each step, is it a physical or chemical change?
3. On what evidence is your answer to (2) based?
4. What tests can you propose to confirm your answers to (2) and (3)?

Student Sheet

Science as Inquiry

The Cannon and Friends

Procedure:

Demonstrations will be done in class. Make careful observations and notes. Identify all the changes that take place in each demonstration and prepare an argument based on evidence as to whether the change is chemical or physical.

Student Sheet

Science as Inquiry

Writing with Color

Overview:

In this activity you will use chemical solutions to draw or write on various writing surfaces and compare the effects.

Procedure:

Make careful observations and notes as you carry out each of the below exercises, identify all the changes that take place in each, and prepare an argument based on evidence as to whether the change is chemical or physical. Some changes involve complex chemistry that you will learn to explain much later, but you may be able to explain others. Use only a damp swabstick to write or draw with solutions. Do not make the swabstick too wet and be sure to use a clean one each time.

1. Write a message on white paper using phenolphthalein solution. Allow to dry. Spray gently with dilute base solution. Do not get too wet.

2. Write a message on goldenrod paper using dilute acid (vinegar). Write another using dilute base solution. Compare. Try other colored papers.

3. Write a message on white paper using cobalt chloride solution. Allow to dry. It should be nearly invisible. Warm the paper with a heat lamp or hair dryer.

4. Write a message on the magic slate using the stylus provided or your finger. Why does the message disappear when you lift the top sheet? Is the message retrievable? Does this mean the change is not reversible? Why or why not?

5. Prepare a writing surface by rubbing a small piece of poster board lightly with ferric chloride crystals. Paint with solutions of potassium thiocyanate, potassium ferrocyanide, or tannic acid.

6. Prepare a writing surface by rubbing a small piece of poster board lightly with a mixture of potassium ferrocyanide crystals and ferric ammonium sulfate crystals. Paint on this with water.

7. Spray a piece of white paper with dilute potassium thiocyanate solution. Allow to dry. Paint on this with a solution of iron chloride or ferric ammonium sulfate.

8. What are the changes occurring when you write “normally” with a crayon or pencil on a white paper? Examine these for types of change just like all the other exercises.

Science as Inquiry

The Good, the Bad, and the Ugly Popcorn

What happens when popcorn pops?

Procedure:

Your group is to determine the following parameters for at least one sample of popcorn:

1. The average mass and volume of unpopped corn.
2. The average mass and volume of popped corn.
3. Evidence for what happens during the popping process. What changes take place? Are they physical or chemical?
4. What is the percentage of unpopped kernels in a batch?
5. What evidence can be gathered as to why certain kernels don't pop?
6. Does the process used for popping affect the results (volume, mass, quality of popped corn)?
7. Are there any manufacturer's claims on the packet that can be tested or checked from the information determined above? Which is the best buy and why?

You will devise your own procedures, but be sure to have the teacher approve them before you carry them out.

Hints:

1. Volumes of cups may be calibrated using water and the measuring cylinder. How can you account for the air included with the popped corn?
2. Be sure to use masses that are well within the range of the balance provided.
3. Make observations at all times, and record the observations for someone else to read.
4. If time permits, carry out each test more than once. How do you handle the situation when the results are not the same?
5. If the kernels in a batch look as if they fall into different types, you may wish to sort them first and handle each type separately.
6. To gain evidence for the changes occurring, pop single kernels in the Erlenmeyer flask over a burner or hot plate (***use caution!***). Stopper the flask with a stopper with one small hole. Use a clamp or

other holder to hold the hot flask. You may need to practice till you get "perfect" popping. The best procedure inverts the flask the moment popping occurs, which prevents burning of the popped corn. Then pop at least five massed kernels, one at a time. Observe the flask closely for evidence of changes. Check mass of the kernels after popping.

7. To test for damaged kernels:

   Place about 10 g of unpopped corn into the cool Erlenmeyer flask. Add 25 mL of iodine test solution (containing iodine and potassium iodide). Swirl well for at least two minutes. Decant the solution from the corn. It can be used again, so place in storage bottle in lab. Rinse kernels with water to remove any remaining test solution. Dry kernels on a paper towel and count the number that have purple color.

Science as Inquiry

The Chemical History of a Candle
Lecture I

A Candle—The Flame—Its Sources—Mobility & Brightness

By Michael Farraday (1791–1867), from a course of six lectures on the chemical history of a candle

I propose to bring before you, in the course of these lectures, the Chemical History of a Candle. There is not a law under which any part of this universe is governed which does not come into play and is touched upon in these phenomena. There is no better, there is no more open door by which you can enter into the study of natural philosophy than by considering the physical phenomena of a candle.

A Candle

Here are a couple of candles commonly called dips. They are made of lengths of cotton cut off, hung up by a loop, dipped into melted tallow, taken out again and cooled, then redipped, until there is an accumulation of tallow round the cotton....The candle I have in my hand is a stearin candle, made of stearin from tallow. Then here is a sperm candle, which comes from the purified oil of the spermaceti whale. Here, also, are yellow bee's-wax, from which candles are made. Here, too, is that curious substance called paraffine, and some paraffine candles, made of paraffine obtained from the bogs of Ireland.

And how are these candles made? I have told you about dips, and I will show you how molds are made. Let us imagine any of these candles to be made of materials which can be cast. “Cast” you say. “Why, a candle is a thing that melts, and surely if you can melt it you can cast it.” Not so. It is wonderful, in the progress of manufacture, and in the consideration of the means best fitted to produce the required result, how things turn up which one would not expect beforehand. Candles can not always be cast. A wax candle can never be cast. It is made by a particular process which I can illustrate in a minute or two, but I must not spend much time on it. Wax is a thing which, burning so well, and melting so easily in a candle, can not be cast. However, let us take a material that can be cast. Here is a frame, with a number of molds fastened to it. The

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Farraday, M., "The Chemical History of a Candle." As reprinted in *Faraday's Chemical History of a Candle.* Chicago: Chicago Review Press, 1988.

first thing to be done is to put a wick through them. Here is one—a plaited wick, which does not require snuffing—supported by a little wire. It goes to the bottom, where it is pegged in; the little peg holding the cotton tight, and stopping the aperture so that nothing fluid shall run out. At the upper part there is a little bar placed across, which stretches the cotton and holds it in the mold. The tallow is then melted, and the molds are filled. After a certain time, when the molds are cool, the excess of tallow is poured off at one corner, and then cleaned off altogether, and the end of the wick cut away. The candles alone then remain in the mold, and you have only to upset them, as I am doing, when out they tumble, for the candles are made in the form of cones, being narrower at the top than at the bottom; so that, what with their form and their own shrinking, they only need a little shaking and out they fall. In the same way are made these candles of stearin and of paraffine. It is a curious thing to see how wax candles are made. A lot of cottons are hung upon frame, as you see here, and covered with metal tags at the ends to keep the wax from covering the cotton in those places. These are carried to a heater, where the wax is melted. As you see, the frames can turn round; and, as they turn, a man takes a vessel of wax and pours it first down one, and then the next, and the next, and so on. When he has gone once round, if it is sufficiently cool, he gives the first a second coat, and so on until they are all of the required thickness. When they have been thus clothed, or fed, or made up to that thickness, they are taken off and placed elsewhere. I have here, by the kindness of Mr. Field, several specimens of these candles. Here is one only half finished. They are then taken down and well rolled upon a fine stone slab, and the conical top is molded by properly shaped tubes, and the bottoms cut off and trimmed. This is done so beautifully that they can make candles in this way weighing exactly four or six to the pound, or any number they please.

We must not, however, take up more time about the mere manufacture, but go a little farther into the matter. I have not yet referred you to luxuries in candles (for there is such a thing as luxury in candles). See how beautifully these are colored; you see here mauve, magenta, and all the chemical colors recently introduced, applied to candles. You observe, also, different forms employed. Here is a fluted pillar most beautifully shaped; and I have also here some candles sent me by Mr. Pearsall, which are ornamented with designs upon them, so that, as they burn, they have, as it were, a glowing sun above, and a bouquet of flowers beneath. All, however, that is fine and beautiful is not useful. These fluted candles, pretty as they are, are bad candles; they are bad because of their external shape. Nevertheless, I show you these specimens, sent to me from kind friends on all sides, that you may see what is done and what may be done in this or that direction; although, as I have said, when we come to these refinements, we are obliged to sacrifice a little in utility.

Sources of the Flame

Now as to the light of the candle. We will light one or two, and set them at work in the performance of their proper functions. You observe a candle is a very different thing from a lamp. With a lamp you take a little oil, fill your vessel, put in a little moss or some cotton prepared by artificial means, and then light the top of the wick. When the flame goes down the cotton to the oil, it gets extinguished, but it goes on burning in the part above. Now I have no doubt you will ask how is it that the oil which will not burn of itself gets up to the top of the cotton, where it will burn. We shall presently examine that; but there is a much more wonderful thing about the burning of a candle than this. You have here a solid substance with no vessel to contain it, and how is it that this solid substance can get up to the place where the flame is? How is it that this solid gets there, it not being a fluid? Or, when it is made a fluid, then how is it that it keeps together? This is a wonderful thing about a candle.

We have here a good deal of wind, which will help us in some of our illustrations, but tease us in others; for the sake, therefore, of a little regularity, and to simplify the matter, I shall make a quiet flame, for who can study a subject when there are difficulties in the way not belonging to it? Here is a clever invention of some costermonger or street-stander in the market-place for the shading of their candles on Saturday night, when they are selling their greens, or potatoes, or fish. I have very often admired it. They put a lamp-glass round the candle, supported on a kind of gallery, which clasps it, and it can be slipped up and down as required. By the use of this lamp-glass, employed in the same way, you have a steady flame, which you can look at, and carefully examine, as I hope you will do, at home.

You see then, in the first instance, that a beautiful cup is formed. As the air comes to the candle, it moves upward by the force of the current which the heat of the candle produces, and it so cools all the sides of the wax, tallow, or fuel as to keep the edge much cooler than the part within; the part within melts by the flame that runs down the wick as far as it can go before it is extinguished, but the part on the outside does not melt. If I made a current in one direction, my cup would be lop-sided, and the fluid would consequently run over; for the same force of gravity which holds worlds together holds this fluid in a horizontal position, and if the cup be not horizontal, of course the fluid will run away in guttering. You see, therefore, that the cup is formed by this beautifully regular ascending current of air playing upon all sides, which keeps the exterior of the candle cool. No fuel would serve for a candle which has not the property of giving this cup, except such fuel as the Irish boggwood, where the material itself is like a sponge and holds its own fuel. You see now why these beautiful candles that I have shown you, which are irregular, intermittent in their shape, and can not, therefore, have that nicely-formed edge to the cup which is the great beauty in a candle. I hope you will see that the perfection of a process— that is, its utility— is the better point of beauty about it. It is not the best looking thing, but the best acting thing, which is the most advantageous to us. This good-looking candle is a bad burning one. There will be a guttering round about it because of the irregularity of the stream of air and the badness of the cup which is formed thereby. You may see some pretty examples (and I trust you will notice these instances) of the action of the ascending current when you have a little gutter run down the side of a candle, making it thicker there than it is elsewhere. As the candle goes on burning, that keeps its place and forms a little pillar sticking up by the side, because as it rises higher about the rest of the wax or fuel, the air gets better round it, and it is more cooled and better able to resist the action of the heat at a little distance. Now the greatest mistakes and faults with regard to candles, as in many other things, often bring with them instruction which we should not receive if they had not occurred. We come here to be philosophers, and I hope you will always remember that whenever a result happens, especially if it be new, you should say, “What is the cause? Why does it occur?” and you will, in the course of time, find out the reason.

Then there is another point about these candles which will answer a question - that is, as to the way in which this fluid gets out of the cup, up the wick, and into the place of combustion. You know that the flames on these burning wicks in candles made of bees’-wax, stearin, or spermaceti, do not run down to the wax or other matter, and melt it all away, but keep to their own right place. They are fenced off from the fluid below, and do not encroach on the cup at the sides. I can not imagine a more beautiful example than the condition of adjustment under which a candle makes one part subserve to the other to the very end of its action. A combustible thing like that, burning away gradually, never being intruded upon by the flame, is a very beautiful sight, especially when you come to learn what a vigorous thing flame is—what power it has of destroying the wax itself when it gets hold of it, and of disturbing its proper form if it come only too near.

But how does the flame get hold of the fuel? There is a beautiful point about that—*capillary attraction.* “*C*apillary attraction!” you say—”the attraction of hairs.” Well, never mind the name; It was given in old times before we had a good understanding of what the real power was. It is by what is called capillary attraction that the fuel is conveyed to the part where combustion goes on, and is deposited there, not in a careless way, but very beautifully in the very midst of the center of action, which takes place around it. Now I am going to give you one or two instances of capillary attraction. It is that kind of action or attraction which makes two things that do not dissolve in each other still hold together. When you wash your hands, you wet them thoroughly; you take a little soap to make the adhesion better, and you find your hands remain wet. This is by that kind of attraction of which I am about to speak. And, what is more, if your hands are not soiled (as they almost always are by the usages of life), if you put your finger into a little warm water, the water will creep a little way up the finger, though you may not stop to examine it. I have here a substance which is rather porous—a column of salt—and I will pour into the plate at the bottom, not water, as it appears, but a saturated solution of salt which can not absorb more, so that the action which you see will not be due to its dissolving any thing. We may consider the plate to be the candle, and the salt the wick, and this solution the melted tallow. (I have colored the fluid, that you may see the action better). You observe that, now. I pour in the fluid, it rises and gradually creeps up the salt higher and higher; and provided the column does not tumble over, it will go to the top If this blue solution were combustible, and we were to place a wick at the top of the salt, it would burn as it entered into the wick. It is a most curious thing to see this kind of action taking place, and to observe how singular some of the circumstances are about it. When you wash your hands, you take a towel to wipe off the water; and it is by that kind of wetting, or that kind of attraction which make the towel become wet with water, that the wick is made wet with the tallow. I have known some careless boys and girls (indeed, I have known it happen to careful people as well) who, having washed their hands and wiped them with a towel, have thrown the towel over the side of the basin, and before long it has drawn all the water out of the basin and conveyed it to the floor, because it happened to be thrown over the side in such a way as to serve the purpose of a siphon. That you may the better see the way in which the substances act one upon another, I have here a vessel made of wire gauze filled with water, and you may compare it in its action to the cotton in one respect, or to a piece of calico on the other. In fact, wicks are sometimes made of a kind of wire gauze. You will observe that this vessel is a porous thing; for if I pour a little water on to the top, it will run out at the bottom. You would be puzzled for a good while if I asked you what the state of this vessel is, what is inside it, and why it is there? The vessel is full of water, and yet you see the water goes in and runs out as if it were empty. In order to prove this to you I have on to empty it. The reason is this: the wire, being once wetted, remains wet; the meshes are so small that the fluid is attracted so strongly from the one side to the other as to remain in the vessel, although it is porous. In like manner, the particles of melted tallow ascend the cotton and get to the top; other particles then follow by their mutual attraction for each other, and as they reach the flame they are gradually burned.

Here is another application of the same principle. You see this bit of cane. If I place this piece of cane on a plate containing some camphene (which is very much like paraffine in its general character), exactly in the same manner as the blue fluid rose through the salt will this fluid rise through the piece of cane. There being no pores at the side, the fluid can not go in that direction, but must pass through its length. Already the fluid is at the top of the cane; now I can light it and make it serve as a candle. The fluid has risen by the capillary attraction of the piece of cane, just as it does through the cotton in the candle.

Now the only reason why the candle does not burn all down the side of the wick is that the melted tallow extinguishes the flame. You know that a candle, if turned upside down, so as to allow the fuel to run upon the wick, will be put out. The reason is, that the flame has not had time to make the fuel hot enough to burn, as it does above, where it is carried in small quantities into the wick; and has all the effect of the heat exercised upon it.

There is another condition on which you must learn as regards the candle, without which you would not be able fully to understand the philosophy of it, and that is the vaporous condition of the fuel. In order that you may understand that let me show you a very pretty but very commonplace experiment. If you blow a candle out cleverly, you will see the vapor rise from it. You have, I know, often smelt the vapor of a blown-out candle, and a very bad smell it is; but if you blow it out cleverly you will be able to see pretty well the vapor into which this solid matter is transformed. I will blow out one of these candles in such a way as not to disturb the air around it by the continuing action of my breath; and now, if I hold a lighter taper two or three inches from the wick, you will observe a train of fire going through the air till it reaches the candle. I am obliged to be quick and ready, because if allow the vapor time to cool, it becomes condensed into a liquid or solid, or the stream of combustible matter gets disturbed.

Structure of the Flame

Let us look a little at the form of the flame as you see it under the glass shade. It is steady and equal, and its general form is that which is represented in the diagram, varying with atmospheric disturbances, and also varying according to the size of the candle. It is a bright oblong, brighter at the top than toward the bottom, with the wick in the middle, and besides the wick in the middle, certain darker parts towards the bottom, where the ignition is not so perfect as in the part above. There is a current formed, which draws the flame out; for the flame which you see is really drawn out by the current, and drawn upward to a great height . . . by that prolongation of the current in the diagram. You may see this by taking a lighted candle, and putting it in the sun so as to get its shadow thrown on a piece of paper. How remarkable it is that that thing which is light enough to produce shadows of other objects can be made to throw its own shadow on a piece of white paper or card, so that you can actually see streaming round the flame something which is not part of the flame, but is ascending and drawing the flame upward. Now I am going to imitate the sunlight by applying the voltaic battery to the electric lamp. You now see our sun and its great luminosity; and by placing a candle between it and the screen, we get the shadow of the flame. You observe the shadow of the candle and of the wick; then there is a darkish part, as represented in the diagram, and then a part which is more distinct. Curiously enough, however, what we see in the shadow as the darkest part of the flame is, in reality, the brightest part; and here you see streaming upward the ascending current of hot air which draws out the flame, supplies it with air, and cools the sides of the cup of melted fuel.

I can give you here a little farther illustration, for the purpose of showing you how flame goes up or down according to the current. I have here a flame—it is not a candle flame—but you can, no doubt, by this time generalize enough to be able to compare one thing with another: what I am about to do is to change the ascending current that takes the flame upward into a descending current. This I can easily do by the little apparatus you see before me. The flame, as I have said, is not a candle flame, but it is produced by alcohol, so that it shall not smoke too much. I will also color the flame with another substance, so that you may trace its course; for, with the spirit alone, you could hardly see well enough to have the opportunity of tracing its direction. By lighting this spirit of wine we have then a flame produced, and you observe that when held in the air it naturally goes upward. You understand now, easily enough, why flames go up under ordinary circumstances: it is because of the draft of air by which the combustion is formed. But now, by blowing the flame down, you see I am enabled to make it go downward into this little chimney, the direction of the current being changed. Before we have concluded this course of lectures we shall show you a lamp in which the flame goes up and the smoke goes down, or the flame goes down and the smoke goes up. You see, then, that we have the power in this way of varying the flame in different directions.

The Mobility and Brightness of the Flame

There are now some other points that I must bring before you. Many of the flames you see here vary very much in their shape by the currents of air blowing around them in different directions; but we can, if we like, make flames so that they will look like fixtures, and we can photograph them— indeed, we have to photograph them- so that they become fixed to us, if we wish to find out every thing concerning them. That, however, is not the only thing I wish to mention. If I take a flame sufficiently large, it does not keep that homogeneous, that uniform condition of shape, but it breaks out with a power of life which is quite wonderful. I am about to use another kind of fuel, but one which is truly and fairly a representative of the wax or tallow of a candle. I have here a large ball of cotton, which will serve as a wick. And, now that I have immersed it in spirit and applied a light to it, in what way does it differ from an ordinary candle? Why, it differs very much in one respect, that we have a vivacity and power about it, a beauty and a life entirely different from the light presented by a candle. You see those fine tongues of flame rising up. You have the same general disposition of the mass of the flame from below upward, but, in addition to that, you have this remarkable breaking out into tongues which you do not perceive in the case of a candle. Now, why is this? I must explain it to you, because, when you understand that perfectly, you will be able to follow me better in what I have to say hereafter. I suppose some here will have made for themselves the experiment I am going to show you. Am I right in supposing that any body here has played at snapdragon. I do not know a more beautiful illustration of the philosophy of flame, as to a certain part of its history, than the game of snapdragon. First, here is the dish; and let me say, that when you play snapdragon properly you ought to have the dish well warmed; you ought also to have warm plums and warm brandy, which however, I have not got. When you have put the spirit into the dish, you have the cup and the fuel; and are not the raisins acting like the wicks? I now throw the plum into the dish, light the spirit, and you see those beautiful tongues of flame that I refer to. You have the air creeping in over the edge of the dish forming these tongues Why? Because, through the force of the current and the irregularity of the action of the flame, it can not flow in one uniform stream. The air flows in so irregularly that you have what would otherwise be a single image broken up into a variety of forms, and each of these little tongues has an independent existence of its own. Indeed, I might say, you have here a multitude of independent candles.

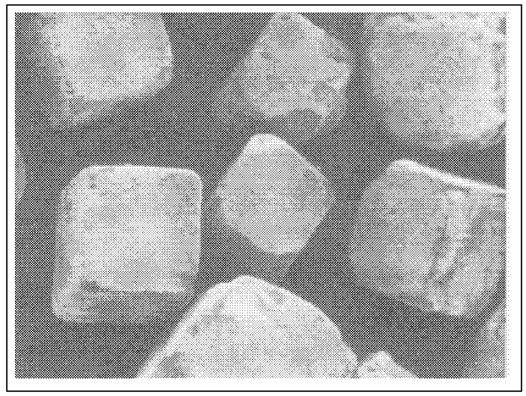
You must not imagine, because you see these tongues all at once, that the flame is of this particular shape.

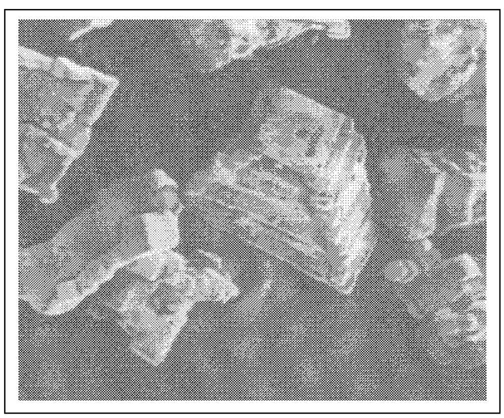
A flame of that shape is never so at any one time. Never is a body of flame, like that which you just saw rising from the ball, of the shape it appears to you. It consists of a multitude of different shapes, succeeding each other so fast that the eye is only able to take cognizance of them all at once. In former times I purposely analyzed a flame of that general character, and the diagram shows you the different parts of which it is composed. They do not occur all at once; it is only because we see these shapes in such rapid succession that they seem to us to exist all at one time.

Science in Personal
and Social Perspectives

Salt

When I was in the grocery store recently I noticed, alongside the table salt, several salt substitutes. I wondered, “What are these products? Should I be using something called Lite Salt™ instead of ordinary salt?” I did a little investigating and here’s what I found out. Common salt, sodium chloride, NaCI, contains equal numbers of positively charged sodium ions, Na+, and negatively charged chloride ions, Cl-. These ions are needed to regulate your body fluids and help maintain your blood volume. They also play a part in the contraction of your muscles and help your nerves function. If you have a 70-kilogram body (154 pounds) it contains approximately 250 grams of sodium chloride.





Both types of salt contain only sodium chloride, NaCl, but their crystal structures look very different when magnified 66 times by a scanning electron microscope.The top figure shows common table salt, which has cubic crystals. The figure to the left shows flake salt, found in the brand Salt Sense. Flake salt has hollow pyramid-shaped cyrstals taht give the product lower density. Flake salt tends to cling to some foods bettter than cubic salt crystals, and some say that flake crystals taste saltier because they expose a learger surface area of NaCl to the taste buds of your tongue.

You lose about three grams a day in urine, sweat, and feces, and need to replace what you lose. This is easy because there’s plenty of sodium in the food we eat. But we like the taste of salty foods so much that most of us eat more salt than we need, adding it during cooking or sprinkling it on at the table.

Shake it on

You probably eat 8 to 10 grams of salt daily. When you’re fit and healthy this doesn’t matter. “The person with normal kidney and heart function and satisfactory blood pressure does not need to restrict salt intake because the kidneys regulate salt and body fluid,” says cardiologist Charles Schulman, M.D., assistant clinical professor of medicine

By Trevor Smith. Reprinted with permission from *Chem Matters*, December 1992, pp. 4–6.

at Harvard Medical School. "If you eat salty foods and drink lots of liquids, you will pass larger quantities of water and salt," he explains.

Several factors affect blood pressure. Though it has *not* been shown that salt makes blood pressure rise, it appears that some people with high pressure can lower it by eating less salt. Because doctors can't predict which of us will develop problems from eating too much salt, the National Research Council of the National Academy of Sciences recommends a limit of 6 grams a day. Grocery stores sell salt substitutes—products that taste salty but contain less or no sodium—for people who wish to lower their sodium intake.

Salt Switch

To a chemist, the term "salt" indicates a category of chemicals. The compound we commonly call salt, sodium chloride, is just one of thousands of salts. Sodium chloride is the one that we say tastes salty, but many others have some degree of salty taste. Unfortunately they have some bitterness in their taste, too.

One way to counter the bitterness of some salt substitutes (remembering "a spoonful of sugar helps the medicine go down") is to mask it with sweetness. More often, acid compounds, which taste sour, are used to mask bitter tones.

The nonsodium salt that comes closest to ideal is lithium chloride but, because it has serious side effects, it cannot be used in food. Potassium chloride is the clear choice as a salt substitute because it tastes quite salty and has no side effects. Unfortunately, potassium chloride has a bitter, metallic aftertaste. Take a look at the contents of some salt substitutes to see what is added to mask the undesirable aftertaste:

• Morton Lite Salt™, "with half the sodium of table salt," contains sodium chloride, potassium chloride, magnesium carbonate, and dextrose (a form of glucose sugar).

• Morton Salt Substitute™ contains potassium chloride with fumaric acid and monocalcium phosphate.

• Nu-Salt™ contains potassium chloride with potassium tartrate and "flavor derived from food yeast" as taste modifiers.

Salt Sources

Rock salt, which is also known by its mineral name halite, is mined from underground deposits. It is blasted, crushed, screened, then hoisted to the surface for shipment. Relatively impure, it is not used in food but is sold for de-icing roads, cooling ice cream makers, and softening water.

Solar salt is produced from a solution of saltwater, or brine. The brine may come from the sea, a saline lake such as Great Salt Lake, Utah, or an underground deposit, and is pumped into large shallow pans where the sun and wind evaporate the water. This can take as long as a year, depending on the sun, wind, and rainfall. Heavy equipment, such as front-end loaders, is used to scoop up the salt and move it to a processing plant. Solar salt is not considered food grade because it is exposed to heavy equipment, dust, bird droppings, etc.

Evaporated salt is typically produced by pumping fresh water into an underground deposit where the water dissolves the salt but leaves most of the impurities below, then pumping it back to the surface as a saturated solution. The brine enters a large vat which is heated by steam to evaporate the water. The evaporated water (steam) is used to heat a second vat of brine that operates at a lower pressure. Most of the heat energy is recycled in a series of evaporating vats. Finally, the

• No Sal™ contains potassium chloride with potassium tartrate, adipic acid, and fumaric acid.

• Adoph's Salt Substitute™ contains potassium chloride and tartaric acid.

Fluffy Salt

One of the products in the grocery store caught me by surprise. On the front, the label of Salt Sense™ boasted that it contained "33% less sodium." But on the back, the label said NO SALT SUBSTITUTES—ALL NATURAL FLAVOR. A close reading of the ingredient list indicated that it contained more than 99% sodium chloride. How, I wondered, could something that is practically 100% salt contain 33% less sodium than regular salt? It made no sense—until I read the label more closely.

Salt Sense contains "33% less sodium per teaspoon." Had the manufacturer found a way to make a teaspoon of salt contain less salt? A call to the Akzo Salt Corporation revealed that this was the case. Salt Sense is flake salt, which has a lower bulk density than regular cubic table salt. The manufacturers even claimed that Salt Sense tastes more salty than common rock salt (because the flake shape exposes a larger area of salt to your taste buds) but I haven't confirmed that. By this time I had learned more about salt than I ever learned in school. And what I had learned led me to some questions:

Q. Should you use a salt substitute instead of ordinary salt?
A. Only if your doctor tells you to. For most of us, a normal intake of sodium chloride is fine, and not a health problem.

Q. Is it possible to make salt with less salt than regular salt?
A. Yes . . . and no. See the box *Salt Sources.*

Q. Do salt substitutes really taste as good as table salt?
A. You can answer this for yourself in a taste test. See the *Chem Matters Classroom Guide.*

Salt Sources *cont.*

crystals are filtered from the brine, dried, and screened. The result is the familiar cubic crystals of table salt.

Flake salt is a special variety of evaporated salt made by the Alberger process in which brine is heated to nearly 150 °C under pressure to keep it from boiling. Then, in a series of closed vessels called flashers, the pressure is released, water evaporates, and the brine cools to 108 °C. When the brine passes from the last flasher to an open evaporation pan, tiny crystals form at the surface and are held up by surface tension. As a crystal grows heavier it sinks a little, then continues to grow to the surface, following the edges of the first crystal. When it sinks again, new edges grow, eventually forming a series of hollow rectangles. This form of evaporated salt is called **hopper salt.** When hopper salt is stressed the rectangles break, giving flake salt.

With a hand lens or microscope you can readily see the difference between the flake salt in Salt Sense and the granulated crystals in ordinary table salt. The different shapes also make them cling to surfaces differently. Sprinkle a small amount of each salt on a piece of notebook paper (it may be easier to see on black construction paper). Raise one end of the paper until the crystals move downhill. The granulated salt tumbles to the bottom whereas the flakes hug the surface and move reluctantly. This is why flake salt is used on foods such as pretzels and crackers; it sticks to the food during processing.