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**February 2015 Teacher's Guide for**

***ChemDemos Demystified***

**Table of Contents**

[About the Guide 2](#_Toc410166912)

[Student Questions 3](#_Toc410166913)

[Answers to Student Questions 4](#_Toc410166914)

[Anticipation Guide 6](#_Toc410166915)

[Reading Strategies 7](#_Toc410166916)

[Background Information 9](#_Toc410166917)

[Relative strength of forces 18](#_Toc410166918)

[Connections to Chemistry Concepts 20](#_Toc410166919)

[Possible Student Misconceptions 21](#_Toc410166920)

[Anticipating Student Questions 21](#_Toc410166921)

[In-Class Activities 22](#_Toc410166922)

[Out-of-class Activities and Projects 25](#_Toc410166923)

[References 26](#_Toc410166924)

[Web Sites for Additional Information 27](#_Toc410166925)

[General Web References 32](#_Toc410166926)

# About the Guide

Teacher’s Guide editors William Bleam, Regis Goode, Donald McKinney, Barbara Sitzman and Ronald Tempest created the Teacher’s Guide article material. E-mail: [bbleam@verizon.net](mailto:bbleam@verizon.net)

Susan Cooper prepared the anticipation and reading guides.

Patrice Pages, *ChemMatters* editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide. E-mail: [chemmatters@acs.org](mailto:chemmatters@acs.org)

Articles from past issues of *ChemMatters* can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013.

The *ChemMatters* DVD also includes Article, Title and Keyword Indexes that covers all issues from February 1983 to April 2013.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558.

Purchase information can be found online at [www.acs.org/chemmatters](http://chemistry.org/chemmatters/cd3.html).

# Student Questions

The burning candle

* 1. List three observations made in the burning candle demonstration when the beaker is placed over the burning candle.
  2. What is the formula for paraffin wax?
  3. Describe the change in moles of gaseous reactants and products as the burning of paraffin proceeds.
  4. Explain in your own words why the water level inside the beaker rises.
  5. What role does air pressure play in your explanation?

The deflected stream of water

* 1. Describe what happens when a stream of water is brought close to a charged rod or balloon.
  2. In the water molecule, why is oxygen negative and hydrogen positive?

Faulty demonstration of the greenhouse effect

* 1. What happens in this greenhouse effect demonstration after the heat lamp is turned on, but before the carbon dioxide is added?
  2. What happens after the carbon dioxide is added?
  3. Why is this NOT a good demonstration of the greenhouse effect?

# Answers to Student Questions

The burning candle

* 1. **List three observations made in the burning candle demonstration when the beaker is placed over the burning candle.** *Observations made when the beaker is placed over the burning candle:*

1. *The flame grows smaller,*
2. *The flame goes out,*
3. *A smoke trail appears, and*
4. *The water level inside the beaker rises.*
   1. **What is the formula for paraffin wax?** *The formula for paraffin wax is C25H52.*
   2. **Describe the change in moles of gaseous reactants and products as the burning of paraffin proceeds.** *The reaction begins with one mole of wax (solid) and 38 moles of oxygen gas. As the reaction proceeds, the wax and oxygen are consumed and 25 moles of carbon dioxide and 26 moles of water vapor are produced. Some of the carbon dioxide is dissolved in the water, and (almost) all of the water vapor condenses into liquid water.*
   3. **Explain in your own words why the water level inside the beaker rises.** *Answers to “why the water level inside the beaker rises” may vary, but these ideas should be part of a good explanation:*
      1. Although more gas is produced than is consumed, some oxygen is consumed, some of the CO2 produced dissolves and most of the water vapor produced condenses, leaving less gas in the beaker after the reaction than before the reaction, and
      2. The temperature of the gases inside the beaker decreases after the candle goes out, and with lower temperature comes lower pressure, so the gas pressure inside the beaker is less than air pressure outside the beaker. This causes the outside atmosphere to push the water up into the beaker, decreasing the volume of gas inside the beaker until the air pressure outside and the gas pressure inside the beaker are equal.
   4. **What role does air pressure play in your explanation?** A greater a*ir pressure outside the beaker than the gas pressure inside the beaker is the cause of the water level rise.*

The deflected stream of water

* 1. **Describe what happens when a charged rod or balloon is brought close to a stream of water.** “*As the balloon or glass rod moves close, the stream of water deflects toward it at a dramatic angle.”*
  2. **In the water molecule, why is oxygen negative and hydrogen positive?** *In the water molecule, oxygen is negative and hydrogen is positive because oxygen atoms, being more electronegative, pull electrons away from the less electronegative hydrogen atoms in each oxygen-hydrogen bond.*

Faulty demonstration of the greenhouse effect

* 1. **What happens in this greenhouse effect demonstration after the heat lamp is turned on, but before the carbon dioxide is added?** *In this greenhouse demonstration, after the heat lamp is turned on, the rocks inside the beaker get warmer.*
  2. **What happens after the carbon dioxide is added?** *After carbon dioxide is added, the temperature in that beaker increases by 1–2 oF within 5–15 seconds.*
  3. **Why is this NOT a good demonstration of the greenhouse effect?** *This is a faulty demonstration of the greenhouse effect because the greenhouse effect is based on the fact that carbon dioxide absorbs infrared radiation and re-emits it into the atmosphere. In this demonstration, the carbon dioxide merely sits on the bottom of the beaker, trapping the heat (infrared radiation) of the rocks inside the beaker, not allowing it to escape into the air around it. In the other beaker, the air inside circulates with outside air, allowing heat to flow out of that beaker.*

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Sometimes the explanation for demonstrations found in textbooks is incorrect. |
|  |  | 1. The air you breathe contains about 40% oxygen. |
|  |  | 1. Paraffin wax used in most candles is a carbohydrate. |
|  |  | 1. A burning candle produces more moles of gaseous products than the gaseous reactants that are consumed. |
|  |  | 1. A glass rod can become electrically charged when rubbed with silk cloth. |
|  |  | 1. Opposite charges repel. |
|  |  | 1. Tap water is electrically neutral, with an equal number of positive and negative charges. |
|  |  | 1. Water vapor and carbon dioxide contribute to the greenhouse effect. |
|  |  | 1. Carbon dioxide absorbs infrared radiation. |
|  |  | 1. Carbon dioxide is less dense than air. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading and writing strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies:***

1. Links to **Common Core Standards for Reading**:\
   1. ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
   2. ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
2. Links to **Common Core Standards for Writing**:
   1. ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
   2. ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
3. **Vocabulary** and **concepts** that are reinforced in this issue:
   1. Skepticism
   2. Amino acid
   3. Protein
   4. Enzyme
   5. Organic molecular structures
   6. Polymer
4. To help students engage with the text, ask students which article engaged them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teacher’s Guide has suggestions for further research.

**Directions**: As you read, complete the graphic organizer below to explain the phenomena described in the article.

|  |  |  |  |
| --- | --- | --- | --- |
| **Phenomenon** | **Observations** | **Incorrect explanation** | **Correct explanation, with evidence** |
| **Burning candle** |  |  |  |
| **Deflected stream of water** |  |  |  |
| **Greenhouse effect demonstration** |  |  |  |

# Background Information

**(teacher information)**

**More on why teachers do demonstrations**

Here are a few quotes about the use of demonstrations by famous chemistry educators:

*“To approach demonstrations simply as chances to show off dramatic chemical changes or only to impress students with the ‘magic’ of chemistry is to fail to appreciate the opportunity they provide to teach scientific concepts and descriptive properties of chemical systems… In planning a lecture demonstration, I always begin by analyzing the reasons for presenting it.”*

~ Bassam Shakhashiri (1984)

(excerpted from “Using lecture demonstrations to promote the refinement of concepts: the case of teaching solvent miscibility”, <http://www.rsc.org/images/Ashkenazi%20paper1%20final_tcm18-85041.pdf>).

*“I still recall the very first time I ever saw a chemical demonstration on the overhead projector. It was more than 25 years ago, and the demonstrator was Clark Bricker from the University of Kansas. He added a few drops of ammonia to a solution containing ferric ions. The beauty, simplicity, and clear visibility of that demonstration impressed me so much that I have been doing demonstrations … ever since.”*

~ Doris Kolb

(excerpted from “The purpose of chemical demonstrations”, <http://www.nvon.nl/sites/nvon.dev.com/files/lesmateriaal/showdechemie1/A1_6_Childs_waarom%20demoproeven.pdf>)

*“The joy of chemical experimentation has been well recognized, at least from the early days of alchemy, and our appreciation of chemical charm probably dates back to the prehistoric discovery of ways to make and control fire.*

*Therefore, it seems useful to coin the term* ***exocharmic*** *reaction (from the Greek exo-, turning out) and, particularly in our role as chemistry teachers, to seek and share techniques for liberating as much charm as possible from the chemical changes our students see in the laboratory and classroom demonstrations.”*   
 ~ Richard Ramette

(excerpted from the introduction to Volume 1 of Bassam Shakhashiri's *Chemical Demonstrations: A Handbook for Teachers of Chemistry*)

**More on the history of the candle demonstration**

Michael Faraday is credited with doing the first large-scale demonstration(s) involving the burning of a candle. In 1848 he presented a series of six lecture-demonstration sessions, *The Chemical History of a Candle*, at the Royal Institution in London, U.K. This series, part of a long-running (1825–present) series of lectures at the Royal Institution is called the Christmas Lectures. Faraday presented his lecture-demonstrations to school-aged children, to popularize science, and chemistry in particular. He then (1861) had the six lectures assembled into a book by the same title. The book is still available today, both in print and online. (<https://archive.org/details/chemicalhistoryo00faraiala>)

The content of the Six Lectures included:

**Lecture 1:** A Candle: The Flame - Its Sources - Structure - Mobility - Brightness

**Lecture 2:** Brightness of the Flame - Air necessary for Combustion - Production of Water

**Lecture 3:** Products: Water from the Combustion - Nature of Water - A Compound - Hydrogen

**Lecture 4:** Hydrogen in the Candle - Burns into Water - The Other Part of Water - Oxygen

**Lecture 5:** Oxygen present in the Air - Nature of the Atmosphere - Its Properties - Other Products from the Candle - Carbonic Acid - Its Properties

**Lecture 6:** Carbon or Charcoal - Coal Gas Respiration and its Analogy to the Burning of a Candle - Conclusion

(<http://en.wikipedia.org/wiki/The_Chemical_History_of_a_Candle>)

A recent *ChemMatters* article provided a thorough description of the history and chemistry of candles (Rohrig, B. The Captivating Chemistry of Candles. *ChemMatters* **2007**, *25* (4), pp 4–7). Information from that article on the basic chemistry of candles includes:

[For all candles] the components are the same—a source of fuel and a wick. Today, nearly all candles are made from paraffin [which serves as a fuel]. Paraffin is a by-product of the distillation of petroleum, or crude oil. Paraffin is actually a mixture of several different heavier hydrocarbons. The wick is generally composed of tightly wound cotton or nylon fibers that make up a sturdy type of twine. All wicks are treated with various flame-retardant solutions. [Otherwise], the wick would be destroyed by the flames. You can think of the wick as the pipeline through which the fuel travels to the surface, making it available for combustion. …what happens when a candle is lit? Touched by a flame, the wick quickly conducts heat to the surface of the wax where melting begins. Liquid wax travels through the wick by capillary action. After the liquid wax travels to the top of the wick…it vaporizes upon contact with the burning flame. Combustion occurs as hot wax vapor combines with oxygen, producing the candle flame.

**More on criticism of the article’s greenhouse demonstration**

**“The Greenhouse Effect and Global Warming are quite real. Let's be sure the demonstrations we recommend to fellow educators are authentic, and get the science right!” This is the disclaimer at the top of this Web page from Climate Change Education.org:** <http://climatechangeeducation.org/hands-on/difficulties/heating_greenhouse_gases/problem_examples/bill_nye/index.html>**. According to this organization, “**We are a team of teachers, docents, scientists, engineers, techs, artists, students and parents providing pro bono services for thousands of climate education programs worldwide. While primarily based at science museums and the University of California, we work with hundreds of schools, programs and science institutions around the world to strengthen the climate education community.”

**Their site provides copious amounts of information about many (all?) of the variations on the greenhouse effect demonstration, like the one in the Tinnesand article. The site has lots of photos and videos showing the demonstrations, and a lot of science to explain why each of these demonstrations does NOT work as it is supposed to, or does not demonstrate the science it says it does. It provides a wealth of information on the topic.**

Many versions and variations exist of the demonstration described in the article. This 4:34 video clip from “Climate Change 101” shows one variation, with Bill Nye demonstrating “the greenhouse effect” using jars, small Earth globes, thermometers and heat lamps (0:50–1:30). (<http://player.vimeo.com/video/28991442>) Unfortunately, this demonstration suffers from some deficiencies similar to those of the article’s greenhouse demonstration—a confined space, infrared radiation that does not enter the jar, etc.—and some that are new: too much Earth, not enough air/CO2, possibly fabricated data.

And this site provides myriad evidence in a single report explaining why this simple experiment a) can’t work and b) didn’t work for Nye and Al Gore, who worked together on the full-length video. The experimenter very carefully attempted to duplicate the Nye experiment, with the expectation of obtaining the same results—which he did not realize. While the report is not without its own flaws, it does show the problems of doing a demonstration that is supposed to show something totally different from what it actually shows.

(<http://wattsupwiththat.com/climate-fail-files/gore-and-bill-nye-fail-at-doing-a-simple-co2-experiment/>)

In the experiment at Tufts University cited as a reference by author Tinnesand in the *ChemMatters* article, heat lamps indirectly warmed temperature sensors (shaded from the lamp) in open plastic containers. After an ambient (albeit elevated) temperature was reached (about 27 oC), carbon dioxide was added to one of the containers. The temperature immediately began rising in that container until it reached a maximum, approximately.7 Co higher than that of the container with air. (See graph below.)

They believed that the cause was the density of carbon dioxide suppressing air circulation around the sensor, rather than its ability to absorb and re-radiate infrared energy into the surroundings. But to test their hypothesis the experimenters tried a new approach. They evacuated the carbon dioxide container, allowed it to cool down, and began again. This time, they added argon instead of carbon dioxide. The authors explain their logic, and their results.

To determine whether the temperature rise when CO2 is added is a result of CO2’s infrared absorption rather than from density effects, we replicated the experiment in the second container using argon gas rather than carbon dioxide. Argon’s mass (40 u) is close to that of CO2, and thus its effect on the convective heat transport should be similar, but because it is a monatomic gas, it has no infrared absorption bands. Therefore, the radiative greenhouse effect does not occur for argon, and it represents a good experimental control for separating radiative and convective effects.

The curve labeled “Ar” in Fig. 2 [below] shows the response when the second container was filled with argon. The temperature rose by approximately the same amount and at the same rate as for CO2. Because Ar does not absorb infrared radiation, the temperature rise when Ar is added must be due to suppression of the convective heat transfer rather than to radiative effects, just as in the case of real greenhouses. We conclude that the experiment is a demonstration of a “greenhouse effect,” but not of the radiative phenomena responsible for climate change.

CO2

Ar

CO2 added

Ar added

35

33

**Temperature (C)**

31

29

27

25

200 400 600 800 1000 1200 1400

**Time (s)**

*Fig. 2. (Color online) Temperature variation when the containers are filled with carbon dioxide and argon, as indicated, after steady state is reached in air. The heat lamps are on throughout the time shown. When either gas is added, at the times shown by the arrows, the temperature rises toward a new steady-state value before decreasing when the gas level drops below the level of the temperature sensor. The effects of the two gases are almost identical. Because argon does not absorb infrared radiation, the temperature increase must be due to other effects.*

*(*[*http://rtobin.phy.tufts.edu/Wagoner%20AJP%202010.pdf*](http://rtobin.phy.tufts.edu/Wagoner%20AJP%202010.pdf)*)*

The authors then present mathematical models to verify their claims. Their conclusion:

Our results demonstrate that the temperature rise observed in a popular classroom demonstration1 arises not from the radiative greenhouse effect responsible for global warming but primarily from the suppression of convective heat transport between CO2 and air due to the density difference between the two. This density difference, much like the roof of a real greenhouse, suppresses gas mixing at the CO2-air interface and therefore inhibits heat transfer. The magnitude of the radiative effect is more than an order of magnitude smaller and is difficult to demonstrate convincingly. The interpretation of other similar demonstrations2–5 differs in detail, but is subject to the same considerations.

Our results apply only to the interpretation of classroom scale demonstrations; they do not call into question the effects of anthropogenic greenhouse gases on the Earth’s climate or existing models of those phenomena.

And this final paragraph applies directly to the intent of the entire Tinnesand article:

Although not an accurate demonstration of the physics of climate change, the experiment we have considered and related ones are valuable examples of the dangers of unintentional bias in science, the value of at least a rough quantitative prediction of the expected effect, the importance of considering alternative explanations, and the need for carefully designed experimental controls. Specifically, the use of argon as a test gas is an important supplement to the comparison of air and carbon dioxide because it allows effects due to the higher density of CO2 to be separated from those related to its infrared absorption.

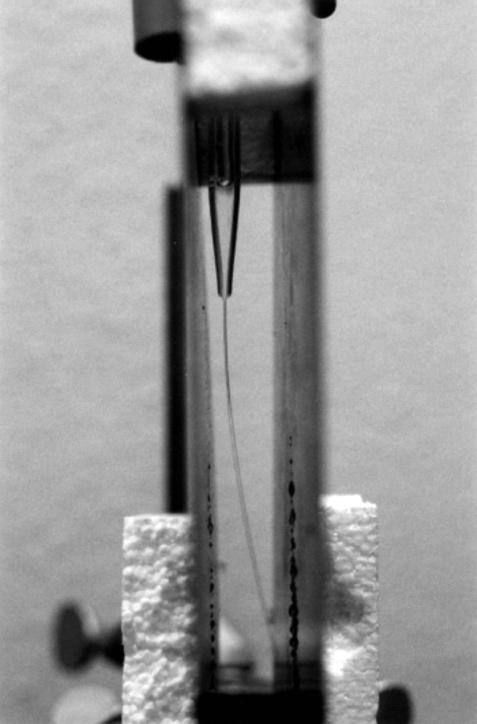
(Wagoner, P.; Chunhua, L.; Tobin, R. Climate change in a shoebox: Right result, wrong physics. *Am. J. Phys* **2010** *78*, (5), pp 536–540; <http://rtobin.phy.tufts.edu/Wagoner%20AJP%202010.pdf>)

Before leaving this study, it is interesting to note that the authors noticed the sudden decrease in temperature at the 1200 second mark for both carbon dioxide and argon and attempted to explain that apparent discrepancy (since the lamps were still lit). They tested another system by placing a small lit candle in the bottom of the container to test for carbon dioxide. As time progressed, the level of carbon dioxide decreased, presumably as some was circulating through to the top of the container and out. Mathematical calculations involving the diffusion rate of carbon dioxide led them to conclude that the 1200 second interval is the length of time needed for the carbon dioxide to escape, subsequently allowing air to circulate freely and thus reduce the temperature. The argon showed approximately the same amount of time needed for it to escape. Since both gases have approximately the same molecular mass, this is consistent with diffusion rate calculations.

**More on criticism of the article’s deflection of a polar liquid demonstration**

The article from the *Journal of Chemical Education* referenced in the Tinnesand article mentions that several groups have been successful in observing deflection of streams of nonpolar liquids in experiments similar to those done to show deflection in polar liquids.

The authors explain that

A casual interpretation of the figures [pictures showing deflection with polar liquids and none with nonpolar liquids] could give some students the impression that the mere presence of molecular dipoles gives rise to a net force on the liquid droplets in an electric field, but of course in a uniform electric field dipoles experience only a torque, and no net force.

It’s this idea of torque that most sources use as the explanation for the deflection. See this site, for instance: <https://www.youtube.com/watch?v=VhWQ-r1LYXY&feature=player_embedded>. It provides great visuals to explain how the water molecules rotate, but this alone would not cause the water stream to move toward the charged rod. Without the idea of the induced charge on the water molecules, allowing charge build-up within the stream, the explanation is woefully incomplete.

The authors continue:

Dipolar entities can only undergo deflection in a nonuniform electric field whose strength varies significantly on the length scale of the dipole. Intuition suggests that any nonuniformity in the electric field near a charged rod a few centimeters in diameter, or an electrified balloon, must be far too small to have any detectable effect on molecular dipoles.

*Figure 1. Electrical deflection of a distilled water droplet stream in a uniform electric field. The aluminum deflector plates were separated by 2-cm Styrofoam spacers (one is visible out of focus at the top of the image) and were insulated from the supporting clamp by other Styrofoam spacers visible at the bottom of the image. The plate on the left was grounded and a potential was induced on the righthand plate by a statically electrified balloon (outside the field of view to the right).*

In fact, the explanation for electrical deflection of a polar liquid droplet stream is that the polar liquid droplets carry an induced electrical charge. … The effect results from a charge separation in the water droplet as it forms, induced by the charge on the nearby deflection device. As the droplet separates, a fraction of the like charges repelled by the deflector statistically remain behind in the water reservoir so that the droplet acquires a net charge opposite to the charge on the deflector and is attracted to it.

(Williams, P.; Ziaei-Moyyaed, M.; Goodman, E. Electrical Deflection of Polar Liquid Streams: A Misunderstood Demonstration. *J. Chem. Ed.* **2000**, *77* (11), pp 1520–1523,

<http://pubs.acs.org/doi/pdfplus/10.1021/ed077p1520>, available online only to subscribers)

The authors further report that “Finally, we were able to deflect a droplet stream of a nonpolar liquid (tetrachloroethylene),” the experiments for which are explained in the rest of the article. They further report in the article:

The behavior of C2Cl4 was particularly interesting. With a vigorously electrified balloon it was just possible to detect a very weak deflection in a C2Cl4 stream even though this liquid is nonpolar. Brindle and Tomlinson reported that a strong deflection could be observed in a CCl4 stream under conditions of low humidity (*8*); Vemulapalli and Kukolich (*9*) and Shakhashiri (*10*) observed deflection of benzene and *n*-hexane, respectively (attributed in ref *9* to forces on induced dipoles and in ref *10* to dielectrophoresis, the lowering of potential energy when a dielectric material moves from a region of lower to higher electric field). Given that the electric field near our charged balloon (ca. 10 cm radius) was only slightly inhomogeneous and that no deflection was observable in a strongly inhomogeneous field even for water in our re-creation of the Vemulapalli and Kukolich experiment when the droplets formed in an electrically screened region, induced charging, even of insulating liquids, seems to be the only general explanation for all of these observations.

**More on other demonstrations that are not quite what they seem**

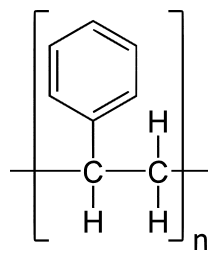
**“Dissolving” Styrofoam**™

In this demonstration, the teacher will place copious amounts of Styrofoam™ peanuts or other Styrofoam™ packaging into a beaker containing acetone. The Styrofoam™ appears to “disappear” into the acetone, with some bubbling, while closer inspection shows that some opaque viscous liquid material still exists in the acetone at the bottom of the beaker.

The usual explanation is that the acetone is “dissolving” the Styrofoam™. While this seems like a reasonable explanation, dissolving usually means the solute, the material being dissolved, truly disappears into the solvent, the material that is doing the dissolving. The fact that viscous liquid matter still remains in the mixture indicates that this is not a case of true dissolving.

Styrofoam™ is the Dow Chemical Company trade name for expanded polystyrene (EPS). (We’ll explain the expanded part shortly.) Polystyrene (PS) is a long-chain polymer composed of many styrene monomers. Styrene, (C8H8)n [at right:   
a) structural formula, b) space-filling model], is essentially a phenyl group (benzene ring) attached to an ethylene. Polystyrene is essentially a chain of ethylene reactive groups on which phenyl groups are alternately attached to the chain of carbon atoms in the ethylene groups. The polymer has the structural formula c) at right. The subscript “n” in the formula represents a large number of styrene monomers, perhaps a few thousand.

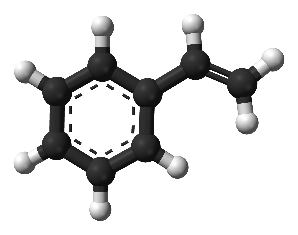
c) Polystyrene



Styrene

a) Structural b) Space-filling

formula model



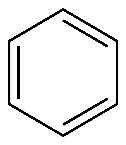
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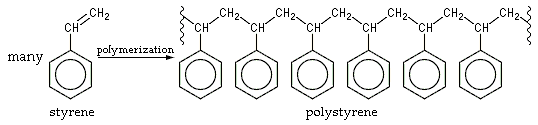
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*(Image sources: b)* [*http://en.wikipedia.org/wiki/File:Styrene-from-xtal-2001-3D-balls.png*](http://en.wikipedia.org/wiki/File:Styrene-from-xtal-2001-3D-balls.png)*, c)* [*http://upload.wikimedia.org/wikipedia/commons/6/60/Polystyrene.svg*](http://upload.wikimedia.org/wikipedia/commons/6/60/Polystyrene.svg)*)*

The diagram below shows the polymerization of styrene, where the double bond in the ethylene group is broken, and where the monomer reactive groups subsequently link together into the long chain polymer.



*(*[*http://upload.wikimedia.org/wikipedia/commons/1/10/Polystyrene\_formation.PNG*](http://upload.wikimedia.org/wikipedia/commons/1/10/Polystyrene_formation.PNG)*)*

When polystyrene is produced, many long polymer chains are formed and they become entangled with one another. These entanglements result in many attractions between the long chains, and this makes polystyrene a rigid plastic.

Expanded polystyrene (EPS) is made by adding a material called a blowing agent to already (slightly) pre-expanded polystyrene beads. The blowing agent is, or produces, a gas that expands the polystyrene further, trapping the gas inside pockets or cells within the polymer. This greatly increases the volume of the polymer, thereby vastly decreasing its density (DPS = 1.05 g/cm3, DEPS = 0.02–0.20 g/cm3).

When EPS is added to acetone, the acetone softens the polymer, working its way between the polystyrene chains, loosening the entanglements and allowing the chains more freedom of motion. As the chains loosen, the cells within the polymer structure that contain the gas soften and swell. This increases the space between the polymer strands, which allows the trapped gas within the cells to escape, so that only the original polystyrene is left; thus the *apparent* dissolution of the EPS foam as it shrivels down to almost nothing, and the macroscopic bubbling as the gas molecules escape. The PS remains as a softened mass in the acetone bath. If the bulk of the acetone is poured off and the remainder allowed to evaporate, the polystyrene lump becomes hard and brittle, as is the normal state of polystyrene.

There are many examples of this activity shown on YouTube and elsewhere on the internet. Unfortunately, almost all of these—if they offer an explanation at all—will say that the acetone “dissolves” the EPS. Here are a few examples. (More are cited in the “More Web Sites for Additional Information”, later in this Teacher’s Guide.)

In this short YouTube video clip (1:54) that nicely shows the dissolving of a large amount of expanded polystyrene in a small volume of acetone, the title is rather generic (but alright)—it just says “Acetone and Styrofoam”—but the movie clip itself has the wrong title embedded in the video—Magically *Dissolving* Styrofoam”: (<https://www.youtube.com/watch?v=h9Jx8NRkWTo&feature=player_embedded>, or this source of the same video clip (1:55), in case you can’t access YouTube at your school: <http://wn.com/styrofoam_and_acetone>)

This video clip (2:07), “Acetone Dissolving Styrofoam”, would be good to show if you want to use a video to demonstrate the phenomenon instead of actually doing the demonstration yourself in class. While it offers no talk at all, it shows a bit more controlled experiment (apparently in a lab), showing close-up video of the softening of the EPS cup and the resulting puddle of polystyrene: <https://www.youtube.com/watch?v=_7e1zljg8Oo&feature=player_embedded>.

This YouTube video news clip (3:53) with scientist Carl Nelson from “Imagination Station” provides a correct (albeit brief) interpretation of “Dissolving Styrofoam with Acetone” (Note that the title is still wrong). The video mentions that EPS is as much as “98% air”. At the end Nelson dissolves a Styrofoam head. (<https://www.youtube.com/watch?feature=player_detailpage&v=6S4zfMdjQxY>)

Finally, Flinn Scientific offers a basically correct explanation (and lab activity) in their *ChemFax* “Styrofoam Peanuts and Acetone”. Here’s what they say:

When the polystyrene peanuts are added to the acetone, the peanuts seem to dissolve. They do not really dissolve in the acetone, but go through a process called “swelling” that allows the trapped gases to escape. To put it another way, the polystyrene is “de-foamed.” If the bulk of the acetone is decanted off and the residual polystyrene/ acetone is allowed to dry, the result is a solid polystyrene disk.

(<http://www.flinnsci.com/media/620357/91075.pdf>)

**Using balloons to show that air has weight or mass**

To show that air has weight or mass, this demonstration has been used. The teacher will use a double pan balance or a balanced meter stick (hanging freely from a fulcrum at the center). Two deflated balloons of equal size are attached, one at each end. One is then detached, inflated, tied off, and reattached. The meter stick is then supposed to sag downward. This allows the teacher (and therefore, the students) to conclude that air has mass. Unfortunately, this is not quite the whole story. William Beatty explains further on his Web site, “Recurring Science Misconceptions in K-6 Textbooks”:

Unfortunately this experiment isn't very honest. When immersed in atmosphere, buoyancy causes full and empty balloons to weigh the same. One balloon shouldn't pull down the stick. But then why does the above experiment work? Usually it doesn't! In fact, the experiment will fail unless you know the trick: you must inflate the balloon near to bursting. The experiment secretly relies on the fact that the air within a high-pressure balloon is denser than air within a low pressure balloon. Of course the demonstrator never mentions this to the students, and the books which contain this demonstration don't mention density effects either. Obviously the density effects do not *directly* demonstration [sic] anything about the weight of air, so it's dishonest to tell students that this demonstration can directly weigh some air.

(<http://amasci.com/miscon/miscon4.html#balloon>)

So, using two partially-filled, appearing-to-be-inflated balloons in this demonstration won’t work the way they’re supposed to work to show that air has mass, even though the internet is replete with video clips showing the demonstration working just “as expected”. Often, though, these demonstrations are very crude and use very rough fulcrums (fulcra?) (e.g., a finger for balancing), or meter sticks that are very crudely balanced to start, so changes may not be that noticeable anyway.

The mass of air demonstration utilizes the idea of buoyancy of air to account for the way the two balloons SHOULD behave, if both balloons are just filled to maximum volume, without overfilling either one. Then, when one is popped, its (complete) remains and the other filled balloon should stay balanced, because the mass of the air inside the balloon is the same as the mass of the air it displaced before popping. And the reason it doesn’t work is because typically the two balloons are overfilled, meaning there is more air and hence, more mass in the still-filled balloon than “one balloon’s worth”—the mass of air in the atmosphere supporting it.

Another version of this demonstration is to have the two inflated balloons already attached to the meter stick so that they are balanced, one on each end. Then the teacher sticks a pin in one of the balloons to puncture it. It happens very quickly, and the punctured, now-deflated balloon typically drops and the inflated one on the other end of the stick rises. This about.com Web site provides a description of the experiment: (<http://weather.about.com/od/lessonplanselementary/ht/air_has_mass.htm>).

This video clip of four different student attempts of this experiment (using a lighter instead of the pin to puncture the balloon) shows the primary problem with this method: <https://www.youtube.com/watch?v=ENkW7yJ4rkw&feature=player_embedded>. In three of the four tests, you can see balloon pieces flying away from the balloon, and in the fourth, it is so shredded that you can’t tell if pieces are missing. So, if balloon parts that *were* there when the balloons were balanced are *not* there after the bursting, is it so surprising that the intact, inflated balloon is heavier? The whole is indeed heavier than some of its missing parts.

Flinn’s “Air Has Mass” video (15:00) shows several methods to use to demonstrate that air has mass. In the first 6 minutes the presenter shows one method: she produces some carbon dioxide with vinegar and baking soda in a 1-L plastic bottle. She masses the entire system and zeroes it out on the balance. Then she opens the cap a bit to release some of the gas (you hear the p-f-f-t). Then she masses the bottle again and it has lost mass. So, by deduction, the gas inside the bottle must have had mass that was removed when the cap was opened. It might be good for you to do the demonstration yourself for your classes, as the balance readings may be somewhat confusing to students. In the second half of the video the presenter uses buoyancy to show air has mass. This one may cloud the issue a bit because it is an indirect approach and is more difficult for students to visualize. Also note that this video is directed at a teacher audience. <https://www.youtube.com/watch?v=UKd2TwoJbzY&feature=player_embedded>

This video from “*Do* Try This at Home” shows the standard equal-arm meter stick with inflated balloons and one of them is punctured. The inflated balloon’s end of the meter stick sinks and the end with the deflated one rises, indicating to the experimenter (Mr. G) that “air has mass”. This is actually his second experiment. The first one is shown in an “oops” or blooper outtake at the end of the video, where he does the experiment and the two balloons stay balanced after one has been deflated. The experimenter concludes that he has to do the demonstration again (the “again” is the one he shows in detail in the first 80% of the video). Too bad, because he had it right the first time (the “oops”). (<https://www.youtube.com/watch?feature=player_embedded&v=Bv_tS6-qCJ4>)

**The hydrophobic effect—Water and oil don’t mix**

A mixture of vegetable oil and vinegar (as in salad dressing) is a commonly used example of the “hydrophobic effect”—“Oil and water don’t mix.” The oil floats on top of the vinegar/water mixture on the bottom. This supports the chemistry rule concerning solubility and miscibility that “likes dissolve likes”—polar substances dissolve other polar substances (vinegar and water), and non-polar substances dissolve other non-polar substances. Although this is generally true—and has lots of chemistry to back it up, an incomplete understanding of the rule may result in students believing that substances that are hydrophobic (i.e., “water-fearing”) (non-polar substances) repel or are repelled by water, or at least that they have very little attraction for water molecules.

But that is absolutely not true. Oil molecules do attract water, with much greater force of attraction than they have for other oil molecules, although this attraction may not be obvious. Dr. Kevin Lehman of the University of Virginia explains further:

We can observe the consequence of this greater attraction when we put a drop of oil on a clean surface of water. Before hitting the surface, the oil will be in the shape of a spherical droplet. This is because the oil molecules are attracted to one another and a spherical shape minimizes the number of oil molecules that are not surrounded by other molecules. When the oil hits the surface of the water, it spreads out to form a thin layer. This happens because the attractions between the oil and water molecules gained by spreading over the surface is larger than the oil-oil attraction lost in making a large oil surface on top of the water. If a sufficiently small drop of oil is put on the surface, it will spread to form a single molecular layer of oil. By measuring the area produced, one can get a simple estimate for the size of each oil molecule and thus Avogadro's number.

Given these strong interactions, why does not each oil molecule dive into the water solution and surround itself with the favorable water attractions? The reason is that to do so, it must come between water molecules that are already attracting each other! The strength of water-water attraction is much higher than water-oil interactions, and thus there is a net cost of energy in putting the oil molecules into a water solution. Thus the vast majority of oil molecules stay out of the water, though as many as will fit will hang on to the surface water molecules that do not have a full complement of partners.

(<http://www.faculty.virginia.edu/lehmannlab/badchemistry.html#hydrophobic>)

Essentially, the non-polar oil molecules have only van der Waal forces—

(dipole-dipole interactions) and London dispersion forces (instantaneous induced-dipole dipole interactions) of attraction—while water has these AND hydrogen bonding forces of attraction. The van der Waal forces are sufficiently strong to hold oil molecules together (after all, they *are* in the liquid state, indicating fairly strong interactions). But the hydrogen bonding holding water molecules together are far more attractive than the forces that oil molecules can bring to bear that would be required to separate water molecules from one another to allow oil molecules to intercalate between them. Thus, “oil and water don’t mix”.

Here is a table that summarizes relative strengths of the various forces of attraction between and within molecules.

## Relative strength of forces

|  |  |  |
| --- | --- | --- |
| **Focus of force** | **Bond type** | **Dissociation energy (kcal/mol)** |
| Intramolecular | Ionic Lattice Energy | 250-4000 |
|  | Covalent Bond Energy | 30-260 |
| Intermolecular | Hydrogen Bonds | 1-12 (about 5 in water) |
|  | Dipole–Dipole | 0.5–2 |
| van der Waals | London Dispersion Forces | <1 to 15 (estimated from the enthalpies of vaporization of hydrocarbons) |

Note: this comparison is only approximate – the actual relative strengths will vary depending on the molecules involved. Ionic and covalent bonding will always be stronger than intermolecular forces in any given substance. [Ed. Note: I added the first column to clarify the areas of interaction.]

(<http://en.wikipedia.org/wiki/Intermolecular_force>)

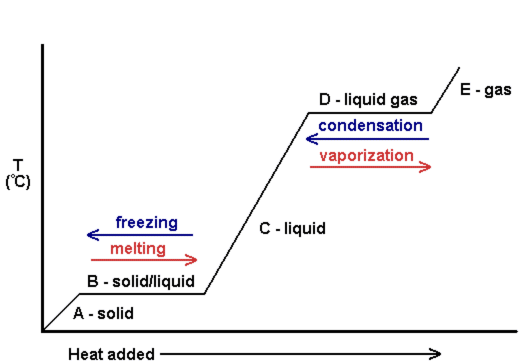
So just remember, when you discuss with students the chemistry rule that “likes dissolve likes”, their incomplete understanding of intermolecular attractive forces may lead them to believe on a simplistic level that this means “‘unlikes’ **repel** ‘unlikes’”—which is NOT true! This possible student misconception may require a bit more explanation in class when you discuss intermolecular attractions and secondary bonding. Here is a good basic Web site from Mark Ophardt’s *Virtual ChemBook* (Elmhurst College) that describes and explains the types of intermolecular forces: <http://www.elmhurst.edu/~chm/vchembook/160Aintermolec.html>.

**“You can see ‘steam’.” (NOT)**

Many a student (and even, many a teacher?) has made this statement.   
After all, if you boil water in a pot at home, or even in a beaker in the lab, you can *see* the steam billowing out of the top, right? Well, actually, no. What you see isn’t steam, but water vapor that has condensed from steam. As the hot steam (>100 oC) escapes the liquid, it immediately comes in contact with the cooler air molecules. The gaseous water molecules cool down instantly and condense into tiny droplets of liquid water. These droplets form the mist or cloud that you see as “steam”.

Heat water in a tea kettle at home or, in the lab, in a flask with a small opening, until the water is boiling vigorously. Look carefully right at the opening of the container and you will see—nothing! Actually, that’s steam you’re *not* seeing. Look at the billowing cloud and you will see—not steam, but condensed water droplets. In between the opening and the beginnings of the cloud is steam, billowing, but invisible, because it is still a gas for that brief moment before it collides with cooler air and condenses. See “In-Class Activities”, #1 for a class demonstration to show students what steam can do.

**“Steam can’t get hotter than 100oC.”**

 Many students believe this, and perhaps it’s partly our fault. We probably show them the typical phase-change diagram showing ice below 0 oC going to ice at 0 oC, to water at 0 oC, to water at 100 oC, to steam at 100 oC, and maybe even to steam above 100 oC. But we probably never do much with that last piece of information. Yet, super-heated steam is very useful, in heating large buildings in big cities and in many industrial uses—in manufacturing and in chemical processes. “In-Class Activities”, #1 below provides you with a demonstration to use to show your students the heating of steam to temperatures above 100 oC.

*(*[*http://www.kentchemistry.com/images/links/matter/HeatCool.gif*](http://www.kentchemistry.com/images/links/matter/HeatCool.gif)*)*

How many of us pursue “letter E” on the graph with our students?

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Demonstrations**—While this is not exactly a chemistry “concept”, it is an essential ingredient in many chemistry teachers’ arsenal of classroom activities. The three demonstrations in this article accentuate the negative aspects of using demonstrations in the chemistry classroom. The positive aspects may include greater student interest, greater student understanding, greater concept “staying power” in students’ minds, greater ability of students to make connections between the concept(s) central to the demonstration and other chemistry concepts, and greater familiarity with the physical and chemical properties involved in actual chemical systems, to name a few.
2. **Combustion**—the burning candle under the beaker demonstration can be used to show students one of the products of combustion, carbon dioxide; if you were to test the gas left in the beaker with limewater, it would turn cloudy, indicating the presence of CO2.
3. **Gas laws**—the rise of the water in the beaker is at least partially due to the decrease in gas temperature inside the beaker, an example of Charles’ Law (gas volume [of gas inside the beaker, shown by the rise of the water level] varies directly with temperature). Note that this would NOT be a good demonstration to use to illustrate Charles’ Law the first time it is introduced to students, as this demonstration is overly complicated by the chemical reaction that precedes the volume change; but it can be used to review Charles’ Law after you’re assured that students understand the relationship.
4. **Static electricity**—In the deflection of the stream of water demonstration, the balloon rubbed on hair or the glass rod rubbed with silk both are used to transfer charge from one object to another, causing the deflection of the stream. In a separate demonstration, they are used to display the electrical nature of matter and the relative ease with which electrons are transferred from one material to another, creating static electricity and charge potential differences.
5. **Polarity of molecules**—Although the deflected stream of water doesn’t rely on the polarity of the water molecules, the effect is much more obvious with polar molecules than with nonpolar molecules. This is because it is easier to induce a charge in molecules that already have charge separations within the molecular structure.
6. **Electronegativity**—The electronegativity differences between oxygen and hydrogen (and the asymmetric shape of the water molecule) result in water being a polar molecule.
7. The electromagnetic spectrum—In the greenhouse effect demonstration, carbon dioxide (and other gases) in the atmosphere absorb infrared radiation and re-emit it into the atmosphere and back to Earth, while most gases in the atmosphere are transparent to infrared radiation.
8. **Gas density**—The greater density of carbon dioxide in the one beaker prevents mixing of the gases which, in turn prevents the transfer of heat from inside the beaker to the air outside. Indeed, carbon dioxide is frequently used to show the density difference of various gases. An aquarium is partially filled with CO2 and large soap bubbles are floated inside the aquarium. They rest on the CO2 layer of gas (which, of course, is otherwise invisible).
9. **Light and the electromagnetic spectrum**—If you really dig into the greenhouse effect with students, they will discover that greenhouse gases absorb and re-radiate wavelengths of light based on their bonds’ natural frequencies of vibration.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“The water level rises inside the beaker because all the oxygen is being used in the burning process.”** *The article has corrected this misconception:*

T*he water level rises because*

1. S*ome of the reactant gas, oxygen, has been consumed, and much of the products have been either dissolved in the water (CO2) or condensed into the water (H2O vapor produced), leaving less gas inside the beaker at the end than at the beginning, thus lowering gas pressure inside the beaker; and*
2. *The heated air inside the beaker cools down, lowering the gas pressure inside the beaker.*

*Both these factors result in the atmospheric pressure outside the beaker forcing the water up into the beaker until gas pressure inside is once again equal to air pressure outside the beaker.*

1. **“The water deflects because the charge on the balloon attracts the opposite charge within each polar water molecule.”** *This would seem to be a logical explanation, but the article explains that it is the induced charge on the water molecules opposite to that on the charged object that causes the deflection.*
2. **“The temperature of the air inside the beaker increases because carbon dioxide is a greenhouse gas.”** *The gas inside the beaker increases in temperature solely because the carbon dioxide settles to the bottom of the beaker and inhibits circulation that prevents cooling of the inside of the beaker. It is warmed because it is in contact with the warm rocks, and that heat can’t escape the beaker.*
3. **“Demonstrations are no good because they don’t tell the truth.”** *This is only true in rare instances, and informed teachers will not purposefully deceive students just to “show them a good time”; rather, they will only use demonstrations that correctly show a specific chemical phenomena, and they will work with students to understand the chemical principles behind the demonstration.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“In the candle-under-the-jar demonstration, how do we KNOW that all the oxygen isn’t used up when the candle goes out?”** *Michael Faraday saw this one coming. He kept a mouse in his experiment and it was able to survive on the oxygen that remained in the container after the candle had gone out. OK, so we don’t want to torture mice anymore. Instead, if you redo the standard candle-under-the-jar experiment with two candles in the jar, one tall and one short, the tall one will go out first and the smaller candle will continue to burn, indicating there is still oxygen in the container. If the candles stayed lit until all the oxygen were used up, both candles would go out at the same time.*
2. **“Will the liquid level still rise if we keep the temperature high enough to prevent the water vapor from condensing?”** *This is an interesting question. The answer to the question is probably, “no”, for two reasons. First, if the temperature is hot enough   
   (>= 100 oC) such that the water vapor doesn’t condense, that means that we have all 26 moles of water, or nearly 2/3 of the original 38 moles (of oxygen) in the gaseous state, AND we probably have almost ALL of the 25 moles of carbon dioxide produced, also in the gaseous state. This is because the solubility of carbon dioxide is greatly decreased at this high temperature, as is true for all gases—gas solubility decreases with increased temperature. This means we have 51 moles of gaseous material in the same beaker where we originally had only 38 moles of gas, resulting in greater gas pressure after the combustion than originally.*

*In addition, we also have an elevated temperature inside the beaker, relative to ambient temperature (100 oC vs. perhaps 20 oC). At the higher temperature, gas pressure is also increased (Charles’ Law).*

*Both these factors will result in the greater gas pressure forcing liquid water out of the beaker, thus lowering the water level inside the beaker. However, this would be a very difficult experiment to perform, as the liquid water inside the beaker would be boiling at this elevated temperature. Thus, we would need to substitute another liquid for the water, one that would not become gaseous at the temperature at which the experiment is conducted. Of course, changing the liquid adds one more variable to the experiment, one which could affect the outcome.*

1. **“Will nonpolar liquids also be attracted to the charged rod or balloon?”** *Nonpolar liquids are also attracted to the rod or balloon, but with far less force (and therefore less than noticeable deflection). This is because, although the charged rod can still induce a charge in the nonpolar liquid, the electrons in that liquid are more evenly distributed and it is more difficult for them to be moved around. A very strong electrical field would have to be brought close to the stream of nonpolar liquid to cause a noticeable deflection.*
2. **“Are there ANY demonstrations that faithfully represent the effect of carbon dioxide on the Earth’s atmosphere?”** *The Earth atmosphere is such a huge system that it is very difficult to scale that down to a workable demonstration. The atmosphere’s huge size and complexity are two of the reasons the whole idea of global warming—or even climate change in general—is so hard to pin down. Mathematical models can come close to simulating all the variables in the atmosphere, but the devil’s in the details.*

## In-Class Activities

**(lesson ideas, including labs & demonstrations)**

1. Faraday’s “The Chemical History of a Candle” has been discussed in the “Background Information” section, above. The respected ChemStudy curriculum from the 1960s opened the year with the student experiment “Observations on a Burning Candle”, anticipating students’ following in Faraday’s footsteps. One such procedure is here: <http://boomeria.org/labschem/exper1.pdf>. It might be of interest to compare those experiments with information provided in this paper from the National Institute of Standards and Technology: Characterizations of Candle Flames.” <http://fire.nist.gov/bfrlpubs/fire05/PDF/f05141.pdf>.
2. If you want to pursue the burning-of-a-candle-under-a-jar demonstration more critically, here’s how to ignite the candle electrically—internally, after the entire set-up is ready to go. This avoids any air loss or gain prior to burning beginning. (<http://www.physics.umd.edu/deptinfo/facilities/lecdem/services/demos/demosi1/i1-64.htm>)
3. You can show this 3:07 YouTube video clip from “Mythbusters tests global warming theory” that shows a much more controlled experiment that replicates the atmosphere, using methane and carbon dioxide: <https://www.youtube.com/watch?v=pPRd5GT0v0I>. This clip shows how they controlled some of the variables in the experiment.
4. Following a discussion of the greenhouse gas demonstration, you can do a simple demonstration with carbon dioxide to verify its high density. Fill a clear container with CO2, either from a tank or from the chemical reaction between vinegar and baking soda, generated in another container and piped into the clear one. Then pour the gas only—no liquid—from the clear container over a lit candle. The flame will go out. Classroom discussion can then follow concerning the cause of the flame being extinguished.
5. You could use the 4:34 video clip from “Climate Change 101” that shows Bill Nye demonstrating “the greenhouse effect” using jars, small Earth globes, thermometers and heat lamps (0:50–1:30) and ask your students to identify the problems with the video. It is a variation on the article’s greenhouse demonstration. (<http://player.vimeo.com/video/28991442>)

Then you could show them this site that provides myriad evidence in a single report explaining why the Nye-Gore simple experiment above a) can’t work and b) didn’t work for Nye and Al Gore, who worked together on the full-length video. While the report is obviously written by a “climate change denier”, it does show the problems of doing a demonstration that is supposed to show something totally different from what it actually shows. Beware that the report is rather detailed, and itself contains a few problems (that students could be asked to search for).

(<http://wattsupwiththat.com/climate-fail-files/gore-and-bill-nye-fail-at-doing-a-simple-co2-experiment/>)

1. In case you wanted to actually *do* a greenhouse activity (similar to the one in the Tinnesand article) with your classes, here’s a good source: “Activity 12, ‘What is a greenhouse?’” from the University Corporation for Atmospheric Research. The procedure differs from that in the Tinnesand article in that no CO2 is used; instead, slots are cut in one bottle and not in the other (one allowing circulation and one, not), so if there is a difference in heating rates, it’s not going to be a density consideration. This activity contains a student version and a teacher version. The student (and teacher) version provides diagrams to show the preparation of the two systems. The teacher version is aware of problems with simplistic experiments meant to represent large Earth systems, as evidenced by the following statement:

**Cautionary Note:** The analogy between the plastic cover and the atmosphere is not a perfect one. Greenhouse covers prevent heat losses from convection (air movement carrying away the heat) as well as by radiation (direct transfer of heat energy). The atmosphere prevents only heat loss by radiation. The greenhouses used in this activity serve as a crude model of the actual atmospheric process and are only of limited use in understanding the nature and scope of the actual Greenhouse Effect.

(<http://www.ucar.edu/learn/1_3_2_12t.htm>)

For information leading up to the activity above, this page provides background information on what the greenhouse effect is: <http://www.ucar.edu/learn/1_3_1.htm>.

This page gives students a second activity, which allows for more variation in the outcome: Activity 13, “What Factors Impact a Greenhouse?” (<http://www.ucar.edu/learn/1_3_2_13t.htm>)

1. The Office of Science Education at the Jefferson Lab National Accelerator presents the phenomenon of water being deflected by a charged rod on their “Frostbite Theater” video clip (2:08). They also present a wrong explanation of the deflection, saying the water molecules rotate so that their partial charge opposite that of the charged rod moves toward the rod and their partial charge the same as the rod moves away from the rod, causing the deflection: <https://www.youtube.com/watch?v=VhWQ-r1LYXY>. Here is a correct, albeit short (1:13) explanation—induced charge: <https://www.youtube.com/watch?v=p1f6zLysilU>.
2. Here’s the polar-nonpolar charged rod deflection demonstration, done with a water stream and an oil stream. The teacher demonstrates while he explains the difference between polar and nonpolar substances. (<https://www.youtube.com/watch?v=k4AdJ2PSIco>)
3. Here’s another take on the deflection of water demonstration. A magic wand that does miraculous things to a stream of water—an old physics trick involved creating a parabola shaped spray of water by taking a finely tipped glass tube connected to a rubber hose attached to the cold water faucet and allowing the stream of droplets of water to fall into a sink. When the teacher points a black wand (a rubber rod which has been rubbed with flannel or fur) near the stream, the fine spray coalesces into larger drops and into a single stream of water. The fine spray consists or a large number of fine droplets of water carrying the same electrical charge. The water droplets repel each other resulting in the fine spray. The black rod made of ebonite and charged with static electricity by rubbing it with fur or flannel neutralizes the charge on the droplets of water as the rod is brought near the spray. The droplets no longer repel each other. They coalesce into larger drops and form a single stream of water. The flow of water and height of the stream can be controlled with a pinch cock attached to rubber hose.
4. “The “open” structure of Styrofoam™ can be dramatically demonstrated by placing a few milliliters of acetone in the bottom of a Petri dish and then setting an empty Styrofoam™ (expanded polystyrene—EPS) cup in the acetone. As the EPS “dissolves” in the acetone (for the real explanation of what occurs, see “More on other demonstrations that are not quite what they seem—Dissolving Styrofoam™”), the cup rapidly disappears. The open structure of the EPS (many cells) creates a large amount of surface area upon which the reaction takes place. Alternatively, a few centimeters of acetone can be placed in a large opaque container like a coffee can. Styrofoam™ packing “peanuts” can be added to the can. They will “disappear”. The number that can be added is rather amazing.

Care should be exercised in handling the acetone. It is very flammable, and in addition, the demonstration should probably be done in a fume hood. The product should not be flushed down the drain. The excess acetone should be allowed to evaporate in the fume hood, and the relatively dry product should then be packaged in plastic Ziploc bags and properly disposed of in the trash.” (Teacher’s Guide, *ChemMatters*, October 2000, accompanying article: “Packaging: Keeping Food Safe, Fresh, and Available”. Please explain to students that the process is not really dissolving.

1. Following a critical discussion of the air-has-mass demonstration, this is a good demonstration (or student experiment) to test students’ understanding of buoyancy of air in the atmosphere. It involves the law of conservation of mass. In a sealed zipper plastic bag, react sodium carbonate and vinegar. Put the vinegar in a small, loosely stoppered vial or test tube. Make a solution of Na2CO3, put it in another vial, stopper loosely and place both vials into the bag. Seal the bag and place it on the balance to note its initial mass. Ask students to predict what will happen to the mass of the system when the chemicals react inside the bag. Unstopper the vials through the bag, pour the contents of both into the bottom of the bag. Now put it back on the balance and watch its mass as the reaction proceeds. The mass actually decreases, due to the volume of CO2 produced by the reaction inside the bag displacing air outside the bag. The atmosphere buoys up the bag, thereby decreasing its mass. Even though the mass of the bag and contents remains constant before and after the reaction, the mass of the system *appears* to decrease. So much for students believing the Law of Conservation of Mass—UNLESS you explain the results using buoyancy. You can always try the experiment again, only this time use a glass airtight container (e.g., an Erlenmeyer flask with stopper). This time, buoyancy is constant, so the mass should not change.
2. You can’t see steam. (See “You can see ‘steam’.” In the “Background Information” section above.) You can do a classroom demonstration to show students the difference between steam and condensed water vapor, and that steam can get hotter than 100 oC. (Becker, R. “Question from the Classroom”. *ChemMatters* **2009**, 27 (3), p 2)
3. A fun activity and a good example of the actual operation of “hydrophilic” and “hydrophobic” materials is illustrated by comparing the properties of regular sand and the commercially available “Magic Sand.” Magic sand is hydrophobic. It is sand coated with a material that prevents it from attracting water (“repel” is not the proper word, but that does summarize what its observed behavior seems to be). Consequently if you cover it with water and then remove it, the sand is dry! (available at Educational Innovations, <http://www.teachersource.com/product/magic-sand/chemistry> or Steve Spangler Science, <http://www.stevespanglerscience.com/magic-sand.html>)
4. You can show students the value of skepticism in science and in their daily life in this *ChemMatters* article about a water purification device. You can probably duplicate the experiments in the article (OK, maybe not the one with the atomic absorption spectrometer). This article relates directly to the chemistry course chapter on redox. (Hesse, J. Mystery Matters:Tainted Water. *ChemMatters* **1988**, *6* (3), pp 13–15)
5. You could use this pair of video clips to show how science actually works. The first is a segment of a video by Veritasium (1:50–5:07) that shows a stream of water being deflected by a charged object, and the narrator explains the phenomenon—incorrectly, even by the old standard. The second clip follows up on that Veritasium explanation and offers its own experiments, focusing on the premise that if a prediction is made based upon a model (hypothesis) and the prediction doesn’t match what actually happens, then the model or hypothesis must be wrong, and we have to rethink our explanation. True to form, the second video leaves the question open-ended, pending further experimentation.

Veritasium video (3:57): <https://www.youtube.com/watch?v=jIMihpDmBpY>.

“When Veritasium Gets it Wrong!” (8:53): <https://www.youtube.com/watch?v=3Ev_k__U3Io>.

# Out-of-class Activities and Projects

**(student research, class projects)**

1. A student might be interested in experimenting to find out whether adding extra CO2 dissolved in the water affects the amount of gas (water level) in the candle/jar experiment. Perhaps using club soda instead of the water would be a place to start?
2. Students can research online for other “bad” demonstrations that the teacher could then perform with them to uncover—and correct—the problem areas.
3. You could use this pair of video clips to show how science actually works. The first is a segment of the video by Veritasium (1:50–5:07) shows a stream of water being deflected by a charged object, and the narrator explains the phenomenon—incorrectly. The second clip (8:54) follows up on that Veritasium explanation and offers its own experiments, focusing on the premise that if a prediction is made based upon a model (hypothesis) and the prediction doesn’t match what actually happens, then the model or hypothesis (Veritasium’s) must be wrong, and we have to rethink our explanation. True to form, the second video leaves the question open-ended, pending further experimentation.  
   Veritasium video: <https://www.youtube.com/watch?v=jIMihpDmBpY>.  
   When Veritasium Gets it Wrong! video: <https://www.youtube.com/watch?v=3Ev_k__U3Io>.
4. Students can test a well-established “truth”. Everyone knows that shaking an unopened can of soda, and then opening it right away results in an explosion of bubbles—and soda—out of the can. And everyone *knows* that tapping the sides of the can after it’s been shaken is the way to avoid the “big splash, right? But maybe it’s not the tapping that makes things right. Students can experiment to find the truth. (Becker, R. Question from the Classroom. *ChemMatters* **2008**, *26* (1), pp 2–3)

# References

**(non-Web-based information sources)**



**30 Years of *ChemMatters***

Available Now!

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [http://ww.acs.org/chemmatters](http://www.acs.org/chemmatters)**. Scroll about half way down the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**

Hesse, J. Mystery Matters:Tainted Water. *ChemMatters* **1988**, *6* (1), pp 13–15. Skepticism plays a large role in science, as perhaps it should in daily life. This article tells the story of a family considering the purchase of a water purification device being sold by a salesman. Healthy skepticism and an understanding of chemistry save the day.

Cardulla, F. Pseudoscience—Too Good to be True? *ChemMatters* **2002,** *20* (1), pp 4–5. While this article doesn’t deal with chemistry demonstrations, it does deal with the need for students to remain skeptical (or maybe, more correctly, analytical) about things they hear of or read about. Cardulla suggests “sifting through the claims” and “using science—REAL science” to find out the truth about things that sound too fantastic to be true.

Herlocker, H. Life in a Greenhouse. *ChemMatters* **2003**, *21* (3), pp 18–21. Author Herlocker describes the greenhouse effect and explains it in terms of molecular vibrations of the greenhouse gases. She compares both their effectiveness at absorbing and re-radiating infrared energy, and their relative abundances in the atmosphere. This would be a good introductory article for students who want to learn more about the actual greenhouse effect.

Becker, R. Question from the Classroom. *ChemMatters* **2005**, *23* (1), p 2. In this article, author Bob Becker discusses the student misconception that only the wick burns when a candle burns. He talks about flash point when showing that candle wax by itself doesn’t get hot enough to burn when you try to light it with a match.

Becker, R. Question from the Classroom. *ChemMatters* **2006**, *24* (2), pp 2–3. In this article, author Becker discusses the “oil and water don’t mix” or hydrophobicity demonstration, and its accompanying—possibly wrong—explanation. He addresses the misconception that oil and water have no attraction for one another, or may actually repel one another. Becker has a knack for explaining tough concepts at a level students can understand—and appreciate.

Becker, R. Question from the Classroom. *ChemMatters* **2008**, *26* (1), pp 2–3. Here’s another demonstration that we all know is true—or is it? Becker investigates the role that tapping on the sides of a can of soda plays in preventing an explosion of bubbles and soda when opening a closed, shaken can of soda.

# Web Sites for Additional Information

**(Web-based information sources)**

**More sites on why teachers *do* demonstrations**

This document from George Bodner, Professor of Chemistry at Purdue University, published in the *Journal of the Royal Society of Chemistry*, U.K (2001), explains the benefits to teachers of doing chemistry demonstrations. (“Why Lecture Demonstrations Are ‘Exocharmic’ For Both Students And Their Instructors”, <http://chemed.chem.purdue.edu/chemed/bodnergroup/PDF_2008/71%20Demos%20UCEd.pdf>)

This paper from Elisha Swanson discusses in some detail the pros and cons of using demonstrations in the classroom: <http://bradley.bradley.edu/~campbell/elishapaper.htm>.

If you want to know more about whether or not demonstrations actually improve student understanding/retention of concepts, read this Masters’ Thesis, *The Use of Classroom Demonstrations to Improve High School Students’ Ability to Understand Concepts in Chemistry*. It discusses many research studies testing that very hypothesis. The author’s own study involved testing differences in understanding of a concept between students who merely observed the demonstration and those who were first asked to predict what would happen, observe the demonstration, and then compare their prediction to the actual outcome. As might be expected, predictions and analysis of outcome improved understanding.

(<http://etd.lsu.edu/docs/available/etd-06272013-101731/unrestricted/(shelton)thesis.pdf>)

Here’s a second, similar study with similar results, *Interactive lecture demonstrations:*

*a tool for exploring and enhancing conceptual change*, from the Department of Science Teaching, the Hebrew University of Jerusalem, Israel: <http://www.rsc.org/images/Ashkenazi%20paper2%20final_tcm18-85042.pdf>.

**More sites on teaching using demonstrations**

Hubert Alyea (1903-1996), a Princeton professor and world-renowned chemical demonstrator was recorded for posterity doing one of his world-famous chemistry demonstration sessions in this video (28:26): <https://www.youtube.com/watch?v=jSw7cHfxbu8>. The presentation here is very fast-paced, but it gives you the flavor of this master-demonstrator and why his demonstration sessions, “Lucky Accidents, Great Discoveries and the Prepared Mind”, were almost always standing-room only. He not only taught chemistry with his demonstrations, he also taught life skills and attitudes. His advice to the (primarily student) audience, “Be expert, be human and have self-confidence.” And he had stories about famous scientists to illustrate each point. For those us (old-timers) lucky enough to have actually attended his demonstration extravaganza, well, as the saying goes, we’re lucky enough.

Carleton College collaborates with many other colleges in the Interactive Lecture Demonstration (ILD) method of teaching. This site provides detailed information about the method: <http://serc.carleton.edu/introgeo/demonstrations/index.html>.

Chemistry demonstrator David Katz provides this 5-page discussion, “The Art of Effective Demonstrations: <http://www.chymist.com/Effective%20demonstrations.pdf>.

**More sites on sources of demonstrations (to learn how to do them yourself)**

This Web site offers information on the now-5-volume set of *Chemical Demonstration: A Handbook for Teachers of Chemistry* books edited by Bassam Shakhashiri. They are widely recognized as the definitive set of books on chemical demonstrations. This Web page shows the titles of all the demonstrations in each of the 5 books. (<http://scifun.chem.wisc.edu/DemoSeries/demoser.html>) The series of books is for sale on the site.

This site offers 60 demonstrations, by title, from Bob Becker, chemistry teacher and demonstrator par excellence. He specializes in simple demonstrations to illustrate a specific point. (<http://chemmovies.unl.edu/chemistry/beckerdemos/bd000.html>)

An online *Chemical Demonstrations Booklet*, by Magda Wajrak, of the School of Natural Sciences at Edith Cowan University, in Western Australia is available as a pdf document (2008 copyright). The 43-page booklet contains very detailed instructions and safety information on 21 demonstrations for 19 different topics in a typical high school chemistry course. Close-up photographs before and after the event show in detail what students are expected to see in the reaction(s). [Note that the booklet contains several demonstrations that have safety concerns here in the U.S., such as using a zinc/mercury amalgam, and using KMnO4 with 30% H2O2.] (<http://www.ecu.edu.au/__data/assets/pdf_file/0006/358557/ECU_Chemical_Demos_Booklet.pdf>)

In 1995, the Royal Society of Chemistry published a book, *Classic Chemistry Demonstrations*, compiled by Ted Lister. The book contains 100 chemistry demonstrations that cover the gamut of topics in a typical high school chemistry course. They even have correlation tables that show the reader what demonstration relates to what topic, so you can choose a demonstration based on what you are teaching that day! General safety is discussed for each chemical, all in one section of the book. Keep in mind that this book is now 20 years old, so you will need to ascertain the safety of the chemicals and the demonstration for yourself (as always). SDSs need to be reviewed for safety before you do any of these (or any) demonstrations. All the demonstrations are organized the same way, with topic, timing, level, description, apparatus, chemicals, method/alternative method, visual tips, teaching tips, theory, notes, extensions, and safety. (<http://www.rsc.org/learn-chemistry/content/filerepository/CMP/00/001/001/Classicdemos_full.pdf>)

Many sites such as this one <http://chemistry.about.com/od/chemistrydemonstrations/> from about.com provide chemistry demonstrations as well. Unfortunately, the directions and descriptions and safety precautions are often lost in the myriad advertisements that seem to cover the screen.

The Department of Chemistry and Biochemistry at James Madison University sponsors their ChemDemo Web site at <http://sites.jmu.edu/chemdemo/category/lesson-plans>. Here, seventeen (17) demonstrations are shown, complete with directions, lesson plans, student handouts, PowerPoints, etc. Forty-six (46) more are shown that have a complete set of directions (still very complete), but no PowerPoints or lesson plans. The set of tabs at the top separates the groups for you.

This Royal Society of Chemistry (U.K.) site provides a series of 19 videos of chemistry demonstrations aimed at teachers who might want to reproduce the demonstration live with their students in class. Each video is accompanied by notes or pdf files, some taken from the *Classic Chemistry Demonstrations* booklet mentioned above. (<http://www.rsc.org/Education/Teachers/Resources/Practical-Chemistry/Videos/>)

**More sites on sources of video demonstrations (in case you don’t want to do them yourself, or want to *learn how* to do them yourself)**

This series of videos showing 12 demonstrations done by Professor John Dolhun of MIT, accompanied by Professor Bassam Shakhashiri of UW-Madison, are part of the MIT Open Courseware program: <http://ocw.mit.edu/high-school/chemistry/demonstrations/videos/>. Teaching notes accompany each video to help teachers do the demonstration live in their own classroom.

Mr. Kent’s Chemistry Page provides a set of 6 Web pages containing 65 videos showing various physical and chemical demonstrations. The KentChemistry site also contains 6 HD videos on chemistry demonstrations. (<http://www.kentchemistry.com/KentsDemos6.htm>)

This Web site from Chemicum, scientists and lecturers from the University of Tartu in Estonia, is gathering/producing videos for “100+ Experiments in Chemistry”. The site, developed for high school teachers, is in the development state. Some of the videos presently appear only as video clips, with no commentary/narration (blue links—these are still under development), while others (green links) appear with commentary on the screen describing the demonstration set-up and what’s happening, and then offer explanations (which can be paused to give you time to develop those for your class. There is even a drawing tool on-screen so that you can pause the video and draw (in multiple colors) as on a SmartBoard® to emphasize a point or to give students more information. There is a bit of a learning curve to discover what all the tools on the screen border can do (they blink on and off as the video begins, but it’s too fast to actually recognize the buttons). However, this seems like it would be a very useful Web site, especially for teachers who don’t want to, or can’t, do demonstrations in their classes. (<http://www.chemicum.com/chemistry-videos/>)

**More sites on history of the burning candle demonstration**

Here is an online source of the original Faraday book *The Chemical History of a Candle*: <https://archive.org/details/chemicalhistoryo00faraiala>. The Gutenberg Project also has a text-only version available here: <http://www.gutenberg.org/ebooks/14474>.

**More sites on the burning candle demonstration**

The *Journal of Chemical Education* published an article in their January 2008 issue entitled “A Bright Spark: Open Teaching of Science Using Faraday’s Lectures on Candles”. It details how the three authors used Faraday’s candle lectures to prepare an original inquiry-based lesson on candle burning. The lesson proceeds through a series of questions posed by the teacher that eventually take students through most of the experiments Faraday did in his lecture series. (Walker, M.; Groger, M.; Schluter, K. A Bright Spark: Open Teaching of Science Using Faraday’s Lectures on Candles. J. Chem. Educ., **2008**, 85 (1), p 59, <http://pubs.acs.org/doi/abs/10.1021/ed085p59>) (abstract only—full pdf document available online only by subscription)

This 13-page document, “Candles under Jars”, provides a very detailed explanation of all of the problems associated with the burning candle demonstration: <http://misconceptions.science-book.net/wp-content/uploads/2011/09/Chap2-1.pdf>.

**More sites on the greenhouse effect demonstration**

Here’s another site for the “Climate Change 101” (4:33) video clip of the Bill Nye greenhouse gas experiment discussed previously in this Teacher’s Guide: <http://vimeo.com/28991442>.

This site contains lots of information about the greenhouse effect. It provides several charts showing how solar energy enters and leaves our Earth system. (<http://zebu.uoregon.edu/1998/es202/l13.html>)

And this site, <http://www.ems.psu.edu/~fraser/Bad/BadGreenhouse.html>, shows us many misconceptions we have about the greenhouse effect. And note, he pulls no punches!

**More sites on electrostatic deflection of liquids demonstration**

Here’s a 0:15 video clip showing the deflection of water by a glass rod. Charging is optional (must have been done off-screen). (<https://www.youtube.com/watch?v=w8Z7HuA07to&feature=player_embedded>)

This 4:12 video clip from Flinn Scientific features Irwin Talesnick, from Queen’s University, Ontario, CA. Presenting this demonstration to teachers, he discusses the difference between polar and nonpolar molecules and uses two burets with water and toluene to show deflection with water and no deflection with toluene. He shows that both negative and positive rods attract water. As these videos from Flinn are meant to be teaching tools, he offers no explanations. (<https://www.youtube.com/watch?v=KfcVf_PdXjk>)

This 2:08 video clip from Frostbite Theater (“Cold Cuts … No baloney, just science!”) from the Office of Science Education at the Jefferson Lab National Accelerator provides a great (albeit *incorrect*) explanation of the deflected water stream, based on the rotating of the polar water molecule such that the end of the molecule that moves toward the charged rod is the oppositely charged side. (<https://www.youtube.com/watch?v=VhWQ-r1LYXY&feature=player_embedded>)

This 5:12 video clip of a classroom lesson on polar and nonpolar molecules shows side-by-side demonstrations of liquid streams of oil and water as the teacher discusses why they are polar and nonpolar and why the nonpolar stream is not deflected. The explanation is the old standard, “The positive part of the stream is attracted to my negative rod.” (<https://www.youtube.com/watch?v=k4AdJ2PSIco>)

This site from the journal of the American Association of Physics Teachers, *The Physics Teacher*, (*Phys. Teach.* 52, 266 (2014)), reports on research done trying to deflect a *horizonta*l surface of a still liquid using a charged rod, and finally, using a van de Graaff generator: <http://scitation.aip.org/content/aapt/journal/tpt/52/5/10.1119/1.4872403>. Photos are included.

**More sites on other demonstrations that are not quite what they seem**

**The “Dissolving” Styrofoam™ in acetone demonstration**

About.com usually has correct explanations of chemical phenomena, but in this case, their explanation needs a bit of work as they discuss the solubility of Styrofoam in “Dissolve Styrofoam in Acetone”: <http://chemistry.about.com/od/polymers/a/Dissolve-Styrofoam-In-Acetone.htm>.

This short video clip (0:45) from Steve Spangler Science’s “Sick Science” series shows a foam cup disappearing in acetone: <https://www.youtube.com/watch?feature=player_embedded&v=Bb6-hpe2KcY>. The only explanation given on the discussion page is that, “The acetone easily dissolves the polystyrene, leaving very little residue.” Neither of the statements is exactly true; the [expanded] polystyrene doesn’t actually dissolve, and there’s lots of polystyrene “residue” (although, relative to the original amount of expanded polystyrene, the amount of “defoamed” EPS is small). The rest of the description focuses only on the various ways you can make the demonstration fun for kids to watch, not further explanation.

**The air has mass demonstration**

This video clip (1:30) shows two ways to show that air has mass. The first is the bursting balloon experiment as described previously in this Teacher’s Guide, with one change: the balloon is cut at the neck, where the balloon is relatively unstretched. That results in the slow release of air, so that the balloon doesn’t burst, shred, and send balloon shrapnel all over the room. The deflated balloon seems to weigh less than the still-inflated one. So again, both balloons must have been inflated to their maximum, putting more air in the remaining inflated balloon under pressure, meaning more air mass. The second way uses a small soccer ball weighed (massed?) on a balance, deflated, and then inflated, to show that the air pumped in actually has mass. This is a more direct way of showing the mass of air—or that air has mass. (<https://www.youtube.com/watch?v=sCqVUmoOojI&feature=player_embedded>)

Even this 4-second clip artist’s illustration of the balanced balloons changing level on the meter stick after bursting one balloon indicates pieces of “balloon shrapnel” remaining at the bottom of the screen, which would make the deflated balloon lighter, no matter what: <https://www.youtube.com/watch?v=UY1q_Jg_tiQ&feature=player_detailpage>.

This 1:45 video clip of a teacher in a classroom shows part of his lecture/demonstration to show air has mass, using a 1-L soda bottle and a “fizz-keeper”. He weighs the bottle “empty” and then pumps it up with the fizz-keeper to put more air in and weighs it again. More air, more weight. (<https://www.youtube.com/watch?feature=player_detailpage&v=kmpPh_wV0JI>)

**The hydrophobic effect demonstration**

This Wikipedia site provides a bit more detail about the reason that oil and water don’t/can’t mix: <http://en.wikipedia.org/wiki/Hydrophobic_effect>. Part of the article is suspect, but the section “The origin of hydrophobic effect” provides clear information. This link <http://en.wikipedia.org/wiki/Entropic_force#Hydrophobic_force> within the aforementioned article provides more depth.

This site from Brandeis University provides a cohesive picture (a professor’s class lecture, actually) of the entropy-driven reactions preventing mixing of hydrophobes (nonpolar molecules) with water: <http://www.bio.brandeis.edu/classes/biochem104/hydrophobic_effect.pdf>. It also clearly defines what the hydrophobic effect is and why it exists.

# General Web References

**(Web information not solely related to article)**

We’ve cited lots of Web pages from the ChemMovies Server operated by Dave Brooks, at the University of Nebraska-Lincoln, in many past Teacher’s Guides. But the home page provides links to entire other internal database sites that cover the gamut of chemistry for high schools. Here are the major tabs: *Doing Chemistry, Microscale Experiments, Biotechnology, Becker Demo Series, Smallscale Experiments, ChemSource, Redox Project, LABS Project,* and *ChemAnimations*. Each tab takes you to a wealth of chemistry information. And it’s all free! Enjoy! (<http://dwb4.unl.edu/Chemistry/chemmovies.html>)

The 5-volume set of books *Chemical Demonstration: A Handbook for Teachers of Chemistry*, edited by Bassam Shakhashiri of the University of Wisconsin-Madison, is widely recognized as the definitive set of books on chemical demonstrations. Each book focuses on specific areas of chemistry (e.g., book 1 covers thermochemistry, chemiluminescence, and color and equilibria of metal ion precipitates and complexes, while book 3 covers acids and bases and liquids, solutions and colloids). Each demonstration provides: a brief description of the demonstration; a materials list; step-by-step procedure to do the demonstration; explanation of the hazards involved; information about storage and disposal of the chemicals used; a detailed explanation of the chemistry behind the demonstration and the principles illustrated; and a list of references. This Web page shows the titles of all the demonstrations in each of the 5 books, a total of 335 demonstrations! It also shows where the books can be purchased. More books in the set are expected in the future. (<http://scifun.chem.wisc.edu/DemoSeries/demoser.html>)

I listed this site in the “More sites on sources of video demonstrations”, but it deserves to be bookmarked as a general reference, a source of video demonstrations whenever you need one. The site from Chemicum, scientists and lecturers from the University of Tartu in Estonia, has videos for “100+ Experiments in Chemistry” (110 presently). Check it out at <http://www.chemicum.com/chemistry-videos/>.