The How and The Why

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Abstract

How? By examining the behavior of the ordinary substances of our everyday lives. Why? To understand what science is and how the principles of science not only govern the physical world we live in but affect as well the societal judgments we make in managing that world. This How/Why duo evolves into two themes that play major roles in teaching chemistry to non-science students: 1) The substances of our daily lives are all chemicals. (Use plenty of common consumer products in lecture demonstrations.) 2) An understanding of science helps clarify some of the most important societal problems we currently face. (What are some realistic alternatives to the gasoline engine?) This paper will explore these topics in detail.

Introduction
Abstract

First, a disclaimer. I have written a textbook for nonmajors, "The Extraordinary Chemistry of Ordinary Things." In principle, I'd prefer that the following presentation remain at some distance from the textbook and its contents. In practice, my sense of how and why chemistry ought to be taught to nonscience students constitutes the core of what I have put into the textbook, and the contents of the textbook serve as fine illustrations of the *How* and the *Why* of this presentation. So while I am uneasy that what follows is closely connected in spirit and in examples to the textbook, I see no way around the dilemma except to come clean at the very start.

Much has been written about the inherent value of teaching science and chemistry to nonscience students, often from the viewpoint of chemistry as a liberal art. I'm more concerned about practical aspects, particularly:

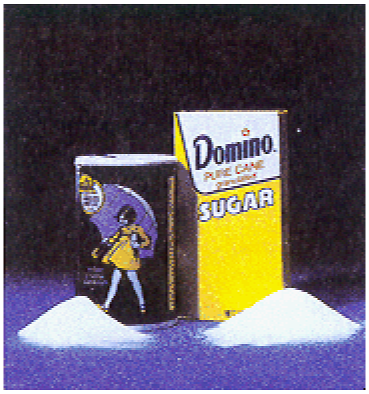
- **that students come to understand that we deal constantly with chemicals, and that when we label these substances of our everyday lives as "chemicals" we do not characterize them as inherently evil, and**

- **that students learn enough chemistry to be able to make intelligent societal decisions about chemicals and their effects.**

The How

As often as possible, use common, everyday substances, especially consumer products, to illustrate chemical principles. Lecture demonstrations performed with chemicals that come from reagent bottles may well demonstrate chemical principles in spectacular ways, but they also serve to emphasize the remoteness of the reagents -- the chemicals -- from our everyday lives. On the other hand, pouring the materials out of boxes or bottles that bear the labels of consumer products available in supermarkets or drugstores nicely connects the science of chemistry with our own everyday lives.

I like to begin with table salt and table sugar, among the most mundane of substances.

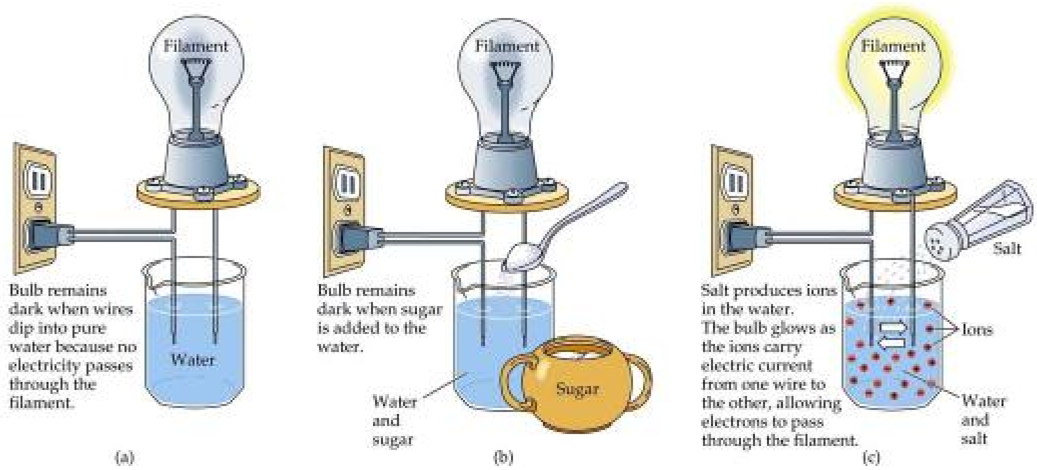


Ask students if, given two unlabeled piles of the white, crystalline substances, they could tell which is which. This begins a discussion that culminates in a most unusual method for distinguishing salt from sugar: an examination of their effects on the electrical conductivity of common tapwater.

The demonstration, which uses an electric bulb screwed into a socket with two protruding bare copper wires, gives rise to an impressive bit of classroom theater. The results are well known, but it's nice to include in the patter an observation that the demonstration presents a hazard of electrocution. "If my hair stands on end, my eyes light up, and I start emitting sparks, the course is ended and everyone gets an A."

(I carry out the demonstration with common tap water, water containing some table sugar, and water containing some table salt. The illustration below shows three sets of apparatus; I use only one, cleaning off the disconnected bare wires after each use, with a dramatic show of caution as I touch each *disconnected* wire.)

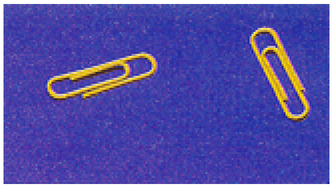
This starts us off with some chemistry of the most common of household substances and moves us quickly to electrolytes, ions, and related topics.



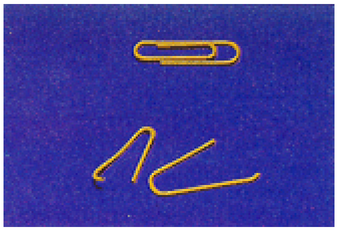
A pile of paper clips gives us an entry to atoms. Granted, we're not dealing with the chemicals that constitute the physical paper clips themselves, but the clips, singly and as a group, represent atoms nicely. A pile of paper clips

can be divided and subdivided repeatedly

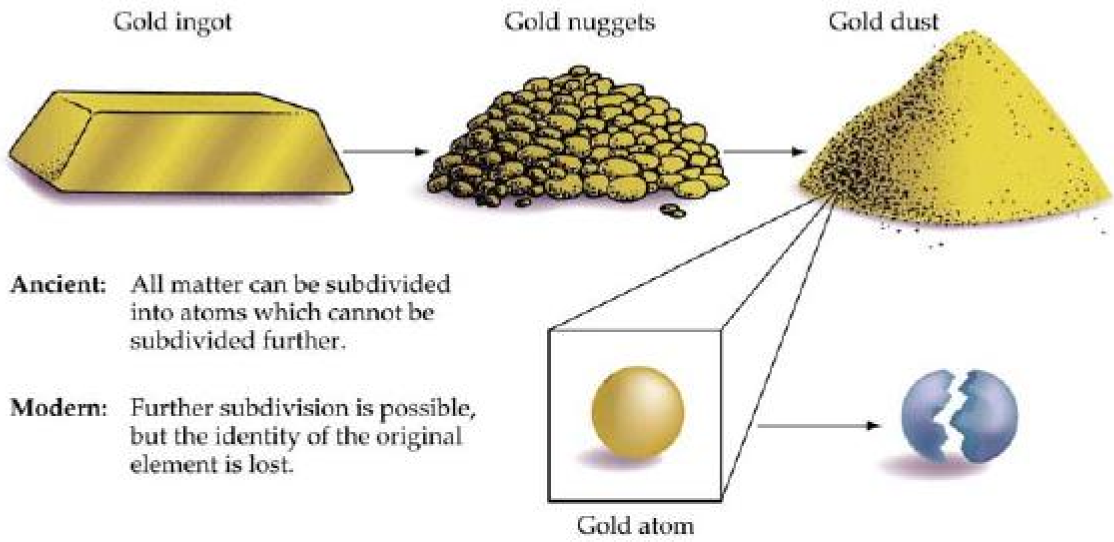
until we're down to just one paper clip, an "atom" of paper clips. This is the smallest particle of the pile of paper clips that we can identify as a paper clip.



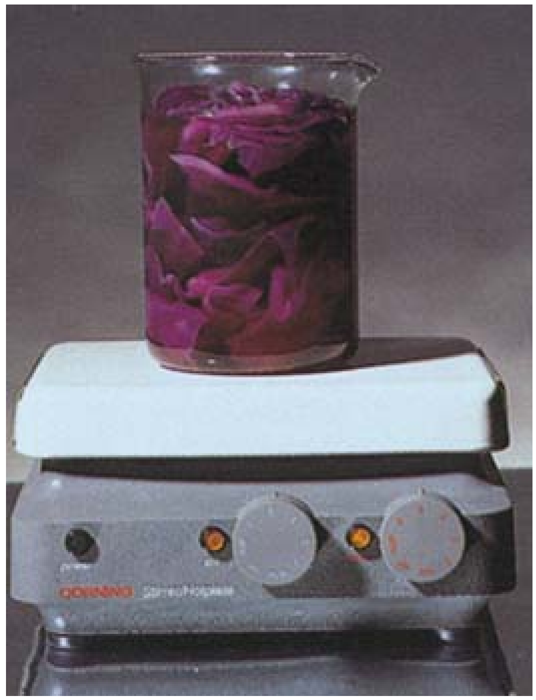
Then what do we do? Well, it's possible to "subdivide" that single paper clip further, into two pieces. But it isn't easy, and when we do break apart the single paper clip we no longer have a paper clip. We now have something new, perhaps a couple of ornaments for pierced ears, or maybe crude fishhooks. And so it is with atoms.



A bar of gold offers a popular extension of the concept, transferring the process of division and subdivision to a chemical, now an element.



So much for introductory examples. For more advanced chemical concepts, still employing substances (chemicals) of everyday life, we can use the anthocyanins of red cabbage as acid-base indicators,



illustrate redox as galvanized tacks decolorize a drugstore iodine solution,

and watch a vitamin C tablet decolorize drugstore iodine (illustrating both redox and the antioxidant properties of vitamin C)

only to have the color return on addition of a drop of household bleach (as the recently formed I^- is oxidized back to the original I_2).

Adding a drop of bleach to a control tablet of vitamin C shows that the returned color doesn't come from an interaction of the bleach solution and the vitamin C itself, and opens the way to a discussion of the scientific method.

Finally, we can generate air pollution in the classroom, in front of the students,

by lighting a match in a candle flame and swinging the still-flaring match under a piece of kitchen paper wet with an anthocyanin (red cabbage) solution. Snuffing out the flaring match in the anthocyanin solution produces a nicely visible red spot.

A control demonstration, in which the other end of the extinquished match is ignited in the candle flame and extinguished on the wet paper, does not produce a red spot. This demonstrates that the red spot came specifically from the flaring match and is not produced generically by flames.

Adding a drop of vinegar to a different region of the wet paper shows that the red spot results from an acid (SO_2) in the flare and leads to a discussion of sulfur-contaminated fuels as a source of acid-rain.

The Why

This last demonstration provides a nice transition to the *Why* of teaching chemistry to nonscience students. If the red spot is produced by an acid generated by the flaring match, then has striking the single match in the classroom actually polluted the classroom air? Would a million of us generate air

pollution by striking a million matches at the same time? Do we produce acid rain by striking matches? One match? A million matches? What, in the end, *is*pollution?

The discussion is moved along by a demonstration in which you dissolve a teaspoon of table salt in a glass of water and ask if anyone would drink from it. Then perform a series of dilutions in which the original solution and each subsequent solution is diluted by a factor of 10.

Ask if anyone would drink from the second glass? from the third? the fourth? the*n*th? This brings us to the question of what pollution is, how we might define it, and perhaps most important, the distinction between our own, individual senses of what level of contamination is acceptable to each of us individually, and what level is acceptable to us as a common society.

This last, societal level is set by the federal government, run by our elected officials. (It's 160 ppm for sodium in community water supplies; a simple calculation pinpoints the glass where pollution ends, or begins.) Among the questions I ask: "Shall we consider pristine sea-water, untouched by any human activity, to be polluted"?

The *Why* then -- aside from any consideration of chemistry as a component of a liberal education -- is one of the foundations of effective self-government.

We can extend the concept to some of our more pressing societal issues, such as the question of alternative sources of energy for our cars. Does the use of fossil fuels really contribute significantly to global warming? What are the costs and benefits of replacing gasoline by electric power? Where would all this newly needed electric power come from? From plants that operate, themselves, on fossil fuels? Would it be generated by nuclear power plants? What does our knowledge of chemistry contribute to our analysis of the benefits, the risks, the costs?

Somewhere in this discussion I always propose using wind power to move our cars. Equip the cars with sails on their roofs, I say, like our sailboats, and let the wind move them directly. This would be easy enough if we drive with the wind behind us, or to our sides. If we want to drive directly into the wind we simply tack back and forth along our streets as a sailboat would. In this case we'd hardly recognize the difference between the resulting zig-zag travel of our cars along our highways and the way we normally drive in Miami.

But the important point is that deciding which source of alternative power would be the most attractive requires an understanding of the chemical consequences of each.

Conclusion

One of the most frequent requests I get in my end-of-term evaluations is for more demonstrations with the common substances (chemicals) of our everyday lives. These demonstrations move chemicals from the esoteric to the commonplace. So much for the *How*.

As for the *Why*, we owe it to our students to equip them intellectually for the decision-making roles they will play as mature citizens. What better way than by providing them with an understanding of the substances that not only form the universe they live in, but that shape each moment of their daily lives, the substances we educators call *chemicals*.