The False Dichotomy of Chemical and Physical Changes

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A long time ago people observed changes in matter and attempted to classify them as either chemical or physical. Perhaps this classification made sense then, but does it now?

If the temperature or pressure of a sample of water is changed, its characteristic properties also change. Heating water changes its density, viscosity, refractive index, and other characteristic properties. And if heated above its boiling point, water changes to steam. If the water sample is returned to its initial temperature, the steam condenses and the characteristic properties return to their initial values. But if carbon is burned to form a gas, one cannot get the original carbon back by returning the gas to the original temperature and pressure of the carbon.

There seems to be something important and fundamentally different about these changes. A long time ago someone called one a physical and the other a chemical change. Labeling these changes caused others to think that they understood what happens when water is heated and carbon burned. They probably thought, "Permanent changes affect the chemical nature of matter, but those that can be reversed affect only the physical nature of matter." It may have made sense at the time, but how does labeling and classifying changes help students to know and understand what happened?

Consider another change in water. Copper(II) sulfate and sodium chloride, both white salts, dissolve in water to form respectively blue and colorless solutions. What caused the changes in colors? Was dissolving a chemical or physical change? Are the original solid substances recovered if the solvent evaporates? Deciding whether dissolving is a chemical or physical change becomes "word play" or "definition nitpicking." Such distinctions distort and obscure the learning of science.

Later investigators helped us to understand these changes. The concept of atomicity was enlightening. Chemical composition became a laboratory challenge. Chemical reactions were carefully and laboriously studied. Testable explanations were posited to explain the chemistry of heating water, burning carbon, and dissolving salts. Subsequently, these explanations were tested. The practice of classifying changes into chemical and physical categories began to fade away.

Many scientists realized decades ago that classifying changes of matter as either chemical or physical may have worked in a former time, but new knowledge made these categories irrelevant. Medicine came to a similar conclusion after seeing that not all diseases are caused by foreign substances entering the body. For example, does a foreign material cause sickle cell anemia or Huntington's disease? As more was learned about the Kuiper Belt beyond Neptune, astronomers have met to decide what is and is not a planet. Sadly, Pluto was released from the planet team without a change in any of Pluto's properties. This is the fate of labels and rules in science—they change because our knowledge increases and not because nature changes.

None of the editions of *Introductory Physical Science* (*IPS*) have classified changes and properties of matter as either chemical or physical, nor will they. The authors are aware that many state standards insist on identifying changes as either chemical or physical. State achievement tests have questions requiring students to distinguish between chemical and physical changes. But do chemists classify changes and properties in their laboratories?

Teaching arbitrary categories, like chemical or physical changes, has never been a part of the *IPS* curriculum. No *IPS* student has been taught a difficult scientific concept by "dumbing it down" to their level, or a useless concept because it appears on state standards, or one that he or she must relearn correctly at a later date.

IPS students are treated as mature learners while in the middle school, and the authors are vigilant to ensure that only sound science is presented in the *IPS* course. *IPS* students perform laboratory experiments to:

1. measure characteristic properties of solids, liquids, and gases;
2. separate mixtures by use of distillation, solvent extraction, and paper chromatography;
3. separate compounds into their constituent elements by use of electrolysis and chemical reactions; and
4. synthesize chemical compounds.

These processes, regardless of whether they might be classified as physical or chemical, are used to develop the fundamental and useful ideas of mixtures, pure substances, elements, and compounds. Students can use these ideas for many years in future study and everyday life.