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tested demonstrations

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An Analogical Verification of the Discontinuity of Matter Based on the Law of Definite Proportions

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Is matter continuous or discontinuous? Is a piece of wood composed of a continuous mass with not even the smallest crevice in its innermost recess or of ultimate particles separated by empty spaces, so infinitely small that they are unable to be seen?

The origin of this question dates back many centuries to ancient Greece—where the continuous theory and the atomic theory of matter were developed, their principal advocates being Aristotle and Democritus, respectively. These two currents of thought, with all their variants, have run parallel through the course of history, first one predominating, and then the other. Chemistry, whose purpose is the study of matter, had to confront this problem from the very beginning and the development of its theory was greatly checked until a final solution was found.

The following demonstration offers a simple analogical procedure that permits the student to obtain data that decisively proves one of the two hypotheses. This is accomplished by contrasting their predictions to a known experimental law. This way the hypothesis that predicts the experimentally observed law is the correct one. The procedure is thus the same as that followed by scientists when they investigate. In order to visualize and to better manipulate the suppositions of both hypotheses, this demonstration uses the analogy of representing continuous matter with Play-Dough® and discontinuous matter with nuts and bolts.

The experimental law that is used in each case to prove whether the hypothesis is valid will be Proust's Law of Definite Proportions. The advantages of this law are that first it possesses a simple structure and second that it clearly points to one of the two hypotheses as true thus definitely eliminating the other.[1]

The following demonstration is especially apt for the high school level when the Laws of Chemical Combinations are first being studied. I have used it at various times in class, always with excellent results. It is a formative exercise because: (1) it treats one of the most important problems in the history of philosophy and science, (2) it permits the practice of the scientific method, (3) it offers a good opportunity to practice the use and manipulation of the balance.

Demonstration

Let us consider the reaction of substance A with substance B, supposing first that matter is continuous and afterwards that it is discontinuous. In each case we will see if the Law of Definite Proportions is carried out.

Matter is Continuous

Substances A and B will be represented in this first case by two pieces of different-colored Play-Dough®, yellow and blue for example.

(1) Take a piece of yellow Play-Dough® and another of blue Play-Dough®, but of different sizes. Weigh them. Simulate the chemical reaction between A and B by massing the pieces together. In this way, it can be observed that no quantity of A or B is left out of the "reaction." Calculate the ratio of weight A/B that took part in the "reaction."

(2) Now take two other pieces of Play-Dough® more equal to each other in size. Repeat the operations. Calculate the ratio A/B and thus observe the difference between this result and the former one.

Conclusion: Departing from the hypothesis that matter is continuous, we cannot arrive at the Law of Definite Proportions.

Matter is Atomic

In this part, substance A will be represented by nuts and substance B by bolts, all of equal size and shape within their respective classes.[2]

(1) Take two heaps, one of nuts and one of bolts, making sure that one is larger than the other. For example, let us suppose that we have more bolts than nuts. The reaction is simulated in this case by screwing the bolts into the nuts one by one. Due to their greater number, however, some of the bolts remain free. In other words, there is an excess of one of the "reactants." "Decompose" the "molecules" AB thus formed by unscrewing them. Weigh the nuts and bolts which formed them separately, thus finding the ratio of weight A/B.

(2) Repeat the operation with two different heaps and with the new data obtained, calculate the ratio A/B again; the result will coincide with the original one.

Conclusion: Departing from the atomic hypothesis, we can explain the Law of Definite Proportions.[3] This can be used as a proof that matter is discontinuous.

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[1] Asimov, I., "A Short History of Chemistry," Doubleday, New York, **1965**, pp. 72–73.

[2] The weight of each bolt should be approximately 1–1.5 g and that of each nut approximately 0.5–1 g. There should be a difference of at least 0.2 g between them.

[3] An easy way to explain the Law of Multiple Proportions based on Atomic Theory is to screw one bolt into two nuts. In this way "molecules" A_2B are formed which can be compared to "molecules" AB.

Chemistry Concatenated

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A series of consecutive chemical reactions featuring reversible equilibria has been developed. There are nine major color changes most of which feature alternation between colorless and colored solutions, all resulting from colorless