An Introduction to Chemistry

This course has two basic structures in the textbook. The first is a group of fundamental tools necessary to work within chemistry and the second is a fundamental group of ideas required to progress in chemistry. The former includes units, methods of problem solving, atomic structure and how chemicals are named, for example. This material is primarily learned through memorization. The ideas we will cover include heat transfer and chemical bonding. Both are central to learning chemistry and progressing through all chemistry courses.

You need to know the definitions of scientific terms accurately. Like all of the sciences, chemistry has a unique vocabulary. Some technical words used in chemistry will have meanings similar to the same words used in everyday speech; others will have very different meanings. For example, to someone working in an appliance store, the word "element" might refer to the heating coil in a toaster. Needless to say, it means something entirely different to a chemist. Just as one cannot speak a foreign language without knowing its vocabulary, one cannot understand chemistry without learning its terminology. In this chapter we will cover some of the basic concepts necessary to begin discussing chemistry. **Know the definitions of underlined words**.

1.1 The Nature of Chemistry

Read this section on your own.

1.2 A Scientific Approach to Problem Solving

The process called the "scientific method" is process of problem solving that will most consistently produce the true answer. The process is value neutral and relies on a logical use of information to move from step to step. The process can be applied to almost any problem, scientific or otherwise. There are three components associated with the scientific method: the hypothesis, theory and law.

The process always begins with observations from which a problem is identified. In chemistry, it might be that you want to make a new compound or improve the preparative yield of an existing one. Outside of the physical sciences, it could be that you want to understand why people choose to shop in a store instead of online or how to make a better barbeque sauce. The process for answering these questions is essentially the same.

For the chemistry example, the observations might be the experiments that showed a need for the compound or the knowledge that the current process is wasteful of the materials you begin with. Once you have a problem, you propose one or more ways to solve the problem. Generally, more proposed solutions are better to increase the likelihood of at least one working. Then you try the solution(s) to test which one(s) work. At this point, you select the most promising solution and test if modifying it makes it work better. The process is iterative and you make more modifications until your result isn't an improvement. If the best you can get isn't satisfactory, then you try another one of the hypotheses.

Theories can arise from applying the scientific method, but it isn't a requirement. If you want to make a stronger cup of coffee, the hypothesis would be adding more ground coffee beans to the hot water will lead to a stronger cup of coffee, which is what happens. Even so, there is no theory of stronger cups of coffee. Theories are attempts to explain large questions in science that usually have broad application. In chemistry, you'll learn Dalton's Atomic Theory. Here, Dalton took many observations made over centuries and suggested that the existence of atoms could explain why chemicals reacted and behaved the way they do. For example the fact that compounds react in fixed ratios is consistent with atoms forming compounds with fixed formulae.

Formally, a hypothesis is a tentative, testable explanation for a set of observations. A theory is a well-tested and established explanation for a set of observations. (i.e. it is a hypothesis after repeated successful testing.)

In contrast, there are scientific laws, which are very different and separate from scientific theories. While theories are explanations, laws are essentially statements of fact. Theories never become laws. The law of gravity is a mathematical equation that describes how quickly a body will move towards a heavier one as a function of their masses. There is no reason for why this equation works in the law and it is always correct. Over the centuries there have been multiple theories that attempt to explain the equation though.

1.3 The Particulate Nature of Matter

Central to an understanding of chemistry is acceptance of the idea that all matter is composed ultimately of atoms. Matter is anything that has mass and occupies space. In ancient Greece, more than one model for the tiniest amounts of matter were proposed. Because he was most famous and no way to test the various proposals existed, Aristotle's view that matter could be infinitely subdivided became generally accepted. In the 1600's and 1700's, experiments whose results were more consistent with very tiny particles than a continuous division of matter were conducted. In combination, John Dalton proposed in 1808 the existence of atoms. Somewhat amazingly, his basic description of atoms still holds today.

Chemists are interested in three of the states of matter: solids, liquids, and gases. Solids have definite shapes and volumes, while liquids have definite volumes, but whose shapes are changeable, and gases have both volumes and shapes than can change. Simple analogies for each would be: bricks in a wall for solids, a box filled with balls for liquids, and a lotto machine for gases. There is a common mistake made by people about liquids. It's easy to accept that solids are tightly packed and that gas molecules are widely separated because of what you would have to do to penetrate them. What is commonly misunderstood is that liquids are almost as tightly packed as solids, it's just that in liquids the particles slide past one another relatively easily, whereas in solids they are strongly adhered to each other.

1.4 Classifying Matter

This section has much nuance because many of the terms have overlapping features. We begin with a basic classification of matter. Substances are materials with a definite, fixed composition. That is, they are made of a single thing (pure). A piece of gold or the acetylene used in a welder's shop are both pure substances. There are two basic kinds of substances, elements and compounds. In an element, there is only one type of element present, while in a compound there are two or more elements chemically bound to each other.

Another kind of matter is the mixture, a combination of two or more substances. Mixtures may be homogeneous or heterogeneous. Homogeneous mixtures are uniform in appearance and have the same properties throughout, while heterogeneous mixtures have two or more distinct phases. Solutions are a kind of homogeneous mixture. A common example of this is when one substances dissolves in a second substance (e.g. salt dissolved in water). If you were to pull several tablespoons of the salt water out of the glass, you would find they all tasted identical, looked identical, boiled at the same temperature, etc.

In contrast, different samples of the same heterogeneous substance would likely have different properties, even if the differences are small. Imagine filling a box with 100 balls of which 90 were red and 10 blue. You shake the box and pull 10 balls out. Statistically you would have 9 read and 1 blue ball, but sometimes you would have 10 red and no blue, while in others you might have 8 red and 2 blue. If the balls were molecules, you can see how they might have different properties. (e.g. if you averaged the red and blue, you would see the color change as the ratio of red to blue changed). A salad is a classic heterogeneous mixture.

August 21, 2023