When atoms interact with one another to form molecules or larger structures, the molecules have different properties than their component atoms; they display what are often referred to as emergent properties, where the whole is more than, or different from the sum of its parts. In a similar way groups of atoms or molecules have different properties from isolated atoms/molecules. For example while groups of atoms/molecules exist in solid, liquid, or gaseous states, and often have distinct colors and other properties, isolated atoms/molecules do not; there are no solid or liquid isolated atoms and they do not have a color or a boiling point. So the obvious question is, how many atoms or molecules need to aggregate before they display these emergent properties, before they have a color, before they have a melting point, boiling point, heat capacity, and other properties that isolated atoms do not? The answer is not completely simple, as you are probably slowly coming to expect. As we add more and more atoms or molecules together their properties change but not all at once. You have probably heard about nanoscience and nanotechnologies, which have been the focus of a great deal of research and economic interest in the past decade or so. Nanoparticles are generally classified as being between 1 and 100 nm in diameter (a nanometer is one billionth of a meter or $1 \times 10^{-9}$ m). Such particles often have properties that are different from those of bulk (macroscopic) materials. Nanomaterials can be thought of as a bridge between the atomic-molecular and macroscopic scales.

Assuming that they are pure, macroscopic materials have predictable properties and it doesn’t really matter the size of the sample. A macroscopic sample of pure gold behaves the same regardless of its size and if Archimedes (ca. 287–212 BCE) were alive today, he could tell you whether it was pure or not based on its properties, for example, its density. But gold nanoparticles have different properties depending upon their exact size. For example, when suspended in water, they produce colors ranging from orange to purple, depending on their diameter (see Figure). Often the differences in the properties displayed are due to differences in the ratio of surface area to volume, which implies that intermolecular forces (forces between molecules) are more important for nanomaterials. As we cluster more and more particles together, the properties of the particles change. Biomolecules generally fall into the size range of nanomaterials, and as we will see their surface properties are very important in determining their behavior.

Unfortunately when we are talking about the properties of atoms and molecules versus substances and compounds, it can be difficult, even for experienced chemists, to keep the differences clear. In addition different representations are often used for different organizational levels; it is an important skill to be able to recognize and translate between levels. We will be using a range of representations to picture atoms and molecules; chemists (and we) typically use various shorthand rules, methods, and chemical equations to represent molecular composition, shape, and behaviors. But just knowing the equations, often the only thing learned in introductory chemistry courses, is not sufficient to understand chemistry and the behavior of atoms and molecules. Much of the information implied by even the simplest chemical equations can easily be missed—or misunderstood—if the reader does not also have a mental picture of what the diagram or equation represents, how a molecule is organized and its shape, and how it is reorganized during a particular reaction. We will be trying to help you get these broader pictures, which should you make sense of the diagrams and equations used here. That said, it is always important to try to explicitly identify what you are assuming when you approach a particular chemical system; that way you can go back and check whether your assumptions are correct.