We see things because photons hit the back of our retinas and are absorbed by specialized molecules (proteins and associated pigment molecules). This leads to changes in protein structure and initiates a cascade of neuron-based cellular events that alters brain activity. So where do these photons come from? First and foremost they can be emitted from a source (the Sun, a light bulb, etc.) that appears to shine and can be seen in the dark. Alternatively, photons can be reflected off a surface; in fact most of the things we see do not emit light, but rather reflect it. A red T-shirt appears red because it absorbs other colors and reflects red light. Photons can also be refracted when they pass through a substance. A cut diamond sparkles because light is refracted as it passes through the material and exits from the many facets. Refraction is caused when photons bump into electrons, are absorbed, and then (very shortly thereafter) are re-emitted as they travel through a material. These processes take time, so the apparent speed of light slows down. It can take a photon many thousands of years to move from the core to the surface of the Sun because of all the collisions that it makes during the journey.

To explain why metals (and graphite) are shiny, we invoke a combination of reflection, refraction, and the energy levels of MOs. When a photon of light is absorbed and reemitted, the electron moves from one orbital to another. Let us consider a piece of metal at room temperature. When a photon arrives at the metal’s surface it encounters the almost continuous band of MOs. Most photons, regardless of their wavelength, can be absorbed because there is an energy gap between orbitals corresponding to the energy of the photon. This process promotes electrons up to a higher energy level. As the electrons drop back down to a lower energy level, the photons are re-emitted, resulting in the characteristic metallic luster. Metals actually emit light, although this does not mean metals glow in the dark (like a light bulb or the Sun). Instead, metals absorb and re-emit photons, even at room temperature.

The color of a particular metal depends upon the range of wavelengths that are re-emitted. For most metals the photons re-emitted have a wide range of wavelengths which makes the metallic surface silvery. A few metals, such as copper and gold, absorb light in the blue region and re-emit light with wavelengths that are biased toward the red end region of the spectrum (400–700 nm) and therefore they appear yellowish. This is due to relativistic effects way beyond the scope of this book, but something to look forward to in your future physical chemistry studies!

Now we can also understand why metals emit light when they are heated. The kinetic energy of the atoms increases with temperature which promotes electrons from low to higher energy orbitals. When these electrons lose that energy by returning to the ground state, it is emitted as light. The higher the temperature the shorter the wavelength of the emitted light. As a filament heats up, it first glows red and then increasing whiter as photons of more and more wavelengths are emitted.

This chapter has brought us to a point where we should have a fairly good idea of the kinds of interactions that can occur among atoms of the same element. We have seen that the properties of different elements can be explained by considering the structure of their atoms and in particular the way their electrons behave as the atoms interact to form molecules or large assemblies of atoms (like diamond.) What we have not considered yet is how atoms of different elements interact to form compounds (substances that have more than one element). In Chapter 4 we will take up this subject and much more.

Questions to Answer

1. What properties indicate that a substance is metallic?
2. Why are metals shiny?
3. How can metallic properties be explained by the atomic-molecular structure of Al (for example)?
4. Why can we see through diamond but not aluminum? How about graphite?

5. Why does aluminum (and for that matter all metals) conduct electricity? What must be happening at the atomic-molecular scale for this to occur?

6. What does the fact that diamond doesn’t conduct electricity tell you about the bonding in diamond?

7. How do the bonding models for diamond and graphite explain the differences in properties between diamond, graphite, and a metal like aluminum?

8. Why is it OK to use different models to describe bonding in different species?

References