# Observations, Theories, and the Planets

Humans have always been fascinated by the heavens—by the behavior of the sun by day and the stars by night. Although more accurately measured now thanks to precise instruments, our basic *observations* of their behavior have remained the same over the past 4000 years. However, our *interpretations* of these observations have changed dramatically. For example, around 2000 B.C. the Egyptians postulated that the sun was a boat inhabited by the god Ra, who daily sailed across the sky.

Over the years, patterns in the changes in the heavens were recognized and, through marvelous devices such as Stonehenge in England, were connected to the seasons of the year. People also noted that seven objects seemed to move against the background of "fixed stars." These objects (actually the sun, the moon, and the planets Mercury, Venus, Mars, Jupiter, and Saturn) were called the "wanderers." The planets generally seemed to move from west to east, but sometimes they seemed to slow down and even to move backwards for a few weeks.

Eudoxus, born in 400 B.C., tried to explain these observations. He imagined the earth as fixed in space and the planets as attached to a set of transparent spheres, each slightly larger than the previous one, that moved at different rates around the earth. The stars were attached to a fixed outermost sphere. This model, although clever, still did not account for the "backward" movement of some of the planets. Five hundred years later Ptolemy, a Greek scholar, worked out a plan more complex than that of Eudoxus, in which the planets were attached to the edges of spheres that "rolled around" the spheres of Eudoxus. This model accounted for the observed behavior of all the planets, including the apparent reversals in their motions.

Because of a natural human prejudice that the earth should be the center of the universe, Ptolemy's model was assumed to be correct for more than a thousand years, and its wide acceptance actually inhibited the advancement of astronomy. Finally, in 1543, the Polish cleric Nicholas Copernicus postulated that the earth was only one of the planets, all of which revolved around the sun. This "demotion" of the earth in status produced violent opposition to the new model, and in fact Copernicus's writings were "corrected" by religious officials before scholars were allowed to use them.

The Egyptian sun-god, Ra (drawn on papyrus).

The Copernican theory persisted and was finally given a solid mathematical base by Johannes Kepler. Kepler's hypotheses were in turn further refined 36 years after his death by Isaac Newton, who recognized that the concept of gravity could account for the positions and motions of the planets. However, even the brilliant models of Newton were discovered to be incomplete by Albert Einstein, who showed that Newton's ideas were just a part of a much more general model.

Thus the same basic observations were made for several thousand years, but the explanations—the models—changed remarkably from the Egyptians' boat of Ra to Einstein's relativity.

The lesson is that our models (theories) inevitably change and that we should expect them to do so. They can help us make scientific progress, or they can inhibit our progress if we become too attached to them. Although the fundamental observations of chemistry will remain the same, the models given in a chemistry text written in 2090 will certainly be quite different from the ones presented here.

## The Discovery of the Noble Gases

The story of the discovery of the noble gases shows the importance of careful experimental work and of knowing when a difference between two measurements is significant. In the 1880s, the English physical scientist Lord Rayleigh measured the densities of some common gases and found to his surprise that the density of nitrogen obtained from air by removal of oxygen, carbon dioxide, and water was 1.2561 g/L, whereas the density of nitrogen obtained by burning ammonia

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(l)$$

was 1.2498 g/L under the same conditions.

Lord Rayleigh asked chemists to explain the difference in density between atmospheric nitrogen and nitrogen obtained from a nitrogen compound by chemical reaction. The British chemist William Ramsay suggested that nitrogen from the atmosphere must contain an unknown dense gas.

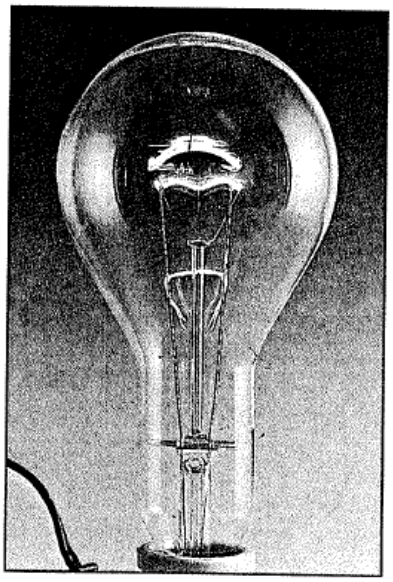
Rayleigh and Ramsay then treated the nitrogen obtained from air with hot magnesium metal. When hot, magnesium metal reacts with nitrogen forming magnesium nitride:

$$3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$$

After all the nitrogen had reacted, a small amount of a denser gas was left. The denser gas indeed proved to be a new element that Rayleigh and Ramsay named argon. The name "argon" is derived from the Greek word *argós*, which means inactive.

There was no place in the periodic table of that time for an unreactive gaseous element and Ramsay suggested addition of another group between the halogens (Group VIIA) and the alkali metals (Group IA). In 1898 Ramsay separated three more noble gases from the atmosphere: neon, krypton, and xenon. This left room in Group 0 for two more elements and Ramsay discovered both of them. In 1903 he showed that helium is produced by the radioactive decay of radium, and in 1910 he detected radon in the radioactive material given off by radium.

Rayleigh received the Nobel prize for physics in 1904 for his discovery of argon and Ramsay received the 1904 Nobel prize for chemistry for his discovery of the other noble gases—neon, krypton, xenon, and helium—and their places in the periodic table.



*Incandescent light bulbs are filled with argon to prevent reaction of the hot filament with oxygen.*

**Discussion**

1) To what extent is scientific knowledge empirically based (based on observations in the natural world)? Use an example from one of the stories.

2) In what sense is scientific knowledge not always empirically based? Use an example from one of the stories.

3) Think about the first story (Observations, Theories, and the Planets). How is it possible that humans can look at the same evidence and make different conclusions?