Cosmic Chemistry: Planetary Diversity

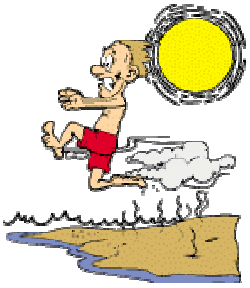
Greenhouse Effect

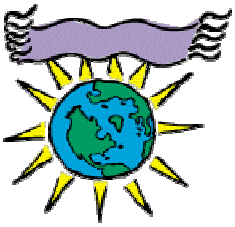
STUDENT TEXT

The climates of Earth, Venus, and Mars are largely controlled by the way in which their atmospheres interact with electromagnetic radiation and not by their proximity to the sun, as one might initially think. The major phenomenon that operates to control climate is the greenhouse effect.

Understanding the greenhouse effect is a simple matter of knowing two principles, both of which are introduced and explored extensively in the Student Activity, "Here Comes the Heat" of this module. The first principle to recognize is that everything glows. To put it another way, everything emits thermal electromagnetic radiation and the wavelength of the radiation depends on the temperature of the object emitting the radiation. The hotter an object is, the shorter will be the wavelength of the emissions and vice versa. To put it another way, hotter is bluer and cooler is redder. The sun's temperature is such that it emits light mostly in the visible part of the spectrum. Cool objects, like ice cubes, emit radiation, but the emission falls in the infrared range of wavelengths, where our narrowly tuned eyes are unable to detect it. Consequently, ice cubes do not appear to have color. Nevertheless, the emitted radiation from a cold object—such as an ice cube—can be measured with sensitive instruments that detect the infrared portion of the electromagnetic spectrum. Your understanding of this principle will be reinforced if you read the Student Text, "Here Comes the Heat."

The second important principle that was explored in "Here Comes the Heat" relates to the interaction of light with atmospheric gases. Some wavelengths are allowed to pass unscathed through planetary atmospheres, while other wavelengths are absorbed. As a rule, atmospheric gases are transparent to visible light. Therefore, most of the sun's radiation passes through the Earth's atmosphere, and much of it gets absorbed by planetary surfaces (like asphalt parking lots and sandy beaches). This absorption of radiant energy heats the surface, causing it to glow and emit thermal radiation back into space, not as visible light, but as electromagnetic radiation in the infrared. You do not see the infrared radiation coming from a hot parking lot surface in the summer, but you certainly feel it on your skin.





On an airless planet, a balance develops between absorption and unrestricted re-radiation of thermal energy, providing a steady state surface temperature. But this is not what happens on planets such as Earth, Venus, and Mars, all of which have an atmosphere containing molecules such as water and carbon dioxide. Herein lies the source of the greenhouse effect: these molecules trap and absorb some of the thermal infrared radiation emitted from the glowing surface. In effect, these molecules act like a blanket that surrounds the planet and retains thermal energy.

The amount of thermal energy absorption (or greenhouse warming) depends on the thickness of the atmospheric blanket, as measured by pressure, and on the composition of the atmosphere. The surface temperatures of Venus (480 C), Earth (24 C) , and Mars (-143 C) correlate to a first approximation with the surface pressures on the three planets. That is to say, the more atmospheric gas there is, the more the infrared radiation can be absorbed.

The composition of the atmospheres of these three planets is also a factor in determining the extent of greenhouse warming. The dominant atmospheric gases on Earth (nitrogen and oxygen) are poor infrared absorbers. The triatomic molecules carbon dioxide and water are much better absorbers of infrared radiation, as is the pentatomic molecule methane, CH_4. These trace molecules give rise to the greenhouse effect on Earth. It is worth noting that the documented increase in atmospheric carbon dioxide levels over the past century is thought by some scientists to have led already to some amount of global warming. However, global climate is extremely complex and is affected by many things, including sunspot activity, and so on. Consequently, there is uncertainty and continuing debate concerning the relationship between global climate and the accumulation of greenhouse gases in the atmosphere.

The atmospheres of Venus and Mars are mostly made up of carbon dioxide. This gas is a very good infrared absorber. So, both of these planets have greenhouse effects. This is especially true of Venus, which suffers a double whammy in that it

has both a thick atmosphere and one that is made up mostly of very good infrared absorbers. The greenhouse effect on Mars is less pronounced because the atmosphere is much thinner than that on Venus.

It is important to recognize that not all of the re-radiated surface thermal energy is trapped in the atmosphere. If this were the case, Earth would be a terribly hot, inhospitable place. A portion of the re-radiated energy does leak back into space. A radiative balance has been achieved over the millennia on Earth, as well as on other planets, in which an essentially stable, steady state temperature has been reached. This temperature obviously is higher than it would be in the absence of an atmosphere, but it is lower than it would be if the atmosphere trapped re-radiated energy with 100% efficiency.