OPERATION OZONE!

Time: 2-3 hours.

Standards:
Standard #4: Energy in the Earth System

4b. Know the fate of incoming solar radiation in terms of reflection,absorption, photosynthesis.

4c. Students know the different atmospheric gases that absorb the Earth's thermal radiation and the mechanism and significance & significance of the greenhouse effect.

Topical Objectives:

Learn importance of atmospheric ozone.
Learn about interaction between ozone and UV light

Materials:

UV sensitive beads.
Sunscreen (various SPF)
Sunglasses

Preparation:
Order beads from Educational Innovations.

Procedure:
Students will receive a baggie of beads and design their own experiment to answer the following questions (students were also given the option of coming up with their own question at my discretion). The beads turn color when exposed to UV light. Students will turn in a lab report including Problem, Hypothesis, Procedure, Data, and Conclusion.

1. Do clouds block some or all UV rays?
2. Is old sunscreen as effective as new sunscreen?
3. Do T-shirts block some or all UV rays?
4. Does windshield glass block some or all UV rays?
5. Are all of the windows in a car equal when it comes to blocking UV rays?
6. Does SPF 30 sunscreen give twice the protection of SPF 15?
7. So UV filtering sunglasses really block UV rays?
8. Is exposure to UV rays at midday as great as exposure to UV rays at other times during the day?
9. Is sunlight reflected from a white surface as dangerous as direct sunlight?
10. Does water reflect all or some UV rays?
11. Are UV rays able to travel through water?

BACKGROUND INFORMATION:
Ozone Science: The Facts Behind the Phase out

The Earth's ozone layer protects all life from the sun's harmful radiation, but human activities have damaged this shield. Less protection from ultraviolet light will, over time, lead to higher skin cancer and cataract rates and crop damage. The U.S., in cooperation with over 160 other countries, is phasing out the production of ozone-depleting substances in an effort to safeguard the ozone layer.

I. The Ozone Layer

The Earth's atmosphere is divided into several layers. The lowest region, the troposphere, extends from the Earth's surface up to about 10 kilometers (km) in altitude. Virtually all human activities occur in the troposphere. Mt. Everest, the tallest mountain on the planet, is only about 9 km high. The next layer, the stratosphere, continues from 10 km to about 50 km. Most commercial airline traffic occurs in the lower part of the stratosphere.

Most atmospheric ozone is concentrated in a layer in the stratosphere, about 15-30 kilometers above the Earth's surface. Ozone is a molecule containing three oxygen atoms. It is blue in color and has a strong odor. Normal oxygen, which we breathe, has two oxygen atoms and is colorless and odorless. Ozone is much less common than normal oxygen. Out of each 10 million air molecules, about 2 million are normal oxygen, but only 3 are ozone.

However, even the small amount of ozone plays a key role in the atmosphere. The ozone layer absorbs a portion of the radiation from the sun, preventing it from reaching the planet's surface. Most importantly, it absorbs the portion of ultraviolet light called UVB. UVB has been linked to many harmful effects, including various types of skin cancer, cataracts, and harm to some crops, certain materials, and some forms of marine life.

At any given time, ozone molecules are constantly formed and destroyed in the stratosphere. The total amount, however, remains relatively stable. The concentration of the ozone layer can be thought of as a stream's depth at a particular location. Although water is constantly flowing in and out, the depth remains constant.

While ozone concentrations vary naturally with sunspots, the seasons, and latitude, these processes are well understood and predictable. Scientists have established records spanning several decades that detail normal ozone levels during these natural cycles. Each natural reduction in ozone levels has been followed by a recovery. Recently, however, convincing scientific evidence has shown that the ozone shield is being depleted well beyond changes due to natural processes.

II. Ozone Depletion

For over 50 years, chlorofluorocarbons (CFCs) were thought of as miracle substances. They are stable, nonflammable, low in toxicity, and inexpensive to produce. Over time, CFCs found uses as refrigerants, solvents, foam blowing agents, and in other smaller applications. Other chlorine-containing compounds include methyl chloroform, a solvent, and carbon tetrachloride, an industrial chemical. Halons, extremely effective fire extinguishing agents, and methyl bromide, an effective produce and soil fumigant, contain bromine. All of these compounds have atmospheric lifetimes long enough to allow them to be transported by winds into the stratosphere. Because they release chlorine or bromine when they break down, they damage the protective ozone layer. The discussion of the ozone depletion process below focuses on CFCs, but the basic concepts apply to all of the ozone-depleting substances (ODS).

In the early 1970s, researchers began to investigate the effects of various chemicals on the ozone layer, particularly CFCs, which contain chlorine. They also examined the potential impacts of other chlorine sources. Chlorine from swimming pools, industrial plants, sea salt, and volcanoes does not reach the stratosphere. Chlorine compounds from these sources readily combine with water and repeated measurements show that they rain out of the troposphere very quickly. In contrast, CFCs are very stable and do not dissolve in rain. Thus, there are no natural processes that remove the CFCs from the lower atmosphere. Over time, winds drive the CFCs into the stratosphere.

The CFCs are so stable that only exposure to strong UV radiation breaks them down. When that happens, the CFC molecule releases atomic chlorine. One chlorine atom can destroy over 100,000 ozone molecules. The net effect is to destroy ozone faster than it is naturally created. To return to the analogy comparing ozone levels to a stream's depth, CFCs act as a siphon, removing water faster than normal and reducing the depth of the stream.

Large fires and certain types of marine life produce one stable form of chlorine that does reach the stratosphere. However, numerous experiments have shown that CFCs and other widely-used chemicals produce roughly 84% of the chlorine in the stratosphere, while natural sources contribute only 16%.

Large volcanic eruptions can have an indirect effect on ozone levels. Although Mt. Pinatubo's 1991 eruption did not increase stratospheric chlorine concentrations, it did produce large amounts of tiny particles called aerosols (different from consumer products also known as aerosols). These aerosols increase chlorine's effectiveness at destroying ozone. The aerosols only increased depletion because of the presence of CFC - based chlorine. In effect, the aerosols increased the efficiency of the CFC siphon, lowering ozone levels even more than would have otherwise occurred. Unlike long-term ozone depletion, however, this effect is short-lived. The aerosols from Mt. Pinatubo have already disappeared, but satellite, ground-based, and balloon data still show ozone depletion occurring closer to the historic trend.

One example of ozone depletion is the annual ozone "hole" over Antarctica that has occurred during the Antarctic Spring since the early 1980s. Rather than being a literal hole through the layer, the ozone hole is a large area of the stratosphere with extremely low amounts of ozone. Ozone levels fall by over 60% during the worst years.

In addition, research has shown that ozone depletion occurs over the latitudes that include North America, Europe, Asia, and much of Africa, Australia, and South America. Over the U.S., ozone levels have fallen 5-10%, depending on the season. Thus, ozone depletion is a global issue and not just a problem at the South Pole.

Reductions in ozone levels will lead to higher levels of UVB reaching the Earth's surface. The sun's output of UVB does not change; rather, less ozone means less protection, and hence more UVB reaches the Earth. Studies have shown that in the Antarctic, the amount of UVB measured at the surface can double during the annual ozone hole. Another study confirmed the relationship between reduced ozone and increased UVB levels in Canada during the past several years.

Laboratory and epidemiological studies demonstrate that UVB causes nonmelanoma skin cancer and plays a major role in malignant melanoma development. In addition, UVB has been linked to cataracts. All sunlight contains some UVB, even with normal ozone levels. It is always important to limit exposure to the sun. However, ozone depletion will increase the amount of UVB, which will then increase the risk of health effects. Furthermore, UVB harms some crops, plastics and other materials, and certain types of marine life.

For more information, see the Ozone Depletion Process page.

III. The World's Reaction

The initial concern about the ozone layer in the 1970’s led to a ban on the use of CFCs as aerosol propellants in several countries, including the U.S. However, production of CFCs and other ozone-depleting substances grew rapidly afterward as new uses were discovered.

Through the 1980s, other uses expanded and the world's nations became increasingly concerned that these chemicals would further harm the ozone layer. In 1985, the Vienna Convention was adopted to formalize international cooperation on this issue. Additional efforts resulted in the signing of the Montreal Protocol in 1987. The original protocol would have reduced the production of CFCs by half by 1998.

After the original Protocol was signed, new measurements showed worse damage to the ozone layer than was originally expected. In 1992, reacting to the latest scientific assessment of the ozone layer, the Parties decided to completely end production of halons by the beginning of 1994 and of CFCs by the beginning of 1996 in developed countries.

Because of measures taken under the Protocol, emissions of ozone-depleting substances are already falling. Based on measurements of total inorganic chlorine in the atmosphere, which stopped increasing in 1997 and 1998, stratospheric chlorine levels have peaked and are no longer increasing. The good news is that the natural ozone production process will heal the ozone layer in about 50 years.

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Natural sources of UV

The Sun emits ultraviolet radiation in the UVA, UVB, and UVC bands, but because of absorption in the atmosphere's ozone layer, 99% of the ultraviolet radiation that reaches the Earth's surface is UVA. (Some of the UVB and UVC light is responsible for the generation of the ozone layer.)
Ordinary glass is partially transparent to UVA but is opaque to shorter wavelengths while Silica or quartz glass, depending on quality, can be transparent even to vacuum UV wavelengths. Ordinary window glass passes about 90% of the light above 350 nm, but blocks over 90% of the light below 300 nm.[1][2][3]
The onset of vacuum UV, 200 nm, is defined by the fact that ordinary air is opaque below this wavelength. This opacity is due to the strong absorption of light of these wavelengths by oxygen in the air. Pure nitrogen (less than about 10 ppm oxygen) is transparent to wavelengths in the range of about 150–200 nm. This has wide practical significance now that semiconductor manufacturing processes are using wavelengths shorter than 200 nm. By working in oxygen-free gas, the equipment does not have to be built to withstand the pressure differences required to work in a vacuum. Some other scientific instruments, such as circular dichroism spectrometers, are also commonly nitrogen purged and operate in this spectral region.
In humans, prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eye, and immune system [6].
UVC rays are the highest energy, most dangerous type of ultraviolet light. Little attention has been given to UVC rays in the past since they are filtered out by the atmosphere. However, their use in equipment such as pond sterilization units may pose an exposure risk, if the lamp is switched on outside of its enclosed pond sterilization unit.

Ultraviolet photons harm the DNA molecules of living organisms in different ways. In one common damage event, adjacent Thymine bases bond with each other, instead of across the "ladder". This makes a bulge, and the distorted DNA molecule does not function properly.
Ultraviolet (UV) irradiation present in sunlight is an environmental human carcinogen. The toxic effects of UV from natural sunlight and therapeutic artificial lamps are a major concern for human health. The major acute effects of UV irradiation on normal human skin comprise sunburn inflammation (erythema), tanning, and local or systemic immunosuppression. Matsumura, Y. & Ananthaswamy H. N., Toxicology and Applied Pharmacology (2004) [7]
UVA, UVB and UVC can all damage collagen fibers and thereby accelerate aging of the skin. In general, UVA is the least harmful, but can contribute to the aging of skin, DNA damage and possibly skin cancer. It penetrates deeply and does not cause sunburn. Because it does not cause reddening of the skin (erythema) it cannot be measured in the SPF testing. There is no good clinical measurement of the blocking of UVA radiation, but it is important that sunscreen block both UVA and UVB. UVA light is also known as "black light" and, because of its longer wavelength, can penetrate many windows. It also penetrates deeper into the skin than UVB light and is thought to be a prime cause of wrinkles.

The reddening of the skin due to the action of sunlight depends both on the amount of sunlight as well as the sensitivity of the skin ("erythemal action spectrum") over the UV spectrum. UVB light can cause skin cancer. The radiation excites DNA molecules in skin cells, causing covalent bonds to form between adjacent thymine bases, producing thymidine dimers. Thymidine dimers do not base pair normally, which can cause distortion of the DNA helix, stalled replication, gaps, and misincorporation. These can lead to mutations, which can result in cancerous growths. The mutagenicity of UV radiation can be easily observed in bacteria cultures. This cancer connection is one reason for concern about ozone depletion and the ozone hole.
As a defense against UV radiation, the body tans when exposed to moderate (depending on skin type) levels of radiation by releasing the brown pigment melanin. This helps to block UV penetration and prevent damage to the vulnerable skin tissues deeper down. Suntan lotion, often referred to as "sun block" or "sunscreen", partly blocks UV and is widely available. Most of these products contain an SPF rating that describes the amount of protection given. This protection, however, applies only to UVB rays responsible for sunburn and not to UVA rays that penetrate more deeply into the skin and may also be responsible for causing cancer and wrinkles. Some sunscreen lotion now includes compounds such as titanium dioxide which helps protect against UVA rays. Other UVA blocking compounds found in sunscreen include zinc oxide and avobenzone. There are also naturally occurring compounds found in rainforest plants that have been known to protect the skin from UV radiation damage, such as the fern Phlebodium aureum.

What to look for in sunscreen:
UVB protection: Padimate O, Homosalate, Octisalate (octyl salicylate), Octinoxate (octyl methoxycinnamate)
UVA protection: Avobenzone
UVA/UVB protection: Octocrylene, titanium dioxide, zinc oxide, Mexoryl (ecamsule)

Another means to block UV is sun protective clothing. This is clothing that has a "UPF rating" that describes the protection given against both UVA and UVB.

High intensities of UVB light are hazardous to the eyes, and exposure can cause welder's flash (photokeratitis or arc eye) and may lead to cataracts, pterygium [8] [9], and pinguecula formation.

Protective eyewear is beneficial to those who are working with or those who might be exposed to ultraviolet radiation, particularly short wave UV. Given that light may reach the eye from the sides, full coverage eye protection is usually warranted if there is an increased risk of exposure, as in high altitude mountaineering. Mountaineers are exposed to higher than ordinary levels of UV radiation, both because there is less atmospheric filtering and because of reflection from snow and ice.

Ordinary, untreated eyeglasses give some protection. Most plastic lenses give more protection than glass lenses, because, as noted above, glass is transparent to UVA and the common acrylic plastic used for lenses is less so. Some plastic lens materials, such as polycarbonate, inherently block most UV. There are protective treatments available for eyeglass lenses that need it which will give better protection. But even a treatment that completely blocks UV will not protect the eye from light that arrives around the lens.