Iowa Science Teachers Journal

Volume 13 | Number 2 Article 9

1976

Aerosols and the Atmosphere

Darrel Hoff
University of Northern Iowa

AEROSOLS AND THE ATMOSPHERE

Darrel Hoff
Department of Earth Science
University of Northern Iowa
Cedar Falls, Iowa 50613

Introduction

In recent months concern has been expressed about the effect of certain aerosol sprays on the protective ozone layer of the atmosphere. This is a current environmental issue and it seems an appropriate topic for discussion in the high school science classroom. Like many environmental issues, the aerosol issue is not as clearly defined as is sometimes presented in the general media, and it should therefore be approached with an open mind by both teachers and students.

What is the basic concern in this issue?

In our atmosphere at altitudes of about 20 to 120 kilometers two chemical reactions occur involving ultraviolet radiation and oxygen which produce the substance called ozone (O_3). At about 50 to 120 kilometers, dangerous, short-wavelength, ultraviolet rays are absorbed by oxygen molecules and oxygen atoms are produced. Some of these highly reactive atoms combine with molecular oxygen to form ozone (O_3). At about 25-50 kilometers additional lethal ultraviolet energy is absorbed by the ozone. The equation describing these processes is:

$$O_3 \rightleftharpoons O_2 + O \qquad (1)$$

Ozone concentrations are very low, approximately 1 ozone (O_3) molecule per 100,000 other molecules. In fact if all of the ozone were compressed to ground level pressure it would make a layer less than one-half a centimeter thick. This statement emphasizes the delicate nature of ozone protection. Why then the concern over ozone?

Ozone

Ozone acts as a filter for dangerous and lethal ultraviolet energy. Should larger amounts of this energy reach the earth due to a depletion of the ozone layer a variety of possible effects could occur including; weather and climate changes, increased mutation rates in animals and plants, and an increase in the incidence rate of skin cancer among the light skinned people of the world. It is this latter point that is most often mentioned in discussion concerning ozone depletion, and it is about this point that the greatest uncertainty exists.

Concern about depletion of the ozone layer surfaced some years ago in connection with the development of the supersonic transport (SST) airplane. In order to operate with maximum efficiency, the SST has to fly in the stratosphere at altitudes of 15 to 20 kilometers. Products of its exhaust includes two nitrogen oxides and it is believed that their production would lead to ozone depletion by the two following reactions:

$$NO + O_3 \rightleftharpoons NO_2 + O_2 \qquad (2)$$

$$NO_2 + O \rightleftharpoons NO + O_2 \qquad (3)$$

It is now fairly well confirmed that had the proposed U.S. fleet of 500 SSTs been built, the ozone layer would have been depleted by approximately 15%, with a substantial resultant increase in the rate of skin cancer. It should be noted that the lower operating altitudes of existing European SSTs produce substantially reduced effects.

A second critical mechanism for ozone depletion results from the production of nitrogen oxides from atmospheric nuclear explosions. Low altitude nuclear explosions are thought to be less of a threat because of the relatively high concentration of nitrogen compared to oxygen. Hence, many of the nitrogen oxide molecules formed recombine with the free nitrogen atoms according to this equation:

$$NO + N \rightleftharpoons N_2 + O \qquad (4)$$

However, at higher altitudes this reaction would play a lesser role and the reaction given below would predominate:

$$N + O_2 \rightleftharpoons NO + O \qquad (5)$$

Each nitrogen oxide molecule would be capable of destroying an ozone molecule according to equation (3) above.

The most recently proposed threat to the ozone layer comes from a far less dramatic source than either the SST or nuclear weapons. It comes in the form of fluorocarbon coolants and propellants for aerosol sprays. This threat, if it may be called that, seems less well defined than the other two, and it is this concern that has generated the most media coverage. What is the basis of the concern?

In 1972, F. Sherwood Rowland of the University of California at Irvine proposed that the two fluorocarbons $CFCl_3$ and CF_2Cl_2 from aerosol sprays slowly drift upwards where high energy ultraviolet rays slowly break their carbon-chlorine bonds and produce free chlorine atoms. These free chlorine atoms would in turn react with the ozone and free oxygen atoms in the following manner:

$$Cl + O_3 \rightleftharpoons ClO + O_2 \qquad (6)$$

$$ClO + O \rightleftharpoons Cl + O_2 \qquad (7)$$

Although there seems to be little disagreement about the theoretical possibilities of these reactions, there is sharp disagreement about the actual effects on the atmosphere and on the possible human dangers involved.

These compounds collectively called *freons* are standard coolants in refrigerators and air conditioners, and in recent years have found increasing use as propellants for aerosol sprays. Their choice for these tasks was based on their cost, low toxicity and non-flammability. What do the experts say about the possible hazards of continued use of freon both as a refrigerant and an aerosol propellant?

Harvard scientists concluded that if fluorocarbon production and use continues at its present rate of increase, the ozone layer will be reduced by 10% by the year 1996 and 16% by the end of the century. In his study, Dr. Rowland estimates that a 2% decrease in O_3 would occur during the 1980's. Another source indicates that even if aerosols were banned by 1980, the depletion would reach 14% to 15% by the year 2000. Others feel that the entire question is entirely speculative and one leading British meteorologist has labeled the entire theory as *utter nonsense*.

What about the human effects? Like every other scientific problem that involves a large population of subjects being affected by a large number of variables, the exact prediction of effects is difficult.

The National Academy of Science suggested that a 5% ozone reduction would produce an additional 8,000 cases of skin cancer per year among the white population in the U.S. A government report suggests that a 1% decrease would produce 2,100 to 15,000 new cases annually. A current article in a science teaching journal suggests the skin cancer rate would increase by 20 to 30 percent if the ozone concentration dropped 10 percent.

Whatever the facts of the matter or the projection of its effects, the prestigious National Academy of Sciences has formed a special committee consisting of twelve distinguished scientists to report on the problem by 1978. The obvious problem here is that the delay in reporting time may lead to a decrease in ozone which in turn may lead to an accelerated cancer rate.

To indicate the unusual nature of this complex environmental issue it might be noted in passing that one way to monitor chlorine levels in the atmosphere is by using the ultraviolet absorption stellar photometer on board the Copernicus orbiting astronomical satellite. It has been proposed that the stellar spectrum be examined for the amount of chlorine present when a given star is directly overhead, and again when it is seen at a slant angle through the atmosphere. The differences in quantities measured will indicate the amount of chlorine present in the atmosphere.

Instructional Implications

There are a number of questions that can be posed and studied both in the classroom and by the students on their own outside of the classroom. These transcend the traditional science content oriented questions, as indeed do most questions of a scientific and technological nature. Possible investigative questions include:

1. What are the molecular weights of the two common freons? What is the average molecular weight of air? How do the freons reach the upper atmosphere?

2. If ozone production is a reversible reaction, why doesn't depletion of one product on one side of the equation (ozone in equation (1) above) lead to a re-establishment of the equilibrium in such a fashion to relieve the stress according to Le Chatelier's principle?

3. What is the percentage of active ingredients in an aerosol can, and what percentage is propellant?

4. What percentage of propellants are freons, and what percent are nonfreons?

5. What is the total annual investment in fluorocarbon production? What percentage of this is for propellants?

6. What is the average cost per ounce of *active* ingredient purchased as an aerosol as compared to a nonaerosol applicator of such products as deodorants, shave cream, etc.?

7. What is the means of disposal of the old refrigeration units and aerosol cans in your community?

8. Have you ever read the warnings on an aerosol can? Read one and comment on the types of hazards warned against.

9. Record the personal use of aerosols in your family. Inquire why members of your family prefer aerosols. Ask older members of your family how they applied these products before the manufacture of aerosols.

Conclusion

Whatever the outcome of the scientific issues involved, many students can be led to consider the aerosol issue on grounds of safety and economy that may help them to make wiser environmental decisions even in the absence of conclusive data concerning atmospheric effects.

References

Ann. 1975. Ask a star. *Chemistry* 48(7):5.

Ann. 1975. Endangered blanket of ozone. *Chemistry* 48(1):25-26.

Ann. 1975. The fluorocarbon-ozone controversy. *Chemistry* 48(9):3.

Lubkin, G. B. 1975. Fluorocarbons and the stratosphere. *Physics Today* 28(10):34-39.

Moore, J. and E. Moore. 1975. Ozone. *Science Teacher* 42(7):33-34.

Report of the Federal Task Force on Inadvertent Modification of the Atmosphere (Stock No. 038-000-00226-1.) 1975. *Fluorocarbons and the environment*. U.S. Government Printing Office.

Ritz, W. 1975. Investigating the aerosol issue. *Today's Education* 64(3):46-48, 96.

* * *

1976 NSTA Convention Site

The 1976 regional convention for NSTA will be November 18-20, in Minneapolis, Minnesota.

* * *

ACS Study

The American Chemical Society, through its Council Committee on Chemical Education, is studying practical solutions for improving chemistry instruction in high school.

The present draft of tentative guidelines emphasize the central position of laboratory-centered instruction in chemistry. It calls for support for this position through specific policy decisions and actions from college and university chemistry departments, schools of education, local school officials, state education officials, national scientific and professional organizations, industry, and of course, teachers. To be placed on the mailing list for the final draft of the developing guidelines, write to ACS Guidelines Project, Patricia Lemaire, Department of Educational Activities, American Chemical Society, 1155 16th Street, N.W., Washington, D.C. 20036.

* * *

Behavior Molding

"The planets will move as they always have whether we adopt a geocentric or heliocentric view of the heavens . . . but, the behavior of man is not independent of the theories of human behavior that men adopt."

Leon Eisenberg