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The Great Spray Can Debate

The debate generated by publication of the Rowland-Molina fluorocarbon-ozone depletion model[1] is over a scientific phenomenon whose potential dangers are worldwide and long term. Resolution of this debate, in its scientific, technological, economic and political aspects, is dependent at the deepest level on the application of both pure and applied scientific understanding. The following pages propose a curriculum scenario, for use in high school chemistry classrooms, that takes the problems raised by the technological, economic, political contexts of the fluorocarbon controversy as its point of focus.

Historical Introduction

June 1974 marked publication of the first scientific paper indicating potentially catastrophic effects from continued use of such seemingly innocuous products as deodorant and hair sprays. This incredible warning, unbelievable at first even to its authors, generated four Congressional hearings: two in the House, two in the Senate. The first of these was held in December 1974 by the Subcommittee on Public Health and Environment of the House's Commerce Committee. The Subcommittee chairman, Paul Rogers (Dem., Fla.) introduced those hearings[2] with these cryptic remarks

> Since coming to the Congress, I have never begun hearings with such an eerie feeling . . . The idea that we may in fact be destroying the layer of atmosphere which protects us from the sun's rays is both rather staggering and frightening . . .
>
> The entire matter rings of a science fiction tale, one we have all heard, about how a planet now barren was destroyed by its very inhabitants. Had not the evidence been brought forth by such reputable men of science, it would seem like black humor, that every human on Earth may be in danger by billions of aerosol cans.

The relevance of science, the need for the widest possible understanding of its nature and content, was strikingly illustrated later that day by Subcommittee member Richardson Preyer (Dem., N.C.). After listening to the testimony of leading atmospheric scientists, Congressman Preyer responded[2] as follows

> Mr. Chairman, when I came over today I thought we would have a hearing that would be a standard conflict between the environmentalists and industry and I can only say I am stunned by what we have heard here.
>
> There has not been inflammatory rhetoric or alarmist language but here we have some of the most distinguished scientists in America telling us about the problem.
>
> I think these could be the most important hearings the committee has ever had. It looks like all of us laymen in this country have got to learn a new subject now. We recently had to learn constitutional law and then we had to be economists and now we have to become chemists and mathematicians. No wonder people long for the good old days.

Congressman Preyer speaks of the relevance of chemistry. Understanding of the chemical principles involved in public policy issues such as this is essential, and is the concern of the initial phase of this curriculum proposal.

Phase 1: The Scientific Dimension

This phase is a pure science analysis, using lab-classroom tools and methodologies.

Optimum Use: To deliver a body of basic factual information which will motivate and aid students in understanding and integrating their observations and experiences in chemistry classes.

Content: To illustrate the scope and breadth of scientific facts, concepts, principles involved in the fluorocarbon-ozone depletion hypothesis.

Science content directly relating to the controversy may be very briefly summarized as follows

(1) The inert character of certain widely used fluoro-carbon gases ensures their long lifetimes and hence their collection, undiminished, in the lower atmosphere.
(2) They slowly but inexorably move upward, rising above the bulk of stratospheric ozone which absorbs and so shields us from hard ultraviolet radiations emitted by the sun.
(3) Now above, and hence no longer protected by this ozone, the previously inert fluorocarbon molecules are broken apart by this radiation into extremely reactive fragments.
(4) These reactive fragments are capable of attacking and destroying significant portions of stratospheric ozone—such destruction maximizing some 50–100 yr after release of the fluorocarbons at ground level.
(5) An increased amount of ultraviolet radiation (that portion no longer absorbed in the stratosphere) would then reach the Earth's surface. This radiation is known to cause skin cancer, damage crop plants as well as other living systems, possibly be indirectly responsible for weather modification.

Several examples of how the controversy illuminates the relevance of chemistry immediately suggest themselves. Study of chemical equations takes on added meaning when used to represent two of the so-called "Chapman" reactions, first proposed in 1930 by meteorologist Sydney Chapman[3] to account for the existence of stratospheric ozone. First, oxygen molecules are split into reactive atoms by absorption of ultraviolet radiation from the Sun: $O_2 + uv = O + O$. This is analogous to the breakup of fluorocarbon molecules mentioned in (*3*) above. These reactive O atoms then join with other O_2 molecules to form ozone: $O + O_2 = O_3$.

The need for an understanding of elementary chemistry is further illustrated by the following portion of Congressional testimony[2] by atmospheric scientist Ralph Cicerone; addressing (*4*) above

> The relevant chlorine oxides catalytic cycle is represented by

	Cl	+	O_3	=	ClO	+	O_2
and	ClO	+	O	=	Cl	+	O_2
net	O_3	+	O	=	O_2	+	O_2

Condensed from an article which received 2nd prize in the 1976 NSTA-Gustav Ohaus Awards Program for innovations in elementary and secondary science teaching.

[1]Molina, M. J., and Rowland, F. S., "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalyzed Destruction of Ozone," *Nature,* **249,** 810 (1974a).

[2]"Fluorocarbons—Impact on Health and Environment," *Hearings before the Subcommittee on Public Health and Environment of the Committee on Interstate and Foreign Commerce, House of Representatives,* 93d Congress, 2d Session, Serial No. 93-110, December 11 and 12, 1974.

[3]Chapman, S., "A Theory of Upper Atmospheric Ozone," *Quart. J. Roy. Meteorol. Soc.,* **3,** 103, 1930.

The net result is that an available ozone molecule and an available O atom re-form two molecules of O_2 in nature's stratosphere . . . . Thus the cycle removes . . . ozone molecules each time it proceeds. In the process, the chlorine atom is first converted to chlorine oxide, then back to chlorine. Thus, the chlorine atom is not consumed and the set of reactions . . . exemplifies catalysis.

In addition to scientific understanding, students must be sensitive to the philosophical and moral issues involved, to the nature and just use of scientific knowledge. Hence phase 2 of the proposed curriculum suggests ways in which to address this concern. We focus on the philosophical implications of different levels of understanding—how we define and perceive scientific, moral, legal truths.

Phase 2: The Philosophical Dimension

Examination of the interface between science and social values—the philosophical and moral perspectives raised by the fluorocarbon issue.

Optimum Use: To increase student awareness of the (1) scope and nature of human knowledge; (2) limitations of scientific knowing—the meaning and use of scientific models; (3) moral issues involved in attempts to resolve the controversy. To use this totality of knowing to evolve a just, workable solution to the fluorocarbon problem.

Content: To use projective techniques, experiments, role-play activities in exploration of various versions of "the truth" and the influence of subjective perception.

Philosophy traditionally tackles questions not yet amenable to scientific enquiry. The following are suggestive of activities to aid students in approaching this difficult phase.

1) Show color slides of various subjects: a hazy New York City skyline, the Grand Canyon, closeup of a leaf or flower, other scenes likely to evoke wide areas of response. For each slide, ask students to write one sentence that, for them, defines its truth. The hazy New York skyline might, for example, evoke responses about the pollution, the beauty or ugliness of the buildings.
2) Ask students to read their sentences out loud, using them to initiate discussion about the different levels of knowing. An artist or poet will know a leaf in ways biologists cannot; a geologist will "read" and know the Grand Canyon in ways lay people cannot.
3) With reference to discussion outcomes from 2), attempt to isolate the categories of knowledge. Address questions such as how we arrive at workable definitions and perceptions of scientific, legal, moral truths; how we come to know these truths; how much of this knowing comes from within the individual.
4) Provide students with a "black box" (a sealed box containing some "unknown" object), and ask them to evolve models of the objects within. Require that they specify the experiments, observations, reasoning that led to their proposed model.
5) Use the outcomes from 4) to discuss the nature and meaning of a scientific model. Introduce the classic fable of the blind king of a blind kingdom asking blind aides to describe an elephant. Use the response "spearlike" from the aide touching a tusk, "treelike" from the aide touching a leg, "snakelike" from the trunk toucher, etc., to emphasize the lack of absolute truth.

An interesting example within the present controversy of how an individual's truth gives direction to his work: James Lovelock, the British scientist who first detected widespread presence of fluorocarbons in the atmosphere, subscribes to what he terms the "Gaea Hypothesis." Named for Gaea, the Greek personification of the earth as a goddess, it postulates an idyllic equilibrium between man and nature, evolved over the million-odd years of man's existence, enabling nature to compensate and adjust to any man-made environmental disturbance. A comforting, if unprovable belief, but one that helps to illuminate Lovelock's (and the aerosol industry's) view of fluorocarbons.

6) Ask students to read excerpts from Congressional hearings, industry statements on the fluorocarbon issue and list the positions taken by each of the groups giving testimony.

The awareness that very different interest groups are directly involved in the controversy leads naturally into a third, so-called career education phase of the proposed curriculum. This is due to the wealth of occupations and different bodies of knowledge that come into play trying to solve the fluorocarbon problem. This intersection of careers suggests a natural and exciting way for students to study career possibilities that have relation to science. These might include, besides scientific research in an academic setting, law and related legal services, the entire industry-business spectrum, politics and public service careers.

Phase 3: The Career Education Dimension.

This phase includes a study of the wealth of occupations and different bodies of knowledge involved in resolution of the fluorocarbon issue—an intersection of careers that relate to science.

Optimum Use: To acquaint students with the variety and nature of careers touched and influenced by the aerosol-ozone controversy, and to direct student attention to science-related careers available to them.

Content: To involve students in role-play and interview activities of working adults presently involved in these science-related careers, which provide means of exposing youngsters to adults in work settings that carry them beyond the confines of the science classroom into the world of working professionals.

This final phase of the curriculum scenario suggests the following activities to help direct student attention to a variety of science-related careers in the world of work.

1) Ask students to survey Congressional testimony, industry statements, newspaper and magazine articles relating to the controversy, and from this survey, to create a list of careers that come into play in this controversy. Each student is then asked to role-play a working adult engaged in one of the listed careers. Invite guest speakers engaged in some of these careers to support this activity.
2) Direct students to set up and conduct a Congressional hearing on the controversy, in which each student plays his/her career role as they imagine it to be in an actual hearing. The range of chosen careers should include several Congressmen, from which a committee chairman would be selected; industry public relations people, engineers, legal staff, executives, businessmen; academic scientists; Federal government representatives from regulatory, environmental, other agencies.

   The aim here would be to focus on the job titles, the specific careers being role-played, as students try to imagine how the adults being represented would react and respond in such a hearing.
3) With reference to actual Congressional hearings, student discussion should focus on the extent to which the role-play was real.
4) Each student is asked to talk about his/her current career plans, and to then choose one career from the above listing and role-play experience that most closely fits his/her present career plan.
5) Each student is asked to create a set of interview questions that will illuminate the dimensions of a single career. The intent is to force the student to think of the kinds of questions which, when answered, would give one a feel for the career—make it understandable. Some guidelines:
   a) Career context: what kind of organization would offer such a career? A university? Government? Private Industry? What is the goal of this organization? To develop consumer goods? Influence public policy? To regulate? To make money?
   b) Operational characteristics of the career: what does one do daily in this job? What specific tasks and responsibilities are associated with it? What social status does it bring? Purpose here is to aid student in picturing the career in action.
   c) Practical employment information: how and where do I train for this job? How do I apply for it? How do I ensure my getting it?
   d) Attitudes toward the present fluorocarbon issue that such a job might require: are you aware of the attitudes required? Do they coincide with your own? This forces the student to define his/her own position.
6) Ask students to form small groups (of 3 or 4) by career interest: all "lawyers" in one group, "academic scientists" in another. Each group now evolves a questionnaire from the questions listed in 5), sets up and keeps an appointment with an adult now involved in their career, administers the questionnaire.

7) Each group is asked to write up and present to the entire class a report distilling the responses to the interview questionnaire, and including their reactions to those responses. Each student needs to ask: do I want this career for myself? Why or why not?

8) Initiate a large group discussion, evolving from 7), airing additional insights and attitudes about the fluorocarbon issue. What influence did the controversy have on each student's career plans?

Conclusion

Because the fluorocarbon issue must be resolved by a public policy decision based on a scientific model, because it will be legislated by politicians, because such legislation will affect a segment of industry and hence the economy, because enforcement involves regulatory machinery and the law, this is an issue that focuses and hence unifies all human knowledge. This knowledge must be brought to bear on a problem that is world-wide and long term.