LETTERS

Ecological Sacrifice

As an expression of environmental concern, the printing of the 1972 AAAS annual meeting program on "ecology text paper" clearly puts the AAAS on the side of the environmental good guys. But there is a problem therein which should be pointed out in the interest of scientific accuracy. The problem lies in the ambiguity of the word "recycled." The note on page 2 of the program implies that through economic and esthetic sacrifice used milk cartons and paper plates have been diverted from the stream of solid waste destined for the town dump and have become a useful medium for the publication of the AAAS agenda. This implication is not correct.

If there was an economic sacrifice, it did not relieve the burden of postconsumer waste. Almost all the paper stock used as a raw material for the program paper consisted of industrial scrap generated by a mill manufacturing special food paperboard. This scrap, considered high-grade material, brings over $50 a ton in the secondary market. There was obviously an esthetic sacrifice, because the halftones are not clear.

It's a pity to have accepted lower quality at increased expense; it was not necessary to do this on behalf of the environment. It is possible to purchase recycled paper containing a relatively high percentage of postconsumer waste on which halftones are reproduced with the same clarity as they are on virgin pulp paper. The relatively high cost of the paper used is probably better explained by factors of demand rather than by increased costs of manufacture.

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pH: Another View

The opinions concerning *p*H expressed by Seeman (Letters, 8 Sept. 1972, p. 835) appear to be all to widely shared, even by some editors who permit authors to report "hydrogen ion concentrations" calculated from their *p*H measurements.

An excellent account of the development of the various *p*H scales is to be found in the monograph by Bates (*1*). It is true that when Sørensen first proposed the *p*H scale, it was defined in terms of hydrogen ion concentration. This definition, now long obsolete, continues to be a source of confusion. It came to be realized that the actual measurements of *p*H by various methods involve not the concentration but the activity of the hydrogen ion. Since the absolute activity of the hydrogen ion or any other single ion is not susceptible to measurement, *p*H measurements are actually measurements of the differences of hydrogen ion activity between unknown solutions and standard buffers of assigned *p*H values. It is not legitimate to convert experimentally measured *p*H values into "hydrogen ion concentrations."

The true significance of *p*H is that it is an index of the chemical potential of the proton, not only the proton existing free (or hydrated), but the dissociable proton incorporated in proton-donor molecules. Even when free protons are present in small numbers, those in proton-donor molecules may be in abundance. The hydrogen ion differs fundamentally from a stable ion like the sodium ion in that the average life of a hydrogen ion is short (10^{-6} second or less). There is continual release of protons from donor molecules and recombination into acceptor molecules, with a very large rate of turnover. The stochastic treatment of the concentration and movement of the hydrogen ion is totally different from that of a stable, permanent ion.

The misconception of the significance of *p*H as a measure of the concentration of hydrogen ions is the source of the recurring concern about the numbers of hydrogen ions contained in small subcellular compartments, a concern first expressed in 1934 by Netter (*2*). It was thought that if a compartment were so small as to contain only a few hydrogen ions, the random motion of the hydrogen ions into and out of the compartment would result in fluctuations so great as to render the concept of *p*H meaningless.

Let us consider a spherical compartment of radius 62 angstroms with a volume of 10^{-18} liter. If this compartment contains a 0.1 molar phosphate buffer of *p*H 7, the probability is low that a single hydrogen ion will be found in it at any instant, the statistical number of hydrogen ions being about 0.06. Yet this volume contains about 30,000

each of the proton-donor and proton-acceptor species of phosphate ions. The ratio of these two species, which determines *p*H, will not undergo significant statistical variation, and the concept of *p*H is entirely valid.

Chance (*3*) demonstrated experimentally that "proton noise" was not significant in a single mitochondrion. There is probably no subcellular aqueous compartment recognizable as such, even by electron microscopy, that is so small that the chemical potential of the proton, as expressed by *p*H, would not have a stable value, and for which the concept of *p*H as it applies to large volumes has ceased to have the same validity.

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References

1. R. G. Bates, *Determination of pH: Theory and Practice* (Wiley, New York, 1964).
2. H. Netter, *Pfluegers Arch. Gesamie Physiol. Menschen Tiere* **234**, 680 (1934).
3. B. Chance, *Nature* **214**, 399 (1967).

Nuclear Energy and Growth

Alvin M. Weinberg recently cited the Club of Rome report (*1*) in defense of his proposed policy for nuclear energy development (Letters, 1 Dec. 1972, p. 933). "The simple fact is that mankind can avoid the catastrophe predicted by the Club of Rome . . . only if an essentially inexhaustible energy source is developed." I protest the use he has made of our findings. On page 131 of our report we ask rhetorically whether the assumption of infinite energy would alter the outcomes projected by our model. While energy is not explicitly included in our model relationships, the effect of unlimited energy can be partially explored through the assumption of effectively infinite resources. The assumption of infinite resources did not alter our general conclusions.

Of much more relevance to the Weinberg-Edsall exchange is that part of our report in which we describe the implications of a long delay between the generation of persistent pollutants and their appearance in the environment. Wherever the delay is long, vast amounts of pollution may be generated before there is any possibility of effective countermeasures by society.