

## letters

with transitions that have occurred from 1948 to present. It may be useful to study the transitions that occurred before 1948.

**Table 2. Transition Probability**

| "Magic" Letter | TP                   |
|----------------|----------------------|
| "r"            | $7.5 \times 10^{-1}$ |
| "n"            | $5.0 \times 10^{-1}$ |
| "y"            | $3.3 \times 10^{-1}$ |
| "d"            | 0.0                  |

Also, not enough data is available to predict how the Watergate perturbation will affect the APS as a whole, or future transitions. It remains to be seen if a politician with the "magic" letter "d" can jump from the RN level (or for that matter the DN level) to the WH level. Sorenson's theory and this corollary should add to our understanding of this quadrennial phenomenon.

### References

1. T. C. Sorenson, "The Case for a Strong Presidency," *Has the President too much Power*, (Charles Roberts, ed.), Harper's Magazine Press, New York (1973), page 27.
2. B. Woodward and C. Bernstein, *All the President's Men*, Simon and Schuster, New York (1975).
3. B. Woodward and C. Bernstein, *The Final Days*, Simon and Schuster, New York (1976).
4. T. H. White, *Breach of Faith*, Atheneum Publishers, New York (1975).

LYNN HUGH MALONE

3/8/77

Madison, Tenn.

### More on coal reserves

A recent letter by Albert Bartlett (December, page 9) discusses the relationship between the rate of consumption  $C$  of a finite resource, the growth in consumption  $k$ , and the length of time  $T$  this resource will last. I wish to point out that the introduction of an additional parameter in the equations (arising from considerations of realistic goals) provides a more balanced assessment of the situation and results in much larger estimates for  $T$ .

The case of coal is a good example. Assume that it is desired for coal to gradually replace oil and gas for energy production, especially where it is currently competitive, such as in the generation of electricity (this premise must be re-examined if the required growth in consumption exhausts coal reserves in an unacceptable time). Therefore, it is necessary to increase the current rate of consumption,  $C_0$  (at time  $t = 0$ ) to the ideal rate  $C_i$  (attained at time  $t = t_i$ ); once this is achieved, the growth in consumption  $k$  need only increase as fast as the

population grows (for a constant energy consumption per individual). Since  $C = C_0 \exp(kt)$ ,

$$t_i = \frac{1}{k} \ln \frac{C_i}{C_0} \quad (1)$$

For  $t_i$  to be meaningful, the length of time the reserves will last at the growth in consumption  $k$  ( $T$  in Bartlett's letter) must be such that  $t_i < T$ , which implies

$$k > \frac{C_0}{R_0} \left( \frac{C_i}{C_0} - 1 \right) \quad (2)$$

where  $R_0$  is the value of coal reserves at  $t = 0$ . The value of coal reserves at  $t = t_i$  is given by

$$R_i = R_0 - \frac{C_0}{k} \left( \frac{C_i}{C_0} - 1 \right) \quad (3)$$

Since the current US fertility rate is below that needed for population stability with a consequent leveling off of the population in the early 21st century, a simple model is to assume that for  $t > t_i$ ,  $C = C_i$ . The additional time to exhaust the reserves is thus simply  $R_i/C_i$ , and the total time to exhaust the reserves is [from (1) and (3)]

$$T_i = \frac{R_0}{C_i} + \frac{1}{k} \left( \frac{C_i}{C_0} - 1 + \ln \frac{C_i}{C_0} \right) \quad (4)$$

For comparison, the following set of values is taken from Bartlett:  $R_0 = 1.5 \times 10^{12}$  metric tons,  $C_0 = 5 \times 10^8$  metric tons per year,  $k = 6.69\%$  per year.  $C_i$  is a new parameter, which must be chosen to meet the needs of society. If the current consumption of coal were doubled, all present electric power generation could be performed with coal. With this in mind, I choose an even more plentiful target of  $C_i = 5C_0$  as a sample desirable goal. (This gives a considerable safety margin and allows for increases in population and non-electric uses of coal.) The time to attain this rate of consumption is, from (1),  $t_i = 24$  years, and the total time to exhaust the reserves is given by (4),  $T_i = 612$  years. Is this time sufficient to develop alternative energy sources? If not, a decrease in  $k$  and/or a more modest goal  $C_i$  should be chosen.

This type of analysis illustrates the choices to be made when confronted with a nonrenewable resource, which ultimately poses the dilemma of long-term vs. short-term benefits and includes a measure of optimism for the time scale of the development of alternative sources.

ANTONIO MOGRO-CAMPERO

General Electric Co.

2/10/77

Schenectady, N.Y.

**THE AUTHOR COMMENTS:** If one reduces the rate of growth of consumption of US coal below a steady exponential growth it is clear that one will thereby extend the life of the resource. The model of Mogro-Campero does just this. His model does not call for us to recognize or wrestle with the problems of reversing

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For further information on this interesting application, call or write Chromatix for a copy of *A Demonstration of One Atom Detection* (which includes a block diagram of the experiment and original data) by G. S. Hurst, M. H. Nayfeh, and J. P. Young (Physical Review A, Vol. 15, page 2283, June 1977)

A team of atomic physicists and chemists recently reported the detection of a single cesium atom in the presence of  $10^{19}$  argon atoms and  $10^{18}$  methane molecules. This unique selectivity is achieved by a technique called resonance ionization spectroscopy (RIS).

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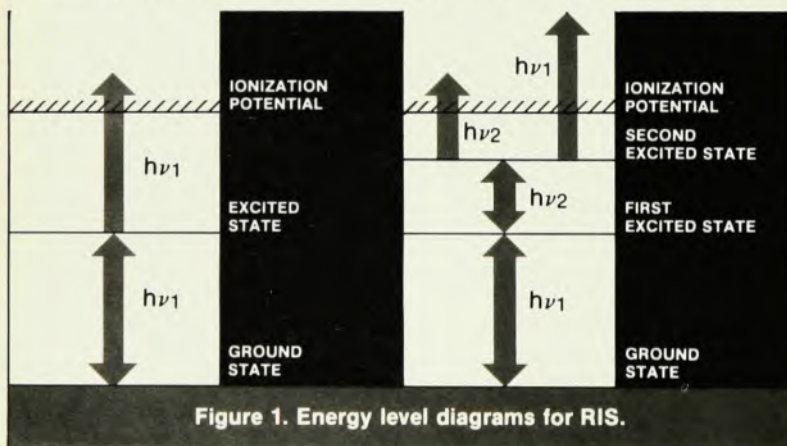


Figure 1. Energy level diagrams for RIS.

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## letters

our national obsession for growth. His model would allow us to continue to escalate our rates of consumption of coal for a period  $t_i$  and would thrust on our children the onerous task of reversing this trend. This brings to mind David Brower's observation that promoting continued growth in the rates of consumption of our natural resources is simply a sophisticated way of stealing from our children. It is my hope that we could start moving in the direction of the program that I outlined, which would make our coal last forever.

ALBERT A. BARTLETT  
*University of Colorado  
Boulder, Colorado*

2/23/77

## Plea for help

After ten years of study in the United States, I have returned to my home, Guatemala, with the purpose of helping to establish a measure of scientific competence and independence in our country. Now that I am back I feel compelled to write a plea for help from our more affluent colleagues abroad.

Scientists in developing countries are plagued by a lack of resource, not only in laboratory instrumentation and supplies, but also for the purchase of books and journals. Our institution, the only one in the country with programs in pure sciences, was set back financially by damages caused in last year's earthquake, and as a result our library has remained rather poor. Anyone who wishes to help with a donation of books and/or scientific journals that may be lying idle is encouraged to contact me.

Thank you.

SERGIO ARAGON  
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6/14/77

## Hierarchy of sciences

The letter of James Edmonds (March, page 88) raises two questions, one serious, one silly. The first question—what is fundamental in science—is one for which each of us has his own idea.

For the sake of argument, however, I will abstract from Webster and my own ideas to suggest that a fundamental study in science is that irreducible set of definitions, postulates, ideas and rules for connecting the foregoing with observation and from which understanding of less fundamental studies may be derived. Thus for two disciplines, we may sometimes have the situation where one is fundamental and one is derived, each relative to the other.

If one leaves off observation, one might also apply the definition to mathematics

and find that there are fundamental and derived mathematical studies. However, here one immediately sees a difficulty. Consider two geometries based on mutually exclusive postulates. Neither can be said to be more fundamental than the other.

The physicist has, over the last 100 years, obtained the impression that there is a hierarchy of studies, the lower or more "fundamental" generally containing the upper or "derived." Thus one expects to derive the rules of chemistry, how atoms behave in molecules, from the more fundamental study of quantum mechanics of nuclei and electrons, and, similarly, one expects to derive nuclear physics from the more fundamental study of the physics of particles, once its rules become clear. Even in this conventional picture, however, one must make allowance for the possibility that new postulates or definitions must be added to obtain the derived from the fundamental. For example (leaving aside quantum mechanics) one must add the ideas of randomness and averages to the postulates of classical mechanics to obtain statistical mechanics. Hence there may be subjects that fit into the hierarchy, but which nevertheless require new postulates and definitions. This is not dissimilar from Gödel's demonstration that in any system of mathematics one may define hypotheses that are testable for truth or falsehood, only by adding to the postulates of the system. Until one has shown by solution (or at least rigorous demonstration of the possibility of solution) of the problems which arise "naturally" within the context of a complex system, using the postulates of a simpler system, one can't be sure that additional postulates will not be required to encompass the more complex system.

As another example, it seems to me that there are fundamental and open questions in biophysics. Certainly the laws of physics are obeyed by the constituents of biological systems. Still, no one has shown that any predictive theory of any important biological properties can be derived from the physics of constituent atoms and molecules without the addition of new definitions and ideas (that is, the ideas of language must certainly be used in understanding the molecular basis of life, and these are not derivable from the physics of atoms and molecules).

Suppose, however, that the hierarchy exists without the exceptions and orthogonal directions that may, nonetheless, exist. There is no indication that it ever ends. That is, if a subquantum physics is finally ironed out, no one can ever disprove the existence of a subphysics beyond that, which may eventually be discovered by accelerating particles to still higher energies. The situation is at least as indeterminate on the cosmic scale, and with respect to connecting cosmology to microscopic physics. Eventually our re-

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