student's review is also evident. For example, an entire chapter is devoted to population cage experiments. Perhaps this should be included for completeness, but many contemporary *Drosophila* population geneticists question whether theses studies tell us much about selection in natural populations. There are occasional interpretations and assertions that would, not unexpectedly, be debatable among colleagues, but for the most part Powell resists presenting dogma or self-serving paradigms. This is not a controversial work, nor was it meant to be.

Powell states that his efforts are directed toward first-year graduate students seeking a research problem; toward *Drosophila* workers who are not evolutionary biologists, but who seek an evolutionary perspective; and toward evolutionary biologists who do not study *Drosophila*, but who need to familiarize themselves with the many contributions of *Drosophila* research. His book should be successful on all these counts. This book is a most useful resource, and I expect our lab copy to become well worn by graduate students and colleagues.

Browsings

Animal Groups in Three Dimensions. Julia K. Parrish and William M. Hamner, Eds. Cambridge University Press, Cambridge, 1997. 395 pp., illus. $90. ISBN 0-521-46204-7.

Schools of fish, flocks of birds, and swarms of insects are cohesive wholes that seem to transcend the properties of their individual members. The authors in this volume present a variety of perspectives on studying such groups, including data collection, analytical methods, behavioral ecology and evolution, and mathematical modeling.

Licensed to Kill? The Nuclear Regulatory Commission and the Shoreham Power Plant. Joan Aron. University of Pittsburgh Press, Pittsburgh, PA, 1997. 200 pp., illus. $45. ISBN 0-8229-4044-2. Paper, $18.95. ISBN 0-8229-5649-7.

Recounted here is the saga of the decisions to build and then abandon a $5.5-billion power plant, and the breakdowns of government policy-making and public trust. Aron explores the implications for future decisions about technology that present large-scale risk, and offers suggestions for avoiding similar fiascoes.

Mobile Multimedia Communications. David J. Goodman and Dipankar Raychaudhuri, Eds. Plenum, New York, 1997. 324 pp., illus. $95. ISBN 0-306-45772-5.

This collection of 36 technical papers is from a 1996 workshop on delivering advanced information technology to a mobile population. The research on networks, protocols, media access, and signal processing will be important in creating the technology required to merge Internet and mobile communications services.

Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse. John Boreman, Brian S. Nakashima, James A. Wilson, and Robert L. Kendall, Eds. American Fisheries Society, Bethesda, MD, 1997. 264 pp., illus. Paper, $39. ISBN 1-888569-06-9.

This analysis discusses how and why the resources declined (citing persistent recruitment overfishing as the major reason), and various management considerations that might lead to their recovery.

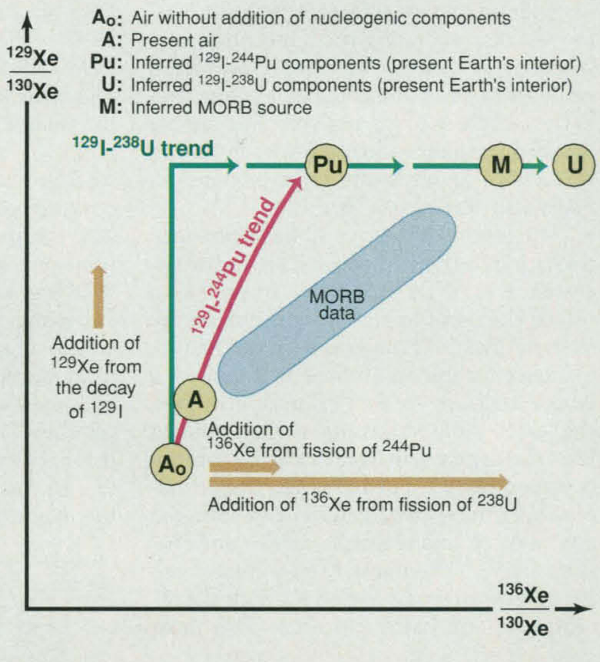
RESEARCH: GEOCHEMISTRY

Xenon's Inside Story

Ichiro Kaneoka

Terrestrial xenon isotopes are especially important in the effort to understand Earth's evolution, mainly because they include decay products of extinct nuclides such as ^{129}I and ^{244}Pu that were present during the formation of the early solar system. Moreover, isotopic compositions of the atmosphere are different from those inferred from extraterrestrial materials, so understanding the interplay between mantle and atmospheric reservoirs is important. This is because the atmosphere, with its substantial amounts of these isotopes, is thought to have been formed by degassing from Earth's interior. Hence, its characteristics should reflect the properties of the original material from which Earth was formed. As reported on page 877 of this issue, Kunz *et al.* (*1*) have used precision mass spectrometry on mid-ocean ridge basalts (MORBs) to resolve a number of questions about the xenon budget of Earth.

This budget is complex. The decay product of ^{129}I is ^{129}Xe, and ^{244}Pu undergoes fission to produce excesses in $^{131\text{-}136}$Xe, whereas ^{130}Xe is protected from secondary addition of any possible reaction products. Thus, isotopic ratios such as ^{129}Xe/^{130}Xe, ^{136}Xe/^{130}Xe, and so on reflect the evolutionary history of material that retains Xe, giving constraints on the early history of Earth (*2*). It has been revealed that some terrestrial samples such as MORBs, CO_2 well gas, and diamonds show excesses in ^{129}Xe and $^{131\text{-}136}$Xe compared with atmospheric xenon (*3*, *4*). On the basis of such observations, the past occurrence of ^{129}I in Earth's interior has been widely accepted. However, the occurrence of ^{244}Pu is controversial because fission-produced components from ^{238}U can also give excesses in $^{131\text{-}136}$Xe isotopes and the patterns of fissiogenic xenon between ^{244}Pu and ^{238}U are rather similar with small dif-



Interior trends. Schematic plot indicating the variation in the ^{129}Xe/^{130}Xe and ^{136}Xe/^{130}Xe ratios. Variations in the ^{129}Xe/^{130}Xe and ^{136}Xe/^{130}Xe ratios are controlled by ^{129}I/^{130}Xe and (^{244}Pu + ^{238}U)/^{130}Xe, respectively, including the time of degassing. The solid arrow line in red indicates an evolution trend for the ^{129}I-^{244}Pu system, whereas the solid arrow line in green indicates an evolution trend for the ^{129}I-^{238}U system. The inferred MORB source value based on Kunz *et al.*'s data (*1*) suggests a mixing between the two systems. The shaded MORB area indicates the data obtained by them.

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ferences. It has been reported that an Indian Ocean gas-rich MORB glass shows xenon that is consistent with the ^{238}U fission spectrum (5). On the other hand, excess ^{129}Xe is commonly correlated with excess $^{131-136}Xe$. It has been argued that the correlation between excess ^{129}Xe and excess $^{131-136}Xe$ should be established by components that have similar time dependence, such as ^{129}I and ^{244}Pu, because diamonds also show such correlation (4). Because the amount of each excess xenon isotope in terrestrial materials is quite small, however, it is a hard task to separate each component, and analytical uncertainties in those samples were too large to distinguish each possibility.

In addition, on the basis of helium and neon isotope analogies, the occurrence of solar noble gases in Earth's interior is often inferred even for xenon isotopes. Because atmospheric xenon isotopes are definitely different from solar compositions, if solar Xe isotopes do occur in Earth's interior, a change in the hypothesis for the origin of the atmosphere and the evolutionary history of Earth would be required.

Kunz *et al.* (1) have succeeded in confirming the occurrence of fission-produced xenon components from ^{244}Pu in Earth's interior by using a special MORB sample, together with the information that the xenon in Earth's interior is of atmospheric composition, except for the occurrence of fission-produced Xe and ^{129}Xe created by radioactive decay. They have concluded that among the fission product components of Xe observed, about 30% is attributed to the component from ^{244}Pu and the remnant to ^{238}U (see figure). This is the first experimental evidence that the Xe derived from fission of ^{244}Pu surely exists in Earth's interior. Their analytical success depends on two main factors: technical improvements including the application of a counting system to measure quite small amounts of gases and the special properties of the sample used for analyses. The sample is called popping rock and has been known to contain anomalously large amounts of magmatic noble gases (6).

The results of Kunz *et al.* have provided a solution to the controversies over the occurrence of ^{244}Pu in Earth's interior and solved the paradox that only the signature of short-lived ^{129}I remains with no definite evidence for the occurrence of ^{244}Pu with a longer half-life in Earth's interior. Thus, the early rapid degassing model from at least the depleted mantle of Earth's interior is strengthened. Furthermore, the occurrence of atmospheric xenon apart from the addition of nucleogenic ^{129}Xe and fissiogenic $^{131-136}Xe$ implies the common origin of the terrestrial xenon for both the atmosphere and Earth's interior. This is an important constraint on the evolution of Earth, and some special process is required to produce terrestrial xenon compositions that are definitely different from those of extraterrestrial materials. This seems to favor the model of secondary degassing for the occurrence of the atmosphere, at least for the major part of xenon isotopes. On the other hand, relative excess xenon contributions from ^{129}I and ^{244}Pu estimated from the atmosphere and the MORB sample are different. Excess $^{129}Xe(^{129}I)/^{136}Xe(^{244}Pu) = 4.3$ for the atmosphere has been suggested (7), whereas that estimated from the MORB (1) is about 9.8. After the end of nucleosynthesis, the value of excess $^{129}Xe(^{129}I)/^{136}Xe(^{244}Pu)$ retained in the solid material should decrease with time because of the difference in the half-life of ^{129}I and ^{244}Pu. If the terrestrial atmosphere was formed by early degassing from Earth's interior where the MORB magma is formed, the value of excess $^{129}Xe(^{129}I)/^{136}Xe(^{244}Pu)$ for the atmosphere should not be less than that in Earth's interior. Yet the observed value is the opposite of what is expected from a simple degassing model of the atmosphere from Earth's interior. This may require some modification in both the degassing model for the evolution of the atmosphere and the evolution model of Earth. Because we have not yet established the heavy noble gas compositions (argon, krypton, and xenon) for the ocean island basalt source, the problem may also be related to their identifications. This knowledge about xenon in Earth's interior surely helps to clarify the model of Earth's formation and demonstrates the need for further information.

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BIOCHEMISTRY

The Era of Pathway Quantification

Daniel E. Koshland Jr.

On page 895 of this issue, Ferrell and Machleder (1) highlight a new era in our understanding of cellular metabolism. Knowledge of metabolic processes in cells can be roughly divided into three eras: the Era of Pathway Identification (1890–1950), the Era of Pathway Regulation (1950–1980), and the Era of Pathway Quantification (1980–?). In the first era, the individual steps in the biochemical pathways were identified. In now classical studies, the substrates, products, and enzymes of pathways such as glycolysis, fatty acid metabolism, and nucleic acid metabolism were identified by Emden, Meyerhoff, Warburg, Kornberg, Cori, Brown, Goldstein, and many others (2). In the second era, the control of pathways through feedback, feedforward, cooperativity, allostery, phosphorylation, and covalent modification was delineated by Pardee, Krebs, Fischer, Stadtman, Jacob, Monod, this author, and many others (3). In the third era, now in its childhood, the quantification of pathways is being examined to calculate the rates at which metabolites and substrates are produced and degraded in cells and in organs.

Ferrell and Machleder (1) examine the turning on and off of the cell cycle in oocytes, showing that this control process is quantitatively "ultrasensitive" (4) and that the enzymes responsible are the mitogen-activated protein kinase (MAP kinase) cascade. In their report, they examine this process in intact oocytes (1); in a previous paper, Huang and Ferrell analyzed a cell-free system of the same MAP kinase cascade (5). Because individual enzymes of the cascade do not show cooperativity, it seems clear that some form of zero-order ultrasensitivity or multistep ultrasensitivity (4) is at work in this pathway, likely involving the kinetics of phosphorylation and dephosphorylation in the enzymes of the kinase cascade.

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