RARE-EARTH INFORMATION CENTER NEWS

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RARE EARTHS GROW

Having been in the rare earth field since mid-1952 it has been with interest, excitement and pleasure, and occasionally some misgivings, that I have witnessed the growth of the research activity and industry during these 22 years. I am not writing to cite the landmarks of accomplishments since the 1950's—these will be duly noted upon their anniversary dates in future issues of this newsletter—but rather to look to the future, especially the growth of consumption and uses of rare earth materials.

Since 1967, despite several valleys and peaks, the usage of rare earths has increased by very nearly 20% per year—truly a phenomenal growth rate. With acceptance of rare earth additions to glass (decolorizing) and steels (as a desulfuring agent) this growth rate would be expected to be maintained for the next few years. And with continued research and potential applications such as auto exhaust catalysts and antiknock gasoline additives, an average 20% growth rate for the next decade is not at all inconceivable.

Stopping for a moment to reflect, we quickly realize that after a number of years growing by 20% per annum, even a small quantity will expand to a very large one. In 1973 about 15,000 tons of rare earth oxide equivalent were consumed in the United States alone. Generally it is thought that the remainder of the world consumes an equal amount. The most recent information on rare earth world-wide resources indicated 18.7 millions of tons of oxide deposit have been identified (J. W. Adams and M. H. Staatz, *U.S. Geol. Survey Prof. Paper No. 820*, pp. 547-56, U.S. Government Printing Office, Washington, D.C., 1973). A quick mathematical calculation indicates that in the year 2008 disaster will strike and no longer will there be any rare earths around—except for a few precious vials some scientists had the foresight to hide on the laboratory shelf or in a desk drawer.

Although we do not subscribe to the "Club of Rome" doomsday philosophy, one should realize that the world's supply of rare earths are finite. In reality the "2008 disaster" will never occur in such a sudden manner since supply and demand will cause a slower growth rate in the 1990's. Furthermore, recovery and secondary usage of rare earths will be an important segment of the industry; new sources of rare earths will continue to be discovered and known resources will be better evaluated (from 1970 to 1974 the known resources have increased by 83%). These factors and competition from other materials will push back the day of reckoning well into or beyond the 21st century.

National Academy Elects Margrave

John L. Margrave

Rare Earther John L. Margrave, Rice University, has been elected to the National Academy of Sciences. He was one of 95 Americans newly elected to membership in February of this year. Election to the Academy recognizes distinguished and continuing achievements in original research and is one of the highest honors that can be accorded an American scientist or engineer.

M AND M--ANDM

The proceedings of the 19th Annual Conference on Magnetism and Magnetic Materials, held in Boston, Nov. 13-16, 1973, are now available in a two-volume set as the **AIP Conference Proceedings No. 18, Magnetism and Magnetic Materials**–1973, C. D. Graham, Jr. and J. J. Rhyne, eds. (American Institute of Physics, New York, 1974). The cost is $25.00.

Well over a third of the 300+ papers and abstracts presented deal with rare earth metals, alloys, compounds and amorphous systems. Among the topics discussed are the preparation, investigation and application of bubble devices, optical properties, magnetic properties, critical phenomena, spin waves, theory and applications.

Most of the papers dealt with rare earth garnets for bubble devices and rare earth-cobalt permanent magnets.

MEETING

11TH RE CONFERENCE PROGRAM

The 11th Rare Earth Research Conference committee has rounded up a galaxy of rare earth stars as invited speakers to illuminate the extensive technical sessions planned for the four-day conference to be held Oct. 7-10, 1974, at Traverse City, Michigan.

Astronaut Harrison H. Schmitt, the first scientist-astronaut on the moon, will give the plenary address on the opening day of the conference. His topic, quite naturally, will be Lunar Geology.

Also planned for the opening day will be a special Frank H. Spedding Symposium to honor the founder and first director of the U.S. Atomic Energy Commission's Ames Laboratory. Spedding, one of the foremost of modern rare earth researchers, will conclude the special symposium with a talk entitled Some Remarks on the Rare Earths by a Fifty-Year Student of the Subject.

A complete listing of invited speakers and their topics appears below. The presenters' names are in boldface type.

PLENARY ADDRESS, *Lunar Geology,* Astronaut **Harrison H. Schmitt.**

Electronic Band Structures of the Rare Earth Metals–A Review of Concepts and Results, **H. L. Davis,** Oak Ridge National Laboratory, U.S.A.

Energy Bands, Fermi Surface, and Magnetic Ordering of Rare Earths, **S. H. Liu,** Iowa State University, U.S.A.

Rare Earth Containing Catalysts for Auto Emission Control, **D. W. Johnson,** Bell Laboratories, U.S.A.

Lanthanide Binding Sites on Antibodies and Active Antibody Fragments, **R. A. Dwek, J. A. Knott, A. C. McLaughlin, E. M. Press, N. C. Price, R. Myatt, R. E. Richards, and A. I. White,** University of Oxford, England.

Studies of the Calcium Binding Sites of Porcine and Bovine Trypsin Using Lanthanides as Probes, **J. Reuben, M. Epstein, A. Levitzki,** Weizmann Institute of Science, Israel.

New Developments on the Use of Lanthanide Ions for Structural Probes, **A. V. Xavier,** Instituto Superior Technico, Portugal, and University of Oxford, England.

†Review of Ion-Exchange Technology Used for the Purification of the Individual Rare Earths, **E. J. Wheelwright,** Battelle Pacific Northwest Laboratory, USA.

†Impure Rare Earth Metals, **D. W. Jones and D. A. Hukin,** University of Oxford, England.

†A Part of the Birth and Evolution of Rare Earth Magnetism, **J. J. Rhyne,** Naval Ordnance Laboratory, USA.

†Zeeman Effect for Rare-Earth Ions in Ethylsulfate Crystals, **R. H. Good,** The Pennsylvania State University, USA.

†Some Remarks on the Rare Earths by a Fifty-Year Student of the Subject, **F. H. Spedding,** Ames Laboratory, USAEC, USA.

Uranocene and Related Chemistry, **A. Streitweiser, Jr.,** University of California, USA.

The Structure and Bonding of 4f and 5f π Sandwich Organometallic Compounds, **K. N. Raymond, E. C. Baker, and G. W. Halstead,** University of California, USA.

New Directions in f-Element Compounds: Sigma-Bonded Organometallic Derivatives, **M. Tsutsui, N. Ely and A. Gebala,** Texas A&M University, USA.

Influence of Alloying on the Magnetic Properties of Rare Earth-d Transition Metal Systems, **W E. Wallace,** University of Pittsburgh, USA.

Neutron Crystal Field Spectroscopy in Metallic Rare-Earth Systems, **A. Furrer,** Institut fur Reaktorforschung, Switzerland.

The Rare Earth Lasers, **M. Weber,** Lawrence Livermore Laboratory, University of California, USA.

Spectroscopy of 5f-Systems: Actinides versus Lanthanides, **R. Pappolardo,** GTE Laboratories Incorporated, USA.

Hydrogen in Rare Earth Intermetallics, **K. H. J. Buschow, F. A. Kuijpers, and A. R. Miedema,** Philips Research Laboratories, The Netherlands.

Lanthanide Complexes Derived from Ligands With Non-Oxygen Donor Groups, **T. Moeller,** Arizona State University, USA.

Electronic Structure, Magnetic Exchange and Conductivity in the Magnetic Compounds EuS, GdS and GdP, **G. Guntherodt and P. Wachter,** ETH, Switzerland.

Electronic Phase Transitions in Rare Earth Monochalcogenides Under Pressure and Alloying, **A. Jayaraman,** Bell Laboratories, USA.

Optical Absorption in SmSe and SmTe Under Pressure, **K. Vedam and J. L. Kirk,** The Pennsylvania State University, USA.

Volatile and Organic-Soluble Rare Earth Chelates: From NMR Shift Reagents to Fuel Additives, **R. E. Sievers, J. A. Cunningham, and W. E. Rhine,** ARL-LJ, Aero Space Research Laboratory, Wright Patterson Airforce Base, USA.

NMR Shift Reagents, **R. E. Davis,** University of Texas, USA.

Crystal Chemistry and Chemical Bonding in Ternary Sulfides, **W. B. White,** Pennsylvania State University, USA.

Composes Ln-IIIb-S et Ln-IVb-S, **J. Flahaut, G. Collin, M. Guittard, S. Jaulmes, M. Julien, P. Laruelle, A. Mazurier, D. Messin, and A. Michele,** Laboratoire de Chimie Minerale Structurale, France.

Etude Structurale Des Composes Ternaires Formes Par Les Terres Rares Avec Le Soufre Et Un Second Non Metal, **J. Flahaut, P. Laruelle, C. Dagron, C. Adolphe, J. Etienne, G. Ghemard, O. Loye, N. Rysanek, N. Savigny, and F. Thevet,** Laboratoire de Chimie Minerale Structurale, France.

Crystal Structures and Magnetic Properties of Compounds Type $La_2Fe_2S_5$, **J. Flahaut, F. Besrest, G. Collin and O. Gorochov,** Laboratoire de Chimie Minerale Structurale, associe au CNRS, Universite Rene Descartes, Paris, France, and **R. Plumier,** Centre D;Etudes Nucleaires de Saclay, France.

Magnetoelastic and Related Properties of Rare Earth-Fe_2 Intermetallic Compounds, **A. E. Clark,** Naval Ordnance Laboratory, USA.

Some Aspects of Luminescence and Energy Transfer in Rare Earth Crystals, **J. van der Ziel,** Bell Laboratories, USA.

†Spedding Symposium paper

RIC-DD Acquisitions

RIC-DD-13 Matrix Elements for Many-Electron Atoms. Electrostatic Interaction Energies for Two-Open-Shell Configurations, by J. Karwowski and S. Fraga (1974) 354 pp. (U.S. $35.40) [Airmail Rate C]

RIC Automates Retrieval System

In a continuing effort to improve its service, RIC is changing its information storage and retrieval system. Heretofore a punched card system was used, but with approximately 800 items being added yearly this method proved cumbersome and inefficient. A computer system, developed within the past year with assistance of Ames Laboratory and Iowa State University computer personnel, became operational March 5, 1974. All new articles, reports and books are indexed and retrieved by both author(s) and key word(s). We are also re-indexing all items received by the Center prior to August 1973. It is expected to take about two years to incorporate the entire literature file into the computer system. A typical printout is shown below.

```
Doc. I.D. No. → 973004690
Author(s) → STALINSKI;B          KLETOWSKI;Z          HENKIE;Z
Title → ELECTRICAL RESISTIVITY OF RESN3 SINGLE CRYSTALS (RE = LA, CE
        PR AND ND)
Reference → PHYS. STAT. SOLIDI (A) 19, K165-8 (1973)
Key Words → 1973          LASN3          CESN3          PRSN3
            NDSN3         SINGLE-CRYSTAL NEEL-TEMP      MAG-TRANS-TEMP
            RESISTIVITY   RES-RESISTIVITYT<10           T<298
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A description of this system can be found in "Operation and Maintenance of the Rare-Earth Information Center's Information Retrieval System (RICIRS)", by J R. Jordan, R. P. Sun, and C. G. Maple. IS-3388 (July 1974). Copies are available free from the Center.

Rare Earths In the News

ARC LAMP

A new, high-efficiency arc lamp which uses a unique combination of cerium, cesium and samarium iodides has been developed by Westinghouse Electric Corp. The new lamp, said by Westinghouse to produce 60% more light per watt of input power than fluorescent lamps of comparable whiteness, has exhibited a luminous efficiency of 130 lumens per watt.

AMORPHOUS SUPERCONDUCTOR

Dr. Pol Duwez, California Institute of Technology, and two of his students, W. L. Johnson and Sui-Joe Poon, have announced the development of an amorphous superconductor made from a gold-lanthanum alloy. The alloy was prepared as a thin film (0.005 mm thick) by splat cooling.

TUBULAR RESISTOR

The French Atomic Energy Commission has announced the development of a doped lanthanum chromite material (called PYROX) for heating resistors or electrodes for use at high temperatures in oxidizing environments. Temperatures up to 1850°C can be attained with low power consumption when the material is used as a tubular resistor. It is also said that a controlled degree of oxidation of the component being treated can be achieved.

Anisotropic Metals On Review

Among the approximately 60 metallic elements, about one half have electrical conductivities which are anisotropic, including 16 of the 17 rare earths. Although research was, for some time, directed primarily at the simpler cubic, isotropic elements, renewed interest in non-cubic structures in the past decade has produced substantial results.

In a recent review [*Adv. Phys.* 23, 315-433 (1974)], C. M. Hurd surveys the isothermal galvanomagnetic properties of the anisotropic metals—electrical resistance, magnetoresistance and Hall effects—with particular emphasis on those elements exhibiting low field intrinsic anisotropy. The heavy rare earths are among the most complicated anisotropic metals, yet their galvanomagnetic properties have been the most thoroughly researched. The rare earther should thus find a wealth of information in this article.

A brief illustrated review of the various non-cubic atomic arrangements and their relationships to observed galvanomagnetic phenomena provides the non-specialist with a basic understanding for experimental purposes. Practical definitions and experimental approaches are outlined for each galvanomagnetic effect.

A guide to the recent literature contains 375 references and covers essentially the last decade, 1964 to 1974, with some earlier authors cited for completeness. Supplementary information is included for each of the metals to help the reader determine the relevance and value of a particular reference.

USEFUL POISON

J. D. Noden reports on a recent study undertaken to develop a burnable poison material suitable for use in a High Temperature Reactor (HTR) with a prismatic core [*Nucl. Eng. Inter.* 18, 641-6 (1973)].

The general requirements for HTR's narrowed the choice of materials to boron carbide and gadolinium oxide. Gadolinium oxide was chosen in the form of a Gd_2O_3/Al_2O_3 ceramic because of its superior irradiation stability.

Analysis of chemical properties revealed an inertness toward graphite and gaseous impurities at high temperatures to the extent that no cladding is necessary. Physical and mechanical studies showed excellent dimensional stability under irradiation with no surface cracking, spalling or powdering. Design form and fabrication methods are also described.

LETTER

To the Editor:

In an article entitled *Explain Enigma* in the March 1974 *RIC News* you state that it is quite likely that an extension of the crystal field methods of S. K. Malik and R. Vijayaraghaven [*Phys. Lett.* 34A, 67 (1971)] and H. W. deWijn, A. M. van Diepen and K. H. J. Buschow [*Phys. Rev.* B7, 524 (1973)] will enable the unusual temperature dependence of the paramagnetic susceptibility of elemental samarium to be understood.

This is not the case.

It has been predicted [A. M. Stewart, *Phys. Rev.* B6, 1985 (1972)] and confirmed by the neutron diffraction experiments of W. C. Koehler and R. M. Moon [*Phys. Rev. Lett.* 29, 1468 (1972)] that effects due to the magnetization of the conduction electrons in samarium are of importance and comparable to those due to crystal fields. Therefore it will be essential to take these effects into account in an analysis of the susceptibility.

Yours Sincerely,
A. M. Stewart
The University of New South Wales
Kensington, N.S.W. Australia

ERRATA

IS-RIC-6, Thermochemistry of the Rare Earths–Parts 1, 2 and 3:

Page 16, line 4: monoclinic SHOULD READ cubic

Page 30: The value for $-\Delta G_f^o$ for Europium Sesquioxide, C-form, cubic (Eu_2O_3) at 900°K which reads 332.378 SHOULD READ 330.038 and at 1000°K 320.652 SHOULD READ 323.252.

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K. A. Gschneidner, Jr. ..... Editor
Bernie Evans, W. H. Smith and Betty Verkade
Staff Writers

Coercivity Not Needed

Highly coercive methods will not be needed to generate interest in a new book entitled **Rare Earth Permanent Magnets**, by E. A. Nesbitt and J. H. Wernick (Academic Press, Inc., New York, 1973) 208 pp., $12.50. This monograph provides good reading for materials scientists, engineers and students interested in permanent magnet research and development.

Elementary aspects of permanent magnetism, rare earth elements, their alloys with iron, copper and cobalt, and magnetic properties of these compounds are discussed in the first three chapters. The preparation and properties of cast permanent magnets (Ch. 4) and permanent magnets based on powders (Ch. 5) are presented. Finally, the relatively new rare earth permanent magnets are compared with established permanent magnet materials. Subject and author indexes are included.

FY 1975 Support

Contributions are being received for Fiscal Year 1975 from RIC's financial supporters, many of them substantially over individual firm's previous year's support. So far 19 firms have sent checks or made their 1975 pledges.

It appears our suggestion that contributors consider increasing their support to RIC by the same rate as their rare earth product volume was not at all unreasonable. Under this contribution formula, our support could be considered a barometer of the rare earth industry in general and we're glad the outlook is so bright for so many of you.

Contributions so far have come from:

American Metallurgical Products Co., U.S.A. (6)*
Atomergic Chemetals Co., U.S.A. (3)
Brown, Boveri & Company, Limited, Switzerland (3)
Companhia Brasileira De Technologia Nuclear Usina Santo Amaro, Brasil (3)
Foote Mineral Company, U.S.A. (3)
Th. Goldschmidt AG, Germany (6)
W. R. Grace & Co., U.S.A. (7)
GTE Laboratories, Inc., U.S.A. (3)
GTE Sylvania, U.S.A. (3)
Kolon Trading Co., Inc., U.S.A. (2)
Leico Industries, Inc., U.S.A. (6)
Lunex Company, U.S.A. (5)
A/S Megon & Co., Norway (6)
Molybdenum Corporation of America, U.S.A. (7)
Reactor Experiments, Inc., U.S.A. (5)
Ronson Metals Corporation, U.S.A. (7)
Treibacher Chemische Werke, Austria (3)
United States Radium Corporation, U.S.A. (5)
Wako Bussan Co., Ltd., Japan (6)

*years in support of RIC including present fiscal year.

Phase Data for RE-Co Magnets

Researchers concerned with the general metallurgical behavior of rare earth-cobalt magnet materials or the properties to be expected of a particular mixed rare earth-cobalt alloy will find a convenient source of information in a recent review by A. E. Ray [*Cobalt*, 13-20 (1974)].

Ten rare earth-cobalt phase equilibria investigations have been reported since 1966 when RCo_5 alloys were first identified as possible permanent magnet materials. From these and 39 additional references, Ray has compiled the phase diagrams of all of the six technologically important rare earths—Y, La through Nd, and Sm.

RE's Shed Light On X-Ray Anomaly

The anomalous line-like structures, which have hindered identification of valence band density states in lanthanum, may be part of the continuum spectrum according to R. J. Liefeld, A. F. Burr and M. B. Chamberlain, *Phys. Rev. A* 9, 316-22 (1974). Examination of a sequence of M-series x-ray spectra for closely spaced electron-excitation energies reveals energy-dependent structures characteristic of a classical scattering resonance. They occur in the vicinity of the M_5 and M_4 inner levels and display intensities which correspond to the statistical weights of these levels.

To explain these phenomena, the authors suggest the existence of an intermediate negative-ion bound state involving an excited $3d$ electron and a captured incident electron initially in bound orbitals around the $3d$ vacancy. Decaying radiatively, the $3d$ electron reverts to its original state and the captured electron occupies a $4f$ orbital above the Fermi level. It is predicted that a similar mechanism should be operative whenever an inner quantum level is being filled, *viz.* the transition metals, lanthanides and actinides. Wave function calculations and an examination of cerium spectra are said to support this interpretation [M. B. Chamberlain, A. F. Burr and R. J. Liefeld, *Phys. Rev. A* 9, 663-7 (1947)].

These observations are relevant to a variety of other spectral studies including appearance-potential and continuum-limit spectroscopies.

Rare-Earth Information Center
Energy and Mineral Resources Research Institute
Iowa State University
Ames, Iowa 50010