Rare-Earth Information Center NEWS

AMES LABORATORY

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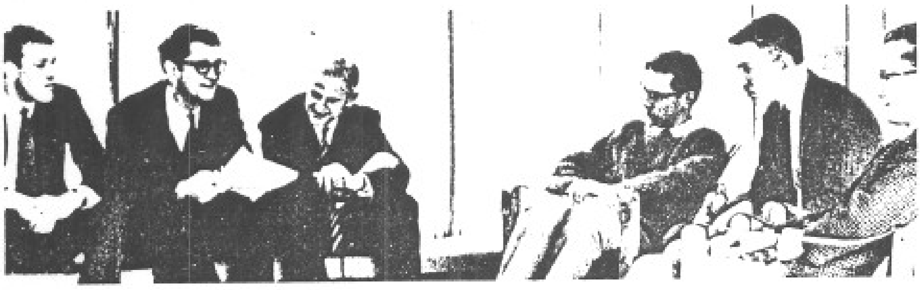

BIRMINGHAM GROUP — Pictured from left are J. D. Speight, Dr. I. R. Harris, Prof. G. V. Raynor, R. C. Mansey, Dr. M. Norman and T. B. Merryfield.

Birmingham Rare-Earth Metallurgy Group

The main programme of the University of Birmingham, England, Rare-Earth Research Group is the physico-metallurgical investigation of alloys and intermediate phases of rare-earth metals with each other and with selected non-rare-earth metals (to date: thorium, zirconium, indium, tin and palladium), in order to contribute to the theory of alloying as applied to these materials.

Metallographic, lattice spacing and magnetic susceptibility methods have been used. Much of the work has been concentrated on alloys containing the metal cerium as solute, whose effective atomic diameter depends upon the environment in the alloy. The most important factors involved are the strain energy of alloy formation and the number of valency electrons per atom in the solvent.

Gadolinium alloys are being systematically studied; the apparent atomic diameter of gadolinium in solid solution is sensitive to the presence or absence of magnetic interactions. Alloys based on ytterbium are also under examination.

Though much effort is concentrated on binary solid solutions, ternary solid solutions are of increasing importance since the relevant factors can be continuously varied from those in a system MR to those characteristic of M'R. Intermediate phases are also studied, and it is found that the factors which are important in solid solutions determine the behaviour of cerium and gadolinium in intermediate phases.

Future plans of the group include detailed studies of magnetic susceptibilities and other physical properties as functions of temperature over a wide range, with a view to definition of the electronic constitutions of rare-earth metals in alloys.

Studies are also in progress on the relationship of the sequence of crystal structures in intra-rare-earth alloy systems to the crystal structures of the pure metals and the variation of this with atomic

(Continued on Page 5)

4f Ligand Field Interactions

Analysis of thermochemical data of lanthanide 1:3 diglycolate and dipicolinate complexes indicates that ligand field stabilization effects involving 4*f* electrons contribute a few hundred calories to the heat of formation. The details of this study were presented in *Nature* (*211*, 1172-3 [1966]) by L. A. K. Staveley, D. R. Markham and M. R. Jones of the University of Oxford.

We would also like to point out that approximately four years ago, G. P. Espinosa suggested on the basis of lattice parameter data of lanthanide iron garnets that the 4*f* electrons interacted with the crystal field (J. Chem. Phys. 37, 2344 [1962]).

These conclusions suggest that the influence of the 4*f* electrons in the lanthanides, though small, is not negligible and may play an important role in the chemistry, physics and metallurgy of these elements.

Rare Earthers Around The World

International Happenings—

Rare-Earth Research–Europe

During the latter days of August and early September the editor criss-crossed Europe visiting a number of universities and one industrial research laboratory. The kind and generous hospitality extended to us by our hosts and hostesses during our brief but delightful visit was deeply appreciated and will be fondly remembered for many years to come. Although we saw many interesting things and had many enjoyable experiences, both scientific and non-scientific, I shall henceforth limit the discussion to the scientific highlights of the trip.

GERMANY

The first stop on my European trip was a visit with Dr. Fritz Weigel of the Institute for Inorganic Chemistry at the University of Munich. Dr. Weigel is the foremost authority on the inorganic chemistry of promethium. Unfortunately, because of new building construction, his hot chemical facilities have been shut down for about a two-year period, and I was unable to see them. The inorganic chemistry of promethium and its relationship to that of the remaining lanthanide elements is quite important because in several instances the chemistry of the promethium bridges the gap or differences between different chemical behaviors of neodymium and samarium.

Of historic interest, I saw some of the original rare-earth compounds and solutions of Wilhelm Prandtl, one of the early prominent rare-earth chemists. These materials were purified by the tedious fractional crystallization technique, and are now property of the Bavarian Academy of Sciences.

HOLLAND

At the Philips Research Laboratories, Einhoven, I visited Drs. K. Buschow and J. Van Vucht. Dr. Buschow is involved in crystallographic, phase diagram and magnetic susceptibility studies on the rare earth-aluminum, -germanium and related alloys. Dr. Van Vucht's present interests are mostly concerned with superconducting materials composed of non-rare-earth metals; however, in the past he has made some studies on rare-earth alloys.

Most of our discussions centered on the electronic nature of rare-earth metals and alloys, as determined from magnetic, crystallographic, and specific heat measurements, and from alloying principles.

ITALY

The next stop in our itinery was the University of Genova, where I visited with Professor A. Iandelli and his co-workers Drs. G. Bruzzone and C. L. Olcese. Their main interests are the crystal chemistry and magnetic properties of the rare-earth intermetallic compounds and the nature of the valency of cerium, europium and ytterbium in intermetallic phases. Our discussions were mostly concerned with the determination of valency of cerium, europium and ytterbium in intermediate phases from magnetic susceptibility and molar volume considerations. The reliability and limitations of these data were also reviewed.

AUSTRIA

Technical University of Vienna.

At the Institute of Applied Physics, I visited Dr. H. Kirchmayr and some of his co-workers. They are working on rare earth-mercury phase diagrams and an amalgam process for preparing intermetallic phases which may be difficult or impossible to prepare by ordinary techniques. The amalgam process consists of dissolving stoichiometric amounts of a rare-earth and some other metal, such as manganese or cobalt, in liquid mercury. The liquid mercury is filtered to remove the mercury-rare earth-manganese solid alloy. The mercury is removed from this ternary alloy by heating in vacuum and the residue, which consists of finely divided rare-earth and manganese in intimate contact, is further heated to form the desired rare-earth intermediate phase. Magnetic susceptibilities and crystallographic studies are being made on the resultant compounds.

University of Vienna.

While at the Institute of Physical Chemistry, I visited Professor H. Nowotny and several of his coworkers. Dr. Nowotny is the foremost authority on the crystal chemistry of the transition metal carbides, borides, silicides, germanides, gallides, etc. Of particular interest are their results concerning the stabilization of $AuCu_3$ type compounds of the R_3M stoichiometry, where M is Ga, In, Tl, Sn and Pb, by small amounts of carbon.

(Continued on Page 8)

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The Editor Reports—

Durham Rare-Earth Conference

The conference took place at the picturesque city of Durham located in beautiful rolling hills of Northeast England. Our cordial hosts, Drs. W. D. Corner and K. N. R. Taylor, were very well organized, and the conference and extracurricular activities came off quite smoothly.

This conference was primarily concerned with the solid state physics and metallurgy of the rare earths. Seven invited papers and 39 contributed papers were presented during the conference which attracted 150 participants. Of these, 14 were from the United States, 9 from France, 7 from Russia, 4 from Denmark, 3 each from Germany, Holland and Switzerland and 1 each from Brazil, Finland, Italy and Sweden. The remainder were from the United Kingdom.

There was much interest in most of the papers plus a great deal of discussion and exchange of information and ideas among the participants.

The papers presented at the conference will *not* be published in the form of conference proceedings. The authors were asked to publish the papers in appropriate journals whenever the results of their investigations are ready for publication. Long abstracts of the papers, however, were available to all the conferees.

GUEST LECTURERS

The invited papers in general consisted of two parts; a brief review of the latest developments in a particular area, and a summary of the speaker's own recent researches. The magnetic properties of rare-earth garnets were reviewed by R. F. Pearson of the Mullard Research Laboratories, Redhill, England. The behavior of the metals at high pressure was discussed by D. Block of the Laboratory of Electrostatics and the Physics of Metals, Grenoble, France. K. H. Hellwege of the Technical University of Darmstadt, Germany, talked about spectral studies of oxides and magnetically ordered materials. The four remaining talks were concerned with the rare-earth metals and alloys: anisotropy and magnetostriction by A. E. Clark (U. S. Naval Ordnance Laboratory, White Oak, Md.); electronic properties by W. E. Wallace (University of Pittsburgh, Pa.); physical metallurgy by K. A. Gschneidner, Jr. (Iowa State University, Ames, Ia); and spin waves by P. Wolf (International Business Machine Corp., Zurich, Switzerland).

RESEARCH REPORTS

Of the contributed papers, eight dealt with various aspects of spectral studies of rare earths: infrared spectroscopy of rare-earth magnesium nitrates and ethylsulfates; doping of rare earths in a variety of hosts, such as alkaline-earth fluorides, LaF_3, $LaAlO_3$ and YVO_4; the Faraday effect in rare-earth chloride solutions; the $M_{IV,V}$ emission spectra; and the correlation of spectral data with the structure of rare-earth phosphates.

Three papers dealt with neutron diffraction studies on cerium, terbium, and magnon-scattering from the magnetically ordered metals.

Mössbauer studies were discussed in four talks, which dealt with europium, rare-earth-iron Laves phases, gold intermetallic compounds, and the use of Coulomb-excited Mössbauer levels to study quadrupole moments.

Eight talks were concerned with magnetic properties. Subjects covered in these talks were: inclusion of the crystalline electric field gradient effects in the Weiss molecular field model to explain the magnetic behaviors of the heavy rare-earth metals; the magnetic properties of dysprosium, of noble metal and intra-rare-earth solid solution alloys, and of RFe_7, R_5Si_4 and R_5Ge_4 compounds; the magneto-crystalline anisotropy and the stability of magnetic moments in the metals; and the temperature dependence of the spin wave energies of terbium.

Nuclear magnetic resonance study of gadolinium Laves phases, and para-magnetic resonance investigations of rare earth-noble metal solid solution alloys, cobalt Laves phases, and rare earth-Group V compounds were the topics of four other papers.

The physical metallurgy of the rare-earth metals and alloys was discussed in four papers. The specific items covered dealt with a review of the recent metallurgical developments at the A. A. Baikov Metallurgical Institute in Russia, effect of impurities on microstructures, the erbium-hydrogen system, and preparation of rare earth-Group V compounds.

The eight remaining contributions covered a variety of topics, which do not fall into the above categories. These talks were concerned with: secondary electron emission, x-ray isochromat investigations, high and low temperature specific heats, elastic moduli, optical and electrical properties of thin metallic films, magneto-optic Kerr effect in $NdCo_5$, and MF_2-RF_3 phase diagrams ($M = Ca$, Sr, Ba and $R =$ rare earth).

Because of space limitations the exact titles, authors and their affiliations have not been included in the above conference report. RIC, however, will be glad to furnish this information for a particular subject matter(s), so that you may contact the author or authors for more detailed information.

THE NAME OF THE GAME

The term rare earths has its origin with the early discovery of these elements. The word *rare* arises from the fact that these elements were discovered in scarce minerals. The word *earth* comes from the facts that they were first isolated from their ores in the chemical form of oxides and that the old chemical terminology for oxide is earth.

NUCLEAR APPLICATIONS

American Nuclear Society Meeting

Five papers of interest to rare-earth scientists were prsented at the 1966 Annual Meeting of the American Nuclear Society at Denver, Colo., June 20-23. These articles, described below, are available in Trans. Am. Nucl. Soc. 9, [1] (1966).

OAK RIDGE

C. F. Leitten, Jr. and R. J. Beaver report that the majority of the problems in the use of lanthanide oxides as neutron absorbing materials have been solved ("Technology and Performance of Lanthanide-Oxide Neutron Absorbers," p. 10). In particular, europium oxide now appears to be acceptable for such a use. The fabrication difficulties of Eu_2O_3 dispersions in steels have been overcome by new agglomeration processes and by a careful selection of dispersants and cladding materials which are free of silicon.

Additions of compounds such as MoO_3 or TiO_2 have been found to give europium oxide the corrosion resistance it needs for use in pressurized-water reactor systems. The irradiation behavior of both the hydration-resistant and the nonhydration-resistant europium oxide-containing specimens is acceptable.

BROOKHAVEN

The actual use of two lanthanide oxides as neutron absorbants is described by J. B. Godel and J. M. Hendrie ("High-Flux-Beam Reactor Control-Rod Blades and Drive Mechanisms," p. 10). The activity of the Brookhaven High Flux Beam Reactor is controlled by eight main control-rod blades containing a dispersion of 30 vol % Dy_2O_3 in stainless steel for most of the rod length and a dispersion of 30 vol % Eu_2O_3 at the high burnup tip. Eight auxiliary blades utilize an Eu_2O_3 absorber for the entire length. Additional information concerning the testing program and driving mechanisms is given in the article.

GENERAL ELECTRIC

Studies of the applications of rare-earth oxides in reactors were also made by W. G. Baxter and J. W. Tenhundfeld ("A Materials, Fabrication, and Design Feasibility Study for a High-Temperature, Uncooled, Articulating Control Rod," p. 12). Twelve materials were metallographically evaluated as cladants at temperatures of 1000-1040°C for periods up to 8000 hours. The best two materials were then used as cladding for a Ni-Dy_2O_3 cermet and tested for dimensional stability, microstructure and chemical stability.

A fabrication study was performed on the chosen clad Ni-Dy_2O_3 cermet. Fabrication of the core is also explained in the article. Included in this study were investigations on the wear in the hinge of the articulating rod and on the friction coefficient of the cladding material at elevated temperature.

HYDROXIDE SOLS

In a different area of nuclear science, S. R. Buxton, C. J. Hardy and M. H. Lloyd, all of Oak Ridge National Laboratory, reported on "The Preparation and Nature of Rare-Earth Hydroxide Sols, and Implications on Transplutonium Element Oxides," (p. 14). These investigators found that particles in the rare-earth hydroxide precipitate slowly change into rod-shaped crystals upon aging. A spontaneous change from a damp paste into a translucent sol occurs when a large proportion of the precipitate has been converted to the crystalline form.

Microspheres of controlled size may then be prepared by dehydration of the sol with an immiscible long-chain alcohol. Typical diameters of 50 to 200 μ, surface areas of 0.02 to 0.07 m^2/g, crushing strengths of around 650 grams for 150 μ diameters, and densities near the theoretical crystalline density were reported.

Trivalent actinide behavior is analogous to rare-earth behavior according to preliminary work.

ACTIVATION ANALYSIS

The fifth paper of interest is "The Determination of Terbium, Erbium, Ytterbium, and Yttrium by Neutron Activation Analysis," by General Atomics scientists F. M. Graber, H. R. Lukens, and K. Heydorn (p. 87). Pre-irradiation separation of the Tb-Er-Yb-Y fraction, followed by neutron activation is utilized in this method. Sensitivity was reported to be 0.8 μg of Er and 0.5 μg Y in one milligram of lanthanum with irradiations of 6 and 18 sec respectively in a thermal neutron flux of 4.3×10^{12} n/(cm² sec) and fission-spectrum neutron flux of 3.5×10^{12} n/(cm² sec). Detection of 0.0005 μg Tb and 0.01 μg Yb was achieved with an irradiation of five hours in a thermal-neutron flux of 1.8×10^{12} n/(cm² sec).

The procedure is rapid and straightforward and gives reasonable yields without serious fractionation of the rare-earth group, according to the authors. The major disadvantage appears to be in working with samples containing low levels of rare-earth elements where application of this method is not completely successful.

(Continued on Page 5)

Rare! Earthly Goofs

Vol. I, No. 3, Sept. 1966

Page 2, Col. 1

The story on Lunex failed to carry the location of the firm. Lunex Company is located at Pleasant Valley, Iowa.

Page 3, Photo caption

The name of Harvey Burkholder, general supervisor of the rare earth-separations pilot plant at Ames Laboratory (extreme right in back row) was inadvertently omitted from the photo caption.

Page 4, Col. 1

In the story entitled *Magnetism 1965*, the year should read 1964 in the second line of the first paragraph.

NUCLEAR APPLICATIONS

(Continued from Page 4)

RESERVE SAFETY SYSTEM

The use of gadolinium nitrate as a reactor poison in a shutdown system has been described in "Gadolinium Nitrate Injection as an Auxiliary Shutdown System for Savannah River Reactors" by L. A. Heinrick of E. I. du Pont de Nemours and Co., *Nucl. Safety 7*, 175-9: 184 (Winter 1965-1966).

In an actual test of the poison's speed and efficiency, it was found that a production reactor could be shut down within a few seconds after injection initiation and kept in that condition. Repurification of the moderator by circulation through an ion exchange system resulted in a poison removal rate said to be equivalent to 98% efficiency for the purification system.

The du Pont scientists conclude that the device is a reliable reserve safety system and that future operations of the reactor would not be impaired or seriously delayed by its use.

IN SPACE

Pm-147 has been proposed for use in a radioisotope-heated reaction control thrustor in a paper entitled, "Advanced Low-Thrust Propulsion Systems for Station Keeping and Stability Control of the NASA Manned Orbital Research Laboratory (MORL): Resistojets and Radioisotope Thrustors". The study was reported by M. Goodman of Douglas Aircraft Co. at the Fifth Electric Propulsion Conference of the Am. Inst. Aeronautics & Astronautics, San Diego, California, March 7-9, 1966. [CONF-660310-2]

The purpose of the radioisotope is to heat the propellant as it flows through the propellant tubes in the thrusting system. Pm-147 was chosen on the basis of its half life, radiation characteristics, availability and fuel form.

New Vacuum Gauge

A new gauge which measures the vacuum in "free" space, using beta-emitting ^{147}Pm, has been proposed by B. W. Schumacher, E. Aruja and H. R. Falckenberg, all of the Ontario Research Foundation, Toronto. A useful working range from 10^{-3} to 0.2 torr was found by the authors. An extension of the upper range from 10 to 10^{-13} torr is believed possible. [Paper presented at the Third International Vacuum Congress, Stuttgart, Germany, June 28 to July 2, 1965. (CONF-650643-2)]

RADIATION SHIELDING MATERIALS

Radiation shielding materials which contain either dysprosium or gadolinium provide the highest combined neutron and photon shielding efficiencies of any commercial product, according to W. C. Hall, president of Chemtree Corp., Central Valley, N. Y.

One of the new materials, containing 35% Dy and 40% Pb, has a neutron scatter cross section of about 60% that of lithium hydride for equal mass. The rare-earth product was found to yield a slightly better thermal neutron capture and markedly better photon attenuation.

The gadolinium-containing materials were reported to have a photon attenuation similar to that of tungsten on a mass basis.

BIRMINGHAM GROUP

(Continued from Page 1)

number. In extension of this work, wide ranges of temperature and pressure will be covered by using equipment which is now available. Though not primarily aimed at phase diagram determination, the programme gives rise to useful information in this field.

MEETINGS

They're Coming — Closer!

A partial list of invited speakers who have consented to participate in the Sixth Rare Earth Research Conference has been announced by Wallace C. Koehler, chairman. The speakers, their institutions and topics are listed below:

J. S. Anderson, Oxford University, Oxford, England
"Non-Stoichiometry and Defects in Solid State Chemistry of the Lanthanides"

A. J. Freeman, National Magnet Laboratory, M.I.T.
"Band Structure, Fermi Surface, and Electronic Properties of Rare-Earth Metals"

K. A. Gschneidner, Jr., Ames Laboratory
"Problems and Progress in Metallurgy of the Rare Earths"

K. H. Hellwege, Institute for Technical Physics, Darmstadt, Germany
"Optical Properties of Rare-Earth Compounds"

Howard E. Kremers, American Potash and Chemical Corp.
"Use of the Rare Earths"

D. B. McWhan, Bell Telephone Laboratories
"Magnetic Properties of Rare-Earth Alloys Under Pressure"

Therald Moeller, University of Illinois
"Current Problems and Studies in the Coordination Chemistry of Rare-Earth Metals Ions"

H. Bjerrum Møller, Atomic Energy Research Establishment, Riso, Denmark
"Inelastic Scattering of Neutrons by Spin Waves in Terbium"

H. Pauthenet, National Commission for Scientific Research, Grenoble, France
"Properties of Rare-Earth Metals Under Pressure"

P. N. Yocum, R.C.A. Laboratories
"Rare-Earth Chemistry and Laser Devices"

Kei Yoshida, University of Tokyo
"Spin Wave Theory of Rare-Earth Metals"

(Continued on Page 8)

Liquid Extraction Group of the Ames Laboratory

LIQUID EXTRACTION GROUP — Standing from left are Roger F. Sebenik, Thomas C. Owens, Richard W. Rahn and S. Edward Mead. Seated from left are Terry G. Lenz, Dr. Morton Smutz and S. Gopala Krishnan Nair.

Chemical Engineering Group I at Ames Laboratory is interested in developing techniques for predicting the optimum operating conditions required to make a desired separation of rare earths in a multistage continuous countercurrent extractor. When this goal is reached, it will be possible to minimize the amount of expensive trial-and-error investigations required to determine the proper extraction conditions. Such techniques will also be applicable to other systems of interest to the Atomic Energy Commission.

Because the thermodynamics of concentrated solutions of mixed electrolytes is not well understood, it is necessary to correlate equilibrium data empirically. The Group has successfully correlated equilibrium data for the tributyl phosphate (TBP) - HNO_3 - $R(NO_3)_3$ - H_2O system and is doing similar work with the di (2 ethyl hexyl) phosphoric acid (D2EHPA) - HCl - RCl_3 - H_2O system.

The problem of determining the separation that can be made under given operating conditions using TBP as the solvent has been solved by computer methods. Research in progress is concerned with optimizing the conditions based on the highest return on the investment.

It is well known that D2EHPA extracts many solutes by so-called "liquid ion exchange." This Group has found that one or more other mechanisms of extraction also take place at even moderate concentrations. This is particularly true for rare-earth nitrates and perchlorates.

Simulated column runs have been used to determine the operating conditions required to produce a lanthanum product of greater than 99.8 percent purity starting with a didymium chloride mixture. Two extraction cascades were employed.

A mixer-settler extractor has been developed specifically for the D2EHPA - diluent - RCl_3 - HCl - H_2O system. This extractor will be used to obtain a high purity lanthanum product.

"Indeed, We Haven't Any"

The Research Materials Information Center (RMIC) at Oak Ridge National Laboratory has asked our help in obtaining the following materials.

Rare Earth Material	Purity	Form
Ce Metal	4N	SX*
hydroxides	—	SX*
oxyfluorides	—	SX*

*SX - single crystal

If you can shed some cerium, hydroxides or oxyfluorides on the subject, please correspond directly with Dr. T. F. Connally, Research Materials Information Center, Oak Ridge National Laboratory, Oak Ridge, Tenn. 37830. We would appreciate a carbon copy of your correspondence.

Rare Earths In the News

Transparent Ceramic

A new yttria-thoria ceramic has been developed at General Electric. At a meeting of the American Ceramic Society at University Park, Pa., Dr. R. C. Anderson and Dr. P. J. Jorgensen stated that the ceramic is transparent and can withstand temperatures in excess of 2200°C.

This material contains 10 mol % of thoria dissolved in cubic yttria. The microscopically small pores which scatter light are removed from between the powder particles by heat treating. Polishing results in a ceramic with an "exceptional transparency" to visible and infrared light.

The transmission cutoff occurs in the ultraviolet range at 0.24 micron and at about nine microns in the infrared range. Light absorption is low and the transmitted light has a minimum distortion.

"STATE OF THE ART"

Current uses of rare-earth phosphors in the lighting and TV industries are outlined in a recent *Chemical Week* article. The review, "Rare-Earth Future Glows," pp. 79-81 of the Oct. 8, 1966 issue, describes the improvements in mercury vapor lamps, fluorescent tubes and color TV when rare-earth phosphors are used.

The expansion in rare-earth production, brought about by the new demands for rare-earth oxides, is also described (see below). A brief survey of four of the leading suppliers of rare-earth products includes their present facilities and methods of production, and their plans for expansion in the future.

Those of you who are interested in this aspect of rare-earth technology will find this review a concise summary of the "state of the art."

(Continued on Page 7)

Rare Earth — Cobalt Magnets

The magnetic behaviors of rare earth-cobalt, RCo_5, intermetallic compounds have been reviewed by R. Lemaire of the Laboratory of Electrostatics and Physics of Metals, Grenoble, France, in the September, 1966 issue of *Cobalt*, No. 32, pp. 132-140. In this article, "Magnetic Properties of the Intermetallic Compounds of Cobalt with the Rare Earth Metals and Yttrium," a brief survey of the known rare earth-cobalt phase diagrams, crystallographic data and magnetic properties is presented.

Levitation melting was used to prepare the RCo_5 compounds, since these alloys react with all the common refractory metals and oxides which might be used as crucibles.

The major portion of the article deals with the magnetic properties of the RCo_5 compounds, especially $CeCo_5$, $NdCo_5$ and $TbCo_5$. Magnetization data as a function of temperature, Curie temperatures (which range from 464°C for $CeCo_5$ to 747°C for $SmCo_5$ and $TmCo_5$) and the magnetic structures are discussed. For $CeCo_5$, the Ce atom has no magnetic moment, suggesting it is tetravalent, and the entire magnetization of the compound is due to the Co atoms. For $NdCo_5$, the magnetic moments of the Nd atoms are aligned parallel to those of the Co atoms. But for $TbCo_5$ the magnetic moments of the Tb atoms are aligned antiparallel to those of the Co atoms. The direction of easy magnetization for the $NdCo_5$ and $TbCo_5$ compounds at low temperatures (below −50° and +100°C, respectively) is in the basal plane of these hexagonal compounds, but as the temperature is raised the direction rotates, such that above 20° and 180°C, respectively, the direction of easy magnetization is parallel to the *c*-axis.

Another paper on this subject is to be published in a later issue of *Cobalt*.

Oxidation Resistant Yttrium

Protection of yttrium metal articles from oxidation and corrosion at temperatures up to 900°C for at least 60 hours has been obtained through a process patented by D. R. Wilder and C. D. Wirkus, Ames Laboratory, Ames, Iowa, for the Atomic Energy Commission. [Pat. No. 3,266,928, August 16, 1966].

A mixture of vanadium oxide and aluminum oxide suspended in a low-boiling liquid medium is applied to the yttrium article to be coated. This material is then fired at 1100 to 1250°C, resulting in a crystalline glass coating. The yttrium surface which is to be coated does not need to be precleaned, although better results are obtained when it is.

RARE EARTHS IN THE NEWS

(Continued from Page 6)

Expand Production Facilities

Three companies in the rare-earth industry have announced the expansion of production facilities. American Potash and Chemical has a new rare-earth solvent extraction unit under construction at its West Chicago, Ill., plant which will double the firms capacity for the production of both yttrium and europium oxide upon completion in the Spring of 1967.

Molybdenum Corp. of America has recently completed expansion of its capacity for europium oxide production at its Mountain Pass, Calif. site from 12,000 to 20,000 pounds annually. Also planned at the Mountain Pass location is the expansion of the company's rare-earth flotation mill from 30 to 50 million pounds per year.

At Louviers, Colo., Yttrium Corp. of America has begun operation of a production facility for 180,000 pounds of pure yttrium oxide annually. Also under construction are facilities for producing high-purity lanthanum, praseodymium, and neodymium oxides.

Liquid Lasers

A new type of liquid laser has been developed by A. Heller and A. Lempicki of General Telephone and Electronics Laboratories (GT&E), Bayside, New York. Using neodymium oxide dissolved in selenium oxychloride, an energy output of about 100 times greater than that previously achieved by liquid lasers was obtained. The energy produced is said to be comparable to that of solid-state lasers of similar size under identical operating conditions. In some modes, the GT&E laser solution's gain is so high that laser action is achieved without the usual end-mirrors.

The use of selenium oxychloride as solvent is stated as the basic principle underlying the high energy output of this laser. Such a solvent does not contain light atoms ($Z<8$) which cause dissipation of energy by vibrational losses. This effect was demonstrated by the enhancement of the luminescence of neodymium in aqueous solution when deuterium was substituted for hydrogen.

Liquid lasers have several inherent advantages. With no practical limit on a liquid laser's length, the ultimate energy output of the liquid laser may be higher than that of crystalline lasers, since the energy output of a laser is related to volume of active medium. Liquid laser material may be circulated to provide cooling and thus overcome the problem of heat build-up in laser mediums. In addition the liquid laser has the capacity to repair itself, even after heat produces bubbles.

Further information concerning the Nd^{3+}: $SeOCl_2$ liquid laser is available in *App. Phys. Letters* 9, 106-110 (1966).

RANKS 28th IN ABUNDANCE

Cerium, which is the most abundant rare earth, ranks 28th in the abundances of the naturally occuring elements and is more plentiful than beryllium, cobalt, germanium, lead, tin, or uranium.

Reports, Brochures, Booklets

RARE EARTH TECHNICAL BULLETIN

We have recently received a technical bulletin, *Yttrium and the Rare Earths*, published by the Michigan Chemical Corp.

The technical bulletin lists rare-earth oxides, metals and salts and includes a description of these plus information on their properties, uses, handling precautions, and shipping regulations.

This new technical bulletin may be obtained by writing to:

Michigan Chemical Corp.
2 North Riverside Plaza
Chicago, Ill. 60606

1965-66 Publications Book

The Ames Laboratory 1965-66 *List of Publications* is available for distribution.

The booklet lists more than 200 research and development (R&D) reports and journal publications in the areas of chemistry, engineering, physics and metallurgy which issued from the Ames Laboratory during Fiscal Year 1966. A significant number of these papers and reports deal with rare-earth investigations.

Information on how to obtain copies of R&D reports, plus an order form for requesting reprints of journal publications from the Laboratory appear on the inside, back cover of the booklet.

The booklet will be distributed to RIC subscribers on request.

If your institution publishes a similar list, we would be happy to announce it in this column.

RARE-EARTH RESEARCH

(Continued from Page 2)

ENGLAND

At the University of Birmingham I visited with Drs. G. V. Raynor, R. I. Harris and their co-workers. A more complete description of their research interests are presented in our column *Rare-Earthers Around the World*, page 1.

Our discussions dealt with the variation of lattice parameters of solid solution alloys (intra-rare earth, and rare earth-gold, -silver, -palladium, and -thorium) and the crystal chemistry of intermediate phases.

The last few days in Europe were spent at the Rare-Earth Conference in Durham, England. A complete report of this aspect of the trip is given on page 3.

NOT SO RARE

Twenty five percent of the naturally occuring elements are scarcer than thulium. Thulium is more plentiful than cadmium, gold, iodine, mercury, platinum, or silver.

MEETINGS

(Continued from Page 5)

Dr. Alvin Weinberg, Director of Oak Ridge National Laboratory, will be the banquet speaker. ORNL is co-sponsor of the conference along with the Air Force Office of Scientific Research, Directorate of Chemical Sciences.

Rare Earths From Apatite

Scientists of the U. S. Geological Survey, Washington, D. C., have indicated [*Chem. and Eng. News* 44, No. 44, 52 (1966)] that apatite, the principal mineral in phosphate rock, could be an important industrial source of the rare earths. Although rare earths constitute only 0.01 - 0.1% of the mineral, large amounts of apatite are processed yearly in wet-process phosphoric acid production, thus significant quantities of rare earths are available for potential recovery.

An additional bonus to this source lies in the fact that the cost of mining, beneficiating, processing and solubilizing the rare earths would already be paid for in the course of phosphoric acid production.

Marine apatite contains a relative enrichment of the middle-and higher-atomic weight lanthanides. It is estimated that 8.5 million tons of apatite will be processed in the United States during 1966 for phosphoric acid. More than 5000 tons of rare earths could be extracted from this source.

[Ed. note: Typpi Oy, a nitrogen plant at Oulu, Finland, has for many years produced rare earths by extraction from apatite].

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