

AUTHORS — AUGUST 1990

COLD FUSION

A REVIEW OF THE INVESTIGATIONS OF THE FLEISCHMANN-PONS PHENOMENA

John O'M. Bockris (top) (BSc, 1945, and DSc, 1952, chemistry, University of London, United Kingdom) is a distinguished professor of chemistry at Texas A&M University. His research interests are in the areas of quantum electrochemistry, photo-electrochemistry, electrocatalysis, bioelectrochemistry, corrosion, and the splitting of water. **Guang H. Lin** (center) (BSc, chemical physics, Chinese Science and Technology University, China, 1965; MS, 1983, and PhD, 1985, physics, University of Colorado) is currently a senior research scientist at Texas A&M University. His current interests include ultrahigh-pressure physics, lasers, steady-state chemical dynamics, hydrogen evolution from water, and cold fusion phenomena. **Nigel J. C. Packham** (bottom) (BSc, City of London Polytechnic, United Kingdom; postgraduate studies at Imperial College of Science and Technology, United Kingdom) is currently a graduate student at Texas A&M University. His research interests include bacterial production of hydrogen from waste material, laboratory automation, and surface electrochemistry.

*John O'M. Bockris
Guang H. Lin
Nigel J. C. Packham*



BHABHA ATOMIC RESEARCH CENTRE STUDIES IN COLD FUSION

P. K. Iyengar (top) [MSc, physics, University of Travancore, India, 1952; PhD, University of Bombay (UB), India, 1963] has been with the Bhabha Atomic Research Centre (BARC) since it was founded. He led the team that designed and built India's first plutonium-fueled fast reactor. His current interests include materials science, accelerators, nuclear power technology, and emerging nuclear energy schemes. He is also chairman of the Indian Atomic Energy Commission. **M. Srinivasan** (bottom) [BSc, University of Madras, India, 1957; BARC Training School (BARCTS), India, 1958; MSc, 1966, and DSc, 1984, UB, India] is head of the Neutron Physics Division of BARC. His interests include zero-power reactor noise analysis, reactor kinetics and

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S. K. Malhotra
D. G. Gaonkar
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safety, nuclear criticality physics, the neutronics of fusion reactor blankets, and cold fusion. **S. K. Sikka** (top right) (BSc, Punjab University, India, 1960; BARCTS, India, 1961; MSc, 1967, and PhD, 1970, UB, India) specializes in high-pressure physics. **A. Shyam** (top left) (MSc, physics, University of Delhi, India, 1975; BARCTS, India, 1961; PhD, UB, India, 1980) is involved in the study of various configurations of Z pinches and is currently responsible for the design and construction of a 500-kJ capacitor bank facility for plasma experiments. **V. Chitra** (second from top right) (BARCTS, India, 1976; MSc, physics, American College, India, 1987) is a member of the fusion research group at BARC, where she has been working on Z pinches and plasma focus. **L. V. Kulkarni** (second from top left) (Dipl., electronics and radio engineering, 1972) works on nuclear particle detectors, pulse processing circuits, and associated electronics for counting systems. **R. K. Rout** (third from top right) (MSc, physics, Utkal University, India, 1984; BARCTS, India, 1985) has worked on plasma focus experiments, specializing in X-ray diagnostics. He is currently working on cold fusion studies, particularly tritium assay using potassium X-ray measurements and autoradiography. **M. S. Krishnan** (third from top left) (BARCTS, India, 1959; MSc, chemistry, UB, India, 1968) leads a group of chemists working on the physicochemical aspects of heavy water production processes. The group is currently involved in research and development of heterogeneous catalysis in tritium enrichment and detritiation of organic compounds. **S. K. Malhotra** (fourth from top right) (MSc, organic chemistry, Agra University, India, 1976; BARCTS, India, 1977) has been actively involved in the development of hydrophobic catalysts for hydrogen production. He is also studying mass spectrometry of hydrogen and deuterium in organic compounds. **D. G. Gaonkar** (fourth from top left) (MSc, UB, India, 1971) joined BARC in 1956. He is involved in preparing deuterated organic compounds and production of D_2 gas by electrolysis of heavy water. **H. K. Sadhukhan** (fifth from top right) (BChE, Jadhavpur University, India, 1959; BARCTS, India, 1962; MSE, University of Michigan, 1967) is head of the Heavy Water Division and is involved in the design and engineering of heavy water production plants based on the H_2S/H_2O exchange process. **V. B. Nagvenkar** (fifth from top left) (MSc, chemistry, UB, India, 1967) has been working on capillary gas chromatography of isotopic molecules and hydrogen/deuterium isotope exchange in metal or alloy systems. **M. G. Nayar** (sixth from top right) (BSc, chemistry, Kerala University, India, 1957; BE, chemical engineering, Jadhavpur University, India, 1961; BARCTS, India, 1962; MS, nuclear engineering, North Carolina State University, 1968) is conducting pilot plant studies of advanced electrolyzers for commercial exploitation of this new technology. His current interests include developing electrolyzers for cold fusion studies. **S. K. Mitra** (sixth from top left) (BSc, chemistry, and M. Tech., chemical engineering; BARCTS, India, 1973) has been developing advanced high-pressure, high-amperage electrolysis cells for hydrogen production. He is currently working on pilot plant studies of advanced electrolyzers. **P. Raghunathan** (bottom right) (BSc, chemistry, University of Madras, India, 1971; BARCTS, India, 1972) is currently engaged in pilot plant studies for hydrogen production using modular electrolyzers with porous nickel electrodes. His current interests include water electrolyzers, electrochemistry, and cold fusion. **S. B. Degwekar** (bottom left) (BSc, physics, Pune University, India, 1976; BARCTS, India, 1977) worked in the field of theoretical reactors physics, particularly integral transport theory. He is also interested in the theory of stochastic processes as applied to zero-power reactor noise techniques and passive neutron assay of plutonium. He is currently investigating the stochastic aspect of neutron emission in cold fusion

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R. Sundaresan
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R. Kalyanaraman
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P. N. Moorthy
K. S. Venkateswarlu
B. Yuvaraju
K. Kishore
S. N. Guha
M. S. Panajkar
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experiments. **T. P. Radhakrishnan** (top right) (MSc, Kerala University, India, 1957; BARCTS, India, 1958; PhD, University of London, United Kingdom, 1966) specializes in electroanalytical chemistry, electrochemical instrumentation, hydrogen entry in metals, corrosion, and thermal analysis. **R. Sundaresan** (top left) (BARCTS, India, 1964; MSc, 1970, and PhD, 1975, UB, India) works in the areas of electroanalytical chemistry and polarography. **J. Arunachalam** (second from top right) (BSc, University of Mysore, India; BARCTS, India, 1974) works on high-resolution gamma-ray spectrometry, neutron activation analysis, and charged-particle activation for compositional characterization of materials with respect for trace and ultratrace levels of impurities. He developed the pattern recognition approach to multivariate analysis for interpretation of spectral and nonspectral data in earth, forensic, and environmental sciences. **V. S. Raju** (second from top left) (MSc, nuclear physics, Andhra University, India, 1974; BARCTS, India, 1975) is a member of the Analytical Division of BARC. He has been working on surface characterization techniques using ion beam analysis for various applications. **R. Kalyanaraman** (no photograph available) (MSc, chemistry, University of Delhi, India, 1958; BARCTS, India, 1958; PhD, physical chemistry, UB, India, 1967) works in the fields of thermochemistry and high-temperature electrochemistry. **S. Gangadharan** (third from top right) (BSc, University of Madras, India, 1959; BARCTS, India, 1960; PhD, University of Pittsburg, 1969) is head of the Analytical Chemistry Division at BARC. His interests include nuclear analytical chemistry using neutrons and charged particles; their application to the materials, forensic, and environmental sciences; and ultratrace analysis for compositional characterization of pure materials using nuclear, electrochemical, and spectrochemical methods. **G. Venkateswaran** (third from top left) (MSc, chemistry, University of Madras, India, 1970; BARCTS, India, 1971; PhD, physical chemistry, UB, India, 1983) specializes in material compatibility studies in nuclear reactor applications, water reactor fuel performance evaluations, reactor water chemistry, and reactor safety. **P. N. Moorthy** (fourth from top right) (BSc, University of Madras, India, 1959; BARCTS, India, 1960; PhD, physical chemistry, University of Durham, United Kingdom, 1966) is head of the Applied Chemistry Division of BARC. He specializes in radiation and photochemistry. His research interests include polymers, electrochemistry, and environmental chemistry. **K. S. Venkateswarlu** (fourth from top left) (DSc, recoil chemistry, Andhra University, India, 1961) joined BARC in 1955. His interests include recoil chemistry and water chemistry of nuclear and thermal power stations. He was head of the Water Chemistry Division of BARC until his retirement in 1989. **B. Yuvaraju** (fifth from top right) (MSc, Indian Institute of Technology, India, 1987; BARCTS, India, 1988) works on reactor chemistry problems. **K. Kishore** (fifth from top left) (BARCTS, India, 1966; PhD, chemistry, UB, India, 1980) is involved in hot atom chemistry, solvent extraction, radiation effects on catalysts, pulse radiolysis, and electrochemistry. **S. N. Guha** (sixth from top right) (BARCTS, India, 1963; PhD, chemistry, UB, India, 1989) specializes in radiation and photochemistry, electrochemistry, pulse radiolysis and flash photolysis, the chemical aspects of solar energy, and reactions in micellar media. **M. S. Panajkar** (bottom left) (MSc, chemistry, Nagpur University, India, 1962; BARCTS, India, 1963; PhD, polymer chemistry, UB, India, 1978) has worked in gas and liquid chromatography, mass spectrometry, radiation chemistry, radiation-induced polymerization, pulse radiolysis of organic compounds and computerization of pulse radiolysis experiments. **K. A. Rao** (bottom right) (BARCTS, India, 1959; MSc, physical chemistry, UB, India, 1965) is working on development of gas chromatography



and related instrumentation. His interests include hot atom chemistry, radiation chemistry, and catalysis. **P. Raj** (top right) (MSc, physics, Agra University, India, 1962; BARCTS, India, 1963; PhD, physics, UB, India, 1972) is head of the Materials Science Section of BARC. His current interests are microscopic hyperfine and structural investigations in a variety of materials including metal-hydrogen systems and amorphous alloys. **P. Suryanarayana** (top left) (MSc, Andhra University, India, 1962; PhD, UB, India, 1980) is interested in ultrapurification, crystal growth, and hydrogenation of materials for hydrogen storage. **A. Sathya-moorthy** (second from top right) (MSc, University of Madras, India, 1967; PhD, UB, India, 1976) is interested in solid-state studies of hydrogen-metal systems, particularly hydrogen storage materials. **T. Datta** (second from top left) (BARCTS, India, 1975; PhD, chemistry, UB, India, 1984) works in the field of nuclear fission using radiochemical techniques. His interests include neutron coincidence counting for plutonium assay, neutron multiplicity studies, and positron annihilation spectroscopy. **H. Bose** (third from top right) (MSc, physical chemistry, University of Delhi, India, 1973) has worked at BARC since 1975 in the field of reactor chemistry. His current interests include electrochemical studies of gallium solutions. **L. H. Prabhu** (third from top left) (BARCTS, India, 1958; PhD, physical chemistry, UB, India, 1967) works in the field of reactor chemistry. He is currently head of the Reactor Chemistry Section of the reactor operations and maintenance group at BARC. **S. Sankaranarayanan** (fourth from top right) (BSc, physics, University of Madras, India, 1980) leads a group of reactor physics responsible for the operation physics aspects of the BARC research reactors. His current interests are reactor physics, reactor safety, and analytical heat transfer. **R. S. Shetiya** (fourth from top left) (PhD, chemistry, UB, India, 1973) has worked in the field of reactor chemistry at BARC since 1959. He has worked on metal complexes, radiolysis of aqueous solutions, and radiation stability of ion-exchange resins. He is currently involved in studying the irradiation behavior of neutron poisons in reactors. **N. Veer-araghavan** (fifth from top right) (BSc, physics, University of Madras, India, 1950) has been with BARC since 1956. As associate director of the reactor operations and maintenance group, he is responsible for the safe and efficient operation of all the BARC research reactors. **T. S. Murthy** (fifth from top left) (MSc, chemistry, Andhra University, India, 1957) joined BARC in 1958 and is currently director of the isotope group. His interests include studies in organic exchangers, development of radiation sources and their applications for industrial radiation processes, and measurement of tritium content in groundwater samples for hydrological investigations. **B. K. Sen** (sixth from top right) (MSc, chemistry, Patna University, India, 1973; BARCTS, India, 1975) has developed tritiated polymers for tritium-activated luminous compounds and light sources. He has also been involved in the development and assay of tritium-labeled compounds. **P. V. Joshi** (sixth from top left) (MSc, chemistry, UB, India, 1977) has participated in the development of sealed neutron tubes for oil well logging and neutron activation by 14-MeV neutrons. He has also worked on deuterium- and tritium-loaded target preparation. **K. G. B. Sharma** (bottom right) (MSc, chemistry, Mysore University, India, 1980; BARCTS, India, 1981) has worked on hydrogen isotope separation by palladium chromatography. **T. B. Joseph** (bottom left) (BSc, chemistry, Kerala University, India, 1975) is currently working on electrolytic enrichment of tritium and liquid scintillation counting in groundwater samples for hydrological investigations. **T. S. Iyengar** (see top right on next page) (MSc, physics, Kerala University, India, 1958; BARCTS, India, 1959; PhD, UB, India) specializes in tritium monitoring, particularly liquid scintillation spectrometry.



V. K. Shrikhande (center) (BSc, chemistry, Shivaji University, India, 1969; BARCTS, India, 1970) has worked on the development of gaseous devices such as hollow cathode lamps and glass-to-metal seals. He has also worked on deuteration of machined titanium targets for cold fusion experiments. **K. C. Mittal** (bottom) (MSc, physics, Punjab University, India, 1974; BARCTS, India, 1975; PhD, physics, UB, India, 1986) has worked on the physics of relativistic electron beam and ion beam generation and propagation using vacuum and gas-filled diodes. He helped to develop the technique for deuteration of titanium targets. **S. C. Misra** (no photograph available) (MSc, physics, Agra University, India, 1958; BARCTS, India, 1959; PhD, physics, 1980) leads a group in the field of radiation metrology. His work includes studies with 14-MeV neutrons and other problems related to radiation standards. **M. Lal** (no photograph available) (BARCTS, India, 1960; MSc, physics, UB, India, 1975) is interested in basic studies and applications of energy-dispersive X-ray fluorescences and proton-induced X-ray emission in the biological, medical, environmental, and metallurgical sciences. **P. S. Rao** (no photograph available) (MSc, physics, Banaras Hindu University, India, 1959; BARCTS, India, 1960) is involved in radiation dosimetry and testing of radiation detectors used in reactor control and radiation monitoring.



ACHIEVEMENT OF AN INTENSE COLD FUSION REACTION

Yoshiaki Arata (top) (Dr. Eng., Osaka University, Japan, 1957) is an academican at the Japan Academy of Science and a professor at Kinki University. He worked at Osaka University as a professor and director of the Welding Research Institute from 1972 to 1988. His research activities include development of ultra-high-energy density beam technology and cold fusion. **Yue-Chang Zhang** (Dr. Eng., Osaka University, Japan, 1986) has been an associate professor at Shanghai Jiao-Tong University, China, since 1985 and a guest professor at Osaka University since 1988. Her research activities include cold fusion and welding technology.

*Yoshiaki Arata
Yue-Chang Zhang*



MEASUREMENT OF EXCESS HEAT AND APPARENT COINCIDENT INCREASES IN THE NEUTRON AND GAMMA-RAY COUNT RATES DURING THE ELECTROLYSIS OF HEAVY WATER

Charles D. Scott (top) [BS, MS, and PhD, chemical engineering, University of Missouri and the University of Tennessee (UT)] joined the staff at the Oak Ridge National Laboratory (ORNL) in 1957; he is a member of the Chemical Technology Division. He has held a series of research and development positions in that division, and at present he is a senior research fellow and director of energy research programs. He also heads a research group investigating the "cold fusion" phenomenon. His primary research interests are with heterogeneous interactions, with an emphasis in separation science and technology and bio-processing research. He also serves as an adjunct professor of chemical engineering at UT, Knoxville. **John E. Mrochek** (bottom) (PhD, chemistry, Iowa State University, 1964) joined ORNL in 1964. He is chemistry coordinator for energy research programs in the Chemical Technology Division. His work has spanned many areas during his tenure at ORNL, including thermodynamics of solvent extraction, water electrolysis, mass spectrometry, analytical biochemistry, biochemical separations,

*Charles D. Scott
John E. Mrochek
Timothy C. Scott
Gordon E. Michaels
Eugene Newman
Milica Petek*



biomedical instrumentation development, research and instrumentation development for coal conversion, and research on the immobilization of hazardous wastes. **Timothy C. Scott** (top) (BS, chemical engineering, UT, Knoxville, 1980; PhD, chemical engineering, University of Wisconsin, Madison, 1985) has spent the last 5 years in the energy research programs of the Chemical Technology Division at ORNL as a principal investigator and group leader in the area of multiphase separation science research. In addition, he is an adjunct associate professor in the Department of Chemical Engineering at UT, Knoxville, with both teaching and graduate research responsibilities. His interests include biotechnology, nuclear fuel reprocessing, reaction engineering, and separation science and technology. **Gordon E. Michaels** (center) is the manager of the Office of Planning and Program Development at ORNL's Chemical Technology Division. From 1977 to 1988, he worked in the U.S. Atomic Vapor Laser Isotope Separation (AVLIS) Program, and for 6 years served as manager of the AVLIS Process Science and Analysis Section at ORNL. His current interest is in the development of advanced isotope production technologies. A photograph and a biography for **Eugene Newman** were not available at publication time. **Milica Petek** (bottom) (PhD, University of Zagreb, Yugoslavia, 1964) is a research chemist at ORNL, providing technical support to the radioassay laboratory. From 1973 to 1977, she was a postdoctoral fellow, first at University of North Carolina, Chapel Hill, and later at the State University of New York, Buffalo, developing methods for *in situ* determinations of electrogenerated species. She was associated with Allied Chemical Corporation, working on improvement in the industrial electrolytic fluorine production. She joined ORNL in 1977 to work on hydrogen isotope separation of bipolar palladium electrodes and electrodeposition of isotope target materials. Prior to coming to the United States, she worked for 13 years at the Rudjer Boskovic Institute in Zagreb, Yugoslavia, in the field of applied electrochemistry.



NUCLEAR FUSION EXPERIMENT IN PALLADIUM CHARGED BY DEUTERIUM GAS

Sebastiano Aiello (top right) is a researcher at the Istituto Nazionale di Fisica Nucleare (INFN). His current interests are photon- and heavy-ion-induced fission and reaction mechanisms in heavy-ion-induced reactions at low and intermediate energies. **Enrico De Filippo** (top left) is a postgraduate student in physics at the Università de Catania. His current interest is reaction mechanisms in heavy-ion-induced reactions at low and intermediate energies. **Gaetano Lanzaó** (center right) is a researcher at INFN. His interests include neutron- and gamma-ray-induced fission and reaction mechanisms in heavy-ion-induced reactions at low and intermediate energies. **Salvatore Lo Nigro** (bottom left) is a professor of nuclear spectroscopy at the Università de Catania. His interest lies in fission induced by neutrons, photons, and heavy ions. **Angelo Pagano** (bottom right) is a researcher at INFN. His interests include fission of uranium targets induced by gamma rays and heavy ions and reaction mechanisms in heavy-ion-induced reactions at low and intermediate energies.

*Sebastiano Aiello
Enrico De Filippo
Gaetano Lanzaó
Salvatore Lo Nigro
Angelo Pagano*



METHOD FOR INVESTIGATION OF FUSION REACTIONS IN CONDENSED MATTER

Photographs and biographies for **M. Bittner**, **A. Meister**, **D. Ohms**, **E. Paffrath**, **D. Rahner**, **R. Schwierz**, **D. Seeliger**, **K. Wiesener**, and **P. Wüstner** were not available at publication time.

M. Bittner
A. Meister
D. Ohms
E. Paffrath
D. Rahner
R. Schwierz
D. Seeliger
K. Wiesener
P. Wüstner

NEUTRON MONITORING AND RELATED MEASUREMENTS DURING ELECTROLYSIS OF HEAVY WATER WITH PALLADIUM AND TITANIUM CATHODES: ACTIVITY REPORT

Photographs and biographies for **A. Foglio Para**, **V. Sangiust**, **P. L. Cavallotti**, **U. Ducati**, and **P. F. Bortignon** were not available at publication time.

A. Foglio Para
V. Sangiust
P. L. Cavallotti
U. Ducati
P. F. Bortignon

HOW COLD FUSION CAN BE CATALYZED

Johann Rafelski (top) (PhD, University of Frankfurt, Federal Republic of Germany, 1973) is a physics professor and has been director of the Institute of Theoretical Physics and Astrophysics at the University of Cape Town from 1983 to 1987, when he joined the Department of Physics at the University of Arizona. He has served in various positions at the University of Pennsylvania, Argonne National Laboratory, and the University of Frankfurt. His main areas of interest include heavy-ion collisions, vacuum structure, neural nets, and muon-catalyzed and cold fusion. **Mikolaj Sawicki** (bottom) (MS, 1970; PhD, 1976; and Habilitation, 1987, Warsaw University, Poland) is an associate professor of physics at Warsaw University. He has worked at Bonn University, Hannover University, SLAC, and Virginia Tech. He is currently on sabbatical leave at the University of Arizona. His main areas of interest include few body physics, intermediate energy nuclear physics, field theory, and relativistic dynamics. **Mariusz Gajda** (no photograph available) [MS, Warsaw Institute of Technology, Poland, 1981; PhD, Institute of Physics of Polish Academy of Sciences (PAS), 1985] was first at the Institute of Physics PAS and then at the Institute for Theoretical Physics PAS. He is currently a research associate at the University of Arizona. His main fields of interest are quantum optics, nuclear physics, and cold fusion. **David Harley** (no photograph available) is a graduate student at the University of Arizona. He completed his BS(Hons) at the University of Cape Town in 1987 and is scheduled to obtain his PhD on muon-catalyzed fusion in 1991. His main interests include muon-catalyzed fusion and structure of the Higgs vacuum.

Johann Rafelski
Mikolaj Sawicki
Mariusz Gajda
David Harley



A DYNAMICAL MODEL FOR COLD FUSION IN DEUTERATED PALLADIUM

Eugenio Tabet (top) (PhD, physics, University of Rome, Italy, 1963) is head of the Physics Laboratory at the National Institute of Health, Rome. His research activity is related to the physics of superfluid liquids (helium and superconductors), the phenomenology of the electromagnetic response of superconducting systems, and the renormalization of two-dimensional disordered systems. He is also active in the field of energy-related environmental problems. **Alexander Tenenbaum** (PhD, physics,

Eugenio Tabet
Alexander Tenenbaum



University of Rome, Italy, 1970) is associate professor in the physics department of the University of Rome. His research activity is related mainly to collective properties in condensed matter, in biophysics, solid-state physics, physics of metals, transport properties, and chaos-to-order transition. He is an expert in computer simulation.

THE ROLE OF VELOCITY DISTRIBUTION IN COLD DEUTERIUM-DEUTERIUM FUSION

Robert A. Rice (top) (BS, physics, Case Western Reserve University, 1988; MS, physics, Purdue University, 1990) is a graduate research assistant in the Department of Physics at Purdue University. His research interests include theoretical nuclear physics and the few-nucleon problem. **Gary S. Chulick** (center) (BS, 1977, and MS, 1979, John Carroll University; PhD, Case Western Reserve University, 1988) is a postdoctoral research associate in the Department of Physics at Purdue University. His current research interests are in theoretical nuclear physics and geophysics. **Yeong E. Kim** (bottom) (BS, chemistry and mathematics, Lincoln Memorial University, 1959; PhD, physics, University of California, Berkeley, 1963) was employed at Bell Laboratories from 1963 to 1965. From 1965 to 1967, he was a postdoctoral fellow at Oak Ridge National Laboratory. Since 1967, he has been professor of physics at Purdue University. He was a member of the National Science Foundation review panel for the Stanford Physics Accelerator and has been a consultant for Los Alamos National Laboratory since 1974. His interests are in theoretical nuclear physics, gravitational theory, theoretical geophysics, and nuclear fusion. **Jin-Hee Yoon** (no photograph available) (BS, physics, Seoul National University, Korea, 1986) is a graduate research assistant in the Department of Physics at Purdue University. Her research interests include theoretical nuclear physics and the few-nucleon problem.

*Robert A. Rice
Gary S. Chulick
Yeong E. Kim
Jin-Hee Yoon*

