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HEALTH AND SAFETY RESEARCH DIVISION

PROGRESS REPORT
Period Ending April 30, 1978

OAK RIDGE NATIONAL
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HEALTH AND SAFETY RESEARCH DIVISION

PROGRESS REPORT

for Period Ending April 30, 1978

S. V. Kaye, Director

Date Published: August 1978

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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Introduction

The Health and Safety Research Division (HASRD) was organized in April 1977 to augment the Laboratory's capabilities to deal with the broad problem of understanding how energy technologies affect man. Most of the research components of the Laboratory's former Health Physics Division were incorporated into HASRD. Also, in April 1977, the Analysis and Assessments Section of the Environmental Sciences Division and the Medical Radioisotope Group of the Operations Division were transferred to HASRD. The initial regular staff was approximately 110, with about 65 additional people as guests, students, loaners from other ORNL divisions, and consultants.

The research goal of the Health and Safety Research Division is to conduct basic and applied research that contributes new scientific knowledge with emphasis in biophysical areas that lead to a better understanding of how alternative energy-related technologies affect man.

Included in the basic research are fundamental processes that are important to understand formation, mobility, toxicity, detection, and characterization of pollutants. The applied research includes the integration of data from basic and applied studies through development of concepts and methodologies that can be used for energy-related assessments with primary focus on the health and safety of man. The division has no responsibilities for on-site health and safety.

The division is organized into four sections (see organization chart at the end of the report). The Chemical Physics Section and the Biological and Radiation Physics Section are involved in basic research, and the Biomedical Effects and Instrumentation Section and the Technology Assessments Section are concerned with applied research and assessments. This first progress report is divided into four main sections which follow the organizational structure of the division. Our intent in compiling this thirteen-month progress report is to provide a series of brief technical capsules with a complete publication list for those readers desiring additional information on any of the reported activities.

One challenge faced by all of the staff during the initial year of the new division was to make HASRD a smoothly operating and productive scientific organization. We feel that we have succeeded in this important objective, and this progress report is a testimony to that fact. During the course of our first year, minor reorganizations and staff changes were necessary to strengthen our capabilities. We now have an organizational structure that will allow us to carry out our long-range goals in basic physical research, as well as in areas of biomedical, environmental, and assessments research. Major growth continues in the assessment sciences, including development and demonstration of supportive instrumentation, dosimetry, biophysical transport modeling, and development of methodologies to assess potential health impacts. One of the problems encountered in our first year has been recruitment of an adequate number of specialized staff.

A continuing challenge will be to integrate the many capabilities of the division's staff so that they are complementary and supportive in areas that are of prime importance to the basic goals of the Oak Ridge National Laboratory. We are confident that we can meet this challenge effectively.

Part I. Biological and Radiation Physics

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Activities within this section consist primarily of basic physics research studies directed toward providing new scientific knowledge of the fundamental properties of matter in all phases (gas, liquid, and solid) and of processes and mechanisms important in the interaction of pollutants with the environment and with biological materials. ←

Progress this year is reported under the headings of the five groups within the section. A new program in Studies of Physical Parameters for Health Protection from Chemical Pollutants has been initiated this year. The program represents a redirection of our former analytic dosimetry effort which is being phased out. The new program involves strong collaboration with members of the Biology Division of NRC.

Our program in High Voltage Research dealing with the development of superior gaseous and liquid dielectrics for energy conservation during electrical energy distribution has been substantially increased this year. An International Symposium on Gaseous Dielectrics was organized and hosted by us during the year at the request of the Department of Energy. All reports indicate the symposium was very successful. The proceedings have now been sent to press and will appear in the near future. We are initiating a significant effort in the study of the environmental effects of gaseous dielectrics, and this activity has been identified by a separate research proposal.

The acquisition of a new scanning electron microscope has been a very useful addition to our Submicron Physics Program. The first measurement of a surface potential at the atomic level was achieved this year in this program. The surface potential is responsible for the agglomeration of charged aerosol particles and their adhesion to surfaces and filters. Very accurate measurements of the shapes of the soft x-ray absorption and emission edges of the alkali metals lithium and sodium were made by members of our Physics of Solids and Macromolecules Group. These measurements, made using the National Bureau of Standards (NBS) synchrotron facility, were sufficiently accurate and complete to resolve long-standing debates in the literature.

Collaboration between members of our Transport and Surface Physics Group and the Swiss Institute of Nuclear Research (SIN) continued with the invitation by SIN for one member of our group to spend two months working at SIN in order to assist in setting up a program for planning radiotherapy treatments with pion beams. We have calculated electron interaction probabilities in polystyrene. This represents the first construction of such data for plastics and

organic insulators. Charged particle wake phenomena, which were first described quantitatively by our group, continued to find new manifestation in radiation physics. This year an unexplained splitting of excited electron states on channeled ions was found to be produced by the wake accompanying the ions. We have discovered an analytical solution to the problem of the image potential of a charge in the vicinity of a pinhole. This represents a theoretical effort complementing our experimental Submicron Physics Program.

ANALYTIC DOSIMETRY

This activity was phased out during the year, and the effort was redirected to studies of physical parameters for health protection from chemical pollutants, as described in the next section. However, several projects dealing with dosimetry for radon and radon daughters were completed. A Workshop on this subject was held at ORNL on April 12-13, 1977. The Workshop discussions were focused on technical questions, such as aerosol characterization, lung deposition and clearance, mucous membrane structure, average vs local lung doses, and the conversion of working level month to dose and dose equivalent. Twelve invited experts attended. An ORNL report, ORNL-5348, summarizing the discussions and containing statements by some of the participants has been published. A *Bibliography on the Dosimetry of Radon and Radon Daughters*, ORNL-5284, was issued. Another report, ORNL-5338, *Guide to the Literature in the Dosimetry, Mechanism, Pathology, Epidemiology, and Environmental Aspects of Radon, Its Daughters, and Its Decay Products*, was completed and will be issued in the near future.

STUDIES OF PHYSICAL PARAMETERS FOR HEALTH PROTECTION FROM CHEMICAL POLLUTANTS

This project has replaced Analytic Dosimetry. The object of the new studies is the development and understanding of physical and biological concepts and principles on which a system for health protection against pollutants can be based. The potential hazards of chemical pollutants from the production and utilization of energy will be the principal concern of this work. From the start, the development of this program has taken place in strong collaboration with members of the ORNL Biology Division.

Initial investigations have concentrated on metals, an important class of toxicants. In addition to there being extensive biological data available for metals, their metabolism appears to be simpler than that of other classes of toxicants, e.g., polynuclear aromatic hydrocarbons. In addition, experimental techniques, methodology, and facilities are already available in the Biology Division for studies of metals. Actual experimental and theoretical work has begun in two areas: (1) the effect of metals on RNA synthesis rates and the fidelity of DNA synthesis and (2) the toxic and nontoxic effects of metals on tRNA.

ATOMIC, MOLECULAR AND HIGH VOLTAGE PHYSICS

The Negative Ion States of Polyatomic Molecules: Their Cross Sections for Formation, Lifetimes, Modes of Decay and the Dependence on Molecular and Electronic Structure.

Our trochoidal electron monochromator, allowing for electron beams with full widths at half maximum of ~ 0.02 eV, has been applied to the detection of fine structure in the energy-loss spectrum and negative-ion resonances of polyatomic molecules and to the identification of the mechanism of energy-loss in electron-molecule collisions. The positions of the three negative ion states (configurations $\pi^* \cdot$, $\sigma^* \cdot$, and $\sigma \cdot$) of fluorobenzenes in the vapor phase have been determined. These are 1.13 (1.35), 1.15 (1.35), (4.50) eV for benzene; 0.82 (0.91), (1.40), (4.66) eV for fluorobenzene; 0.53 (0.62), (1.41), (4.51)

eV for p-difluorobenzene; (0.77), (0.77), (4.48) eV for 1,3,5-trifluorobenzene; 0.34 (0.50), (1.29), (4.51) eV for 2,3,5,6-tetrafluorobenzene; 0.15 (0.35), (1.19), (4.53) eV for pentafluorobenzene; and (0.42), (0.42), (4.50) eV for hexafluorobenzene. The numbers in parentheses are the 0 - 0 transitions. On the basis of these data, the first π -electron affinities of the isolated molecules of these compounds are equal to -1.13, -0.82, -0.53, -0.77, -0.34, -0.15, -0.42 eV for benzene, fluorobenzene, p-difluorobenzene, 1,3,5-trifluorobenzene, 2,3,5,6-tetrafluorobenzene, pentafluorobenzene, and hexafluorobenzene, respectively. The present results have been discussed in connection with previously published data on the negative ion states of benzene and benzene derivatives and have been theoretically treated. The results of simple first-order perturbation theory are in reasonable agreement with experimental data. A partial wave cross section analysis of the experimental data on the negative ion resonances of benzene has also been made.

Our integrated and systematic studies on the absolute rates and cross sections for electron attachment to chemical pollutants and related substances focused on the per-fluorocarbons $C-C_2F_5$, $1,3-C_2F_5$, $C-C_2F_5$, $C-C_2F_5$, $C-C_2F_{10}$, $C-C_2F_{12}$, and $C-C_2F_{14}$. These organic molecules were found to be among the strongest known electron scavengers, and they are of unique significance to the environment. Electron attachment rates as a function of the pressure-reduced electric field, E/P_{red} , have been measured for trace amounts ($\sim 10^{-7}$ torr) each of the above compounds in mixtures with nitrogen and argon (pressures 500-2000 torr). From the attachment-rate constant data, the attachment cross sections, $\sigma_A(e)$, as a function of electron energy, e , have been determined using our swarm-unfolding technique. Although the positions of the maxima in $\sigma_A(e)$ vary only slightly among these compounds, the magnitude and energy dependence of $\sigma_A(e)$ depend strongly on structure. These molecules are among the strongest known electron scavengers and exhibit some of the highest breakdown strengths measured to date.

Finally, the lifetimes of metastable atomic and molecular negative ions have been synthesized, and a wider understanding has been endeavored. Previous discussions have been extended, basic knowledge on simple molecules has been related to that on complex polyatomics, and a coherent picture has been attempted. Special emphasis has been accorded to the lifetimes of long-lived parent negative ions, their modes of formation and decay, and their relation to molecular structure.

The Fragmentation of Atmospheric Halocarbons Under Low-Energy Electron Impact

The mass spectrometric identification of the products of multiple fragmentation of atmospheric halocarbons induced by collisions of slow (~ 10 eV) electrons continued in an effort to identify precursors of atmospheric reaction products. Having completed a systematic study on aliphatic hydrocarbons, we focused on aliphatic perfluorocarbons. A multiplicity of ions is produced with a great variation in their yields and energy dependence. This clearly shows the fragility of polyatomic molecules toward low-energy electrons: slow electrons are far more disruptive in their impacts with polyatomic molecules than are low-energy photons. The fragmentation patterns are very strongly dependent on the details of molecular structure. These conclusions are exemplified by the results on two such perfluorocarbons namely, perfluoro-2-butyne ($2-C_2F_4$) and perfluoro-2-butene ($2-C_2F_4$). For $2-C_2F_4$ in the low-energy (0-10 eV) range the predominant negative ion formed is $2-C_2F_4^{*-}$ (93% of all negative ions formed in this energy range). No ion, other than $2-C_2F_4^{*-}$, was detected at 0.0 eV, while other ions formed at higher energies include $C_2F_4^{*-}$, F^- , and CF_3^- . In contrast to $2-C_2F_4$, electron impact on $2-C_2F_4$ results in the formation of the parent ion $2-C_2F_4^{*-}$ and the numerous negative ion fragments $C_2F_4^{*-}$, $C_2F_3^{*-}$, $C_2F_2^{*-}$, C_2F^{*-} , $C_2F_4^{*-}$, CF_3^- , and F^- . Both $C_2F_4^{*-}$ and

$C_2F_5^{*-}$ are formed at nearly zero electron energy. The lifetimes toward autodetachment of the parent ions $2-C_2F_5^{*-}$ and $2-C_2F_5^{*-}$ were measured. Also, a number of the fragment ions (those denoted by the asterisk) were found to be metastable with autodetachment lifetimes $>10^{-10}$ sec. The fragmentation patterns of such compounds and their relation to molecular structure are under intense study.

Electrons in Gases and Liquids

We have measured electron drift velocities as a function of temperature for ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and neopentane ($C(CH_3)_4$), and on the basis of these data Ramsauer-Townsend minima were discovered in the momentum-transfer cross sections, σ_m , for all of these gases. The position of the Ramsauer-Townsend minimum and the magnitude of σ_m at the minimum are 0.12, 0.14, 0.14, and 0.25 eV and 1.2, 3.0, 4.6, and 5.8 $\times 10^{-16}$ cm² for ethane, propane, butane, and neopentane, respectively.

As part of our efforts to expand basic knowledge from atoms and simple molecules to complex polyatomic systems of radiobiological interest, we looked into the energetics of the negative ion states of atoms and small molecules. Through a collaborative study with the Physics Department of The University of Tennessee and the Chemistry Department of The University of Chicago, a scheme correlating negative ion states of atoms and small molecules whose parentages can be either ground or excited neutral states has been developed. This treatment allowed prediction of the electron affinities of a number of atoms and small molecules.

Recent knowledge on the initial interactions of slow (0 to 20 eV) electrons with O_2 has been coherently synthesized and discussed with emphasis on elastic and inelastic electron scattering from negative ion resonances of and electron attachment to O_2 and autodetachment of O_2^{*-} . One of the significant conclusions reached is: Electrons with energies >3 eV lose their energy (elastically and inelastically) predominantly *indirectly*, via the O_2^- ($X^2\Sigma_g^-$) negative ion state.

Among the fill gases that are employed in proportional counters is P-10, a mixture of 90 argon and 10 methane. It is readily apparent that the presence of an electron-attaching impurity (such as O_2) in the fill gas will degrade the performance of the proportional counter. In order to explore this problem, we measured the electron attachment rate as a function of mean electron energy and partial and total pressure for O_2 in P-10. Measurements have also been made of the electron drift velocities as a function of the pressure-reduced electric field in P-10 and were found to be in disagreement with published data. The data have been modeled, and the results are of practical utility.

The experimental setup for our studies on electron capture and drift in liquid media and on the energetics and kinetics of charge-separated states in liquids using high-resolution negative ion spectroscopy has been completed, tested, and is now in operation. Difficulties in connection with the purification system required the development of new additional purification steps.

The probability of recombination of an electron and a positive ion in a nonpolar liquid depends upon the mobility and diffusion coefficient (i.e., the electron transport coefficients) of the electron. Except at infinite relative separation, the electron always finds itself in the Coulomb electric field of the positive ion. We have presented a theory of recombination based on the results from nonequilibrium thermodynamics, which takes into account the electric field dependence of the transport coefficients of the electron. Results for the escape probability depend upon the nature of the liquid. This is in better agreement with experimental data than the simple theory of Onsager where the escape probability is independent of the liquid and depends only upon the temperature.

A uniform treatment of electron-molecule and electron-ion (jointly called pair recombination) processes has been presented within the uniform theory of electron kinetics in non-polar liquids for the two cases: (1) the pair recombines following dissociation and (2) the pair recombines from uncorrelated partners originating in the bulk of the liquid. All known interactions were taken into account including solvent screening of the interaction potential between the electron and its partner, electric field dependence of the electron transport coefficients, electron tunneling, and chemical activation. Simply stated, the theory predicts that the ratio of the quantum yield for photoionization of a molecule to the rate constant for recombination of the ionization fragments should be a constant that is independent of the nature of the molecule and depends solely upon the properties of the liquid.

Interphase Physics

Our work on the interfacing of the phases, which links the electron transport and recombination processes in gases with that on similar processes in the condensed phase, has provided the necessary prerequisite for linking physics with chemistry and here with life sciences, continued. We have shown earlier that the electron mobility, μ , for ethane (C_2H_6), and propane (C_3H_8) decreases with increasing gas density, N . We have now found that a similar behavior is exhibited by neopentane [$C(CH_3)_4$]. This is contrary to the case of CH_4 , where μ increases with N . Additionally, we have shown that electrons are more mobile in the liquid with respect to the gas for C_2H_6 and C_3H_8 . We have concluded that there are two major factors which affect the dependence of μ on the medium's density: (1) electron capture and loss which causes a delay in electron motion with increasing N and (2) a decrease in electron scattering cross section with increasing N , which causes an increase in μ . Process (2) becomes very important for gases whose μ possess a Ramsauer-Townsend minimum at low-electron energies (<0.5 eV) which shifts toward lower energy with increasing density. From the experimental evidence we have obtained so far, it appears that process (1) dominates over (2) for C_2H_6 , C_3H_8 , and C_4H_{10} , and process (2) dominates over (1) for CH_4 over the entire density range from the dilute gas to the liquid. For $C(CH_3)_4$, (1) dominates at low gas density, but it is overshadowed by (2) at high gas densities. The above findings, coupled with those on the Ramsauer-Townsend minima we discovered in polyatomic-molecules, provide an explanation for the drastic changes in electron mobilities in gases and liquids for structurally similar molecules (e.g., pentane and neopentane).

Measurements on electron attachment to CO_2 in N_2 at total pressures from 500 to 25,000 torr have been completed, and a preliminary analysis of the results indicates that the mechanism is quite complicated and presumably involves competition between electron attachment and detachment processes involving both CO_2 and N_2 molecules. Similar work on O_2 in high pressure gases has been successfully linked to electron attachment to O_2 in liquid media and provided additional evidence that the lifetime of O_2^{*-} in the fourth vibrational level of the $X^2\Sigma_g^-$ negative ion state is 2 psec, a result of great theoretical significance.

In an effort to link gaseous data on the ionization yields and ionization energy thresholds with those on similar species in the liquid phase we initiated work on the photoionization of molecules in liquids. The need for accurate knowledge of the minimum energy, I_L , required to ionize a molecule embedded in a liquid is overwhelmingly pressing. An apparatus has been designed and built for the measurement of I_L for fluorescent pure liquids or for fluorescent organic molecules (solutes) dissolved in minute amounts in various liquids (solvents). Our method establishes the threshold for solute ionization by monitoring its fluorescence quantum yield as a function of excitation photon wavelength. Preliminary studies have been made on 2-ethylnaphthalene, a fluorescing polycyclic aromatic hydrocarbon which is liquid at room

temperature. Our original experimental apparatus has been greatly improved and is being applied to the accurate determination of ϵ_0 of polycyclic aromatic hydrocarbons in liquid media (e.g., perylene in n-hexane).

The Basic Physics of Gaseous Insulators: Optimization of the Gas Dielectric

The multiple needs in high voltage (power) insulation dictate the development of a variety of gaseous insulating systems, each appropriate for the specific need. Such optimal systems comprise multicomponent gas mixtures carefully designed as to components and properties on the basis of detailed physicochemical knowledge, especially on the interactions of low-energy (< 20 eV) electrons with atoms and molecules.

In systematically designing the multicomponent gas mixture, the quantity

$$\int_0^\infty f(\epsilon, E/P) d\epsilon \quad (1)$$

should be maximized.

$$\int_0^\infty f(\epsilon, E/P) d\epsilon \quad (2)$$

should be maximized. In (1) and (2), $f(\epsilon, E/P)$ and ϵ_0 are, respectively, the electron attachment and electron impact ionization cross sections, $f(\epsilon, E/P)$ is the electron energy distribution as a function of the electron energy ϵ and the pressure-reduced electric field E/P , and I is the ionization threshold energy.

The choice of the appropriate components to optimize (1) and (2) requires detailed knowledge of the basic cross sections and their energy dependencies.

The basic role of electron attachment as a function of electron energy has been shown from our results on perfluorocarbons. To maximize (1), the multicomponent insulator should contain one or more electronegative (more precisely, electron attaching) components which collectively yield a large $\sigma_a(\epsilon)$ over a wide energy range. Many of the perfluorocarbons studied possess large $\sigma_a(\epsilon)$ up to ~ 1.5 eV, and a comparison with the corresponding V_d values suggests that the higher the energy range over which $\sigma_a(\epsilon)$ is large the better the dielectric.

The role of the electron energy distribution function and the underlying electron energy-loss mechanisms and scattering cross sections has also been investigated. For a given value of E/P , $f(\epsilon, E/P)$ should be shifted to low energies to optimize (1) and (2). It is also important that one or more compounds have strong electron slowing-down properties especially in the subexcitation energy range. The direct effect of the electron scattering cross sections $\sigma_{sc}(\epsilon)$, especially via negative ion resonances, on the dielectric strength has been demonstrated.

Other important aspects of the basic physics of gaseous dielectrics include the ionization cross section $\sigma_i(\epsilon)$ and the electron affinity of the dielectric gas molecules. Through the use of such detailed fundamental knowledge, we are systematically able to approach the problem of optimizing the multicomponent gas dielectric.

High Voltage Research (Gaseous and Liquid Dielectrics)

Our search for new dielectric gases with vapor pressure greater than one atmosphere (at ambient temperature) continued. A number of such new gases have been found which have high

dielectric strengths. Some of these gases and their dielectric strengths (numbers in parentheses, relative to that of one for SF_6) are: 2-C₂F₄ (perfluoro-2-butyne) (0.2); 2-C₂F₄ (perfluorobutene-2) (1.7-1.8); c-C₄F₈ (perfluorocyclobutene) (1.7); 1,3-C₂F₄ (perfluoro-1,3-butadiene) (1.4); c-C₄F₈ (perfluorocyclobutane) (1.3-1.4). In general, the perfluorocarbons were found to have the highest dielectric strength out of all the compounds we have investigated so far.

Many compounds with vapor pressures less than one atmosphere at room temperature were found to have higher dielectric strengths than SF_6 at comparable pressures. The breakdown strengths (values in parentheses) of some of these relative to that of one for SF_6 are: c-C₄F₈ (mixture of 1,2- and 1,3-perfluorodimethylcyclobutane) (2.3-2.4); c-C₅F₁₀ (perfluorocyclopentene) (2.1-2.2); c-C₆F₁₂ (perfluorocyclohexene) (1.9-2.2); C₇F₁₄ (perfluoromethylcyclohexane) (2.1); C₈F₁₆ (perfluoro-1,3-dimethylcyclohexane) (2.3); C₈F₁₈ (octafluorotoluene) (2.2); C₇F₁₂ (perfluoroheptene-1) (1.2). These low vapor pressure compounds, although unsuitable by themselves as dielectrics due to their low vapor pressures at room temperature, may have potential use as additives to high pressure buffer gases such as N_2 .

A number of binary and multicomponent gas mixtures of several strongly electron attaching gases (e.g., 2-C₂F₄, SF_6 , c-C₄F₈, 2-C₂F₄ and C₂F₆) and several buffer gases (e.g., N_2 , CO_2) were found to exhibit substantial synergistic effects and to have excellent breakdown strengths. Some of the salient features of our systematic study of gas mixtures are: (1) 2-C₂F₄ is a very effective additive in multicomponent mixtures, (2) pure N_2 seems to be generally better as a buffer gas than CO_2 , (3) use of C₂F₆ with SF_6 + 2-C₂F₄ shows distinct synergism, and (4) proper combination of electron attaching and electron slowing-down (buffer) gases can give rise to cooperative effects that increase the breakdown strength. It is worth mentioning that mixtures with N_2 of perfluorocarbons whose γ_{a} extend to high energies do not suffer from the characteristic saturation effect exhibited by the SF_6/N_2 mixtures.

Practical, Industrial and Environmental Aspects of Gaseous Dielectrics

For practical applications we have studied the effects of highly nonuniform fields, surface roughness, gas pressure and gas temperature on the dielectric strength. Furthermore, we addressed ourselves to the problem of carbon deposits, conducted corona inception studies, initiated studies with impulse voltages, and showed that current radiographic techniques of energized high voltage gas insulated cables are unlikely to lead to breakdown. In cooperation with the Biology Division and the Information Services Division, the toxicity of some of our best gaseous dielectrics has been assessed. In addition, practical breakdown voltage studies using cylindrical electrode geometry for the four dielectric gases, hexafluoro-2-butyne, perfluorocyclobutane, perfluorobutene-2, and sulfur hexafluoride and their binary mixtures with N_2 have shown that all three fluorocarbons are still superior insulators to SF_6 in nonuniform fields.

The decomposition of the dielectric gas is an important environmental consideration. Our studies in this area are divided into four parts: (1) studies of the initial decomposition under electron impact, which identify the initial products; (2) studies of the decomposition of the dielectric after breakdown analysis of the long-lived products as a function of the energy input; (3) studies of the intermediate reactions that lead from the initial (1) to the final (2) products; and (4) studies of the decomposition of the dielectric under prolonged period of electric stress.

A close interaction between the applied and fundamental aspects of gas dielectrics is an integral part of our program.

Particle Interactions in Holes

One of the submicron structures accessible to physical investigation is the hole (micro-hole, pinhole, pore). Such features are found in biological systems, in membrane (micropore) filters, and in nuclear dosimeters. The mechanisms whereby these holes pass or collect aerosols, bacteria, viruses, and charged particles can only be speculated about at this time. An electron gun and electron scattering apparatus developed last year were used to study the deflection of electrons during passage through various pinholes. The data were analyzed to yield three results. First, the pinhole was found to resemble an electron lens in its reflection action. This effect represents an aberration in electron optical devices, particularly electron microscopes and may present a previously unsuspected lower limit to the resolution obtainable. Second, an effective electrostatic potential was calculated from each set of scattering data, and the average is shown in Fig. 1-1. This is the first measurement of surface potential at the atomic level, and this measurement is important because this potential is responsible for the agglomeration of charged aerosol particles and their adhesion to surfaces and filters. Third, calculations using the experimentally derived potential were begun to determine the theoretical efficiency of a nucleopore filter for submicron aerosol particles. Preliminary calculations produced efficiency curves that were similar in shape to accepted curves but shifted to larger particle sizes by an order of magnitude (as shown in Fig. 1-2).

Fig. 1-1. Electrostatic potential in pinhole. Diameter of laser vaporized hole is 9 micrometers in 0.6 micrometer gold foil. Potential is for electron energies from 2 to 40 eV.

Fig. 1-2. Efficiency of Nuclepore filter. Solid curve is theory of Spurny for platinum aerosol particles and 10 micrometer holes. Dashed curve is calculation based on potential of Fig. 1-1 and the assumptions of single charged particles and Stokes law drag.

Surface Waves on Submicron Cylinders

Reflection of light from submicron particles is used as an indication of the size, shape, and number of these particles in an air or liquid sample and is dependent upon the behavior of the electrons on the surface; yet these surface energy states are poorly understood. For cylindrical particles a collective electron response (plasma) has been postulated by Mizumski. Here, the plasma wave spirals around the cylinder in a barberpole pattern when the electrons are excited by light of a particular wavelength and angle. This year we re-examined the Mizumski theory and revised the theory of Ashley and Hubbell. In the former we found that an important term ($k \sin \theta \sin \phi$) had been omitted which altered the expected reflectance substantially. The new nitrogen and dye lasers purchased last year were used to measure the reflectance of metal and anthracene-coated micron-size fibers. The pattern is a diverging hollow cone of light, which, when intercepted by a screen, gives a circular image. The intensity around this circle was in qualitative agreement only with both theories as shown in Fig. 1-3. The minima in the Ashley and Hubbell theory and the experiment are identified by the use of Mizumski theory and labeled $n = 1, 2, \dots$. We cannot say as yet whether or not the Mizumski response occurs exactly as predicted. Other work with fibers will use an additional recently completed facility in the Particle Interaction in Holes apparatus which will allow us to scatter low-energy electrons from fibers and their environs as another measure of surface electronic behavior. All of the above studies are being aided immensely by the acquisition during this year of a scanning electron microscope which enables us to characterize physically our holes and fibers before and after study.

Precision Measurements of the Electronic Properties of Liquids and Solutions

Over the last several years the optical and dielectric properties of a dozen liquids have been determined between photon energies of 3 and 26 eV using the open dish reflectance technique. In an effort to improve the accuracy of the reflectance measurements we have attempted

Fig. 1-3. Intensity of light from reflecting cylinder. Laser light at $5790 \text{ \AA}$ reflects from Ag coated quartz fiber 1.1 micrometers in diameter. Theory and experiment agree well in positions of minima but disagree in overall shape. Minima are numbered using Mizumski theory and are thought to correspond to plasma wave excitation.

to introduce a new measurement technique which avoids one of the principal causes of uncertainty, the gold reference mirror, and takes advantage of the presence of the vapor. In this method, the ionization of the vapor along the optical path both before and after reflection at the liquid is measured with a double ion chamber. The instantaneous ratio of these ion currents is simply related to the required reflectance, independent of fluctuations in the light source. This year, seven refinements were made to the apparatus which gave much increased accuracy in reflectance measurements. Complete data were taken on liquid glycerol and some data on liquid formamide. Results on glycerol agreed well in the region of overlap with previous data although the maximum in the new data of 13.2% was somewhat higher than in the old (12.9%) data of Heller et al.,¹ as shown in Fig. 1-4. The new data extended to a high photon energy, 24.4 eV, and dielectric functions were obtained (Figs. 1-5 and 1-6). The plasma energy was shifted to 22 eV (from 20.4 eV) in the new data. Photoemission from liquid formamide was studied at 17 eV photon energy. Large currents were found, and these measurements will be continued.

Fig. 1-4. Reflectance of glycerol as a function of photon energy. Region between 10 eV and 13.7 eV, joining the Heller et al. data and the new data, is extrapolated to join the former smoothly.

Fig. 1-5. Real and imaginary parts of the dielectric function of glycerol.

Fig. 1-6. Energy loss function of glycerol. Maximum at 22 eV is attributed to a collective electronic excitation.

PHYSICS OF SOLIDS AND MACROMOLECULES

Optical properties of Condensed Media

Transmittance and/or reflectance data were obtained for selected liquids and solids using photons from the infrared to the soft x-ray region (0.5 to 82 eV). Optical and electronic properties of materials of biological interest, such as polyethylene measured over the energy range from 2 to 82 eV, were interpreted in terms of the response of the electrons in the material to ionizing and electromagnetic radiations. Data were also obtained on some simple metals for elucidation of theories of both ordered and disordered (biological) systems. For example, values of the optical constants were obtained by ellipsometry for liquid tin at 261°C over the energy range 0.5 to 3.8 eV and interpreted in terms of the nearly-free-electron model. Optical measurements of various types were made, on request, for others both inside and outside ORNL. These included the transmission of thin plastic films and of LiF windows, the reflectance of several types of machined mirrors for possible use in the solar tower concept, the

reflectance of the surfaces of LiF for a study of the effect on deposition of films over etched and post-burned substrates. The intensity calibration of light sources used in photo-irradiation of organic photoresist experiments in lithography was very critical, and the polarization introduced by a grazing incidence monochromator. A detailed study was made of the polarization introduced by gratings used at grazing incidence in monochromators designed for the vacuum UV to soft x-ray regions, including synchrotron radiation.

Emission Spectra from Condensed Media

The energy widths and the separation in energy of the soft x-ray absorption and emission edges of the alkali metals lithium and sodium were measured very accurately. Previous measurements of the two edges for a given metal had been made by different research groups using different instrumentation. In the present case both absorption and emission were measured using the same spectrometer at the National Bureau of Standards (NBS) synchrotron facility; hence relative energy calibration uncertainties were removed. A separation of 0.10 ± 0.02 eV was found between the K x-ray emission and absorption edges of lithium and a separation of 0.09 ± 0.01 eV between the L_{2,3} x-ray emission and absorption edges of sodium. These data resolved long-standing debates in the literature as to what physical processes are responsible for producing the detailed shapes of the edges. The effects of incomplete lattice relaxation on the core hole explain the observed results for both lithium and sodium. Preliminary data were also obtained for beryllium, aluminum, and magnesium.

Emission spectra in the 2500 to 6000 Å region were obtained from silver and gold thin metal films irradiated with electrons of energies from 10 to 1500 eV. Since electron attenuation lengths in condensed media are ~ 10 Å at these energies, the electrons probed only the surface regions of the samples. In general, both transition radiation, peaked at the volume plasmon energy, and radiative decay from surface plasmons were seen. For rough films, the surface plasmon radiation dominated the emission, persisting down to the lowest incident electron energy. For these films the emission intensity at a given wavelength was found to have a linear dependence on electron energy. A theory was then proposed to explain this observed dependence.

Attenuated Total Reflection Techniques

Attenuated total reflection (ATR) techniques were used to obtain the refractive index and thickness of LiF films. The coupling of photons into resonances in the LiF film was seen as reflectance minima which are related to the refractive index and thickness of the film. With the LiF film maintained in vacuum, the positions of the resonances changed with time after its deposition corresponding to a change in the refractive index, n . Representative results are shown in Fig. 1-7 for four different wavelengths. In each case the refractive index increased from 1.3 to 1.4, or close to the crystalline value, in the course of a few days. This implies that the LiF, loosely packed when first deposited, anneals over a period of time to the more closely packed crystalline configuration. When observations were obtained with the LiF film exposed to the atmosphere, the change seen in n with time was much smaller. These results become significant when an optical system, involving reflection or antireflection coatings, must be designed for maximum efficiency. It is apparent that one has to know the correlation between the properties of the coating as deposited and in its final state. Deterioration of coatings on exposure to anticipated environmental conditions could also be detected by this technique. A detailed theoretical analysis was made for a multilayer system near the resonance condition for optical guided modes in order to understand such systems more fully.

Fig. 1-7. The refractive index, n , of LiF as a function of time, t .

In the conventional ATR experiment the incident light is parallel. For these conditions the "Goos-Hänchen" shift or lateral displacement of the beam was calculated and found to be significant for modes with small damping. An alternative ATR method was developed using focused, or nonparallel incident light. The reflected beam now contains information about a large region in k -space instead of only one point as in the conventional method. When a screen is put in the reflected beam, the dispersion relation in k -space can be seen as dark lines. This method was used to obtain photographs showing the dispersion relation of guided waves associated with a grating. In this case the dispersion relation shows "band gaps" or discontinuities caused by interference between the prism-coupled and grating-coupled modes.

Holographic Gratings

Studies on the fabrication of holographic gratings were continued. Blazed holographic gratings formed using optical guided modes have greater efficiencies than reported previously. An on- to off-blaze first order intensity ratio at normal incidence was obtained as high as 6:1 over the visible region. The best absolute efficiency, over 50% at the blaze wavelength, is considerably better than that reported by others for holographic gratings at normal incidence. Holographic gratings were fabricated which are corrected for astigmatism for wavelengths in the vacuum UV energy region. The signal-to-noise ratio for these gratings is similar to, or better than, that for a comparable conventional ruled grating in the vacuum UV region. The next step is to produce gratings that are both blazed and corrected for aberrations in a specified wavelength region. This method has great potential. When fully developed it will be possible to produce gratings quickly and cheaply with any desired characteristics. One grating has already been supplied to others for use with a tunable pumped dye laser.

TRANSPORT AND SURFACE PHYSICS

Dosimetry for Pion Beams

The Monte Carlo computer code, PION-1, for calculating dose distributions in matter from pions and their secondary particles has continued to be used and improved. As part of our collaborative research effort with the Swiss Institute for Nuclear Research (SIN), a member of the SIN staff spent two months at ORNL, and a member of our group spent a similar period at

107. The code PION-I, originally written in FORTRAN-IV for an IBM-360 computer system was modified to be compatible with a CDC-6600 computer system and was installed to run at SLAC. It will be used to assist in the development of a pion radiotherapy treatment planning program for the bimodular beam at SLAC. At the same time input data needed for PION-I are being measured at SLAC. The group from Forschungszentrum, Karlsruhe, Germany, has measured the particle production spectra from pion capture in carbon and will be measuring the spectra for capture in nitrogen, oxygen, calcium, and other elements. We have modified PION-I to replace the calculated spectra previously used by the measured spectra. Measurements will also be made by the Karlsruhe group of the cross sections for in-flight interactions and these data will be incorporated into PION-I when available. We are now beginning calculations to study effects occurring within a few cell diameters of a boundary between two media such as tissue and bone. The question of the importance of interface effects was raised as a result of experience during early clinical trials of pion radiotherapy at Los Alamos Scientific Laboratory.

Mean Free Paths and Energy Losses of Electrons in Polystyrene

Information on mean free paths and energy losses of electrons with energies ~ 10 keV is important for such diverse areas as electron microscopy, LEED, dielectric breakdown, and dose calculations. During the past several years, experimental measurements and theoretical calculations of these quantities have become available for a wide variety of materials, including insulators. However, there is a dearth of information on plastics or organic insulators. The purpose of this work is to provide theoretical calculations of energy losses and mean free paths of electrons in the organic insulator polystyrene for electrons of energy from 5 eV thru 10 keV.

For electron energies ~ 10 keV, inelastic processes are principally determined by interactions with the electrons in the medium. The general theoretical methods employed to calculate the interaction probabilities have been described in some detail in earlier studies on non-organic materials. For the valence electrons in polystyrene, the interaction probability as a function of incident electron energy and energy transfer, from which mean free paths and energy losses are derived, is determined by the dielectric response function. This dielectric response function has been derived from a model insulator theory based on detailed studies of the optical properties of solid polystyrene. The cross section for excitation of electrons from the K shell of carbon atoms is obtained from generalized oscillator strength calculations. The contribution to the inverse mean free path from the C K-shell electrons is small (1%). If our result for $\dots$ is extrapolated to higher energies, it is found to be in excellent agreement with an experimental measurement at 20 keV by Swanson and Powell. Our result for the energy loss per unit pathlength is in excellent agreement with predictions of the Bethe-Bloch theory at $E = 10$ keV. A detailed account of this work has been published as a technical report.

Electron Inelastic Mean Free Paths and Energy Losses in Aluminum

Extensive experimental data exist on mean free paths and energy loss rates in aluminum metal for a wide range of electron energies. Theoretical values of energy loss rate (or stopping power) based on the Bethe-Bloch theory are available for electron energies ~ 10 keV. To complement these values we have done a detailed study of the mean free path and energy loss rate for electrons from a few electron volts above the Fermi level through 10 keV for this material. Our calculations are based on the electron gas model to describe the response of

the conduction band electrons and on generalized oscillator strength calculations to describe ionization of the inner shells of the ion cores in the solid. Effects such as damping, ion-core polarizability, and exchange and correlation corrections have been studied. These produce substantial changes in mean free paths and energy loss rates (mainly for electron energies < 40 eV) from those calculated neglecting such effects. The importance of these corrections is difficult to assess due to the large uncertainties in experimental data in this low-energy region. However, over the broad energy range from 100 eV to 10 keV our results for mean free paths and energy loss rates are in quite good agreement with the more abundant and reliable experimental data available in this energy range. A detailed account of this work has been prepared for publication.

Interaction of Slow Protons with an Electron Gas: Influence of Damping

Estimates of the energy loss of slow protons (proton energies < 20 keV) interacting with solids are frequently made using a free-electron-gas model to describe the electronic response of the solid.²¹ Our earlier work on electrons interacting with an electron gas²² showed that significant changes occur in the mean free paths and energy losses for low-energy electrons when one includes damping in the electron gas to account, in a phenomenological fashion, for the decay of elementary excitations as must occur in real solids. Similar calculations were performed for the energy loss rate for slow protons interacting with an electron gas to determine the influence of damping on the energy loss rate of a heavy, charged particle. The response of the electron gas, with damping, was based on the dielectric function formulation of Mermin;²³ estimates of the damping rate for the case of solid carbon were obtained from experimental measurements of the optical properties.²⁴ Our results for the energy loss rate of protons in carbon show increases of 15 to 25% over the energy loss rate calculated assuming no damping. The increase depends on the proton's velocity with the larger values occurring for lower velocities. Changes in energy loss rate of this size may have important implications for estimates of the energy deposited in, for example, the walls of a fusion system or in a tissue medium. Calculations for aluminum metal also show increases in the energy loss rate for protons, but of a smaller amount since the damping rate is smaller for aluminum than for carbon. For both materials the increases in energy loss rates due to the influence of damping provide much better agreement with the experimental data of Arkhipov and Gott²⁵ than calculations made neglecting damping.

Impact-Parameter Dependence of Energy Losses by Channeled Ions

A great deal of valuable information is now being obtained on the dependence of swift ion energy losses on impact parameter relative to a given atom. The best data come from channeling experiments, the bulk of which are carried out at ORNL.²⁶ We have developed a theory of the energy loss of swift, channeled ions as a function of position in the channel.²⁷ It is based on a model in which the response of valence electrons is computed from a nearly-free-electron gas theory and the response of inner shells from an atomic theory of excitation on different ion cores of the solid. Although the model is undergoing refinement, it is capable of explaining in some detail the dependence of energy loss on the distance of an ion from a best-channeled planar trajectory and the energy loss of a partially screened ion in channeling configuration, as well as other similar data. We are working toward the improvement of this scheme by the use of more accurate representations of matrix elements for atomic excitation and through the development of the theory of energy loss in a weakly inhomogeneous plasma system.

Projectile-Charge Dependence of Stopping Powers

Recent systematic experiments^{1,2} on the energy loss of swift ions of atomic number Z_1 ranging from 1 to 9 in several different solids offer an excellent opportunity to test current theories of energy loss. In particular, it is expected that Z_1 corrections to the Bethe stopping power formulae, the theory which was first developed by workers in this division, should be substantial for these experiments. We have analyzed these data assuming that the effective charge, Z_1^* , of an ion with velocity v_1 , may be computed from the semiempirical formula^{3,4} $Z_1^* = Z_1 \{1 - \exp[-0.95 v_1/Z_1^{1/3} v_0]\}$, where $v_0 = e^2/\hbar$. (Z_1 is replaced by Z_1^* in the Bethe-Bloch formula and in the theory of the Z_1 effect.⁵) We evaluated high-velocity forms of the Z_1 -proportional stopping power contributions by the method of moment integrals. This procedure leads to results which are in excellent agreement with experimental data and yields inner-shell corrections in good accord with theory.⁶

Wake-Splitting of Excited Electron States on Channeled Ions

Recent experiments^{1,2} with swift, channeled ions having atomic number Z_1 ranging from 5 to 9 and which carry a single electron in a K -orbital state show resonant excitation of the electron due to a coherent, periodic perturbation by the atoms in the bounding crystal rows. This excitation is primarily from the hydrogenic $1S$ ground state to an $n = 2$ state. A splitting is observed in the $n = 2$ states which may be attributed partly to the wake of electronic density fluctuations generated by the ion in its motion through the solid. We have analyzed the splitting by applying the theory of the wake developed earlier by us.⁷ We have shown that the matrix element of the perturbing wake potential between any two hydrogenic states $|nlm\rangle$ and $|n'l'm'\rangle$ may be written

$$\langle n'l'm'|V|nlm\rangle = -\frac{Z_1}{2\pi} \int \frac{d^3k}{k^2} \frac{1}{\epsilon_{\mathbf{k}} - k_{\parallel} v_1} \langle n'l'm'|e^{i\mathbf{k}\cdot\mathbf{r}}|nlm\rangle,$$

where $\epsilon_{\mathbf{k}}$ is the dielectric function of the solid and where atomic units are used throughout. It is found that the splitting is primarily due to coupling between the 200 and 210 states. Degenerate state perturbation theory yields an approximate expression for ΔE , the energy splitting, as

$$\Delta E = \frac{Z_1 - 1}{Z_1} \frac{3}{v} \ln \left[\frac{v^2 + s}{v^2 - s} \frac{v^2 - s + Z_1^2/2}{v^2 + s + Z_1^2/2} \right],$$

where $s = (v_0^2 - v_p^2)^{1/2}$ and v_p is the plasma energy of valence electrons in the solid. The predictions of this theory are in quite reasonable agreement with experiment. This work was done in collaboration with O. H. Crawford of the Chemistry Division.

The Image Potential of a Charge Near a Circular Aperture in a Conducting Screen

The image force on a particle near a macroscopic body is of importance in determining the efficiency of filters, the dispersal of particulate pollutants, and the adhesion of particles to surfaces, among a host of other important applied problems. The well-known solution for the force on a point charge located near a perfectly conducting surface is transparently simple. However, when the surface is other than planar or spherical, there is considerable difficulty

in obtaining comparably simple expressions for the image force. We have succeeded in obtaining a closed analytical expression for the image potential of a charge located at an arbitrary position relative to a circular hole in an infinite conducting screen. This expression reduces to a simple analytical formula for the case where the charge is located on the axis of symmetry of the system.

Our solution was obtained by using a method related to that due to Copson,¹³ who found the potential due to an electrified conducting disk. Our approach is carried out by transforming the integral equation for the surface charge density so that it applies to the aperture geometry and by solving the resulting integral equation, which is of the Abel type, in closed form. When a charge Q is located on the axis at a distance z from an aperture of radius a , we find that the electric scalar potential is given by

$$\phi(z) = -\frac{Q}{2z} \left[\frac{a}{z} - \tan^{-1} \left(\frac{a}{z} \right) + \frac{\partial z}{z^2 + a^2} \right]$$

Numerical results for the more general case of an off-axis charge will be published.

Dicuster Effects in the Simultaneous Ionization of K and L Shells of Atoms

Workers at Bell Labs¹⁴ have recently reported the results of a search for interference effects in the ionization of K and L shells of atoms by swift, ion dicusters in solids. Interference, or vicinage, effects are due to the proximity of the ions which make up the dicuster. Such effects could produce an increase, or in some cases a decrease, in the probability for forming a shell vacancy in an ion which is part of a cluster in comparison with this probability for a single ion of the same velocity. The results of this search were essentially negative and may be easily explained theoretically, except for that part of their data which deals with the K-satellite spectrum of aluminum. These satellites are thought to originate from a double ionization process in which vacancies are generated simultaneously in both the K and L shells. We have calculated this effect for diprotons, constraining one of the protons to pass through the center of the atom (zero impact parameter) while averaging over random orientations of the other at a fixed distance from the first. The final state of the ejected L electron is approximated by a plane wave, and the probability of L-shell ionization is evaluated using the Feynman parameterization method. We find that the vicinage term in this expression is proportional to the square of the ratio of the L-shell radius to the dicuster separation. We estimate that the contribution of the vicinage term to the ratio comparison made for H^+ and H_2^+ bombardment of aluminum to be about 0.1, which is consistent with experimental data.¹⁴

Electron Transport in Liquid Water

A description of our Monte Carlo program for computing the transport of electrons in liquid water has been given elsewhere.¹⁵ This program was constructed as part of an overall effort to correlate observed biological effects in systems in which water is the main constituent with initial physical effects of corpuscular radiation. Our effort is distinguished from others in current use at various laboratories in that the fundamental inelastic interaction probabilities used in the transport calculation are taken from experimental data on the dielectric properties of liquid water,¹⁶ rather than from those pertaining to the vapor. These data indicate that pronounced collective effects occur in the liquid phase, resulting in a strong upward shift in the spectrum of inelastic losses to valence electrons as water is condensed from the vapor.

We have revised extensively our scheme for inferring electron inelastic interaction probabilities from experimental optical data. We fit these data with analytical functions, which are better conditioned to expected asymptotic forms than the Drude functions employed earlier. Extrapolation to obtain the response function for intermediate and large momentum transfer is carried out using sum rules together with general information about the generalized oscillator strength of the water molecule. The mean excitation energy appearing in the Bethe-Bloch stopping power formula was computed from the optical data extrapolated to large energies and was found to be 75 eV compared with the value of 65.1 eV recommended in NAS-R² Publication 1133 for water.

REFERENCES

1. UT R & D Subcontract.
2. Computer Sciences Division.
3. Instrumentation and Controls Division.
4. Consultant.
5. Student.
6. Part-time employee.
7. Postdoctoral Fellow.
8. Dual capacity.
9. Biology Division.
10. Guest assignment.
11. Alien guest.
12. G. Miziumski, *Phys. Rev. A* 40:187 (1972).
13. R. D. Birkhoff, J. C. Ashley, H. H. Hubbell, Jr., and L. C. Emerson, *Phys. Rev. A* 67(4):564-69 (1977).
14. J. M. Heller, Jr., R. D. Birkhoff, M. W. Williams, and L. R. Painter, *Phys. Rev. A* 52(1):25-31 (1972).
15. E. T. Arakawa et al., *ORNL-5308*, pp. 20-6.
16. Research sponsored in part by the Deputy for Electronic Technology, Air Force Systems Command, under Interagency Agreement DOE F40-226-70.
17. J. C. Ashley, C. J. Tung, R. H. Ritchie, and V. E. Anderson, *Phys. Rev. A* 15:23(6):1833-37 (1976), and references contained therein.
18. H. Swanson and C. J. Powell, *Phys. Rev. A* 145(1):195-208 (1966).
19. J. C. Ashley, C. J. Tung, R. H. Ritchie, and V. E. Anderson, *Research Report RADC-TR-78-32* (February 1978).
20. J. C. Ashley, C. J. Tung, and R. H. Ritchie, "Electron Inelastic Mean Free Paths and Energy Losses in Solids: I. Aluminum Metal," (to be published).
21. T. L. Ferrell and R. H. Ritchie, *Phys. Rev. A* 16(1):115-23 (1977), and references contained therein.
22. J. C. Ashley and R. H. Ritchie, *Phys. Rev. A* 83(2):K159-K163 (1977); J. C. Ashley, C. J. Tung, and R. H. Ritchie (to be published).
23. H. D. Mermin, *Phys. Rev. B* 1(5):2362-63 (1970).
24. M. W. Williams and E. T. Arakawa, *Phys. Rev. A* 43(8):3460-63 (1972).
25. E. P. Arkhipov and Yu. V. Gott, *Sov. Phys. Usp.* 29(4):614-18 (1969).
26. See, e.g., S. Datz et al., *Phys. Rev. A* 38(20):1145-48 (1977), and references contained therein.
27. J. C. Ashley and R. H. Ritchie, "The Energy losses of Channeled Ions--the Bohr Theory Revisited," *Preprint of the International Symposium on Atomic Physics, Moscow, U.S.S.R.* (in press).

28. J. C. Asnley, R. H. Ritchie, and W. Brandt, *Phys. Rev. B* (5):2393-97 (1972); *Phys. Rev. A* (8):2402-8 (1973); *Phys. Rev. A* (10):737 (1974).
29. L. C. Northcliffe, *Phys. Rev.* 120(5):1744-57 (1960); *B. Betz Exp. Mod. Phys.* 44(3):465-539 (1972).
30. E. Bonderup, *R. Dan. Vidensk. Selsk. Medd.* 35(17):1-20 (1967).
31. S. Datz et al., *Phys. Rev. Lett.* 30(13):847-47 (1973).
32. See R. H. Ritchie, W. Brandt, and J. C. Asnley, *Phys. Rev. B* 14(1):1000-07 (1976), and references contained therein.
33. E. T. C. *Proc. Superf. Phys. Conf.* 8(2):14-19 (1971).
34. A. Lurio, H. H. Andersen, and L. L. Klibanova, *Phys. Rev. B* 11(1):20-27 (1975).
35. R. H. Hamm et al., *1975 Symposium on Neutron Scattering, Trieste, Italy, September 1975, EUR-5452 d-e-F*, pp. 1037-53.
36. J. R. Heller, Jr., *Phys. Rev. B* 11(1):20-27 (1975).

Part II Biomedical Effects and Instrumentation

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The section's research programs, which are focused on improving man's health and safety, are concerned with the promotion of beneficial nuclear applications through the development of new radiopharmaceuticals for diagnosis or therapy and the assessment of risk and protection of man from harmful effects of radiation and chemical insults. Methodologies for quantifying radiation dose to organs are developed from metabolic models and Monte Carlo transport calculations. These are correlated with population studies and observed health effects for the development of risk factors and appropriate exposure limits. The implications of new energy technologies are assessed for their impact on human health with effort toward developing appropriate dose concepts and risk factors for nonnuclear technologies. Protection of workers is sought through the development of advanced instrumentation with increased sensitivity for rapid detection of polynuclear aromatics and other chemical hazards in the work environment.

NUCLEAR MEDICINE AND BIOMEDICAL RADIOISOTOPE TECHNOLOGY

The preparation of radiolabeled compounds that have applications in biomedical and environmental research and the development of nuclear medicine image processing procedures are the objectives of this program.

A variety of tissue specific agents have been designed for use both to image and also to investigate the pathophysiology of the target organs. The radionuclides which have been studied include ^{14}C , ^{32}P , ^{119}mPt , and ^{125}mTe . In collaboration with the Oak Ridge Associated Universities several ^{14}C labeled amino acids have been prepared, and several of these compounds have been used to image the human pancreas. The antineoplastic agent cyclophosphamide has been labeled with ^{32}P , and the combined cytotoxic and radiotoxic effects of this agent have been investigated in KB tumor cell-line. A unique class of ^{125}mTe labeled steroids has been prepared as potential adrenal imaging agents, and high quality adrenal images of several animal species have been obtained using some of these agents. A variety of structural analogs of these compounds have been prepared and used to define the structural features affecting adrenal uptake. Several telluro amino acids have also been prepared as potential pancreatic imaging agents. A series of ^{119}mPt labeled platinum ammine complexes has been prepared to study the structure-antitumor activity relationships for such complexes. The cisdichlorodiammine platinum (II) complex has been labeled with ^{119}mPt and distributed on a wide scale in various Medical Cooperative Programs studying the properties of this important agent.

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In the area of medical imaging, a two-dimensional Fast Fourier Transform has been made operational for the PDP-11 version of the Oak Ridge Imaging System (ORIS). Publicity for the ORIS system has brought response from a wide variety of academic and private institutions.

METABOLISM AND DOSIMETRY

The Metabolism and Dosimetry Group is concerned with the estimation of dose from radionuclides taken into the body or suspended in air or water surrounding the body. These estimates make use of the International Commission on Radiological Protection (ICRP) Reference Man data, for which the group is largely responsible. Also, dosimetric methods developed within the group use a mathematical phantom approximating Reference Man for estimating photon absorbed fractions by Monte Carlo methods, thereby replacing the previous crude estimates based on first-collision dose calculations. Another major development involves the computerization of decay data to provide listings of all energy emissions associated with a nuclear transformation, including x rays and Auger electrons of various intensities. The subsequent linking of these developments together into a computer code for providing S values (i.e., dose per unit accumulated activity in an organ) has been a major timesaving technique in the sequence of dose estimation. Additionally, metabolic models are being provided for most of the internal dose estimations being made presently by both national and international groups including the Department of Energy (DOE), Nuclear Regulatory Commission (NRC), ICRP, and the Medical Internal Radiation Dose Committee (MIRD). A major activity of the group has been supplying dosimetric data based on the above methodologies and metabolic data for the forthcoming report of ICRP Committee 2. This report will incorporate the concept of risk due to stochastic and nonstochastic effects as recommended by the Commission in its recent publication No. 26. Data are being generated for approximately 250 radionuclides. The decay data will be published in an ICRP blue cover report, and the dose estimates, annual limits on intake (ALI), and derived air concentrations (DAC) will appear in the report constituting the Committee's recommendations.

Another major effort is directed toward developing mathematical phantoms, similar to the Reference Man phantom, and metabolic models for estimating doses to children. Such estimates are required by regulatory agencies for assessing risks to exposed populations. Also, a metabolic model has been derived from literature data for astatine to assess its dose hazard in the ^{235}U fuel cycle. Estimates have been made of doses to 23 target organs from a ^{201}Tl labeled gall bladder scanning agent.

PUBLIC HEALTH AND DEMOGRAPHIC STUDIES

The major focus of the project is the use of appropriate demographic and epidemiological techniques to analyze vital statistics for regions containing energy sites of interest to DOE. The analysis involves both time series and spatial components, with the establishment of a pre-facility baseline as a key parameter. The primary causes of death being examined are stillbirths, infant deaths, congenital malformations, and cancer. As the project becomes more involved with fossil fuel facilities, emphasis will be given to other causes, especially respiratory diseases. In all analyses a control area (state or the nation as a whole) is used for comparison purposes. The project's results can be used in assessments, impact statements and analyses, and policy decisions requiring information on health effects of energy systems, while the staff provides technical expertise to DOE as needed.

In FY 1978 the project members examined mortality data for the Mound Laboratory area. The project members were also asked by DOE/Division of Biomedical and Environmental Research (DBER) to examine incidence rates around selected counties containing naval shipyards. In addition, studies have continued in birth related trends in the area surrounding Oak Ridge.

Reports on results to date are contained in ORNL/TM-5805 (in review) and in progress reports and working papers to DOE/DBER. Studies on birth related trends in the area surrounding Oak Ridge are almost completed while analyses for Mound Laboratory and the shipyards are continuing.

DOSIMETRY FOR HUMAN EXPOSURE

Risks from radiation exposure and criteria for radiation protection are being investigated in these studies on the dosimetry of human exposures. We recently provided the first accurate assessment of dose to bone marrow - one of the most radiosensitive organs - from irradiation of the body by neutrons. Bone-marrow dosimetry for x and gamma rays was also extended in this study to energies and exposure situations that were unavailable in the literature. A special application of the results was the estimation of dose to the active bone marrow of the Japanese A-bomb survivors. Considerable time and effort has been spent in the past year reviewing results of similar calculations attempted recently by the Japanese National Institute of Radiological Sciences and Science Applications Incorporated. Several manuscripts are in preparation on these reviews.

Data from animal experiments and from studies of the Japanese A-bomb survivors indicate that current radiation protection criteria for neutrons may not be as conservative as thought, and changes in these criteria may be warranted. Results of our dosimetry studies and results from medical and epidemiological studies of the A-bomb survivors are now being used to make estimates of the total cancer risks to man from neutrons. These estimates of risk from leukemia and other cancers will provide an improved basis for making sound judgments regarding the adequacy of current radiation protection criteria and monitoring practices for neutrons. The issue is important and must be given careful consideration because conditions exist for potentially significant neutron exposures of workers at fission power reactors and will exist at future fusion power reactors as well.

ASSESSMENT OF FUSION TECHNOLOGY

Work in the assessment of fusion technology has two complimentary programs: Analysis and Assessment and Physical Studies in support of Fusion Health and Safety. In the analysis portion of the program, we seek to identify potential sources of hazard and to quantify the uncertainties in the pertinent parameters relating the identified potential hazard to some measure of risk. Once the uncertainties for potential hazards are quantified, priority ranking is carried out and suggestions are made for reducing either the unknowns or risk; occasionally, we elect to perform research to achieve those ends within the program.

A review of the metabolic and environmental data was made for niobium. The study resulted in a number of recommendations for and against the initiation of several specific research projects.

Environmental assessments for tritium are imprecise because conversion of tritium gas to tritium water (most toxic form) is not well understood. Experimental and theoretical studies are underway that should help to alleviate the uncertainty.

CANCER RISK ASSESSMENT BASED ON THE SYSTEMIC RESPONSE TO CELL DEATH

Linear relations between the death of cells and incidence rates of a wide variety of late radiation-induced biological effects have been demonstrated. It has been noted frequently that tissue renewal from surgery, toxic or hyperplastic stimuli, growth hormones, immunological treatment, chemotherapy of nonmalignant disorders, etc. is usually accompanied by an increased

risk of cancer. Because the mitotic index, labeling index, labeled-mitoses curves, rate of DNA or of specific protein synthesis, etc. are considered inadequate to characterize the time integral kinetics of the tissue, efforts to quantify carcinogenesis in terms of proliferation apparently have not been made.

Our simple approach has been somewhat unique because we rely on mathematical biophysical simulation techniques in order to estimate the surviving fraction of cells in a critical tissue or organ. We believe we have established a direct, quantitative relationship between tissue renewal and cancer rates (assuming that some transformed cells are present), which suggests a simple model of risk-assessment. This model assumes that cytotoxicity which triggers cell proliferation may permit altered cell populations to become tumors; however, cytotoxicity which (a) retards cell proliferation, (b) selectively blocks transformed cells from proliferating (if repair processes continue), or (c) destroys transformed cells, may produce no observable excess of tumors. For tumor growth, this simple risk-assessment model requires no assumptions about the exact number of initiating events per cell or the number of cells at risk; instead it bases the demand for proliferation on cytotoxicity and assumes that the exact number of neoplastic-cell transformations, their death rate, and repair rate are unimportant. The only requirement is that a sufficient number of altered cells exist or is produced by the insult in order to respond to the proliferation stimulus caused by the inactivated-cell population.

WORKPLACE MONITORS FOR SYNFUEL POLLUTANTS

Our primary goal is to produce new and improved devices for detection of synthetic fuel pollutants in the workplace. Efforts have focused on the design and fabrication of a portable derivative ultraviolet absorption spectrometer (DUVAS). The automated device is designed to detect gases and vapors ranging in complexity from H_2S , SO_2 , and NO_x to the more volatile polynuclear aromatic (PNA) compounds such as naphthalene and its alkyl derivatives. Measurements in real time will permit compliance with Occupational Safety and Health Administration (OSHA) regulations at coal gasification facilities. The DUVAS will be used for vapor characterization studies at the University of Minnesota, Duluth (UMD) low Bru coal gasifier. Its capability for measuring trace amounts of phenolic compounds in polluted aqueous streams has recently been demonstrated. This will allow on-line monitoring of effluent purification procedures.

The problem of monitoring surfaces contaminated with complex organic mixtures is being addressed by application of room temperature phosphorescence (RTP). The minimum level of detection is in the subnanogram range for many PNAs. The RTP technique, coupled with synchronous scanning, time resolution, and derivative signal recording, will be used to fabricate a light pipe luminescope for direct observation of selected compounds on real surfaces or for the analysis of solvated PNAs spotted on a moving paper tape. The latter approach could be used for analysis of PNA-containing blood and urine samples.

Synchronous excitation-and-emission spectroscopy enhances the ability to screen rapidly unfractionated or coarsely fractionated PNA mixtures. Any commercially available UV or visible spectrometer can be used, provided the excitation and emission monochromators can be interlocked. The method has potential for incorporation into the EPA hierarchy for LEVEL I screening and analysis of large numbers of synfuel pollutant samples. Rapid screening of an undifferentiated waste water from the Synthanol gasifier permits easy identification of phenol and 2-methylnaphthalene as shown in Fig. 2-1.

Fig. 2-1. Normal and synchronized fluorescence spectra of Synthane gasifier by-product water in methanol.

REFERENCES

1. Consultant.
2. Postdoctoral Fellow.
3. Computer Sciences Division.
4. T. D. Jones, *Health Phys.* 71:269 (1977).
5. G. D. Kerr, T. D. Jones, J. M. L. Hwang, and F. L. Miller, "An Analysis of Leukemia Data from Studies of Atomic Bomb Survivors Based on Estimates of Absorbed Dose to Active Bone Marrow," *Proceedings of the International Conference on Environmental Health Problems*, Vol. 3, pp. 714-18, Paris, France, April 24-30, 1977.
6. I. Hashizume, T. Maruyama, K. Nishizawa, and K. Fukuhisa, *Health Phys.* 18:67 (1977).
7. D. C. Kaul and R. Jarka, Science Applications Incorporated, Schaumburg, Illinois, Personal communications (1977).
8. H. H. Rossi and C. W. Mays, "Leukemia Risk from Neutrons," *Health Phys.* (to be published).
9. T. D. Jones, J. A. Auxier, D. G. Jacobs, and G. D. Kerr, "Risk of Environmental Cancer Based on Cytotoxicity," *Health Phys.* (to be published).
10. C. E. Easterly and K. E. Shank, *Health Phys.* 33:1001 (1977), ORNL/TM-5496 (November 1977).
11. J. E. Phillips and C. E. Easterly, *Health Phys.* 34:1001 (1978), ORNL/TM-5963 (May 1978).
12. United Nations Scientific Committee on the Effects of Atomic Radiation, *Annual Report 1977*, 1977 Report to the General Assembly, pp. 577-78.

Part III. Chemical Physics

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Basic research in the Chemical Physics Section is directed toward increasing our understanding of a variety of physical and chemical interactions which proceed at the molecular level. Results of this research are relevant to energy-related problems in atmospheric physics and chemistry, radiation chemistry, radiation biology, pollutant detection technology, laser development and analytical applications of laser techniques.

Progress over the past year is reported under eight headings: (1) Energy Pathways in Irradiated Gases, (2) Resonance Ionization Spectroscopy Experiments and One-Atom Detection, (3) Resonance Ionization Spectroscopy Experiments with Molecules, (4) Studies of Molecular Clustering Phenomena, (5) Collisional Ionization, (6) Multiphoton Spectroscopy of Molecules, (7) Theoretical Atomic and Molecular Studies, and (8) Theory of Laser Interaction with Quantum Systems. We have limited the descriptive material to include only research highlights under each of these headings. However, for the interested reader, detailed accounts of the research summarized herein can be found in the papers that are referenced in this chapter.

ENERGY PATHWAYS IN IRRADIATED GASES

Detailed studies have been carried out on energy pathways following proton excitation of Ar-F₂ mixtures^{1,2,3,4} and Kr-F₂ mixtures. Quenching rates at thermal energy have been determined for Ar(¹P₁), Ar(³P₁), Ar(³P₂), Kr(¹P₁), and Kr(³P₁) by F₂. In the case of Ar-F₂ mixtures it was shown that only Ar(¹P₁) + F₂ leads to (ArF)^{*} with an appreciable efficiency, while in Kr-F₂ mixtures at least two of the long-lived excited states produce (KrF)^{*} following collisions with F₂. The quenching rate of (ArF)^{*} by F₂ has been determined, and it has been shown that (ArF)^{*} is also converted to (Ar₂F)^{*} in the process (ArF)^{*} + 2Ar → (Ar₂F)^{*} + Ar. The lifetime of (Ar₂F)^{*} was shown to be about 180 nsec, and its quenching rate constant by F₂ was determined. In Ar-F₂ mixtures, Ar₂(¹Δ_g) is also converted to (ArF)^{*} in collisions with F₂. In fact, the conversion of Ar₂(¹Δ_g) to (ArF)^{*} is even more efficient than the conversion of Ar(³P₂). In both Ar-F₂ and Kr-F₂ mixtures, ion-ion recombination is observed at the higher pressures; but at low densities of Ar₂⁺ and F₂⁺, the rate controlling process is the conversion of F₂⁺ to F₂⁺ by three-body collisions. The Kr-F₂ study is continuing.

A rather detailed study⁵ of Ne-N₂ mixtures has been carried out with particular attention being given to charge transfer processes [monitored by time-resolved studies of the N₂(B_u⁺ → X_g⁺) transition]. The experiment gives indirect evidence for the existence of Ne⁺. Overall quenching rates were determined for Ne⁺ and Ne⁺, and the overall fluorescence spectrum was studied.

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Other studies¹² concentrated on charge transfer and Penning ionization in He-N₂, He-CO, He-CO₂, and He-H₂S mixtures. Charge transfer rates were determined for He⁺-N₂, He⁺-CO, He⁺-H₂S, and He⁺-CO.

RESONANCE IONIZATION SPECTROSCOPY EXPERIMENTS AND ONE-ATOM DETECTION

A new measuring technique which can detect a single atom of a given type, even in the presence of 10^{10} or more atoms of another kind, with good space and time resolution, was used to study the density fluctuation of less than 100 cesium atoms in a small volume of space filled with inert gases.¹³ Repeated measurements of the absolute number of atoms in a defined volume at an arbitrary time were recorded for the first time in order to obtain a statistical distribution giving the fluctuation of the number of atoms around the mean value.

A major advancement¹⁴ in the one-atom detection technique makes it possible to detect with microsecond-time resolution single neutral atoms resulting from the stopping of energetic heavy ions in a buffer gas. This detection at the one-atom level, which gives the first direct evidence of nearly complete charge neutralization of stopped energetic ions, is shown to be possible even under extremely adverse conditions due to free electrons and various other radiation products associated with a densely ionized track in a gas. Technical aspects of this development are described in Fig. 3-1.

Fig. 3-1. Schematic of apparatus used to detect a single atom emitted from the nucleus of another atom. A signal generated in the surface-barrier detector indicates the occurrence of a single fission process. After the initial ionization has been swept with the collector plates, a laser pulse is used to remove one electron from the single atoms. The electron is drifted into a proportional counter and detected as a single event.

The one-atom detection technique has been used to search for atoms which are created from the neutralization of heavy ions as they lose their energy in a gas. When ^{252}Cf decays by binary fission, Cs^{56+} ions are formed 14% of the time (in the heavy-mass peak). Thus, these ions were injected into a gas at a low rate such that the cesium neutral atom could be searched for individually and at a known time after its production. A delay of a few microseconds allowed time for collection of the 3×10^4 electrons created by the 80-MeV Cs^{56+} energy; then a pulsed laser was fired along each particle track to remove one electron from each cesium atom by the saturated two-step resonance ionization process. These electrons were then drifted

into a gas proportional counter and detected individually to measure the probability that a neutral cesium atom would be found at the end of the fission particle track. Our results show that a cesium neutral species is formed about 14% of the time and thus nearly all Cs^{n+} ions become Cs^0 when the ions are thermalized in P-10 (90% Ar plus 10% CH_4) counting gas. The one-atom detector can also be used to obtain other details of particle track structure. For example, it is possible to detect even one negative ion created in a track where nearly 100 MeV of energy is absorbed; and it is likewise possible to determine the population of quantum selected excited states left in the wake of these tracks.²¹

A new technique was reported²² for the study of gas amplification fluctuation in proportional counters. Use was made of pulsed laser beams to carry out two-step resonance ionization spectroscopy (RIS) of cesium atoms which were seeded at very low concentration into the counting gas. With this independent determination of the fluctuation of the gas amplification, one can determine the Fano factor which enters into the statistics of the ionization of gases by swift charged particles. Accordingly, RIS measurements were made in P-10 gas; and the fluctuations in pulse heights were compared with fluctuations observed with x-ray sources to obtain Fano factors. We found, for photoelectrons at 2.6 keV and at 5.9 keV stopping in the counting gas, the Fano factors 0.31 ± 0.10 and 0.21 ± 0.10 , respectively.

RESONANCE IONIZATION SPECTROSCOPY EXPERIMENTS WITH MOLECULES

Because of the success of one-atom detection and its already widespread application, we have extended RIS studies to colliding atoms (i.e., quasi-molecules and also to the study of stable molecules).

A laser excitation and ionization process was used to measure Cs-Ar interaction forces at long range. With energy densities of 1 J/cm^2 , nonlinear excitation persists as far out as 70 Å at one atmosphere of argon. This method provides extreme sensitivity (even single absorption events can be measured) which allows absolute measurements on the very far wing where absorption or fluorescence becomes vanishingly small. Line broadening data were reported²³ which find direct application to the selective detection of one kind of atom in the background of many more atoms of other types. We showed that molecular (e.g., CsI) photodissociation can be used to produce a spatially-defined population of atoms in their ground states at a well-defined time. Such sources of atoms can be combined with time- and space-resolved one-atom detectors in a number of novel experimental arrangements. We proved that all of the CsI molecules in the central portion of a laser beam could be dissociated to neutral cesium and iodine atoms in their ground states. This, along with the previous demonstrations that each cesium atom can be ionized with another pulsed laser, proves that single molecules of CsI can be detected. We also obtained new information on the photodissociation of CsI, including the absolute cross section as a function of wavelength.

Laser techniques for the production of free atoms at time $t = 0$ and their detection at $t > 0$ have been developed to measure the diffusion of cesium atoms in argon and the reaction of cesium with O_2 in argon gas. The method introduced for the study of alkali halide photodissociation is well suited to rather direct measurements of the diffusion of small numbers of alkali atoms in various gases and to a remarkably simple determination of the rate of reaction of free atoms with various other atoms or molecules. Thus, we presented a new method for the study of diffusion and chemical reaction kinetics; and we gave results on the diffusion coefficient of cesium in argon gas and on cesium reactions with O_2 in argon gas.

In Fig. 3-2 we show the experimental arrangement which permitted measurement of (1) the absolute cross section for the photodissociation of molecules, (2) the neutral diffusion of atoms, and (3) the rate of reaction of an atom with other atomic molecular species. References

24 and 25 give results on absolute cross sections for photodissociation of CsI molecules as a function of wavelength, the diffusion of cesium in argon, and the rate of reaction of cesium with O_2 in an argon buffer gas.

Fig. 3-2. Experimental arrangement for time-resolved studies of reactive atoms. The pulsed UV laser dissociates molecules into atoms at time $t = 0$; the visible laser is used to detect free atoms at $t > 0$. Diffusion coefficients and chemical kinetic rates can be deduced from the experimental data. In this work the source beam (UV) has a diameter of 0.5 mm and the detector beam (visible) has a diameter of 7 mm. The plate separation is 2.7 cm and the length of the guarded collector is 4.0 cm in the direction parallel to the laser beams.

STUDIES OF MOLECULAR CLUSTERING PHENOMENA

Experimental studies of the formation of van der Waals clusters of molecules have come to maturity within the past year. The clustering is achieved via the rapid quasi-isentropic expansion of a gas through a sonic nozzle and is observed with a time-of-flight mass spectrometer. The results of these studies fall into several areas.

1. The kinetics of cluster formation. The buildup and decay of mass-identified clusters as a function of the nozzle driving pressure can provide rate constants for the condensation processes in the sonic expansion.

2. Accurate heats of formation. The cooling of the gas in the isentropic expansion eliminates "hot-band" effects on the appearance potentials of ions produced in the mass spectrometer. This has been critically examined in the case of O^+ , derived from CO and N_2O .

3. Evaporative electron attachment. Electron attachment to a van der Waals cluster can produce species unobtainable by conventional means. An example is the CCl_4^- ion, formed by electron attachment to a mixed carbon tetrachloride-carbon dioxide cluster.

4. Solvation effects on electron affinities. A normally unstable ion may be quite stable when solvated in a van der Waals cluster. Our observation of the $[\text{CO}]_n^-$ ions, with $n \geq 2$, directly illustrates this.

5. Preparation of collision complexes. The ionization of van der Waals molecules offers a direct route to ion-molecule collision complexes. Our observation of internal ion-molecule reactions in ionized clusters of water, ethylene, and nitrous oxide illustrates this.²⁴

These observations are discussed more extensively in refs. 26-28.

COLLISIONAL IONIZATION

The collisional ionization processes

where A is an alkali atom and MX a molecule are presently of great interest and have been the subject of extensive experimental investigation within the last year. When the electron affinity (EA) of the molecule MX is positive (i.e., the ground state of the negative ion MX^- lies at a lower potential energy than the ground state of the neutral molecule MX) reaction (1) usually proceeds with a large cross section ($>10^{-16}$ cm²). Measurement of the threshold for the reaction as a function of the relative kinetic energy of the reactants A and MX can yield reliable values of the electron affinity of MX. These EA values may be difficult to obtain by other means and are fundamental to an understanding of electron attachment and negative ion stability.

During the past year negative ion products resulting from collisions between orthogonal, crossed beams of alkali metal atoms (Na, K, Cs) and the octahedral hexafluorides MF_6 (M = S, Se, Te, Mo, W, Re, Ir, Pt, and U)^{27,28} have been examined in the energy region from 0 to 40 eV (lab). Studies of the dependence of the reaction thresholds upon the temperature of the target molecules SF_6 , SeF_6 , and TeF_6 yielded $EA(SF_6) = 0.46 \pm 0.2$ eV, $EA(SeF_6) = 2.9 \pm 0.2$ eV, and $EA(TeF_6) = 3.3 \pm 0.2$ eV.²⁹ The electron affinities of the other hexafluorides were found to be remarkably large and are probably greater than 5 eV. In similar studies electron affinities were found for the series SF_n (n = 5, 4, 3), for the methane derivatives CH_3NO_2 , CH_3Br , and CH_3I , and for the molecule tetracyanoquinodimethan (TCNQ).³¹ For TCNQ, for UF_6 , and for vinylene carbonate ($C_3O_2H_2$) electron impact studies were also made to complement the collisional ionization data. The negative ion states and modes of dissociation of vinylene carbonate were successfully accounted for by an analysis employing molecular orbital theory.³²

To extend the range and power of the collisional ionization studies, the apparatus shown in Fig. 3-3 has been used to make measurements differential in both energy and in scattering

Fig. 3-3. Apparatus. Diameter of interaction chamber 43.2 cm. Distance from alkali source to filament of neutral particle detection B (when located at $\theta = 0$) 76.0 cm. Flight distance through electrostatic analyzer A 12.4 cm.

angle of both positive and negative products from reactions (1) and (2). Studies of cesium and potassium collisions with H_2O , D_2O (ref. 33) D_2O (ref. 34) and C_2H_4 (ref. 35) have been made. In each case the motivation for the study lay in the need for more detailed understanding of the negative ion states of the molecule MX^- . In particular in the case of H_2O , we wished to obtain information on the nature of the lowest lying H_2O^- state. A minimum in this A^- state might lead to the production of H^+ through reaction (1) at a lower relative kinetic energy than is necessary to produce OH^- through reaction (2). The results (Fig. 3-4) showed conclusively that the H^+ and OH^- onsets were equal to within ± 0.1 eV.

Fig. 3-4. Base of figure: Energy distribution of K^+ atoms scattered at 5° (lab angle) in the reaction $\text{K} + \text{D}_2\text{O} \rightarrow \text{OD}^- + \text{K}^+ + \text{D}$ for a K beam energy of 96.5 eV. Top four spectra in order from bottom: $-Q$ distributions for K impact energies of 36.5, 76.5, 56.5, and 36.5 eV. The small peak, apparent in the 36.5 eV data, is due to the presence of a small amount of O_2 in the scattering chamber. The value of Q indicates the endothermicity of the reaction. The minimum endothermicity of 7.6 eV shown by the arrow is equal within the experimental uncertainty to the sum of the ionization potential of K, 4.34 eV, and the known $\text{D}(\text{S}) + \text{OD}^-(\text{I})$ limit of the A^- state of D_2O^- , at 3.28 eV, indicating that the OD^- and K^+ thresholds are indeed equivalent and correspond to this limit.

MULTIPHOTON SPECTROSCOPY OF MOLECULES

We have maintained an active effort in multiphoton spectroscopy using the intense field of a focused pulsed dye laser to induce near-simultaneous absorption of more than one photon. This multiphoton absorption may be detected by monitoring fluorescence or by observing multiphoton ionization. Since the selection rules for this process differ from those governing normal single photon transitions, multiphoton spectroscopy has great promise for examination of normally forbidden transitions. In addition, in favorable cases greater specificity and sensitivity are possible than with standard optical detection techniques.

In the past year we have extended our multiphoton studies to new systems and investigated modifications of the basic techniques. We have conducted studies on the five-membered aromatic heterocyclics, in particular pyrrole, a contaminant in synfuel processes. Using pyrrole, we are currently investigating the use of multiphoton ionization spectroscopy with visible lasers as a means of observing optical transitions in the 5-10 eV region. Comparison studies show that the Rydberg levels and photoionization thresholds determined by three-photon absorption agree well with those determined by vacuum ultraviolet techniques. The multiphoton methods also allow observation of Rydberg states which are symmetry forbidden to the single photon transitions.

A further refinement in techniques has been the use of two independently tunable dye lasers. The first laser pumps an individual excited level by one- or two-photon absorption; transitions involving higher excited states are induced by a second laser. By pumping a single vibrational-rotational level tremendous spectral simplification is gained along with greatly increased sensitivity. For example, Fig. 3-5 shows a portion of the molecular iodine three-photon ionization spectrum from a high vibrational level of the $\tilde{B}$ state. Two vibrational progressions are clearly assignable. In contrast, the residual spectrum due to four-photon ionization from the ground state by the tuned laser (seen above 5000 Å) is intractably complex. The use of two tunable lasers promises to have other advantages; for example, the high peak power of the pump laser is sufficient to saturate many weak singlet-triplet transitions, allowing investigation of triplet-triplet absorptions.

Fig. 3-5. Three-photon ionization of molecular iodine pumped to the $V = 43$, $J = 12$, 16 levels of the $\tilde{B}$ electronic state. The labeled vibrational progressions are due to two-photon resonances with electronic states at $60,000 \text{ cm}^{-1}$. Note the enhancement relative to the normally intense four-photon ionization signal from ground state iodine at wavelengths above 5000 Å.

THEORETICAL ATOMIC AND MOLECULAR STUDIES

New theoretical results have been obtained in the areas of elastic and inelastic electron collision phenomena; molecular negative ion formation and molecular fragmentation; and molecular spectroscopic parameters.

The possible role of rotational scattering resonances in determining very low-energy electron scattering by ortho- and para-hydrogen and molecular deuterium was carefully examined. Through extensive calculations of conditions which result in resonant scattering, it was demonstrated that the combined effect of two or more neighboring molecules are required to sustain rotational resonances in H_2 or D_2 (ref. 36). Thus, the experimental data from high-pressure and/or low-temperature electron drift studies require a multiple scattering formalism for their explanation or scattering from molecular dimers rather than single molecules.

A complex optical potential method which was developed previously¹⁷ for studies of multi-channel electron scattering has been improved through the inclusion of electron exchange effects in the complex nonlocal optical potential.¹⁸ The method is particularly attractive for applications in which excitation and ionization channels make significant contributions to total electron scattering cross sections but below the energy region where the Born approximation is applicable. The calculations gave very good agreement with recent experimental data on differential electron-hydrogen scattering cross sections.

The results of experiments on molecular fragmentation of $C_2H_4^+$ by photoionization and by collisional formation have been used to demonstrate the role which angular momentum plays in unimolecular dissociation kinetics.¹⁹ On the basis of a theoretical quasi-equilibrium model developed earlier,^{20,21} strong differences in kinetic energy distributions of ionic fragments from $C_2H_4^+$ dissociations were shown to follow from the different angular momentum distributions of the ions that were formed by the two different modes of formation.²² Results of these studies are important in other related work on dissociative processes in molecular cluster ions.

Complementary to experimental investigations of molecular negative ions, described elsewhere, theoretical investigations of electron affinities of polar molecules have continued to yield new insights into electron binding properties of such systems. In one study, determinations were made of the magnitude of Born-Oppenheimer electron affinities which are required in order to insure that negative ions of polar molecules are still stable when nuclear motion is included in the molecular Hamiltonian. It was found that a binding energy of only about ten times the molecular rotational constant is required in order to mathematically guarantee a stable negative ion.²³ In another study the total long-range interactions from permanent and induced molecular dipole forces were examined to establish the range of polarizabilities and permanent dipole moments that are required in order to guarantee the existence of molecular anions with thermal stability.²⁴ The important role in electron binding of long-range interactions which arise from the polarizability of a polar molecule was demonstrated for the first time. This work emphasizes the importance of having polarizability information on strongly polar molecules; an area which is almost devoid of experimental data. This study also emphasizes the benefits to be gained from our cooperative program with New York University involving polarizability measurements on heavy metal atoms.²⁵ These studies will, in the future, provide needed information on polarizabilities of polar molecules.

A systematic study of electronic transition probabilities of diatomic molecules has revealed very useful trends in isovalent molecular sequences.²⁶ This work has led to a proposed diatomic molecular periodic table for interpolating molecular data in a fashion analogous to that which can be derived from the periodic table of the elements.²⁷

THEORY OF LASER INTERACTION WITH QUANTUM SYSTEMS

The most important applications of resonance ionization spectroscopy seem to be: (1) the detection of rare events, (2) the study of transport phenomena, (3) fundamental measurements related to line broadening phenomena and photophysics, (4) the study of kinetic processes, and (5) analytical chemistry for the study of surfaces and gases in situations where ultra-high sensitivity is required. In almost all of the above applications there are collisional effects on the response of the atoms selected for detection; there is the possibility of background effects due to multiphoton ionization or collisional-induced absorption by impurity atoms, and, finally, the pulsed lasers used have bandwidths which are much larger than the reciprocal of the pulse length. Correspondingly, the situation calls for a rather detailed understanding of subjects such as: (1) the role of laser coherence time on the description of laser beam-atom interactions, (2) the role of line-broadening effects which might destroy sensitivity in the presence of intense laser fields, (3) the interaction of pulsed laser fields with atoms and the effect of pulse shape, (4) the effects of the multiphoton ionization of impurities on sensitive and selective detection by resonance ionization spectroscopy, and (5) the study of energy transfer or collisional redistribution which could prevent the saturation of the resonant ionization process.

During the past year we have continued our effort to develop expertise related to collisional line broadening in the presence of intense laser beams, collisional-induced resonances in the multiphoton ionization of atoms, the effect of laser pulse shape on two- and three-photon ionization, the role of collisional relaxation and laser coherence time on the applicability of rate equations to laser interaction problems, and the effect of line broadening and laser coherence time on laser-induced fluorescence. Additional theoretical effort has been devoted to modeling the results of our experiments on the excited state kinetics of Ar-F₂ mixtures, our experiment on the far wing line broadening of cesium resonance lines by argon, the experiment on proportional counter statistics, and the evaluation of the expected sensitivity of our experiments using laser fluorescence in order to analyze the molecular species in a supersonic nozzle jet.

REFERENCES

1. Instrumentation and Controls Division.
2. Chemistry Division.
3. Consultant, University of Tennessee.
4. Guest assignment, Auburn University.
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13. C. H. Chen and M. G. Payne, *J. Opt. Soc. Am.* 32(6):358 (1978).
14. C. H. Chen, J. P. Judish, and M. G. Payne, "Energy Transfer Processes in Proton-Excited Ar-Xe and Ar-F₂ Mixtures," *J. Opt. Soc. Am.* (in press).
15. C. H. Chen, M. G. Payne, and J. P. Judish, "Kinetic Studies of ArF* in Proton-Excited Ar-F₂ Mixtures," *J. Opt. Soc. Am.* (in press).

16. G. H. Chen, M. G. Payne, and J. P. Judish, "Kinetic Studies of Ar-F Mixtures by Resonant Excitation," *J. Chem. Phys.*, **67**:3376 (1977). (to be published).
17. G. H. Chen, J. P. Judish, and M. G. Payne, *J. Chem. Phys.*, **67**:2713 (1977).
18. G. H. Chen, J. P. Judish, and M. G. Payne, *J. Chem. Phys.*, **67**:3376 (1977).
19. G. S. Hurst, M. H. Hayfeh, and J. P. Young, *J. Chem. Phys.*, **67**:2293 (1977).
20. S. D. Kramer, C. E. Bemis, Jr., J. P. Young, and G. S. Hurst, "One-Atom Detection in Individual Ionization Tracks," *J. Chem. Phys.* (in press).
21. G. S. Hurst, S. D. Kramer, C. E. Bemis, Jr., and J. P. Young, "Detection of Single Atoms in Particle Tracks," *Proc. 1977 Int. Conf. on Atomic and Molecular Physics*, May 22-26, 1978, Brussels, Belgium (to be published).
22. G. S. Hurst, S. L. Alfman, M. G. Payne, F. A. Marshall, and F. L. Soohoo, "Resonant Ionization Studies of the Fluctuation of Proportional Counters," *J. Chem. Phys.* (in press).
23. M. H. Hayfeh, G. S. Hurst, M. G. Payne, and J. P. Young, *J. Chem. Phys.*, **67**:604 (1977).
24. L. W. Grossman, G. S. Hurst, M. G. Payne, and S. L. Alfman, *J. Chem. Phys.*, **67**:70 (1977).
25. L. W. Grossman, G. S. Hurst, S. D. Kramer, M. G. Payne, and J. P. Young, *J. Chem. Phys.*, **67**:207 (1977).
26. C. E. Klots and R. N. Compton, "Electron Attachment to Carbon Dioxide Clusters in a Supersonic Beam," *J. Chem. Phys.*, **67**:1799 (1977).
27. C. E. Klots and R. N. Compton, "Electron Attachment to van der Waals Polymers of Carbon Dioxide and Nitrous Oxide," *J. Chem. Phys.* (in press).
28. C. E. Klots and R. N. Compton, "Electron Attachment to van der Waals Polymers of Water," *J. Chem. Phys.* (in press).
29. R. N. Compton, P. W. Reinhardt, and C. D. Cooper, *J. Chem. Phys.*, **66**:2023 (1977).
30. R. N. Compton, *J. Chem. Phys.*, **66**:4478 (1977).
31. R. N. Compton, P. W. Reinhardt, and C. D. Cooper, "Collisional Ionization Between Alkali Atoms and Some Methane Derivatives: Electron Affinities for CH₃NO, CF₃I and CF₃Br," *J. Chem. Phys.* (in press).
32. R. N. Compton and H. C. Schweinler, "Formation of Gas Phase Negative Ions in Vinylene Carbonate," *J. Chem. Phys.* (in press).
33. P. J. Warmack, J. A. D. Stockdale, and P. N. Compton, *J. Chem. Phys.*, **68**:916 (1978).
34. P. J. Warmack, J. A. D. Stockdale, and P. N. Compton, *J. Chem. Phys.*, **68**:159 (1978).
35. P. J. Warmack, J. A. D. Stockdale, and P. N. Compton, *J. Chem. Phys.*, **68**:1322 (1977).
36. W. R. Garrett, *J. Chem. Phys.*, **66**:2305 (1977).
37. G. D. Alton, W. R. Garrett, M. Reeves, and J. E. Turner, *J. Chem. Phys.*, **66**:2132 (1977).
38. P. W. Coulter and W. R. Garrett, "Electron-Hydrogen Scattering by Complex Optical Potential Methods," *J. Chem. Phys.* (accepted for publication).
39. C. E. Klots, *J. Chem. Phys.*, **75**:1526 (1971).
40. C. E. Klots, *J. Chem. Phys.*, **75**:10422 (1971).
41. C. E. Klots, D. Mintz, and T. Baer, *J. Chem. Phys.*, **66**:5100 (1977).
42. O. H. Crawford and W. R. Garrett, *J. Chem. Phys.*, **66**:4968 (1977).
43. W. R. Garrett, "Thermally Stable Negative Ions of Polar Molecules," *J. Chem. Phys.* (submitted for publication).
44. J. A. D. Stockdale, L. Schumann, H. H. Brown, Jr., and B. Bederson, *J. Chem. Phys.*, **7**:938 (1977).
45. R. Hefferlin, *J. Chem. Phys.*, **68**:19335 (1978).
46. R. Hefferlin and R. Campbell, "A Diatomic Molecular Periodic Table for Interpolating Data and Orbitals," *J. Chem. Phys.* (submitted for publication).
47. M. G. Payne, J. E. Turner, and V. E. Anderson, "Evaluation of Approximation Methods for the Calculation of Transition Probabilities by Comparing with Numerical Solutions to the Optical and Radiative Collision Problems," (to be published).
48. M. H. Hayfeh, *J. Chem. Phys.*, **66**:927 (1977).
49. M. G. Payne and C. W. Choi, *Proc. 1977 Int. Conf. on Atomic and Molecular Physics*, June 6-9, 1977, Rochester, N.Y. (in press).

50. M. H. Nayfeh and M. G. Payne, "Radiative Collision-Induced Photoionization," (in press).
51. M. G. Payne, "Laser-Induced Inelastic Processes in Atom-Atom Collisions," Division of Electron and Atomic Physics Meeting, American Physical Society, December 5-7, 1977, Knoxville, Tenn. (invited paper); *Bull. Am. Phys. Soc.* 22:1316 (1977).
52. M. G. Payne, S. W. Choi, and M. H. Nayfeh, "Laser-Induced Collisional Excitation Transfer," *Proceedings of the International Conference on Multiphoton Processes*, June 6-9, 1977, Rochester, N.Y. (in press).
53. M. G. Payne and S. W. Choi, "Three-Photon Ionization of Atoms near a Two-Photon Resonance," *Proceedings of the International Conference on Multiphoton Processes*, June 6-9, 1977, Rochester, N.Y. (in press).
54. M. G. Payne, "Three-Photon Ionization with Pulsed Lasers," (to be published).
55. G. S. Hurst, M. G. Payne, J. P. Young, and S. D. Kramer, "Resonance Ionization Spectroscopy and One-Atom Detection," (to be published).
56. C. H. Chen, M. G. Payne, and J. P. Judish, "Kinetic Studies of Ar⁺ and Ar²⁺ in Proton-Excited Ar⁺ Mixtures," *Phys. Rev. A* (in press).

Part IV. Technology Assessments

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The Technology Assessments Section (TAS) has as its primary objective evaluation of impacts on man due to environmental pollutants. This section brings theoretical methodology development-application activities and experimental laboratory-field activities to a common focus on assessment questions.

Theoretical studies in assessment methodology have concentrated in the past year on computerization of state-of-the-art models for internal radiation dosimetry and development and evaluation of environmental transport models. Methodology applications continued to cover a broad spectrum of radiation exposure scenarios. Potential exposure situations requiring assessment arise from assorted deployments of all parts of nuclear fuel cycles, including comparisons of alternative uranium and thorium based cycles, and preliminary evaluations of advanced reactor fuel concepts.

Field activities in TAS during the year have consisted of numerous trips with mobile laboratories to take measurements and collect samples for the purpose of characterizing and documenting the current radiological status of formerly used Manhattan Engineer District/Atomic Energy Commission (FED/AEC) sites. This survey program encompasses research activities in the areas of survey design, instrumentation development, sample analysis, and data reduction and analysis. Other laboratory activities within TAS center around the unique capabilities of the Health Physics Research Reactor (HPRR) as an irradiation source. Typically the HPRR was involved in testing and intercomparison of dosimetry and criticality alarm systems and in exposure of physical and biological experiments.

BIOTRANSPORT AND DOSIMETRY MODELS

Internal Dosimetry

Under sponsorship of the Nuclear Regulatory Commission (NRC), a project has been undertaken in the Methodology Development Group to implement advanced dosimetric and environmental transport models and data bases for realistic estimation of radiation doses to the general public from releases of radionuclides to the environment. The first phase of this work has concentrated on providing systematic information for calculation of internal and external dose to man. Three products of this activity are the SFACTOR and INREM II computer codes and the first volume of a tabulation of internal dose conversion factors for radionuclides taken into the body by inhalation and ingestion.

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The dose equivalent to the ICRP code is a sum of inhalation, ingestion, and external dose. Each intake is associated with a target organ and has been translated to the equivalent dose to the target organ due to 1.0 of the exposure dose is the 1.0 distributed to the source organ. The methods of calculation are based largely on the definitions established by ICRP for the end point of equivalent dose to the target organ and the ICRP code.

The ICRP II code accepts inhalation and ingestion and external data for each radionuclide in a standard, for a specified intake of the parent radionuclide, estimates the dose equivalent to each of a given list of target organs due to resultant activity in all source organs for which data are given. The intake is by inhalation or ingestion. The dose contribution of daughters which form in the body is included in the calculation. The lung model proposed by a task group of the International Commission on Radiological Protection (ICRP) is the basis for estimating microgram-days residence of inspired particulates and radioactive progeny in the respiratory tract, as well as absorption into the blood. A four-compartment category model of the GI tract similar to that analyzed by Bernard is used to estimate dose to the walls of the tract and absorption of radioactivity from it. Retention of radionuclides in other organs is represented by linear combinations of decaying exponential functions. The ICRP II code is discussed in detail by Killough et al.

These computer codes are being used in the preparation of a tabulation of dose conversion factors (respiratory intake) for many of the radionuclides that occur in routine releases from nuclear fuel cycles. The first volume includes 68 radionuclides of mass number less than 150. The second volume is in press and contains information for 13 radionuclides with mass numbers ranging from 152 to 252.

Carbon-14 Studies

Radioactive ^{14}C is formed as a by-product of nuclear power generation, and a part of it is released to the environment and results in radiation dose to man. Three scenarios of worldwide release of ^{14}C from nuclear facilities have been proposed for the period 1975 to 2020. These scenarios have been used to perform an assessment of the radiation dose to the world population and associated potential health effects from this source of ^{14}C . Measures of health impact were derived from the scenarios through the use of a revised version of the multicompartment model of the global carbon cycle described by Killough,¹⁰ dose-rate factors from a study by Killough and Bonner,¹¹ and health-effect incidence factors recently recommended by the ICRP.¹² The scenarios for worldwide ^{14}C releases due to nuclear power generation are a pessimistic scenario in which all ^{14}C projected to be produced in fuel cycles is released, an optimistic scenario that assumes a decontamination factor of 100 for fuel reprocessing, and an intermediate scenario that simulates a phased improvement in the effluent treatment technology at reprocessing plants. The results of the calculations are estimates of cumulative potential health effects as shown in Table 4-1. For comparison, the table exhibits corresponding estimates for the natural ^{14}C formed between 1975 and 2020 and the 6 MCi of ^{14}C produced by nuclear explosives between 1945 and 1974 (based on a tabulation of kiloton yields by Carter and Moghissi¹³). These estimates assume a world population that increases to 12.2 billion by 2025 and remains stationary thereafter. Killough and T¹⁴ give further details.

It is assumed that the rate of depletion is proportional to the concentration of the pollutant in the air.

where C is the concentration of the pollutant in the air.

where C_0 is the initial concentration of the pollutant in the air.

where x is the downwind distance.

where x_0 is the initial downwind distance.

where x_0 is the initial downwind distance.

The depletion of airborne pollutant plumes resulting from dry deposition on ground surfaces must be taken into account when estimating pollutant concentrations in air at distances downwind from their sources. This can be done by using a reduced release rate instead of the actual release rate for the pollutant in atmospheric dispersion equations. The reduced release rate is the actual rate of release multiplied by a depletion fraction. If dispersion is estimated by the widely used Pasquill-Gifford equation,^{11,12} the depletion fraction (f_d) for dry deposition processes is represented by the expression

$$f_d = \exp \left\{ - \left(\frac{z}{H} \right)^{1/2} \int_0^x \frac{\exp \left[- \frac{1}{2} \left(\frac{H}{z} \right)^2 \right]}{z} dx \right\} \quad (1)$$

where

- v_d = deposition velocity,
- U = mean wind speed,
- H = effective release height,
- z = vertical dispersion coefficient,
- x = downwind distance.

The depletion fraction is not easily calculated because the integral expression must be evaluated numerically.

The AIRSOS-II computer code¹³ was used to calculate depletion fractions for use in dispersion calculations. The code numerically evaluates the integral expression of Eq. (1) by use of subroutine QX, which is based on Simpson's rule. The depletion fractions are listed in tabular form¹⁴ for downwind distances ranging from 35 to 200,000 m and for release heights ranging from 1 to 400 m for a deposition velocity of 0.01 m/sec and a wind speed of 1 m/sec. The calculations were made for Pasquill atmospheric stability categories A through G using σ_z values recommended by G. A. Briggs in a publication by Gifford.¹⁵ The tabulated depletion fractions in ref. 21 are for downwind distances and release heights spaced so that linear

interpolations would provide good approximations for all intermediate values. The values can be easily converted to easily to other descriptive information and wind roses.

Dispersed Source Analysis

Multiple dispersed sources of air pollutants include emissions from combustion of coal and fuel oil in homes, schools, and commercial establishments and emissions from vehicles. Concentrations in air of pollutants such as sulfur dioxide (SO_2), particulates, hydrocarbons, or carbon monoxide (CO) emitted from such dispersed sources may be estimated by treating them as though they were being emitted uniformly from square areas near ground level. The APEAS computer code¹ was written to perform area source calculations for dispersed sources or for true area sources of air pollutants.

The code calculates average ground-level concentrations of an air pollutant for each of 400 grid squares of a 20 by 20 grid resulting from area emissions of the pollutant from all 400 grid squares. Input data include the total emission rate from the 20 by 20 grid, the fraction of the total emitted from each of the 400 grid squares, and the grid size. APEAS does not employ meteorological data as input but instead uses several arrays of 400 $\times$ 50² values to describe pollutant behavior derived from a point-source model or computer code that does employ annual-average meteorological data. A uniform meteorology over the 20 by 20 grid area must be assumed in APEAS.

APEAS has been used to study air pollution sources in Roane County, Tennessee.² It has also been used to predict atmospheric dispersion of radionuclides resuspended from the tailings piles of uranium mills. Another recent application was reported in an Environmental Sciences Division research proposal to the National Science Foundation for paleoecological studies of atmospheric dispersion of ancient pollen.

STANDARDIZED RADIOACTIVE DECAY DATA SETS FOR USE IN RADIATION DOSIMETRY

The availability of evaluated decay data for a large number of radionuclides is of fundamental importance for radiation dosimetry. We have used a computer-based system developed by the Nuclear Data Project at ORNL to obtain the energies and intensities of the atomic and nuclear radiations from radionuclide decays in a format suitable for application to radiation dosimetry calculations. This system is described in refs. 26 and 27.

This system has been used to produce a compilation of decay data for a group of 240 radionuclides of potential importance in routine releases from nuclear fuel cycle facilities. Data have also been evaluated for an additional 150 radionuclides of potential importance in various assessment activities. The data published in ref. 26 have been used to calculate S-factors for internal dose and dose-rate conversion factors for external exposure using the code EXREM III.²⁸ The radioactive decay data are continually being revised as new information is available in the literature.

MODEL EVALUATION

The purpose of this project is to evaluate environmental transport and dose calculational models employed in the assessment of the radiological impact of routine and accidental radioactive discharges from nuclear facilities. This includes the identification of these models,

¹ c_x/Q = ground-level concentration of the pollutant in air (.) divided by its release rate from the source (Q).

the evaluation of their conceptualization, simplifying assumptions and data bases, the estimation of their uncertainties, and, if possible, the recommendation of the models and parameters which are best suited to particular assessment situations. Where needs are identified, recommendations will also be made for further environmental and biomedical research.

An intensive effort is currently being directed at an evaluation of models recommended by the NRC in their Regulatory Guide 1.109. These models are being subjected to a systematic evaluation methodology which is designed to facilitate the identification of critical parameters and to specify additional improvements required to reduce the uncertainty associated with the use of the models.

Significant accomplishments of the project have been made in the areas of model-evaluation methodology development and application of the methodology to the terrestrial food chain transport of transuranic elements, technetium, and radioiodines. The methodology has also been applied to investigations of models and associated parameter values used to estimate atmospheric dispersion, plume depletion and deposition, and those used in calculating internal dose conversion factors for ^{239}Pu and ^{99}Tc .

A detailed progress report describing the activities carried out in the Model Evaluation Program is available.³ The organization of a workshop on the application of models to the environmental assessment of radionuclides, held in Gatlinburg, Tennessee, on September 6-9, 1977, was a special task performed by the Methodology Development and Evaluation Group. Participants at the Workshop were experts selected to discuss the strengths, weaknesses, and developmental needs of existing radiological assessment models and computer codes. The proceedings of this Workshop have been documented.⁴

A general need for validation experiments in order to test the accuracy and precision of model predictions has been identified. Otherwise, model uncertainty can only be estimated through a statistical analysis of data available for input which may produce misleading results. The scope of the project will be expanded to include the evaluation of surface and groundwater transport models and the design and organization of experimental research for the purposes of validation of model predictions of critical importance.

ALTERNATIVE FUEL CYCLE TECHNOLOGY

The Technology Assessment Section is involved in a program directed by Savannah River Laboratory to assess the environmental effects of alternate fuel cycle technologies. The section's primary contribution to this program has been an assessment of the effects of building structures, which act as shielding devices, on radiation doses from routine releases of radionuclides to the atmosphere. In addition, an analysis was performed to investigate the potential importance of resuspension on the airborne concentration of radionuclides during the operating period of a facility. Finally, work has begun to develop models to estimate potential long-term population dose commitments resulting from releases of long-lived radionuclides to the environment.

We have estimated dose reduction factors from building shielding⁵ for a source term from a hypothetical fuel reprocessing facility.⁶ For a typical family dwelling, the internal dose reduction factor from inhalation is estimated to be 0.7 to 0.8 for radionuclides occurring in particulate form. For the same source term, an average structure with 9-cm-thick concrete walls provides an estimated external dose reduction factor of 0.5.

Calculations of the concentration of airborne radionuclides at any location from routine releases to the atmosphere during operation of a facility usually assume that the contribution from resuspension is negligible. We have tested this assumption by calculating resuspended air concentrations using different models for the resuspension factor.⁷⁻¹⁰ Our analysis

shows that if the resuspension factor has a constant value of about 10^3 m^{-1} , then resuspension is indeed negligible over extended operating lifetimes of a facility. If, however, the resuspension factor is taken to be a time-dependent quantity with an initial value as large as 10^4 m^{-1} which then decreases with some characteristic halflife to a value near 10^3 m^{-1} (refs. 33 and 34), we find that the calculated resuspended air concentrations during the operating period of the facility can be larger than the original steady-state air concentration itself. Although there are data to suggest that such large resuspended air concentrations are unrealistic, this analysis demonstrates that resuspension cannot be neglected during a continuous atmospheric release unless upper limits for the initial resuspension factor and the time constant (values considerably less than those proposed in the literature) are established.

We have begun a project to develop models to assess potential long-term population dose commitments following shutdown of a nuclear fuel cycle facility. The long-lived radionuclides of interest include ^{238}U , ^{239}Pu , and a variety of actinides. A literature review of models currently in use for estimating long-term dose commitments by the exposure pathways of interest and a review of experimental and theoretical results of relevance to the application of these models has largely been completed. These investigations have led to the belief that the potentially most fruitful and realistic approach to assessing dose commitments over a period of thousands and millions of years is to apply specific activity and probabilistic models, which basically assume that man's exposure to the deposited activity over long periods of time can be defined in terms of man's exposure to naturally occurring radionuclides and stable elements in the earth's crust. Such models are particularly attractive in that they bypass detailed (and poorly understood) long-term considerations of the various exposure pathways.

INTEGRATED NUCLEAR ASSESSMENTS

This program has recently been established to support DOE's Division of Technology Assessment (DTA) mission relating to the development and implementation of nuclear energy technology. The DTA mission is to provide an overview of environmental, health, and safety issues and to serve as a resource to the Assistant Secretary for Environment (ASEV) for information relating to environmental, health, and safety impacts associated with energy technologies. The Environmental Development Plan (EDP) is the means whereby environmental, health, and safety concerns are identified. The EDPs are designed to insure that environmental, health, and safety research is carried out in a manner timely to the needs of the developing technology. Information on the environmental, health, and safety impacts associated with various energy technologies is provided through assessments designed to quantify the impact of technology on society. This program contributes to both aspects of the DTA mission through support of the EDP process and through a number of integrated assessments focusing on specific aspects of the nuclear fuel cycle.

The support of the EDP process has focused on the EDP addressing Advanced Isotope Separation. As part of this effort a procedure has been established to evaluate information on the environmental, health, and safety concerns associated with the development and deployment of uranium metal and uranium hexafluoride enrichment technologies. The evaluation is the first step in the establishment of a center for standards and health effects material relating to uranium metal and uranium hexafluoride separation technologies.

In support of the DTA mission to carry out assessments to quantify and evaluate the effects of technology on society, an assessment is being carried out to address the impacts associated with the operation of uranium mills. Information identified in this assessment

helped back into the EOP process and contributed to the development of an EOP on Uranium Mining, Milling, and Conversion. This step in the EOP process is very important since it is through this type of work that the key concerns associated with development and deployment of a new technology are addressed.

ASSESSMENT OF CONSUMER PRODUCTS CONTAINING RADIONUCLIDES

Methodology development for this project was essentially completed. The COMBOS computer code ¹⁰ was modified to calculate doses to nine body organs, bremsstrahlung production, doses from a variety of isotopic sources, and radiation shielding effects both within volume sources and in external absorbers. Minor modifications of the new calculational routine are anticipated prior to final documentation of the computer code during FY 1979, as scheduled.

By modeling their working conditions, a set of exposure conditions was defined for each major group of persons involved in transporting and distributing consumer products (e.g., local delivery, drivers). These sets can be combined to represent any commonly used distribution scheme. The exposure conditions and modeling technique are being reviewed prior to publication.

The COMBOS methodology was applied in assessments of several products. Table 4-2 summarizes results of four completed assessments. These include one for the Final Environmental Statement on spark-gap ignitators containing ⁶⁰Co (ref. 39) and those for recently introduced liquid-crystal-display wristwatches containing H gas and conventional timepieces with hands and dials containing either ⁹⁰Pb or ²¹⁰Pb in self-luminous paints. All timepiece assessments are in final review. Assessments for other products are in progress.

TABLE 4-2. Results of completed radiation dose assessments for consumer products containing radionuclides.

Product	Dose rate (mrem/yr)		Exposure conditions
	Internal	External	
Spark-gap ignitor	0.0001	0.0001	1000 hr/yr
Liquid-crystal display wristwatch	0.0001	0.0001	1000 hr/yr
Conventional wristwatch	0.0001	0.0001	1000 hr/yr
Self-luminous paint	0.0001	0.0001	1000 hr/yr

¹⁰ COMBOS is a computer code for calculating radiation dose rates from various sources.

¹¹ COMBOS is a computer code for calculating radiation dose rates from various sources.

¹² COMBOS is a computer code for calculating radiation dose rates from various sources.

¹³ COMBOS is a computer code for calculating radiation dose rates from various sources.

¹⁴ COMBOS is a computer code for calculating radiation dose rates from various sources.

RADIOLOGICAL IMPLICATIONS OF RECYCLED METALS FROM DECOMMISSIONED NUCLEAR FACILITIES

Almost all alternatives for decommissioning nuclear facilities will generate scrap materials containing radionuclides. Some of this scrap might consist of equipment or materials that, despite being radioactively contaminated, would be suited for sale on the

commercial salvage market. This project was initiated to estimate generically the possible radiological implications of such sales.

General common processes and procedures used to recover, recondition, and reuse scrap metals were identified. Various groups of persons were identified who would be exposed to the metals and the conditions under which they would be exposed were modeled.

Using the above scenarios, total radiation doses were calculated for the recycling of 30 Mm of ferrous or nonferrous metal scrap that was contaminated with the equivalent of 10 dCi of a radionuclide per gram of scrap metal. This was repeated for 27 radionuclides that might be found in metal recovered from a decommissioned nuclear power plant. As expected, doses to individuals within a group and in different groups varied widely. Variations in doses from the different radionuclides were as great as five orders of magnitude.

Results of this study are being documented. When available, this document will provide sets of radionuclide- and exposed-group-dependent dose factors. These factors will be useful for estimating radiation doses from recycled metals contaminated with any combination of nuclides considered.

ENVIRONMENTAL ANALYSES OF NONPROLIFERATIVE FUEL CYCLE SYSTEMS

Thorium/uranium nuclear fuel cycles are currently being studied via several U.S. programs. Commercialization of any one of the several alternative systems, and deployment of a large number of reactors, with associated mining and milling, reprocessing and waste management operations, could result in significant changes in fuel cycle overall environmental impact, when compared to the currently deployed light-water reactor (LWR) systems.

During the past year, our Assessment Applications Group has been involved in both the Nonproliferation Alternative Systems Assessments Program (NASAP), and the HTRP Fuel Recycle Development Program (HFRDP), with the purpose of assessing the radiological impact of various aspects of the thorium fuel cycles. The NASAP is directed toward the identification of internationally-acceptable fuel cycle options which pose inherently low risks of nuclear weapons proliferation, without sacrificing the major benefits of nuclear energy. The HFRDP focuses specifically on reprocessing and refabrication options for the High Temperature Gas-Cooled Reactor (HTGR) fuel cycle.

Our contribution to the NASAP began this year with the preparation of two reports, ORNL/TM-6069 (ref. 40) and PNL-2415 (ref. 41). The first of these reports identifies areas in which research is necessary to allow detailed evaluation of the environmental hazards associated with thorium fuel cycles. The report concludes that behavior of high specific activity uranium and thorium isotopes (^{233}U , ^{235}U , ^{232}Th) in man and in aquatic and terrestrial food chains is insufficiently understood. Significant uncertainties, therefore, may occur in the estimation of doses associated with thorium fuel cycle systems. The second of the above reports presents an evaluation of environmental assessment strategies developed in collaboration with scientists at Battelle Northwest Laboratories for use in the NASAP, and an identification of key environmental and health issues associated with the fuel cycle alternatives.

Our work this year under the HFRDP has resulted in the preparation of the radiological safety portions of an environmental impact statement for a proposed HTGR "hot" fuel reprocessing demonstration facility at ORNL, which will use spent fuel from the Fort St. Vrain (Colorado) power reactor. The study estimates a maximum total-body dose to an individual near the ORNL boundary of 0.14 millirem via one-year airborne releases from the facility. Total dose to the population within a 50-mile radius of the facility is estimated as 1.6 mrem (total body). Doses via liquid releases are similarly low.

In conclusion, work performed by our Assessments Applications Group this year in the area of nonproliferation fuel cycle systems indicates significant weaknesses in the data available for future, detailed environmental assessments. Analyses performed to date, however, have not revealed serious obstacles, from an environmental standpoint, to the licensability of realistic nonproliferative fuel cycle alternatives.

RADIOLOGICAL ASSESSMENT OF THE MINING AND MILLING OF WESTERN THORIUM ORES

Recent emphasis on work leading to the use of ^{233}Th in breeder reactors has emphasized the need for a thorough hazard assessment of all components of the thorium fuel cycle. During the past year, our group has been involved in a study of the potential radiological impact of mining and milling thorite ore.

Western U.S. thorium resources constitute a major fraction of total U.S. reserves. It is likely that large-scale mining of thorium will occur in such areas as the Lemhi Pass in Idaho and Montana and the Wet Mountains near Pueblo, Colorado.

Efforts by the Metals and Ceramics and Chemical Technology Divisions, ORNL, resulted in a definition of mine/mill flow charts and radionuclide source terms for hypothetical operations at both of the above sites. As the ores in these regions are high-grade (average ThO_2 -equivalent content: 0.5 %), the potential for the release of quantities of ^{232}Th , ^{228}Ra , and ^{232}Th as dusts and ^{222}Rn as a gas (followed by rapid decay to ^{214}Pb , ^{214}Bi , and ^{214}Po) is significant.

The AIPDOS-II computer code¹ was used to estimate radiological doses from one year of plant operation to both a maximally exposed individual located one mile downwind from the facilities and to the population within a 50-mile radius. Site-specific information was acquired concerning population, crop and food-producing animal distributions near the sites. Difficulties were encountered in modeling wind-suspended dust from the large thorium ore pile associated with the mill. This source (potentially significant) was therefore excluded from analysis, and an interdivisional task group was organized to assess the possibility of deriving such a model.

The calculated maximum doses resulting from a one-year operation of a thorium mine/mill complex were moderate. Total-body 50-year dose commitment to a maximally exposed individual was 0.4 millirem. Doses to bone and lungs for this individual were 9.5 and 35.3 millirem, respectively. Population doses were calculated to be low, between 0.2 and 3 man-rem (depending upon site and meteorology in question), due to the remote location of the two sites. A detailed report of the analysis will be published by ORNL in August 1978.²

ASSESSMENT OF POPULATION DOSES FROM RELEASES OF ^{222}Rn RESULTING FROM URANIUM MINING AND MILLING ACTIVITIES

Estimates of potential exposures, inhalation dose and ingestion dose to populations of the United States, Canada, and Mexico resulting from uranium mining and milling releases of ^{222}Rn in the western United States have been calculated by using a continental-scale meteorological model developed by the National Oceanic and Atmospheric Administration (NOAA).³ The model estimated concentrations of ^{222}Rn and ^{210}Pb in the northern Western Hemisphere arising from a unit release of 1 kCi/year of ^{222}Rn at four locations. These sites were: Grants, New Mexico; Falls City, Texas; Casper, Wyoming; and Wellpinit, Washington. Contour maps of NOAA model distributions of radon and lead air concentrations were plotted.

Integrated population exposures due to inhalation were obtained by combining air concentrations of ^{222}Rn and ^{210}Pb with available demographic data for the United States, Canada,

and Mexico between 20° and 60° latitude. Estimates of these exposures were presented in man-psi/m. The U.S. population received the highest exposure of 32.1 man-psi/m, followed by Mexico at 21.4 man-psi/m and Canada at 12.4 man-psi/m. A dose conversion factor of 1.1 millirem/(psi-m) was used for continuous annual exposure to ^{210}Pb and its short-lived daughters. Dose conversion factors for ^{210}Pb and ^{210}Po inhalation were also developed. By combining these factors with derived population exposures, integrated man-rem doses to appropriate organs from inhalation of ^{210}Pb and its daughters were obtained. Population lung dose to the United States, Canada, and Mexico were 321, 124, and 214 rem, respectively.

Estimating population dose from inhalation took into account the deposition of ^{210}Pb in 1979 and the subsequent resuspension of ^{210}Pb and its alpha-emitting daughter, ^{210}Po . The effect of resuspension on population dose was considered for 100 years after deposition. Initially the entire dose effect from resuspension occurs during the year of deposition and the next year following.

Lead-210 ingestion exposure was obtained by calculating the ^{210}Pb content of standard diet commodities from model-derived ^{210}Pb air concentrations and literature values of air-to-food ^{210}Pb transport. Integrated population exposure in man-psi was obtained after correction for projected population size. Conversion factors for whole-body, lung, bone, kidney, and liver dose from ^{210}Pb ingestion were developed. Integrated man-rem population doses were calculated by combining these factors with derived population exposures.

POTENTIAL RADIOLOGICAL IMPACTS OF RECOVERY OF URANIUM FROM WET PROCESS PHOSPHORIC ACID

This study was performed through an interagency agreement between the Environmental Protection Agency (EPA) and the Department of Energy (DOE) to evaluate the potential radiological impacts of uranium recovery from wet process phosphoric acid in Florida. The scope of the work included a literature search, field radiation measurements, and radiological assessments.

A previous study on milling of uranium ore is most closely related to the subject study. However, a major difference (and advantage in terms of impact) is that in the processes for recovery of uranium from phosphoric acid, the uranium is already dissolved, with no additional mining, leaching or tailings disposal required. The major problem in the uranium recovery plant is from dusting in calcination and packaging operations. These operations are very similar to the corresponding operations in uranium ore milling.

Removal of uranium from phosphoric acid also has a positive impact in the sense that deposition of uranium and its decay products on agricultural lands and on urban gardens and grasses in fertilizers is reduced.

A joint ORNL/EPA report on the study is in the final stages of preparation.

ASSESSMENT OF RADIATION EXPOSURES TO WORKERS IN A SMELTER PROPOSED FOR RECOVERY OF IRON FROM CIP CUP SCRAP

A scenario for operation of a proposed portable smelter has been developed by National Lead Company of Ohio for recycling radioactively contaminated ferrous scrap arising from the CIP CUP modifications at uranium enrichment facilities of DOE. The present study complements that proposal by developing a methodology for assessing probable radiation exposures. The principal result is a set of tables of radiation dose conversion factors for estimation of external whole-body doses and 50-year whole-body internal dose commitments. Calculations were made for 30 radionuclides using the CONDOS and AIRDOS-II computer codes.

Tables for occupational workers at the smelter include job-specific dose factors for direct exposures to design-specific identified sources (masses of contaminated materials).

and dose factors for exposure via inhalation, immersion in contaminated air, and ingestion. The table for exposures to the general public via stack emissions at distance up to 50 miles from the smelter includes dose factors for exposure via air-immersion, contaminated ground surface, inhalation, and ingestion.

Equations have been developed for straightforward applications of these dose factors to site-specific cases given prior knowledge of: (1) locations of contaminating radionuclides in the spent metal, airborne concentrations of fission products, effectiveness of smelter in separating radionuclides from product metal, amount of contaminated material ingested, amount of contaminated emission from the stack, local meteorology, demography, etc. Accuracy of predictions is limited both by uncertainties in these input factors and by assumptions behind the calculated dose factors. Assumptions, approximations, and limitations of the method have been considered as well as some nonroutine and nonradiological hazards.

DEVELOPMENT OF "AS-LOW-AS-REASONABLY-ACHIEVABLE" (ALARA) GUIDES FOR THE NUCLEAR FUEL CYCLE

Assessment of the environmental and radiological impacts of fuel cycle facilities was continued during the year. The assessments were prepared for use by Office of Standards Development in formulating "as-low-as-reasonably-achievable" (ALARA) guides in the design and siting of fuel cycle facilities. The studies on uranium milling, fabrication of enriched uranium dioxide LWR fuel, fabrication of uranium-plutonium oxide LWR fuel, LWR fuel reprocessing, fabrication of HTGR fuel containing ^{235}U and thorium, and reprocessing of HTGR fuel containing ^{235}U and thorium have been issued as ORNL/TM and ORNL/NUREG/TM reports.

During the year reports were completed on the conversion of recycled uranium hexafluoride and the conversion of yellowcake to uranium hexafluoride: part 1, the fluorination-fractionation process. Work was initiated on part 2 of this latter report, the solvent extraction-fluorination process. With the completion of this study, the entire ALARA project will have been completed.

Aside from the use of the studies by NRC to develop ALARA guidelines by correlating costs of waste treatment with environmental impact of waste effluents, the ALARA reports have been used extensively as reference sources for such information as source-term generation, dose estimates by pathways, and cost-benefit calculations in the assessment analysis of proposed and existing nuclear fuel cycle facilities and in alternate fuel cycle studies.

The methodologies used to estimate potential doses to individuals, populations, and to biota other than man were developed by TAS in the CUEV program. The revised version of the computer code AIPDOS-IF which incorporates the latest improvements in the various methodologies was used during the year in estimating dose from airborne effluents.

ENVIRONMENTAL STATEMENTS OR APPRAISALS FOR THE NUCLEAR FUEL CYCLE FACILITIES

During the year radiological assessments for a variety of fuel cycle facility licensing activities, including fuel fabrication, in situ solution mining of uranium, proposed new uranium mills, conventional mining of uranium, and aboveground uranium leaching operations were completed. This work was supported by NRC through the Energy Division of ORNL. The assessments of preoperational and operational radiological monitoring programs and individual and population dose estimates from routine and potential accidental releases of radionuclides to the environment were contributed to the NRC projects. Methodologies and computer codes developed within TAS were used in calculating radiological dose estimates.

As a result of guidelines (40 CFR 1500.13) issued by the Council on Environmental Quality, NRC has been required to reassess ongoing projects to minimize adverse environmental effects, even though the project may have been initiated prior to the enactment of the National Environmental Policy Act (NEPA). The result of such an evaluation (environmental impact appraisal [EIA]) will determine the need for a full environmental impact statement (EIS). In those cases where a permit or license-granting activity is necessary (i.e., any new application which requires NRC licensing and/or permitting activity), a full environmental review of the significant environmental aspects of that activity must be evaluated. C

In situ solution mining of uranium is an alternative to conventional mining methods currently used to extract uranium. Basically, the in situ leaching method involves the injection of leaching solution into a uranium-bearing ore body, mobilization of the uranium, and removal of the uranium-bearing solution via production wells. Uranium is then extracted from the leach solution in surface recovery facilities.

Environmental advantages of in situ mining include minimal disturbance, no mill tailings, minimal subsidence, and safer work conditions for the miner; however, the in situ leaching method presents a potentially significant impact on groundwater, particularly with respect to water quality.

The various NRC projects for which radiological assessments were completed or initiated during the year are shown in Table 4-3. With the possible exception of the Apollo plant which requires further monitoring data, none of the fuel fabrication plants will require a full environmental impact statement since the environmental impact of these existing facilities was judged minimal upon appraisal.

Table 4-3. Radiological Assessments Completed or Initiated During 1977

Facility	Assessment
Fuel Fabrication	
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
In Situ Mining	
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Waste	
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed
Advanced Fuel Elements, Inc.	EIA completed

EIA = Environmental Impact Appraisal; EIS = Environmental Impact Statement; EIS = Environmental Impact Statement; EIS = Environmental Impact Statement.

SPECIAL ASSIGNMENTS

Several requests for assistance in preparation of position documents, assessments of radiological impacts, and critical reviews of federal agency documents were accommodated this year by members of the Assessments Applications Group.

At the request of the Division of Technology Overview, DOE, an Environmental Development Plan for Space Applications was prepared. This work entailed the identification of environmental issues and requirements associated with the use of nuclear power sources in space applications and the development of an R&D strategy to ensure that environmental concerns are addressed during development of the space technology.

At the request of the Office of Environmental Policy Analysis, DOE, a generic radiological impact analysis was made for abandoned uranium mill tailings. This analysis is to be used in the formulation of provisional criteria for decontamination and decommissioning of real estate by DOE.

A site-specific radiological impact analysis of the Weldon Spring, Missouri, Chemical Plant was made for DOE-ORO to determine the necessity for decontamination of a portion of this site where residual uranium (and daughter) radionuclides exist.

Several staff members critically reviewed the EPA's proposed "Guidance on Dose Limits for Transuranic Elements in the General Environment" and "DOE Compliance with EPA Proposed Transuranic Environmental Regulation" for the Department of Energy.

RADIOLOGICAL SURVEYS OF INACTIVE URANIUM MILLS AND FORMERLY UTILIZED MED/AEC SITES

In response to a request from DOE (then ERDA), the Off-Site Pollutant Measurements Group organized a radiological field monitoring team to conduct surveys at inactive uranium mills in western states and at a number of industrial facilities, predominantly located in eastern states, used during the early days of this nation's atomic energy program. The distribution of these survey locations is shown in Fig. 4-1. At the inactive uranium mill sites, one generally finds a tailings pile and vacant mill buildings or foundations of demolished buildings. The MED/AEC properties include undeveloped land where radioactive wastes were stored, facilities where research was conducted on radioactive materials, and industrial plants where uranium and thorium were refined or made into metal sheets or bars. The objective of surveys at inactive uranium mill sites is to characterize the spread of radioactive tailings material to the surrounding environment, whereas at MED/AEC sites, the specific objective is to characterize the current radiological status of each of the properties.

Fig. 4-1. Geographical distribution of radiological survey sites.

During the early surveys, it became evident that an efficient, thorough approach for surveying large buildings and land areas was needed. Methods suggested by statistical theory were modified as necessary to allow practical survey techniques and to yield easily interpretable and readily understood survey results. Each area to be surveyed on a site is divided by a rectangular grid system, as illustrated in Fig. 4-2. Measurements taken at grid points or at preassigned intervals within the smaller blocks ("survey blocks") formed by the grid system are considered to be "unbiased" and are used to estimate average contamination levels. The number of grid points required in a particular area is decided on the basis of results of a brief preliminary survey made with alpha, beta-gamma, and gamma survey meters. The means and standard deviations of the different types of preliminary measurements in the area are inserted into a formula which yields an estimate of the number of measurements necessary to determine average conditions with no more than a 25% error at the 95% confidence level. Methods have been devised to test the sufficiency of the sample size after sampling, to measure the "local" and "global" variability of radiological conditions, and to estimate worst-case conditions using a minimum number of measurements.

Fig. 4-2. Example of the grid system used to establish measurement points in a radiological survey of a large land area.

A single radiological survey may yield several thousand individual radiation and radioactivity measurements. In addition, as many as three or four hundred surface and subsurface soil, water, and sediment samples may be collected and returned to ORNL for the analysis of radionuclide concentrations. Water samples are analyzed by the ORNL Analytical Chemistry Division. Estimates of the concentration of a wide assortment of radionuclides in soil and

sediment samples are obtained using a Ge(Li) detector and multi-channel analyzer; the gamma spectra obtained are analyzed by computer techniques. Observed gamma-ray lines are compared with those in an extensive library of radionuclides.

During the survey of the former MED/AEC sites, it was observed that in areas where residues containing pitchblende raffinates exist near the surface, elevated concentrations of ^{222}Rn daughters may occur in the air. While several methods have been developed for measuring concentrations of daughters of ^{222}Rn and ^{220}Rn in air, the possibility of significant levels of ^{222}Rn and its daughters in air had been discounted. The observation of these elevated levels of ^{222}Rn daughters has led to the development of a method for the simultaneous measurement of daughters of all three radon isotopes in air. This method involves the use of a high resolution alpha spectrometer to obtain the spectrum of alpha particles emitted from materials collected on a high efficiency membrane air filter. A computer code (RAT) was written for the analysis of these alpha spectra and the estimation of radon daughter concentrations.

All data are analyzed and a final report is prepared (after a comment period) to serve as a permanent record of the current radiological status of each facility. Data from these surveys serve as a comprehensive resource for making estimates of average radiological exposures to on-site and off-site population groups. These estimates are made by using the survey data as source terms for methodologies that assess the resulting exposure to man. The estimated radiation exposures are placed in perspective through comparisons to applicable federal and state guidelines for radiation workers and for members of the general public. In addition, comparisons are made between these site-related radiation exposures and exposures to background radiation. These site-specific dose assessments are used by DOE in discussions with members of regulatory agencies, property owners, and during meetings with local officials and members of the public. The assessments are also used by DOE as input to the preface of the reports for surveys of MED/AEC sites.

All uranium mill site surveys have been completed, and the preparation of ORNL reports presenting the survey results is underway. Surveys have been completed at most of the MED/AEC sites, and reports of survey results are being released to the public in a series of DOE reports assigned to the Assistant Secretary for Environment.

HEALTH PHYSICS RESEARCH REACTOR

The Health Physics Research Reactor (HPRR) is the principal research tool for the Dosimetry Applications Research (DOSAR) Facility. It is a small, unshielded, unmoderated fast reactor fueled with an enriched uranium-molybdenum alloy. It can be operated to yield up to 10^7 fissions in the pulse mode and can generate up to 10 kW in the steady state mode. Dose rates deliverable to a fixed geometry experiment may be adjusted over 12 orders of magnitude. The typical unshielded neutron to gamma-ray dose rate is about 7. Two new spectrum-modifying shields, one of concrete and one of steel and concrete, have been designed and constructed to allow the experimenter to select from a wider range of neutron to gamma ratios and dose rates. The neutron spectra and doses through these shields have been evaluated.

The HPRR was used primarily in the areas of nuclear engineering training for universities; radiobiological research in collaboration with the ORNL Biology Division, the Comparative Animal Research Laboratory and others; radiation dosimetry research conducted largely by the DOSAR; and nuclearly pumped laser experiments for Redstone Arsenal. The principal users of the HPRR are listed in Table 4-4 along with the percentage of total reactor use for the past two years.

The HPRR is a unique research tool, and the staff intends to use it even more fully during the future. Plans for increased utilization include involving more universities in training programs, seeking more basic dosimetry research, encouraging wider use by radiobiologists, and inviting ideas for materials irradiation research.

Table 4-4. Principal users of the Health Physics Research Reactor

User	Percentage of reactor use	
	1976	1977
Universities for training	22.5	36.6
DPAR	19.2	17.0
Biology Division (ORNL)	22.9	15.1
Redstone Arsenal	8.1	10.4
Lawrence Livermore Laboratory Physical Sciences Center	6.0	7.0
East Tennessee State Univ.	7.3	4.7
Dosimetry Intercomparison Studies	3.8	2.5
Comparative Animal Laboratory	1.6	1.1
Others	6.0	5.6
University of Alabama Birmingham Medical Center	1.2	0.0

Use is defined as operating time for the HPRR.

See the Dosimetry Intercomparison Studies section of this report for details.

DOSIMETRY INTERCOMPARISON STUDIES

Nuclear Accident Dosimetry Intercomparison

The fourteenth Nuclear Accident Dosimetry (NAD) Intercomparison Study was held July 13-22, 1977, for 35 participants representing 15 different institutions. Ten groups, including four foreign laboratories, made measurements of the mixed neutron-gamma radiation fields at the HPRR which was operated in a pulse mode to simulate nuclear excursions. The other five groups consisted of observers and those contributing to the lecture and workshop portions of the program. Preliminary results from this study giving the mean values and standard deviations of the measured kerma and doses are presented in Table 4-5.

Table 4-5. Preliminary results of the fourteenth Nuclear Accident Dosimetry Intercomparison Study

Pulse	Shield	Missiles (10%)	In-air kerma		Phantom dose	
			Neutron (rad)	Gamma (rad)	Neutron (rad)	Gamma (rad)
1	Steel/concrete	6.2	115 ± 41	43 ± 9	134 ± 37	72 ± 8
2	Unshielded	7.9	728 ± 231	118 ± 18	793 ± 176	198 ± 49
3	Concrete	5.4	118 ± 45	46 ± 6	129 ± 46	74 ± 10

Personnel Dosimetry Intercomparison

The fourth in a series^{63, 65} of personnel dosimetry intercomparison studies (PDIS) was conducted during the period March 15-23, 1978. In total, 22 groups outside of ORNL participated in PDIS IV by mailing dosimeter to ORNL for simultaneous exposure at the HPOR to dose equivalents normally encountered in routine personnel monitoring. As of this date the results of only a few participants have been received, and thus it is too early to draw any conclusions regarding this study; however, the reference dosimetry performed in-house has been completed. The results of the reference dosimetry and a summary of the exposure conditions are given in Table 4-6.

Table 4-6. Exposure conditions of the fourth Personnel Dosimetry Intercomparison Study.

Ref.	Shield	Fissions	Absorbed dose	
			Neutron (millirad)	Gamma (millirad)
	None	1.16×10^{13}	51	32
	Lucite	6.14×10^{13}	47	41
3	Concrete	7.97×10^{13}	52	27
4	Steel/concrete	8.24×10^{13}	53	24
5	None	1.16×10^{13}	46	15
6	Lucite	6.14×10^{13}	52	43
7	Concrete	7.97×10^{13}	49	33
8	Steel/concrete	8.24×10^{13}	48	33

Environmental Dosimetry Intercomparison

The third International Intercomparison of Environmental Dosimeters was held at ORNL during the period July 13-August 15, 1977. Collaborating in this series of intercomparisons⁶⁶⁻⁶⁸ are the Environmental Monitoring Laboratory of the Department of Energy, the University of Texas, School of Public Health at Houston, and ORNL. A total of 109 participants from 26 countries sent in a total of 978 dosimeters to be tested. This study had as its objective the performance evaluation of dosimeters in an artificially enhanced gamma-radiation field in which the radiation came principally from one direction. The participants provided at least six dosimeters each, two for the field exposure, two for the laboratory exposure, and two controls. The field exposures were conducted in an area that had been contaminated with ^{137}Cs while the laboratory exposures were conducted with a ^{60}Co source calibrated by the National Bureau of Standards. The radiation fields were monitored with a high-pressure argon ion chamber, and the spectral qualities were measured with a Ge(Li) detector. The results indicated that thermoluminescent dosimeters are the most reliable and that film-based dosimeters probably are unsuited to environmental monitoring. Consideration is being given now to establishing this intercomparison as a periodic service; ORNL will host this intercomparison one more time.

DOCKET FILE EVALUATION

The Nuclear Regulatory Commission was asked by the General Accounting Office (GAO) to give a surance that no residual public hazard exists at formerly licensed sites, and TAS

has agreed to assist ORNL by evaluating the records that exist in the NRC Docket File System for these sites. The docket folders contain source material and special nuclear material licenses, with supporting correspondence and other documents such as inspection reports. A methodology for docket file evaluation and an analysis form for computer input of the docket data were developed and analysis of the files is now in progress. The primary objective is to determine if existing documentation provides reasonable assurance that a given site is free from residual radioactivity which constitutes a significant public hazard and is suitable for release to unrestricted public or private use. A secondary objective is to decide which expired license files can be reduced to computer notations and the original docket folders destroyed.

As of May 1, 1978, about 25% of the docket folders had been analyzed. This is only a preliminary screening, but it suggests that the ORNL evaluation will find from the available documentation that greater than 90% of the sites in question will be suitable for unrestricted use, that 2 to 3% will not be suitable for unrestricted use unless documentation available elsewhere shows otherwise, and that approximately 5% will need some sort of site investigation.

REFERENCES

1. Part-Line.
2. Operations Division.
3. Environmental Sciences Division.
4. Leave of absence.
5. M. S. Snyder, M. R. Ford, G. G. Warner, and S. B. Watson, *A Tabulation of Bone Equivalent per Microcurie-yr for Source and Target Organs of an Adult for Various Radioisotopes*, Part 1, ORNL-5000 (1974).
6. D. E. Dunning, Jr., J. C. Pleasant, and G. G. Killough, *SEACODE: A Computer Code for Calculating Bone Equivalent to a Target Organ per Microcurie-yr Residence of a Radioisotope in a Source Organ*, ORNL/NUREG/TM-85 (November 1977).
7. P. E. Morrow, D. V. Bates, B. R. Fish, T. F. Hatch, and T. T. Mercer, *Health Phys.* 12: 173-207 (1966).
8. S. R. Bernard, "A Model for Estimation of Mean Activity Present in Segments of the Gastrointestinal Tract at Any Time Post-ingestion," in *Health Physics Division Annual Progress Report for Period Ending July 31, 1968*, ORNL-4316 (October 1968).
9. G. G. Killough, D. E. Dunning, Jr., and J. C. Pleasant, *SEACODE: A Computer Implementation of Bone Models for Estimating the Bone Equivalent to Ingested or Inhaled or Injected Radioisotopes*, ORNL/NUREG/TM-84 (June 1978).
10. G. G. Killough, D. E. Dunning, Jr., S. R. Bernard, and J. C. Pleasant, *Estimation of Internal Bone Equivalent to Ingested or Inhaled or Injected Radioisotopes: Summary of Results Relative from Nuclear Fuel-Cycle Facilities*, Vol. 1, ORNL/NUREG/TM-190 (June 1978).
11. G. G. Killough, *A Diffusion-Type Model of the Global Carbon Cycle for the Estimation of Dose to the World Population from Release of Carbon-14 to the Atmosphere*, ORNL-5269 (May 1977).
12. G. G. Killough and P. S. Romer, *Health Phys.* 34:141-159 (1978).
13. International Commission on Radiological Protection, *ICRP Publication 26, Annals of the ICRP*, 1(3) (1977).
14. M. W. Carter and A. A. Moghissi, *Health Phys.* 33:55-71 (1977).
15. G. G. Killough and V. E. Till, "Scenarios of ^{14}C Release from the World Nuclear Power Industry 1975-2020 and Estimated Radiological Impact," *Health Phys.* (in press).
16. F. Pasquill, *Atmos. Environ.* 90:1069 (1961).
17. F. A. Gifford, Jr., *Health Phys.* 2(4):47 (1961).
18. I. Van der Hoven, "Deposition of Particles and Gases," in *Atmospheric and Atomic Energy*, 1968 (D. Slade, Ed.), USAEC TID-24190 (1968), pp. 207-208.
19. R. E. Moore, *The AIRDOSE-11 Computer Code for Estimating Radiation Dose to Man from Airborne Radioisotopes Released from Nuclear Facilities*, ORNL-5245 (April 1977).

20. Subroutine QX was originally written by D. E. Dunning, Jr., and later modified by J. F. Hull and further modified by D. P. Stewart.
21. R. E. Moore, Calculation of the Deposition of Airborne Pollutant Fluxes Through Dry Deposition Processes, ORNL/TM report in review.
22. F. A. Gifford, Jr., *Environ. Sci. Tech.* 17(1):68 (1976).
23. R. E. Moore, APPAS: A Computer Code for Estimating Air Pollutant Concentrations from Dispersed Sources, ORNL/TM-6364 (May 1968).
24. C. E. Miller and R. E. Moore, "Verification of a Methodology for Computing Ground-Level Air Concentrations of SO₂ and Suspended Particulates for Both Point and Dispersed Sources," in *Proceedings of the Joint Conference on Applications of Air Pollution Meteorology*, December 23-December 25, 1977, Salt Lake City, Utah, American Meteorological Society, Boston, MA.
25. M. F. Harris, 1977, and Jerry S. Olson, *The Role of Terrestrial Ecosystems in the Global Carbon Cycle and the Effects of Climate Change on Carbon Annuity and Distribution*, National Science Foundation, DEB-7726722 (August 1977).
26. D. C. Kocher, *Nuclear Decay Data for Radionuclides Generated in Routine Releases from Nuclear Fuel Cycle Facilities*, ORNL/KUREG/TM-102 (August 1977).
27. D. C. Kocher, M. B. Embank, and H. J. Martin, "Standardized Radioactive Decay Data Sets for Use in Radiation Dosimetry," in *Proceedings of IAEA Symposium on National and International Standardization of Radiation Dosimetry*, Atlanta, Georgia, December 5-9, 1977, to be published.
28. D. K. Trubey and S. V. Kaye, *The EISEN III Computer Code for Estimating External Radiation Doses to Populations from Environmental Releases*, ORNL-TM-4322 (December 1973).
29. C. W. Miller, *The Evaluation of Models Used for the Assessment of Radionuclide Releases to the Environment*, Progress Report for the Period April 1976 through December 1977, ORNL-5382 (June 1978).
30. F. O. Hoffman, D. L. Staeffer, C. W. Miller, and C. I. Garten, Jr., *Proceedings of a Symposium on the Evaluation of Models Used for the Environmental Assessment of Radionuclide Releases*, Gatlinburg, Tennessee, September 6-9, 1977, CONF-770901 (May 1978).
31. D. C. Kocher, in *NEP Fuel Reprocessing and Beryllin Program Quarterly Report for Period July 1 to September 30, 1976*, ORNL/TM-5660 (November 1976), p. 105.
32. R. E. Cooper, *Population Dose Estimates Resulting from Radioactive Materials Discharging from a Nuclear Reprocessing Facility*, Savannah River Laboratory Report, DPST-78-217 (January 1978).
33. *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*, Appendix VI, Calculation of Reactor Accident Consequences, U. S. Nuclear Regulatory Commission Publication NASH-1400 (October 1975).
34. L. R. Anspaugh, J. H. Shinn, P. L. Phelps, and W. C. Kennedy, *Health Phys.* 29:571 (1975).
35. B. G. Bennett, "Transuranic Element Pathways to Man," in *Transuranic Pollution in the Environment*, International Atomic Energy Agency, Vienna (1976), p. 367.
36. D. C. Kocher, in *Alternative Fuel Cycle Technology with High Fuel Cycle Efficiency Program Quarterly Report for Period October 1 to December 31, 1977*, ORNL/TM-6206 (February 1978), p. 8-1.
37. F. R. O'Donnell, O. W. Burke, F. H. Clark, and L. R. McKay, *CONRAD - A Model and Computer Code to Estimate Population and Individual Radiation Doses to Man from the Distribution, Use, and Disposal of Consumer Products that Contain Radioactive Materials*, ORNL/TM-4663 (May 1975).
38. G. G. Killough and L. R. McKay, compilers, "Estimation of Individuals and Population Doses from Consumer Products that Contain Radioactive Materials," Chap. 5 in *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment*, ORNL-4992 (March 1976).
39. U. S. Nuclear Regulatory Commission, *Final Rulemaking Statement: Licensing Exemption from Licensing Requirements for Spent-Fuel Immersion in the Reactor Shielding*, NUREG-0319 (December 1977).
40. H. R. Meyer, J. E. Till, E. A. Bordietti, D. E. Dunning, C. S. Fore, C. T. Garten, S. V. Kaye, K. A. Kirkscey, C. A. Little, R. E. Moore, P. S. Rohwer, C. C. Travis and J. P. Witherspoon, *General Population Assessment System Development Program (GAPSD) - Preliminary Environmental Assessment of Chemical and Radiological Systems*, ORNL/TM-6069 (in preparation).

41. R. M. Emery, M. L. Warner, H. R. Meyer, C. A. Little and J. E. Till, *Environmental Assessment Strategies in Support of the Nonproliferation Alternative Systems Assessment Program (NASAP)*, PNL-2415 (October 1977).
42. E. S. Bomar, W. D. Bond, H. R. Meyer, L. E. Morese, V. J. Tennery, J. E. Till, and E. G. Yalcintas, *Environmental Assessment of Advanced FEP Fuels: Radiological Analysis of Thorium Mining and Milling*, ORNL/TM (in preparation).
43. J. L. Heffter, A. D. Taylor, and G. J. Terber, *A Regional-Continental Scale Transport Diffusion, and Deposition Model*, NOAA Technical Memo ER2 ARL-50, Air Resources Laboratory, Silver Spring, Maryland (1975).
44. Statistics Canada, *Population Projections for Canada and the Provinces, 1972-2001*. Information Canada, Ottawa, Ontario K1A 0T6 (June 1974).
45. U.S. Bureau of the Census, *Projections of the Population of the United States: 1977-2050*, Current Population Reports Series P-25, No. 704, U.S. Government Printing Office, Washington, D.C. 20402 (July 1977).
46. U.S. Bureau of the Census, *Mexican Population Projections: 1970-2000 (Series "B")*, Unpublished data (October 1977).
47. R. S. Morse and G. A. Welford, *Health Phys.* 21:53-55 (1971).
48. Food and Agriculture Organization of the United Nations, *Provisional Food Balance Sheets, 1972-73 Average*, Liaison Office for North America, 1776 F. Street, Northwest, Washington, D.C. 20437 (1975).
49. P. J. Magno, P. R. Groulx, and J. C. Spidianakis, *Health Phys.* 18:383-88 (1970).
50. M. B. Sears, R. E. Blanco, R. C. Dahlman, G. S. Hill, A. D. Ryon, and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As-Low-as-Practicable" Guides - Milling of Uranium Ores*, ORNL/TM-4903, Vol. 1 (May 1975).
51. F. J. Hurst, W. D. Arnold, and A. D. Ryon, "Progress and Problems of Recovering Uranium from Wet-Process Phosphoric Acid," Presented at the 26th Annual Meeting of the Fertilizer Industry Roundtable, Atlanta, Georgia, October 1976.
52. J. H. Cavendish, (ed.), *Feasibility Study of a Portable Smelter for Scrap Metals*, National Lead Co. of Ohio, Cincinnati, Ohio, NLCO-1132 (1976).
53. B. Edison, *Scenario for Smelting Contaminated Steel Scrap from CIP Portsmouth Gaseous Diffusion Plant Site, Piketon, Ohio*, National Lead Co. of Ohio, Cincinnati, Ohio (1977).
54. W. H. Pechin, R. E. Blanco, R. C. Dahlman, B. C. Finney, R. B. Lindauer, and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As-Low-as-Practicable" Guides - Fabrication of High-Water Reactor Fuel from Enriched Uranium Oxide*, ORNL/TM-4902 (May 1975).
55. W. S. Groenier, R. E. Blanco, R. C. Dahlman, B. C. Finney, A. H. Kibbey, and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle for Use in Establishing "As-Low-as-Practicable" Guides - Fabrication of High-Water Reactor Fuels Containing Plutonium*, ORNL/TM-4904 (May 1975).
56. B. C. Finney, R. E. Blanco, R. C. Dahlman, G. S. Hill, F. G. Kitts, R. E. Moore, J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Reprocessing of High-Temperature Gas-Cooled Fuel*, ORNL/NUREG/TM-5 (September 1976).
57. W. Davis, Jr., R. E. Blanco, B. C. Finney, G. S. Hill, R. E. Moore and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Reprocessing of High-Temperature Gas-Cooled Reactor Fuel Containing U-233 and Thorium*, ORNL/NUREG/TM-4 (May 1976).
58. J. W. Roddy, R. E. Blanco, B. C. Finney, G. S. Hill, R. E. Moore, and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Conversion of Reactor Uranium to UF₆*, ORNL/NUREG/TM-37 (August 1977).
59. M. B. Sears, R. E. Blanco, B. C. Finney, G. S. Hill, R. E. Moore, and J. P. Witherspoon, *Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle - Conversion of Yellowcake to Uranium Hexafluoride, Part 1. The Fluorination-Fractionation Process*, ORNL/NUREG/TM-7 (September 1977).
60. R. W. Leggett, H. W. Dickson, and F. F. Haywood, "A Statistical Methodology for Radiological Surveying," to be presented at the IAEA Symposium on Advances in Radiation Protection Monitoring, Stockholm, Sweden, June 26-30, 1978.

61. P. T. Perdue, R. W. Leggett, and F. F. Haywood, "A Technique for Evaluating Airborne Concentrations of Daughters of Radon Isotopes," presented at the *National Radiation Environment III Symposium*, Houston, Texas, April 23-28, 1978.
62. H. M. Dickson and L. W. Gilley, *Proceedings of the IAEA Symposium on National and International Standardization in Radiation Dosimetry*, Atlanta, Georgia, December 5-9, 1977.
63. H. M. Dickson, W. F. Fox, and F. F. Haywood, *1974 Intercomparison of Personnel Dosimeters*, ORNL/TM-4786 (January 1976).
64. L. W. Gilley, H. M. Dickson, and D. J. Christian, *1976 Intercomparison of Personnel Dosimeters*, ORNL/TM-5672 (December 1976).
65. L. W. Gilley and H. M. Dickson, *Third Personnel Dosimetry Intercomparison Study*, ORNL/TM-6114 (in preparation).
66. H. M. Dickson, F. F. Haywood, and K. Becker, *Tenth Dosimetry Intercomparison*, ORNL/TM-4566 (March 1975).
67. T. F. Gesell, G. de P. Burke, and K. Becker, *Health Phys.* 30:125 (1976).
68. G. de P. Burke, T. F. Gesell, and K. Becker, in *Proceedings of the Tenth Midyear Topical Symposium of the Health Physics Society*, Saratoga Springs, New York (1976) pp. 555-63.

Theses, Publications, Presentations, and Awards

Theses

W. L. Chen

An Evaluation of the Distribution of Absorbed Dose in Child Phantoms Exposed to Diagnostic Medical X Rays (Georgia Institute of Technology) (December 1977).

S. J. Cutter

Evaluation of Polymers for Fast Neutron Personnel Dosimetry by the Electrochemical Etching Technique (Purdue University) (June 1977).

S. E. Deus

The Development of a Mathematical Phantom Representing the Reference 10-Year-Old Child for Use in Dose Calculations (University of Sao Paulo) (in preparation).

P. W. Schenique

Investigación de Posibilidades en la Utilización de Partículas Carbazoles con Materiales (Universidad Autónoma de Barcelona).

J. R. Frazier

Negative Ion Resonances in the Fluorocarbons and Birefringence (University of Tennessee) (March 1978).

L. W. Grossman

Studies of Single Atoms of Lithium Using Resonance Ionization Techniques (University of Kentucky) (August 1977).

H. R. Meyer

The Uptake of Plutonium by Immobilized Materials (Colorado State University) (April 1977).

J. E. Phillips

The Conversion of Tritium Gas to Tritium Oxide (University of North Carolina) (December 1977).

R. L. Roswell

High Resolution Ultrasonic Imaging of Animal and Human Tissue In-Vivo (Rensselaer Polytechnic Institute) (May 1977).

J. J. Shonka

Fast Neutron Dose Distribution in a Heterogeneous Phantom (Georgia Institute of Technology) (in preparation).

F. J. Stagle

A Study of the Application of the As-Low-As-Reasonably-Achievable Concept to Occupational Radiation Exposures from Liquid and Solid Radioactive Waste Processing at Operating Light Water Reactors (University of Tennessee) (August 1977).

P. S. Stansbury

In Phantom Spectrometry of Medical Diagnostic X Rays (Georgia Institute of Technology) (May 1977).

Publications

- S. Ahmed and C. C. Travis
"Stability Criteria for Second Order Differential Systems," *Proceedings of the American Mathematical Society* (in press).
- M. Anderson, S. Nir, J. M. Heller, Jr., and R. H. Ritchie
"Optical Constant and Dispersion Functions of Polystyrene, Cellulose, and Fucose. Measurements in Vacuum Ultraviolet," *Journal of Chemical Physics*, **67**, 1000 (1977).
- B. R. Appleton, R. H. Ritchie, D. A. Smith, and V. E. Anderson
"Radiationless Electron Capture by SF₆ in Solution," *Chem. J. Chem.*, **55**, 2133-43 (1977).
- E. T. Arakawa, M. W. Williams, and R. H. Ritchie
"Self-Supporting Thin Films of Polystyrene," *Thin Solid Films*, **52**, 101 (1977).
- E. T. Arakawa and R. H. Williams
"Polarization Produced by Grazing Incidence Reflectors," *Proceedings of the VII International Conference on Vacuum Ultraviolet Radiation Physics*, Strasbourg, France, Sept. 6-9, 1977, Vol. III, pp. 150-2, R. C. Caslex, R. Poley and N. Poley, eds. (1977).
- E. T. Arakawa, M. W. Williams and T. Itagaki
"Optical Properties of Arc-Evaporated Carbon Films Between 0.6 and 3.8 eV," *J. Appl. Phys.*, **48**:3176-7 (1977).
- E. T. Arakawa, M. W. Williams and James A. R. Samson
"Polarization by Gratings Used at Grazing Incidence," to be published in *Appl. Opt.*
- D. Arora and J. E. Turner
"Theoretical Method for Solving a Two-Level Collision System," *Phys. Rev. A* **17**:614 (1976).
- J. C. Ashley and R. H. Ritchie
"The Influence of Damping on the Mean Free Path of Low Energy Electrons in an Electron Gas," *Phys. Status Solidi B* **83**(2):K159-K163 (1977).
"The Energy Losses of Channeled Ions--the Bohr Theory Revisited," *Proceedings of the VII International Conference on Atomic Collisions in Solids*, Moscow State University Publishing House, Moscow, U.S.S.R. (in press).
- J. C. Ashley, C. J. Tung, R. H. Ritchie and V. E. Anderson
"Inverse Mean Free Path, Stopping Power, CSDA Range, and Straggling in Polystyrene for Electrons of Energy ≤ 10 keV," Rome Air Development Center Technical Report, RADC-TR-32 (1978) 37 pp.
- J. K. Baird
"Kinetics of Electron Capture by SF₆ in Solution," *Can. J. Chem.*, **55**:2133-43 (1977).
Letter to the Editor, *Nucl. Sci. Technol.* **52**(3):2 (1978).
- J. K. Baird, V. E. Anderson and S. A. Rice
"Comment on Probability of Escaping Neutralization When the Mobility is Field Dependent," *J. Chem. Phys.*, **67**:3842 (1977).

J. K. Baird and S. A. Rice

"Uniform Theory of the Kinetics of Electrons in Nonpolar Liquids," *Brit. J. Appl. Phys. Ser. 2*, 22:1332 (1977).

P. R. Bell and R. S. Dillon

ORNL-The Oak Ridge Imaging System Operations Manual, ORNL/TM-5875/V2 (December 1977) 179 pp.

"Comparison of Some Nonlinear Smoothing Methods," *Proceedings of the 5th International Conference of Information Processing in Medical Imaging Conference*, ORNL-BCTIC-2, p. 596 (January 1978).

P. R. Bell and J. M. Dougherty

ORNL-The Oak Ridge Imaging System Operations Manual, ORNL/TM-5875/V3 (April 1978) 413 pp.

"Statistical Process Control Methods," *IEEE Trans. Nucl. Sci.* (in press).

P. R. Bell and J. M. Dougherty

ORNL-The Oak Ridge Imaging System Operations Manual, ORNL/TM-5875/V4 (April 1978) 413 pp.

"Statistical Process Control Methods," *IEEE Trans. Nucl. Sci.* (in press).

P. D. Birkhoff, J. C. Ashley, H. H. Hubbell, Jr., and L. C. Emerson

"Light Scattering from Micron Size Fibers," *J. Opt. Soc. Am.* 67(4):564-69 (1977).

P. D. Birkhoff, H. H. Hubbell Jr., D. B. Smathers and H. L. Barnawell

"Electron Gun Filament Supply," *J. Elec. Spec. Rel. Phen.* 11:231-33 (1977).

P. D. Birkhoff, L. R. Painter and J. M. Heller, Jr.

"Measurement of Reflectance by Gas Ionization," *Appl. Opt.* 16(9): 576-79 (1977).

B. Birks, C. E. Easterly and L. G. Christophorou

"Stokes and Anti-Stokes Fluorescence of 1,12-Benzoperylene in Solution," *J. Phys. Chem.* 81:4231-36 (1977).

E. Blanco, R. C. Dahlman, W. Davis, Jr., B. C. Finney, W. S. Groenier, G. S. Hill, A. H. Kibbey, F. G. Kitts, R. B. Lindauer, R. E. Moore, W. H. Pechin, J. W. Roddy, A. D. Ryan, R. D. Seagren, M. B. Sears and J. P. Witherspoon

"A Cost/Benefit Analysis of Methods for Controlling the Release of Radioactive Materials in the Nuclear Fuel Cycle," *Proceedings of the International Conference on Nuclear Power and Its Fuel Cycle, Salzburg, Austria, May 2-13, 1977*, IAEA-CN-36/429.

B. G. Blaylock and J. P. Witherspoon

"Evaluation of Radioisotopes Released from the Light-Water Reactor Nuclear Fuel Cycle to the Aquatic Environment," *Proceedings of the Mineral Cycling Symposium, SRP, Nov. 28-May 1, 1977*, ERDA-CONF-760429.

F. D. Boercker, R. M. Davis, F. G. Goff, J. S. Olson and D. C. Parzyck

Energy and Coal: A Southern Perspective, ORNL/TM-5900 (August 1977).

M. E. Boling and M. L. Randolph

"Effects of X Irradiation on a Temperate Bacteriophage of *Haemophilus influenzae*," *J. Virol.* 22:47-53 (1978).

W. Brandt and R. H. Ritchie

"Velocity Spectra of Convoy Electrons Emerging with Swift Ions from Solids," *Phys. Lett. A* 62:374 (1977).

R. S. Caswell, J. J. Coyne and M. L. Randolph

"Kerma Factors for Issue Compositions, Compounds and Mixtures," *Proceedings of Workshop on Physical Data for Neutron Dosimetry* (in press).

1. A. Callcott and E. T. Arakawa
"The Low Soft X-Ray Emission and Absorption Spectra of Li^+ ," to be submitted to *J. Phys. Chem.*
"Temperature Dependence of Li^+ X-Ray Emission from Lithium," *J. Phys. Chem.*, 89:147 (1977).
2. A. Callcott, E. T. Arakawa and D. L. Ederer
"The Emission and Absorption X-Ray Edges of Li^+ ," in *Excited States of Atoms and Molecules*, Vol. 1, M. G. Foster, M. Pouey and R. Pouey, eds. (1977).
"Emission and Absorption X-Ray Edges of Lithium," *J. Phys. Chem.*, 86:1885 (1977).
3. H. Chen, J. P. Judish and M. G. Payne
"Kinetic Studies of Ne-N_2 by Proton Excitation," *J. Chem. Phys.*, 67:1713-17 (1977).
"Charge Transfer and Penning Ionization of N_2 , CO , CO_2 , and H_2S in Proton-Excited Helium Mixtures," *J. Chem. Phys.*, 67: 3376-81 (1977).
"Energy Transfer Processes in Proton-Excited Ar-Xe and Ar-F_2 Mixtures," *J. Phys. Chem.* (in press).
4. H. Chen and M. G. Payne
"Ar F^* Radiative Lifetime Measurement," *J. Chem. Phys.*, 85:356-60 (1978).
5. H. Chen, M. G. Payne and J. P. Judish
"Kinetic Studies of ArF^* and ArF_2^* in Proton-Excited Ar-F_2 Mixtures," *J. Chem. Phys.* (in press).
6. L. Chen, J. W. Poston and G. G. Warner
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
7. W. Chester and R. G. Chester
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
8. R. G. Chester
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
9. G. Christophorou
"Elementary Electron-Molecule Interactions and Negative Ion Resonances at Subexcitation Energies and Their Significance in Gaseous Dielectrics," in *Excited States of Atoms and Molecules*, Vol. 1, M. G. Foster, M. Pouey and R. Pouey, eds. (1977), Vol. III, pp. 51-72.
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
10. G. Christophorou, F. S. Gant and V. L. Anderson
"Long-Lived Parent Negative Ions Formed via Nuclear-Excited Feshbach Resonances. Part 5. Effective Number of Degrees of Freedom Participating in the Sharing of the Ion's Excess Energy," *J. Chem. Phys.*, 73:1004-11 (1977).
11. G. Christophorou, M. W. Grant and G. L. McCorkle
"Interactions of Slow Electrons with Benzene and Benzene Derivatives," (book chapter) *J. Chem. Phys.*, 86:413-526 (1977).
12. G. Christophorou, G. P. Jones, R. G. Rai, R. A. Mathias, M. G. Pace, G. W. Bouldin, A. A. Christodoulides and G. G. Chan
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).
"Excitation of H_2 by H^+ and He^+ in the Laboratory," *J. Chem. Phys.*, 86:1000-1003 (1977).

L. G. Christophorou, D. P. James, P. F. Pai, P. A. Matulis, M. G. Pace, D. W. Bouldin, A. A. Christodoulides and C. C. Chan

"Ionization Cross-Section Measurements of Gaseous C_2F_4 , C_2F_6 , and C_2F_8 by the Photoelectron-Photoion Coincidence Method," *J. Chem. Phys.*, 86: 5084-5091, 1987. OPL/TM-6384 (June 1978).

L. G. Christophorou, D. P. James, P. F. Pai, M. G. Pace, P. A. Matulis and D. W. Bouldin

"Ionization Cross-Section Measurements of Gaseous C_2F_4 , C_2F_6 , and C_2F_8 by the Photoelectron-Photoion Coincidence Method," *J. Chem. Phys.*, 86: 5084-5091, 1987. OPL/TM-6384 (June 1978).

L. G. Christophorou and D. L. McCorkle

"Experimental Evidence for the Existence of a Ramsauer-Townsend Minimum in Liquid CH_4 and Ar (Kr and Xe) and Gaseous C_2H_6 and C_2H_4 ," *J. Chem. Phys.*, 85:1876-84 (1977).

R. N. Compton

"On the Formation of Positive and Negative Ions in Gaseous UF_6 ," *J. Chem. Phys.*, 67(10): 4478-85 (1977).

R. N. Compton and C. D. Cooper

"Negative Ion Properties of Tetracyanoquinodimethane: Electron Affinity and Compound States," *J. Chem. Phys.*, 66(10):4325-29 (1977).

R. N. Compton, P. W. Reinhardt and C. D. Cooper

"Collisional Ionization between Alkali Atoms and Some Methane Derivatives: Electron Affinities for CH_3NO , CF_3I , and CF_3Br ," *J. Chem. Phys.* (in press).

R. N. Compton, P. W. Reinhardt and W. P. Garrett

"Uranium hexafluoride Negative Ions from Surface Reactions Involving Uranium and Fluorine," *J. Chem. Phys.*, 66(10):4712-13 (1977).

R. N. Compton and R. C. Schweinler

"Formation of Gas-Phase Negative Ions in Vinylene Carbonate," *J. Chem. Phys.* (in press).

P. W. Coulter and W. P. Garrett

"Electron-Hydrogen Scattering by Complex Optical Potential Methods," *J. Chem. Phys.* (in press).

J. J. Cowan and B. Aničin

"Longitudinal and Transverse Displacements of a Bounded Microwave Beam at Total Internal Reflection," *J. Opt. Soc. Am.*, 67:1307 (1977).

J. J. Cowan and E. T. Arakawa

"Blazed Holographic Gratings Formed with Optical Guided Waves," *Optical Gratings and Related Optoelectronic Devices*, Vol. III, pp. 20-22, M. C. Castex, M. Pouey and N. Pouey, eds. (1977).

D. J. Crawford, R. W. Leggett, F. F. Haywood, R. W. Doane, W. F. Fox, W. H. Shipbaugh and D. R. Stone

"Fast Ionization of C_2F_4 by C_2F_6 and C_2F_8 ," *J. Chem. Phys.*, to be published as a DOE report.

O. H. Crawford and W. P. Garrett

"Electron Affinities of Polar Molecules," *J. Chem. Phys.*, 66(11):4968-70 (1977).

O. H. Crawford, H. F. Krause, R. H. Ritchie, S. Datz, C. D. Moak, P. F. Dittner, J. Gomez del Campo, J. A. Biggerstaff, P. D. Miller, P. Hvelplund and H. Knudsen

"Orbital Energies of Electrons on Channeled Ions in Resonant Coherent Excitation Processes," to be submitted to *J. Chem. Phys.*

James A. Crumb and James K. Baird

"Reactivity/Rate Constant Ratio for Scavengers of Charged Particles in Nonpolar Liquids," submitted to *J. Chem. Phys.*

- R. M. Davis, D. C. Parzyck, D. J. Bjornstad, R. B. Honea, A. S. Loeb and E. Peele
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/TM-5638 (1977).
- A. Davis, Jr., F. F. Haywood, J. L. Danek, R. E. Moore, L. R. Wagner, E. M. Rupp and P. J. Walsh
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/EPA-2 (in press).
- D. E. Dunning, Jr., D. C. Pleasant and G. G. Killough
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/NUREG/TM-85 (1977) 300 pp.
- H. W. Dickson
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/OEPA-4 (in preparation).
- H. W. Dickson and L. W. Gilley
"Personnel Dosimetry Intercomparison Studies at the ORNL Health Physics Research Reactor," to be published in the Proceedings of the 1977 Conference on Health Physics, San Francisco, California, December 1977.
- H. W. Dickson, L. W. Gilley, L. B. Holland and D. R. Ward
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/TM-4637 (in preparation).
- H. W. Dickson, G. S. Hill and P. T. Ferdue
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/TM-6272 (in preparation).
- H. W. Dickson, R. W. Leggett, F. F. Haywood, W. A. Goldsmith, W. D. Cottrell and W. E. Fox
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," DOE/EV-0005/1 (November 1977).
- H. W. Dickson, M. J. Ryan, P. W. Doane, W. R. Shipbaugh and W. M. Johnson
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," to be published as a DOE report.
- C. E. Easterly and R. E. Shank
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," ORNL/TM-5496 (November 1977).
- C. E. Easterly, R. E. Shank and R. L. Shoup
"Radiological Aspects of Fusion Power," *IEEE Trans. Nucl. Energy*, 26(2):1243-15 (1977).
- P. M. Echenique, W. Brandt and P. H. Ritchie
"The Wake Induced in Condensed Matter by Swift Ions," to be submitted to *Phys. Rev. Lett.*
- L. C. Emerson, S. -I. Jeon, M. W. Williams and E. T. Arakawa
"Optical and Dielectric Properties of Adenine Below 30 eV," to be published in *Phys. Rev. Lett.*
- R. M. Feery, M. L. Warner, H. P. Meyer, C. A. Little and J. E. Till
"The Effect of Temperature on the Rate of Ionization of Gaseous Argon," PNL-2416 (1977).
- M. E. Fair and J. E. Turner
"Faculty Institute in Applied Health Physics--A Program to Help Meet Future Requirements for Health Physics Technologists," *Health Phys.*, 34:273 (1978).
- T. L. Ferrell and P. H. Ritchie
"Energy Losses by Slow Ions and Atoms to Electronic Excitation in Solids," *Phys. Rev. Lett.*, 38:1115 (1977).

M. R. Ford, W. S. Snyder, L. T. Dillman and S. E. Watson

"Maximum Permissible Concentration (MPC) Values for Spontaneously Fissioning Radionuclides," *Health Phys.* 33:35-43 (1977).

M. R. Ford, W. S. Snyder and S. E. Watson

"(MPC)₂ Values for Isotopes of Plutonium," submitted for publication in *Health Phys.*

J. R. Frazier, L. G. Christophorou, J. G. Carter and H. C. Schweinler

"Low-Energy Electron Interactions with Organic Molecules: Negative Ion States of Fluorobenzenes," submitted for publication in *J. Chem. Phys.*

R. B. Gammage

"Current Situation for Exoelectron Dosimeters of BeO Ceramic in Neutron Dosimetry,"

Proceedings of the 1977 Workshop on Neutron Dosimetry, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 11-17, 1977.

"Recent Developments in Experimental Solid State Integrating Devices for Fast Neutron Personnel Dosimetry," published in *Health Phys.* as the proceedings of Workshop on Neutron Personnel Dosimetry, Health Physics Society Meeting, Atlanta, Ga., July 14-18, 1977.

Ed., *Proceedings of the Second OECD Workshop on Advances in Personnel Dosimetry: Neutron Dosimetry in the 1970s*, ORNL/CONF-770361 (December 1977).

R. B. Gammage and J. S. Cheka

"Reference Bank of Exoelectron Dosimeters," *Proceedings of the Symposium on Neutron and Gamma-Ray Dosimetry for Radiation Dosimetry*, Atlanta, Ga., July 14-18, 1977.

R. B. Gammage, J. S. Cheka and T. F. Gesell

"A Passive Environmental Radon-222 Monitor Based on the Exoelectron Dosimeter," submitted for publication in *Health Phys.* (in press).

R. B. Gammage and D. J. Christian

"Meeting Regulatory Standards with BeO Ceramic TLD," *Proceedings of the 1977 Workshop on Neutron Dosimetry*, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 11-17, 1977.

R. B. Gammage and S. J. Cotter

"Evaluation of Different Polymers for Fast Neutron Personnel Dosimetry Using Electrochemical Etching," *Proceedings of the 1977 Workshop on Neutron Dosimetry*, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 11-17, 1977.

R. B. Gammage, J. W. Thorngate, H. W. Parkinson, A. R. Hawthorne and T. Vo-Dinh

"Improved Personnel Dosimetry for Protection Against Synfuel Pollutants," Poster session paper at IAHA Meeting in New Orleans, May 26, 1977.

"On the Desirability of the Health Physics Society Assuming Responsibilities in the Non-nuclear and Nonradiation Fields," *Health Phys.* (in press).

R. B. Gammage, T. Vo-Dinh, A. R. Hawthorne, J. H. Thorngate and W. W. Parkinson

"A New Generation of Monitors for PIA Compounds from Synthetic Fuel Production," *Proceedings of the 1977 Workshop on Neutron Dosimetry*, R. Freudenthal and W. W. Parkinson, eds., Raven Press (in press).

"New Techniques for Measuring PIA in the Workplace," invited review article accepted for publication in *Health Phys.* (in press).

W. R. Garrett

"Rotational Resonances in Low-energy Electron Scattering by H₂ and D₂," *J. Chem. Phys.* 66(6): 2305-14 (1977).

"Electron Affinities of Strongly Polar Molecules," *J. Chem. Phys.* 81:23:141 (1978).

W. R. Garrett and M. G. Payne

"Applications of Model for Cell Survival: The Fixation Time Picture," *Health Phys.* 33: 201-11 (1978).

L. W. Gilley and H. W. Dickson

"Fast Neutron Dosimetry with BeO Ceramic TLDs," ORNL/TM-6114 (in preparation).

F. M. Glass and R. D. Birkhoff

"A Simple Electrometer-Ratiometer of High Sensitivity and Precision," to be published in *IEEE Trans.*

R. V. Griffith, D. E. Hankins, R. S. Gammage, E. Tomasino and R. W. Wheeler

"Recent Development in Personnel Neutron Dosimeters: A Review," to be published in *IEEE Trans.*

L. W. Grossman and G. S. Hurst

"Development of a Simple and Accurate Method for the Study of Reactive Atoms," ORNL/TM-6014 (September 1977).

L. W. Grossman, G. S. Hurst and M. G. Payne

"A Sensitive, Absolute and Time-Resolved Method for the Study of Reactive Atoms," *Chem. Phys. Lett.* 50(2):207-9 (1977).

L. W. Grossman, G. S. Hurst, M. G. Payne and S. L. Allmon

"Saturated Photodissociation of CsI," *Chem. Phys. Lett.* 50(1):70-73 (1977).

R. N. Hamm, H. A. Wright, R. Katz, J. E. Turner and R. H. Ritchie

"Calculated Yields and Slowing Down Spectra for Electrons in Liquid Water--Implications for Electron and Photon RBE," to be published in *IEEE Trans.*

R. N. Hamm, H. A. Wright, J. E. Turner and R. H. Ritchie

"Spatial Correlation of Energy Deposition in Irradiated Liquid Water," *IEEE Trans. Nucl. Sci.* 24:1171-1175 (1977).

A. P. Hawthorne and R. P. Gardner

"A Proposed Model for Particle-Size Effects in the X-Ray Fluorescence Analysis of Heterogeneous Powders that Includes Incidence Angle and Nonrandom-Packing Effects," submitted for publication in *IEEE Trans.*

A. P. Hawthorne and J. H. Thorngate

"Preliminary Results from Second-Derivative Absorption Spectrometry Applied to Monitoring of PNA," *IEEE Trans. Nucl. Sci.* 24:1171-1175 (1977), CONF-770361, 1977, p. 95.

"Improving Analysis from Second-Derivative UV-Absorption Spectrometry," *IEEE Trans.* 17:724 (1972).

A. P. Hawthorne, J. H. Thorngate, R. B. Gammage and T. Vo-Dinh

"Developments of a Prototype Instrument for Field Monitoring of PNA Vapors," to be published in the *IEEE Trans. Nucl. Sci.*

"Trace Organic Analysis Using Second-Derivative Spectroscopy," to be published in *IEEE Trans. Nucl. Sci.*

A. P. Hawthorne, T. Vo-Dinh, J. H. Thorngate and R. B. Gammage

"Spectroscopic Methods for Monitoring Occupational Exposure to Synfuel Pollutants," Poster session paper at IAEA meeting in New Orleans, May 26, 1977.

R. L. Hayes, L. C. Washburn, B. W. Wieland, T. T. Sun, T. A. Butler and A. P. Callahan

"Rapid Synthesis and Purification of Amino Acids Labeled with Carbon-11," *Int. J. Radiat. Biol.* (in press).

F. E. Haywood, J. E. Burden and B. W. Dickson

"Development of a Simple and Accurate Method for the Study of Reactive Atoms," to be published as a DOE report.

F. E. Haywood, W. A. Goldsmith, P. T. Perdue, W. E. Fox and W. H. Shipbaugh

"Development of a Simple and Accurate Method for the Study of Reactive Atoms," ORNL/TM-5251 (November 1977).

F. F. Haywood, D. R. Stone, R. W. Leggett, D. J. Crawford, M. H. Shinpaugh, R. W. Doane and W. F. Fox

Biological Effects of the Fluorine-19 Radioisotope: Chemical Composition Transfer Property, ORNL-5284, ORNL, Knoxville, to be published as a DOE report.

Ray Hefferlin

"Further Progress in Systematics of Free Diatomic-Molecule Electronic-Transition Intensity Constants," *J. Quant. Spectrosc. Radiat. Transfer* 19:335-38 (1978).

"Wavelength-Dependent and Electronic System Oscillator Strengths for Free Diatomic Molecules of Astrophysical Importance," *Transition Intensity Transitions*, D. K. Hsu, ed., Chemical Rubber Co. Press, Inc. (in press).

Ray Hefferlin and R. Campbell

"A Diatomic Molecular Periodic Table for Interpolating Data and Orbitals," *Chem. Phys. Lett.* (in press).

J. M. Heller, Jr., R. D. Birkhoff and L. R. Painter

"Isotopic Effects in the Optical and Dielectric Functions of H₂O and D₂O in the Vacuum UV," *J. Chem. Phys.* 67(5):1858-60 (1977).

G. S. Hill and A. Brodsky

"Biological Data Used in Dose Calculations," to be published in *Handbook of Radiation Measurements and Protection*, A. Brodsky, ed., Chemical Rubber Co. Press, Inc.

F. O. Hoffman

"A Reassessment of the Deposition Velocity in the Prediction of the Environmental Transport of Radioiodine from Air to Milk," *Health Phys.* 32:437-41 (1977).

"A Review of Measured Values of the Milk Transfer Coefficient (f_m) for Iodine," *Health Phys.* (in press).

F. O. Hoffman, W. Feldt, K. Brüssermann, D. Gumprecht, K. Hübel and R. Wolter

"A Generic Calculation Procedure for the Assessment of Radiation Exposures from Radioactive Discharges into Surface Waters" (Allgemeine Berechnungsgrundlagen für die Bestimmung der Strahlenexposition durch Radioaktive Einleitungen in Oberflächengewässer), 1. Fließgewässer, *Environmental Protection of the Pollution Prevention Commission*, Federal Ministry of the Interior, Federal Republic of Germany (1977).

F. O. Hoffman, C. W. Miller, D. L. Shaeffer and C. T. Garten, Jr.

"Computer Codes for the Assessment of Radionuclides Released to the Environment," *Health Phys.* 18(3):343-54 (1977).

F. O. Hoffman, D. L. Shaeffer, C. W. Miller and C. T. Garten, Jr.

"Evaluation of Models for Assessing Compliance with Environmental Radiation Regulations," *Proceedings of the American Nuclear Society, 11th Winter Meeting, San Francisco, Calif., December 6, 1977*, pp. 120-121.

Compilers, *Proceedings of a Workshop on the Evaluation of Models Used for the Environmental Assessment of Radionuclide Releases*, Oak Ridge, Tenn., Sept. 6-8, 1977, CONF-770901 (May 1978).

F. O. Hoffman, C. W. Miller, D. L. Shaeffer, C. T. Garten, Jr., R. W. Shor and J. T. Enslinger

A Simplified, Unifurcated Computer Code Applicable to Environmental Assessment of Radionuclide Releases, ORNL/TM-5830 (April 1977).

C. F. Holoway and J. E. Turner

Health Effects in the Atmosphere: Meteorology, Pathology, Epidemiology, and Environmental Assessment of Radon, Its Daughters and Progenies, ORNL-5338 (June 1978).

C. F. Holoway, J. E. Turner, M. L. Johnson and A. S. Loebl

Biological Effects in the Atmosphere of Radon and Its Daughters, ORNL-5284 (February 1978).

- B. L. Houser, C. F. Holoway and D. G. Madewell
 "The Use of Rare Earth Radionuclides and Other Bone-Seekers in the Evaluation of Bone Lesions in Patients with Multiple Myeloma or Solitary Plasmacytoma," *Radioisotopes*, ORNL-5226 (October 1977).
- H. H. Hubbell, Jr., J. D. Allen, Jr., and R. D. Birkhoff
 "Rutherford Revisited--Deflection of an Electron in Inverse First, Second, and Third Power Central Fields," *Am. J. Phys.* 45(9):826-32 (1977).
- K. F. Hübner, G. A. Andrews, R. L. Hayes, J. K. Poggenburg and A. Solomon
 "The Use of Rare Earth Radionuclides and Other Bone-Seekers in the Evaluation of Bone Lesions in Patients with Multiple Myeloma or Solitary Plasmacytoma," *Radioisotopes* 125:171-6 (1977).
- K. F. Hübner, G. A. Andrews, L. Washburn, B. W. Wieland, W. D. Gibbs, R. L. Hayes, T. A. Butler and J. D. Winebrener
 "Tumor Localization with 1-Aminocyclopentanre [^{11}C] Carboxylic Acid: Preliminary Clinical Trials with Single Photon Detection," *J. Nucl. Med.* 18:1215-21 (1977).
- G. S. Hurst
 Book review of "Neutron Dosimetry for Biology and Medicine, ICRU Report No. 26," *Health Phys.* 34:283 (1977).
 "Definition of One-Atom Detection," *Isotopes* (in press).
- G. S. Hurst, S. L. Allman, M. G. Payne, K. A. Marshall and K. L. Sookoo
 "Resonant Ionization Studies of the Fluctuation of Proportional Counters," *Isotopes* (in press).
- G. S. Hurst, M. H. Nayfeh and J. P. Young
 "One-Atom Detection using Resonance Ionization Spectroscopy," *Phys. Rev. A* 15:2283-92 (1977).
- G. S. Hurst, M. H. Nayfeh, J. P. Young, M. G. Payne and L. W. Grossman
 "Selective Single Atom Detection in a 10^{10} Atom Background," *Adv. in Atomic and Molecular Physics*, J. L. Hall and J. L. Carlsten, eds., Springer-Verlag, New York and Heidelberg, 1977, pp. 44-53.
- H. Inokuti, Y. Itikawa and J. E. Turner
 "Addenda: Inelastic Collisions of Fast Charged Particles with Atoms and Molecules--The Bethe Theory Revisited," *Phys. Rev. A* 50(1):23 (1978).
- D. R. Jackson and A. P. Watson
 "Disruption of Nutrient Pools and Transport of Heavy Metals in a Forested Watershed near a Lead Smelter," *J. Environ. Qual.* 6(4):331-8 (1977).
- D. R. James, L. G. Christophorou, R. Y. Pai, M. O. Pace, R. A. Mathis and D. W. Boulton
 "Breakdown Voltages of Some New Unitary and Multicomponent Gas Mixtures," *J. Chem. Phys.* 67:2196-2215 (1977).
- D. R. James, L. G. Christophorou, R. Y. Pai, M. O. Pace, R. A. Mathis, I. Sauer and C. C. Chan
 "Dielectric Strengths of New Gases and Gas Mixtures," *J. Chem. Phys.* 67:2196-2215 (1977).
- J. P. Johnson, L. G. Christophorou and J. C. Carter
 "Fragmentation of Aliphatic Chlorocarbons under Low-Energy (10 eV) Electron Impact," *J. Chem. Phys.* 67:2196-2215 (1977).
- T. D. Jones
 "CHORD Operators for Cell-Survival Models and Insult Assessment to Active Bone Marrow," *Health Phys.* 71:269-83 (1977).
 "Radiation Protection Based on Risk: No RBE," submitted for publication in *Health Phys.*
 "A Once and Future Kind of Risk Assessment," submitted for publication in *Health Phys.*

T. D. Jones, D. G. Jacobs, J. A. Auxier and G. D. Kerr

"Risk of Environmental Cancer Based on Cytotoxicity," submitted for publication in *Radiat. Environ.*

T. D. Jones and J. M. Poston

"Isotropic and Cloud Source Irradiation by Monoenergetic Neutrons and Photons," *Health Phys.* 34:83-95 (1978).

J. P. Judish

"Measurements of the Low Temperature of Surface Resistance of Lead at Frequencies from 136 MHz to 472 MHz," *Phys. Rev. B* 15:4412-24 (1977).

M. S. Keener and C. C. Travis

"Focal Points and Positive Cones for a Class of n^{th} Order Differential Equations," *Trans. Am. Math. Soc.* 237:331-51 (1978).

R. H. Kennedy, L. J. Deal, F. F. Haywood and W. A. Goldsmith

"Management and Control of Radioactive Wastes from Uranium-Milling Operations," to be published in the *Proceedings of the IAEA International Conference on Nuclear Power and Its Fuel Cycle*, Salzburg, Austria, May 1-8, 1977.

G. D. Kerr

"Wartime Nuclear Projects in Japan," *Science* (in press).

G. D. Kerr, T. D. Jones and J. M. L. Hwang

"Neutron Fluence-to-Dose Conversion Factors for Am-B and Am-Be Sources," *Health Phys.* (in press)

G. D. Kerr, T. D. Jones, J. M. L. Hwang, F. L. Miller and J. A. Auxier

"An Analysis of Leukemia Data from Studies of Atomic-Bomb Survivors Based on Estimates of Absorbed Dose to Active Bone Marrow," *Proceedings of the Fourth International Congress of the International Radiation Protection Association*, Paris, France, Apr. 24-28, 1977, Vol. 3, pp. 714-18.

G. D. Kerr, M. T. Ryan and P. T. Perdue

"Measurement of Airborne Concentrations of Thoron Daughter Products by Alpha Particle Spectrometry," *Proceedings of the Eleventh Biennial Technical Symposium of the Health Physics Society*, San Diego, 1977, Nov. 17-18, 1978.

A. H. Kibbey, H. W. Godbee and G. S. Hill

"Estimated Radiological Doses from the Gaseous Effluents of a Model High-Level Waste Solidification Facility," *Proceedings of the American Nuclear Society National Meeting on "The Role of the Low Level Waste,"* Chicago, Ill., Mar. 12-16, 1977, CONF-780304.

G. G. Killough

"Evaluation of the Total Thoron Dose for the Estimation of Lead in the World Population from a Survey of Thoron-220 in the Atmosphere," ORNL-5262 (May 1977).

G. G. Killough, D. E. Dunning, Jr., S. R. Bernard and J. C. Pleasant

"Formulation of Internal Dose Calculations to SS Target Organs for Radionuclides Administered by Inhalation," *Health Phys. Environ. Radiat. Biol. Symp.*, Vol. 1, ORNL/NUREG/TM-190 (June 1978).

G. G. Killough, D. E. Dunning, Jr., and J. C. Pleasant

"Model for a Computer Implementation of a Simple Model for the Internal Dose to Organs of Man from an Inhalation of Radionuclides," ORNL/NUREG/TM-84 (June 1978).

G. G. Killough and P. S. Rohwer

"A New Look at the Dosimetry of ^{14}C Released to the Atmosphere as Carbon Dioxide," *Health Phys.* 34:141-59 (1978).

G. G. Killough and J. E. Till

"Scenarios of ^{14}C Release from the World Nuclear Power Industry 1975-2020 and Estimated Radiological Impact," *Environ. Sci.* (in press).

C. E. Klotz

"Studies of Rydberg State Reactions," *J. Chem. Phys.* 66(11):5240-41 (1977).

C. E. Klotz and R. N. Compton

"Electron Attachment to Polymers of Nitrous Oxide and Carbon Dioxide," *Bull. Am. Phys. Soc.* 23:140 (1978).

"Electron Attachment to Carbon Dioxide Clusters in Supersonic Beam," *J. Chem. Phys.* 67(4):1779-80 (1977).

C. E. Klotz, Donald Mintz and Tomas Baer

"Role of Angular Momentum in Unimolecular Kinetics: Kinetic Energy Release in Fragmentation of C_2H_6^+ ," *J. Chem. Phys.* 66(11):5100-4 (1977).

D. C. Kocher

Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities, ORNL/NUREG/TM-102 (August 1977).

D. C. Kocher, W. B. Ewbank and M. T. Martin

"Standardized Radioactive Decay Data Sets for Use in Radiation Dosimetry," to be published in the *Proceedings of the 1978 Symposium on National and International Standardization of Radiation Dosimetry*, Atlanta, Ga., Dec. 6-8, 1977.

S. D. Kramer, C. E. Bemis, Jr., J. P. Young and G. S. Hurst

"One-Atom Detection in Individual Ionization Tracks," *Phys. Lett.* (in press).

E. Kretschmann

"The ATR Method with Focused Light—Application to Guided Waves on a Grating," *Opt. Commun.* (in press).

D. K. Larsen and R. G. Chester

Initiation, Emergency Response in Illinois, Alabama and Texas, ORNL-5242 (March 1978).

R. W. Leggett, C. J. Barton, W. D. Cottrell, M. T. Ryan, F. F. Haywood, P. T. Ferdue, H. W. Dickson, J. L. Danek, J. E. Burden, M. G. Mason, D. L. Anderson, R. W. Doane, B. S. Ellis, R. E. Hamilton and W. H. Shinpaugh

Ecological Survey of the Millington Plant Area, St. Louis, Missouri, to be published as a DOE report.

R. W. Leggett, J. E. Burden, M. T. Ryan, D. L. Anderson, B. S. Ellis and D. J. Christian

Ecological Survey of the Alton Plant and Area, Alton, Illinois, to be published as a DOE report.

R. W. Leggett, W. D. Cottrell, J. E. Burden and M. T. Ryan

Ecological Survey of the Stone Island, Oak Ridge Reservation, Tennessee, New York, to be published as a DOE report.

R. W. Leggett, W. D. Cottrell and H. W. Dickson

Ecological Survey of the Army Industrial Park, Cincinnati, New York, to be published as a DOE report.

R. W. Leggett, W. D. Cottrell, R. W. Doane and D. J. Christian

Ecological Survey of the Ames Plant, Ames, Iowa, New York, to be published as a DOE report.

R. W. Leggett, W. D. Cottrell, F. F. Haywood, W. H. Shinpaugh, R. W. Doane and W. M. Johnson

Ecological Survey of the Former Hanford, Inc., Metal Refining Facility, Portland, Oregon, to be published as a DOE report.

R. W. Leggett, H. W. Dickson, W. D. Cottrell, F. F. Haywood, D. L. Anderson, W. F. Fox and C. A. Golden

Biological Survey of the Former Bales Plant Property, Texasville, New York, to be published as a DOE report.

R. W. Leggett, F. F. Haywood, C. J. Barton, W. D. Cottrell, P. T. Perdue, M. T. Ryan, J. E. Burden, D. R. Stone, R. E. Hamilton, D. L. Anderson, R. W. Doane, B. S. Ellis, W. F. Fox, W. M. Johnson and W. H. Shinpaugh

Biological Survey of the Former West River Water Plant, Conowingo, Pennsylvania, to be published as a DOE report.

Biological Survey of the Pennsylvania Railroad Landfill Site, Blairsville, Pennsylvania, to be published as a DOE report.

R. W. Leggett, F. F. Haywood, M. T. Ryan, P. T. Perdue, E. G. Wagner and C. J. Barton

Biological Survey of the Property at 9500 Inter Avenue, Hazelwood, Missouri, to be published as an NRC report.

R. W. Leggett and L. R. Williams

"Multiple Fixed Point Theorems for Problems in Chemical Reactors Theory," to be published in *J. Math. Anal. Appl.*

C. A. Little

"Plutonium in a Grassland," to be published in *Transuranium Elements in the Environment*, W. C. Hanson, ed., U. S. Department of Energy.

C. A. Little and F. W. Whicker

"Distribution in Rocky Flats Soils," submitted for publication in *Health Phys.*

C. A. Little, F. W. Whicker and T. F. Winsor

"Plutonium in a Terrestrial Ecosystem at the Rocky Flats Plant, Colorado," submitted for publication in *Nature*.

R. A. MacRae, E. T. Arakawa and M. W. Williams

"Refractive Indices of Transparent Solvents," to be published in *J. Chem. Eng. Data*.

J. P. McBride, R. E. Moore, J. P. Witherspoon and R. E. Blanco

Biological Impact of Airborne Effluents of Coal-Fired and Nuclear Power Plants, ORNL-5315 (August 1977).

D. L. McCorkle, I. G. Christophorou, D. V. Maxey and J. G. Carter

"Ramsauer-Townsend Minima in the Electron Scattering Cross Sections of Polyatomic Gases: Methane, Ethane, Propane, Butane and Neopentane," *J. Phys. A* (in press).

H. R. Meyer and J. E. Till

"Characterization of the Existing Environment--Meteorology," and "Environmental Impacts--Radiological Impacts," and "Potential Effects of Accidents," *Environmental Impact Statement for the Engineering Test Project at Oak Ridge National Laboratory*, ORNL/DEIS (April 1978).

"Global/Generic Studies," *HTGR Fuel Reactor Development Program Annual Report*, ORNL-5423 (in press).

"Toxicity and Dispersal Hazards of Uranium-233 Fuel," *Interim Assessment of Uranium Fuel Cycle System*, D. E. Bartine, C. M. Newstead, and L. S. Abbott, eds., ORNL-5388 (in press).

H. R. Meyer, J. E. Till, E. A. Bondiotti, D. F. Dunning, C. S. Fore, C. T. Garten, Jr., S. V. Kaye, K. A. Kirkscey, C. A. Little, R. E. Moore, P. S. Rohwer, C. C. Travis and J. P. Witherspoon

"Nonproliferation Alternative Systems Assessment Program (NASAP)," *Interim Assessment of Thorium-Uranium Fuel Cycle Systems*, ORNL/TM-6069 (in press).

J. B. Milnes, A. F. McFee and J. W. Poston

"Chromosomal Aberrations in Swine Leukocytes after *in Vivo* or *in Vitro* Exposure to Fission Neutrons," *Radiat. Environ.* 71:3 (1977).

C. W. Miller

"A Critique of the Determination of Atmospheric Stability Categories for Assessing Airborne Releases of Radionuclides," *Health Phys.* (in press).

"An Examination of Gaussian Plume Dispersion Parameters for Rough Terrain," *Atmos. Environ.* (in press).

"The How and Why of Air Pollution Control," *Ecology* (in press).

"Using a Sulfation Plate: Study for Undergraduate Independent Projects in Physics," *Am. J. Phys.* 45(4):400-1 (1977).

C. W. Miller, D. E. Dunning, Jr., J. T. Ensminger, C. T. Garten, Jr., F. O. Hoffman, H. R. Meyer, D. L. Shaeffer and R. W. Shor

Compilers, *The Evaluation of Models Used for the Assessment of Radionuclide Releases to the Environment, Progress Report for the Period April 1976 through December 1977*, ORNL-5382 (in press).

C. W. Miller, F. O. Hoffman and D. L. Shaeffer

"The Importance of Variations in the Deposition Velocity Assumed for the Assessment of Airborne Radionuclide Releases," *Health Phys.* (in press).

C. W. Miller and R. E. Moore

"Verification of a Methodology for Computing Ground-Level Air Concentrations of SO_2 and Suspended Particulates for Both Point and Dispersed Sources," *Proceedings of the Joint Conference on Applications of Air Pollution Meteorology*, November 28-30, December 2, 1977, Salt Lake City, Utah, American Meteorological Society, Boston, Mass.

C. W. Miller, T. H. Ortor, C. J. Barton and R. E. Moore

Indicators from Diesel-Fuel Combustion, Air Quality Data, and Meteorology for Fernald County, Tennessee, Spring 1976, ORNL-5343 (December 1977).

R. E. Moore

The ARIAN-11 Computer Code for Estimating Radiation Dose to Man from Airborne Radionuclides in Areas Surrounding Nuclear Facilities, ORNL-5245 (April 1977).

J. K. Munro, R. J. Luxmoore, C. C. Begovich, K. R. Dixon, A. P. Watson, M. R. Patterson and D. R. Jackson

"Transport Model to Predict the Movement of Pb, Cd, Zn, Cu, and S through a Forested Watershed," *Final Report of the Regional Transport Model for Air Pollution Control*, CONF-760962-1 (1977).

M. H. Nayfeh

"Two-Photon Ionization of Colliding Atoms," *Phys. Rev. A* 16:927-32 (1977).

M. H. Nayfeh, G. S. Hurst, M. G. Payne and J. P. Young

"Collisional Line Broadening using Laser Excitation and Ionization," *Phys. Rev. Lett.* 39:604-7 (1977).

M. H. Nayfeh, G. S. Hurst and J. P. Young

"Collisional Broadening of Cs Resonance Lines using Two-Photon Ionization," *Final Report of the International Conference on Multiphoton Ionization, June 1977, Houston, Texas*, (in press).

M. H. Nayfeh and A. H. Nayfeh

"Adiabatic Following in Two-Photon Transition," *Proceedings of the Fourth Quantum Conference on Chemical and Physical Processes, June 1977, Houston, Texas*, (in press).

M. H. Nayfeh and M. G. Payne

"Radiative Collision-Induced Photoionization," *Phys. Rev. A* (in press).

T. W. Oakes, K. E. Shank, C. E. Easterly and L. R. Quintana

"Concentration of Radionuclides and Stable Elements in Fruits and Vegetables," *Final Report of the 1976 Annual Conference on Environmental Health Research, June 1977, Houston, Texas*, June 7-9, 1977 (in press).

R. V. O'Neill, B. S. Ausmus, D. R. Jackson, R. I. Van Hook, P. Van Voris, C. Washburn and A. P. Watson

"Monitoring Terrestrial Ecosystems by Analysis of Nutrient Export," *Water, Air, and Soil Pollut.* 8:271-77 (1977).

M. O. Pace, L. G. Christophorou, D. R. James, R. Y. Pai, R. A. Mathis and D. W. Bouldin

"Improved Unitary and Multicomponent Gaseous Insulators," *IEEE Trans. Electron. Electr.* EI-13:31-36 (1978).

D. C. Parzyck, E. W. Brocksen and W. R. Emanuel

"Regional Analysis and Environmental Impact Assessment," *Proceedings AEC/CEC Symposium on Regional Analysis of Environmental Impacts*, Oak Ridge, TN. (in press).

D. C. Parzyck, R. J. Olson and E. M. Rupp

"Health Impacts Associated with Sulfur Dioxide Releases from Facilities Sited in the NCUA Base Case Scenario," *A Report on the National Coal Utilization Assessment*, ORNL/TM-6122 (in press).

D. C. Parzyck, E. M. Rupp and H. M. Braunstein

"Characterization of Coal Technologies in a Report on the National Coal Utilization Assessment," *A Report on the National Coal Utilization Assessment*, ORNL/TM-6122 (in press).

D. C. Parzyck, S. M. Shaw, W. V. Kessler, R. J. Vetter, D. C. Van Sickle and R. A. Mayes

"The Toxicity of Cadmium in Pregnant Rats Fed a Zinc-Deficient Diet," *Bull. Environ. Contam. Toxicol.* 19(2):206-14 (1978).

M. G. Payne and C. W. Choi

"Collisional-Induced Resonances in Two-Photon Ionization of Excited State Atoms by Strong Laser Fields," *Proceedings of the International Symposium on Multiphoton Processes*, New York, NY, 1977, in press.

"Three-Photon Ionization of Atoms near a Two-Photon Resonance," *Proceedings of the International Symposium on Multiphoton Processes*, New York, NY, 1977, in press.

M. G. Payne, C. W. Choi and M. H. Nayfeh

"Laser-Induced Collisional Excitation Transfer," *Proceedings of the International Symposium on Multiphoton Processes*, New York, NY, 1977, in press.

H. R. Petty, E. T. Arakawa and J. K. Baird

"Methods to Determine the Temperature Dependence of the Pre-exponential Factor of the Arrhenius Equation from Thermogravimetric Data," *J. Chem. Phys.* 11:417 (1977).

H. R. Petty, J. A. Crumb, V. E. Anderson, E. T. Arakawa and J. K. Baird

"New Differential Bottcher-Onsager Method Used to Determine Polarizability and Apparent Radius of $\text{SiO}_2(\text{WO}_3)_x$," *J. Chem. Phys.* 81:696-703 (1977).

J. E. Phillips and C. E. Easterly

"Cadmium Pollution and Impacts on Life in the Pacific," ORNL/TM-5963 (May 1978).

"Sources of Tritium," *Sci. Rep.* (in press).

J. K. Poggenburg

"Theoretical Study of the Reaction of Hydrogen with Water Vapor," *J. Chem. Phys.* 107:1071-1078 (1977).

"Theoretical Study of the Reaction of Hydrogen with Water Vapor," *J. Chem. Phys.* 107:1071-1078 (1977).

"Theoretical Study of the Reaction of Hydrogen with Water Vapor," *J. Chem. Phys.* 107:1071-1078 (1977).

S. A. Rice and J. K. Baird

"Uniform Theory of Electron Kinetics in Nonpolar Liquids," submitted for publication in *J. Chem. Phys.*

R. H. Ritchie and M. Brandt

"Projectile-Charge Dependence of Stopping Powers," *Phys. Rev. A* 17:2102 (1978).

R. H. Ritchie, R. N. Farn, J. E. Turner and H. A. Wright

"The Interaction of Swift Electrons with Liquid Water," to be published in the *Proceedings of the Third Conference on Microcalorimetry*, Brussels, Belgium, May 12-16, 1978.

R. H. Ritchie, R. N. Farn, M. W. Williams and C. T. Arakawa

"Dispersion Relations of Elementary Excitations when Damping is Present," *Phys. Stat. Solidi B* 44:567-73 (1977).

R. H. Ritchie and A. Howie

"Electron Excitation and the Optical Potential in Electron Microscopy," *Phil. Mag.* 36:463 (1977).

J. W. Roddy, R. F. Bianco, B. C. Finney, G. S. Hill, R. E. Moore and J. P. Witherspoon

"Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle—Comparison of Results from the DOE, ORNL/NUREG/TM-37 (August 1977).

P. S. Rohrer

"Internal and External Dosimetry," *Proceedings of a Conference on the Evaluation of Methods Used for the Environmental Assessment of Radioactive Releases*, CONF-770901 (April 1978).

R. L. Roswell, R. E. Goans and J. H. Cantrell, Jr

"High Resolution Microprobe Scanning of Animal and Human Tissue *In Vivo*," ORNL/TM-5934 (August 1977).

E. M. Rupp, D. C. Parzyck, P. J. Walsh, R. S. Booth, R. J. Raridon and E. L. Whitfield

"A Composite Hazard Index for Assessing Limiting Exposures to Environmental Pollutants. Applications Through a Case Study," *Environ. Sci. Technol.* (in press).

M. T. Ryan, F. F. Haywood, R. W. Leggett, E. W. Doane, W. M. Johnson and W. H. Shinpaugh

"Initial Field Survey of the Former AEC-22, C-22A Airport Storage Site, St. Louis, Missouri, to be published as a DOE report.

M. T. Ryan, R. W. Leggett, F. F. Haywood, W. H. Shinpaugh, R. W. Doane and W. M. Johnson

"Final Field Survey of the AEC-22, C-22A Airport Storage Site, St. Louis, Missouri, to be published as a DOE report.

M. B. Sears, R. F. Bianco, B. C. Finney, G. S. Hill, R. E. Moore and J. P. Witherspoon

"Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents in the Nuclear Fuel Cycle—Comparison of Results from the DOE, ORNL/NUREG/TM-7 (September 1977).

L. M. Scott, G. G. Warner and J. W. Poston

"Theoretical Evaluation of Optimum Detector Size and Positioning for Low-Energy γ -Ray Gamma Spectrometry," *Nucl. Phys.* 33:583-93 (1977).

V. E. Shank, T. W. Oakes and C. E. Easterly

"Development of a Method for the Evaluation of the Environmental Impact of a Nuclear Reactor Fuel Plant," ORNL/TM-6369 (in press).

V. E. Shank and C. E. Easterly

"Development of a Method for the Evaluation of the Environmental Impact of a Nuclear Reactor Fuel Plant," ORNL/TM-6369 (in press).

W. S. Snyder

"Basic Concepts in the Assessment of Human Exposures and Risks," *Proceedings of the Third International Conference on Environmental Health, Geneva, Switzerland, September 1977, Vol. 1, pp. 1-10.*

W. L. Snyder

"Pathways from Reactor to Food Chains," *Environmental Health Perspectives*, Vol. 2, pp. 469-79.

W. L. Snyder, M. P. Ford and G. G. Warner

"Distribution of Dose within the Body from a Single Ingested Reactor or α Source," *Environmental Health Perspectives*, Vol. 2, pp. 469-79.

"Estimates of Specific Absorbed Fractions for Radiation Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom," *Environmental Health Perspectives*, Vol. 2, pp. 469-79.

D. P. Spears, J. D. Allen, Jr., V. E. Anderson, R. D. Birkhoff, G. Rosemann, M. H. Mattell, Jr., and R. Zauper

"Scattering of Low-Energy Electrons on Micron-Size Pinholes," submitted for publication in *Am. J. Phys.*

P. S. Stansbury

"Evaluation of the Reactor to Food Chain Pathway," ORNL/TM-5273 (October 1977).

"Evaluation of the Reactor to Food Chain Pathway," ORNL/TM-5273 (October 1977).

J. A. Stockdale, L. Schumann, J. H. Brown, Jr., and G. Bederson

"High-Temperature Atomic Beam Source," *Rev. Sci. Instrum.* 48:17-19 (1977).

J. H. Inoué

"Evaluation of the Reactor to Food Chain Pathway," ORNL/TM-5273 (October 1977).

J. E. Till, E. G. Hoffman and J. E. Dunning, Jr.

"A New Look at ^{137}Cs Released to the Atmosphere," *Environmental Health Perspectives*, Vol. 2, pp. 469-79.

J. E. Till and G. G. Killough

"Scenarios of ^{137}Cs Release from the World Nuclear Power Industry 1955-2025 and Estimated Radiological Impact to the Population," *Environmental Health Perspectives*, Vol. 2, pp. 469-79.

C. C. Travis, E. L. Etkin and R. A. Hinkley

"Convergence of the Series for the Solution of the Volterra Integral Equation," *Math. Sci.*, ORNL-5411 (May 1978).

C. C. Travis and G. E. Webb

"Convergence, Regularity and Uniform Continuity Properties of Strongly Continuous Cosine Families," *Adv. Math.* 3:555-67 (1978).

"An Abstract Second Order Semilinear Volterra Integrodifferential Equation," *Adv. Math.* (in press).

"Second Order Differential Equations in Banach Space," *Adv. Math.* (in press).

"Perturbation of Strongly Continuous Cosine Family Generators," *Adv. Math.* (in press).

C. J. Tung, J. C. Ashley, R. D. Birkhoff, R. H. Ritchie, L. C. Emerson and V. E. Anderson

"Electron Slowing-Down Flux Spectrum in Al₂O₃," *Phys. Rev.* 16(7):3049-55 (1977).

C. J. Tung and R. H. Ritchie

"Electron Slowing Down Spectra in Aluminum Metal," *Phys. Rev.* 16:4302 (1977).

J. E. Turner

"Minimum Dipole Moment Required to Bind an Electron--Molecular Theorists Rediscover Phenomenon Mentioned in Fermi-Teller Paper on Another Subject Twenty Years Earlier," *Am. J. Phys.* 45(8):758 (1977).

"Semi-Classical Quantization of Electron Dipole System," submitted for publication in *Am. J. Phys.*

[illegible]

1. *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1971).

[illegible]

© 1999 by John Wiley & Sons, Inc.

10. "The Role of the Modern Physicist in the Development of New Energy Sources," *ibid.*, 1977, p. 10.

DECLASS. AUTHORITY: 25 USC 552, 552A

Estimated values for relative change in average equivalent CO_2 and CH_4 in the region
1990-2010: 1990-2010

 

Journal of Management Studies, 19(6), 701-718.

Manuscript accepted for publication, 1999, and revised manuscript accepted for publication, 2000.

[illegible]

REPORT: "The... of... for the '... Organic Analysis,' to...
in... of the... for... in... (1955)." (1955).

1. *Journal of Spectroscopy*, for the Analysis of Polymeric Aromatic Compounds, 1979, 1, 1-10.

body in at least 10 patients by two known spectroscopists, to be published in a book on the subject.

J. de-Weert and M. J. Winzinger

High Temperature Phosphorimetry, as a "low Spectrochemical Meth. of Analysis," review paper to be published in *Anal. Chem.* 37, 1965, 1711.

D. L. Walsh and R. L. Hamrick

"Radioactive Materials--Determinants of Dose to the Respiratory Tract," *Annals* 1: 2
 1977, pp. 33-42. American Physiological Society, Bethesda, Md. (1977), pp. 233-42.

P. J. Walsh, G. G. Killough, D. C. Parzyck, P. C. Rohrer, F. M. Rupp, B. L. Whitfield, P. S. Booth and P. J. Baridon

1977). -- *Journal of the American Ornithologists Union*, 91: 100-101. (April 1977).

P. J. Walsh, G. G. Killough and P. S. Pohwer

"A Composite Hazard Index for Assessing Limiting Exposures to Environmental Pollutants: Formulation and Derivation," *Environ. Sci. Technol.* (in press).

 

1. "The Impact of the El Niño - Event of 1982-83 on the Amazon", *Rev. Bras. Geogr.*, 22(1989) (1992).
 2. "Interações Hidrológicas do Rio São Francisco com o Atlântico", *Rev. Bras. Geogr.*, 57(2):320-28 (1997).
 3. "Interação do El Niño com o Rio da Amazônia", *Rev. Bras. Geogr.*, 23(1990) (1978).
 4. "Interação Hidrológica do Rio São Francisco com o Atlântico", *Rev. Bras. Geogr.*, 56(1996).

McIntyre, A. A., Ireland, T. J., Cox, E. L., Hayes, and T. A. Butler

100

100-443887-100

 

Wright, S. G., and J. L. Bishop, and J. E. Turner

air intake.

J. McIntyre and H. Ozer

Young, G. W., White, G. J., Clark, J., Narayan, W. H., Christie, M., Murakami, P. W., King and Kraver

"Laser Annealing of Boron-Implanted Silicon," *IEEE Trans. Electron Devices*, 32:139-4, (1978).

Presentations

E. T. Arakawa

"Energy Research at the Oak Ridge National Laboratory," Physics Department, Millsaps College, Jackson, Miss., Mar. 30, 1978.

E. T. Arakawa, T. A. Callcott and D. L. Ederer

"The L_{α} X-ray Emission and Absorption Edges of Na," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

J. C. Ashley and R. H. Ritchie

"Energy Loss of Channeled Ions--The Bohr Theory Revisited," Seventh International Conference on Atomic Collisions in Solids, Moscow, USSR, Sept. 19-23, 1977.

J. C. Ashley, C. J. Tung, R. C. Birkhoff and R. H. Ritchie

"Electron Slowing-Down Spectra in Aluminum Metal," IEEE Annual Conference on Nuclear and Space Radiation Effects, Williamsburg, Va., July 12-15, 1977.

J. C. Ashley, C. J. Tung and R. H. Ritchie

"Mean Free Path and Energy Loss of Electrons in Polystyrene," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

J. K. Baird

"Laser Fusion," Department of Physics, College of William and Mary, Williamsburg, Va., Apr. 1, 1977.

"Physics and Chemistry of Electrons in Fluids," Department of Chemistry, University of Florida, Gainesville, Fla., May 6, 1977.

"Kinetics of Electrons in Nonpolar Liquids," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Sept. 12, 1977.

"Physics and Chemistry of Electrons in Nonpolar Liquids," School of Chemical Sciences, University of Illinois, Urbana, Ill., Oct. 5, 1977.

"Pathological Science," ALE Lecture, School of Chemical Sciences, University of Illinois, Urbana, Ill., Oct. 5, 1977.

"Theory of Recombination of Electron-Hole Pairs in Nonpolar Liquids," Department of Physics, University of Kansas, Lawrence, Kans., Jan. 30, 1978.

"Pathological Science," Department of Physics, Western Kentucky University, Bowling Green, Ky., Feb. 27, 1978.

"Physics of Laser Fusion," Society of Physics Students, Department of Physics, Appalachian State University, Boone, N. C., Mar. 2, 1978.

"Laser Fusion Reactor Design," Department of Physics, Appalachian State University, Boone, N. C., Mar. 2, 1978.

"Chemical Scavenging of Electron-Hole Pairs in Nonpolar Liquids," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Mar. 13, 1978.

"Recombination of Electron-Hole Pairs in Nonpolar Liquids," Department of Chemistry, Brookhaven National Laboratory, Upton, N. Y., Apr. 13, 1978.

"Recombination of Electron-Hole Pairs in Nonpolar Liquids," Interdisciplinary Physical Sciences Seminar, Yale University, New Haven, Conn., Apr. 17, 1978.

"Recombination of Electron-Hole Pairs in Nonpolar Liquids," Department of Chemistry, University of Toronto, Toronto, Canada, Apr. 20, 1978.

P. R. Bell

"Origin of the Solar System," Oak Ridge Associated Universities Traveling Lecture Series, Huntington College, Montgomery, Ala., Dec. 6, 1977.

P. V. Bell and J. M. Dougherty

"Nonlinear Image Processing Methods," IEEE Symposium on Nuclear Medicine, San Francisco, Calif., Oct. 17, 1977.

S. R. Bernard

"Dosimetric Data and a Metabolic Model for Selenium," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

"Dose Commitment Estimates Based on Urinary Excretion Data for the Case of Human Exposure to $^{238}\text{PuO}_2$," 23rd Annual Conference on Bioassay, Environmental, and Analytical Chemistry, Jackson Lake, Wyo., Sept. 15-16, 1977.

"A Metabolic Model for Astatine," American Association for the Advancement of Science 144th National Meeting, Washington, D. C., Feb. 12-17, 1978.

"Compartment Models and Metabolic Models in Internal Dose Estimation," Department of Mathematics, University of Alabama, Huntsville, Ala., Mar. 31, 1978.

R. D. Birkhoff, L. R. Painter and J. M. Heller, Jr.

"Vacuum JV Reflectance of Liquid Glycerol by Gas Ionization," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

J. E. Bloor

"Bonding Model for Electron Affinities in Polyatomic Molecules," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 8, 1977.

C. H. Chen

"Energy Pathways of Pure Gases and Gas Mixtures by Proton Excitation," IEEE International Conference on Plasma Science, Troy, N. Y., May 23-25, 1977.

"Energy Pathway Studies of Gas Mixtures and Their Application to Gas Lasers and Pollutant Detection," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 29, 1977.

C. H. Chen, J. P. Judish and M. G. Payne

"Charge Transfer Studies of Ne-II by Proton Excitation," 30th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.

C. H. Chen, J. P. Judish, M. G. Payne and G. S. Hurst

"Kinetics of Pure Gases and Gas Mixtures by Proton Excitation," Los Alamos Scientific Laboratory's Information Exchange on Lasers for Isotope Separation, Albuquerque, N. M., May 17-19, 1977.

C. H. Chen, M. G. Payne and J. P. Judish

"Kinetic Studies of Ar-F₂ Mixtures by Proton Excitation," 30th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.

A. A. Christodoulides, L. G. Christophorou, R. Y. Pai and C. M. Tung

"Electron Attachment to Perfluorocarbon Compounds, I.," American Physical Society, Washington, D. C., Apr. 24-27, 1978.

L. G. Christophorou

"Metastable Negative Ions, Their Lifetimes and Implications for Physical and Biological Science," 25th Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.

"High Voltage Gaseous Insulators," Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 6, 1977.

"The Interactions of O₂ with Slow Electrons," International Conference on Singlet Oxygen and Related Species in Chemistry and Biology, Pinawa, Manitoba, Canada, Aug. 22-24, 1977.

"The Lifetimes of Metastable Negative Ions," Hahn-Meitner Institute, Berlin, Sept. 7, 1977.

"Elementary Electron-Molecule Interactions and Negative-Ion Resonances at Subexcitation Energies and Their Significance in Gaseous Dielectrics," XIIIth International Conference on Phenomena in Ionized Gases, Berlin, GDR, Sept. 11-17, 1977.

"Gaseous Insulators: The Oak Ridge Program," Electric Power Research Institute Headquarters, Washington, D. C., Sept. 23, 1977.

L. G. Christophorou

"Modes of and Cross Sections for Formation of Negative Ions," American Chemical Society Meeting, Little Rock, Ark., Dec. 4-6, 1977.

M. S. Chung, T. A. Calicott and E. T. Arakawa

"Radiation from Silver Films Bombarded by Low-Energy Electrons," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

R. B. Compton

"Negative Ions," Physics Department, University of Kentucky, Lexington, Ky., Nov. 4, 1977.

"Laser Application in Physical and Life Sciences," ORNL In-House Continuing Education Program, Oak Ridge National Laboratory, Oak Ridge, Tenn., Fall 1977.

"Resonant Multiphoton Ionization of Pyrrole," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Jan. 23, 1978.

"Negative Ion States of Complex Molecules and Molecular Clusters," Gas Phase Ion Thermochemistry Symposium, Anaheim, Calif., Mar. 14-15, 1978.

"Multiphoton Ionization of Molecules," Physics and Chemistry Departments, Yale University, New Haven, Conn., Mar. 31, 1978.

R. W. Compton, P. W. Reinhardt and G. D. Cooper

"Collisional Ionization Reactions between Alkali Atoms and Some Methane Derivatives," 10th International Conference on the Physics of Electronic and Atomic Collisions and Satellite Meeting, Paris, France, July 28-30, 1977.

G. D. Cooper and R. B. Compton

"Negative Ion Properties of Fluoranol, Chloranol, and Bromanol: Electron Affinities," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

S. J. Cotter and P. B. Sannage

"Evaluation of Plastics for Fast Neutron Dosimetry by the Electrochemical Etching Technique," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

H. W. Dickson

"Proper Design and Operation Minimize Health Hazards at Power Reactors," Medical Planning and Care in Radiation Accidents Seminar, Oak Ridge Associated Universities, Oak Ridge, Tenn., Mar. 9, 1977.

"Fission and Principles of Reactors," Health Physics and Radiation Protection Course, Oak Ridge Associated Universities, Oak Ridge, Tenn., Mar. 15, 1978.

"Nuclear Accident Dosimetry," Health Physics and Radiation Protection Course, Oak Ridge Associated Universities, Oak Ridge, Tenn., Apr. 7, 1978.

H. W. Dickson and R. W. Doane

"A Survey Instrument for Alpha Spectroscopy," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

H. W. Dickson and L. W. Gilley

"Personnel Dosimetry Intercomparison Studies at the ORNL Health Physics Research Reactor," IAEA International Symposium on National and International Standardization in Radiation Dosimetry, Atlanta, Ga., Dec. 5-9, 1977.

J. S. Eldridge, T. W. Oakes and J. E. Turner

"A Rapid Method for the Determination of Iodine-131 Concentration in Milk Due to Fallout," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

T. L. Ferrell, P. M. Echenique, V. E. Anderson and R. H. Ritchie

"The Force on an Ion Moving Near a Surface," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

M. R. Ford, W. S. Snyder and S. B. Watson

"(MPC) Values for Plutonium Isotopes as a Function of Particle Size," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

P. B. Gamage and J. S. Chelka

"Reference Bank of Excitation Dosimeters," Symposium on National and International Standardization in Radiation Dosimetry, Atlanta, Ga., Dec. 5-9, 1977.

R. B. Gamage and D. J. Christian

"Meeting Regulatory Standards with BeO Ceramic TLD," 11th Midyear Symposium of the Health Physics Society, San Diego, Calif., Jan. 16-19, 1978.

M. R. Garrett

"Laser Applications in Physical and Life Sciences," ORNL In-House Continuing Education Program, Oak Ridge National Laboratory, Oak Ridge, Tenn., Fall 1977.

"Electron Affinities of Strongly Polar Molecules," 13th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.

"Advanced Laser Technology for Pollutant Measurements," DBER Physical and Technology Program Contractors' Workshop, Oak Ridge National Laboratory, Oak Ridge, Tenn., Feb. 9-10, 1978.

"The Question of Thermally Stable Reagents for Polar Molecules," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Mar. 6, 1978.

R. B. Hahn, J. Neufeld, R. H. Ritchie, J. E. Turner and H. A. Wright

"Calculation of Statistical Distribution of Energy Deposition along Electron Tracks in Water," 75th Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.

R. L. Hayes, D. J. Rafter and J. A. Butler

"Copper-64 as a Possible Positron Tomographic Agent for Detection of Cancer," Annual Meeting of the Southeastern Chapter of the Nuclear Medicine Society, Winston-Salem, N. C., Oct. 13, 1977.

Ray Hefferlin

"Intensity Constants for Diatomic Molecular Electronic Transitions--Status Report," Sandia Laboratory, Albuquerque, N. M., May 12, 1977.

"A Proposed Periodic Table for the Diatomic Molecules," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 15, 1977.

"A Periodic Table for Diatomic Molecules," 30th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.

J. H. Heller, Jr., P. D. Birkhoff and L. R. Painter

"Isotopic Effects on the Electronic Properties of H₂O and D₂O in the Vacuum UV," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

C. Hesemann, J. C. Ashley, P. D. Birkhoff, H. H. Hubbell, Jr., R. H. Ritchie, D. P. Spears and R. Zauper

"Evidence for Surface Plasma Waves in Cylinders," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

F. O. Hoffman

"Environmental Assessment of Radioactivity Releases," University of Tennessee, Knoxville, Tenn., May 1977.

"Evaluation of Models for Assessing Compliance with Environmental Radiation Regulations," American Nuclear Society, San Francisco, Calif., Nov. 27-Dec. 2, 1977.

"An Environmental Critique of Nuclear Power," Clemson University, Clemson, S. C., January 1978.

"A Radiological Assessment of Nuclear Fuel Reprocessing," University of Virginia, Charlottesville, Va., February 1978.

"Quantification in Environmental Impact Assessment," Georgia Institute of Technology, School of Nuclear Engineering, Atlanta, Ga., April 1978.

F. O. Hoffman, C. W. Miller, D. L. Shaeffer and C. T. Garten, Jr.

"A Compilation and Preliminary Evaluation of Models Used for the Assessment of Radionuclides Released to the Environment," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

C. F. Holoway,

"Guide to Radioactive Waste Management Literature," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

B. L. Houser, C. F. Holoway, G. G. Madewell and J. E. Turner

"Guide to Radioactive Waste Management Literature," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

R. P. Howland, M. L. Rindolph and J. S. Wesson

"Computer Data File on Ultraviolet Radiation," American Society for Photobiology, San Juan, Puerto Rico, May 1977.

S. S. Hurst

"One-Atom Detection and Related Research," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 22, 1977.

"Atomic Physics: Resonance Ionization Spectroscopy and One-Atom Detection," Course on Laser Applications in Physical and Life Sciences, Oak Ridge National Laboratory, Oak Ridge, Tenn., Oct. 2, 1977.

"Selective Detection of Single Atoms in a 10^{14} Atom Background--The Ultimate Detection Story," Department of Physics, University of Kentucky, Lexington, Ky., Nov. 5, 1977.

"One-Atom Detection," Brookhaven National Laboratory, Upton, L.I., N. Y., Nov. 8, 1977.

"One-Atom Detection," Department of Physics, Columbia University, N. Y., Nov. 11, 1977.

"One-Atom Detection and Its Application to Chemistry," Conference on Chemical Applications of Lasers--Present Status, Chapel Hill, N. C., Nov. 30-Dec. 2, 1977.

"Detection of Atoms: One-at-a-Time," Department of Physics, Portland State University, Portland, Oreg., Dec. 5, 1977.

"One-Atom Detection," EG&G Conference on Applications of One-Atom Detection to Environmental Monitoring, Las Vegas, Nev., Dec. 7, 1977.

"Resonance Ionization Spectroscopy and One-Atom Detection," OBER Physical and Technological Program Contractors' Workshop on Advanced Laser Technology for Pollutant Measurements, Oak Ridge National Laboratory, Oak Ridge, Tenn., Feb. 9-10, 1978.

"One-Atom Detection," Department of Physics, Auburn University, Auburn, Ala., Feb. 17, 1978.

"Detection of Single Atoms," Department of Physics, New Mexico State University, Las Cruces, N. M., Mar. 27, 1978.

"Detection of Single Atoms," Department of Physics, Arizona State University, Tempe, Ariz., Mar. 29, 1978.

"Detection of Single Atoms," University of Arizona, Tucson, Ariz., Mar. 30, 1978.

"Chemical Studies of Single Atoms," Department of Chemistry, University of Tennessee, Knoxville, Tenn., Apr. 4, 1978.

"Chemical Studies of Single Atoms," Department of Physics, North Carolina State University, Raleigh, N. C., Apr. 17, 1978.

"One-Atom Detection and the Solar Neutrino Problem," Department of Physics, University of Tennessee, Knoxville, Tenn., Apr. 25, 1978.

G. S. Hurst, M. H. Nayfeh and J. P. Young

"A Laser Technique for the Detection of Single Atoms," EG&G, Santa Barbara, Calif., Apr. 11, 1977.

"A Laser Technique for the Detection of Single Atoms," Lawrence Berkeley Laboratory, Berkeley, Calif., Apr. 13, 1977.

"A Laser Technique for the Detection of Single Atoms," Los Alamos Scientific Laboratory, Los Alamos, N. M., Apr. 20, 1977.

G. S. Hurst, M. H. Nayfeh, J. P. Young, M. G. Payne and I. W. Grossman

"Selective Single-Atom Detection in a 10^{14} Atom Background," Third International Conference on Laser Spectroscopy, Jackson Hole, Wyo., July 4-8, 1977.

- D. R. James, L. G. Christophorou, R. Y. Pai, M. O. Pace, R. A. Mathis and D. W. Bouldin
 "Breakdown Voltages of Some New Unitary and Multicomponent Gas Mixtures," Conference on Electrical Insulation and Dielectric Phenomena, Colonie, N. Y., Oct. 17-20, 1977.
- D. R. James, L. G. Christophorou, R. Y. Pai, M. O. Pace, R. A. Mathis, I. Sauers and C. C. Chan
 "Dielectric Strengths of New Gases and Gas Mixtures," International Symposium on Gaseous Dielectrics, Knoxville, Tenn., Mar. 6-8, 1978.
- B. P. Johnson, J. D. Hoeschele and R. O. Rahn
 "Comparative Binding Studies of Cis- and Trans-Dichlorodiamine Pt (II) (DDP) to DNA," Joint Biophysical Society and American Physical Society Meeting, Washington, D. C., March 1978.
 "Comparative Binding Studies of Pt-195m Radiolabeled Cis- and Trans-Dichlorodiamine Pt (II) (DDP) to DNA," American Chemical Society Middle Atlantic Regional Annual Meeting, Hunt Valley, Md., Apr. 7, 1978.
- T. D. Jones
 "CHORD Operators for Insult Assessment and the Application to Stem Cell Survival," 25th Annual Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.
 "CHORD Operators for Insult Assessment and the Application to the Radiosensitive Cells of the T-B Tree," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.
 "Leukemia Incidence Based on Cell Survival," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.
- G. D. Kerr
 "Publishing in Technical and Scientific Journals," Annual Spring Meeting of the North Carolina Chapter of the Health Physics Society, Wrightsville Beach, N. C., Mar. 18-19, 1978.
 "Radon Analysis," Health Physics and Radiation Training Program, Oak Ridge Associated Universities, Oak Ridge, Tenn., Mar. 22, 1978.
- G. D. Kerr, T. D. Jones, J. M. L. Hwang, F. L. Miller and J. A. Auxier
 "An Analysis of Leukemia Data from Studies of Atomic-Bomb Survivors Based on Estimates of Absorbed Dose to Active Bone Marrow," Fourth International Congress of the International Radiation Protection Association, Paris, France, Apr. 24-30, 1977.
- G. D. Kerr, M. T. Ryan and P. T. Perdue
 "Measurement of Airborne Concentrations of Radon-220 Daughter Products by Alpha-Particle Spectrometry," Health Physics Society 11th Midyear Topical Symposium on Radiation Instrumentation, San Diego, Calif., Jan. 17-18, 1978.
- G. G. Killough
 "Some Aspects of Environmental Transport and Dosimetry of ^{14}C Released to the Atmosphere as Carbon Dioxide," 22nd Annual Meeting of the Health Physics Society, July 6, 1977.
 "Mathematical Models of the Global Carbon Cycle," Mathematics Colloquium, East Tennessee State University, Johnson City, Tenn., Apr. 5, 1978.
- C. E. Klotz
 "Role of Angular Momentum in Unimolecular Kinetics," American Society for Mass Spectrometry, 25th Conference, Washington, D. C., May 1977.
 "Electron Attachment to Polymers of Nitrous and Carbon Dioxide," 13th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.
 "Giant Bimolecular Rate Constants," Oak Ridge Associated Universities Traveling Lecture, Cornell College, Mount Vernon, Iowa, October 1977.
 "Van der Waals Molecules," Oak Ridge Associated Universities Traveling Lecture, University of Colorado Medical School, Denver, Colo., October 1977.
 "Supersonic Nozzle Beams," 11th Annual Physical and Technological Programs Contractors' Meeting, Gaithersburg, Md., March 1978.

F. F. Knapp, Jr.

"Potential Pancreatic Imaging Agents--The Synthesis of Te-123m Labeled Telluro Amino Acids," Society of Nuclear Medicine, Southeastern Chapter Annual Meeting, Winston-Salem, N. C., Oct. 13, 1977.

"Tellurium-123m Labeled Steroids--A New Class of Potential Adrenal Imaging Agents," Medical Division Weekly Seminar Series, Oak Ridge Associated Universities, Oak Ridge, Tenn., Dec. 5, 1977.

F. F. Knapp, Jr., and K. P. George

"Te-123m Labeled 24-Nor-23-(Isopropyl Telluro)-5 α -Cholane: A New Potential Adrenal Imaging Agent," Annual Meeting of the Society of Nuclear Medicine, Chicago, Ill., June 20, 1977.

F. F. Knapp, Jr., and A. P. Callahan

"The Synthesis of Te-123m Labeled Steroids," Annual Meeting of the Society of Nuclear Medicine, Chicago, Ill., June 21, 1977.

F. F. Knapp, Jr., K. R. Ambrose and A. P. Callahan

"Te-123m Labeled Telluro Amino Acids--A New Class of Pancreatic Imaging Agents," Annual Meeting of the Society of Nuclear Medicine Radiopharmaceutical Science Council, Atlanta, Ga., Jan. 22, 1978.

S. D. Kramer

"Use of Lasers in Gas Phase Chemical Kinetics," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 20, 1977.

"Laser Principles and Characteristics," Laser Applications in Physical and Life Sciences Course, Oak Ridge National Laboratory, Oak Ridge, Tenn., Sept. 16, 1977.

"Nonlinear Optical Spectroscopy," Department of Physics, Western Kentucky University, Bowling Green, Ky., Nov. 14, 1977.

"One-Atom Detection," Lawrence Livermore Laboratory, Livermore, Calif., Nov. 28, 1977.

"One-Atom Detection using Resonance Ionization Spectroscopy," Department of Physics, Harvard University, Cambridge, Mass., Mar. 23, 1978.

"One-Atom Detection of Fission Fragments from ^{252}Cf ," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Apr. 24, 1978.

E. Kretschmann and J. J. Cowan

"Investigation of Surface Plasmons and Guided Waves by Focused Light," American Physical Society, Washington, D. C., Mar. 27-30, 1978.

C. A. Little

"Health Hazards of Plutonium," Oak Ridge Associated Universities, Oak Ridge, Tenn., April 1978.

D. L. McCorkle, E. G. Christophorou, D. V. Maxey and J. G. Carter

"Ramsauer-Townsend Minima in CH_4 , C_2H_2 , C_2H_4 , C_2H_6 , and $\text{C}(\text{CH}_3)_4$," American Physical Society, Knoxville, Tenn., Dec. 5-7, 1977.

C. W. Miller, F. O. Hoffman, D. L. Shaeffer and C. T. Garten, Jr.

"A Compilation and Preliminary Evaluation of Models Used for the Assessment of Radionuclides Released to the Environment," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

C. W. Miller and R. E. Moore

"Verification of a Methodology for Computing Ground-Level Air Concentrations of SO_2 and Suspended Particulates for Both Point and Dispersed Sources," American Meteorological Society/Air Pollution Control Association Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah, Nov. 29-Dec. 1, 1977.

T. G. Miller

"Nuclear Laser Optimization Experiments," IEEE International Conference on Plasma Science, Troy, N. Y., May 23-25, 1977.

K. H. Nayfeh

"Search for Free Quarks," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 8, 1977.

K. H. Nayfeh, G. S. Hurst and J. E. Young

"Collisional Broadening of Cs Resonance Lines Using Two-Photon Ionization," International Conference on Multiphoton Processes, Rochester, N. Y., June 6-9, 1977.

K. H. Nayfeh and A. H. Nayfeh

"Adiabatic Following in Two-Photon Transition," Fourth Conference on Coherence and Quantum Optics, Rochester, N. Y., June 8-9, 1977.

K. H. Nayfeh, M. G. Payne and G. S. Hurst

"Laser Assisted Inelastic Scattering," Gordon Conference, Wolfeboro, N. H., July 4-8, 1977.

T. W. Oakes, K. E. Shank and C. E. Fexterly

"Concentrations of Radionuclides and Selected Trace Metals in Fruits and Vegetables," 11th Annual Conference on Trace Substances in Environmental Health, Columbia, Mo., June 7-9, 1977.

"Verification of an Air-Transport Code Using Iodine-131 as a Tracer," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

F. R. O'Donnell

"The CONDO Methodology for Estimating Radiation Doses from Radioactive Products," Radiation Control Program Directors' Meeting, Atlanta, Ga., Oct. 18, 1977.

M. G. Pace, L. G. Christophorou, D. R. James, R. Y. Pai, R. A. Mathis and D. W. Bouldin

"Improved Unitary and Multicomponent Gaseous Insulators," Conference on Electrical/Electronics Insulation, Chicago, Ill., Sept. 26-29, 1977.

R. Y. Pai, L. G. Christophorou and A. A. Christodoulides

"Electron Attachment to Perfluorinated Compounds, II," American Physical Society, Washington, D. C., Apr. 24-27, 1978.

D. C. Parzyck

"Environmental and Human Health Aspects of the ORNL Regional Studies Program," Argonne National Laboratory, Argonne, Ill., July 1977.

"Application of a Radiological Assessment Methodology to Waste Management," Waste-Burial Technology Meeting, Santa Fe, N. M., March 1978.

M. G. Payne

"Laser Switched Inelastic Atomic Collision Processes," Chemical Physics Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 25, 1977.

"Interaction of Laser Light with Matter," Laser Applications in Physical and Life Sciences Course, Oak Ridge National Laboratory, Oak Ridge, Tenn., Sept. 23, 1977.

"Multiphoton Ionization," Department of Physics, Auburn University, Auburn, Ala., Oct. 21, 1977.

"Laser-Induced Inelastic Processes in Atom-Atom Collisions," Division of Electronic and Atomic Physics, American Physical Society, Knoxville, Tenn., Dec. 5-7, 1977.

"Energy Pathways: Laser Fluorescence and Laser Ionization," DBER Physical and Technological Programs Contractors' Workshop on Advanced Laser Technology for Pollutant Measurements, Oak Ridge National Laboratory, Oak Ridge, Tenn., Feb. 9-10, 1978.

M. G. Payne and C. W. Choi

"Collisional-Induced Resonances in the Two-Photon Ionization of Excited State Atoms by Strong Laser Fields," International Conference on Multiphoton Processes, Rochester, N. Y., June 6-9, 1977.

"Three-Photon Ionization of Atoms near a Two-Photon Resonance," International Conference on Multiphoton Processes, Rochester, N. Y., June 6-9, 1977.

- M. G. Payne, C. W. Choi and M. H. Rayfeh
 "Laser-Induced Collisional Excitation Transfer," International Conference on Multiphoton Processes, Rochester, N. Y., June 6-9, 1977.
- P. T. Perdue, R. W. Leggett and F. F. Haywood
 "A Technique for Evaluating Airborne Concentrations of Daughters of Radon Isotopes," Natural Radiation Environment III Symposium, Houston, Tex., Apr. 23-28, 1978.
- J. K. Poggenburg
 "Nuclear Reactions and Reactor Production of Radioisotopes," IAEA Inter-Regional Training Course on the Preparation, Control and Utilization of Radiopharmaceuticals, University of Southern California, Los Angeles, Calif., July 19-20, 1977.
- R. H. Ritchie
 "The Penetration of Swift Ion Clusters in Matter," Department of Physics, University of Wisconsin, Madison, Wis., Apr. 1, 1977.
 "The Penetration of Swift Charged Particles in Matter," Department of Physics, University of Alabama, Huntsville, Ala., Apr. 12, 1977.
 "Ion Cluster Penetration Phenomena," Department of Physics, University of Sussex, Sussex, England, June 14, 1977.
 "Collective Effects in Charged Particle Track Formation," Department of Physics, University of Delaware, Newark, Del., Dec. 7, 1977.
 "Plasmons, Molecules and Clusters," Department of Physics, Washington University, St. Louis, Mo., Jan. 25, 1978.
- R. H. Ritchie, R. W. Hamm, H. A. Wright, J. E. Turner, W. K. Garrett and F. W. Hecker
 "Transport Parameters of Swift Electrons in Liquid Water," 25th Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.
- P. S. Rohwer
 "Summary of the Current Applications of Models for Calculating the Dose to Man from Internal and External Modes of Exposure," A Workshop of Models Used for the Environmental Assessment of Radionuclide Releases, Gatlinburg, Tenn., Sept. 6-9, 1977.
- D. L. Shaeffer
 "A Model Evaluation Methodology," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., May 1977.
 "AQUAMOD--A Computer Code for Simulating the Bioaccumulation and Transport of Radionuclides in Aquatic Environments," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.
- V. E. Shank, C. E. Easterly and T. W. Oakes
 "Radiological Health Implications in Developing Fusion Power," 105th Annual Meeting of the American Public Health Association, Washington, D. C., Oct. 30-Nov. 3, 1977.
- W. S. Snyder, S. R. Bernard, M. R. Ford and J. W. Poston
 "A Review of the Metabolic Models and the Dosimetry Used for Internal Dose in WASH-1400," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.
- W. S. Snyder, M. R. Ford and G. G. Warner
 "Distribution of Dose within the Body from a Photon Emitter Present in an Organ," International Congress of the International Radiation Protection Association, Paris, France, Apr. 24-30, 1977.
- W. S. Snyder and J. E. Turner
 "Review and Assessment of Problems in the Dosimetry of Rn and Rn Daughters," 25th Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.
- D. P. Spears, J. D. Allen, Jr., V. E. Anderson, R. D. Birkhoff, C. Hiesemann, H. H. Hubbell, Jr., and R. Zauper
 "Scattering of Low-Energy Electrons on Micron-Size Pinholes," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

7. 5. 1977

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"International Conference on the Environmental Impact of Nucleonics," New York, 1977. University of Florida, Gainesville, Fla., Nov. 14, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"Separation of the Environmental Impact of Nuclear Industry 1975-2000 and Estimated Radiological Doses to the Population," American Nuclear Society, San Francisco, Calif., Nov. 27-Dec. 2, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"Signal Detection and Fast Fourier Transform of Molecules," Atomic and Molecular Physics, Department of Physics, New York University, New York, Nov. 14, 1977.

"The Role of the Health Physicist in the Development of Safe Energy Sources," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

T. Vo-Dinh and R. B. Gammon

"Recent Developments in Multicomponent Analysis by Room-Temperature Phosphorescence," Chemical Instrumentation Award Symposium, American Chemical Society Meeting, Anaheim, Calif., March 1978.

G. G. Warner

"Absorbed Doses during Breast X-Ray Therapies," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

R. J. Warrack, J. A. D. Stockdale and R. N. Compton

"Formation of UF_6 by Impact of Cs Atoms," 13th Annual Gaseous Electronics Conference, Palo Alto, Calif., Oct. 18-21, 1977.

"Collisional Ionization of Fast-K Atoms by CH_3CN ," Division of Electronic and Atomic Physics, American Physical Society Meeting, Knoxville, Tenn., Dec. 5-7, 1977.

L. C. Washburn, T. T. Sun, B. W. Wieland, R. L. Hayes, G. A. Andrews, K. F. Hünner, W. D. Gibbs, T. A. Butler and I. R. Collman

"C-11 Labeled Amino Acids: DL-Tryptophan, ACBC; Clinical Studies: ACPC, Valine," Annual Meeting of the Society of Nuclear Medicine, Chicago, Ill., June 20, 1977.

A. P. Watson

"Disruption of Macronutrient Pools in Forest-Floor Litter near a Lead Mining-Smelting Complex," Department of Botany, University of Toronto, Toronto, Ontario, Canada, Nov. 9, 1977.

S. B. Watson, W. S. Snyder and M. R. Ford

"TIMED: A Computer Program for Calculating Cumulated Activity as a Function of Time after Deposition," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-8, 1977.

M. W. Williams and E. T. Arakawa

"Polarization Produced by Grazing Incidence Monochromators," American Physical Society, Miami, Fla., Nov. 21-23, 1977.

J. P. Witherspoon

"Environmental Impact of the Nuclear Fuel Cycle," Tennessee Technological University Aquatic Station, Smithville, Tenn., June 28, 1977.

"Release of Radioactivity from Uranium Mills and Radwaste Treatment Costs," American Nuclear Society, San Francisco, Calif., Nov. 30, 1977.

B. F. Witherspoon

"Radiation Dose: From the Nuclear Fuel Cycle," Physics and Radiation Protection Course, Oak Ridge Associated Universities, Oak Ridge, Tenn., Apr. 5, 1978.

A. D. Williamson

"Resonant Two-Photon Ionization of Atomic Cesium," International Conference on Multiphoton Processes, Rochester, N. Y., June 6-9, 1977.

"Laser Applications to Molecular Spectroscopy," Naval Research Laboratory, Washington, D. C., Jan. 3, 1978.

"Multiphoton Ionization of Molecular Iodine," Annual Meeting of the American Chemical Society, Anaheim, Calif., Mar. 14-15, 1978.

"Multiphoton Ionization Spectroscopy," Chemical Physics Seminar, Stanford Research Institute, Menlo Park, Calif., Mar. 22, 1978.

A. D. Wright

"Present States of Computational Methods Applied to Pion Radiotherapy," European Center for Nuclear Research (CERN), Geneva, Switzerland, June 30, 1977.

"Calculations of Dose Distributions for Treatment Planning for Pion Radiotherapy," Radiobiology Institute, University of Zurich, Zurich, Switzerland, July 13, 1977.

"Monte Carlo Calculations for Pion Dose Distributions," German Nuclear Research Center, Karlsruhe, Germany, July 27, 1977.

"PION 1: A Monte Carlo Computer Code for Calculating Dose Distributions for Pion Beams," University of Kuppental, Kuppental, Germany, Aug. 4, 1977.

H. A. Wright, R. A. Hamm and G. E. Turner

"Monte Carlo Techniques," AAPM Charged Beam Task Group Workshop, Los Alamos, N. M., Mar. 16-19, 1978.

H. A. Wright, R. A. Hamm, G. E. Turner, R. M. Pitman and R. Katz

"Following Down Spectra from Electrons in Liquid Water," 25th Meeting of the Radiation Research Society, San Juan, Puerto Rico, May 7-12, 1977.

M. G. Valcintas and G. Salicrú

"A New Method of Dose Determination in CT," 22nd Annual Meeting of the Health Physics Society, Atlanta, Ga., July 3-6, 1977.

"Detail Dose Measurements on EMI Computerized Tomography," Annual Meeting of the American Association of Physicists in Medicine, Cincinnati, Ohio, August 1977.

"Evaluation of Patient Dose in CT," International Symposium on Computerized Tomography, Miami, Fla., March 1978.

J. P. Ybong

"Laser Spectroscopy and the Specific Detection of Single Atoms," American Chemical Society, Cleveland, Ohio, May 25, 1977.

"Analytical Applications of Resonance Ionization Spectroscopy," DBER Physical and Technological Programs Contractors' Workshop on Advanced Laser Technology for Pollutant Measurement, Oak Ridge National Laboratory, Oak Ridge, Tenn., Feb. 9-10, 1978.

Awards

F. O. Hoffman

Award of distinction, Section Editor, Environmental Effects, *Nuclear Safety*, 1978 Communication Competition Award, Society for Technical Communication.

G. S. Hurst, M. H. Mayfeh, J. P. Young, M. G. Payne and E. B. Wagner

IR-100 Award, *One-Atom Detector* (1977)

Division Manpower Distribution and Organization

HEALTH AND SAFETY RESEARCH DIVISION

Manpower Distribution as of April 30, 1978

Department of Energy Programs	Staff	Loanees from Other ORNL Divisions	Consultants	Postdoctoral Fellows, Students and Guests	Total
Ag - Energy Supply/Research and Technology Development	12	2	1		15
CI - Conservation/Utilities	5		2	5	12
GK - Environmental Research and Development	43	12	11	5	71
HK - General Science and Basic Research	20	1	6	1	28
KN - Decontamination and Decommissioning	16				16
Work-for-Others	13	3	1	1	18
Total	109	18	21	12	160

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160. M. Brandt, Physics Department, New York University, New York, NY 10003
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164. A. Brodsky, Office of Standards Development, U. S. Nuclear Regulatory Commission, Washington, DC 20555
165. F. A. L. Burch, Department of Medical Physics, University of Leeds, General Infirmary, Leeds 1, England
166. George Burger, Gesellschaft für Strahlen und Umweltforschung, 8042 Neuherberg, Post Oberschleissheim, Inghstadtter Landstrasse 1, Munich, Federal Republic of Germany
167. J. S. Burton, 1585, 650 East Sunset Road, Las Vegas, NV 89101
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181. D. R. Davy, AAEA Research Establishment, Private Mail Bag, Sutherland, NSW, Australia
182. L. J. Deal, Associate Director for Field Operations, Division of Operational and Environmental Safety, U. S. Department of Energy, Washington, DC 20545
183. J. Dennis, Head, Health Physics Department, National Radiological Protection Board, Harwell, Didcot, Berks., England
184. G. W. Dolphin, National Radiological Protection Board, Bldg. 566, Harwell, Didcot, Oxfordshire, OX11 0RQ, England
185. Keith Eckerman, Radiation Assessment Branch, U. S. Nuclear Regulatory Commission, Washington, DC 20555
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