MASTER

RADIOLYSIS STUDIES ON REACTIVE INTERMEDIATES

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ABSTRACT

Research highlights are briefly reviewed concerning studies of excess and solvated electrons, development of new electron spin resonance methods for maximizing the geometrical information about the surroundings of paramagnetic species in disordered systems, atom and ion solvation, and studies on other reactive intermediates. Titles of 155 research publications and 182 scientific talks presented on these areas are given.

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RADIOLYSIS STUDIES ON REACTIVE INTERMEDIATES

The efficient utilization and storage of energy requires an incisive understanding of energetic chemical reactions. In order to optimize and control chemical reactions it is necessary to develop a thorough knowledge of the physical and chemical characteristics of energetic reaction intermediates.

During the tenure of this contract we have carried out a rather incisive study of a variety of physical and chemical characteristics of excess electrons in condensed media and in particular on the solvation of these excess electrons in a variety of aqueous and organic systems. The solvated electron is one of the most important reactive intermediates in high energy reactions that has been studied in recent years and our work has helped to rather well characterize both the experimental and theoretical characteristics and properties of these reactive species. Since solvated electrons are often studied best in disordered media such as glassy solvents, our laboratory has also been quite active in the development of several advanced electron spin resonance methods for the study of radical environments in disordered systems. The key focus here is on the environment of a radical or radical ion rather than on the structure of the paramagnetic species itself. This has culminated recently in the development and application of electron spin echo methods to the study of radical environments which is rapidly becoming a popular technique. The development of these methods has allowed us to study ion and atom solvation in a more detailed way than has hitherto been possible. In addition we have carried out a variety of other studies on reactive intermediates mainly by using electron spin resonance techniques. Two books have also been published both on solvated electrons and on new time domain electron spin resonance techniques during the tenure of this contract.

During the ten and a half year term of this contract a hundred and fifty five research papers have been published on the above topics. In addition one hundred and eighty two invited lectures on topics related to these research topics have been presented. Also, nine Ph.D. theses have been completed. The detailed results

arising from this contract are fully reported in the scientific publications. In this report we briefly organize the areas studied and highlight some of the accomplishments in Section 1. In Section 2 contains a full list of the research publications, Section 3 contains a list of the scientific talks presented, and Section 4 contains a list of Ph.D. theses completed.

1. Research Highlights

Reference numbers indicated below refer to the numbered research publications listed in Section 2.

1.1. Studies of Excess and Solvated Electrons

Knowledge of excess electrons in condensed media is a fundamental and important chemical problem. Sudden injection of charge into a dielectric may lead to stable delocalized or localized electron states. The energy states and transport properties of excess electrons in condensed media determine the insulating properties of dielectrics necessary for electrical storage and transmission, electronic properties of amorphous semiconductors as well the limitations on chemical reactions involving electron tunneling and ionic solvation. Localized electrons are also important intermediates in photo or chemically generated charge transfer reactions, electrochemistry, catalysis, model photosynthetic systems and radiation processes. A detailed knowledge of the physical and chemical characteristics of excess electrons is thus essential to the efficient utilization of such diverse reaction types for energy production, use and storage.

When an excess electron is first injected into a dielectric medium it remains delocalized or becomes localized depending upon its energy in the conduction state relative to its energy in the localized state. Conduction state energies have been measured directly in various alkane liquids and a model has been developed to relate these energies to values for the conduction state energy in glassy matrices.^{59,77}

In general except for methane and a few other hydrocarbons with a

symmetrical molecular structure the electron becomes localized. In polar liquids and solids the electron also becomes localized. Once the electron becomes localized the question then is what additional rearrangement occurs in the electron's first solvation shell to reach a stable equilibrium state. This is called the process of solvation and we have been able to study it kinetically by using pulse radiolysis techniques,^{17,20,67,76,106,107} laser photo-ionization methods,^{114,131} and low temperature radiolysis at 4K.^{49,136} In general the process of electron solvation can be understood in terms of simple dipole orientation of the first solvation shell molecules. We have been able to develop a simple theory for the time scale of this dipole orientation in terms of the magnitude of the molecular dipole which successfully predicts the time-scale and the trends with molecular structure that are found experimentally.^{53,55,88} Several reviews of the process of electron localization and solvation have also been published.^{50,115,140,141}

A systematic study of the energy level structure of solvated electrons in matrices of varying polarity was carried by combining optical absorption and photoconductivity measurements. This allows one to determine whether the upper state is bound or free in the condensed medium. We were the first to carry out successful photoconductivity studies on polar aqueous systems,² and carried out a comprehensive series of studies on aqueous systems.^{5,6,9,16,60} Subsequently, systems of decreasing polarity were studied including alcohols¹⁰² ethers,^{22,24} amines,³⁰ and alkanes.^{30,41} Most of these studies were oriented toward solvated electrons in their equilibrium state with respect to the first solvation shell molecules. More recently we have been able to study presolvated molecules which can be trapped by irradiation at temperatures as low as 1.6K in polar aqueous and alcoholic matrices.^{117,120,125,130,152} Several reviews of energy level determinations of solvated electrons in various matrices have been published.^{10,33,35,50,56,64} A comprehensive picture of the energy level structure and its dependence upon matrix polarity has

emerged from this work.

Since localized electrons rearrange their local environment in the process of solvation to reach an equilibrium structure, a key question for their characterization is to determine this structure. Since the solvated species is typically in a disordered system this structural determination is very difficult. However, we have devised a number of methods utilizing electron spin resonance in disordered glassy matrices which have allowed the solvated electron structure to be determined for the first time. These methods include matrix ENDOR,²⁹ analysis of forbidden spin flip satellite lines,⁴⁶ analysis of second moment electron spin resonance lineshapes,⁷⁰ and most importantly, analysis of electron spin echo modulation. These methods have been used to determine the solvated electrons' geometrical structure in various glassy matrices over a range of polarities including aqueous glasses,^{29,46,74,75,85,101} alcohol glasses,^{137,143,151} ether glasses,^{70,134} and alkane glasses^{91,147} This work has recently been reviewed.¹⁵⁰ Not only has the specific first solvation shell structure been determined in each case but also the structure has indicated what type of interactions are the most important in creating it. In the most polar matrices very strong chemical bonding or exchange forces seem to dominate the solvation shell structure, in less polar matrices like alcohols a simpler electron charge interaction with a molecular dipole seems to be the dominant interaction, whereas for relatively nonpolar matrices like ethers and alkanes the dominant interaction appears to be the electron charge interacting with the molecular polarizability. These studies have given the first comprehensive picture of the actual geometrical structure of solvated electrons.

Coincident with our experimental studies of the energy level structure and the geometrical structure of solvated electrons we have also developed a theoretical picture of these aspects. This theory has been called the semicontinuum model because it is based on a semicontinuum type of potential which involves both short range charge dipole and charge polarizability interactions and with the first solvation shell molecules and longer range polarizability interactions with the remaining

medium molecules.^{12,37} The model has been most definitive and successful when applied to energy level structure in polar matrices. It has been able to predict optical absorption bands in both aqueous matrices^{12,37} and alcohol matrices.^{14,37} It has also been able to successfully predict the spectral shifts observed during the solvation process itself in terms of dipole reorientation²⁶ and to predict pressure effects on the spectra.³¹ Bound-free transitions can also be studied within the theoretical framework.⁴⁵ The model uses hydrogenic wave functions for simplicity but we have also investigated the effects of using Gaussian wave functions.⁵⁸ Finally, the model predicts the stability of dielectrons⁴⁰ which have been detected in the solid phase but not yet in the liquid phase.

More recently we have attempted to develop a theoretical model for electron solvation nonpolar matrices like alkanes. Our first model was a micro dipole model which considered bond dipole interactions with the electron⁶¹ but this has been shown to be inconsistent with electron spin echo studies of the geometrical structure⁷ and has been replaced by a structured semicontinuum model⁹⁸ which emphasizes charge polarizability interactions and has proved quite successful. It has been used to predict the optical absorption spectra of solvated electrons in alkanes⁹⁸ and alcohol-alkane mixtures,⁸⁷ the temperature dependence of solvated electron bands,¹²¹ and the ground state energy in terms of predicting whether or not the electron is localized.¹¹⁹ The semicontinuum model for polar matrices has been reviewed in some detail⁵⁰ and more recently we have written a comprehensive review of all models for solvated electron energy level structure and geometry including our own.¹⁴² In general, these models are relatively successful in terms of explaining the energy level structure and the effects of various experimental parameters on the energy level structure or the optical absorption spectra. However, the models are less successful in predicting the geometry of the solvated electron now that that has been determined experimentally as explained above. It fails to predict the structure in very polar systems like aqueous matrices where one has

a bond dipole oriented first solvation shell structure instead of a molecular dipole oriented structure. However, the semicontinuum models do predict a molecular dipole oriented structure which is seen for alcohol.

Trapped electrons in glassy matrices may be photoexcited to a conductive state in which they are characterized by a mobility. We used a time-of-flight method to make the first measurements of drift mobilities of photoexcited electrons in aqueous matrices,^{28,48,60,135} and also extended such measurements to organic glasses.⁶² Drift mobilities may, however, be subject to trapping effects and other artifacts,¹³⁵ so we developed special apparatus to measure the true microscopic mobility or Hall mobility. This necessitated the development of a double modulation measurement technique satisfactory for high impedance matrices.^{21,25} This led to the first successful measurements of Hall mobilities of photoexcited electrons in aqueous matrices.^{18,48} The Hall mobility was found to be surprisingly high for a disordered matrix and supported the idea of true conduction states for electrons in these media. Short reviews of this work have appeared.^{33,35,56}

Other workers have used time-of-flight and conductivity methods to measure the mobility of electrons in various liquid alkanes. We made measurements of the conduction electron level in liquid methane and ethane⁵⁹ and showed how this information could be extrapolated to values of this conduction electron energy level in glassy matrices.⁷⁷ This serves to help explain the magnitude of the electron mobilities found in these systems. In related theoretical studies we were able to show how the electron mobility may be estimated in liquid alkanes²³ and we developed a criterion for electron localization in liquid alkanes of varying molecular structure.⁶⁸

Electron reactivity has been studied in less detail than have the above topics. We made several studies of the scavenging effects of electrons in glassy matrices which addressed problems of the electron energy dependence on the scavenging efficiency³ and the temperature dependence of the scavenging efficiency.^{93,132}

The effect of hole traps on the efficiency of electron trapping in aqueous systems was also studied.³² Our most detailed studies in this area, however, have been on the process of charge separation following photoionization of an organic molecule in aqueous or organic glassy matrices. This process can be studied by measuring various characteristics of the recombination luminescence due to recombination of the electron and the parent cation in both liquids^{73,82,153,154,155} and in glassy matrices.^{57,72,80,104,113} In particular the temperature dependence of the recombination fluorescence allows one to distinguish between electron tunneling and electron diffusive recombination as well as to evaluate the effect of degrees of solvation on the efficiency of the recombination.¹⁰⁴ We also were able to demonstrate the first clear example of photoionization energy dependence on the initial decay rate of electron-cation recombination.⁸⁰

1.2. New ESR Methods for Studies of Radicals in Disordered Systems

One general direct method for examination of short-lived, reactive chemical intermediates is matrix trapping. Matrix trapping is typically most efficient in disordered matrices. Therefore we have sought to develop methods to maximize the chemical information available from trapped species in disordered matrices where spectroscopic resolution is often poor. Electron spin resonance (ESR) is quite specific for detecting radicals and radical ions so we have concentrated on the development of new ESR methods to study such species in polycrystalline and glassy matrices.

We have used continuous wave (cw) saturation methods for the study of radical environments and the spatial distribution of radicals. When radicals and radical ions are produced by ionizing radiation their spatial distribution is an important question since the ionizing radiation is deposited nonuniformly in liquids and solids. We have studied the spatial distribution and have shown it to be nonuniform, depending upon the polarity of the matrix for trapped electrons in a variety of organic glasses¹⁵ and also for the concomitant radicals produced with the electrons

in aqueous and organic glasses.²⁷ These two species turn out to have different spatial distributions. In addition, we have studied the effect of the type of ionizing radiation on the spatial distribution of radicals in polymethylmethacrylate¹⁹ and have also studied the effect of thermal decay of the radicals in this polymer on their spatial distribution.¹¹ Saturation studies have also been used to probe the different types of environments of silver atoms trapped in aqueous matrices.¹ We have critically examined the analysis of saturation curves⁵⁶ and have extended the analysis to the common experimental case in which magnetic field modulation is used.⁷⁹ We have also shown how the differential saturation of allowed and forbidden ESR lines may be used to distinguish radial and angular modulation mechanisms for electron spin lattice relaxation⁸¹ and have applied this to trapped hydrogen atoms⁹² and used it to look for correlations between spin lattice relaxation and thermal decay of radicals.⁹⁵

The electron spin lattice relaxation time is measured indirectly by cw saturation measurements. In order to measure it directly we have used a pulsed saturation recovery method and have designed and built a spectrometer for such studies.¹⁰⁰ On measuring the spin lattice relaxation time versus temperature for solvated electrons and small radicals in disordered systems we found that the relaxation was much more efficient at very low temperatures than conventional theories could account for. Therefore, we developed a new theory based on the modulation of the electron nuclear dipolar interaction by tunneling modes of surrounding matrix nuclei which are presumed to be of high density in disordered systems and dominant at low temperatures, typically below 20K.¹⁰⁰ Extensive experiments on the spin lattice relaxation time temperature dependence for trapped electrons and hydrogen atoms in aqueous and organic glasses,¹⁰⁸ for silver atoms in polycrystalline aqueous and glassy organic matrices,¹¹² for methyl radicals in glassy organic matrices,¹²² have added support to this new theoretical relaxation mechanism. This work has been reviewed specifically¹³³ and more generally with

respect to other types of electron spin relaxation mechanisms in nonionic solids.¹²⁷

More subtle ESR techniques are required to study electron spin-electron spin interactions. These interactions can be studied relatively directly by electron electron double resonance or ELDOR. By using ELDOR we discovered cross saturation between trapped electrons and radicals in organic glassy matrices.^{34,42} We also found that a proper analysis of the ELDOR lineshapes allows determination of the cross relaxation time³⁹ and allows one to evaluate the importance and mechanism of spin diffusion.¹⁰³ By carrying out a theoretical analysis of the relationship between dipolar cross relaxation times and dipolar interaction distances it has been possible to determine these distances between different types of radicals produced in the same glassy matrix.⁹⁴ The work on spin-spin interaction studied by ELDOR has been reviewed recently.¹¹⁰

In order to study the geometry of the surroundings of radicals in disordered matrices and more specifically to determine solvation shell structures of paramagnetic ions and radicals we have developed four different ESR methods.

Electron nuclear double resonance or ENDOR has been used for some time to study very weak hyperfine interactions including those of matrix nuclei around a paramagnetic species. However, in disordered systems one generally only has a single line called the matrix ENDOR line and it is necessary to develop some sort of a lineshape analysis to obtain information from this. We have carried out analyses of the matrix ENDOR signals of trapped electrons in various glassy matrices²⁹ and for trapped hydrogen atoms in both polycrystalline and glassy matrices.³⁶ Although some information is obtained from a matrix ENDOR analysis more information is usually obtained from the following methods.

Allowed ESR transitions occur with no change in the nuclear spin state, however, in some cases forbidden ESR transitions in which the nuclear spin state also changes are detectable. These are often called forbidden spin flip satellite lines. We were able to detect these transitions for the first time for solvated

electrons in aqueous matrices by working at a 35 GHz microwave frequency.⁴⁶ Subsequently, we developed the theory of these lines to a greater degree than before which allows one to determine the number and distance of the interacting nuclei that contribute to these forbidden transitions.⁶⁵ This new analysis has been applied to trapped hydrogen atoms,⁶⁵ solvated electrons in aqueous matrices,⁷⁴ and to solvated electrons in methanol glass where it was necessary to carry out ESR experiments at 70 GHz in order to see the satellite lines.¹³⁷ In addition, we carried out a satellite line analysis on the PO_3^{2-} radical in a single crystal to test our analysis procedure.⁷⁸ This method of analyzing forbidden spin flip satellite lines is of considerable use since it gives both the number and distance of the surrounding magnetic nuclei around the paramagnetic species. Its limitation is that in many cases the satellite lines are simply not resolvable, so it is a specific technique of considerable interest when these transitions are detectable.

A more general technique is to use a second moment lineshape analysis of the ESR lines in the presence of varying degrees of isotopic substitution for the magnetic nuclei that are contributing to the unresolved hyperfine interaction comprising the bulk of the linewidth. We have developed a theory for this type of analysis in disordered systems⁵¹ and have applied to solvated electrons in alkaline ice using deuterium substitution⁷⁴ and oxygen-17 substitution.⁸⁵ We have also used this second moment analysis to study the solvated electrons produced in sodium bombarded ice condensates¹⁰⁰ and solvated electrons in a series of specifically deuterated 3-methylpentane glass.¹⁴⁷ The second moment analysis is rather general but it does not give separate information about the number and the distance of surrounding magnetic nuclei around the paramagnetic species. Instead, one must assume either a number or a distance to obtain the other parameter. Thus, this analysis, although more general, does not give as much detail as the satellite line analysis discussed above.

The most general and most detailed technique that we have devised is to carry

out pulsed ESR experiments known as electron spin echo spectrometry in which modulation of the electron spin echo decay envelope is observed. Proper analysis of this modulation can give extremely detailed information about solvation shell structure and the geometry of radical environments. A generalized ratio analysis method for this type of data has been developed.¹³⁴ In addition the effects of phase reversal and quadrupole interaction on the electron spin echo modulation pattern have been studied theoretically.^{86,99} We have built a state-of-the-art high power electron spin echo spectrometer¹³⁹ and have carried out a detailed series of studies on the geometrical structure of solvated electrons in matrices of varying polarity including aqueous matrices,^{43,75} ethanol matrices,^{143,151} ether matrices,^{70,134} and alkane matrices.⁹¹ We have also studied the solvation of silver atoms in ice^{116,138} and in methanol,¹³⁹ as well as the solvation of large anions¹⁴⁵ and cations.¹⁴⁶ Finally, we have used electron spin echo modulation methods to initiate studies on radical orientation on surfaces.¹⁴⁴ The method of electron spin echo modulation analysis has been comprehensively reviewed.¹²⁶ It appears to be a method that is gaining wide acceptance which will be used in a variety of areas in the future.

1.3. Studies of Atom and Ion Solvation

Hydrogen atoms can often be formed and stabilized by radiolysis of acidic aqueous matrices at low temperature. We have studied the nature of the hydrogen atom surroundings or traps by electron nuclear double resonance studies³⁶ and by forbidden spin flip satellite line analyses of electron spin resonance spectra.⁶⁵ In acidic aqueous matrices we have shown that four surrounding hydrogen atoms constitute the trapping site. We have also used differential saturation to show that the spin lattice relaxation of trapped hydrogen atoms is dominated by an angular modulation mechanism.⁹² In addition we have suggested a correlation between the spin lattice relaxation times and the thermal decay rate of trapped

hydrogen atoms⁹⁵ which relates to the rigidity of the first solvation shell of these trapped hydrogen atoms.

In general, hydrogen atoms are not trapped or stabilized in organic matrices at 77K however, we have discovered that in mixed matrices of alcohol and water hydrogen atoms can be trapped and that the efficiency of trapping is related to the excess thermodynamic functions of mixing.⁴

Perhaps the most interesting example of atom solvation is that of silver atom solvation in aqueous systems.— We have studied this rather extensively^{13,105,116,123,124,102,138} and have shown that silver atoms initially formed by reaction of an electron with a silver atom at 4K are not in an equilibrium environment. Brief warming to 77K causes one water molecule to reorient to form a strong hydrogen bond with the silver atom in a solvation process. Once the silver atom is solvated and its temperature is lowered to 4K the process can be reversed or desolvation can occur by optical excitation. The exact geometrical changes involved in these solvation and desolvation processes has been worked out by the various new electron spin resonance methods applicable to disordered systems. The solvation of silver atoms in methanol was also studied in detail but the changes were much less dramatic than in the case of aqueous matrices.¹³⁹ However, in ethanol-water mixed matrices a number of interesting effects occur in the first solvation shell of silver atoms as the mole fraction of ethanol is increased.¹⁴⁹

The solvation shell structure of tetracyanoethylene anion has been studied in detail for solvation in methanol, acetone and dimethylsulfoxide. In methanol the first solvation shell consists of four molecules arranged tetrahedrally around the anion while in acetone and dimethylsulfoxide only two molecules seem to be required for the first solvation shell.¹⁴⁵ The solvation of cupric ion has also been studied in methanol and acetone matrices. In both cases there are six first solvation shell molecules with their molecular dipoles oriented towards the cupric ion and arranged approximately octahedrally.¹⁴⁶ In mixed matrices of methanol and

acetone it has also been possible to study preferential solvation quantitatively for the first time by using electron spin echo modulation methods.¹⁴⁶ It was found that methanol preferentially solvated cupric ion with a 78% greater probability than acetone over a wide mole fraction range.

1.4. Studies on other Reactive Intermediates

Several studies have been carried out using the spin trapping method in which a nitron is added to a reaction mixture in order to react with a transient radical to produce a more stable nitroxide radical which can be observed by electron spin resonance. We have used this technique to demonstrate that hydrogen atoms are indeed formed in alkane radiolysis⁵² although they cannot be seen directly by transient methods except in methane. We also found that hydrogen atoms are formed in the radiolysis of fluorinated alcohols⁹⁷ and have detected cyanoalkyl radicals in the radiolysis of liquid nitriles.⁹⁰ Spin trapping has also been used in the solid state to study the initial radicals produced in irradiated methanol⁵⁴ and their changes as the irradiation temperature is changed.⁸⁴

The identity of several organic radical intermediates in radiolysis reactions have been determined by electron spin resonance. The anisotropic hyperfine tensor of the radical in irradiated hexatriacontane has been determined.⁴⁴ The CHCl_2 radical has been shown to be the predominant radical formed in gamma irradiated CH_2Cl_2 .⁶⁹ The radicals produced as a function of temperature in the radiolysis of methyltetrahydrofuran in adamantane have been studied in some detail.⁸³ In some cases pairs of radicals are formed in irradiated solids which can be detected by their large dipolar interactions. We have studied the thermal decay of radical pairs in several different systems.⁶³

In aqueous systems we reinvestigated a report of the formation of H_3O^+ and found it to be fallacious.³⁸ We also studied the O^- radical in irradiated alkaline ice glass and by using oxygen-17 confirmed the identification of this species from

its hyperfine tensor.

By using laser flash photolysis we have studied the decay of doublet excited states of thiocyanate complexes of chromium-III.¹¹¹ We have also made a detailed kinetic model of carbon dioxide radiolysis and studied it numerically for a variety of initial conditions.¹⁰⁹

1.5. Books and Miscellaneous

During a trip to Japan in 1974 the author visited a number of laboratories in radiation chemistry and wrote an analysis of radiation chemistry research in Japan.⁷¹

Two books have been published. One is entitled "Electron Solvent and Anion Solvent Interactions"⁸⁹ which deals with the various problems of electron localization and solvation. The second book "Time Domain Electron Spin Resonance"¹²⁸ gives a current picture of various time domain methods in ESR with emphasis on electron spin echo methods.

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3. Scientific Talks Presented

The following 182 talks were given on DOE supported research during the contract period at scientific conferences and by invitation at a number of universities and research institutes.

- T-1 Photoionization of Radiation Produced Trapped Electrons, Chemistry Seminar, Utah State University, Logan, Utah, January 26, 1970.
- T-2 EPR and Radiation Chemistry, Chemistry Seminar, University of Michigan at Flint, Michigan, February 9, 1970.
- T-3 Photoionization of Trapped Electrons, Chemistry Seminar, Notre Dame University, South Bend, Indiana, February 19, 1970.
- T-4 Photoionization of Radiation Produced Trapped Electrons, Chemistry Seminar, University of Houston, Houston, Texas, March 2, 1970.
- T-5 Photoionization of Radiation Produced Trapped Electrons, Chemistry Seminar, Texas A and M University, College Station, Texas, March 3, 1970.
- T-6 Trapped Electrons in Irradiated Glasses, Seminar, Institute for Physics Research, Rio de Janeiro, Brazil, March 6, 1970.
- T-7 A Semicontinuum Model for the Hydrated Electron, K. Fueki, D. Feng and L. Kevan, Intl. Meeting on Primary Radiation Effects in Chemistry and Biology, Buenos Aires, Argentina, March 10-14, 1970.
- T-8 Trapped Electrons in Irradiated Frozen Systems, L. Kevan, 3 M Photochemistry Symposium, St. Paul, Minn., May 4-6, 1970.
- T-9 Trapped Electrons on the Rocks, Seminar, University of Minnesota, Minneapolis, Minn., May 6, 1970.
- T-10 Trapped Hydrogen Atoms in Alcohol-Water Mixtures, L. Kevan, Progress and Problems in Contemporary Radiation Chemistry Conference, Mariánské Lázně, Czechoslovakia, June 22-25, 1970.
- T-11 Mobile Electron Reactions in Frozen Aqueous Matrices, L. Kevan, Progress and Problems in Contemporary Radiation Chemistry Conference, Mariánské Lázně, Czechoslovakia, June 22-25, 1970.
- T-12 Radiolytic Energy Transfer Induced by Rare Gases, L. Kevan, Fourth International Congress of Radiation Research, Evian, France, June 29-July 4, 1970.
- T-13 Photoconductivity of Trapped Electrons in Ice, L. Kevan, Danish Radiation Chemistry Conference, Danish AEC Riso, Roskilde, Denmark, September 11, 1970.
- T-14 Photoconductivity in γ -Irradiated Alkaline Ice, I. Eisele and L. Kevan, National Amer. Chem. Soc. Meeting, Chicago, Illinois, September 13-18, 1970.

- T-15 Positive and Negative Ion-Molecule Reactions in C_3F_8 , T. Su and L. Kevan, National Amer. Chem. Soc. Meeting, Chicago, Illinois, September 13-18, 1970.
- T-16 Photoconductivity and Optical Bleaching in Gamma-Irradiated Organic Glasses, L. Kevan, Second International Symposium on Organic Solid-State Chemistry, Rehovot, Israel, September 14-18, 1970.
- T-17 Energy Levels of Trapped Electrons from Photoconductivity Studies, L. Kevan, Chemistry Seminar, Hahn-Meitner Institute, Berlin, Germany, November 19, 1970.
- T-18 Pulse Radiolysis and Photoconductivity Studies of Trapped Electrons, L. Kevan, Chemistry Seminar, Danish AEC Lab, Roskilde, Denmark, November 26, 1970.
- T-19 Energy Levels of Trapped Electrons from Photoconductivity Studies, L. Kevan, Chemistry Seminar, University of Sheffield, Sheffield, England, November 30, 1970.
- T-20 Trapped Hydrogen Atoms Produced by γ -Rays in Alcohol-Water Mixtures at 77°K, H. Hase and L. Kevan, SE-SW Regional Amer. Chem. Soc. Meeting, New Orleans, Louisiana, December 2-4, 1970.
- T-21 Electron Reactions with Transition Elements in Frozen Aqueous Systems, L. Kevan, Transition Element Symposium at SE-SW Regional Amer. Chem. Soc. Meeting, New Orleans, Louisiana, December 2-4, 1970.
- T-22 Physical Properties of Trapped Electrons, L. Kevan, Chemistry Seminar, University of Utah, Salt Lake City, Utah, January 26, 1971.
- T-23 Temperature Dependence of Photobleaching of Trapped Electrons in Glassy Methyltetrahydrofuran: Location of Energy Levels, D.P. Lin and L. Kevan, National Amer. Chem. Soc. Meeting, Los Angeles, Calif., March 29-April 2, 1971.
- T-24 Pulse Radiolysis and Photoconductivity of Trapped Electrons in Glassy Matrices, L. Kevan, Physics Seminar, National Research Council, Ottawa, Canada, April 22, 1971.
- T-25 Spatial Distribution of Radicals in Proton-Irradiated and Gamma-Irradiated Polymethylmethacrylate, W. Kaul and L. Kevan, Third Tihany Symposium on Radiation Chemistry, Tihany, Hungary, May 10-15, 1971.
- T-26 Thermally Stimulated Conductivity of Gamma-Irradiated Triethylamine Glass, A.K. Munjal and L. Kevan, Regional Amer. Chem. Soc. Meeting, Cincinnati, Ohio, June 6-8, 1971.
- T-27 Development of the Semicontinuum Model for Solvated Electrons, D.F. Feng, K. Fueki and L. Kevan, Regional Amer. Chem. Soc. Meeting, Cincinnati, Ohio, June 6-8, 1971.

- T-28 Drift Mobility of Photoexcited Electrons in Alkaline Ice, L. Kevan, Gordon Conference on Radiation Chemistry, New Hampton, New Hampshire, July 12-16, 1971.
- T-29 Kinetic Transformations of Ag^0 by EPR in Gamma-Irradiated Ice Matrices, B. Bales and L. Kevan, Tenth International Symposium on Free Radicals, Lyon, France, August 31-September 3, 1971.
- T-30 Drift Mobility of Photoexcited Electrons in Gamma-Irradiated Alkaline Ice, T. Huang, I. Eisele and L. Kevan, National Amer. Chem. Soc. Meeting, Washington, D.C., September 12-17, 1971.
- T-31 Mechanism of Electron Trapping in Alcohol Glasses, L. Kevan, Physical Chemistry Seminar, Wayne State University, Detroit, Michigan, October 20, 1971.
- T-32 Pulse Radiolysis of Alcohol Glasses at 77°K: Mechanism of Electron Trapping, L. Kevan, CIC Symposium on Pulse Radiolysis, Pinawa, Manitoba, Canada, October 25-27, 1971.
- T-33 Photo-Conductivity and Mobilities of Photoexcited Electrons in Disordered Systems, L. Kevan, Physics Dept. Seminar, Wayne State University, Detroit, Michigan, January 13, 1972.
- T-34 Matrix ENDOR Linewidths of Trapped Electrons in Glassy Matrices at 77°K, L. Kevan, invited lecture, Varian EPR/Double Resonance Workshop, Palo Alto, Calif., January 26-28, 1972.
- T-35 Pulse Radiolysis, L. Kevan, American Chemical Society Student Affiliates, Wayne State University, Detroit, Michigan, February 2, 1972.
- T-36 Electrons on the Rocks, L. Kevan, Chemistry Seminar, Denver University, Denver, Colo., February 25, 1972.
- T-37 Trapped and Photoexcited Electrons in Amorphous Systems, L. Kevan, Chemistry Seminar, Case Western Reserve University, Cleveland, Ohio, March 2, 1972.
- T-38 Energy Level Structure and Mobilities of Electrons in Aqueous and Organic Glasses, L. Kevan, Plenary Lecture, International Conference on Elementary Processes in Radiation Chemistry, Notre Dame, Indiana, April 4-7, 1972.
- T-39 Matrix ENDOR Linewidths of Trapped Electrons in Glassy Matrices at 77°K, J. Helbert, B.L. Bales and L. Kevan, International Conference on Elementary Processes in Radiation Chemistry, Notre Dame, Indiana, April 4-7, 1972.
- T-40 Ion Chemistry in Solids and Gases, L. Kevan, Chemical Engineering Department Seminar, Wayne State University, Detroit, Michigan, May 30, 1972.
- T-41 Matrix ENDOR of Trapped Electrons, L. Kevan, Gordon Conference on Radiation Chemistry, New Hampton, New Hampshire, July 3-7, 1972.

- T-42 ENDOR and ELDOR of the Simplest Radical Ion - A Trapped Electron, L. Kevan, Gordon Conference on Radical Ions, Tilton, New Hampshire, July 10-14, 1972.
- T-43 Properties of Trapped and Mobile Electrons in Pure Ice and in Alkaline Ice, L. Kevan, International Symposium on the Physics and Chemistry of Ice, Ottawa, Canada, August 14-18, 1972.
- T-44 ENDOR of Trapped Hydrogen Atoms in Sulfuric and Phosphoric Acid Glasses and in Polycrystalline Oxyanion Ices, J. Helbert and L. Kevan, National Amer. Chem. Soc. Meeting, New York, New York, August 28-31, 1972.
- T-45 Electron Spin Double Resonance - ENDOR and ELDOR, L. Kevan, Chemistry Seminar, Western Michigan University, Kalamazoo, Michigan, September 25, 1972.
- T-46 EPR Lineshape Studies of Trapped Electrons in Glassy Matrices, B.L. Bales, J. Helbert and L. Kevan, American Physical Society Meeting, New York, New York, January 29-February 1, 1973.
- T-47 Electron Magnetic Double Resonance Studies in Glassy Matrices, L. Kevan, Chemistry Seminar, University of Colorado, Boulder Colorado, January 29, 1973.
- T-48 Electron Magnetic Double Resonance Applications to Radiation Produced Electrons and Radicals, L. Kevan, Invited Lecture, U.S.-Japan Radiation Chemistry Conference, Catalina Island, Calif., February 4-9, 1973.
- T-49 How Big is a Trapped Electron and are Its Second Solvation Shell Dipoles Oriented?, L. Kevan, Chemistry Seminar University of Notre Dame Radiation Laboratory, South Bend, Indiana, March 15, 1973.
- T-50 ENDOR and ELDOR Magnetic Double Resonance Studies of Trapped Electrons, L. Kevan, Chemistry Seminar, UCLA, Los Angeles, Calif., March 19, 1973.
- T-51 Magnetic Energy Transfer Between Two Different Spin Systems Studied by Electron-Electron Double Resonance, H. Yoshida, D.F. Feng and L. Kevan, American Physical Society Meeting, San Diego, Calif., March 20-22, 1973.
- T-52 Energy Levels and Mobilities of Excess Electrons in Glassy Systems, L. Kevan, Chemistry Seminar, Purdue University, Lafayette, Indiana, March 28, 1973.
- T-53 Second Shell Dipole Orientation Around Trapped Electrons in Aqueous Glasses, L. Kevan, Miller Conference, Portmeirion, Wales, April 9-13, 1973.
- T-54 On the Bound-Free Transition Probability of Trapped Electrons in Polar Matrices, L. Kevan and K. Fueki, Miller Conference, Portmeirion, Wales, April 9-13, 1973.

- T-55 ELDOR Studies of Cross Relaxation and Spin Diffusion in Glassy Matrices, Invited Lecture, L. Kevan, Varian ESR Double Resonance Workshop, Vanderbilt Univ., Nashville, Tenn., June 6-8, 1973.
- T-56 Electron Spin Echo Envelope Modulation from Trapped Electrons and Hydrogen Atoms in Glassy Matrices, M. Bowman, L. Kevan and I. Brown, Natl. Amer. Chem. Soc. Meeting, Chicago, Ill., August 26-31, 1973.
- T-57 Photoconductivity of Trapped Electrons in γ -Irradiated 5M K_2CO_3/H_2O Glass, S. Noda and L. Kevan, Natl. Amer. Chem. Soc. Meeting, Chicago, Ill., August 26-31, 1973.
- T-58 Theoretical Relaxation Rates of Dipole Orientation Around An Excess Electron in Liquid Alcohols, K. Fueki, D.F. Feng and L. Kevan, Fifth Gray Memorial Conference, Univ. of Sussex, Brighton, England, September 10-14, 1973. Invited Lecture
- T-59 Double Resonance Studies of Trapped Electrons in Glasses, Invited Lecture, L. Kevan, Southeastern Magnetic Resonance Conference, Tuscaloosa, Alabama, October 11-12, 1973.
- T-60 The Secret Life of Trapped Electrons as Revealed by Spin Echoes and Electron Magnetic Double Resonance, L. Kevan, Chemistry Seminar, Brookhaven National Lab, Upton, New York, October 17, 1973.
- T-61 Proton Arrangement Around Trapped Electrons in Alkaline Ice from Magnetic Resonance Studies, L. Kevan, Invited Lecture at Symposium on Radiation Chemistry of Aqueous Systems, Moscow, USSR, December 10-12, 1974.
- T-62 EPR Double Resonance of Radicals in Glassy Matrices, L. Kevan, Chemistry Seminar, Institute of Chemical Kinetics and Combustion, Novosibirski, USSR, January 30, 1974.
- T-63 EPR Double Resonance of Radicals in Glassy Matrices, L. Kevan, Physics Seminar, Institute of Semiconductors, Kiev, USSR, February 27, 1974.
- T-64 Structure of Trapped Siberian Electrons, L. Kevan, Chemistry Seminar, Hahn-Meitner Institut, Berlin, Germany, March 11, 1974.
- T-65 Structure of Trapped Siberian Electrons, L. Kevan, Chemistry Seminar, University of Paris, Laboratory of Chemical Physics, Orsay, France, March 18, 1974.
- T-66 Structure of Trapped Siberian Electrons, L. Kevan, Chemistry Seminar, University of Salford, Salford, England, March 20, 1974.
- T-67 Proton Arrangement Around Trapped Electrons in Alkaline Ice and Trapped Hydrogen Atoms in Acid Glass Deduced from a Study of Satellite Lines in Electron Spin Resonance Spectra, M.K. Bowman, L. Kevan and R.N. Schwartz, Central Regional Amer. Chem. Soc. Meeting, Detroit, Michigan, April 22-24, 1974.

- T-68 Electron Conduction Band Levels in Liquid Alkanes, S. Noda and L. Kevan, Central Regional Amer. Chem. Soc. Meeting, Detroit, Michigan, April 22-24, 1974.
- T-69 Effect of Photoionization Energy on the Distance Distribution Between Trapped Electrons and Phenolate Radicals in 10 M Sodium Hydroxide Glass and Alcohol Glasses at 77K, K.K. Ho and L. Kevan, Central Regional Amer. Chem. Soc. Meeting, Detroit, Michigan, April 22-24, 1974.
- T-70 Electron Spin Echoes from Trapped Electrons in Glassy Matrices, Chemistry Seminar, University of Illinois at Chicago Circle, Chicago, IL, May 7, 1974.
- T-71 Electron Spin Echoes from Trapped Electrons in Glassy Matrices, Chemistry Seminar, Argonne National Lab, Argonne, Illinois, June 14, 1974.
- T-72 Trapping Site Structure of Trapped Electrons in Gamma-Irradiated Glassy Methyltetrahydrofuran Deduced from Electron Spin Resonance, Electron Nuclear Double Resonance and Electron Spin Echo Studies at 77K, M.K. Bowman, L. Kevan and I. Brown, Fifth International Congress of Radiation Research, Seattle, Washington, July 14-20, 1974.
- T-73 Ground State Structure of Trapped Electrons in Glassy Matrices, L. Kevan, Fifth International Congress of Radiation Research, Seattle, Washington, July 14-20, 1974. Invited Lecture.
- T-74 Electron-electron Double Resonance Study of Trapped Electrons in Gamma-Irradiated 2-Methyltetrahydrofuran Glass, D.F. Feng and L. Kevan, Fifth International Congress of Radiation Research, Seattle, Washington, July 14-20, 1974.
- T-75 Spectral Shifts of the Solvated Electron in Ethanol and Deuterated Ethanol Glasses at 76K, N.V. Klassen, H.A. Gillis, G.G. Teather, and L. Kevan, Fifth International Congress of Radiation Research, Seattle, Washington, July 14-20, 1974.
- T-76 Trapped Electrons in Ice Matrices Highly Doped with Sodium Hydroxide, L. Kevan, International Conference on Color Centers, Sendai, Japan August 19-23, 1974. Invited Lecture.
- T-77 Ground State Structure of Trapped Electrons in Disordered Matrices, L. Kevan, Chemistry Seminar, Hokkaido University, Sapporo, Japan, August 26, 1974.
- T-78 ENDOR Studies in Disordered Matrices, L. Kevan, Government Industrial Research Institute, Nagoya, Japan, August 28, 1974.
- T-79 ENDOR and DNP of Low Temperature Char Systems, J.N. Helbert, B.E. Wagner, E.H. Poindexter and L. Kevan, National Amer. Chem. Soc. Meeting, Atlantic City, NJ, September 9-13, 1974.
- T-80 Solvation Studies of Electrons in Glasses, L. Kevan, Eighth Caribbean Chemical Conference, Georgetown, Guyana, January 6-10, 1975. Invited Lecture.

- T-81 Consequences of Dipolar Interactions: Electron Spin Echo Spectrometry, L. Kevan, Electron Magnetic Resonance Study Institute, Tortola, Virgin Islands, January 12-19, 1975. Invited Lecture
- T-82 Chemical Applications of Electron Spin Echo and Double Resonance Spectroscopy, Chemistry Seminar, University of Akron, Akron, Ohio, February 11, 1975.
- T-83 Structural Information from Electron Spin Echo Spectroscopy, Chemistry Seminar, Atomic Energy Laboratory, Studviks, Sweden, March 3, 1975.
- T-84 On the Use of the Spin Flip Satellite to Probe the Structure of Trapped Electrons in Glasses, B.L. Bales and L. Kevan, American Physical Society Meeting, Denver, CO, March 31-April 3, 1975.
- T-85 Molecular Orientation Around Trapped Electrons, Larry Kevan, National American Chemical Society Meeting, Philadelphia, PA, April 6-11, 1975. Invited Lecture
- T-86 Electron Spin Echoes in Disordered Solids, Chemistry Seminar, Ohio State University, Columbus, OH, April 11, 1975.
- T-87 Second Moment Analysis of ESR Lines in Disordered Matrices, Seminar Institute of Chemical Physics, Moscow, USSR, April 18, 1975.
- T-88 Mobility and Conduction State Energy Levels of Excess Electrons, Seminar, Ioffe Physical Technical Institute, Leningrad, USSR, April 22, 1975.
- T-89 Electron Spin Echo Studies of Excess Electrons, Seminar, Institute of Physical Chemistry, Moscow, USSR, April 25, 1975.
- T-90 Solvation Mechanism of Excess Electrons in Disordered Systems, L. Kevan, International Conference on Electrons in Fluids, East Lansing, Michigan, June 29-July 3, 1975.
- T-91 Criterion For Excess Electron Localization in Liquid Alkanes, K. Fueki, and L. Kevan, International Conference on Electrons in Fluids, East Lansing, Michigan, June 29-July 3, 1975.
- T-92 Structure of Trapped Electrons in Alkaline Ice from EPR Second Moment and Electron Spin Echo Studies, L. Kevan, P.A. Narayana, B.L. Bales, M.K. Bowman and R.N. Schwartz, Hart International Conference on Radiation Chemistry, Argonne, IL, July 7-9, 1975.
- T-93 Saturation Behavior of Electron Paramagnetic Resonance Lines in the Presence of Magnetic Field Modulation, M.K. Bowman, L. Kevan and H. Hase, National American Chemical Society Meeting, Chicago, IL, August 25-29, 1975.
- T-94 Chemical Applications of Electron Spin Echoes, L. Kevan, Chemistry Seminar, Rice University, Houston, Texas, September 3, 1975.
- T-95 Electron Solvation Mechanisms-Theory and Experiment, L. Kevan, Miller Conference on Radiation Conference, Burgenstock, Switzerland, September 15-19, 1975. Invited Lecture

- T-96 Chemical Applications of Electron Spin Echoes, L. Kevan, Chemistry Seminar, University of Detroit, Detroit, MI, October 1, 1975.
- T-97 Chemical Applications of Electron Spin Echoes, L. Kevan, Physical Chemistry Seminar, Wayne State University, Detroit, MI, October 8, 1975.
- T-98 Chemical Applications of Electron Spin Echoes, L. Kevan, Chemistry Seminar, University of Minnesota, Minneapolis, MN, October 27, 1975.
- T-99 Electron Solvation Mechanisms, L. Kevan, Chemistry Seminar, University of Toledo, Toledo, OH, October 30, 1975.
- T-100 Chemical Applications of Electron Spin Echoes, L. Kevan, Chemistry Seminar, University of Rochester, Rochester, New York, November 26, 1975.
- T-101 Diffusive and Tunneling Recombination of Electrons with Cations in Aqueous and Organic Glasses, K. Ho and L. Kevan, First Chemical Congress of the North American Continent, Mexico City, Mexico, November 30-December 5, 1975.
- T-102 Application of Electron Spin Echoes and EPR Second Moment Analysis to the Determination of Matrix Structure Around Trapped Radicals in Disordered Systems, L. Kevan, P.A. Narayana, S. Schlick, M.K. Bowman, B.L. Bales and R.N. Schwartz, Twelfth International Symposium on Free Radicals, Laguna Beach, CA, January 4-9, 1976.
- T-103 Future Research Trends on Electrons in Condensed Media, L. Kevan, Symposium on Radicals and Electrons in Condensed Media, Caracas, Venezuela, January 26-31, 1976. Invited Lecture
- T-104 Electron Solvation Mechanisms, L. Kevan, Chemistry Seminar, Northern Michigan University, Marquette, MI, February 11, 1976.
- T-105 Structural Studies of Trapped Electrons by Electron Spin Echo Spectrometry, L. Kevan, Highlands Lecture, Virginia Polytechnic Institute and State University, Blacksburg, VA, April 29, 1976.
- T-106 Solvated Electron Structure, L. Kevan, Seminar, Technical University, Lodz, Poland, June 7, 1976.
- T-107 Solvated Electron Structure, L. Kevan, Invited Lecture, Polish Chemical Society, Warsaw, Poland, June 8, 1976.
- T-108 Photoconductive Phenomena and Carrier Transport in Aqueous and Organic Glasses, Invited Lecture, L. Kevan, Gordon Conference on Chemistry and Physics of Photoconductors, Plymouth, New Hampshire, June 21-25, 1976.
- T-109 A New Theoretical Model for the Electronic Structure and Localization of Electrons in Alkanes, T. Kumura, K. Fueki, P.A. Narayana and L. Kevan, International Conference on Electrons in Fluids, Banff, Alberta, Canada, September 5-11, 1976.

- T-110 Structural Studies of Trapped Electrons by Electron Spin Echo Spectrometry, L. Kevan, Chemistry Seminar, University of British Columbia, Vancouver, B.C., Canada, September 13, 1976.
- T-111 Geometrical Structure of Solvated Electrons, L. Kevan, Invited Lecturer, Annual Meeting of the Japanese Society of Radiation Chemistry, Kyoto, Japan, October 10-12, 1976.
- T-112 Semicontinuum Model of Electrons in Hydrocarbons, T. Kimura, K. Fueki, P.A. Narayana and L. Kevan, Annual Meeting of the Japanese Society of Radiation Chemistry, Kyoto, Japan, October 10-12, 1976.
- T-113 Application of Electron Spin Resonance to Radiation Chemistry I, Invited Lecture Series, L. Kevan, Nagoya University, Japan, October 19, 1976.
- T-114 Application of Electron Spin Resonance to Radiation Chemistry II, Invited Lecture Series, L. Kevan, Nagoya University, Japan, October 22, 1976.
- T-115 Application of Electron Spin Resonance to Radiation Chemistry III, Invited Lecture Series, L. Kevan, Nagoya University, Japan, October 26, 1976.
- T-116 Localization and Solvation of Electrons in Condensed Media, L. Kevan, Invited Lecture, Chemical Society of Japan, Nagoya, Japan, October 26, 1976.
- T-117 Localization and Solvation of Electrons in Condensed Media, L. Kevan, Japan Atomic Energy Research Establishment, Takasaki, Japan, October 27, 1976.
- T-118 Localization and Solvation of Electrons in Condensed Media, L. Kevan, Seminar, University of Tokyo, Japan, October 28, 1976.
- T-119 Silver Atom Formation and Trapping in Frozen Matrices, L. Kevan, Research Reactor Institute of Kyoto University, Japan, November 15, 1976.
- T-120 Localization and Solvation of Electrons in Condensed Media, L. Kevan, Radiation Center of Osaka Prefecture, Japan, November 30, 1976.
- T-121 Electron Spin Echo Modulation from Trapped Radicals in Disordered Systems, L. Kevan, Osaka University, Japan, December 13, 1976.
- T-122 Application of Electron Spin Resonance to Radiation Chemistry, Lecture Series, L. Kevan, Hokkaido University, Sapporo, Japan, January 20, 1977.
- T-123 Solvation and Desolvation of Radiation-Produced Silver Atoms in Aqueous Matrices, University Lecture, L. Kevan, Hokkaido University, Sapporo, Japan, January 21, 1977.
- T-124 Electron-Solvent Interactions, Invited Lecture Series of 12 lectures, L. Kevan, University of Paris-Sud, Orsay, France, March 7-May 13, 1977.
- T-125 A Numerical Model of CO₂ Radiolysis, R. Kummeler, C. Leffert, K. Im, R. Piccirelli, L. Kevan and C. Willis, Natl. Amer. Chem. Soc. Meeting, Symposium on Reaction Mechanism, New Orleans, LA, March 20-25, 1977.

- T-126 Electron Spin-Lattice Relaxation Mechanisms of Radiation Produced Trapped Electrons and Hydrogen Atoms In Aqueous and Organic Glassy Matrices, L. Kevan and M.K. Bowman, Invited Lecture, Faraday Discussion on Radiation Effects in Liquids and Solids, Leicester, England, March 23-25, 1977.
- T-127 Localization and Solvation of Electrons in Condensed Media, L. Kevan, Center for Wave Mechanics, C.N.R.S., Paris, France, March 31, 1977.
- T-128 Laser Photolysis Study of Recombination Luminescence of Trapped Electrons in Low Temperature Glasses, M. Ogasawara, and L. Kevan, Annual Meeting of the Japanese Chemical Society, Osaka, Japan, April 1-5, 1977.
- T-129 Known and Unknown Characteristics of Solvated Electrons, L. Kevan, Seminar, University of Paris-Sud, Orsay, France, May 3, 1977.
- T-130 Solvation of Silver Atoms in Aqueous Matrices, L. Kevan, Seminar, Institute of Chemical Kinetics and Combustion, Novosibirsk, USSR, May 23, 1977.
- T-131 Second Moment Studies of the ESR Lineshape of Trapped Electrons in Sodium-Ice Condensates: Relation to the Molecular Structure Around Trapped Electrons, L. Kevan and D.P. Lin, Nat. Am. Chem. Soc. Meeting, Symposium on Radiation Effects, Chicago, IL, August 29-September 2, 1977.
- T-132 Ion and Atom Solvation Structure Studied by Electron Spin Echo Spectrometry, L. Kevan and P.A. Narayana, 26th Intl. Congress of Pure and Applied Chemistry, Tokyo, Japan, September 4-10, 1977.
- T-133 Photoconductivity of Presolvated Electrons in Ethanol Glass, H. Hase, L. Kevan and T. Higashimura, Japan Radiation Chemistry Congress, Hokkaido, Japan, October 6-8, 1977.
- T-134 Solvation Process of Silver Atoms in Ice, L. Kevan, H. Hase and K. Kawabata, Japan Radiation Chemistry Congress, Hokkaido, Japan, October 6-8, 1977.
- T-135 Trapped Electrons in MTHF-Methanol Mixtures: Pulse Radiolysis at 77K and Optical Absorption at 4K, M. Ogasawara, L. Kevan and H. Yoshida, Japan Radiation Chemistry Congress, Hokkaido, Japan, October 6-8, 1977.
- T-136 Silver Atom Solvation and Desolvation in Ice Matrices: Study of Solvation Shell Geometry by Electron Spin Resonance and Electron Spin Echo Methods, L. Kevan and P.A. Narayana, Caribbean Chemical Conference IX, Radiation Chemistry Symposium - Invited Lecture, San Juan, Puerto Rico, December 8-11, 1977.
- T-137 Applications to Disordered Solids, Invited Lecture, L. Kevan, Study Institute on Data Acquisition and Processing in Magnetic Resonance, St. Vincent, West Indies, December 12-18, 1977.

- T-138 Ion and Atom Solvation Structure Studies by Electron Spin Echo Spectroscopy, Seminar, L. Kevan, Atomic Energy of Canada - Chalk River Nuclear Laboratories, January 10, 1978.
- T-139 Pulsed ESR Studies of Ion and Atom Solvation, Seminar, L. Kevan, University of Toronto, Canada, January 12, 1978.
- T-140 Applications of ESR to Chemistry, Seminar, L. Kevan, University of Illinois at Chicago Circle, Chicago, IL, February 9, 1978.
- T-141 Application of ESR to Chemistry, Seminar, L. Kevan, Illinois State University, Normal, IL, February 10, 1978.
- T-142 Pulsed ESR Studies of Ion and Atom Solvation, Seminar, L. Kevan, Drexel University, Philadelphia, PA, April 13, 1978.
- T-143 Optical Absorption Studies of Trapped Electrons Generated and Observed at 1.6K, G. Dolivo and L. Kevan, Radiation Research Society Meeting, Toronto, Canada, May 15-18, 1978.
- T-144 Photoconductivity Associated with Localized Electrons in Glassy Matrices, L. Kevan, Invited Lecture, Gordon Conference on the Physics and Chemistry of Photoconductors, Holderness School, New Hampshire, June 12-16, 1978.
- T-145 Optical Absorption of Localized Electrons Generated at 1.6K in Polar Matrices, G. Dolivo and L. Kevan, Gordon Conference on Radiation Chemistry, Holderness School, New Hampshire, July 17-21, 1978.
- T-146 Electron Spin Lattice Relaxation Via Nuclear Tunneling Modes for Trapped Radicals in Glassy Matrices, M.K. Bowman, L. Kevan and J. Michalik, XXth Colloque Ampere, Tallinn, USSR, August 21-26, 1978.
- T-147 Determination of Vibrational Frequencies Associated with Solvated Electrons, L. Kevan and D.P. Lin, Plenary Lecture, Sixth Conference of the Nordic Society for Radiation Research and Radiation Technology, Hirtshals, Denmark, August 28-31, 1978.
- T-148 Optical Studies of Trapped Electrons Generated and Observed at 1.6K, G. Dolivo and L. Kevan, Sixth Conference of the Nordic Society for Radiation Research and Radiation Technology, Hirtshals, Denmark, August 28-31, 1978.
- T-149 Electron Spin Echo Studies of Radical Orientation on Catalytic Surfaces: CH₂OH Radicals in A, Y and X-Type Zeolites, T. Ichikawa and L. Kevan, National American Chemical Society Meeting, Miami, FL, September 11-15, 1978.
- T-150 Pulsed ESR Studies of Ion and Atom Solvation, Seminar, L. Kevan, Michigan State University, East Lansing, Michigan, October 17, 1978.
- T-151 Pulsed ESR Studies of Ion and Atom Solvation, Seminar, L. Kevan, SUNY-Buffalo and Roswell Park Memorial Institute, Buffalo, NY, November 13, 1978.

- T-152 Electron Spin Echo Modulation Spectrometry, Seminar, Venezuela Institute of Scientific Investigation (IVIC), Caracas, Venezuela, December 4, 1978.
- T-153 Chemical Applications of Electron Spin Echoes, Frontiers in Chemistry Lecture, Wayne State University, Detroit, MI, January 29, 1979.
- T-154 Chemical Applications of Electron Spin Echoes, Chemistry Seminar, Chemistry Seminar, University of Houston, Houston, Texas, March 2, 1979.
- T-155 Chemical Applications of Electron Spin Echoes, Quantum Institute Lecture, University of California at Santa Barbara, May 10, 1979.
- T-156 Optical Absorption Spectra of Localized Electrons Generated at 1.6K in Polar Matrices: Evidence for Presolvated Electrons, G. Dolivo and L. Kevan, Sixth International Congress of Radiation Research, Tokyo, Japan, May 13-19, 1979.
- T-157 Introduction to Electron Trapping and Transfer in Frozen Media, Invited Lecture, L. Kevan, Sixth International Congress of Radiation Research, Tokyo, Japan, May 13-19, 1979.
- T-158 Electron Spin Echo Study of Nd^{3+} Solvation in Alcohol Glasses, R. Janakiraman and L. Kevan, International Symposium on Magnetic Resonance in Chemistry, Biology and Physics, Argonne, IL, June 24-28, 1979.
- T-159 Current Problems in the Localization and Solvation of Excess Electrons in Glasses, Plenary Lecture, L. Kevan, Fifth International Conference on Excess Electrons and Metal-Ammonia Solutions, Aviemore, Scotland, June 25-29, 1979.
- T-160 Electron, Anion and Atom Solvation Structure in Disordered Media, Invited Lecture, L. Kevan, Miller Conference on Radiation Chemistry, Nafplion, Greece, September 10-14, 1979.
- T-161 Introduction to Electron Spin Resonance, L. Kevan, Armed Forces Technical University, Munich, Germany, November 15, 1979.
- T-162 Applications of ESR to Disordered Solids: Forbidden Spin Flip Transitions, L. Kevan, Armed Forces Technical University, Munich, Germany, November 19, 1979.
- T-163 Applications of ESR to Disordered Solids: Second Moment Lineshape Analyses, L. Kevan, Armed Forces Technical University, Munich, Germany, November 22, 1979.
- T-164 Application of Matrix ENDOR to Disordered Solids, L. Kevan, Armed Forces Technical University, Munich, Germany, November 26, 1979.
- T-165 Geometrical Structure of Solvated Electrons, L. Kevan, Ecole Polytechnique Lausanne, Switzerland, November 27, 1979.
- T-166 Peroxy Radicals as Probes of Environmental Motion, Ecole Polytechnique Lausanne, Switzerland, November 28, 1979.

- T-167 Chemical Applications of Electron Spin Echoes, L. Kevan, University of Geneva, Switzerland, November 29, 1979.
- T-168 Matrix ENDOR Lineshape Model for Radicals in Disordered Systems, L. Kevan, University of Geneva, Switzerland, November 30, 1979.
- T-169 Peroxy Radicals As Probes of Environmental Motion, L. Kevan, Armed Forces Technical University, Munich, Germany, December 4, 1979.
- T-170 Chemical Applications of Electron Spin Echoes, L. Kevan, Armed Forces Technical University, Munich, Germany, December 6, 1979.
- T-171 The Use of Electron Spin Echoes to Study the Structure of Molecular Surroundings, L. Kevan, Invited Lecture, Magnetic Resonance Study Institute, Roatan, Honduras, December 30-January 5, 1980.
- T-172 Application of Electron Spin Resonance to Surface Studies, L. Kevan, Armed Forces Technical University, Munich, Germany, February 19, 1980.
- T-173 Silver Atom Solvation and Surface Clustering, L. Kevan, Armed Forces Technical University, Munich, Germany, February 26, 1980.
- T-174 Electron Spin Resonance Studies of Silver Atom Solvation in Ethanol-Water Mixtures, A. Li and L. Kevan, American Chemical Society National Meeting, Houston, Texas, March 24-28, 1980.
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- T-176 Electron Spin Echo Spectrometry: A New Probe for the Geometry of Adsorbed Molecules on Surfaces, L. Kevan and T. Ichikawa, Michigan Catalysis Society Symposium, Detroit, MI, April 22, 1980.
- T-177 Electron Spin Echo Studies of Solvation Shell Geometry, L. Kevan, Invited Lecture in Symposium on Advances in EPR, 14th Great Lakes Regional American Chemical Society Meeting, Macomb, IL, June 4-6, 1980.
- T-178 Chemical Applications of Electron Spin Echoes, L. Kevan, Invited Lecture, UCLA Golden Anniversary Symposium, Los Angeles, CA, June 2-3, 1980.
- T-179 Electron Spin Echo Studies on the Structure of Solvated Radical Ions, L. Kevan, Invited Lecture, Gordon Conference on Radical Ions, Wolfeboro, New Hampshire, June 16-20, 1980.
- T-180 Modulated Electron Spin Echoes: A Probe for the Solvation Geometry of Paramagnetic Species in Bulk and on Surfaces, L. Kevan, Invited Lecture, Third International EPR Symposium, Annual Rocky Mountain Conference, Denver, CO, August 11-14, 1980.
- T-181 Applications of the Semicontinuum Model of Electron Solvation to Trapped Electrons in Single Crystals of D-Sorbitol, S. Schlick and L. Kevan, American Chemical Society National Meeting, Las Vegas, NV, August 25-29, 1980.

T-182 Electron Spin Echo Studies of the Structure of Solvated Ions, L. Kevan,
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4. Ph.D. Theses

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2. Timothy D. K. Su, Ion-Molecule Reactions in Perfluorocarbons, 1971. (Only the early part of Dr. Su's research was supported by the AEC).
3. Ignatz Eisele, Photoconductivity and Photo Hall Effect in Gamma Irradiated Alkaline Ice, 1972.
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5. John Helbert, Matrix ENDOR Studies of Trapped Electrons and Hydrogen Atoms, 1972. (Only the early part of Dr. Helbert's research was supported by the AEC).
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8. Michael K. Bowman, The Electron Spin Lattice Relaxation of Radiation Produced Trapped Electrons and Trapped Hydrogen Atoms in Glassy Matrices, 1975.
9. Ken K. Ho, Recombination Luminescence from Photoionized Organic and Aqueous Glasses, 1976.