PROGRESS REPORT
1978
FOSTER RADIATION LABORATORY
DEPARTMENT OF PHYSICS
McGILL UNIVERSITY

CONTENTS

I. INTRODUCTION

This report summarizes the operation and development of the facilities in the Foster Radiation Laboratory and the research carried out during the calendar year 1978. There are two groups of personnel using the Laboratory facilities regularly: the resident personnel, who occupy office space in the Laboratory, and the non-resident personnel, who come from the Chemistry Department and the Montreal Neurological Institute. The names of the two groups of personnel are listed in Section V of this report. The resident personnel are charged with the responsibility of operating and developing the facilities in the Laboratory. Due to the change in the funding structure for nuclear installations, this report marks the first time that those parts of the research activities of the non-resident personnel are also presented here.

It is satisfying to know that the facilities in the Laboratory have been well used during the past year. As reported in our last year's Progress Report, we have successfully modified the synchrocyclotron to accelerate p, d, ^{3}He and ^{4}He particles to their maximum energies of 100, 50, 133 and 100 MeV, respectively, but the intensity of the helium beams was low. The situation has been improved greatly during the past year

through the installation of a new ion source and modification to the cyclotron's central region. The completion of the revamping of the electrical and control systems has given the accelerator facility a new look. All this and other development of laboratory facilities are outlined in Section II of this report.

The scientific activity and productivity of 1978 has been satisfactory as summarized in Sections III and IV. Although most of the research activities have continued to make use primarily of the proton and deuteron beam facilities, limited use of the alpha beam has begun and more extensive use of both the ^{3}He and ^{4}He beams have been planned. Research interests were continued to be directed on the properties of the far-unstable nuclei and complex nuclear reaction and nuclear fission mechanisms. It has been a rewarding experience to learn that our positron tomography work has acquired an international reputation in the field.

The operation and development of the facilities in the Laboratory was supported by a core grant from the Natural Sciences and Engineering Research Council (NSERC). In addition, direct financial contributions from the University were also received. All the research activities were funded through grants from NSERC, Canada

Council, Medical Research Council and le Ministère de l'Education du Québec. The generosity of these supporters are gratefully acknowledged.

II. LABORATORY OPERATION AND DEVELOPMENT

(a) The Synchrocyclotron

The cyclotron has gone through another year of smooth operation in 1978, except for one major interruption due to faults in the newly installed ion source. During the calendar year, it was used for 5200 hours for research purposes, 78% of which was used by the nuclear physics personnel and the remaining 22% by researchers from the Chemistry Department and the Montreal Neurological Institute. Twenty-two days were devoted to maintenance and services and 8 days were lost due to faults. In addition, 60 days were used for accelerator upgrading.

As stated in our last year's Progress Report, we have succeeded in modifying the cyclotron to accelerate d, $^{3}He^{++}$ and $^{4}He^{++}$ particles as well as the protons. While the deuteron beam intensity was comparable to the proton beam (2 μA), the $^{3}He^{++}$ and $^{4}He^{++}$ beam intensities were weak (~5 nA) and we traced this problem to the insufficient power (2W) of the ion source used. Consequently, a new ion source was designed, constructed and installed in early summer of 1978. The new ion source is of the cold cathode, PIG type with separate water cooling system for both anode and cathode. The ion pulsing circuit can supply output

pulses with an initial voltage spike of 8 kV. After the discharge is initiated, the arc current is constant, and may be varied from 0 to 8 amperes. The average power available in the new source is about 100 times higher than that in the old source. While the intensity of the proton and deuteron beams has remained more or less the same with the new source as with the old source, the intensity of the ^{3}He and ^{4}He beams has increased by a factor of about 100. However, the operation of the new source, though as expected, was not without some grief. In September one of its electrical insulators broke down and inflicted a hole in the cooling water line and flooded the the cyclotron acceleration tank with 2 inches of water. It took us 6 days to restore the operation of the cyclotron.

Although the intensity of the helium beams has increased markedly, it is still falling below our objective. We believe the problem now is space charge limited in the central region of the cyclotron. In anticipation of this problem, when we installed the new dee for the cyclotron last year, we installed a separately excitable auxiliary dee in the cyclotron's central region so as to provide symmetrical acceleration of ions across the dee gap in the central region. We hope that this

arrangement will give us a greater circulating beam accelerated through the space charge region and will also give us less radial oscillation of orbiting beam. However, when we tried to excite the auxiliary dee separately, we encountered a serious difficutly arising from the magnetic coupling between the auxiliary dee and the main dee. This coupling was sufficiently strong so as to interfere with the operation of the R.F. oscillator. The problem was recently solved through a major job of R.F. shielding between the two dees in the cyclotron tank. The performance of the system will be tested in the near future.

Our cyclotron produces beams in pulses of 10 μs wide with a repetition rate of 400 pulses per second. To do on-line spectroscopy experiments with the helium beams, we have to stretch the beams. A stoichastic beam stretcher has been constructed which consists of a Cee and the resonance and phasing electronics. The Cee is a simple water cooled electrode occupying a 72^{o} sector of the cyclotron. The resonance circuit is of the lumped variety but a $\lambda/4$ line has also been tested. The power drive is a 1 keV wide-band power amplifier and the phasing electronics is for sensing the main R.F. sweep and to activate the Cee system. The stretcher has

been installed and performance tests will begin shortly.

In an effort to upgrade the external beam control system, last year we replaced 5 of the 7 power supplies in the beam transport system by highly current regulated power supplies manufactured by Alpha Scientific Inc. (California). The operation of these new supplies has proven to be very satisfactory; their stability is well within the quoted specifications. Consequently, to complete the beamline ugrading, the remaining two power supplies have recently been procured and their installation will be completed before the end of 1978. With the completion of this upgrading, the external beam is expected to have a stability better than 1 part in 10^4.

During the past year, much effort has been devoted to revamping the antiquated power distribution system of the accelerator. This involved laying in a complete new system of 220 V and 550 V three phase wiring, together with their associated master switch assemblies and splitter terminals. In addition, a complete new set of fused switch boxes was installed for the various parts of the cyclotron (i.e. diffusion pumps, roughing pumps, water pumps, R.F. power, etc.), together with the associated control relays. With this installation completed, the power distribution system has now been

modernized and any further power requirements for future developments can be easily met without any shutdown of the facility.

Late in 1977, we started the modernization and centralization of our accelerator operation control system. This painstaking work was finally completed late in the summer of 1978. A new modular control console in the control room and a sub-console in the cyclotron vault have been installed. The latter is used mainly as a service console when maintenance work is done on the accelerator system. All operation controls and monitoring devices for the cyclotron and its associated facilities are now centralized in these two new consoles. All wirings are new and components and parts have been up-dated. In addition, many new features for the control and monitoring have been added to the system. Because of its modular construction, the new control system can easily be expanded to accommodate any additional requirements which may arise in the future.

(b) Data Handling Facilities

The data handling facilities in our Laboratory are centered primarily around a PDP-15 and a PDP-11/34 computer, although an obsolete and erratic PDP-8 computer is still being used occasionally for special

purposes. During the past year, several new features have been added to the PDP-15 computer system. The interface logic for four Tracor Northern 100 MH_z ADC was constructed and commissioned. This facility allows us to perform multispectrum experiments with one or two ADC with the data updated on the fixed wire disk as well as experiments involving multiparameter coincidence with three ADC.

A hardware for sorting events collected in list mode coincidence experiments has been developed. Parameter identification and window limits are set into the hardware by program. The sorter reads the number of words in the event from computer memory using a single cycle data channel. If the event satisfies identification and window requirements then a memory increment transfer is initiated with one of the words of the event, also indicated by program, as the memory address. A fixed off-set is added to the address to locate the spectrum in a suitable part of the memory. The hardware causes program interruption after the list is sorted so that the program can resort the same list with new identification and window requirements or read new data from a magtape.

The PDP-11/34 computer is a recent acquisition and its delivery to our Laboratory was completed in early 1978.

Because of the works mentioned above, its commissioning had been delayed for a few months. The hardware for display and plotting has been completed. The computer is now being used for data analysis. Development of data collection hardware and IEEE-488 link between the PDP-11/34 and PDP-15 computers are in progress.

A CAMAC scope display system for the computers is presently under construction. It will provide us with the capability for point-by-point plot, vector generation on scope, plotting on Complot plotter, alpha-numeric character generation and logic for light pen and switch.

A multiscaler controller for an ND2400 Analyser has been constructed. This is a single width NIM module used with the analyser to perform a variable number of multiscaling cycles (up to a maximum of 999) in one or more quadrants of the 4K memory of the analyser. The controller employs a Signetics 2650 microprocessor and about 512 bytes of program stored in a EPROM. A keyboard and a 6 digit LED display are provided on the front panel to enter the parameters for multiscaling (number of groups and number of cycles in each group). The state of the system is continuously indicated on the display.

(c) Other General Use Experimental Equipment

Last year we completed the construction of an ion transport system for the on-line isotope separator. This system transfers the isotopically separated ions from the separator, which is situated in the high background external beam room, to a station 7 m away in the control room where the background is low. It consists of 3 einzel lenses, 3 horizontal focussing lenses and a 45^{o} deflector, and is capable of focussing the ion beam to a spot of 2 mm diameter. The overall transport efficiency is about 70%. A tape transport system for collecting the ion is presently under construction.

The beta ray spectrometer employing a large intrinsic Ge crystal in a superconducting solenoid for the measurement of high energy beta particles has been a heavily used piece of equipment in our Laboratory for the past few years. It has come to our notice in recent months that the energy resolution of the Ge crystal is deteriorating rapidly. A replacement of it is necessary in the near future.

The 18% Ge(Li) detector procured from ORTEC three years ago was a premium detector. Last year its energy resolution deteriorated badly and was sent back to the Company for rejuvenation. However, the Company failed to restore the detector to its original state.

Consequently we purchased a new 15% HyGe spectrometer from APTEC Engineering (Toronto). This new detector was delivered to us in September but failed to meet our specifications. The Company is presently working on it.

III. PROGRESS IN RESEARCH

This section presents an outline of the progress made in each of the research projects carried out with the facilities in the Laboratory.

1. Studies of Neutron Deficient Xe and Cs Nuclides

(J.E. Crawford, R. Iafigliola, J.K.P. Lee, B. Singh and B.N. Subba Rao)

Experiments have been carried out to probe the structure properties of a series of neutron deficient Xe nuclei through the beta decay of the Cs nuclei. The latter nuclei were produced by the (p,xn) reactions in isotopically separated ^{124}Xe, ^{126}Xe and ^{133}Cs targets. Good evidence exists for the identification of a set of quasi-β and quasi-γ bands in the light transitional even-even Xe isotopes. The second 0^+ states at 1149, 1269, 1313 and 1583 keV in ^{122}Xe, ^{124}Xe, ^{126}Xe and ^{128}Xe, respectively, have been identified using γ-γ angular correlation measurements with a Ge(Li)-NaI(Tl) system. In the cases of ^{124}Xe and ^{128}Xe, third 0^+ states at 1670 and 2599 keV have also been identified. Experiments are being initiated to study the decay properties of the neutron deficient barium nuclei using the ^{3}He and ^{4}He beams on a ^{124}Xe target.

2. Reinvestigation of ^{69}Ge

(J.E. Crawford, S.K. Mark and B.N. Subba Rao)

The structure of ^{69}Ge as observed through the beta decay of ^{69}As which was studied previously in our Laboratory has been reinvestigated. The ^{69}As nuclide was produced by the $^{70}Ge(p,2n)$ reaction and the work was conducted with improved techniques and instruments. Much new information on the level structure and transition property was obtained. The results indicate strong similarity to those of the other N=37 isotones ^{65}Ni and ^{67}Zn. Comparisons with predictions of shell model and collective model calculations were made.

3. Transition Ba Nuclei

(P. Brodeur, S.K. Mark and B.P. Pathak)

The neutron deficient Ba nuclei are known to exhibit transition behaviour. We have conducted a systematic study of this property through the beta decay of the La nuclides, which were produced by the (p,xn) reactions in a ^{130}Ba target. The work on $^{128,129,130}Ba$ is now complete. Many members of the quasi-ground, β and γ bands in ^{128}Ba and ^{130}Ba have been identified. When the level structure and electromagnetic properties of these nuclei are compared with those of the other even-A Ba nuclei, the systematics demonstrate clearly the transition

behaviour of these nuclei. In addition, there is evidence for the occurrence of γ-instability in ^{128}Ba. The systematics of the odd-A Ba nuclides also indicate the transitional nature of their structure. Both the even and odd A Ba nuclei appear to follow the description of the collective model with triaxial deformation.

4. Rare Earth Nuclei Far From Beta Stability

(J. Deslauriers, S.C. Gujrathi and S.K. Mark)

In the past few years, we have devoted a vast amount of effort to the study of the properties of the neutron deficient nuclei with N<82 and bounded by La and Gd. These unstable nuclei were produced by the (p,xn), (p,pxn) and (p,αxn) reactions in stable ^{142}Nd and ^{144}Sm targets. The experiments utilized the high speed X-ray, γ-ray, electron and positron spectroscopy techniques. The work accomplished during the past is outlined below.

Our study of the decay properties of the N=78 isotones is now complete with the completion of the decay study of ^{140}Sm. More than 50 gamma-ray transitions in ^{140}Pm are associated with this decay. ^{140}Sm decay is observed to populate ^{140}Pm ground state with a strong beta strength (77%) and the latter is thus deduced to have a $J^{\pi}=1^{+}$. This is in agreement with our previous work in studying

the decay properties of ^{140g}Pm. The intensities of the low energy electrons have been measured using the new mini-orange spectrometer and conversion coefficients of the strong transitions have been deduced. A decay scheme comprising 18 excited states in ^{140}Pm has been constructed. Positron spectra in coincidence with the strong gamma-ray transitions were measured in order to deduce the total decay energy, and the analysis is still in progress.

Much of our effort during the past year has been directed to the study of the decay of the N=77 isotones. The decay of ^{139g}Sm has been completed and has permitted us to extend the systematics of the odd-A N=78 isotones. From its decay properties ^{139g}Sm was deduced to have a $J^{\pi}=1/2^{+}$ and its half-life has been measured to be 2.57 min. α_K and K/L ratios have been measured for the intense transitions in ^{139}Pm using the mini-orange spectrometer; with these results many spin-parity assignments could be made for the low lying levels. The total decay energy of ^{139g}Sm has been measured to be Q_{EC}=5.43 MeV using the superconducting beta-ray spectrometer. This value agrees very well with the existing mass formulas. A decay scheme comprising 80 transitions and 33 excited states has been constructed. The results of this study are the subject of an article submitted for publication.

The study of the decay properties of ^{138}Pm (t1/2=3.24 min) has been completed. The 2_1^+, 2_2^+, 4_1^+, 3_1^+, 5^- and 6^+ states in ^{138}Nd are observed to be directly fed with log ft values ranging from 5.6 to 6.5. These low log ft values and the wide range of the spins of the populated levels indicate the need for at least two different β-decaying states. An extensive search was made in order to detect a possible isomeric transition but the results were negative and it seems that the expected isomers may not be connected by such a transition. Two isomers having very similar half-lives are thus proposed: a low spin state with $J^\pi = 3^+$ and a high spin state with $J^\pi = 5^-$ or 6^-. With these assumptions the feedings to the observed states in ^{138}Nd can be adequately accounted for. Our study of the decay properties of ^{140}Eu populating states in N=78 ^{140}Sm has been pursued. ^{140}Eu half-life was measured to be 1.6 sec. Its decay is found to populate the ground state, the first 2^+ state and the second 2^+ state in ^{140}Sm. These levels seem to follow very well the systematics of the 2^+ states in the even-even N=78 isotones. Attempts are being made to detect any direct beta feeding to the ground state of ^{140}Sm which would restrict these values to $J^\pi = 1^+$.

Our study on the states of N=77 ^{139}Sm populated in the

decay of ^{139}Eu and ^{139m}Sm has been completed. The half-life of ^{139m}Sm has been measured to be 10.7 sec and its spin is deduced to be $11/2^-$. Three states are observed between the two ^{139}Sm isomers. The spin-parity of these states was deduced from the results obtained with the mini-oran conversion electron spectrometer. ^{139}Eu(t1/2 = 17.9 sec) decay populates the $11/2^-$ ^{139m}Sm state but none of the low spin states; its spin is deduced to be $11/2^-$. Other states above ^{139m}Sm are also populated in this decay. A paper summarizing our findings is presently in preparation.

The decay of 1.6 min ^{136}Pm to states in N=76 ^{136}Nd is still under study. More than 20 transitions have been observed and a decay scheme has been constructed. The ground state band in ^{136}Nd has been observed up to the 6^+ state. The strong beta feeding to the 4^+ and 6^+ states suggests a $J^\pi = 5^+$ assignment for ^{136}Pm. Attempts to measure the total decay energy are presently being made and other experiments are still in progress.

5. Shape Transition in Deformed Nuclei

(A. Kogan, S.K. Mark and B. Singh)

Stable and near stable nuclei in the region $67<Z<72$ are known to possess strong deformation. It is speculated that this deformation should become less dominant as the nuclei are

farther removed from the stable region. We have undertaken a systematic investigation of this transition property using the beta decay spectroscopy techniques. These nuclides were produced by the (p,xn) and (α,xn) reactions in ^{164}Er and ^{170}Yb targets.

During the past year our work was concentrated in the study of the decay properties of ^{160}Tm, which was found to have two beta decaying isomers with half-lives about 70 s and 9.2 m, respectively. The spin of these isomers have been deduced to be 5^+ and 1^- with an energy separation about 40 keV. The structure of ^{160}Er thus deduced when compared with that of the other even-A Er nuclei indicates a smooth change in the deformation of these nuclei. Work on the other Er nuclei and the Yb nuclei are presently in progress.

6. Study of Neutron Deficient Nuclei Near N=50
(S.K. Mark, K. Oxorn and B. Singh)

The structure of neutron deficient nuclei with neutron number in the vicinity of 50 are being investigated. Last year we completed the experimental work on the measurements of the decay properties of ^{94}Rh. Two beta decaying isomers with half-lives 26 s and 71 s and $J = 8^+$ and 3^+, respectively, were observed. Their decays populate members of the quasi-ground state band in the

N=50 ^{94}Ru nucleus with spin values ranging up to 8^+. In addition, negative parity states of 5^- and 7^- were also observed. Total decay energy Q_{EC} = 10.0 ± 0.4 MeV was deduced from positron end-point energy measurements with the superconducting beta ray spectrometer. Observed properties of ^{94}Ru follow well the systematics of the N=50 isotones.

Investigation of the structure of ^{90}Mo from the decay of ^{90}Tc is presently in progress. Two beta decaying isomers of 8 s and 26 s, respectively, have been identified. Preliminary results indicate that the decay of these two isomers populate two separate sets of states with high and low spins, respectively. More extensive measurements are underway.

7. Conversion Electron Measurements

(J. Deslauriers and S.K. Mark)

Last year we reported the construction of a conversion electron spectrometer using the strong Sm CO_5 magnets. The purpose of the spectrometer is to enable us to measure conversion electrons in the presence of a very large positron flux with good efficiency (~25%). The magnets, each has a dimension 2.4 x 1.6 x 0.3 cm and a magnetization along its shortest axis, are arranged symmetrically around a lead core to form a toridal field and are placed between

the source and the Si(Li) detector. High quality electron spectra were obtained with very little interference from the positrons and gamma rays from the source.

We have studied the response function of the spectrometer and found it to depend on the geometry of the magnetic filter and source and detector to filter distances. To perform this study we have to develop some suitable standard sources with conversion electron lines spanned over a wide range of energy. ^{152}Eu and ^{206}Bi were found to be good candidates. ^{152}Eu emits many intense electron lines with energies from 75 to 1400 keV following its decay. The intensities of the electron lines were accurately measured using a Si(Li) detector whose response function has been determined previously using ^{133}Ba and ^{207}Bi sources. Our measurements were found to be more accurate than those reported by previous workers and many existing discrepancies have been clarified. This source can now be used as a standard. A similar study has been undertaken with ^{206}Bi. This radioisotope was produced in the McGill cyclotron by the (p,n) reaction on enriched ^{206}Pb. Many conversion electron lines are emitted in this decay with energies from 100 to 1800 keV. The active ^{206}Bi was extracted from the lead target using chemical separation and then deposited onto aluminum backing. Preliminary measurements were taken and we are

presently trying to improve the technique of source preparation in order to obtain thinner sources, which is important for the accurate determination of the intensities of the low energy electron lines.

8. Delayed Charged Particle Emission

(G. Lolos and S.K. Mark)

Attempts have been made to study the beta delayed charged particle (protons and alphas) emission in heavy nuclei, namely, the Sm, Eu and Gd nuclei. The half-lives of these precursors have been found to be in the range of seconds and the particle spectra are continuous because of the level density of the nuclei involved. The delayed particles were detected with a ΔE-E Si detector system. However, we have encountered serious spectrum distortions due primarily to the very large positron flux background. To minimize these effects, a high transmission efficiency magnetic filter using two strong rare earth magnets are being constructed. This filter is capable of deflecting the most energetic positron encountered away from the detector system and focuss the desired particles of variable energy bands onto the detector. The system will be undergoing a performance test shortly.

9. Monte Carlo Simulation of Electron and Positron Interactions in Ge Detectors

(J.E. Kitching, W. Leo, J. Miskin, R.B. Moore and B. Varley)

The development of Monte-Carlo programs to determine the

response functions of germanium detectors to incident beams of high energy electrons and positrons has been completed. Response functions for both electrons and positrons in the energy range of 0.2 to 8.5 MeV have been computed for various incident beam geometries. The geometries considered were:

a) collimated perpendicular incidence;

b) isotopically emitting point sources, and

c) simulated superconducting solenoid.

Comparisons of the calculated and experimental response functions determined at I.L.L. Grenoble and comparisons of calculated electron and positron backscattering coefficients with the predictions of empirical formulae both reveal good agreement. The computed response functions are instrumental in on going work to unfold beta ray spectra.

10. Investigation of Ge(Li) γ-Ray Detection Efficiencies at High Incident Photon Energies

(J.E. Crawford, J.E. Kitching and B. Varley)

The dependence of the full energy peak detection efficiency of Ge(Li) detectors is often assumed to be of the form $\varepsilon \propto E^k$ where k is an empirical constant. This form of the equation is frequently used to fit experimental efficiency curves and for extrapolation into energy regions where calibration sources are unavailable. Modification of the Monte-Carlo calculation designed for the determination of

electron and positron histories in Ge detectors has been carried out and allows us to determine in some detail the processes involved in the detection of γ rays by both intrinsic Ge and coaxial Ge(Li) detectors. In agreement with several sets of published experimental results, our calculations reveal considerable deviation in the efficiency vs energy curve for photon energies above 2 MeV. A detailed comparison has been made between the computed efficiency of a 96 c.c. coaxial Ge(Li) detector and the experimental curve for the same detector.

The experimental curve was determined using the two photon method in which coincident high and low energy γ-rays of well known intensity are used to fabricate the experimental curve. Gamma-rays resulting from the decay of radioactive sources and from $(p,xn\gamma)$ reactions were employed to obtain an efficiency curve over the energy range 100 keV to 11.6 MeV. Good agreement was found between this measurement and the calculated efficiency curve, both clearly showing the deviation from the extrapolated predictions obtained from the equation $\varepsilon \propto e^{k}$.

Detailed inspection of the γ-ray intensities determined in the calculation reveal that, though the total γ-ray interaction cross-section has a decreasing gradient at

higher energies, the importance of various modes of energy loss from the detector, e.g. the escape of secondary charged particles, increases rapidly with energy resulting in a net downward deflection of the efficiency above ~ 2 MeV.

11. Nuclear Investigations With A Gelium Jet System
(J.E. Kitching and B. Varley)

A helium gas jet transport system for the rapid transfer of short-lived nuclei recoiling from targets under irradiation in the cyclotron external beam to a low background detection area has been constructed. The radioactive nuclei are entrained in helium gas flowing across the back of the target and are transported some 15 meters through small capillary tubing to a computer controlled tape transport system. Total transport time as short as one second has been attained. The efficiency of such a system has been found to be greatly enhanced if microscopic aerosol particles were present in the gas stream. During the development of our system we have produced such particles by addition of small quantities of various organic vapours into the gas flow. These vapours were either condensed or polymerized into suitable particles during passage through the intense radiation field in the target region. We have achieved transport efficiency of the order of 20% to 40% using vapours of benzene, carbon tetrachloride and pump oil, although strong beam intensity dependence of the efficiency and strong

background from irradiation of these carrier vapours were observed. To avoid these problems and improve the reliability of the system, we have constructed a double furnace for the generation of NaCℓ particles. Solid NaCℓ was evaporated in the first furnace, condensed in the helium flow and then re-evaporated and condensed in the second furnace. In this manner, solid spherical aerosol particles having a narrow size distribution in the range from 0.1 to μm in diameter were produced. Using this aerosol generator, we have increased the transport efficiency by 40%. The system is presently used to investigate the beta decay properties of the light mass indium (A<104) and tin (A<108) nuclei.

12. Range Distributions for Monoenergetic Positrons Emitted From A Point Source

(J.E. Kitching and B. Varley)

The determination of the absolute branching ratio of a positron emitting nucleus is obtained by measuring the ratio of γ-rays emitted to the number of positrons annihilated. This ratio, together with a knowledge of the decay scheme enables one to determine the ground state branching ratio. The experiment is usually performed by encapsulating the sample in a suitable absorber thick enough to ensure that no positron may escape. Unfortunately, while the γ-rays are emitted from the source, the emitted positrons migrate through the absorber before annihilating. The difference in solid angles thus subtended to a

detector are different and corrections must be made. (In addition to annihilation in flight). The McGill Monte-Carlo program was used to compute range distribution for several monoenergetic positron sources. The distributions obtained resemble those of the Landau-Symon type common in straggling studies. For ease of computation and interpolation, the fitting has been done with Johnson type distributions. The convolution of the distributions with allowed beta spectra and the consequential change in effective solid angles are being compiled.

13. Beta Spectrometer Response Functions

(D. Hetherington, J.E. Kitching, R.B. Moore and V. Varley)

Several approaches to the deconvolution of the response function of Ge beta detectors have been investigated. Guided by the computer generated response functions (Monte-Carlo calculation) the problem has been divided into two areas depending on whether electron or positron detection is involved.

For electron detection, beta spectra have been deconvoluted using models of the Monte-Carlo response functions. The convergence is slow with no way of accounting easily for differences between the true and modelled response functions. A simple fast approach has been to divide the response function into peak and flat background. The ratio of these is then varied as a function of energy until

known beta spectra are accurately deconvoluted. Families of peak to background ratios may be generated and lend themselves to easy interpolation. Good results for end-point energies, branching ratios and shape factors have been obtained.

Positron beta spectra are far more difficult to analyse in a simple fashion due to the positron annhilation summing effects in the response function. Work is continuing in this area to find the appropriate approximate artificial response function. More experimental data is required, especially to investigate lower limits in shape factor detection.

14. Systematic Studies of Separated Neutron Rich Nuclides

(H. Cheung, H. Huang, J.K.P. Lee and B.N. Subba Rao)

Systematic investigations of the structure of the neutron rich even-A Sn nuclei through the beta decay of the corresponding In isotopes have been continued during the past year. The In nuclides were isotopically separated in our on-line isotope separator. We have completed the work on ^{120}In, confirming the existence of 3 beta decaying isomers, which have been identified to have $J^{\pi} = 1^{+}$, 5^{-} and 8^{-}, respectively. The 8^{-} isomer decays populating mainly the 7^{-}, 8^{-} and 9^{-} states in ^{120}Sn. The experimental decay strengths appear to agree with the assumption that the 8^{-} isomer in ^{120}In and the three states in ^{120}Sn have dominant configurations $(\pi g_{9/2})^{-1}(\nu h_{11/2})$

and $\nu(g_{7/2})(h_{11/2})$, respectively. A two quasi-particle calculation has been performed and the results thus obtained are in agreement with the observed structure of ^{120}Sn.

The decay of ^{122}In has been a difficult case. We speculated earlier that it might be a parallel case with ^{120}In, with 3 decaying isomers. A thorough search yielded two distinct decay half-lives. Using two different production mechanisms. $^{124}Sn(d,\alpha)^{122}In$ and $^{238}U(p,f)^{122}In$, we have succeeded in isolating 3 groups of activities belonging to 3 different isomers in ^{122}In. Further experiments are in progress.

Preliminary data have been obtained from the decay of ^{95}Rb and ^{96}Rb. The half-lives of these nuclides have been measured to be 0.36 s and 0.21 s, respectively. The activities resulting from their decays are complex. These nuclides are beta delayed neutron emitters. Much more experimental work is in progress.

15. Magnetic Moments of 7^- States in Even Tin Nuclei
(R. Iafigliola, J.K.P. Lee and B. Singh)

Even tin nuclei are known to possess high lying 7^- states. The first 7^- state of these nuclei occurs at about 2.2 MeV and has a half-life in the neighbourhood of μs. It has been speculated that these states have a dominant neutron configuration $(d_{3/2})(h_{11/2})$ with small admixtures

of $(d_{5/2})(h_{11/2})$ and $(g_{7/2})(h_{11/2})$. We have undertaken a measurement of the magnetic moments of these states through the determination of their precession frequencies by means of γ-γ angular correlation using a Ge(Li)-NaI(Tℓ) system. The latter has been tested on the 2.4 μs, $(11/2^-)$ 497 keV state in ^{149}Eu which was populated through the beta decay of ^{149}Gd. The results thus obtained agree with those previously reported. To expedite the measurements, we are adding a second NaI(Tℓ) detector into the system. Measurements are presently in progress.

16. Nuclear Fission Studies with an On-Line Mass Spectrometer
(H.C. Cheung, A. Clara, J. Kondylakis, J.K.P. Lee and B.P. Pathak)

During the past year, we have investigated the fission fragment yields induced by deuterons on ^{235,238}U and ^{232}Th, using the on-line mass spectrometer. Isotopic distributions of Rb and Cs at different bombarding energies were obtained. Results indicate that Equal Charge Displacement (ECD) mechanism is likely the dominating reaction for these fission processes. Also, the probability of proton emission prior to scission is high, though no definite quantatative value can be concluded. The odd-even effect of the mass distribution is evident. This could be understood based on a preliminary calculation using a statistical model. The results are being prepared for publication.

17. Proton and Deuteron Induced Fission on ^{233}U

(P. Beeley, N. Mobed, J.K.P. Lee and L. Yaffe)

As a continuing program on the study of charged particle induced fission, the isotopic distributions of Ga, In, Rb and Cs from ^{233}U using the on-line mass spectrometer has been undertaken. These results, together with those from $^{235,238}U$ will give information about the role of the target N/Z ratio on the charge distribution mechanism.

The ^{233}U target assembly was proposed at the Chalk River Nuclear Laboratories. A safety procedure study has been done and the rate of evaporation of ^{233}U from heated target assembly was measured. Some preliminary data from proton beams were obtained. These studies will be extended to deuteron beams. Also, the absolute X-section of the isotopes will be measured to study the relative importance of symmetric and asymmetric fission as a function of target material and particle bombarding energy.

18. Ion Transport System for Isotope Separator

(H.C. Cheung, J.K.P. Lee and R.B. Moore)

When the isotopically separated ions are produced by the isotope separator, they are collected on a plate at the focal plane of the spectrometer. In the past, experimental measurements were performed either at the vicinity of the separator or the sources were extracted manually to a low background area. In the former case, we suffered from

large background interference, and in the latter case, we suffered from speed. Last year, we successfully constructed an ion transport system using electrostatic deflector and focussing lenses. The system is capable of transferring the ions with 70% efficiency to a low background area located 3 meters away from the separator. At present a fast moving tape transport system for collecting the ions for detection is being constructed. The whole system when in operation will allow us to investigate nuclides with half-lives as short as 100 ms.

19. New Approach to Synchrocyclotron Central Region Design
(G.K. Bavaria, J.E. Crawford and R.B. Moore)
Symmetrical acceleration of ions across the dee gap of a synchrocyclotron in its central region may give significantly greater circulating beam accelerated through the space charge region and less radial oscillation of the orbiting beam. Furthermore, modifying the central region so as to make it a separately excited isochronous cyclotron feeding ions into an outer dee which takes them to relativistic speeds via synchrocyclotron acceleration could allow axial external injection of ions into the machine. This could make the synchrocyclotron a rather inexpensive, reliable accelerator of heavy ions, as well as a very intense source of high energy light ions. These possibilities are presently being investigated in our cyclotron with the recently installed central region

auxiliary dee.

20. Absolute Cross-Sections for ^{64}Cu and ^{61}Cu Produced by Deuteron-Induced Reactions in Copper

(M. Diksic, H. Marshall, R.B. Moore, D.C. Santry (CNRL) and L. Yaffe)

Absolute measurements of the production yields of ^{64}Cu and ^{61}Cu by deuterons of energies 5.8 to 49.6 MeV on natural copper have been made. Chemical separations of the copper allowed direct measurements of the 511-keV annihilation radiation. The range in aluminum of deuterons of energy 50.4 MeV was determined to be 1716 ± 2 mg cm^{-2}.

21. Nuclear Charge Dispersion of Light-Mass Nuclides in the Fission of Heavy Elements by Protons of Energies 20-85 MeV

(M. Diksic, J.-L. Galinier, H. Marshall and L. Yaffe)

Cross-sections for the independent formation of ^{76}As, the partially-cumulative formation of ^{77}As and ^{77}Ge, and the cumulative formation of ^{79}As, ^{75}Ge and ^{78}Ge have been measured in the fission of ^{232}Th by protons of energies 35-85 MeV. Charge dispersion curves have been constructed from these data and compared to those obtained in previous work with ^{232}Th. The values of $(Z_A - Z_p)$ for the products investigated are the same as those found for the complementary products, whereas the full-widths at half-maximum are narrower. These results also confirm the very strong dependence of charge distribution parameters on mass which has already been observed in the very light-mass region of fission products of ^{238}U.

22. Measurement and Interpretation of ^{79}Br and ^{81}Br(p,xn) and (p,pxn) Excitation Functions in the Energy Range 10-85 MeV

(M. Diksic, J.-L. Galinier, H. Marshall and L. Yaffe)

A study of (p,xn) and (p,pxn) reactions on ^{79}Br and ^{81}Br was made. The excitation functions were measured in the energy range 10-85 MeV. The excitation functions experimentally obtained were compared with those predicted by intranuclear cascades and two pre-equilibrium models followed by equilibrium evaporation. None of the three computer codes was able to reproduce all excitation functions satisfactorily. The relative success of the computer codes tested is discussed.

23. Preparation of Carrier-Free ^{77}Kr by (p,xn) Reactions on Natural Bromine

(M. Diksic, J.-L. Galiner, H. Marshall and L. Yaffe)

A method of production of carrier-free 1.2-h ^{77}Kr by proton reaction on natural bromine has been developed using a simple separation procedure. A comparison between estimated thick-target yields using NaBr and LiBr as target materials has been made. The level of ^{79}Kr contamination is calculated as 7.7% of the krypton activity.

24. Activation Analysis of Clays and Potteries

(M. Attas, O. Birgul, M. Diksic, J. Fossey, H. Marshall, B.G. Trigger and L. Yaffe)

Samples of clay and pottery from various parts of the world have been analysed by means of proton and neutron activation and X-ray fluorescence techniques. The data have been treated with the multivariate statistical

analysis method for grouping. Pottery and clay samples from different regions of Turkey were analysed for 14 elements. Most of the pottery samples studied belong to Early Bronze and Phyrgian period excavated in Central Anatolia. Only some Phyrgian pottery from Yalincak and Buyuk Tumulus showed a similarity in composition to the major clay bed in this area.

Approximately 200 samples taken from potsherds found in excavations identified with the Early Bronze Age have been analysed for micro-components. The results are in the process of being analysed to determine the geographic origin of the pottery, possible routes of trade and commerce, etc.

Samples of pottery from excavation sites of eight Indian villages in the Lake Ontario and St. Lawrence Valley regions have been analysed for micro-components. The results are being compared with those of the clays from the sites to obtain information on the coherence of samples, provenance, village habits, etc.

25. The Fissionability of ^{232}Th

(C. Chung, J.J. Hogan, E. Gadioli (Milan, Italy) and M. Marsh)

We have completed, and are writing presently, an extensive work, both experimental and theoretical, on the fissionability of nuclei in the region of ^{232}Th. Chien Chung, a graduate student, has measured excitation

functions of (p,pxn), (p,αxn), and (p,pαxn) in the 10-100 MeV bombardments of ^{232}Th at the McGill synchrocyclotron. During the visit of our collaborator, Professor E. Gadioli of the National Institute for Nuclear Physics, University of Milan, Italy, we have carried out exciton model calculations on these reactions testing many theories of fissionability. Making use of ^{232}Th(p,xn) excitation functions measured by several other workers at Berkeley, Orsay, and here at McGill by R. Moore, we have beer able to extract values of Γ_f, Γ_n, Γ_p, and Γ_α from the data as a function of Z^2/A, the fissility parameter, and more importantly, the excitation energy, E^*. We have shown that it is not possible to reproduce the cross-sections of the wide range of reactions (sixteen in all, from (p,n) to (p,2p7n) without an excitation dependent Γ_f/Γ_n. This last point has been somewhat controversial through the years, mostly because of insufficient data in the 50-100 MeV region. A major paper is in its first draft stage.

26. Emission of Alpha Particles in Proton Induced Reactions in ^{48,50}Ti

(K.I. Burns and J.J. Hogan)

We have measured excitation functions for several complex reactions induced by 10-100 MeV protons incident on highly enriched targets of ^{50}Ti and ^{48}Ti. The stress has been on those nuclei in which alpha particles are emitted and even more particularly on multiple emission alphas.

For example, the excitation function of $^{50}Ti(p,3\alpha)^{39}C\ell$ and several $(p,2\alpha xn)$ reactions have been measured. Due to the low cross-sections and the complexity of the reactions, these provide a severe test of the present models of nuclear reactions utilizing pre-equilibrium decay. Mr. Burns has done extensive model calculations on these reactions and has been able to identify and evaluate the mechanisms (direct, pre-equilibrium, and evaporative) leading to alpha particle emission. A paper describing this work is being prepared.

27. Alpha Particle Clustering in the Nucleus
(J.J. Hogan)

Arising from the successes we have had in estimating excitation functions, we performed a series of calculations to determine the extent of alpha particle clustering in the nucleus. This work has been discussed at the International Conference on Clustering Phenomena in June in Winnipeg as well as with Professor P. Hodgson of Oxford and J.J. Griffen of Maryland. The calculation suggests that the extent of alpha particle clustering (on a percentage basis) remains fairly constant between A=50 and A=200. Presently still under discussion as to refinements of the calculation, it is expected that this work will be prepared for publication by the end of 1978.

28. Dynamic Positron Emission Tomography for Measurement of Three Dimensional Regional Cerebral Blood Flow and Regional Metabolic Rate Using Krypton-77 and Fluorine-18 Labelled Chemical Compounds

(G.K. Bavaria, M. Diksic, W. Feindel, S.K. Mark E. Meyer, R.B. Moore, C.J. Thompson, Y.L. Yamamoto and L. Yaffe)

(a) Research and Development of Krypton-77 and Fluorine-18 Positron Emission Tomography

The joint effort of our research groups in the Montreal Neurological Institute and Foster Radiation Laboratory and Chemistry Department, has resulted in pioneer application of this new technique for measurement of topographical changes of regional cerebral blood flow in cerebrovascular disease. Using the Fick principle, each topographical and quantitative regional cerebral blood flow value in every cm^2 of the cross-section of the head is calculated from an individual Krypton clearance curve in each pixel (cm^2) which is obtained after two-dimensional reconstruction of Krypton-77 distribution at 15 to 30 second intervals for 6 to 8 minutes following the non-invasive technique of bolus inhalation of Krypton-77.

Over the last year, we have appraised this positron emission tomography in over 350 patients and have obtained unique and valuable information for evaluating cerebrovascular patients, particularly cases of transient ischemic attack, mild stroke or localization of intracerebral steal phenomenon in arteriovenous malformation cases, for which we may not obtain adequate information from other diagnostic procedures.

In addition, the study of regional glucose metabolism in the human brain using ^{18}F labelled deoxyglucose is presently in progress. It is believed that regional blood flow and glucose metabolic rate are connected with cerebrovascular diseases. Much effort has been devoted to increasing the radiochemical labelling yield during the past year. Hopefully, we will be able to perfect our chemical techniques in the near future.

(b) Development of High Efficiency Positron Device Using Sixty-Four Bismuth Germanate Detectors

This new MNI-BGO positron device was developed and completed by us in June 1978. This new positron device was found to have twenty times better counting efficiency and improved the spatial resolution by less than half of the previous thirty-two NaI crystals positron device, which was built in collaboration with Brookhaven National Laboratory, U.S.A. Our MNI-BGO system has a spatial efficiency resolution (FWHM) of 1.3 to 1 cm without motion and of 0.7 to 0.6 cm with motion, and counting efficiency of 110,000 counts/sec/μCi/cc with a 20 cm diameter phantom using lower and upper energy discriminator between 360 and 660 keV levels.

Positron emission tomography has been gaining increased interest in the last few years and several positron devices have been designed lately. However, our MNI-BGO device is found to be the most efficient positron device available in the world at present. Using our new BGO

positron device, we are now further investigating usefulness of Krypton-77 and ^{68}Ga-EDTA dynamic positron emission tomographic techniques in cerebrovascular cases, particularly assessment of effectiveness of medical and surgical treatments in the occlusive cerebrovascular disease. We are building an additional ring of sixty-four BGO crystals to obtain information of three slices of the cross-section of the head simultaneously during a single inhalation of Krypton-77 for measurement of three dimensional regional cerebral blood flow in the human brain.

The First International Symposium on Positron Emission Tomography was held at the Montreal Neurological Institute, June 1 to 3, 1978, since we have been pioneers in this field. We had over 100 attending from all over the world to discuss this most exciting new field of medical investigation.

IV. SCIENTIFIC PUBLICATIONS DURING 1978

(a) Publications In Refereed Journals

1. "Decay of ^{101}Ag", S.I. Hayakawa, I.R. Hyman and J.K.P. Lee, Nucl. Phys. A296 (1978) 251.

2. "Decay of ^{104,106g,m}In", H. Huang, B.P. Pathak and J.K.P. Lee, Can. J. Phys. 56 (1978) 936.

3. "Decay of ^{120}In", H. Huang, H.C. Cheung, B.P. Pathak, B.N. Subba Rao, L. Lessard and J.K.P. Lee, J. Phys. G4 (1978) 1501.

4. "Cyclotron Production of Positron Emitting Nuclides for Medical Application", S.K. Mark, J. Comp. Ass't. Tomog. 2 (1978) 638.

5. "High Spin States in ^{88,87,86}Zr", J.E. Kitching, P.A. Batay-Csorba, C.A. Fields, R.A. Ristinen and B.L. Smith, Nucl. Phys. A302 (1978) 159.

6. "Cross-Section Measurements and Phase Shift Analysis of p-^{4}He Elastic Scattering in the Energy Range 20-55 MeV", A. Houdayer, N.E. Davison, S.A. Elbakr, A.M. Sourkes, W.T.H. van Oers and A.D. Bacher, Phys. Rev. C. 18 (1978) No. 4.

7. "Gamma-Ray Studies of the Odd-Parity States in Zn Isotopes I: ^{65}Zn", A. Kogan, P.R.G. Lornie, G.D. Jones, M.R. Nixon, H.G. Price, R. Wadsworth and P.J. Twin, J. Phys. G4 (1978) 755.

8. "Gamma-Ray Studies of the Odd-Parity States in Zn Isotopes II: Levels Below 2.0 MeV in Excitation Energy in ^{67}Zn", P.R.G. Lornie, A. Kogan, G.D. Jones, M.R. Nixon, H.G. Price, R. Wadsworth and P.J. Twin, J. Phys. G4 (1978) 923.

9. "Quasi-Band Structure in ^{64}Zn", D.N. Simister, G.D. Jones, F. Kearns, A. Kogan, P.R.G. Lornie, T.P. Morrison, O.M. Mustaffa, H.P. Price, P.J. Twin and R. Wadsworth, J. Phys. G4 (1978) 1127.

10. "Nuclear Spectroscopy in ^{63}Zn: States Below 1.5 MeV", O.M. Mustaffa, A. Kogan, G.D. Jones, P.R.G. Lornie, T.P. Morrison, H.P. Price, D.N. Simister, P.J. Twin and R. Wadsworth, J. Phys. G4 (1978) 99.

11. "Production of ^{24}Na from ^{27}Aℓ by 35-100 MeV Proton", J.J. Hogan, E. Gadioli, Nuovo Cimento 45A (1978) 341.

12. "Evaluation of Krypton-77 Positron Emission Tomographic Studies in Stroke", Y.L. Yamamoto, J. Little, E. Meyer, C.J. Thompson, R. Ethier, W. Feindel, J. Comp. Ass't. Tomog. 2 (1978) 663.

13. "Positome II: A High Efficiency P.E.T. Device For Dynamic Studies", C.J. Thompson, Y.L. Yamamoto, E. Meyer, J. Comp. Ass't. Tomog. 2 (1978) 650.

14. "Physiological Tomography by Positrons", W. Feindel, Y.L. Yamamoto, J. Comp. Ass't. Tomog. 2 (1978) 637.

15. "Confidence Limits for Topographical Cerebral Blood Flow Values Obtained by Krypton-77 Positron Emission Tomography", E. Meyer, Y.L. Yamamoto and C.J. Thompson, J. Comp. Ass't. Tomog. 2 (1978) 662.

16. "Structure of ^{129}Ba from the Decay of ^{129}La", P. Brodeur, B.P. Pathak and S.K. Mark, Z. Physik (accepted).

17. "Structure of ^{69}Ge", B.N. Subba Rao, J.E. Crawford and S.K. Mark, Z. Physik (accepted).

18. "Internal Conversion Electron Measurements Following the Decay of ^{152}Eu", J. Deslauriers and S.K. Mark, Nucl. Instr. and Meth. (accepted).

19. "An Iterative Technique for the Analysis of Detector-Distorted Data and Its Application to Beta-Ray Spectroscopy", D.M. Rehfield, Nucl. Instr. and Meth. (accepted).

20. "A Study of the Beta-Ray Response Function and Performance of an Intrinsic-Germanium Detector Mounted in a Superconducting Solenoid", D.M. Rehfield and R.B. Moore, Nucl. Instr. and Meth. (accepted).

21. "Absolute Cross-Section for ^{64}Cu and ^{61}Cu Produced by Deuteron-Induced Reactions in Copper", M. Diksic, J.L. Galinier, H. Marshall, L. Yaffe, R.B. Moore and D. Santry, Nucl. Instr. and Meth. (accepted).

22. "Measurement and Interpretation of ^{79}Br and ^{81}Br (p,xn) and (p,pxn) Excitation Functions in the Energy Range 10-85 MeV", M. Diksic, J.L. Galiner, H. Marshall and L. Yaffe, Phys. Rev. C (accepted).

23. "Charge Dispersion Studies of Light-Mass Nuclides in the Fission of ^{232}Th by Protons of Energies 35-85 MeV", M. Diksic, J.L. Galiner, H. Marshall and L. Yaffe, J. Inorg. Nucl. Chem. (accepted).

24. "X-Ray Fluorescence Analysis of Turkish Clays and Pottery", O. Birgul, M. Diksic and L. Yaffe, Archaemetry (accepted).

25. "On the Influence of the Mean Free Path Parameter on Intranuclear Cascade Calculations", J.J. Hogan, K.I. Burns, E. Gadioli and E. Gadioli-Erba, Nuovo Cimento (accepted).

(b) Papers Presented at Conferences and Symposia

1. "Nuclei Far From Beta Stability", S.K. Mark, Invited Talk, Eastern Regional Nuclear Physics Conference, C.A.P., Chalk River, April 7-8, 1978.
2. "Structure of N=50 ^{94}Ru", K. Oxorn, B. Singh and S.K. Mark, Eastern Regional Nuclear Physics Conference, C.A.P., Chalk River, April 7-8, 1978.
3. "Structure of ^{139}Pm from the Decay of ^{139g}Sm", J. Deslauriers, S.P. Sud, S.C. Gujrathi and S.K. Mark, Bull. Am. Phys. Soc. 23 (1978) 556.
4. "Cyclotron Production of Unstable Nuclides for Medical Applications", S.K. Mark, Invited Talk, First International Conference on Positron Tomography, McGill University, June 2-3, 1978.

5. "Low Lying Structure of ^{129}Ba", P. Brodeur, B.P. Pathak and S.K. Mark, Bull. Can. Assoc. Phys. 34 (1978) 24.

6. "A Monte Carlo Calculation for Electron and Positron Response Functions in Ge Detectors", B. Varley, J.E. Kitching, W. Leo, J. Miskin and R.B. Moore, Bull. Can. Assoc. Phys. 34 (1978) 23.

7. "Synchrocyclotron Improvements", G. Bavaria, J.E. Crawford and R.B. Moore, Proc. of Eighth International Conference on Cyclotrons and Their Applications, Bloomington, Indiana, Sept. 17-23, 1978.

8. "Studies of the ^{124}Xe and ^{123}Xe Level Structure", K. Sofia, B.N. Subba Rao, A. Kogan and J.E. Crawford, Bull. Can. Assoc. Phys. 34 (1978) 23.

9. "Decay of ^{120}In", H.C. Cheung, H. Huang, B.N. Subba Rao, L. Lessard and J.K.P. Lee, Eastern Regional Nuclear Physics Conference, C.A.P., Chalk River, April 7-8, 1978.

10. "Neutron Multiplicity in the Symmetric Fission Ir(p,f)", B.P. Pathak, L. Nikkinen, L. Lessard and J.K.P. Lee, Bull. Am. Phys. Soc. 23 (1978) 595.

11. "Independent Yield of Rb and Cs Isotopes from $^{238}U(d,f)$", A. Clara, B.P. Pathak and J.K.P. Lee, Bull. Am. Phys. Soc. 23 (1978) 595.

12. "Decay of ^{122}In", H.C. Cheung, H. Huang and J.K.P. Lee, Bull. Can. Assoc. Phys. 34 (1978) 23.

13. "Alpha Particle Clusters in Complex Nuclei: A Semi-Empirical Calculation", J.J. Hogan, Proc. Third International Conference on Clustering Aspects of Nuclear Structure and Reactions", Winnipeg, Manitoba, June 19-23, 1978.

14. "Production of Carrier-Free ^{77}Kr and ^{123}Xe in Proton Irradiation", M. Diksic and L. Yaffe, First International Conference on Positron Tomography, McGill University, June 2-3, 1978.

15. "Krypton-77 Positron Emission Tomography for Evaluation of Medical and Surgical Treatment in Stroke Patients", Y.L. Yamamoto, J. Nuclear Medicine 19 (1978) 701.

16. "Changes of Topographical Regional Cerebral Blood Flow After Surgical Treatment of Stroke; Evaluation of ^{77}Kr Positron Emission Tomography", Y.L. Yamamoto, Stroke 9 (1978) 107.

(c) Theses

"Nuclear Structure Near $1g_{9/2}$ Shell Closure", H. Huang, Ph.D. Thesis, 1978.

"Structure of Ba-129 and 130 Nuclei", P. Brodeur, M.Sc. Thesis, 1978.

"On-Line Study of $^{235,238}U$ Fission Induced by Deuterons", A. Clara, M.Sc. Thesis, 1978.

"Rb and Cs Yield From $^{232}Th(d,f)$", J.C. Kondylakis, M.Sc. Thesis, 1978.

V. PERSONNEL

A. Resident Personnel

(a) Academic and Research Staff

MARK, S.K.	Professor and Director
MOORE, R.B.	Professor
CRAWFORD, J.E.	Associate Professor
KITCHING, J.E.	Associate Professor
LEE, J.K.P.	Associate Professor
GUJRATHI, S.C.	Staff at Dawson College
HOUDAYER, A.	Staff at Ahuntsic College
CHATTERJEE, M.L.	Visiting Scientist from Saha Institute of Nuclear Physics, India (commenced Nov. 1, 1978)
CHEUNG, H.C.	Research Associate (resigned Sept. 15, 1978)
HUANG, H.	Postdoctoral Fellow (commenced Oct. 1, 1978)
KOGAN, A.	Research Associate
LOLOS, G.	Research Associate (commenced June 1, 1978)
PATHAK, B.P.	Research Associate (resigned Sept. 15, 1978)
SINGH, B.	Research Associate (resigned Oct. 31, 1978)
SUBBA RAO, B.N.	Research Associate
VARLEY, B.	Research Associate

(b) Professional and Technical Staff

BAVARIA, Dr. G.K.	Accelerator Physicist
DAVIES, E.	Machinist
DELLA NEVE, M.	Cyclotron Technician
EGYED, J.	Chief Machinist
JORGENSEN, C.	Electronics Technician
KAY, A.R.	Cyclotron Technician
KECANI, S.A.	Machinist
KUCHELA, Dr. K.S.	Electronics Supervisor
LALEFF, S.	Administrative Secretary
MILLS, R.H.	Laboratory Superintendent
NIKKINEN, L.	Project Assistant
PAYMANI, R.	Electronics Technician

(c)

Graduate Students	Degree Sought
BANGOURA, J.M.	M.Sc.
BRODEUR, P.	M.Sc. (completed, August 1978)
CLARA, A.	M.Sc. (completed, August 1978)
DESLAURIERS, J.	Ph.D.
GILES, G.	M.Sc.
HETHERINGTON, D.	Ph.D.
HUANG, H.	Ph.D. (completed, May 1978)
IAFIGLIOLA, R.	Ph.D.
KONDYLAKIS, J.	M.Sc. (completed, August 1978)
MOBED, N.	M.Sc.

(c) Graduate Students (cont'd.)

OXORN, K.	Ph.D.
SHAHIEN, K.	M.Sc.
SOFIA, K.	Ph.D.
TACIK, R.	M.Sc.

(d) Summer Students

CHAN, B.

KENNEDY, I.

TURCOTTE, R.

B. Non-Resident Personnel

(a) Chemistry Department

YAFFE, L.	Professor and Vice-Principal
HOGAN, J.J.	Associate Professor
DIKSIC, M.	Research Associate
MARSHALL, H.	Postdoctoral Fellow
ATTAS, M.	Graduate Student
BEELY, P.	Graduate Student
EDWARDS, J.	Graduate Student
BURNS, K.	Graduate Student
CHUNG, C.	Graduate Student

(b) Montreal Neurological Institute

FEINDEL, W.	Professor and Director
YAMAMOTO, Y.L.	Associate Professor
MEYER, E.	Graduate Student