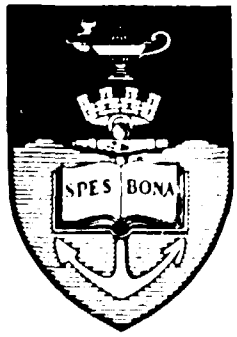
Kerninstituut van die
Suidelike Universiteite

SUNI -- 66

1979-81
Voorsittersverslag
Chairman's Report



Southern Universities
Nuclear Institute

VOORSITTER SE VERSLAG

Vir tydperk 1 April 1979 tot 31 Maart 1981

Gelewer deur professor J. W. R. de Villiers, Voorsitter van die Raad van Beheer, aan die vergadering van die Raad op 23 April 1981.

CHAIRMAN'S REPORT

For period 1 April 1979 to 31 March 1981

Presented by Professor J. W. R. de Villiers, Chairman of the Board of Governors, to the meeting of the Board on the 23rd April, 1981.

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CHAIRMAN'S REPORT FOR THE PERIOD 1 APRIL 1979 TO 31 MARCH 1981

SUNI REPORT NO. 66

The Southern Universities Nuclear Institute (SUNI) is now nineteen years old and it is my pleasant duty to report that, even though a degree of uncertainty exists about the future of SUNI, a consistently high standard of research has been maintained, and that the collaboration between university and SUNI personnel has once again been most fruitful. Multidisciplinary work has also filled a prominent role in our research and has given rise to a large number of interesting projects. For example, medical and life sciences projects have been undertaken in collaboration with the Ischaemic Heart Research Unit at the University of Cape Town, the Department of Pharmacology at the University of Stellenbosch and with the National Accelerator Centre. Other applied projects have been carried out with the National Research Institute for Oceanology, Stellenbosch, with the Percy Fitzpatrick Institute for African Ornithology at UCT, and with the State Museum, Windhoek, South West Africa.

On this occasion I would like to thank the Board of Governors of SUNI and its various committees for their co-operation and support during the term of office of Prof. M. F. Kaplan and, on his resignation, myself as Chairman of the Board. It is also with regret that I have to report that, as from April 1, 1981, Prof. I. J. van Heerden has resigned as Chief Scientist and Officer in Charge of the Institute to take up a professorate in experimental nuclear physics at the University of the Western Cape. We wish him well in his new position and thank him for the long period of service he has given to SUNI. Under his leadership, SUNI has developed into a research institute of world calibre and the SUNI personnel must be commended for the large part they have played in this de-

VOORSITTER SE VERSLAG VIR TYDPERK 1 APRIL 1979 TOT 31 MAART 1981

KISU VERSLAG Nr. 66

Die Kerninstituut van die Suidelike Universiteite (KISU) is vanjaar 19 jaar oud, en dit is vir my baie aangenaam om daarop te wys dat, ondanks 'n mate van onsekerheid wat daar oor die toekoms van KISU bestaan, 'n konstante hoë navorsingstandaard steeds gehandhaaf word en dat die samewerking tussen universiteits- en KISU-personeel weereens vrugbaar was. Multidissiplinêre werk het ook 'n prominente rol gespeel in ons navorsing en het aanleiding gegee tot 'n hele aantal interessante projekte. Mediese en lewenswetenskaplike studies is byvoorbeeld onderneem in samewerking met die Navorsingseenheid vir Hartsiektes aan die Universiteit van Kaapstad, die Departement Farmakologie aan die Universiteit van Stellenbosch en die Nasionale Versnellersentrum. Ander verwante projekte is ook uitgevoer in samewerking met die Nasionale Navorsingsinstituut vir Oseanologie, Stellenbosch, die Percy Fitzpatrickinstituut vir Afrikavoëlkunde, Universiteit van Kaapstad, asook die Staatsmuseum in Windhoek, Suidwes-Afrika.

By hierdie geleentheid wil ek graag die Raad van Beheer van KISU en al sy komitees hartlik bedank vir hulle samewerking en ondersteuning gedurende die ampstermyn van prof. M. F. Kaplan, en na sy bedanking, met my as Voorsitter van die Raad. Dit is ook met spyt dat ek u moet meedeel dat prof. I. J. van Heerden as Hoofwetenskaplike en Beampte-in-Beheer van die Kerninstituut met ingang van 1 April 1981 bedank het om by die Universiteit van Wes-Kaapland 'n professoraat in eksperimentele kernfisika te aanvaar. Ons wil hom bedank vir sy lang dienstermyn by KISU en wens hom alles van die beste toe in sy nuwe werkkring. KISU het, onder sy leierskap, ontwikkel tot 'n navorsingsinstituut van

velopment, and for their dedicated work. The financial support of the Universities of Cape Town and Stellenbosch, the Department of National Education, the Atomic Energy Board and the Council for Scientific and Industrial Research is gratefully acknowledged. Additional funds for capital expenditure on equipment were also obtained from the Cape Provincial Administration.

Although generally acknowledged that the use of the 6 MV Van de Graaff accelerator for basic nuclear physics research is sometimes limited by its low beam energy, the SUNI research effort has shown no signs of decline. In fact the research has been characterized by an ever-increasing degree of sophistication and inventiveness, so that in the period under review, the work carried out at SUNI has provided the basis for 10 M.Sc and 2 Doctorate theses, for 34 publications in international scientific journals and for 15 papers that have been contributed to international conferences which have been attednded by staff members of the two Southern Universities and of SUNI. Since 1964 when the accelerator first became operative, no less than 85 500 hours of accelerator time has been used for a total of 41 M.Sc and 31 Doctorate theses, 260 publications in the international scientific literature and 84 contributed papers at international conferences.

Technical Developments

As mentioned above, the use of the accelerator for basic nuclear physics research is limited by its low beam energy. However, SUNI has continued to develop various peripheral equipment to extend the usefulness of the accelerator for research.

During the period under review, development of SUNI's data handling facilities has focused on the two new PDP 11/34 computer based acquisition systems. Extensive in-house hardware has been designed and constructed by the SUNI electronics staff, including histogram display units for displaying up to 16 spectra on a cathode ray tube,

wêreldgehalte, en die personeel moet geloof word vir hulle groot aandeel in hierdie ontwikkeling en vir hulle toegewyde diens. Die finansiële ondersteuning van die Universiteite van Kaapstad en Stellenbosch, die Departement van Nasionale Opvoeding, die Raad op Atoomkrag en die Wetenskaplike en Nywerheidsnavorsingsraad word met dank erken. Bykomende fondse vir kapitaalaankope is ook van die Kaaplandse Provinsiale Administrasie ontvang.

Alhoewel dit nou algemeen erken word dat die gebruik van die 6 MV-Van de Graaff-versneller vir basiese navorsing in kernfisika al hoe meer beperk raak as gevolg van lae bundelenergie, het KISU se navorsingsprogram geen tekens van afname getoon nie. Inteendeel, 'n steeds toenemende mate van gesofistikeerde navorsing en vindingrykheid is gekenmerk in die werk wat gedurende die verslagtydperk by KISU uitgevoer is. Dit het die grondslag gelê vir 10 M.Sc- en 2 doktorsgrade, 34 publikasies wat in internasionale tydskrifte verskyn het en 15 referate wat deur personeellede van die twee suidelike universiteite en KISU by internasionale konferensies gelewer is. Sedert die versneller in 1964 vir die eerste keer bruikbaar gemaak is, is daar soveel as 85 500 uur versnellertyd gebruik vir 'n totaal van 41 M.Sc- en 31 doktorsgrade, 260 publikasies vir internasionale wetenskaplike tydskrifte en 84 referate wat by internasionale konferensies gelewer is.

Tegniese Ontwikkelinge

Soos reeds gemeld, is die gebruik van die versneller vir basiese navorsing in kernfisika beperk as gevolg van sy lae bundelenergie. Ten spyte daarvan het KISU voortgegaan om verskeie verwante toerusting te ontwerp om die bruikbaarheid van die versneller vir navorsing uit te brei.

Gedurende die verslagtydperk, is die ontwikkeling van KISU se datahanteringsfasiliteit toegespits op die twee nuwe PDP 11/34-rekenaarversamelingsisteme. Omvangryke apparatuur is deur KISU se elektronika personeel ontwerp en gebou, insluitende histogramvertooneenhede, wat tot 16 spektra

multiplexed ADC interfaces operating in memory increment mode, a multi-parameter ADC interface operating in list mode, a magnetic tape interface based on an 8085 microprocessor, and video terminals incorporating keyboard, light pen and function buttons, by means of which the user interacts with the system.

System and applications software has been written to control the acquisition of data from experiments via the above-mentioned hardware, to perform simple data manipulation operations on the acquired data, and to output the data onto disc and magnetic tape for later off-line analysis, either on the PDP 15/76 computer system at SUNI, or the mainframe computers at the two universities.

One system has been installed in the control room during the past year for use by experimenters utilising the accelerator. During the coming year, it is planned to install the second system in the counting room to control the acquisition of data from the automatic sample changer and its associated equipment.

Some Aspects of Research at SUNI

Basic and applied research projects undertaken at SUNI cover a very wide field determined by the interests and expertise of the scientists working with the SUNI facilities. Not all of these can be included in a short popular presentation. Some individual or group undertakings at SUNI over the past two years are given in the following subsections.

1. *Studies of nuclear level parameters using charged particle induced reactions.*

Certain properties of excited nuclear states have been determined by the measurement of charged particles emitted in the nuclear reaction or of the decay gamma-rays of these states to lower lying levels. If measurements are confined to coincident registration of charged particles and their associated gamma radiation, unique results are usually

op 'n skerm kan vertoon, veelkoppelende ASO-koppelvlakke wat deur geheue-inkrementmodus bedien word, 'n multiparameter-ASO-koppelvlak wat opeenvolgend verkry kan word, 'n magneetbandkoppelvlak wat gebaseer is op 'n 8085 mikroverwerker en videoterminale met toetsbord, ligpen en funksieknoppe waarmee wisselwerking tussen die gebruiker en die stelsel plaasvind.

Stelsel- en toepassingsprogrammatuur is ontwikkel om data te beheer wat tydens eksperimente deur bogenoemde apparatuur verkry is, om eenvoudige datahantering te verrig en op skyf- en magnetiese band vas te lê vir latere ontleding, hetsy op die PDP 15/76-rekenaarstelsel by KISU of die rekenaarstelsels van die twee universiteite.

Gedurende die afgelope jaar is een stelsel in die beheerkamer geïnstalleer vir gebruikers van die versneller. Daar word beplan om in die komende jaar 'n tweede stelsel in die telkamer te installeer om dataversameling van die outomatiese monsterwisselaar en verwante toerusting te beheer.

Navorsing

'n Baie wye veld word gedek deur basiese en toegepaste navorsingsprojekte wat by KISU onderneem is deur die belangstelling en vakkundigheid van navorsers wat KISU-fasiliteite gebruik. Sekere individuele of spanpogings wat gedurende die afgelope twee jaar by KISU gedoen is, word in die volgende subafdelings genoem.

1. *Studies van kernvlakparameters waar gebruik gemaak word van gelaaide deeltjiegeïnduseerde reaksies.*

Sekere eienskappe van opgewekte kerntoestande is bepaal deur die meting van gelaaide deeltjies wat uitgeskiet word in 'n kernreaksie of die verval van gamma-strale van hierdie deeltjies na laerliggende vlakke. Indien meting beperk word tot koïnsidenswaarneming van gelaaide deeltjies en hulle geassosieerde gamma-straling, is eenduidige resultate soos vlakenergieë en

obtained for nuclear parameters such as level energies and decay properties, and by applying reaction theories, also for lifetimes, spins and for the mixing ratios of the gamma radiation.

In the past two years charged particle studies at SUNI have also been expanded to include mass-identification for the more complex nuclear reactions in which a variety of charged particle reaction products are often produced. Apart from the total energy of the products, the energy loss of the particle is measured in a very thin solid state detector. Now that commercial detectors with thicknesses smaller than one fiftieth of a millimetre are commercially available, mass identification has become a practical possibility for the energies available at the Van de Graaff accelerator.

Studies of the atomic nuclei potassium-39, potassium-41 and chromium-54 have been completed whilst the investigation of the nuclei chlorine-37, potassium-43, potassium-46 and scandium-51 is in progress. The results for potassium-39 and potassium-41 compare favourably with the shell-model predictions.

2. *Calibrated mono-energetic neutron sources obtained from the SUNI accelerator.*

There are two significant problem areas in studies involving the measurement of neutron induced nuclear reactions. The first concerns the difficulty of neutron detection. Neutron detectors generally have low efficiency (not precisely known and dependent on neutron energy) as well as poor energy resolution. The second problem area results from the poor directional selectivity of neutron detectors. Collimation of the neutron beam and shielding of the neutron detector often introduce their own additional problems.

One approach that eliminates both problem areas in the calibration of detectors for energetic neutrons and in the study of certain reaction cross sections is the use of an

vervaleienskappe gewoonlik vir kernparameters en by die toepassing van reaksieteorieë ook vir die lewensduur, spinwaardes en mengverhouding van die gammastraling verkry.

Oor die afgelope twee jaar is studies van gelaaide deeltjies by KISU uitgebrei om massaidentifikasie vir die meer komplekse kernreaksies in te sluit waarin dikwels 'n verskeidenheid produkte van gelaaide deeltjies voorkom. Afgesien van die totale energie van die produkte, is die energieverlies van die deeltjie in 'n baie dun vastetoestanddetektor gemeet. Noudat kommersiële detektors met 'n dikte kleiner as een vyftigste van 'n millimeter beskikbaar is, het massaidentifikasie, vir energieë beskikbaar by die Van de Graaff-versneller, 'n werklikheid geword.

Studies van kalium-39, kalium-41 en chroom-54 is afgehandel en die ondersoek van chloor-37, kalium-43, kalium-46 en skandium-51 is aan die gang. Die resultate van kalium-39 en kalium-41 vergelyk baie goed met die voorberekeninge van die skilmodel.

2. *Gekalibreerde monoënergetiese neutronbronne verkry vanaf die versneller by KISU.*

Met die meting van neutrongeïnduseerde kernreaksies is daar twee hoofprobleme. Eerstens die waarneming van neutrone. Neutrondetektors het in die algemeen 'n lae doeltreffendheid wat nie altyd presies bekend is nie en wat afhang van die neutronenergie, sowel as 'n swak energieresolusie. Tweedens het neutrondetektors 'n swak rigtingselektiwiteit. Die afskerming van die neutrondetektor en die kollimasie van die neutronbundel skep gewoonlik ook verdere probleme.

Deur gebruik te maak van 'n geassosieerde partikelneutronbron, kon beide probleme oorkom word in die kalibrasie van dié detektors vir energetiese neutrone,

"associated particle neutron source". This source uses reactions such as $D(d,n)^3He$ and $^3H(d,n)^4He$ to produce mono-energetic fast neutron beams of absolutely known flux. Work at SUNI has thus far been restricted to 2 to 6 MeV neutrons from the $D(d,n)^3He$ reaction.

Using the $D(d,n)^3He$ reaction, the neutron detection system is operated in time coincidence with an associated recoil ^3He particle detector whose detection characteristics and geometry are well defined. The number of ^3He ions detected is then precisely equal to the number of tagged neutrons and the size and position of the aperture on the ^3He particle detector determines the direction and directional spread of this neutron beam.

To accommodate the neutron source a special thin (1.5 mm) walled 34 cm diameter aluminium scattering chamber has been constructed. A deuterated polyethylene target is rotated at 5Hz by a motor mounted outside the chamber. The deuteron beam of the 6MV Van de Graaf accelerator is collimated to 1.5 mm in diameter before entering the chamber. After passing through the target it is stopped 2m downstream in a shielded beam dump. The ^3He ions are detected in a surface barrier detector which subtends a small solid angle at the target. Increased neutron beam intensity can be achieved by increasing the deuteron current or the target thickness. However, limitations are imposed by the amount of current which the target can withstand and by the count rate which the surface barrier detector can tolerate without deterioration. We have developed an experimental system in which a relatively intense collimated monoenergetic neutron beam has been produced by means of both improved target fabrication *and* optimization of the ^3He detection system.

Even thin self supporting deuterated polyethylene foils rotated at high speeds typically have a lifetime of only a few minutes for incident beam current of about 2μA. By evaporating thin carbon layers onto both sides of the target foils it has been found that thick target sandwiches in the 200–400 $\mu g.cm^{-2}$ range and rotated at 5Hz

asook in die bepaling van sekere reaksiekansvlakke. So 'n bron gebruik $D(d,n)^3He$- of $^3H(d,n)^4He$-reaksies om 'n bundel monoënergetiese neutrone met 'n vaste bekende vloed te lewer. Tot op hede is by KISU werk gelewer wat beperk was tot 2–6 MeV-neutrone van die $D(d,n)^3He$-reaksie.

As die $D(d,n)^3He$-reaksie gebruik word, word die neutrondetektorsisteem saam met 'n geassosieerde terugslag-^3He-partikeldetektor in tydkoïnsidens gebruik. Die waargenome ^3He-partikels is dan presies gelyk aan die aantal gemerkte neutrone. Verder bepaal die grootte en posisie van die opening op ^3He-partikeldetektor die rigting en spreiding van die neutronbundel.

'n Aluminiumverstrooiingskamer met 'n wand van 1,5 mm en 'n 34 cm-deursnee is ontwerp om die neutronbron te huisves. 'n Gedeutereerde poliëtileenskyf word teen 5 Hz roteer deur 'n motor wat buite die kamer gemonteer is. Die deuteronbundel afkomstig van die 6 MeV-Van de Graaff-versneller word tot 1,5 mm-deursnee gekollimeer voordat dit die kamer binnegaan. Nadat dit deur die skyf is, word dit 2 m verder af in 'n afgeskermde gebied gestop. Die ^3He-ione word waargeneem deur 'n oppervlakversperde detektor wat 'n klein hoekie by die skyf onderspan. Deur die deuteronstroom of die skyfdikte te vergroot, kan die neutronbundelintensiteit verhoog word. Sekere beperkings kom egter na vore, soos die hoeveelheid stroom wat die skyf kan weerstaan asook die teltempo van die oppervlakversperde detektor. 'n Eksperimentele sisteem is ontwerp wat 'n relatief intens gekollimeerde monoënergetiese neutronbundel lewer deur verbeterde skyfvoorbereiding en optimisering van die ^3He-deteksiesisteem.

Selfs die selfondersteunende gedeutereerde poliëtileenfoelies wat teen 'n hoë snelheid roteer, het 'n tipiese leeftyd van slegs 'n paar minute vir 'n invallende bundelstroom van ongeveer 2 μA. Die leeftyd van 'n skyf wat teen 5 Hz roteer en 'n bundel-

can withstand 2,5 μA of deuterons for periods of days. To protect the ^{3}He particle detector an electromagnetic analyser has been attached to the scattering chamber. Magnetic analysis separates the ^{3}He ions from the very high flux of elastically scattered deuterons. With the improved targets and with magnetic analysis on the particle detection system it has been possible to achieve ^{3}He count rates (and therefore neutron flux rates) of up to 10^3/sec.

The high flux capability of the SUNI source has been used to measure the neutron sensitivity of a GM tube at 3 MeV. The source has also been used for various cross section measurements and to measure the efficiency of scintillation counters in the 2–6 MeV region, although in these applications the high flux capability is not required. The energy range of the source will be extended by using the T(d,n) He reaction with tritiated target foils. It has recently been reported that the associated particle method is feasible with high energy neutrons (130 MeV) and it is hoped therefore to use the present source for dosimeter calibration purposes with neutrons up to 200 MeV when the National Accelerator Centre cyclotron comes into operation.

3. *Development and Application of Prompt Nuclear Analysis.*

Over the past few years the trend to "relevancy" has been characteristic of scientific development. In analytical chemistry one of the effects of this trend was the application of better methods to solve complicated chemical problems such as the effects of pollution on ecology or the role of component imbalance in disease. Prompt nuclear methods capable of carrying out multielemental analysis non-destructively have been extensively studied and previously neglected mathematical techniques are now being used to obtain meaningful information from such analyses.

(i) *Multielemental analysis and the application of multivariate statistics.*

There exist several methods capable of yielding multielemental analytical data. Of

stroom van 2,5 μA kan weerstaan, is verleng tot 'n paar dae deur dun koolstoflagies 200–400 μg/cm^2 dik weerskante van die skyffoelie op te damp. Om die ^{3}He-partikeldetektor te beskerm, is 'n elektromagnetiese analiseerder gekoppel aan die verstrooiingskamer. Magnetiese analisering skei die ^{3}He ione van die hoë vloed elasties verstrooide deuterone. Sodoende kon ^{3}He-teltempo's (en dus neutronvloedtempo's) van tot 10^3/sek verkry word.

Die hoë vloedgeskiktheid van die KISU-bron is gebruik om die neutronsensitiwiteit te bepaal van 'n GM-buis by 3 MeV. Die bron is ook gebruik om verskeie kansvlakke te bepaal en om die effektiwiteit van sintillasietellers in die 2–6 MeV-gebied te bereken, alhoewel in dié toepassings hoë vloedgeskiktheid nie vereis word nie. Die energieskaal van die bron sal vergroot word deur die T(d,n)He-reaksie te gebruik met tritiumskyffoelies. Onlangs is gemeld dat die geassosieerde partikelmetode uitvoerbaar is met hoë energie neutrone (130 MeV) en nou word gehoop om die bron vir dosismeter kalibrasiedoeleindes te gebruik met neutrone tot en met 200 MeV wanneer die Nasionale Versnellersentrum in werking is.

3. *Die ontwikkeling en toepassing van pront-kernanalise.*

In die jongste tyd het die neiging tot "relevansie" by wetenskaplike ontwikkeling kenmerkend geword. Een van die gevolge hiervan in analitiese chemie was die toepassing van beter metodes om ingewikkelde chemiese probleme, soos die gevolge van besoedeling op ekologie of die rol van wanbalans in die samestelling van komponente by siektes op te los. Pront-kernmetodes, wat in staat is om nie-vernietigende veelelement-ontledings uit te voer, is op groot skaal bestudeer, en wiskundige tegnieke wat voorheen verontagsaam is, word nou gebruik om betekenisvolle inligting uit sulke ontledings te verkry.

(i) *Veelelementanalise en die toepassing van multivariantestatistiek.*

Daar bestaan verskeie metodes wat in staat is om veelelementanalitiese

these the three methods used at SUNI were particle-induced X-ray emission, (PIXE), particle-induced prompt photon spectrometry, (PIPPS), and neutron activation analysis (NAA). Under normal conditions these methods yield results rapidly and hence are useful for routine application to large numbers of samples. The resulting flow of analytical data is so large that it has become the usual laboratory practice to consider only selected information. However, in problems involving the classification of specimens into groups or the placement of a specimen in known groups, there is often the need to utilise all available data. Examples of such problems studied at SUNI include the effect of nutrition and geography on trace elements in the blood of infants, the study of nutrient elements in apples during their growth period and the classification of archaeological artefacts. The combination of multielemental analysis and multivariate statistics becomes a powerful tool for the study of such problems.

With the cooperation of the Department of Mathematical Statistics and of the Computing Service of UCT different methods of multivariate analysis were applied. All these methods viewed a sample in which n elements had been determined, as a point in n-dimensional space and every method provided a different technique to visualise the grouping of similar samples.

In the single-linkage cluster method a dendogram is obtained showing similar objects as fused into clusters, the extent of dissimilarity being shown by the spacing between them. In particular, the minimal spanning tree yields a similar diagram stressing the interrelationship between nearest neighbours. Non-linear mapping attempts to visualise the set of points by approximating their interpoint distances in two dimensions to the distance in the original space. Non-metric multidimensional

gegewens te lewer. Drie hiervan is by KISU gebruik, nl. partikelgeïnduseerde X-straalemissie (PIXE), partikelgeïnduseerde pront-fotospektrometrie (PIPPS) en neutronaktiveringsanalise (NAA). Onder normale toestande lewer hierdie metodes snelle resultate en daarom is dit nuttig by die toepassing van roetine-ontledings op groot hoeveelhede monsters. Die toevoer van analitiese gegewens is gevolglik so groot dat dit algemene laboratoriumpraktyk geword het om slegs aan geselekteerde inligting aandag te skenk. Probleme wat die klassifikasie van monsters in groepe of die toewysing daarvan tot bekende groepe behels, vereis egter dikwels die gebruikmaking van alle beskikbare inligting. Voorbeelde van sodanige probleme wat by KISU bestudeer is, sluit in die uitwerking van voeding en geografie op die spoorelementinhoud van die bloed van jong kinders, 'n studie van die voedingstofelemente in appels gedurende hul groeitydperk en die klassifikasie van argeologiese kunsprodukte. Die samevoeging van die veelelementontledingstegniek en multivariantestatistiek lei in sulke gevalle tot 'n baie effektiewe analitiese metode.

In samewerking met die Departement van Wiskundige Statistiek en die Rekensentrum van UK is verskillende metodes van multivariante-ontledings toegepas. Elk van die metodes lewer 'n voorstelling waar 'n monster, waarin n-elemente bepaal is, verteenwoordig word deur 'n punt in 'n n-dimensionele ruimte. Elkeen het ook 'n kenmerkende tegniek om die groepering van ooreenstemmende monsters voor te stel.

In die enkelkoppelingsbondelmetode word ooreenstemmende voorwerpe voorgestel as saamgevoeg tot bondels deur 'n dendogram. Die mate waarin daar onderlinge verskillende bestaan, word aangedui deur die spasiëring tussenin. Die minimale-span-boommetode, in die besonder, lewer 'n ooreenstemmende diagram waarin die onderlinge verband tussen naaste bure beklemtoon word. Nielineêre afbeelding poog om die stel punte

scaling generalises the previous approach by considering the order of the interpoint spacing instead of the actual distance. The most sophisticated method of correspondence analysis, while retaining the advantages of the previous methods, also provides a means of visualising the interrelationship between sample groupings and the component chemical elements.

(ii) *Particle-induced prompt photon spectrometry (PIPPS).*

Although PIPPS has been used for many years with proton beams, virtually all the work had previously been carried out at proton energies below 3,5 MeV and for the analysis of light elements. Under those conditions the gamma-rays that were excited were with few exceptions, those from coulomb excitation. With increasing proton energy, the probability for the occurrence of nuclear reactions increased and hence more gamma-rays became available for analytical application, particularly those from higher atomic number elements.

In order to select suitable gamma-rays for the analytical determination of an element and to determine the appropriate proton bombarding energy, it was necessary, not only to evaluate the gamma-ray yields but also to establish the attainable sensitivities over the available proton energy range. Furthermore, since matrix elements could interfere even through gamma-rays of low yields, it was essential to obtain information on the yields of all gamma-rays. Both these aims were achieved by a systematic survey of gamma-rays emitted under uniform experimental conditions from all non-gaseous stable elements bombarded by protons from 3,5 to 6,0 MeV.

The survey, which required the identification and indexing of over 2000 gamma-rays, enabled the five most intense

voor te stel deur 'n benadering van die afstande tussen punte in die n-dimensionele ruimte tot ooreenstemmende afstande in twee dimensies. 'n Veralgemening van hierdie benadering word gevind in die nie-metriese meerdimensionele skaling deurdat die orde van die tussenpuntspasiëring in plaas van die eintlike afstand gebruik word. Die mees verfynde metode van wisselanalise, met inagneming van die voordele van die vorige metodes, lewer ook 'n manier om die onderlinge verband tussen groepering van monsters en die elementelesamestelling voor te stel.

(ii) *Partikelgeïnduseerde pront-fotospektrometrie (PIPPS).*

Ondanks die jarelange bruik van PIPPS met protonbundels, is feitlik deurgaans met protonenergieë onder 3,5 MeV gewerk en dan ook meestal vir die ontleding van ligte elemente. Onder hierdie toestande was die opgewekte gammastrale, op 'n paar uitsonderings na, dié van coulomb-opwekking. Met toenemende protonenergie neem die waarskynlikheid vir 'n kernreaksie om plaas te vind, toe en word meer gammastrale vir analitiese doeleindes beskikbaar gestel, veral dié vanaf elemente met hoër atoomgetal.

Ten einde gammastrale vir die ontleding van 'n element te selekteer en die toepaslike protonbombarderingsenergie te bepaal, was dit nodig om gammastraalopbrengste sowel as die sensitiwiteit oor die beskikbare gebied van protonenergie te bepaal. Aangesien die matrikselemente belemmering kan veroorsaak, selfs deur gammastrale van lae opbrengste, was dit noodsaaklik om inligting oor die opbrengste van alle gammastrale te bekom. Beide hierdie doelstellings is bereik deur 'n sistematiese ondersoek van gammastrale, soos vrygestel onder identiese eksperimentele toestande vanaf alle stabiele elemente, behalwe gasse, en onderhewig aan 'n protonbombardement van 3,5 tot 6,0 MeV.

Uit hierdie ondersoek, wat die identifikasie en indeksering van meer as 2 000

gamma-rays from each element to be identified, and the optimal bombarding energy to be selected. From the data, interference-free sensitivities for the analysis of thick targets were calculated. It was found that the method was essentially useful for rapid analysis of components present in concentrations above mg/g, but under appropriate conditions, about half the elements could be determined at levels lower by a factor of 10. As expected, the best sensitivities were obtained for the light elements, whilst the rare earths were among those elements for which the method was least suitable.

From the information gained during the survey, it was possible to define regions of interest where PIPPS could be applied to analytical problems. Three types of problems were studied. Firstly, the determination of minor components was undertaken in steels, a matrix for which the PIXE method had been shown to be less than satisfactory. Secondly, PIPPS was applied for determining both major and minor components in cement, where rapd analytical data could be useful. Thirdly, the method was used to obtain supplementary data on major components, for archaelogical analyses, where it was necessary to use non-destructive methods.

(iii) *The Study of Bitter Pit in Apples.*

Bitter Pit is a physiological disorder in apples where the cortex cells immediately under the skin collapse, producing characteristic brown indentations on the surface. Severe losses are experienced by apple producers because of this abnormality.

Multivariate analysis of the elements Mg, P, S, Cl, K and Ca in samples from pitted and healthy tissues showed large separations between the two groups. An investigation of a large number of Golden Delicious apple samples taken at five stages during the growth cycle of the fruit, were analysed, by the PIXE method.

gammastrale behels, is die vyf mees intense gammastrale vir elke element sowel as die optimale bombarderingsenergie verkry. Vanaf die gegewens is steuringvrye sensitiwiteite vir ontleding van dik skywe bereken. Daar is gevind dat die metode wesenlik geskik is vir vinnige ontleding van komponente wat teenwoordig is in konsentrasies bo mg/g. Indien die regte toestande egter verkry word, kan ongeveer die helfte van die elemente bepaal word in 'n konsentrasiegebied van 'n faktor 10 kleiner. Na verwagting is die beste sensitiwiteite vir ligte elemente verkry, terwyl seldsame aardes val in dié groep elemente waarop die metode die minste van toepassing is.

Uit die inligting, verkry uit die ondersoek, was dit moontlik om gebiede van belang, waar PIPPS op analitiese probleme toegepas kan word, te defineer. Drie tipes probleme is bestudeer. Eerstens is die bepaling van elemente van laer konsentrasie in staal onderneem. Hierdie matriks is as onbevredigend vir die PIXE-metode bevind. Tweedens is PIPPS ingespan in die bepaling van beide hoë- en laekonsentrasie-elemente in sement, waar vinnige analitiese gegewens 'n belangrike rol speel. Derdens is die metode gebruik om bykomende inligting aangaande hoëkonsentrasie-elemente te verkry in argeologiese ontledings, waar nievernietigende metodes noodsaaklik is.

(iii) *Die Studie van Bitterpit in Appels.*

Bitterpit is 'n fisiologiese afwyking in appels waar die kortekselle, direk onder die skil, ineenstort om die karakteristieke bruin duikies op die oppervlakte te veroorsaak. Appelprodusente ly swaar verliese as gevolg van hierdie abnormaliteit.

Analise met multivariantemetodes van die elemente Mg, P, S, Cl, K, en Ca in monsters vanuit aangetaste en gesonde weefsel het groot verskille tussen die twee groepe getoon. Die PIXE-metode is gebruik om 'n ondersoek te doen op 'n groot aantal monsters van Golden Deliciousappels wat in vyf stadia tydens die groeisiklus van die vrugte gepiuk is.

Results showed that concentrations of all elements determined, increased from the skin towards the centre and from the calyx towards the stalk side of the fruit. The concentration of calcium was found to increase more rapidly with depth than that of the other elements, which agrees with the theory that this element is chemically bound into a water-insoluble compound thus inhibiting the effects of organic acids which have recently been shown to induce Bitter Pit symptoms.

Significantly different concentrations of all the abovementioned elements were found in samples from trees on Ca-treated soils. Sunshine caused an enhancement of elemental concentrations, but the effect was not very significant

Gradual changes in relative and absolute elemental concentrations during the growth cycle were detected using multivariate techniques but these could not, as yet, be correlated with the incidence of pitting.

4. *Solid State and Materials Research*

A solid state research programme was started at SUNI during 1978. Since then this aspect of our research has enjoyed much attention and has led to fruitful and close cooperation with the local universities.

Thin film semiconductor studies have constituted the main part of this programme, much attention being given to metal silicides which form by solid state interaction between metals and silicon during heating. Metal silicides are of great importance to the silicon semiconductor technology as they are widely used as ohmic or rectifying (Schottky) contacts in micro-electronic devices and solar cells.

The main topics have been:

(i) *Radioactive ^{31}Si marker studies of silicide formation.*

A new technique has been developed at SUNI in which radioactive ^{31}Si (half-life = 2,62 hours) is used as a marker to obtain

Die resultate het getoon dat die konsentrasies van al die elemente wat bepaal is, toeneem vanaf die skil na die middelpunt en van die kelk- na die stingelkant van die vrug. Daar is bevind dat die konsentrasie kalsium vinniger met diepte toeneem as dié van die ander elemente. Dit ondersteun die teorie dat hierdie element chemies gebind word in 'n wateronoplosbare verbinding wat die effekte van organiese sure beperk. Daar is onlangs aangetoon dat organiese sure bitterpitsimptome induseer.

Beduidende verskille in die konsentrasies van al bovermelde elemente is gevind in monsters van bome wat in kalsiumbehandelde grond gegroei het. Sonskyn het ook die konsentrasies van die elemente verhoog, maar die effek was nie besonder beduidend nie.

Die geleidelike veranderinge in die relatiewe en absolute konsentrasies van die elemente wat gedurende die groeisiklus deur die gebruik van multi-variante tegnieke waargeneem is, kon tot dusver nog nie gekorreleer word met die voorkoms van bitterpit nie.

4. *Vastetoestand- en Materiaalnavorsing*

Gedurende 1978 is daar met 'n vastetoestandnavorsingsprogram by KISU begin. Sedertdien het hierdie aspek van ons navorsing baie aandag geniet, wat gelei het tot suksesvolle en noue samewerking met die plaaslike universiteite.

Die program behels hoofsaaklik die studie van dunlagiesisteme wat van belang is in halfgeleiertegnologie en aandag is hoofsaaklik verleen aan metaalsilisiede wat gevorm word deur vastetoestandinteraksie tussen metale en silikon gedurende verhitting. Metaalsilisiede speel 'n baie belangrike rol in die silikonhalfgeleiertegnologie en word algemeen as ohmiese of gelykrigtende (Schottky-) kontakte in mikroëlektroniese komponente en sonselle gebruik.

Die hoofonderwerpe is soos volg.

(i) *Radioaktiewe ^{31}Si-merkerstudies van silisiedformasie.*

'n Nuwe tegniek is by KISU ontwikkel waarin radioaktiewe ^{31}Si (halfleeftyd 2,62 uur) gebruik word as merker om basiese

basic information about the solid state interaction between thin metal films and silicon, to form metal silicides. The main advantage of this approach as compared to other marker techniques, is the fact that not only can the diffusing species be identified, but information about the diffusing mechanism and the rate of diffusion can also be obtained.

(ii) *Metal silicide formation in tertiary systems.*

The more stringent requirements imposed by increasingly complex integrated circuit design and very large scale integration (VLSI), has recently led to the use of multilayer or alloy metal films. A need has thus arisen to extend our knowledge of silicide formation with single metal systems, to two metal systems. At SUNI, the kinetics of silicide formation are being investigated for the following tertiary systems; Si/Pd/Cr, Si/Pt/Cr and Si/Ni/Cr. These studies also use radioactive ^{31}Si to obtain information about the diffusion species, mechanism of diffusion and diffusion rate.

(iii) *Oxidation of silicon and metal silicides.*

In silicon semiconductor technology the formation of an insulating layer of SiO_2 is crucial for photolithography, isolation of devices and interconnections, and for the final passivation of devices. Such SiO_2 films are usually formed by the oxidation of silicon and metal silicides in oxygen and steam, at temperatures between 700 °C and 1 300 °C. The kinetics of SiO_2 formation is determined by measuring the thickness of the formed SiO_2 layer with Rutherford backscattering of charged nuclear particles. Radioactive ^{31}Si is also used as a tracer to obtain basic information of the oxidation.

5. *Atomic Physics*

(i) *Beam Foil Spectroscopy (outer shell excitation).*

The research on the energy level structure of highly ionized rare gases was continued and the spectrum of krypton was analysed. Life-time determinations were carried

inligting oor die vastetoestandreaksie tussen dun metaallagies en silikon gedurende silisiedformasie te verkry. Die belangrikste voordeel van hierdie benadering bo ander merker tegnieke is dat nie net die diffunderende spesie nie, maar ook die meganisme en tempo van diffusie bepaal kan word.

(ii) *Metaalsilisiedformasie in tersiêre sisteme.*

Strenger vereistes wat deur die toenemende kompleksiteit van geïntegreerde stroombaanontwerp en grootskaalse integrasie teweeggebring is, het onlangs gelei tot die gebruik van multilagies of metaalallooilagies. Die behoefte het dus ontstaan om ons kennis van silisiedformasie van enkelmetaalsisteme na di-metaalsisteme uit te brei. Die kinetika van silisiedformasie vir die tersiêre sisteme Si/Pd/Cr, Si/Pt/Cr en Si/Ni/Cr word tans by K!SU ondersoek. In hierdie studies word ook van radioaktiewe ^{31}Si gebruik gemaak om inligting oor die diffunderende spesie, diffusiemeganisme en tempo van diffusie te verkry.

(iii) *Oksidasie van silikon en metaalsilisiede.*

Die formasie van 'n isolerende lagie SiO_2 is van die uiterste belang in die silikonhalfgeleiertegnologie vir fotolitografie, isolasie van komponente en tussenkontakte en vir die finale passivering van komponente. Sulke SiO_2-lagies word gewoonlik gevorm deur oksidasie van silikon en metaalsilisiede in suurstof of stoom by temperature tussen 700 °C en 1 300 °C. Die kinetika van SiO_2-formasie is bepaal deur die dikte van die gevormde SiO_2-lagie met Rutherfordverstrooiing van gelaaide kerndeeltjies te meet. Radioaktiewe ^{31}Si is ook as spoorder gebruik om basiese inligting oor die oksidasieproses te bekom.

5.1 *Atoomfisika.*

(i) *Bundelfolie-spektroskopie (Buiteskilopwekking).*

Die navorsing oor die energievlakstruktuur van hoog geïoniseerde edelgasatome is voortgesit en die spektrum van kripton is geanaliseer. Leeftydbepalings is op 'n

out on a large number of energy levels and the experimental values were compared to theoretical values obtained from calculations based on the Coulomb approximation as well as the Hartree-Fock theory. The field of research was extended to include the study of metals and a successful investigation of the spectrum of ionized aluminium in the spectral region 120–500 nm could be carried out. The carbon foils used in beam foil spectroscopy to strip ions, were manufactured using the hydrocarbon-cracking technique where ethylene gas is cracked under high voltage. The useful lifetimes of these foils was markedly longer than that of the normal carbon arc type of foil.

Preliminary experiments were also conducted using a target chamber with a variable magnetic field in order to investigate the excitation of magnetic quantum beats and the determination of g-values of energy levels. This type of experiment requires, as in the case of zero field quantum beats, a very high level of sophistication of the measuring technique and is being further investigated.

(ii) *Inner shell excitation in ion-atom collisions.*

This research is concerned with the excitation mechanisms for the production of vacancies in the inner shells of the atoms involved in heavy ion collisions. The subsequent decay of outer electrons into these inner shell vacancies gives rise to X-ray emission which is studied as a function of collision energy or distance of closest approach of the colliding pair. For example in the study of the Ar-Kr collision system both Ar-K and Kr-L X-ray yields have been measured over a wide range of Ar ion energies (2–20 MeV) and the probability of both K and L X-ray excitation has been measured as a function of atom separation distance at 8 and 10 MeV. The results of this work are to be presented at a forthcoming international conference. Similar studies have also been undertaken for the other collision systems

groot aantal energievlakke uitgevoer en die eksperimentele waardes is vergelyk met teoretiese waardes wat verkry is uit berekeninge gebaseer op die Coulombbenadering asook op die Hartree-Fockmetode. Die navorsingsgebied is verder uitgebrei na die studie van metale en 'n suksesvolle ondersoek van die spektrum van geïoniseerde aluminium kon deurgevoer word in die spektraalgebied 120–500 nm. Die koolstoffoelies, wat in die bundelfoeliespektroskopie gebruik word om ione te stroop, is vervaardig deur middel van die koolwaterstof-krakingstegniek waarin etileengas deur 'n hoë spanning opgebreek word. Die bruikbare ieeftyd van hierdie foelies is wesentlik langer as die normale koolstofboogtipe foelies.

Voorlopige eksperimente is ook deurgevoer met 'n skyfkamer met 'n varieerbare magneetveld ten einde die opwekking van magnetiese kwantumswewinge en die bepaling van g-waardes van energievlakke te ondersoek. Hierdie tipe eksperimentering vereis, net soos in die geval van zero-veldkwantumswewinge, 'n hoë mate van verfyning van die meettegniek, en dit word verder ondersoek.

(ii) *Binneskilopwekking in ioon-atoombotsings.*

Hierdie navorsing is toegespits op die opwekkingsmeganismes vir die skepping van vakatures in die binneskille van die atome betrokke by swaar ioonbotsings. Die opeenvolgende verval van buiteelektrone in hierdie binneskilvakatures, gee aanleiding tot X-straalemissie wat bestudeer word as funksie van botsingsenergie of die kleinste afstand wat die botsingspaar van mekaar af kan wees. In die studie van die Ar-Kr-botsingsisteem is byvoorbeeld beide Ar-K en Kr-L X-straalopbrengste gemeet oor 'n wye gebied van Ar-ioonenergieë (2–20 MeV), en die waarskynlikheid vir beide K- en L-X-straal opwekking is gemeet as funksie van atoomverwyderingsafstand by 8 en 10 MeV. Die resultate van hierdie werk sal binnekort voorgedra word by 'n internasionale konferensie. Soortgelyke studies is

and most recently for the Al-Ar collision system. A modified Penning ion source has been developed at SUNI for acceleration of aluminium ions. These and other studies of inner shell excitation of heavy atoms have been the result of a valuable association with Prof. H. O. Lutz from Bielefeld University in Germany. He has made several short visits to SUNI in the past seven years and the collaboration of Prof. Lutz and his theoretical colleagues in Europe has been an important component of the SUNI research which has led to several publications and conference contributions.

6. *Projects of Biomedical interest.*

(i) *Role of dietary factors in trace element deficiencies and cancer in mammals.*

The technique of X-ray emission spectroscopy, based on electron or photon excitation, is widely utilized as an analytical tool. A recent development in biomedical research is the increasing use of low energy (2 to 5 MeV) ion beams from particle accelerators as the excitation source. In studies at SUNI, the applicability of this PIXE technique was demonstrated by precise, micro-analytical results obtained from the determination of trace elements in mammalian tissue.

Evidence has been accumulating in recent years that diets with a high bran content can significantly reduce the bioavailability of several trace elements to the organism. The reasons for this are not entirely understood at present. One theory (due to Davies and co-workers) suggests that the phytic acid found in the plant protein of food crops binds to minerals such as calcium, manganese iron, zinc and copper to form insoluble phytates, leading to low physiological availability of these minerals for absorption. Foodstuffs rich in phytate, such as wholemeal bread, also contain a high concentration of fibre. Reinhold and others have thus proposed that it is fibre, rather than phytate, that largely determines the availability of bivalent metals for absorption by the intestine.

onderneem vir ander botsingsisteme, soos heel onlangs vir die Al-Ar-botsingsisteem. 'n Gemodifiseerde Penning-ioonbron is by KISU ontwikkel vir die versnelling van aluminiumione. Hierdie en ander studies van binneskilopwekking van swaar atome, is die gevolg van die waardevolle samewerking met prof. H. O. Lutz van die Bielefeld-universiteit in Duitsland. Gedurende die afgelope sewe jaar het hy 'n paar kort besoeke aan KISU gebring, en die samewerking van prof. Lutz en sy teoretiese kollegas in Europa is 'n belangrike komponent van die navorsing by KISU, wat gelei het tot verskeie publikasies en bydraes aan konferensies.

6. *Biomediese Projekte.*

(i) *Die rol van dieetkundige faktore op spoorelementtekorte en kanker by soogdiere.*

Elektron- en foton-geïnduseerde X-straalemissie, word algemeen gebruik as 'n analitiese tegniek. 'n Onlangse ontwikkeling in biomediese navorsing is die toenemende gebruik van ioonbundels van lae energie (2 tot 5 MeV), verkry vanaf versnellers, vir X-straalopwekking. Hierdie benadering van partikelgeïnduseerde X-straalemissie (PIXE) word by KISU gebruik as mikroanalitiese tegniek vir die bepaling van spoorelemente in die weefsel van soogdiere.

Gedurende die afgelope paar jaar het navorsing daarop gedui dat 'n dieet met 'n hoë semelinhoud daartoe lei dat die beskikbaarheid van baie spoorelemente drasties verminder word. Die rede hiervoor is nog nie heeltemal duidelik nie. 'n Teorie van Davies en medewerkers stel voor dat fitiensuur minerale soos kalsium, mangaan, yster, sink en koper bind, om onoplosbare fitate te vorm wat lei tot 'n lae fisiologiese beskikbaarheid van hierdie minerale vir absorpsie. Voedsel wat ryk is aan fitiensuur, soos volgraanbrood, bevat egter ook baie vesels. Reinhold en ander navorsers stel voor dat dit die vesel en nie die fitate is nie wat die beskikbaarheid van bi-metale deur absorpsie affekteer.

Two animal models were chosen for our experimental studies: baboons and rats. The animals were housed at the National Research Institute for Nutritional Diseases of the MRC, and were fed carefully controlled diets. Specimens of liver and oesophagus were obtained at autopsy and analysed for trace element content at SUNI. The results obtained are consistent with the Davies hypothesis of phytate, rather than fibre, as being the important factor in trace element absorption and retention. Deficiencies in such elements as S, K, Ca, Ni and Zn were found. In addition, it was found that those rats on a phytate-supplemented diet (with consequent trace element deficient status) developed more and larger oesophageal tumor nodules after administration of a chemical carcinoten (MBN) than those with normal trace element levels. This leads to the intriguing hypothesis that certain trace elements (such as zinc) play an important role in carcinogenesis, possibly by stimulating lymphocyte production and hence enhancing the immune response of the host.

(ii) *Trace element profiles of normal and malignant tissues in the rat.*

The role of trace elements in neoplasia has received increasing attention in recent years. Trace elements may be of interest as:

(a) Industrial toxins and potential carcinogens (e.g. As, Be, Pb);

(b) Suggested inhibitors of oncogenesis (e.g. Se and Zn);

(c) Factors influencing the growth and development of tumours once a malignant transformation has taken place (e.g. Fe, Cu, Zn); or

(d) Diagnostic indicators of the state of progression of the disease (serum Cu and Zn levels are often cited in this regard).

However, despite vigorous research efforts, none of the studies has removed contradictions or provided a clear understanding of the role of trace elements in

By KISU is hierdie probleme ondersoek deur eksperimente op bobbejane en rotte uit te voer. Die diere is gehuisves by die Nasionale Navorsingsinstituut vir Voedingsiektes van die MNR waar hulle gevoer is met 'n gekontroleerde dieet. Lewer- en slukdermmonsters is geneem en PIXE-analises is by KISU uitgevoer. Die resultate wat ons verkry het, stem ooreen met Davies se hipotese dat fitate en nie die vesels nie, die belangrike aspek is by spoorelementabsorpsie en -opname. 'n Tekort aan S, K, Ca, Ni en Zn is gevind. Ook is daar gevind dat die rotte wat gevoer is met 'n dieet ryk aan fitate, groter en meer slukdermgewasse ontwikkel het, na die toediening van 'n chemiese karsinomiese middel (MBN), as dié met 'n normale vlak van spoorelemente. Hierdie resultate lei tot die interessante hipotese, dat sekere spoorelemente (soos Zn) 'n baie belangrike rol speel by karsinogenese, waarskynlik weens stimulasie van limfselproduksie wat gepaard gaan met 'n verbetering van die immuniteitsreaksie van die proefdier.

(ii) *Spoorelemente in normale en kwaadaardige weefsel van die rot.*

Daar is besondere belangstelling in die rol van spoorelemente by neoplasia. Spoorelemente is van belang as:

(a) Industriële toksines en potensiële karsinogenestowwe (bv. As, Be, Pb);

(b) Stremmiddel van oncogenesis (bv. Se en Zn);

(c) Faktore wat die groei en ontwikkeling van gewasse beïnvloed (bv. Fe, Cu, Zn); of

(d) Diagnostiese indikators van die ontwikkeling van 'n siekte (vlakke van Cu- en Zn-serum word dikwels in hierdie verband aangehaal).

Afgesien van heelwat navorsing, het geen studies nog daarin geslaag om teenstrydighede op te los nie en om 'n duidelike beeld te skep van die rol van spoorelemente

the altered metabolic processes associated with cancer.

Several reasons may be suggested for the present lack of clarity:

(i) The difficulty of obtaining reliable "normal" values, especially in human studies;

(ii) Problems in separating parenchymal cells from surrounding connective and muscle tissue;

(iii) Possible inherent differences in the nutritional requirements and functioning of different tumour types, such as those arising in epithelial and endothelial tissue.

These studies were designed to obviate these difficulties and to provide accurate data in the particular case of rat hepatoma. Lyophilized liver tissue samples were analysed for 10 macro- and trace-elements by proton-induced X-ray emission spectroscopy, using the external ion beam at SUNI. Care was taken to perfuse the liver specimens with sterile saline to minimise contamination from residual dried blood, and to analyse parenchymal cells only.

Comparative data for trace element concentrations in rat liver were obtained by analysing specimens from healthy rats, of the same strain matched for weight, age, sex, and diet. Absolute values for the trace element levels were derived by calibrating our system with standard biological reference materials (NBS Bovine Liver and IAEA animal muscle samples).

Our results indicated increased values of K and Ca in hepatoma versus normal tissue, and depressed values of Cu (by a factor of approximately 2). Other elements such as Fe and Zn are apparently not affected. The investigation was extended to the analysis of subcellular fractions. The same systematic trend was demonstrated in the supernatant, but not in cell nuclei. In particular, Cu concentrations in nuclei derived from normal and hepatoma cells were found to be not significantly different.

in die veranderde metaboliese prosesse wat met kanker geassosieer is. Verskeie redes is al aangegee vir hierdie onsekerhede:

(i) Die probleem om "normale" vlakke van spoorelementkonsentrasies te definieer.

(ii) Probleme om parenchiemselle van omliggende weefsel te skei.

(iii) Moontlike inherente verskille in die voedingsvereistes en funksionering van verskillende tipes gewasse.

Studies is uitgevoer in 'n poging om hierdie probleme te bowe te kom en om akkurate data te verkry in die geval van hepatoma by die rot. Lewermonsters is geanaliseer vir 10 makro- en spoorelemente deur gebruik te maak van protongeïnduseerde X-straalemissie (PIXE). Voorsorg is getref om kontaminasie van residuele bloed te verhoed en om slegs parenchiemselle te analiseer.

Vergelykende data is verkry vir spoorelementkonsentrasies in rotlewers van gesonde rotte met dieselfde gewig, ouderdom, geslag en dieet. Absolute spoorelementkonsentrasies is verkry deur ons sisteem met biologiese verwysingsmateriaal te kalibreer.

Ons resultate toon 'n toename in K en Ca by hepatoma, in vergelyking met normale weefsel, en 'n afname in die Cu-konsentrasie met 'n faktor van ongeveer 2. Ander elemente soos Fe en Zn word blykbaar nie geaffekteer nie. Die ondersoek is uitgebrei na subsellulêre fraksies. Dieselfde sistematiese tendens is in die bodrywende fraksie gevind, maar nie in die selkerne nie. Veral Cu-konsentrasies in die kerne was dieselfde vir beide normale en hepatomiese selle.

These results are consistent with a recent model (proposed by Fisher and Shifrine) for elevated serum copper levels in most forms of cancer

7. *Industrial and environmental applications of nuclear techniques*

The Atomic Energy Board Isotope Unit at SUNI, operating as a branch of SUNI, has continued to apply nuclear techniques to industrial and environmental problems. An interesting project entailed proving that seepage water occurring on the lands of a certain farm originated from a dam on an adjoining farm. A legal dispute was involved since the vineyard production on the waterlogged land apparently suffered. A radioactive tracer chromium-51 in a EDTA carrier solution was released over the bottom of the dam. Water samples were collected over several days from a number of seepage holes below the dam wall up to a distance of approximately 300 metres away. The samples were analysed by first evaporating to near dryness, and then performing γ-ray spectrometry using a GeLi detector. A strong Cr-51 peak was observed within 24 hours at the one observation point and after 96 hours at another one further away from the dam. The results confirmed that seepage originated from the dam and that the lower limit of the contribution to seepage from the dam was 50%.

A large scale tritium tracer test was also conducted in Langebaan Lagoon on behalf of the National Research Institute of Oceanology (NRIO) Stellenbosch, who were under contract to the Department of Planning to develop a mathematical model of the tidal dispersion in the Saldanha Bay/Langebaan Lagoon system. The tritium tracer test extended over more than ten tidal cycles to provide calibration data for the numerical model. The calibration requirements were successfully met. Because tritium can be detected at very low levels using sophisticated techniques the project was extended by collecting further samples over a six month period from the original introduction of the

Hierdie resultate stem ooreen met 'n onlangse model (voorgestel deur Fisher en Shifrine) wat verhoogde koperkonsentrasies by die meeste vorms van kanker voorspel.

7. *Toepassings van kerntegnieke in die omgewing en industrie.*

Die toepassing van kerntegnieke in die omgewing en die industrie word steeds gesamentlik deur die Raad op Atoomkrag se Isotoopeenheid en KISU gedoen. Een interessante projek was om vas te stel of die syferwater wat op 'n sekere plaas voorgekom het, oorspronklik uit 'n dam op 'n aangrensende plaas afkomstig was. 'n Regsgeding het tussen die onderskeie eienaars ontstaan as gevolg van die skade aan die wingerd deur die oormaat water. Die radioaktiewe spoorder, Chroom-51, in 'n EDTA-draeroplossing is oor die bodem van die dam vrygelaat. Watermonsters is oor 'n hele aantal dae geneem uit syfergate onderkant die damwal en tot op 'n afstand van 300 m verder. Die monsters is ontleed deur hulle in te damp tot klein volumes en daarna die γ-spektra met 'n Ge(Li) detektor op te neem. 'n Sterk Cr-51-piek is binne 24 uur by een waarnemingspunt en na 96 uur by 'n ander punt, verder van die dam, waargeneem. Daar is vasgestel dat die syferwater wel gedeeltelik uit die dam afkomstig is en dat die bydrae uit die dam tot die totale syferwater, minstens 50% was.

'n Grootskaalse spoordertoets met tritium is in die Langebaanstrandmeer uitgevoer in samewerking met die Nasionale Navorsingsinstituut vir Oseanologie, wat op hulle beurt op kontrakte van die Departement van Beplanning was om 'n wiskundige model op te stel van die getydispersie in die Saldanhabaai/Langebaanstrandmeer-stelsel. Die spoordertoets het meer as tien getysiklusse gedek om kalibrasiedata vir die numeriese model te verskaf. Die kalibrasievereistes is suksesvol vervul. Die projek is verleng deur 'n verdere ses maande met monsterneming vol te hou aangesien tritium tot baie lae vlakke met gesofistikeerde metodes gemeet kan word.

tracer. A long term residence time calculation for pollutants in the Lagoon has been undertaken and a final report is now in preparation.

A novel application has been the development of a depth gauge for the Jackass Penguin, *Spheniscus demersus* which is being studied by the Percy Fitzpatrick Institute for African Ornithology at UCT. The technique used is an auto-radiographic one where the position of a small radioactive bead (^{32}P) floating on the meniscus in a capilliary depth gauge is recorded on photographic film. The position in the capilliary tube is a function of depth and the density of film blackening is a function of time that was spent at that depth. In field use of the gauge a penguin would wear it for one half, one or more days. The gauge would thus record the integrated duration versus depth for many dives and not individual dives. Initial field tests have been promising and should reveal new data on penguin behaviour. The technique can also be adapted to other marine animals.

One of the main features uncovered in the project on the coastal movements off the Koeberg nuclear power station site which is being undertaken together with the Oceanography department of UCT, is the presence of well-localised small cells of upwelling near headlands in the Melkbosch-strand area. Sea temperature is a signature of upwelling and a three-year time series of hourly sea temperature and wind stress has been analysed using rotary spectral analysis and cross spectral analysis. This reveals dominant frequencies of processes in the area which could be linked to dispersal of the Koeberg nuclear power station coolant discharge.

STUDY AND RESEARCH VISITS OVERSEAS

During the period under review the following staff and associated university staff members have been overseas for study and research.

Berekenings oor die retensietyd van besoedeling in die strandmeer is ook onderneem, en 'n finale verslag word tans daaroor voorberei.

'n Nuwe toepassing van radioisotope was die ontwikkeling van 'n diepte-meter vir die Jackass-pikkewyn, *Spheniscus demersus*, wat bestudeer word deur die Percy Fitzpatrick-instituut vir Afrika-voëlkunde by UK. 'n Outoradiografiese tegniek is gebruik. Die posisie van 'n klein radioaktiewe sfeer (^{32}P), wat op die menuskus in 'n kapillêre buis dryf, word vasgelê op fotografiese film. Die posisie in die buis is 'n funksie van die diepte en die verswarting 'n funksie van die tyd wat op elke diepte deurgebring word. Die pikkewyn dra die diepte-meter vir tydperke wat wissel tussen 'n halfdag en soms enkele dae. Die meter registreer dus die geïntegreerde tydperk wat 'n aantal duike geduur het, en nie individuele duike nie. Voorlopige veldproewe was belowend en sou nuwe gegewens omtrent die gedrag van pikkewyne aan die lig bring. Hierdie tegniek kan ook op ander seediere toegepas word.

Een van die belangrikste eienskappe wat in die projek oor die beweging van die kuswater teenoor die terrein van die Koebergkernkragstasie ontdek is, was die teenwoordigheid van goed gelokaliseerde klein selle van opwelling naby die landpunte in die Melkboschstrandgebied. Die projek is aangepak in samewerking met die Departement Oseanografie van UK. Opwelling word gekenmerk deur die seetemperatuur en 'n driejarige reeks van uurlikse seetemperature en windspanning is ontleed deur gebruik te maak van rotasie- sowel as kruisspektraalanalise. Hierdeur word die dominante frekwensies van prosesse in die omgewing onthul, wat verband kan hou met die dispersie van die Koebergkernkragsentrale se verkoelingswater.

STUDIE EN NAVORSINGSBESOEKE OORSEE

Oorsese studie en navorsingsbesoeke is in die afgelope twee jaar deur die volgende personeel en geassosieerde universiteitspersoneel afgelê:

DR. C. M. COMRIE, Physics Department, University of Cape Town.

During 1979/80 Dr. Comrie spent six months' study and research leave at the University of Sussex, where he joined Dr. D. W. Palmer in a study of irradiation damage in silicon single crystals at low temperatures. Comparison of results obtained from irradiation at 10 K with that at room temperature indicated that the defects introduced at 10 K were relatively immobile—in direct contradiction to theoretical predictions.

Other universities visited during his leave were the University of Cambridge, which has a large Surface Physics group, the University of Lancaster and the University of Modena (Italy), where considerable use of the channelling technique is made in the study of growth of epitaxial silicides.

DR. J. J. KRITZINGER, SUNI

During June and July 1980 Dr. Kritzinger visited six manufacturers in Europe on behalf of the National Accelerator Centre to investigate the manufacture of the resonators required for the 200 MeV separated-sector cyclotron which is to be installed at Faure. The Swiss Institute for Nuclear Research and GANIL in France, where separated-sector cyclotrons are used, were also visited.

In the United States of America the Indiana University separated-sector cyclotron, the linear accelerator at Los Alamos and the 25 MV tandem at Oak Ridge were visited in addition to a manufacturer of radio-frequency power amplifiers. The power amplifiers are also required for the 200 MeV separated-sector cyclotron.

DR. R. PRETORIUS, SUNI

During 1979, Dr. Pretorius spent 2 months' study leave in the USA. Most of this time was spent as a visiting consultant at the IBM, Thomas J. Watson Research Centre, in Yorktown Heights. In one of the research projects in which he participated, use was made of radioactive metal tracers to obtain

DR. C. M. COMRIE, Fisikadepartement, Universiteit van Kaapstad.

Gedurende 1979/80 het dr. Comrie studie-en navorsingsverlof van ses maande deurgebring aan die Universiteit van Sussex, waar hy en dr. D. W. Palmer ondersoek ingestel het na die stralingsbeskadiging in silikonenkelkristalle by lae temperature. 'n Vergelyking van die resultate wat by 10 K met dié by kamertemperatuur verkry is, het getoon dat die defekte veroorsaak by 10 K relatief immobiel is—dit is in direkte teenstelling met die teoretiese voorspellings.

Ander universiteite wat besoek is, is die Universiteit van Cambridge wat 'n groot oppervlaktefisikagroep het, die Universiteit van Lancaster en die Universiteit van Modena (Italië), waar baie gebruik gemaak word van die kanaliseringstegniek vir die bestudering van epitaksiële groei van silisiede.

DR. J. J. KRITZINGER, KISU

Dr. Kritzinger het in Junie en Julie 1980 ses firmas in Europa namens die Nasionale Versnellersentrum besoek. Die doel van die besoek was om 'n geskikte vervaardiger te vind vir die resonatore van die 200 MeV-oopsektorsiklotron wat by Faure opgerig word. SIN in Switzerland en GANIL in Frankryk, waar oopsektorsiklotrone gebruik word, is ook besoek.

In die VSA is die oopsektorsiklotron by die Universiteit van Indiana, die lineêre versneller by Los Alamos en die 25 MV-tandem by Oak Ridge besoek. Die vervaardiging van radiofrekwenskragversterkers vir die 200 MeV-oopsektorsiklotron is met 'n Amerikaanse firma bespreek.

DR. R. PRETORIUS, KISU

Dr. Pretorius was gedurende 1979 met studieverlof van twee maande in die VSA. Hierdie verlof is grotendeels as besoekende konsultant by IBM se Thomas J. Watson-navorsingsentrum in Yorktown Heights deurgebring. In een van die navorsingsprojekte waarin hy betrek is, is gebruik

basic information about the diffusing species, diffusion mechanisms and diffusion rates involved during metal silicide formation. The excellent facilities at IBM for carrying out Rutherford backscattering and ion-channelling, were also used to investigate the epitaxy of metal silicide layers. Dr. Pretorius also attended meetings of the Electrochemical (Los Angeles) and Materials Research Societies (Boston) where he presented invited papers on the use of radioactive ^{31}Si as a marker for studying thin film interaction.

PROF. I. J. VAN HEERDEN, SUNI

During 1980 Prof. van Heerden spent 12 months on study leave with the Nuclear Research Centre at the University of Alberta in Edmonton, Canada. Projects undertaken at the 500 MeV proton accelerator, TRIUMF, in Vancouver included:

(a) a study of the $^{2}H(\vec{p},\gamma)^{3}He$ and $^{2}H(\vec{p},\pi^{0})^{3}He$ reactions at E_p = 200–500 MeV;

(b) a study of the $^{2}H(p,d\pi^{+})n$ reaction at 506 MeV; and

(c) a study of deep hole states in calcium with the $(\vec{p},2p)$ reaction.

Another project undertaken by him at the 7 MeV Van de Graaff accelerator in Edmonton was the elastic scattering of polarized neutrons from ^{2}H, ^{16}O, ^{59}Co and ^{208}Pb at 23 MeV.

He also attended a workshop on 'nuclear structure with intermediate energy probes' held at Los Alamos in January 1980, and two international conferences held in August 1980 on "Polarization phenomena in nuclear physics" and on "the few body problem", at Santa Fe, New Mexico and at Eugene, Oregon respectively.

gemaak van radioaktiewe metaalspoorders om basiese informasie te verkry aangaande diffusiespesies, diffusiemeganisme en diffusietempo wat by metaalsilisiedformasie betrokke is. Die voortreflike fasiliteite vir Rutherford-terugverstrooiing en -ioonkanalisering wat by IBM beskikbaar is, is ook gebruik om die epitaksie van metaalsilisiedlagies te ondersoek. Dr. Pretorius het ook vergaderings van die Elektrochemiese Genootskap (Los Angeles) en Materialenavorsingsgenootskap (Boston) bygewoon waar hy, op uitnodiging, referate oor die gebruik van radioaktiewe ^{31}Si as merker vir die bestudering van dunlagiewisselwerking gelewer het.

PROF. I. J. VAN HEERDEN, KISU

Gedurende 1980 het prof. van Heerden studieverlof van twaalf maande deurgebring by die Kernnavorsingsentrum aan die Universiteit van Alberta in Edmonton, Kanada. Projekte wat onderneem is by die 500 MeV-protonversneller, TRIUMF, in Vancouver sluit in:

(a) 'n studie van die $^{2}H(\vec{p},\gamma)^{3}He$ en $^{2}H(\vec{p},\pi^{0})^{3}He$-reaksies by E_p = 200–500 MeV;

(b) 'n studie van die $^{2}H(p,d\pi^{+})n$-reaksie by 506 MeV; en

(c) 'n studie van diepholtetoestande in kalsium met die $(\vec{p},2p)$-reaksie.

Nog 'n projek wat deur prof. van Heerden by die 7 MeV-Van de Graaff versneller in Edmonton uitgevoer is, was die elastiese verstrooiing van gepolariseerde neutrone vanaf ^{2}H, ^{16}O, ^{59}Co en ^{208}Pb by 23 MeV.

Hy het ook 'n simposium oor "nuclear structure with intermediate energy probes" in Los Alamos in Januarie 1980, asook twee internasionale konferensies in Augustus 1980 oor polarisasie in kernfisika en veeldeeltjieprobleme onderskeidelik in Santa Fe, New Mexico, en Eugene, Oregon, bygewoon.

SCIENTIFIC MEETINGS/WETENSKAPLIKE BYEENKOMSTE

The following scientific meetings were attended by SUNI and associated University personnel.

Die volgende wetenskaplike byeenkomste is bygewoon deur KISU en geassosieerde Universiteitspersoneel.

Workshop on Transfer of Pollutants in Two Southern Hemispheric Oceanic System, Plettenberg Bay (April 1979).

Symposium on Automation in Chemistry, Pretoria (May 1979).

24th Annual Conference of the South African Institute of Physics, Bloemfontein (July 1979).

8th International Conference on Atomic Spectroscopy, Cambridge, England (July 1979

5th International Conference on Medical Physics, Jerusalem, Israel (August 1979).

156th Meeting of the Electrochemical Society, Los Angeles, U.S.A. (October 1979).

Annual Meeting of the Materials Research Society, Boston, U.S.A. (November 1979).

Workshop on Nuclear Structure with Intermediate-Energy Probes, Los Alamos, U.S.A (January 1980).

1st International Workshop on Activation Analysis with Short-lived Nuclides, Vienna, Austria (February 1980).

2nd International Conference on PIXE and Analytical Applications, Lund, Sweden (June 1980).

25th Annual General Meeting of the South African Institute of Physics, Johannesburg (July 1980).

27th Convention of the South African Chemical Institute, Pretoria (July August 1980).

5th International Symposium on Polarization Phenomena in Nuclear Physics, Santa Fe, U.S.A. (August 1980).

9th International Conference on the Few Body Problem, Eugene, U.S.A. (August 1980).

International Conference on Nuclear Physics, Berkeley, U.S.A. (August 1980).

Nuclear Physics Meeting of the American Physical Society, Minneapolis, U.S.A. (October 1980).

Annual Congress of the South African Pharmacological Society, Port Elizabeth (October 1980).

Summer Seminar on Applied Multivariate Analysis, Pretoria (February 1981).

REPORTS AND PUBLICATIONS/VERSLAE EN PUBLIKASIES 1.4.79–31.3.81

1. SUNI REPORTS/KISU VERSLAE

SUNI-57 *C. A. R. Bain*
Tritium tracer dispersion test in Langebaan Lagoon, 1979.

SUNI-58 *Chairman's Report 1977-1979*

SUNI-59 *W. R. McMurray, M. J. Renan*
Data needs for controlled thermonuclear fusion.

SUNI-60 *W. R. McMurray*
Feasibility of research in heavy ion physics using the SUNI accelerator.

SUNI-61 *Annual Research Report 1979.*

SUNI-62 *M. J. Renan*
Report on overseas visit.

SUNI-63 *R. Pretorius*
Report on meetings of the Electrochemical and the Material Research Societies.

SUNI-64 *M. Peisach*
1st International Workshop on Activation Analysis of short-lived nuclides, Vienna.

SUNI-65 *Annual Research Report 1980.*

2. RESEARCH PUBLICATIONS/NAVORSINGSPUBLIKASIES *(SUNI and University Staff in italics)*

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Phys. Rev. **C19** (1979) 740

D. Gihwala, M. Peisach
The determination of manganese in steels by measuring alpha-induced prompt gamma-rays: the importance of high resolution spectrometry.
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F. J. Coetzer, P. van der Westhuizen
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Proc. Int. Symp. Nuclear Activation Techniques in the Life Sciences, Vienna 1978 (IAEA, Vienna, 1979) 479

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D. Gihwala, M. Peisach

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J. Radioanal. Chem. **61** (1981) 131

M. Peisach

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Sediment movement studies using radioisotopes.
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W. F. Lubbe, M. Peisach, G. J. Boulle, L. H. Opie

Regional myocardial blood flow distribution in relation to ventricular fibrillation during the first hour after coronary artery occlusion in the baboon and dog.
Amer. Heart J. (submitted for publication)

M. J. Renan, C. F. Albrecht, D. T. L. Jones

Effects of neoplastic processes on zinc and copper levels in murine hepatocytes.
(Submitted for publication)

3. PAPERS PRESENTED AT CONFERENCES WITH NO PUBLISHED PROCEEDINGS/ONGEPUBLISEERDE REFERATE GELEWER BY KONFERENSIES

Workshop on Transfer of Pollutants in Two Southern Hemispheric Oceanic Systems, Plettenberg Bay (April 1979)

C. A. R. Bain

Aspects of oceanography and marine pollution.

Symposium on Automation in Chemistry, Pretoria (May 1979)

M. Peisach, G. J. Boulle

Automation in nuclear analytical chemistry.

M. Peisach

Operation and maintenance in laboratory automation.

24th Annual Conference of the South African Institute of Physics, Bloemfontein (July 1979)

W. J. Naudé, F. D. Smit, N. J. A. Rust, J. W. Koen

Energietoestande in ^{54}Cr.

J. W. Koen, G. de Villiers, W. J. Naudé, J. A. Stander
Eienskappe van vlakke in ^{48}Ti.

J. A. Stander, W. J. Naudé, J. W. Koen, N. J. A. Rust
Hoekkorrelasiemetinge met die reaksie ^{36}Ar(α,pγ)^{39}K.

J. J. Lawrie, W. J. Naudé
Eienskappe van die reaksie ^{32}S(d,α)^{30}P.

W. R. McMurray
Interpretation of the levels of Th-232 and U-238 in terms of collective band structure.

W. R. McMurray, K. Baruth-Ram, S. M. Perez, F. D. Brooks, G. M. Bartle
Excitation of analogue dipole states in the reactions ^{90}Zr(n,p)^{90}Y and ^{56}Fe(n,p)^{56}Mn.

J. Whittaker, F. D. Brooks, I. J. van Heerden
The cross section for neutron-proton bremsstrahlung at 4,77 MeV.

F. D. Brooks, J. M. Nelson, P. M. Lister, K. S. Dhuga, C. O. Blyth
Vector analysing powers of the reactions ^{12}C(d$^{\rightarrow}$,n)^{13}N and ^{28}Si(d$^{\rightarrow}$,n)^{29}P.

R. Pretorius
The use of nuclear techniques for solid-state studies of thin-film structures.

W. Strydom, R. Pretorius, C. Comrie, J. W. Mayer
Die oksidasie van dun metaal-silisied lagies.

A. P. Botha, R. Pretorius, J. C. Lombaard
Die bepaling van silikon selfdiffusie koëffisiënte in PtSi, Pd_2Si en $CoSi_2$ lagies.

B. R. Meyer
Die bepaling van grondwater parameters naby die Koeberg Kernkragsentrale.

Eighth International Conference on Atomic Spectroscopy, Cambridge, England (July 1979)

M. J. Renan, A. E. Pillay, M. Peisach
Optimization of sensitivity in trace elemental analysis by PIXE.

Fifth International Conference on Medical Physics, Jerusalem, Israel (August 1979)

M. J. Renan, S. J. van Rensburg
Multi-elemental analysis of mammalian tissue by proton-induced X-ray emission.

D. T. L. Jones, F. D. Brooks, S. Wynchank, I. J. van Heerden
Differential dose measurements with T(d,n) and ^{252}Cf neutron sources.

156th Meeting of the Electrochemical Society, Los Angeles, U.S.A. (October 1979)

R. Pretorius
Studies of the growth and oxidation of metal silicides using radioactive ^{31}Si as tracer.

Annual Meeting of the Materials Research Society, Boston, U.S.A. (November 1979)

R. Pretorius
The use of radioactive ^{31}Si as a marker for studying thin-film interaction.

First Int. Workshop on Activation Analysis with Short-Lived Nuclides, Vienna, Austria (February 1980)

M. Peisach

Prompt nuclear analysis.

M. Peisach, D. Gihwala

The determination of minor elements in steels by prompt proton-induced gamma-ray spectrometry.

P. Mony, C. Olivier, M. Peisach

Prompt nuclear analysis in thick samples with charged particles: The validity of Bragg's Law for range correction.

Second Int. Conference on PIXE and Analytical Applications, Lund, Sweden (June 1980)

B. Spoelstra, J. P. F. Sellschop, H. J. Annegarn, *M. J. Renan*

Whole-blood analysis of Kwashiorkor cases by PIXE.

25th Annual Conference of the South African Institute of Physics, Johannesburg (July 1980)

F. D. Smit, N. J. A. Rust, W. J. Naudé, J. W. Koen

Ondersoek van ^{54}Cr met die reaksie $^{51}V(\alpha,p\gamma)^{54}Cr$.

J. A. Stander, W. J. Naudé, N. J. A. Rust, J. W. Koen

Eienskappe van energietoestande in ^{39}K en ^{41}K.

J. A. Stander, W. J. Naudé, R. Saayman

Veeldeeltjieskilmodelberekeninge vir die ^{39}K en ^{41}K atoomkerne.

C. M. Bartle, F. D. Brooks, D. T. L. Jones, W. R. McMurray

A high flux associated particle neutron source.

G. Genis, W. L. Rautenbach

'n Elektronbombardementsisteem om die wegvoer van warmtevloede van groter as 1 kW/cm^2 in die kernwetenskap te bestudeer.

R. Pretorius

The interaction of thin metal films with silicon studied by Rutherford backscattering and radioactive silicon tracing.

M. O. Naudé, R. Pretorius, D. J. Marais

Vastetoestand interaksie tussen silikon en dun chroom, nikkel en platinum lagies.

E. C. Zingu, R. Pretorius, C. Comrie

Thickness effects for $CrSi_2$ formation on epitaxial Pd_2Si.

27th Convention of the South African Chemical Institute, Pretoria (July/August 1980)

M. Peisach

Prompt and Quasi-prompt nuclear analytical chemistry.

D. Gihwala, M. Peisach

Selection of bombarding energies for analysis by proton-induced prompt gamma-ray excitation.

P. Mony, C. Olivier, M. Peisach

The search for molecular effects in range corrections: Fluoride analysis by alpha bombardment.

Fifth Int. Symposium on Polarisation Phenomena in Nuclear Physics, Sante Fe, New Mexico (August 1980)

F. D. Brooks, P. M. Lister, J. M. Nelson, K. S. Dhuga

Vector analysing powers for the $^{12}C(\vec{d},n)^{13}N$, $^{9}Be(\vec{d},n)^{10}B$ and $^{28}Si(\vec{d},n)^{29}P$ reactions.

9th Int. Conference on the Few Body Problem, Eugene, U.S.A. (August 1980)

J. M. Cameron, R. Abegg, *I. J. van Heerden*, D. A. Hutcheon, P. Kitching, W. J. McDonald, C. A. Miller, A. W. Stetz, J. Thekkumthala, H. S. Wildon

Study of the $^{2}H(\vec{p},\gamma)^{3}He$ reaction at E_p=200–500 MeV.

J. Whittaker, F. D. Brook , I. J. van Heerden

Cross section for n-p bremsstrahlung at E_n = 4.8 MeV.

Int. Conference on Nuclear Physics, Berkeley, U.S.A. (August 1980)

W. R. McMurray, K. Baruth-Ram, C. M. Bartle, S. M. Perez, F. D. Brooks

Observation of the analog-dipole state in the $^{90}Zr(n,p)^{90}Y$ reaction.

Nuclear Physics Meeting of the American Physical Society, Minneapolis, U.S.A. (October 1980)

R. Helmer, W. K. Dawson, H. W. Fielding, P. W. Green, S. T. Lam, G. C. Neilson, T. Otsubo, D. M. Sheppard, J. Soukup, *I. J van Heerden*

The University of Alberta Polarised Fast Neutron Facility.

Annual Congress of the South African Pharmacological Society, Port Elizabeth (October 1980)

C. A. Muller, L. P. Opie, M. Peisach, D. Gihwala

Regional coronary flow during cardioselective versus non-selective beta-antagonism in the pig model of acute myocardial infarction.

General Meeting of the American Physical Society, New York (January 1981)

B. Debebe, C. F. Perdrisat, V. Raghunathan, J. M. Cameron, *I. J. van Heerden*, P. Kitching, R. MacDonald, W. J. McDonald, W. C. Olsen, H. S. Wilson, H. W. Fearing, G. A. Miller

Study of $^{2}H(p,d\pi^{+})n$ at 500 MeV.

4. THESES/TESISSE

M.Sc

J. J. Lawrie

Die reaksie $^{32}S(d,\alpha)^{30}P$.
Universiteit van Stellenbosch

G. de Villiers

Sekere kernstruktuureienskappe van ^{48}Ti.
Universiteit van Stellenbosch

D. Gihwala

Elemental analysis by high resolution spectrometry of particle-induced prompt photons.
University of Durban-Westville

A. E. Pillay

Determination of trace metals in human hair by nuclear methods.
University of Durban-Westville

J. V. Pilcher

An interactive computer graphics software package.
University of Cape Town

B. R. Meyer

Application of proton-induced X-ray emission to a multielemental study of Bitter Pit in apples.
University of Stellenbosch

F. D. Smit

Eienskappe van energietoestande in ^{54}Cr.
Universiteit van Stellenbosch

A. P. Botha

Marker and self-diffusion studies in metal silicides using ^{31}Si.
University of Stellenbosch

W. J. Strydom

Die oksidasie van silikon, kobaltdisilisied en platinumsilisied.
Universiteit van Stellenbosch

M. O. Naudé

Solid-state interaction between thin Cr, Ni and Pt films with silicon.
University of Stellenbosch

Ph.D

J. Whittaker

Neutron-proton bremsstrahlung at 4,8 MeV.
University of Cape Town

J. A. Stander

Kernstruktuurstudie van ^{39}K en ^{41}K.
Universiteit van Stellenbosch

SUMMARY OF INCOME AND EXPENDITURE
for the period Jan. 1979-Dec. 1980

OPSOMMING VAN INKOMSTE EN UITGAWES
vir die periode Jan. 1979-Des. 1980

	1.01.79 -31.12.79	1.01.80 -31.12.80	
CURRENT EXPENDITURE			**LOPENDE UITGAWES**
Salaries and associated costs	R240 266	R279 690	Salarisse en verwante koste
General administration	49 287	45 124	Algemene administrasie
Interest paid	3	62	Rente betaal
Accelerator maintenance and development	11 322	9 267	Versneller onderhoud en ontwikkeling
Experimental requirement	43 899	44 790	Eksperimentele benodigdhede
Laboratory equipment	9 946	13 884	Laboratorium uitrusting
Books and periodicals	10 438	8 178	Boeke en tydskrifte
Transferred to capital funds	8 634	39 873	Oorgedra na kapitale fondse
	R373 795	R440 848	
INCOME			**INKOMSTE**
Atomic Energy Board grant	100 000	100 000	Raad op Atoomkrag-toekenning
CSIR grant	32 053	35 405	WNNR-*toekenning*
Department of National Education Subsidy	132 867	175 391	Departement van Nasionaie Onderwys Subsidie
University of Cape Town	45 659	54 225	Universiteit van Kaapstad
University of Stellenbosch	45 659	54 225	Universiteit van Stellenbosch
Sundry income	9 144	13 756	Diverse inkomste
Rent for laboratory space	5 994	5 000	Huur vir laboratoriumruimte
Interest received	2 419	2 866	Rente ontvang
	R373 795	R440 868	
CAPITAL EXPENDITURE			**KAPITAAL UITGAWES**
Building improvements	950	1 450	Gebou verbeteringe
Extensions to Data Handling system (counting room)	—	6 275	Uitbreiding van datahanteringstelsel (telkamer)
Unspent funds	36 558	89 963	Onbestede fondse
	R37 508	R97 688	
FINANCING			**FINANSIERING**
Funds carried forward from previous year	7 874	36 558	Fondse oorgedra vanaf vorige jaar
Donation from C.P.A.	21 000	21 257	Donasie van K.P A.
Transferred from current account	8 634	39 878	Oorgedra van lopende fondse
	R37 508	R97 688	