原子能研究所

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INSTITUTE OF ATOMIC ENERGY

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本年报全面地介绍了原子能研究所1982年（1月1日至12月31日）在核物理、核数据与核技术应用、加速器、核探测技术、计算机与计算数学、放射化学、放射化工、反应堆科学与反应堆工程、放射性同位素研制、稳定同位素分离、放射性三废处理、环境保护与辐射防护等方面研究工作的年度重要进展，重大设备的维护改进、生产运行，学术活动和国际友好往来等情况，还有该所在有关学术期刊上发表文章的目录。

本年报可供从事有关原子能科学技术研究和应用的科技人员、高等院校师生参考。

原子能研究所年报

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前　言

本期年报介绍了本所1982年度的主要科学技术活动。

核物理　理论上用激子模型计算预平衡发射角分布，由福克-普朗克方程出发开展裂变动力学问题较系统的研究，用直接模拟研究重离子深度非弹性散射等工作已取得了一些成果。继续开展了少体与集团方面的工作。进行了核力的夸克效应，讨论了Λ-N相互作用，用Skyrme力计算微观光学势取得较好结果。

继续开展了核反应机制、核裂变、核结构的实验研究和中子核数据的测量。(α,p)反应预平衡发射奇偶效应及α粒子大角反常散射机制的研究取得了一些新结果；开始研究(α,p)三粒子转移反应机制。为进一步开展在束γ谱学研究建立了多普勒移动衰减方法测能级寿命的手段。对^{252}Cf自发裂变进行了进一步的研究；在3MeV中子诱发^{238}U裂变产物研究中，第一次得到了^{87}Kr等五个产物的产额。参加了Nb/Zr作传递样品的14MeV快中子通量国际比对，结果与平均值差0.6%。Am—Be中子源等放射性强度测量也取得了较好效果。

为开展中微子静止质量的测定，基本完成了255°双聚焦电磁分离器改建为弱磁β谱仪的工作。

核数据评价、计算和推荐　完成了一些超钚核的快中子裂变截面评价；编制程序，计算了天然V，Cr，Zr，Hf中子数据和^{235}U，^{238}U，^{239}Pu，^{240}Pu反应截面和次级中子能谱；在中子共振参数方面开展了平均总辐射宽度$\langle\Gamma^0_\gamma\rangle$和$\langle\Gamma^1_\gamma\rangle$的系统学研究。开展了Fe，O，Na中子截面数据的宏观检验，编制了快堆群常数程序KQCS，对快堆临界基准装置和实验进行了分析。在ACOS—500计算机上建立了核数据评价处理系统，并已正式投入使用。

数学和计算机应用　利用特殊算子逼近理论和扰动理论分析了中子迁移方程的结构，并且基本完成了基本增殖率α，增殖因子ν和有效中子增殖因子μ的定性研究，取得了较好的效果。蒙特卡罗和数值计算方法的研究有了新的进展，完成了一批实际问题的计算。完成了8192谱仪ADC-8192缓存/显示TRS-80微型机数据获取处理系统，其他微处理机的应用得到初步推广。

加速器工程技术和带电粒子物理　强流短脉冲电子直线加速器小模型加速器获得了2.5ns的短脉冲束流。进行了100MeV电子直线加速器工程的技术准备工作，56MW脉冲调制器重复频率达300Hz/s，经结构修改后的速调管束流脉冲功率15MW以上不产生自激，高功率行波谐振环路、金属密封法兰和速调管输出窗都达到了承受脉冲功率≥20MW，平均功率≥10kW的水平。串列加速器钢筒已就位，四个实验厅主体结构已完成。Q3D磁谱仪已经技术鉴定，并用^{210}Po源初步检验了离子光学性能；除已有靶站外，又开始了超灵敏质谱静电分析系统和兰姆移动源的设计工作。供惯性约束聚变研究使用的强流脉冲电子加速器已调至设计指标，加速器二极管处电压1MV，电流81.3kA，输出能量5.1kJ，靶上的束斑直径2 mm。开展了束流诊断和初步的物理研究

工作。与此同时，承担了辐照用电子加速器的物理设计和加速管的研制。离子源的研制、离子光学和束流动力学的研究也取得一定的进展。

核探测技术和核电子学 根据生产和科研需要，研制了Si(Li)^{133}Xe测量仪、抽头延迟线读出多丝正比室，带系统校正的快速瞬态数字化测量系统；加速器磁场位置测量数字化装置和氟-氟化氢分析仪电子学线路，仿源多维随机脉冲谱发生器等设备。研制的大体积高纯锗和高分辨硅位置灵敏探测器已达到较好水平。

放射化学和放射化工 完成了UO_2芯块溶解过程中去除碘工艺的研究；开展了Purex流程中放废液回收和纯化镎、钚、铀的研究；继续开展多种萃取剂性能研究；在有机溶剂γ辐解研究中取得了进展，改进了^{242}Cm制备工艺。

继续开展冠醚-铀络合物的化学研究工作，研究了多种冠醚对氯化铀酰和四氯化铀的萃取性能，初步找出了萃取分离铀(Ⅳ)和铀(Ⅵ)的条件。继续进行离子交换法分离铀同位素的工作。

分析化学 研制成功氟-氟化氢分析仪和氧化锆标氧发生器，提出了用于校准氧化锆测氧仪的相异系差校准法。研究建立了灵敏度高和精密度高的痕量钍的荧光络合滴定法及痕量铽、镝和钐的激光-液体荧光法。用火花源质谱法测定煤中36个微量元素和用中子活化分析法测定煤中41个微量元素，为煤的环境评价提供数据。完成了反应堆压力管材料锆铌合金分析。

三废处理 建成了水泥固化实验装置，开展了水泥固化的条件实验。继续进行了聚苯乙烯固化放射性有机溶剂和废树脂的研究；利用天然无机材料Y-377和合成材料钛酸钠，纤维素处理含钚、镅及裂片废水均有一定的进展。

核技术应用 今年新开展的方面主要有离子注入材料改性和辐照改性，并已取得一些结果。由法国引进主要部件的三轴、四圆中子散射谱仪已完成在堆孔道上的安装，并进行了谱仪和计算机控制系统的联调，同时，利用已有的中子衍射谱仪，开展了磁性材料、超导材料和贮氢材料的研究，并取得一些有意义的结果。利用超精细相互作用技术研究分析了银的α辐射损伤机理。利用小型磁谱仪分析氘核散射以研究金属表面氢的深度分布也取得了成果。沟道效应在半导体材料研究中的应用取得了进展。用静电加速器质谱计分析了重水样品中的氚。堆中子活化分析工作配合医学、环保、地质和材料等研究开展了克山病和微量元素关系的分析、北京稻米粉标样和煤及其灰分等元素分析工作。成立了堆中子活化分析常规分析组，利用仪器分析方法，开展了大量样品的分析服务工作。此外，还为生产单位建立了稀土产品中微量^{227}Ac的测定方法。新研制的HPGe探测器碳/氧比能谱测井仪样机经过改进性能也比以前有了提高。在重水堆上建立了中子嬗变掺杂硅的生产线，研究成功硅单晶电阻率标准样片；在轻水堆上开展了中小功率器件用NTD硅的研制工作。建立了正电子寿命谱仪，用于NTD硅的性能分析。

放射性同位素生产和研制 今年生产了放射性同位素8995Ci，共189种，各项指标均超过了计划指标。

堆照放射性同位素^{123}I，^{125}I的制备工艺有了改进。用回旋加速器试制了^{123}I和^{57}Co。从^{235}U裂变产物中试制医用^{99}Mo产品质量达到国际药典规定。利用Bolton-Hunter联接碘化法研制登革热Ⅳ病毒抗体等一些新的碘标记化合物；对多种中草药进

行了首次氚标记，为深入研究这些药物提供了手段。研究了一批新的放射免疫测定盒，同时开始建立了放免药箱的质量控制方法。此外，继续开展了含氚水脱氚研究，制得了两种新型催化剂。

稳定同位素分离 第一次生产了铕、钐、镝稳定同位素，生产的数量和质量也都超过了计划要求。供实验用255°电磁分离器调试完毕，达到了设计指标。

反应堆科学与工程 对重水堆继续进行工艺设备的技术改造，引用微型计算机和工业控制系统，实现了热工和剂量监测等运行参数的实时监测和部分参数的显示分析，为功率闭环控制作准备。强中子源堆的建造施工正在进行；为了提高该堆的安全性和实用性，对原有的设计开展了理论和实验研究，对堆的元件、物理、热工水力、结构都作了设计改进。

反应堆安全研究工作有较大的开展。引进、消化并改进了轻水堆堆芯熔化事故分析程序 MARCH；移植了轻水堆瞬态分析程序 RELAP5/MOD1。参照 FRAP 系统，建立了燃料元件堆内行为稳态分析程序 RYCH。建立了 UO_2 芯块密实、肿胀及裂变气体释放的物理模型。开展了反应堆时空动力学研究。进行了垂直试验段底部再淹没时的传热、水平棒束流道内气液两相压降、水平圆管低含气率下空泡分额和燃料组件定位格架对流场影响的实验研究；中温中压沸腾传热回路正在加紧建设。

压水堆元件考验的准备工作正在进行，完成了考验组件的物理计算、热工水力计算、结构设计、辐照装置设计和考验回路设计以及部分加工。研究了锆合金的物理、机械性能。堆芯测量技术和材料的辐照、腐蚀研究也取得了进展。

辐射防护和环境保护 由于改进了生产工艺和加强了管理，今年我所工作人员的个人剂量当量，^{131}I 的排放量以及工业废水量均比 1981 年降低很多，辐射事故有所减少。还初步开展了我所全面环境影响评价工作。北京市天然外照射贯穿辐射剂量的测量与评价工作已全部完成，估算得出北京居民性腺所受的有效剂量当量率为 72.39mrad/y。

监测技术 人体甲状腺中 ^{131}I 测量装置已用于常规；按照 ISO 规定的国际标准，建立了反应堆烟囱排出物新取样系统。研究建立了环境氚水蒸汽监测中的简易快速取样方法、^{41}Ar 存在时空气中氚水蒸汽的连续监测方法和尿中钚的快速测定方法。研究了低本底大面积 α 屏栅电离室、用于 n,γ 混合场的 LiF 反照率中子个人剂量计、多探头低本底 α 半导体测量装置和用于环境辐射测量的 SG107 型闪烁剂量率仪。医学防护方面，在裂叶马尾藻褐藻酸钠对健康人口服锶的阻吸收效果的研究和氚诱发人淋巴细胞染色体畸变的研究方面取得了可喜的结果。

热泵蒸发技术用于实际造纸黑液的处理具有明显节能效果，并已正式通过鉴定。

参加了核电站选址环境评价工作，提供了具有一定参考价值的资料。

学术活动 1982 年我所举办全所性学术报告会 51 次；参加全国性学术会议 82次，参加国际学术会议 5 次；共提出报告 309 篇，全年发表 327 篇论文报告。此外，国际友人来所参观，讲学与共同工作的有 112 人，作学术报告 45 次。

欢迎对本年报的缺点错误，提出批评指正。

编 者

Preface

This issue of annual report is a summary of the main scientific and technical developments achieved at IAE in 1982.

Nuclear Physics In theoretical nuclear research, some achievements have been obtained in the calculation of angular distribution for pre-equilibrium emission by using exciton model, in the systematic investigation on fission dynamics by means of Fokker-Planck equation and the direct simulation of deep inelastic collision of heavy ions. Researches were continued on few body problems, cluster phenomena and the quark degree of freedom in nuclei, particularly the Λ-N interaction. Moreover, some quite well results were obtained in calculating the microscopic optical potential by the use of Skyrme force.

The experimental researches were continued on the mechanism of nuclear reactions, nuclear fission and nuclear structure, and the measurement of neutron data. Some new results were acquired for the even-odd effect in pre-equilibrium emission of (α,p) reaction and the mechanism of the anomalous large angle scattering of α-particles. Study on the three-nucleon transfer reaction (α,p) was initiated. A Doppler-shift attenuation method for measuring the lifetime of excited states was established in the study of in-beam γ-ray spectroscopy. Study on the spontaneous fission of ^{252}Cf was pursued. In the investigation of 3MeV neutron induced fission of ^{238}U, the yields of five kinds of fission products, such as ^{87}Kr etc., were obtained for the first time. The result of 14 MeV neutron flux by using Nb/Zr as the transfer sample was compared internationally and the data was only 0.6% different from the average value. Some good results were achieved in the measurement of neutron intensity for Am-Be neutron sources.

In order to measure the rest mass of electron antineutrino, a $\pi\sqrt{2}$ double-focussing electromagnetic separator was successfully reconstructed into a β spectrometer with weak field.

Nuclear Data Evaluation The evaluation of the cross section of fast neutron induced fission for some transplutonium nuclides was completed. The neutron data of natural V, Cr, Zr and Hf, the neutron

cross section as well as the secondary neutron spectra of ^{235}U, ^{238}U, ^{239}Pu and ^{240}Pu were calculated. For the neutron resonance parameters, systematic investigation on the average total radiation width $\langle\Gamma_\gamma^0\rangle$ and $\langle\Gamma_\gamma^1\rangle$ was initiated. The macroscopic examination for the neutron cross section of Fe, O and Na was undertaken. KQCS——a computer code of group constants for fast reactor was programmed. The equipment and experiment for fast critical benchmark assembly were investigated with this code. The nuclear data evaluation system based on the computer ACOS-500 was put into operation.

Mathematics and Applications of computer The structure of neutron transport equation was analysed by means of specific operator approximation theory and perturbation theory. Quite good results were obtained in the qualitative studies on the basic breeding ratio α, the breeding factor ν and the effective neutron breeding factor μ. Study on the Monte-Carlo method and the method of numerical calculation were further developed, and the calculation of many practical problems was carried out. A data acquisition and processing system based on TRS-80 microcomputer with 8192 channel ADC and 8192 channel buffer-display set-up was accomplished and the popularization of the applications of some other types of microcomputer was initiated.

Accelerator Technology and Charged Particle Transportation The pulse width of the high current short pulsed electron LINAC was improved to 2.5 ns. The technological preparing of 100 MeV electron LINAC was initiated. The repetition frequency of the 56 MW pulsed modulator was raised to 300 Hz/s. The peak power of the beam of a modified Klystron came up to 15 MW without self-driving. The high power travelling wave oscillation loop, the metal-sealed flange and the exit window of the Klystron all reached a quite high level: peak power$\geqslant$20MW, average power$\geqslant$10kW. The tank of the tandem was put to its right position and the principal parts of the four experimental halls were constructed. The Q3D magnetic spectrometer was technically appraised and its ion-beam optical property was preliminarily tested by using ^{210}Po source. In addition to the beam stations which were being performed, the designs of an electrostatic analyzer for super-sensitive mass spectroscopy and a lamb-shift polarization source were initiated. The high current pulsed electron accelerator for inertial confinement fusion research reached its designed goal in quality——the voltage at the diode was 1 MV, the beam current was 81.3 kA, the

output energy was 5.1 kJ and the beam spot at the target was 2 mm in diameter. The beam diagnosis and the preliminary physical research were started. Besides, the physical design of an electron accelerator used for irradiation and the preparation of its accelerating tube were made. Some progresses were also made in the preparation of ion sources, the study of ion optics and beam dynamics.

Nuclear Detection Technique and Nuclear Electronics In order to meet the requirements of production and scientific research, a ^{133}Xe determination set-up using Si(Li) detector, a multiwire proportional chamber with delay-line read-out system and a fast promptly-digitized measuring apparatus with systematic calibration, a digitized equipment for measuring the position in the magnetic field of an accelerator, the electronic circuits for fluorinehydrogen fluoride analyzer, a multi-dimensional stochastic pulse spectra generator for simulating radioactive source, etc., were developed. The large high purity Ge and high resolution position sensitive silicon detectors were successfully promoted.

Radiochemistry and Radiochemical Engineering The study of iodine elimination technology in the dissolving process of UO_2 pellets was completed. The recovery for medium level radioactive wastes in Purex process and the purification of Np, Pu, and U were investigated. The study of the performances of various extractants was going on. Some progress in studying the γ-radiolysis of organic solvents was made and the technology for preparing ^{242}Cm was improved.

The study of crown ether-uranium complex compound was in progress. The extraction behavior of various kinds of crown ether for treating uranyl chloride and uranium tetrachloride was studied. The conditions for separating U(Ⅳ) and U(Ⅵ) by extraction were preliminarily found out, and the study of the separation of uranium isotopes by ion exchange was under way.

Analytical Chemistry The F-HF analyzer and the ZrO_2 standard oxygen generator were successfully developed and a new method for calibrating ZrO_2 oxygen analyzer——calibration method with systematic errors in opposite phases was suggested. Some methods of high sensitivity and high precision, such as the fluorescence complex titration for trace thorium and the laser-liquid fluorimetry for trace terbium, dysprosium and samarium were established. In order to furnish data for the environmental evaluation of coal, 36 trace elements and 41 trace elements were determined by spark source mass spectrometry and neu-

tron activation analysis, respectively. The analysis of Zr-Nb alloy used for pressure tube of reactor was performed.

Treatment of Radioactive Wastes A set-up for experiments of cement solidification was constructed, by which the conditions for cement solidification were studied. The fixation of radioactive organic solvent and waste resin with polystyrene was continuously investigated. The study of the treatment of waste water containing Pu, Am and fission fragment elements by using the natural inorganic material Y-377 and synthetic sodium titanate, as well as cellulose reaped the first fruits.

Applications of Nuclear Technique The new fields developed in this year were mainly the material modification by ion implantation and irradiation, and some initial results were obtained. A triple-axis and a four-circle neutron diffractometer, of which the principal components were made in France, was installed at the reactor channel and the spectrometer-autocontrol system based on computer was adjusted as a whole. Besides, by using the existing neutron scattering spectrometers and diffractometer,some magnetic materials, superconductors and hydrogen-accumulating materials were investigated, and some significant fruits were achieved, The mechanism of radiation damage induced by α-particles to Ag was studied using hyperfine interaction technique. The hydrogen profiling technique based on deuteron scattering, with a small magnetic spectrometer, was fruitfully applied in the investigation of the depth distribution in a metal surface layer. Channelling effect was applied in semiconductor material research, while the tritium in heavy water was analysed by supersensitive mass spectrometry at the Van de Graaff accelerator. To meet the requirements in medicine, environmental protection, geology and material science, reactor neutron activation analysis was widely used, e. g, in investigating the relation between Ke Shan disease and trace elements, in the analysis of the elements for the standard sample of Beijing rice flour, coal and its ashes. A group for neutron activation analysis service was organized and many samples were analysed by means of instrumental analysis. Moreover, a method for determining trace ^{227}Ac in rare-earth industrial products was established for some departments. The performance of the logging device based on measuring the ratio of carbon to oxygen with HPGe detector was improved. A production line for NTD silicon was constructed at the heavy water reactor and the sample for conducti-

vity standard of silicon monocrystal was fruitfully investigated. Moreover, the preparation of NTD silicon for devices of medium and low power was initiated at the light water reactor. For measuring the performance of NTD silicon, a positron life-time spectrometer was set up.

Production and Preparation of Radioisotopes 189 varieties of radioisotopes were produced and the total activity was 8995 Ci, moreover, all the indices were better than the planned ones.

The technology for preparing radioisotopes ^{123}I and ^{125}I in the reactor was improved. ^{123}I and ^{57}Co were trial-produced by cyclotron. The quality of ^{99}Mo for medical use separated from fission products of ^{235}U met the stipulations of international pharmacopoeia. Some new iodine labeled compounds, such as the virus antibody Ⅳ of Dengue fever etc., were prepared by Bolton-Hunter connecting iodide method. A variety of traditional Chinese medicines were labeled with tritium for the first time so that these medicines can be deeply investigated. Some new radioimmunnoassay kits were developed and the quality control method was initially established. Moreover, the studies on the detritiation of tritiated water were kept on, and two kinds of new catalysts were prepared.

Separation of Stable Isotopes The stable isotopes of Eu, Sm, Dy were produced for the first time. Both the quantity and quality of stable isotopes produced were over the planned targets.

A 255° electromagnetic separator for research purpose was completed and reached its designed specifications.

Reactor Science and Technology The technological transformation of the heavy water reactor went on. By using micro-computer and industrial control system, the real-time monitoring of the operation parameters, such as thermohydraulics and dosimetry monitoring etc., and the display analysis of some parameters were accomplished, which was the first step for power control in closed loop. The strong neutron source reactor was under construction. In order to improve its safety and practicability, theoretical and experimental investigations were made on the original design, and the designs of reactor elements, reactor physics, thermohydraulics and reactor structures were all improved.

Investigations on the analysis of reactor safety were significantly pushed on. The computer code MARCH for core melting accident analysis of light water reactor was imported, mastered and improved,

The code for transient state analysis of light water reactor, RELAP5/MOD 1, was transplanted. With reference to FRAP system, a code RYCH for steady state analysis of fuel behavior inside the reactor was set up. A physical model for describing the compactness, swelling and release of gaseous fission products was established. The time-space dynamics of reactor was studied. The experimental studies were carried out on the heat transfer under the condition of the bottom part of the vertical tubular testing section reflooded, on the pressure drop of the air-water two phase flow in a horizontal tube, on the fraction of bubbles under the condition of low gas content at horizontal circular tubes and on the effect of the grid used for fixing the fuel assemblies upon the flux field. The construction of the boiling heat transfer loop at medium temperature and pressure was being carried out. The preparation for the test of pressurized water reactor elements was under way. The physical calculation for element test, the calculation for thermohydraulics, the design of structure, irradiation set-up and test loop, and the manufacturing of some components were performed. The physical and mechanical characteristics of zirconium alloy were studied, and some progress in the investigations of in-core measurement technique, irradiation and corrosion of materials was made.

Radiation Protection and Environmental Protection As a result of improving the fabrication technology and strengthening the management, the personal dose equivalent of the personnel in this institute, the amount of discharged ^{131}I and industrial waste water was significantly reduced in comparison with 1981, and the number of radiation accidents was also reduced. The comprehensive evaluation of the effect of radiation on environment was initiated. The measurement and evaluation of the natural penetrating radiation was completed, and the effective dose rate equivalent suffered by the inhabitants of Beijing in the sex gland was estimated to be 72.39 mrad/y.

Monitoring Technique The set-up for measuring ^{131}I in human thyroid gland has already been put to routine use. According to the international standard stipulations by ISO, a new sampling system for the exhausts from the reactor stack was built up. A simple and fast sampling method for monitoring the vapour of tritium water in the environment, a continuous monitoring method used for the vapour of tritium water in air containing ^{41}Ar and a fast method for plutonium

determination in urine were studied and established. A low background and large area screen grid ionization chamber for α-particle detection, a neutron personal dosimeter made of LiF for albedo in a n-γ mixed field, a low background semiconductor system with multi-detectors used for α particle detection and a scintillation dosimeter of model SG 107 for environmental radiation detection were investigated. In medical protection, studies on the anti-absorption effect of brown sodium alginate on strontium taken orally by healthy person and the chromosome aberration of human lymphocyte induced by tritium achieved satisfactory results.

The thermal pump evaporation technique used in treating the black liquid from papermaking had a significant effect in energy saving, and passed the formal appraisal. The environmental evaluation on the siting nuclear power station was carried out, by which some interesting reference information was provided.

Academic activities In 1982, there were 51 scientific symposiums sponsored by the institute. The scientists and engineers of this institute attended 82 national conferences and symposiums, 5 international meetings, and 309 papers from this institute were presented at these meetings, and 327 papers were published in various journals. Besides, 112 foreign friends visited this institute. Some of them gave lectures and some coworked with us. 45 lectures were delivered by them.

Shortcomings and mistakes in this issue are unavoidable, any suggestions or criticisms are warmly welcome.

Editor

目　　录

核　物　理

电 物 理

核探测技术

应用数学和计算数学、计算机及数据获取和处理系统