原子能研究所

中国　北京

年报

INSTITUTE OF ATOMIC ENERGY

ANNUAL REPORT

BEIJING, CHINA

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本年报全面地介绍了原子能研究所1983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

1983年我所进行了机构改革和人事调整。中国科学院学部委员、研究员戴传曾担任所长。成立了以中国科学院学部委员、研究员汪德熙教授为主任委员的原子能科学技术委员会。成立了物理、电物理、化学、反应堆工程、电子、同位素生产等六个研究部和安防环保处及放射性计量站。

王淦昌教授担任我所名誉所长。

本期年报介绍了本所1983年度的主要科学技术活动。

核物理　理论工作方面，讨论了非相对论层子模型下的核子-介子顶角结构和用夸克禁闭势描述重子态的问题。对应用Skyrme相互作用作了大量探索，用它较系统计算了偶偶核的截面、弹散角分布取得较好的结果，也计算了核物质质量，探索了扩展到中能和负能量区的问题。与此同时，其他课题有用巴黎势计算核物质饱和性质，高角动量对不对称形变的效应，少体核反应，预平衡统计理论与其他反应理论的关系，考虑趋向平衡过程的核裂变和锕系核能隙参数计算等。

实验方面，继续进行了（α，p）反应中的大角反常散射，三核子转移反应，预平衡发射机制研究，实验表明，预平衡发射几率有对称效应和壳效应。建立了三晶体对谱仪，利用它开展了热中子$^{32}S(n,\gamma)$反应研究，初步分析了反应机制。对^{252}Cf自发裂变长程α粒子能谱和关联性质进行了较细致的研究。完成了8 MeV中子诱发^{238}U裂变的质量分布测定，所测的质量链数是迄今最多的，其中^{113}Ag是第一次被测定。还测量了一些核反应截面和8 MeV中子与氘核弹散的角分布。建立了T(d,n)反应中子平均能量测量的硅探测器法和α通量比法，以及通量测量的伴随粒子法标准靶管，参加了^{252}Eu γ线发射率的国内比对，进行了^{216m}Ho γ线相对强度测量。

测定中微子静止质量工作中，已利用新改建的$\sqrt{2}\pi$双聚焦低能β谱仪、流气式正比管探测系统，开展了^{170}Tm和^{182}Ta内转换电子谱及氚β谱的初测。

核数据评价　完成了20个核的全套中子数据计算机评价处理，推荐了^{59}Co热中子吸收和俘获截面以及^{60m}Co的热中子俘获截面，移植了美国国家核数据中心的核结构和核衰变数据评价物理分析程序，更新了该中心的$A=55$链核结构核衰变数据。计算分析了一些可裂变核由3—20 MeV中子引起的核反应截面和能谱，由于考虑了预平衡发射，谱形有明显改善。还开展了连续区粒子发射双微分截面的计算。此外，为推荐中子共振能区有关数据，建立了人机对话的软件系统。编制了二维扩散燃耗程序。同时，还研究了存在疏失误差时的数据调整与合并的处理方法。

加速器工程技术和带电粒子物理　串列加速器大厅、控制室和辅助系统厂房工程已于1983年9月基本建成，串列加速器由11月份开始正式安装。物理实验厅开始内部装修。在对串列束流动力学传输理论研究的基础上，给出了超灵敏质谱管道和化学管道的理想设计方案。

14MeV强流短脉冲电子直线加速器经调整，10ns，20ns，50ns脉宽的束流参数得到了较符合设计的要求。复杂的闭环冷却系统也改为简单的开环调节系统。在

100MeV电子直线加速器工程技术准备工作方面，速调管在设计工作频率下，已可以有每秒300次的重复频率，输出脉冲功率16MW、平均功率8kW；新型微波负载已达10MW脉冲功率、5kW平均功率的水平；S波段功率源，整体说来，已达到设计指标。

利用1MW，80kA强流短脉冲电子加速器研究了电子束在靶上的能量沉积机制。结果用法拉第筒飞行时间法测速度谱和X射线二极管测等离子体温度都没有发现显著的能量反常沉积。

研制了强流溅射负离子源、弗瑞曼离子源和氩双等离子体离子源，开展一些离子注入材料改性方面的工作。

此外，在电磁场和离子光学计算，束流动力学研究方面也完成了一些工作，取得了一些进展。

数学和计算机应用 对KdV方程的Lax猜想给出了证明。将扰动法应用于反应堆理论分析。对非归一分布的集团蒙特卡罗方法及应用给出了初步的总结。同时，结合我所实际研究课题，完成了不少数学分析和计算工作。

引进的VAX-11/780和PDP-11/44投入了运行，对TQ-6机进行了维修和改进。建立了个人放射性剂量库和器材管理卡片等管理程序系统。为物理实验、热工水力试验、同位素生产、环境保护和油田建设等的需要，研制了一些新数据获取处理硬软件系统。第一次建立了几百米距离级数据获取系统，引进了UNIX操作系统下的获取处理软件，并做了某些改进。

核探测技术 围绕提高半导体探测器能量分辨率继续开展了研究工作，同轴HPGe探测器能量分辨率有了较大提高，同轴Ge(Li)探测器也有所提高。研制了线性较好、稳定性较好的高阻硅γ射线计数器，可用于堆芯功率分布测量。

配合Q3D磁谱仪，研制了一维和二维成像焦面探测器包括相应的核电子学系统。研制了流气式多丝正比计数器，准备用于建立α和β源的强度基准装置。还研制了较小尺寸的球形含氢正比计数管。

1983年用于生产和生活的核探测系统发展较快。离子感烟式火灾报警系统完成了样机试制。对钢板横断面厚度变化进行非接触式测量的F_{2-5}型凸度计和用于静电测量的FH4502型集电式静电计也顺利研制成功。

放射化学 为处理过期的^{252}Cf中子源，对其热室处理的主要工艺进行了研究。继续围绕Purex后处理工艺开展了萃取分离超钚元素、裂片元素的化学行为等研究；研究中发现磷酸三丁脂萃取钚（Ⅳ）有时会产生第二有机相，为此，深入研究了产生的条件。开展了铀的光化学还原、钚的电解还原方法的研究。同时还开展了其它后处理工艺和超钚元素生产工艺研究。在装置方面，研制成功阳阴极共区的电解还原澄清槽和锂玻璃微珠固体闪烁流线监测器。在裂变化学方面，开展了裂变产物快速放化分离Sn和Sb的研究并取得了成功。

继续开展了离子交换法分离铀同位素的研究。同时为了更好地开展冠醚络合物的研究，进行了几种冠醚制备方法的研究。

分析化学 电感耦合高频等离子体发射光谱分析技术有所提高，改进了雾化器、雾

化室，解决了扫描单色器为低浓度元素谱线准确寻找峰位的问题，成功地分析测定了海水成分。建立了高灵敏度的铀钚萤光络合滴定法，开展了激光-液体萤光法测定铕和钐的工作。研制成功袖珍式卤素检漏仪，供推广使用。配合珍珠辐照着色用多种方法测定了珍珠的元素成份。同时配合反应堆工程要求，建立了回路水中溶解氧量、微量氟和高浓低浓重水浓度等的测定方法。

三废处理 研究了放射性有机废液的净化处理工艺、设计了焚烧和固化装置；同时，开展了废树脂苯乙烯固化工艺条件和辐解热解等产品性能研究。研究比较了含硫酸盐高放废液固化玻璃配方，克服了出现黄相问题。用无机材料净化放射性尾气中挥发性钌和离子交换纤维填充床电渗析器的研究也取得了较好的效果。在液膜分离技术方面，研究建立了新型载体二组分液膜体系。

核技术应用 新建立了缓发中子计数法测铀装置。建立了堆中子活化分析的比较器方法和氧化镉中子过滤器的超热中子活化分析方法。完成了首批环境标准参考物质、地质标样的堆中子活化分析，还作了从五台山的泉水到人毛等多种样品的堆中子活化分析，利用康普顿散射和卢瑟福散射原理，沟道效应和时间微分扰动角关联方法开展了分析研究工作。同时，探索了利用瞬发γ活化技术分析煤成分，利用油田岩样自然γ能谱分析铀、钍、钾含量的可行性和蚕茧茧成率非破坏性测量的方法。

中子嬗变掺杂硅研制工作水平有新的进展，已能生产大规模集成电路和核探测器级的材料。在继续为国内单位辐照掺杂的同时，已为国外有关公司辐照了样品。积极开展了γ辐照灭菌和材料改性的研究工作，已初步攻克了珍珠辐照着绿和黑色的技术。

利用中子衍射技术，继续进行了单晶结构分析，磁性材料、超导材料、贮氢材料的性能研究。利用新建立的三轴四圆谱仪，开展了锗酸铋旋声性的研究等新课题。

此外，开展了直流电场作用下α-$LiIO_3$中Li离子迁移行为的研究。在用裂变碎片径迹法研究PET薄膜聚集态结构中还发现了令人感兴趣的现象。

同位素制备和研究 今年生产了放射性同位素169种，10451居里，各项生产指标均超过了计划指标。试制了多种放射性同位素新产品，主要有^{241}Am标准溶液、工业应用的^{210}Po静电消除器、医用缺中子同位素^{111}In和多种氚标记和^{125}I标记化合物。与此同时，在物理测量，放化分离纯化、分析等方面也取得了一些进展。建立了核磁共振检测手段，$4\pi\beta(PC)$-γ符合测量装置-微型机系统，完成了铜基铂选择吸附分离溴、碘与亲和层析法提纯AFP抗体等一批新的工作。

稳定同位素制备方面首次成功地分离了钆。

反应堆科学与工程 改建的重水反应堆，现用UO_2束棒元件取代了原有的金属铀元件，反应堆功率由15MW提高到17.5MW，堆的安全性也得到了改善。该堆的微型计算机和工业控制系统进行了功率闭环程序堆外数值模拟，新操纵台完成设计并开始加工。游泳池式反应堆的HTL集成电路控制保护系统也完成了研制和试验。在两堆上的硅单晶中子掺杂进入生产规模，1983年生产了约两吨。现正在进一步扩大生产并增加品种。

我所研制的微型中子源堆已达到额定工况，辐照管道内的中子通量为$1\times10^{12}n/cm^2\cdot s$，相应热功率为27kW。今后将以此为原型向用户提供商用堆。

1983 年在堆的热工水力、元件、材料方面，围绕秦山核电站元件考验和堆安全分析做了大量工作。元件考验组件和考验装置的堆外考验已完成，为堆内考验进一步作了物理分析、热工水力分析，建立了检漏装置，堆内考验回路和考验后检验用的热室实验装置都在抓紧准备。引进的 RELAP5/MOD1 完成了大型标准题 LOFT-L3-1 的试算，并对秦山核电站一回路中小破口假想事故进行了分析计算。引进了压水堆电站安全壳分析程序，对秦山电站的安全壳进行了基准事故时的响应计算；还从应力腐蚀破裂的角度对安全壳钢材堆焊内衬进行了实验研究。动力堆燃料元件事故分析程序 FRAP-T6 和燃料棒稳态性能程序 FRAPCON-2 也都移植成功。与此同时再淹没时膜态沸腾、UO_2 热导率的气孔率修正、芯块-包壳的接触传热系数及相互的化学物理作用机制，还有碳钢防腐等热工水力、元件、材料工作都取得了较好进展。

堆物理方面，一群半三维节块法和控制棒栅反应性等理论和实验工作也取得了一定进展。

辐射防护和环境保护 增加了一些新项目。进行了人体甲状腺中 ^{125}I 的测定；对工作场所的辐射防护监测范围有所扩大，方法有所改进，异常情况处理及时。开展了环境影响的初步评价工作及其所需的资料调查统计工作，与此相应统一了放射性流出物的监测和计算程序，并且已对我所排出的放射性碘和气载 ^{210}Po 对环境的影响作出了初步评价分析。

辐射防护监测技术 用于 X，γ 射线剂量仪表刻度的次级标准剂量实验室初具规模，已能承担治疗水平与防护水平的 X，γ 射线剂量仪表的刻度。研制了反符合屏蔽低本底 Ge(Li) γ 谱仪，对单一 ^{137}Cs 点源，测 1000 分钟的最小探测限为 $2.2\times10^{-2}Bq$。配合 1983 年研制的一台圆柱形 α 屏栅电离室建立了环境样品（1400cm²）大面积 α 薄膜源的常规制备工艺。研制了 IAE-8401 型可携式高压电离室环境辐射剂量仪。由于具有连续自动获取数据功能，可方便地用于野外测量。建立了牛奶中 ^{131}I 和 ^{125}I 的测定方法，对我所重水反应堆回路的重水泄漏已能进行连续监测。此外，配合外单位的需要，发展了海水中钚和镅的测定技术以及铀矿冶废水中微量铅和镉的测定技术。

1983年发表在国内期刊上的论文报告有 88 篇，国外期刊上的论文报告有 72 篇。此外，国际友人来所参观、讲学与共同工作的有 167 人，作学术报告 32 次。

欢迎对本年报的缺点和错误，提出批评指正。

编 者

Preface

In 1983 the organization reform and transfer of personnel in the institute was performed. Senior research fellow Dr. Dai Chuan-zeng was appointed chief director. The Commission for Science and Technology of IAE headed by senior research fellow prof. Wang De-xi was founded. The Institute consists of six divisions: Nuclear Physics, Electro-physics, Chemistry, Reactor Engineering, Electronics and Isotope Production and also an Environmental Protection and Safty Service and a Radioactivity Dosemetry Station.

The ex-director prof. Wang Gan-chang becomes honorary director.

This Annual Report summarizes the main scientific research and technical developments carried out in IAE during the calendar year 1983.

Nuclear Physics The nuclear theory program encompasses a broad range of nuclear-particle aspects. The nucleon-meson vertex structure on the basis of nonrelativistic quark model and the description of baronic states using quark confinement potential have been studied. Exploring studies have gone into the possible applications of Skyrme interaction, with which the cross sections and the angular distributions of the elastic scattering for even-even nuclides have been calculated systematically, and fairly good results have been obtained. The calculation of the mass of nuclear matter has also been performed, and the expansion to medium and negative energy regions has been investigated. At the same time, some progresses have been made in the subjects, such as the calculations of the nuclear matter saturation properties with the Paris potential, the effects of high angular momentum on asymmetric deformation, few body nuclear reaction, the relation of the statistical theories of the preequilibrium and the other nuclear reaction theories, the fission probability calculation with the equilibrium process taken into account and the calculation of the energy gap of some actinide nuclides and so on.

The experimental research program continues to cover a broad

spectrum. The investigation on the anomalous large angle scattering in (α,p) reaction, three nucleon transfer reaction, and preequilibrium emission mechanism was continued. The symmetry and the shell effects on the probability of preequilibrium emission have been observed. By use of a triple crystal pair spectrometer, which was newly constructed, the thermal neutron reaction $^{32}S(n,\gamma)$ has been studied and the preliminary analysis of the reaction mechanism has been performed. The long range α particle spectrum and its correlation properties for the spontaneous fission of ^{252}Cf have been investigated in some detail. The mass distribution of 8 MeV neutron induced fission of ^{238}U has been measured and the number of the mass chains measured is the largest up to now. The yield of ^{113}Ag was determined for the first time. Some nuclear reaction cross sections and the angular distribution of 8 MeV neutron elastic scattering on deuterium have also been measured. The silicon detector method and the α-flux ratio method for the determination of the mean energy of the neutrons from T(d,n) reaction have been established. The standard target tube for the associated particle method has also been built. The comparison of the γ ray emission rate of ^{152}Eu was conducted on a nation-wide scale. The measurement of the relative intensity of γ ray from ^{166m}Ho has been performed.

In a continuous effort in the determination of the rest mass of electron antineutrino, the internal conversion electron spectra of ^{170}Tm and ^{182}Ta, and the β spectrum of tritium have been preliminarily measured with the $\pi\sqrt{2}$ double-focussing low energy β spectrometer and the gas flow proportional counter system. Further improvement on suppressing the background and enhancing the precision is being made.

Nuclear Data Evaluation The computer evaluation processing of the neutron data for twenty nuclides has been completed. The thermal neutron absorption and capture cross sections for ^{59}Co as well as the thermal neutron capture cross section for ^{60m}Co were recommended. The physical analysis programs for nuclear structure and decay data evaluations of the NNDC were adapted. The nuclear structure and decay data for $A=55$ chain have been renewed. The reaction cross sections and the energy spectra of some fissile nuclei induced by 3—20 MeV neutrons have been calculated and analysed. Impressive improvement in the energy spectra has been obtained by taking account of the preequilibrium emission. The calculation of the double differential

cross sections for particle emission in the continuum region has been done. In order to evaluate the neutron resonance parameters, an interactive software system was completed. A computer code for two dimensional diffusion burnup has been made. Also investigated were the methods for adjusting and combining data with negligence error.

Accelerator Technology and Charged Particle Physics The main hall, the control room and the auxiliary system building of the tandem accelerator were accomplished in September 1983. The installation of the tandem started in November. The installation work on the experimental area has begun. Based on the study of the transport theory of beam dynamics for tandem, ideal designs of the beam lines for ultrasensitive mass spectrometry and chemistry have been proposed.

After adjustment, the beam parameters for 10ns, 20ns, 50ns pulse widths of the 14 MeV high current short pulsed electron LINAC have met the design requirement. The complicated closed-loop cooling system was replaced by a simple open-loop adjusting system. The technological preparation of the 100 MeV electron LINAC was continued. At a repetition frequency of 300 Hz/s, the peak power of the klystron reached 16MW, the average power 8kW. The new type of microwave load has reached 10MW peak power and 5kW average power, Therefore, the s-band power source has met the designing criterion on the whole.

By using the 1MW 80kA high intensity pulsed electron accelerator, the energy deposition mechanism of the electron beam in the target was investigated. Both the velocity spectrum measurement with Faraday Cup TOF method and the plasma temperature measurement by means of X-Ray diode were performed, but no obvious anomalous energy deposition has been observed.

The high intensity ion sputter negative source, the Freeman ion source and the argon duoplasmatron ion source have been fabricated. A low energy ion injecter was built, and some ion implantation work for the modification of material has been done.

Besides, some progresses have also been made in the calculations of electromagnetic field and ion optics, and in the beam dynamics research.

Mathematics and Applications of computer The Lax conjecture for KdV equation has been demonstrated. The perturbation method has been applied to theoretical analyses of nulear reactor. A preliminary summary of the cluster Monte Carlo method for non-normalized

distribution and its application has been made. A lot of mathematical analyses and calculations have been carried out for the research subjects being investigated.

The VAX-11/780 and PDP-11/44 computers have come into operation. Some maintenance and improvement have been done for the computer TQ-6. A management system of personal dose library and IEMS-2 system for inventory management of equipment have been developed. Some new hardware and software systems of data acquisition for nuclear physics and applied nuclear science have also been developed. A data acquisition system hundred metre away from the computer was built for the first time. The acquisition software under UNIX operation system has been introduced, and some improvement has been achieved.

Nuclear Detection Technique The research for improving the energy resolution of semiconductor detectors was continuously conducted. An obvious improvement in the energy resolution has been obtained for the coaxial HPGe detector, and some improvement for the coaxial Ge (Li) detector. High resistivity silicon γ ray counter with good linearity and stability has been fabricated, which can be used to measure the reactor core power distribution.

One-dimentional and two-dimentional focal plane detectors as well as the associated electronics were constructed to match the Q3D spectrograph. The gas flow multiwire proportional counter, which is to be used for a standard facility of α and β source intensity, and small sized spherical hydrogen-containing proportional counter have been constructed.

The development in the nuclear detector system for industrial and daily use, such as ionic smoke sensitive fire alarm system, model F2-5 convexity gauge, and model FH4502 collective electrometer has been achieved.

Radiochemistry In order to process the decommissioned ^{252}Cf neutron source, the processing technology for it in the hot cell was studied. Research projects pertinent to Purex process were continued including the separation of transplutonium elements by solvent extraction, the study of the effect of MBP and DBP on the strong complexing agents and the study of chemical behaviours of fission products. Further study was made to find the conditions under which a second organic phase was formed in the extraction of

Pu(Ⅳ)by TBP. Investigation was also carried out on the photochemical reduction of uranium and electrolytic reduction of plutonium. Meanwhile, other processes for reprocessing spent fuel and the production of transplutonium elements have been studied. In the development of instrumentation and equipment, the design of an electrolytic mixer-settler without diaphragm and the development of an in-line monitor using lithium glass particles as scintillator were both successful. In the field of fission chemistry, the rapid radiochemical separation of Sn and Sb from fission products was studied and the results are satisfactory.

Research was continued on the separation of uranium isotopes by ion exchange. Several methods for the preparation of crown ether were evaluated for the purpose of further study on complexes of crown ether.

Analytical Chemistry After improving the nebulizer and spray chamber and solving the problems related to the correct peak seeking of spectral lines for the elements in low concentrations with scanning monochromator, progress was made in the ICP-AEC analytical technique and constituents at tracer level in sea water were successfully determined. A highly-sensitive method of fluorescence complexometric titration of uranium and plutonium was established, the successfully developed pocket halogen leak detector is ready for more applications. In cooperation with the project on radiation coloring of pearls, several methods were adopted to determine the contents of different elements in pearls. To meet the needs of reactor engineering, analytical methods were developed for the determination of the amount of dissolved oxygen, fluorine at microscopic level and heavy water both at high and low concentrations in the reactor loop water.

Treatment of Radioactive wastes The treatment of radioactive organic liquid waste was studied and a unit of incineration and solidification was developed. Meanwhile, the technological parameters of the styrene polymerization process for spent resin have been studied and investigation was made on the properties of the polymerization product including radiation and pyrolytic stabilities. Various glass recipes for vitrification of high level liquid waste bearing sulfate were compared and the yellow phase was eliminated. Good results have been obtained in the research on the removal of volatile Ru from calciner off-gas with inorganic material and the results of the study on an electrodialyzer filled with ion exchange fiber were satisfactory.

In the project of separation with liquid membrane, a binary liquid membrane system with new carrier was developed.

Applications of Nuclear Technique A delayed neutron counting system for the determination of uranium has been built. The comparator method for reactor neutron activation analysis and the ENAA method using CdO as neutron filter have been developed. The first batch of neutron activation analyses of environmental standard reference material and geological standard reference samples has been carried out, and the other samples analysed range from human hair to spring water of Wutai mountain. Analyses were also performed by means of Compton scattering, Rutherford scattering, channelling effect, and time-differencing perturbed angular correlation. Moreover, the possibilities of analyzing the composition of coal with the PGAA technique and determining uranium, thorium and potassium in rock samples of the oil field with natural gamma-ray spectra analysis have been probed. The nondestructive determination of silkworm cocoon parameters has also been tested.

Some new developments of NTD have been achieved. The materials for LSI and nuclear detectors have been produced. The international co-operation in NTDS has started. The research on the gamma ray irradiation sterilization and modification of materials has been actively conducted. The technique of pearl-colouring induced by irradiation has been preliminarily developed. By neutron diffraction, the studies of the single crystal structure and the proporties of the magnetism material, superconducting material, and the hydrogen storing material have been carried out. The acoustical activity of $Bi_{12}GeO_{20}$ etc. were studied by newly constructed triple axis- and four circle-diffractometer. Besides, the study on the migration of Li ions of α-$LiIO_3$ single crystal under an electrostatic potential was performed. Some interesting phenomena were found in the investigation of the aggregation in PET film by fission track technique.

Development and Preparation of Isotopes 169 varieties of radioisotopes were produced this year, with the total activity amounting to 10, 451 curies. The production yields were over the planned ones.

New kinds of radioisotope products have been successfully trial-produced, among which are the standardized solution of ^{241}Am, the ^{210}Po static eliminator for industrial use, the neutron-deficient isotope ^{111}In for medical use and several compounds labelled by tritium

and iodine-125 respectively. Besides, progress has been made in physical measurement, separation and purification by radiochemical methods and analytical techniques. A nuclear magnetic resonance instrumentation and a $4\pi\beta(PC)-\gamma$ coincidence system interfaced with microcomputer have been developed. Some new projects were completed including the separation of bromine and iodine by selective adsorption on Cu-based platinum and the purification of AFP antibody by affinity chromatography.

In the field of the preparation of stable isotopes, the separation of gadolinium succeeded for the first time.

Reactor Science and Technology In the re-built heavy water reactor, the original metallic uranium elements were replaced by present UO_2 cluster elements, the maximum power of reactor was increased from 15MW to 17.5MW and the safety of reactor was improved. For the micro-computer and industrial control system of this reactor, digital simulation outside reactor for power code in closed loop was carried out. The design of new console was completed and its manufacture initiated. HTL integrated circuit control and protection assembly for swimming pool reactor was developed and tested. Neutron doping of single crystal silicon in both reactors was carried out on production scale. In 1983 the production output was about 2 tonnes. The expansion of production was pursued and the variety was to be increased.

The miniature neutron source reactor developed by the institute reached rated operating conditions. The neutron flux inside the irradiation tube was 1×10^{12} n/cm^2·s and the corresponding thermal power was 27kW. This reactor was a prototype reactor for the commercial ones which will be offered to customers.

In 1983 many studies on thermohydraulics, fuel element, materials involving fuel element test and analysis of reactor safety for Qin-Shan PWR were carried out. The out-of-pile testing of assembly of fuel element and test equipment were accomplished. In order to test inside the reactor, physical analysis and analysis of thermohydraulics were pursued, and leak detecting device was set up. Close attention was paid to the preparation of test loop inside the reactor and experimental equipment of hot cell for post-test examination.

The testing calculation of large scale standard problem LOFT-L3-1 was accomplished with RELAP5/MOD1. The imaginary accident of medium and small break in primary circuit of Qin-Shan PWR

was analyzed and calculated. The containment analysis code for PWR was imported, and response calculation in basis accident for the containment of Qin Shan PWR was made, and experimental investigation for surfacing welding steel liner was carried out in terms of stress corrosion cracking. Accident analysis code FRAP-T6 for fuel element of PWR and code FRAPCON-2 for steady state behavior of fuel rod were successfully adapted. Meanwhile, some progress was made in research works of film boiling during reflooding, porosity correction for UO_2 thermal conductivity, contact heat transfer coefficient and mechanism of chemical-physical interaction between pellet and cladding, and corrosion prevention of carbon steel.

In reactor physics, some progress was achieved in theoretical and experimental investigations, such as one and a half group three dimensional nodal method and lattice reactivity of control rod etc.

Radiation Protection and Environmental Protection Some new programs have been initiated. The measurement of ^{125}I in human thyroid gland has been conducted. The working area being monitored was increased, and the monitoring methods have been improved, so that the unusual situations were handled in time. The investigation and assessment of environmental impact were carried out, and the monitoring and the computer code for the radioactive effluent were unified. A preliminary assessment of the environmental impact by radioactive iodine istopes and airborne ^{210}Po released from the isotope production workshop has been performed.

Monitoring Technique The secondary standard dose laboratory for X- and γ-ray dosimeter calibration has been built, where the X- and γ-ray dosimeters at therapy level and protection level can be calibrated. An anti-coincidence shielding low background Ge(Li) γ spectrometer was constructed, and the minimum detection limit for ^{137}Cs spot source is 2.2×10^{-2}Bq in 1000 minute. The technology of making large area (1400cm^2) thin foil α source has been developed for the screen grid cylindrical ionization chamber. The IAE-8401 type portable high pressure ionization chamber environmental radiation dosimeter has been manufactured. Because of the function of automatic data acquisition, it is convenient to be used in the open field measurement. The method for determination of ^{131}I and ^{125}I in milk was developed. The leakage of the heavy water from the heavy water reactor loop can be continueously monitored. Besides, to meet the industrial needs, the te-

chnique of determining Pu and Am in sea water, and the micro-amount of Pb and Cd in waste water from the uranium mining and hydrometallugical mill was developed.

In 1983 160 papers were published in various journals, 72 papers being in foreign journals. Besides, 167 foreign friends visited this institute. Some of them gave lectures and some coworked with us. 32 lectures were delivered by them.

Editor