UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UNIVERSITY OF CALIFORNIA
RADIATION LABORATORY

Cover Sheet
Do not remove

DECLASSIFIED

INDEX NO. UCRL 152
This document contains 14 pages
and 0 plates of figures.
This is copy 2 of 3. Series B.

Issued to: _____

~~SECRET~~
Classification

Each person who received this document must sign the cover sheet in the space below.

Route to	Noted by	Date	Route to	Noted by	Date

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

Contract No. W-7405-eng-48

PROGRESS REPORT NO. 65

June 15 - July 15, 1948

Berkeley, California

UNIVERSITY OF CALIFORNIA, RADIATION LABORATORY

June 15 - July 15, 1948

PROGRESS REPORT NO. 63

1. 184-inch Cyclotron Program

The cyclotron was used for research experiments ninety-three percent of the 482 hours that the crew was on duty. Increased use of the cyclotron was made by the chemists during this month. A neutron absorber was installed on the wall of the building to prevent the neutron beam emerging from the building outside the concrete shielding during neutron experiments. Work was continued on the strengthening of the supports for the additional concrete roof blocks.

2. 60-inch Cyclotron Program

A program for the acceleration of heavy ions was continued with the use of photographic technique for identifying the particles. Plates were developed which indicated the presence of C^{+6}. Boron trifluoride was also used and coincident with its use deflector insulator trouble occurred. This lead to a slight decrease in operation efficiency. Continued need for Be^{7} dictated the use of protons for the bombardment of lithium. The over-all efficiency for the period is well over 70%.

3. Synchrotron Program

Continued attempts to obtain a betatron beam have been unsuccessful even though quite adequate values of current are obtained at a probe located 315° from the injector. Numerous attempts were made to look for evidence of electrons having made several turns by means of a photomultiplier located so as to pick up photons from an anthracene crystal located in the vacuum chamer. The anthracene was mounted in a lucite rod and protected by a one-half mil aluminum foil. This device is very sensitive to 70 kv. electrons (as provided by the injector) and it is believed that had any electrons made as many as 50 revolutions, there should have been an indication from the anthracene counter which would have been easily detectable.

Repeated measurements of the betatron flux condition indicate that it was satisfied for a period of time entirely sufficient to have provided considerable betatron acceleration.

The machine has been recently dis-assembled in an attempt to determine the cause of the trouble. The program for re-assembly includes means for correcting each of the three possible causes of its failure to perform. New pole tip wedges are being fabricated which will have much higher inter-lamination resistence and which it is hoped will greatly reduce the eddy current fields which occur near the time of injection. As these poles are installed, a program of careful magnetic

measurements will be undertaken to insure that the field is as uniform as can be obtained.

The quartz doughnut will be installed in the machine to take care of the other two possible causes of failure. This should provide a better vacuum and reduce any loss which may have resulted from gas scattering, and will provide a better semi-conducting surface to minimize the chances of insulating patches becoming charged producing electrostatic forces which interfere with the symmetry of the orbits. It is possible that the latter difficulty has been the principal source of trouble since after dis-assembly it was found that some portions of the vacuum chamber were covered with a varnish-like substance which had good insulating qualities. The machine will also be assembled with adequate provision for contracting coils which, from other betatron experience, are known to increase the yield by reducing the fraction of the beam which hits the injector on the first few revolutions.

4. Linear Accelerator Program

Van de Graaff. During the period June 15 to July 15, the Van de Graaff was producing a 4 Mev proton beam 125 hours out of a total working time of 309 hours, or 40.5 percent of the time.

Linear Accelerator. The linear accelerator has been in use on research problems 298 hours. The total trouble outage of the linear accelerator was approximately 2 percent. Eleven percent outage can be charged to inefficient use of the machine. Changes in operating regulations to assure more efficient utilization of the shift time on experiments were introduced June 30. The output current of the machine has been 1 or 2 x 10^{-10} consistently throughout the month, which is higher than previous normal running by a factor of three.

In this period, 65 percent of the bombarding time was devoted to proton-proton scattering with both the counter and photographic techniques in use. The remainder of the time was devoted to carbon (p,d) excitation and absolute cross section measurements, inelastic scattering of protons, excitation curves of short half-life isotopes, and carbon recoils.

In addition, some time was spent determining more fully the energy of the proton beam, and the general R.F. power to beam output characteristics of the machine. The beam energy was found to vary between 32 and 32.3 Mev, depending on operating conditions. From excitation curves of the carbon (p,d) reaction it has been determined that the energy spread of the beam is less than 100 KV at half maximum.

5. Experimental Physics

Meson Experiments. Positive $\pi \rightarrow \mu$ Decay. Ten examples have been observed with tracks of the secondary meson ending in the photographic emulsion. In all cases the energy is about 4 Mev in agreement with the cosmic ray observations.

Ratio of Positive to Negative Mesons. Experiments on detecting mesons of about 4 Mev under conditions of equivalent geometry for both signs have yielded 150 negative mesons and 24 positive mesons (a ratio of 6.2 $\pm$ 2) from a carbon target. Other experiments in which the negative mesons were measured in the forward direction of the ion beam, and the positive mesons in the backward

direction have yielded a ratio of 9 ± 3 for the same quantity.

Stars Formed by Heavy Negative Mesons. Seventy five percent of the 700 negative heavy mesons observed produce observable stars. No secondary mesons have been observed. The number of observed prongs for stars and the corresponding number of mesons observed are tabulated below:

No. of Prongs for Stars	0	1	2	3	4	5	6
No. of Mesons	176	168	153	130	58	12	1

Cloud Chamber Observations. Runs have been made to study background problems involved in the study of mesons deflected from the cyclotron by the magnetic deflector.

Delayed Neutrons -from N^{17}. A cloud chamber study has been made of the energy of these neutrons by observing hydrogen recoils under conditions of reasonably good geometry. The observed energy distribution from about 100 selected tracks has a maximum at between 0.9 and 1 Mev and a somewhat narrower distribution than that reported from counting experiments.

Total Cross Section Measurements for High Energy Neutrons. The previously reported program of cross section measurements employing Bi fission detection has been devoted recently to the n-p and n-d determinations. Pentane and carbon runs are used for the n-p measurement. The amount of carbon used is equal to the number of carbon atoms in the pentane, and is distributed through the region occupied by pentane. Heavy water runs, together with previous determinations of the oxygen cross section, give the n-d value. Careful chemical analyses are made for each substance. Recent results are as follows:

(a) Four runs on carbon: σ_c = .502 ± .005 barns
.490 ± .004
.501 ± .006
.502 ± .004

The second value (.490) was obtained with carbon from a batch of unknown purity.

(b) Three runs on n-p cross section:

σ_{np} = .067 ± .005 barns
.074 ± .002
.073 ± .003

The .067 value was obtained under poor cyclotron vacuum conditions, and without a beam collimator which has been subsequently used. The samples of carbon and pentane have been quantititively analyzed for impurities. The difference between the n-p and n-d cross sections, from measurements up to the present time, is .031 ± .002 barns.

Absolute Cross Sections for High Energy Neutrons. Measurements of differential scattering cross sections, elastic scattering cross sections and absorption cross sections, for Pb, Cu, and Al are approaching completion. A few more measurements of two types are necessary:

(a) Scattered intensity of elastically scattered neutrons at angles over 30°

(b) Estimates of cross section for production of protons capable of activating the detectors.

Tentative values of σ_{el} and $\sigma_{abs.}$ are calculated, which add up to the measured values of σ_{total}, but until the small corrections obtained from the measurements (a) and (b) are determined, it appears advisable to withhold the values. It appears quite clear that σ_{el} is greater than σ_{abs}, instead of being equal as simple theory predicts for these neutron energies.

N-p Scattering. During the past month n-p scattering experiments were made at 40 Mev between 110° and 60° in the center of gravity system. According to observations, the curve is essentially flat in this region, with the intensities at 60° and 90° the same, and the intensity at 110° slightly greater. The neutron energy distribution has been measured and good agreement is had with the stripping theory for energies greater than about 70 Mev, but there are more neutrons found below this energy than the stripping theory alone predicts. The n-p total cross section at 90 Mev has been measured getting .077 $\pm$ .008 barns.

Measurements on the n-p scattering cross sections which have been made are: At 90 Mev the scattering cross section at angle $\phi = 0°$ (protons in the direction of the primary beam); the total cross section using CH_2 detectors instead of fission detectors; at 45 Mev the angular dependence and the total cross section. A comprehensive paper on n-p scattering is being prepared.

Meson Fission Chamber Experiments. A combination proportional counter and fission chamber coincidence arrangement was tried out in the dog house. No mesons were observed, probably because of the very high counting rate in the proportional counter.

A run inside the tank using a Th fission chamber (designed to serve originally as a proportional counter) gave a poor but positive result. Counts which are believed to be due to mesons were found at 81" (380 Mev) but not at 76" (330 Mev). This result is consistent with the counts being due to mesons.

6. Theoretical Physics

The theoretical group has been continuing work on n-p scattering, theories of meson production, and problems connected with the cyclodrome and synchrotron. Good agreement with experiment has been obtained on the shape of the straggling curve observed in the deuteron range measurements. The comparison indicates that the deflected beam has an energy spread of about 1 Mev.

7. Isotope Separation Program

JA Research on Isotope Separation. During this period a cold source type unit has been built and tested; the construction of a duplicate unit has been started. A decision was made to make some tests using the XC magnet, and the design of a 360° cold source unit for this magnet has been started.

Modulation Tests. Tests of 360° cold source unit on JA showed that an Argon beam of up to 25 ma could be modulated at the required frequency of approximately 1.5 mc. In agreement with theory, variations were observed in the intensity of the beam arriving at the second collector as a function of the magnetic field. Maxima were observed corresponding to the third, fourth and fifth harmonics of the cyclic frequency of the beam. The intensity of the beam at the second collector reduced to zero between all maxima excepting one. The reason for the exception is still in doubt but may be attributed in general to the necessity for better resolution.

Drain Tests. Operation of the beam intensity at the first collector to current drain to the C power supply was studied. For these tests no RF voltage was applied. The ratio varied up to unity depending particularly upon the tank pressure. It has been determined that unless a tank pressure of less than 1 ma was maintained some of the beam was scattered to the C liner in transit from source to first receiver. Accordingly, the dimensions of the J slit and collimating slot were reduced in order to operate at as low a tank pressure as possible. Under these conditions, tests are now in progress to study further the drain problem as well as the beam optics at the receivers. It has also been determined that up to 50% of the DC beam arriving at the first receiver can be reflected and collected on the second collector. It has been further determined that within the errors of measurement the total current (i.e., C liner, first collector, second collector and second collector rejected) remains constant under variations of bias voltage on the two collectors.

8. Chemistry

Part A

Chemistry of Transuranium Elements. Mention has been made in UCRL 115, that americium precedes curium off a Dowex resin column when eluted with concentrated HCl, thus showing a firmer chloride complex ion with the americium as compared with curium. This is a reversal in order of elution as compared with HCl at low concentrations and with other eluting agents. A possibility that has been suggested to explain the effects of very high chloride concentration is that complex ions involving 5f orbitals and many chlorides are formed and that the 5f orbitals of americium are more accessible than those of curium.

Following this reasoning Pu(III) should come off the column before americium with concentrated HCl. An experiment testing this point has been carried out confirming the expectation. The eluting agent was 12 M HCl in a 20% alcohol solution.

Radioactive Properties of the Heavy Isotopes. Evidence has been obtained that Pa^{230} produced from the irradiation of Th^{232} with 70 Mev deuterons decays partly by orbital electron capture. This isotope had been previously identified as an 18-day β^--emitter. From the present bombardment x-rays in the protactinium fraction have been observed which decay with approximately the same half-life and there appears to be a sufficient number to correspond to several orbital electron capture events for each β^--emission.

Evidence for the isotope Np^{231} has been obtained following the bombardment of uranium with 100 Mev deuterons. The chemically separated neptunium fraction showed the growth of the Pa^{227} series which would presumably result from the alpha decay of Np^{231}. This series has been described in UCRL-115. The rate of growth was such as to indicate a 1/2 - 1 hour half-life for Np^{231}.

Nuclear Reactions with High Energy Particles. As part of the study of the spallation products from the irradiation of antimony with high energy particles the independent yields of isobars and isomers are being determined. One such case of isomer formation is that of the two independently decaying β^--emitters of Cd^{115}. The literature shows that in the slow neutron fission of uranium the 2.3-day upper state is formed in ten times the yield of the 43-day lower state. In this laboratory it has been shown that the same ratio exists when the isomers are formed from the fission of thorium with 40 Mev helium ions. In the formation by slow

neutron capture by cadmium this ratio is five while from the n,p reaction on In^{115} the two isomers are formed in equal yield. When formed however by spallation reactions on antimony the ratio of the upper state to the lower state is found to be one-third.

Fission of Lead and Bismuth. The data thus far obtained on the fission of the lighter elements by high energy particles indicates that a considerable number of neutrons are lost before a nucleus is produced in which the fission reaction will compete with other reactions. For two isotopes of a given element the threshold for fission should be lower for that of lower mass number. Irradiations were carried out on lead enriched either in Pb^{208} or Pb^{204} with deuterons of 100 Mev and lower energies down to 50 Mev examining the yields of Cu^{67}, Mo^{99} and Ba^{133} fission products. Preliminary results show that at these relatively low energies the yields of fission products are greatest in the sample enriched in Pb^{204}.

Separation of Hafnium and Zirconium. Some success has been obtained in the separation of hafnium and zirconium by extracting a 2 M $HClO_4$ solution with .02 M TTA in benzene. The distribution coefficient (organic/aqueous) is about 8 for zirconium and about 0.7 for hafnium.

Chemistry and Structure of Rare Earth Elements. As a necessary preliminary to precise thermochemical measurements on the heats of solution of PrO_2 and Pr_2O_3 an investigation of methods of preparing these compounds in pure form and known crystal structure suitable for calorimetric study has been undertaken. Preliminary runs in which praseodymium oxides have been heated in air, hydrogen and vacuum at various temperatures suggest that pure Pr_2O_3 may be obtained from any praseodymium oxide of average higher oxidation state by heating in the presence of 1/3 atmosphere of H_2 at 500°C, and probably by thermal decomposition at 10^{-6} mm of Hg at ca. 1000°C. An investigation of an available preparation of praseodymium oxide suggests, both from x-ray data and from a determination of the weight loss on reduction (after first drying at ca. 300°C in air for 15 hours) that the composition of this material is close to that required for PrO_2.

Astatine Chemistry. A preliminary study of the effect of hydrogen peroxide on astatine in aqueous solution has been attempted. Since the absorption of alpha particles in water produces appreciable quantities of hydrogen peroxide the effect of hydrogen peroxide in radio chemical experiments is important whenever a radio element producing alpha particles is used in large quantities. An estimate of the peroxide formation by astatine in solution has not yet been made; however, some preliminary experiments indicate that small amounts of peroxide tend to stabilize the zero state in acid solution.

Most of the previous solvent extraction work has been done in dilute 0.1 - 0.01 molar nitric acid. Since nitric acid always contains some oxider of nitrogen, nitric acid solutions are of uncertain oxidizing or reducing power. Sulfuric or perchloric acids were suggested as more stable acid mediums. Initial experiments indicate that perchloric acid is unsuitable in that it reacts with astatine zero reducing the partition coefficients to a low value. Much higher coefficients have been found in 0.01 molar Sulfuric acid.

Ionization of Fission Fragments. Experimentation begun some time ago on the ionization of the fission fragments when fission is produced by high energy neutrons in uranium has started to give results. The most striking is the disappearance of the two groups of high and low characteristic ionization. These are being replaced by

a single group having its maximum frequency approximately at the energy where the two groups have their minimum. This result is related to the mass distribution of the fragments found some time ago for high energy fission.

Chemistry

Part B

Synthetic and Experimental Chemistry. The synthesis of C^{14} methyl-labeled pyruvic acid has been carried out as follows:

$$\overset{*}{C}H_3CO_2Na \xrightarrow{SO_2(OEt)_2} \overset{*}{C}H_3CO_2C_2H_5 \xrightarrow[NaOCH_3]{C_2H_5OOC\text{-}COOC_2H_5} C_2H_5OOC\text{-}CO\overset{*}{C}H_2CO_2C_2H_5$$

$$\xrightarrow[H^+]{\text{Heat}} \overset{*}{C}H_3COCO_2H + CO_2 + 2\ C_2H_5OH$$

The synthesis of phenylalanine labeled in the side chain in other than the carboxyl position will be undertaken in the near future. The studies on the synthesis of methyl-labeled choline and acetylcholine, bromomalonic acid, and an improved synthesis for the aliphatic alcohols have continued.

A program has been tentatively established and approved whereby C^{14}-labeled compounds prepared by this group will be distributed through the Atomic Energy Commission Office at Oak Ridge. Work is now in progress on setting up the preliminary organization for this synthetic program.

The experiments on the decarboxylation of C^{14} carboxyl-labeled malonic acid have been completed with the decarboxylation of two samples on a scale larger than that reported earlier. In two experiments, 6.0 and 10.0 moles of the carboxyl-labeled acid were decomposed by melting. The scheme for separation of the two active products was improved by minor changes in technique and apparatus so that the frequency ratios of breaking of the C^{12}-C^{12} and C^{12}-C^{14} bonds calculated on all bases agree within rather moderate experimental errors. In Table I below are compared the results obtained with both the large-scale and small-scale apparatus. The bases of calculation in Column 4 are (a) carbon dioxide and malonic acid, (b) malonic acid and acetic acid, and (c) carbon dioxide and acetic acid.

TABLE I

	F_{12-12}	F_{12-14}	F_{12-12}/F_{12-14} Bases		
			A	B	C
Small scale experiments(4)	0.516±0.005	0.452±0.005	1.21±0.017	1.066±0.03	1.14±0.015
Large scale experiments(2)	0.531±0.016	0.474±0.015	1.13±0.03	1.11 ±0.03	1.12±0.03

Biological Chemistry. Tryptophan labeled with C^{14} in the 3-position of the ring has been synthesized and fed to rats; n-methylnicotinamide was then isolated as a picrate from the urines and shown to be active. The position of the label has not been established.

Work is continuing on a procedure for the isolation of inactive melanin from tumor homogenates inoculated with labeled tyrosine.

Photosynthetic Chemistry. Experiments have continued on the feeding of algae radioactive carbon dioxide for short periods of time and the isolation and degradation of the labeled compounds so produced.

The use of anion exchange resins for the purification of amino acids is being studied.

Chemistry

Part C. -Subproject 48 B

Metals and High Temperature Thermodynamics. Work is in progress on the following problems:

1. Thermodynamics of CN and CH.
2. Heats of dissociation of F_2 and HF.
3. Vapor pressure of metals.
4. Gaseous oxides and hydroxides.
5. Thermodynamics of gaseous molybdenum and copper halides.
6. Absorption coefficients of species in sun.
7. Low melting metal alloys.
8. Refractory studies.
9. Construction of 4000° furnace.
10. Structure of solids.

Basic Chemistry. Solvent Extraction. The following problems are under investigation:

1. The aqueous chemistry of zirconium.
2. The formation of the uranyl-TTa chelate in aqueous solutions.
3. Complex ion formation of lanthanum.
4. The basic chemistry of ruthenium.

9. Medical Physics

Part A. Project 48A-I

Radioautographic studies are continuing with radio-yttrium and radio-strontium. New experiments using Y^{91} will be set up shortly.

Metabolic tracer studies are being continued on the following fission products: Cb^{95}, Pr^{143}, Pa^{230}, Ac^{89}, and As^{73}. These studies are a continuation of the very complete summary which has been recently included in the last quarterly report.

Kinetic studies of the uptake of radiostrontium by rachitic rats are being continued, including serial radioautographs to demonstrate any changes in distribu-

tion with time. Experiments have been set up to study the value of massive doses of parathormone, combined with zirconium citrate injections, as a potential decontamination procedure for plutonium and certain other radioactive metals. The value of aluminum hydroxide in the diet as a means of increasing phosphate loss from the body is being investigated as a means of facilitating bone resorption. It has been found to increase the negative phosphate balance in severe phosphorus deficiency and to decrease the absorption of radiophosphorus from the gut following administration by stomach tube.

Work has progressed on two targets from the cyclotron during the past month. A solvent extraction method is being developed to separate tin and indium from a cadmium target bombarded with alphas, and arsenic has been obtained in carrier-free form from a deuteron bombarded germanium target. Solutions of columbium-zirconium, yttrium, and cerium have been received from Oak Ridge and assayed, and physiological preparations of praseodynium, zirconium-columbium, and protoactinium have been made.

Medical Physics

Part B. Project 48A-II

Biological Studies with the Beam of the 184-inch Cyclotron. The effects of the deuteron beam on mammary carcinomas of the type A mice were studied and the dose that causes complete regression of the tumors was determined. It seemed desirable to also establish experimentally the effectiveness of the deuteron beam in giving depth doses to tumors. The deuterons ionize much more densely near the low energy end of their range than at the high energy portion and this property enables one to produce depth doses. 19 mice of strain A were taken and mammary carcinoma tumors were transplanted under the skin. The mice were then exposed to the deuteron beam in such a way that the beam had to cross first through the bodies of the animals and later reached the tumors. The dose was about 4,000 rep in the center of the beam. This amount was necessary to cause regression of the tumors, but it was more than 10 times higher than the total body lethal dose would have been. Due to the shape of the Bragg curve, this large dose was only given in the volume of the tumors, and elsewhere in the body the dose was kept considerably lower. The selective irradiation effect was enhanced by additional rotation of the mice during exposure to the beam around the centers of the tumors. Of the 19 mice irradiated the tumors completely regressed in 8 during the first 14 days and only scar tissue remained. In the other animals, due to inadequate focusing of the beam on the tumors, the effect is not complete and some of the tumors are regrowing on the periphery. None of the animals died from the treatment and the radiation penetrating through their bodies caused only mild effects everywhere except in the tumors. In two animals the white blood counts dropped to 5,000 on the second day, and they returned to normal by the 10th day. Weight loss was negligible in all of the animals. The skin adjacent to the tumors suffered burns, loss of hair, and epilation. It is not certain whether or not the skin lesions will become permanent. There is a definite indication that with better transplantation technique and better focusing of the beam on the tumors, a much higher percentage of the animals will be freed from their carcinomas. Among the 20 controls, 19 exhibit by now very large tumors and there is every indication that all of these animals will die due to the presence of these tumors.

Thus, the principle was demonstrated that by the use of heavy particle ionizing beams it is possible to deliver a large dose somewhere deep in the

animal tissue confined to a small region without causing appreciable acute radiation effects in the tissue through which the radiation penetrated. The animals will be kept until they die to observe the possible incidence of some delayed effects and repeat experiments will be performed to study the radiation effect on tumors in more detail.

Studies with the 184-inch Cyclotron Beam on Chromosomes of Tradescantia. Dr. and Mrs. Norman Giles arrived here from the Biological Laboratories at Oak Ridge to undertake with us a collaborative study of the effect of the particle beams produced by the 184-inch cyclotron on the chromosomes of tradescantia. Some irradiations were carried out to obtain a preliminary survey of the effects and numerous chromosomal abnormalities were found. This study will be continued during the next month.

10. Health Physics and Chemistry

During this period final laboratory details were installed in Bldg. 5, and 12 chemists moved into their new quarters. Survey and decontamination of the vacated sections of Bldg. 4 were carried out.

The Research and Development Section activities included the following:

a. A specially equipped box for Dr. Gofman for processing yttrium and strontium with minimum of exposure is being built.

b. Controlled atmosphere arc stand for Dr. Conway's spectrum analysis of radioactive isotopes is being assembled.

c. One tracer run has been made on the spinner column of the "cow" for extraction of americium from plutonium and samples are ready for analysis. Three centrifilters are being completed for the "cow".

d. Protective box to enable milling of hot targets safely was completed and has been placed in use.

e. A decontamination chamber mockup was built.

f. The alpha-counting "finger" probe was completed and is being tested.

g. Six gloved boxes were prepared, including one completely equipped and shipped to the New York City Golden Jubilee Exhibit.

h. Six constant temperature baths for gloved boxes for microchemical work are being built.

i. A box for transporting bombarded targets was built.

j. The Webb 60" target assembly is practically ready; it is being tested and fitted in the cyclotron.

Development in instrumentation was as follows:

a. Anthracene scintillation counting for gamma detection and for survey work: Circuits operate satisfactorily on small crystals available. Efforts continue, with some improvement, on growth of satisfactory crystals.

b. Proton-recoil survey chamber: Polyethylene diaphragm type chamber operates, but shows evidence of charging-up surfaces.

c. Slow-neutron measurements: Calibration of pocket SN meters underway.

d. Columnar ionization effects in survey chambers is under study to determine whether misleading readings in scattered proton and deuteron fields are likely.

PROGRAM	SUBDIVISION	MAN-MONTHS EFFORT	COMMENTS
1. 184-inch Cyclotron	Operation	12.0	
2. 60-inch Cyclotron	- - -	- - -	Non-Project
3. Synchrotron	R.f. System	4.0	
	General	0.5	
	Injection	1.8	
	Miscellaneous Equipment	3.4	
	Magnet Tests and Operation	0.7	
	Vacuum Chamber	1.4	
4. Linear Accelerator	Linear Accelerator-General	5.5	
	Van de Graaff General	7.5	
	General, Development, etc.	1.5	
5. Experimental Physics	Cloud Chamber	6.0	
	Film Program	5.4	
	Ionization Chamber and Crystal Counter	2.7	
	Neutron-proton Scattering	2.5	
	Proton-proton Scattering	3.5	
	Neutron Diffraction	1.3	
	Meson Range and Decay Measurement	1.0	
	Absolute Cross Section Measurements	2.5	
	Neutron Half Life	1.0	
	Cyclodrome Design Studies	0.5	
	General Physics Research	7.2	
	Magnetic Measuring Equipment	0.4	
	Cyclodrome Magnet	5.3	
6. Theoretical Physics	Synchrotron	0.3	
	Cyclodrome	1.5	
	Cyclotron	0.5	
	Linear Accelerator	0.3	
	General Physics Research	7.6	
7. Isotope Separation	JA Conversion	4.0	
	Nier Spectrometer	1.0	

PROGRAM	SUBDIVISION	MAN MONTHS EFFORT	COMMENTS
8. Chemistry. Part A	Chemistry of Transuranic Elements	7.8	
	Nuclear Properties of Transuranium Elements	3.3	
	Transmutations with the 184-inch Cyclotron	8.5	
	Transmutations with the 60-inch Cyclotron	1.0	
	Analytical and Service	15.5	
	Chemistry of Astatine	1.5	
Chemistry. Part B	Synthetic and Experimental Organic Chemistry	4.7	
	Biological Chemistry	4.8	
	Photosynethetic Chemistry	4.8	
Chemistry. Part C	Metals and High Temperature Thermodynamics	6.5	
	Basic Chemistry, including Metal Chelates	7.5	
	General	2.0	
9. Medical Physics.Part A	Evaluation of Metabolic Properties of Plutonium and Allied Materials in Animal and Man	10.0	
	Decontamination Studies	7.0	
	Radiochemistry	1.5	
	Radioautography	1.5	
Medical Physics.Part B (Project 48A-11)	Uranium Research	0.5	4.0 Consultant Man-Month
	Tumor Metabolism	0.3	0.5 "
	Special x-ray Studies, Radioactive Measurements etc.	0.5	—
	Radioactive Carbon Studies	1.3	—
	Fundamental Medical Research	1.5	1.0 "
	Hematology	—	0.5 "
	Medical Work with 184-inch Cyclotron	0.5	0.5 "
	Fly Genetics	1.0	—
10. Health Physics and Chemistry	Monitoring and Special Problems	8.4	—
	Salvage, Decontamination, Disposal, etc.	4.1	—
	Research and Development	8.6	—