BROOKHAVEN NATIONAL LABORATORY

Quarterly Progress Report July 1 - September 30, 1955

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FOREWORD

This report covers the unclassified research progress of the Laboratory. Abstracts only are given for research activities being reported concurrently in the scientific journals. The appropriate journal or document reference is also given in such cases. A research activity that has not yet reached the stage of journal publication will be reported on in such detail as its progress warrants.

The classified work of the Laboratory is covered in the classified quarterly reports, issued as of the 15th of February, May, August and November. It is in order to expedite the publication of all progress reports that their publication does not coincide with that of the unclassified quarterlies.

The AEC budget activity numbers for the various researches are given in parentheses at the right hand side of the page, alongside the headings to which they pertain. The symbol (†) is used to designate a supporting activity whose cost is distributed to several research activities.

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PHYSICS DEPARTMENT

BNL-367

Summaries of papers submitted for publication by members of the Physics Department during the period July 1 to September 30, 1955 are given below. Titles of papers presented at various meetings during the review period are given at the end of each section. Detailed summaries of these reports will be included in a future progress report when the completed papers are in the process of being published.

High Energy Events, Mesons

(5210)*

HYPERFRAGMENTS AND SLOW K-MESONS IN STARS PRODUCED BY 3-BEV PROTONS. M. Blau. Phys. Rev., in press.

Emission of hyperfragments in 3-Bev proton stars has been investigated. The frequency of hyperfragments per star is 1/1000. Individual events, angular and Z distribution are discussed. No case of associated production has been found.

Five slow K^+ -mesons have been found in the same emulsion volume; in three cases the secondary could not be identified, one case is probably a $K_{\mu 2}$ decay and one other a $K_{\mu 3}$ decay. One possible case of a $K_{e 3}$ meson is also discussed.

INTERACTION OF 750-MEV NEGATIVE MESONS WITH EMULSION NUCLEI. M. Blau and A.R. Oliver.** Phys. Rev., in press.

Interactions of 750-Mev mesons with emulsion nuclei have been investigated. In scanning along 133 μ -meson tracks, several interactions with free protons and protons and neutrons at the edge of nuclei have been found; these events are discussed. The angular distribution of elastic π^- -p and π -n scattering is peaked in the forward direction. About 40 percent of all scatterings are inelastic with production of mesons.

Characteristics of stars induced by 750-Mev mesons are discussed; in particular, the relatively high frequency of stable and excited fragments in these stars seems to suggest that fragments can be emitted by direct meson interaction.

**Permanent address, State College for Teachers, Albany, N.Y.

NOTE ON THE DECAY AND ABSORPTION OF THE θ^0 . A. Pais† and O. Piccioni.†† Phys. Rev., in press.

A suggestion is made on how to verify experimentally a recent theoretical suggestion that the θ^0 -meson is a "particle mixture." It is the purpose of this note to indicate a further consequence of a recent theoretical suggestion (M. Gell-Mann and A. Pais, Phys. Rev. 97, 1387 (1955)) concerning the properties of the θ^0 . The point to be made here is of some interest in that it leads to possible experimental tests of the ideas outlined by Gell-Mann and Pais.

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††Now at University of California, Berkeley, Calif., on leave from Brookhaven National Laboratory.

Papers Presented

Chicago APS Meeting

Positive Pion Scattering by Hydrogen at 260, 300, and 400 Mev. R.S. Margulies.

*For explanation of these numbers, see Foreword.

THE RADIOACTIVE DECAYS OF Rh^{106} AND Ag^{106} . D.E. Alburger and B.J. Toppel. Phys. Rev., in press.

Transitions in Pd^{106} occurring in the decays of Rh^{106} and Ag^{106} have been examined with a 3-crystal pair spectrometer by means of gray wedge pulse height analysis, single and coincidence scintillation spectrometer techniques and an intermediate-image beta-ray spectrometer. In addition to lines previously known, gamma rays of 1.77, 1.96, 2.10, and 2.66 Mev and a possible gamma ray of 1.14 Mev were found in Rh^{106} decay. Gamma rays of energies 0.22, 0.409, 0.51, 0.62, 0.72, 0.805, 1.045, 1.131, 1.205, 1.23, 1.39, 1.55, 1.77, 1.85, 2.1, and 2.63 Mev were observed in Ag^{106} decay. Most of the data can be satisfied by postulating in addition to the five previously known states in Pd^{106} , three new weakly excited levels at 1.85, 2.27, and 2.66 Mev. A lower limit of $\sim 10^{-8}$ sec is estimated for the partial half-life of the 0-0 transition between the second excited and ground states of Pd^{106} .

ELECTRIC-MONOPOLE TRANSITIONS IN ATOMIC NUCLEI. E.L. Church* and J. Weneser.** Phys. Rev., in press. Letter.

Low-energy electric-monopole, or EO transitions, ($\Delta I = 0$, no), proceed solely by internal conversion, with zero units of angular momentum transferred to the ejected electron. Gamma-ray emission of this multipole order is strictly forbidden, although EO pair production is possible for transition energies 2 Mc^2 . It is pointed out that (1) the electric-monopole mode of de-excitation is available between any two equal-parity states of the same spin, zero or otherwise, (2) that in such cases, EO internal conversion may compete favorably with the paralleling magnetic-dipole and electric-quadrupole radiative transitions in heavy nuclei, and (3) that monopole matrix elements, $\langle i | \Sigma r \rho^2 | f \rangle$, may be particularly useful in the study of nuclear structure. The relative and absolute conversion properties of electric-monopole transitions have been calculated relativistically, including the effects of the finite nuclear size and atomic screening. These results have been used to analyze the available experimental data on the $2+ \rightarrow 2+$ transitions in Pt^{196} and Hg^{198} , and to determine upper limits for the monopole matrix elements. These limits appear appreciably smaller than the values deduced for the well-known monopole transitions of the $0+ \rightarrow 0+$ type. The possible significance of these results is considered with reference to current nuclear models.

*Guest scientist from Frankford Arsenal, Philadelphia, Pa.

**Now on leave at the University of Illinois, Urbana, Ill.

RESPONSE OF SODIUM IODIDE CRYSTALS TO ALPHA PARTICLES AND ELECTRONS AS A FUNCTION OF TEMPERATURE. E. der Mateosian, M. McKeown, and C.O. Muehlhause. Phys. Rev., in press.

The response of pure NaI and thallium-activated NaI crystals to α -particles and electrons was studied as a function of temperature. Crystals were grown for this investigation both by the Bridgman and Kyropoulos methods. The magnitude of the scintillations per unit of energy loss in the crystal varied with temperature in a way which agreed with predictions of qualitative theories. The ratio of the α -particle response to the e^- response per unit energy was a constant with temperature for the crystals grown by the Bridgman method (α response/ e^- response ~ 0.7) but reached the value 1.5 for a NaI crystal grown by the Kyropoulos method at -150°C .

A temperature-dependent effect was found in the resolution of the α -particle peaks. The results of the experiment are discussed in the light of current theories.

MULTIPLE INTERACTIONS OF NEUTRONS IN RESONANT SLABS. J.E. Draper. Phys. Rev., in press.

The multiple interactions of neutrons in slabs is considered with emphasis on the case of resonant scatter and capture. The important change of cross section due to neutron energy loss on scattering is included as are the effects of Doppler broadening of resonances and potential scattering followed by a resonant interaction. Calculations are made with and without a resonant self-absorber interposed before the slab. The probabilities are integrated over the resonance. Curves are presented which permit calculation of the ratio of multiple interactions to first interactions.

PROTONS FROM THE BOMBARDMENT OF SEVERAL ELEMENTS WITH 40-MEV ALPHA PARTICLES. R.M. Eisberg,* G. Igo, and H.E. Wegner. Phys. Rev., in press.

Thin targets of Au, Ag, and Cu were bombarded with 40-Mev alpha particles and the energy distributions of protons emitted at 150° were measured. According to the compound nucleus model, the level density of the residual nucleus is equal to $\text{const. } N/E\sigma_c$, where N is proportional to the probability that the compound nucleus emits a proton of energy E , and σ_c is the cross section for the inverse reaction. For each element, $\log(N/E\sigma_c)$ plotted as a function of the excitation energy of the residual nucleus, E_r , is concave downward. This is in qualitative agreement with the Fermi gas level density formula: $\text{const. exp}(A E_r)^{1/2}$. For Au, $N/E\sigma_c$ fits this formula with $A = 5.8 \text{ Mev}^{-1}$ when $E_r > 2 \text{ Mev}$; when $E_r < 2 \text{ Mev}$, $N/E\sigma_c$ increases less rapidly with increasing E_r than the formula. For Ag, $N/E\sigma_c$ fits with $A = 4.7 \text{ Mev}^{-1}$ for all E_r . For Cu, $N/E\sigma_c$ fits with $A = 5.7 \text{ Mev}^{-1}$ when $E_r > 4.5 \text{ Mev}$; when $E_r < 4.5 \text{ Mev}$, $N/E\sigma_c$ increases more rapidly than the formula. In the region of 150° , the cross section for the emission of lower energy protons is isotropic, but the cross section for high energy protons decreases slightly with increasing angle. Thus the energy distributions in the region of small E_r are probably contaminated with protons from non-compound nucleus processes.

*Now at the Physics Department, University of Minnesota, Minneapolis, Minn.

MEAN VALUE CALCULATIONS FOR SPATIAL MULTIPLE SCATTERING. Jean Snover Goldberg,* H.S. Snyder, and William T. Scott.** Phys. Rev., in press. Letter.

In a previous paper (W.T. Scott, Phys. Rev. 85, 245 (1951)), six mean value expressions were given for the Snyder-Scott-Moliere theories of fast charged particle projected multiple scattering in angle and lateral deflection. The present work gives similar mean value calculations for the spatial angular distributions. The spatial calculations by Snyder's method were derived numerically from certain intermediate quantities involved in the projected angle calculations. The agreement with the Moliere values is quite satisfactory. The quantities for which formulas and graphs are given are: arithmetic mean, half-width, $1/e$ width, median, and a gaussian width fitted to the zero-angle scattering intensity.

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THE COMPOUND HYPOTHESIS OF THE HEAVY UNSTABLE PARTICLES. II. M. Goldhaber. Phys. Rev., in press.

The compound hypothesis of hyperons and heavy mesons is restated, to modify

an earlier assumption on the isotopic spin of θ^0 . θ -mesons and $\bar{\theta}$ -mesons (anti-particles) are assumed to have isotopic spin $T = 1/2$, as proposed by Gell-Mann. The total number of heavy mesons (θ -mesons minus $\bar{\theta}$ -mesons) is conserved in strong interactions (fast reactions). The fundamental reaction is thus pair creation of $\theta + \bar{\theta}$, with θ -mesons free and $\bar{\theta}$ -mesons either free or bound to nucleons. $N + \bar{\theta}$ can form $T = 0$ and $T = 1$ multiplets which are identified with the Λ^0 -singlet and the Σ -triplet, respectively. The facts known about hyperons, associated production, and interaction of heavy mesons with nucleons are consistent with these assumptions. A discussion of T -multiplets among hypernuclei is given. Some experiments which may throw new light on the compound hypothesis are discussed.

SIZE DISTRIBUTION OF NEUTRON WIDTHS. D.J. Hughes and J.A. Harvey.*
Phys. Rev. 99, 1032 (1955).

In the program of work carried out with the Brookhaven fast chopper on total cross sections of heavy elements, the neutron widths of levels were found to have an extremely large variation in size in contrast to the near-constancy of the gamma widths. The reduced neutron widths of various nuclides have been combined by plotting the reduced neutron widths relative to the average value for each nuclide rather than in terms of actual widths. The experimental points have been corrected for any distortion because the average value is not accurately known for each nuclide and because an individual nuclide may have levels of 2 spin states. The differential size distribution is compared to predictions from several theories. The experimental distribution of the square root of the neutron width, which is a property more closely related to nuclear structure theory than the width itself, is also compared to theory.

*Now at Oak Ridge National Laboratory.

CROSS SECTIONS AND THE COMPLEX POTENTIAL. C.E. Porter. Phys. Rev., in press. Letter.

A direct connection between the imaginary part of a complex potential and the ratio of the reaction cross section to the elastic cross section is pointed out. With this connection, the strength function at zero energy is related to an integral of the square of the wave function times the imaginary part of the potential.

A 2- STATE AT 8.87 MEV IN O^{16} . D.H. Wilkinson,* B.J. Toppel, and D.E. Alburger. Phys. Rev., in press.

The bombardment of F^{19} by protons of energy greater than 3 Mev, and the beta decay of N^{16} are shown to give rise to gamma rays of energies 2.75 ± 0.02 Mev, 1.90 ± 0.03 Mev, and 1.72 ± 0.03 Mev. The first of these gamma rays is in coincidence with gamma rays of 6.1 Mev while the latter two are in coincidence with gamma rays of greater than 6.3 Mev. The relative intensities are in the ratio of 27:1:3, respectively. These observations imply a state at 8.87 ± 0.02 Mev in O^{16} formed in the reactions $F^{19}(p, \alpha)O^{16}$ and $N^{16}(\beta^-)O^{16}$; this state is very probably 2-. The relevance of this observation for the alpha-particle model of O^{16} is discussed.

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Papers Presented

Chicago APS Meeting

Inelastic and Elastic Scattering of 1.7-Mev Neutrons. S.D. Bloom, G.N. Glasoe, C.O. Muehlhause, and H.E. Wegner.

Electric-Monopole Transitions in Atomic Nuclei. E.L. Church and J. Weneser.
Decay of 72-Second and 49-Day In^{114} . L. Grodzins and H.T. Motz.
Measurement of Γ_n^0/D Ratio by Average Cross Sections. D.J. Hughes and V.E. Pilcher.

The β^- Energy Distribution from Thermal Fission of U^{235} . C.O. Muehlhause and S. Oleksa.

The Measurement of Energy Variation of the Neutron Multiplication, η , for U^{233} , U^{235} , and Pu^{239} in the Thermal Region. H. Palevsky, R.L. Zimmerman, R.M. Eisberg, and D.J. Hughes.

Neutron Total Cross Section of $^{92}\text{U}^{235}$ in the ev Region. V.E. Pilcher, J.A. Harvey, and K.K. Seth.

Polarization in p- α Elastic Scattering. Mary Jean Scott and R.E. Segel.

The Inelastic Scattering of Protons from F^{19} . B.J. Toppel, D.H. Wilkinson, and D.E. Alburger.

Elastic Scattering of 40-Mev Alpha Particles from Light Nuclei. G. Igo, H.E. Wegner, and R.M. Eisberg.

Solid State Physics

(5230)

SPECIFIC HEAT ANOMALY OF FERROELECTRIC CADMIUM NIOBATE AT THE CURIE TEMPERATURE. H.R. Danner and R. Pepinsky.* Phys. Rev. 99, 1215 (1955).

The anomalous specific heat of ferroelectric $\text{Cd}_2\text{Nb}_2\text{O}_7$ has been measured in the region of its Curie temperature, $T_c = 193^\circ\text{K}$, with a vacuum adiabatic calorimeter. The values of the transition energy and the transition entropy change are 18 ± 2 cal/mole and 0.09 ± 0.01 cal/ $^\circ\text{K}$ -mole, respectively. A comparison between the experimental values of the transition entropy change, the spontaneous polarization, and the Curie constant is made.

*The Pennsylvania State University.

SINGLE CRYSTAL NEUTRON ANALYSIS OF TETRAGONAL BaTiO_3 . B.C. Frazer,* H.R. Danner and R. Pepinsky. Phys. Rev., in press. Letter.

The role of neutron diffraction as a complement to the established methods of x-ray crystal structure analysis is well illustrated in the case of tetragonal BaTiO_3 . Two recent x-ray analyses of this structure have been made by Kaenzig (Helv. Phys. Acta 24, 175-216 (1951)) and Evans (Tech. Report No. 24, Philips Laboratories, Inc., 1952) and the latter demonstrated that a unique x-ray solution of the problem is not possible. The atomic displacements turn out to be quite small and this, coupled with the relatively large scattering power of Ba, prevents separation of the effects of coordinate and temperature parameters in the interpretation of x-ray diffraction data. Thus, Evans was led to two structures that gave equally good agreement between calculated and observed data.

This situation no longer persists in the case of neutron diffraction where now the scattering factors are much more nearly the same magnitude, and an unambiguous solution can be obtained. A similar ambiguity has been successfully resolved for tetragonal PbTiO_3 (Shirane, Pepinsky and Frazer, Phys. Rev. 97, 1179 (1955)), where a single crystal x-ray analysis was unable to distinguish four possible structures. In this compound, the large tetragonal distortion permitted sufficient resolution in neutron powder pattern data to select the proper model. However, in BaTiO_3 the tetragonal distortion is only 1 percent (compared to 6 percent in PbTiO_3) which necessitates a single crystal neutron study to solve the structure.

*Guest scientist from Westinghouse Research Laboratories

Neutron data were collected from a small single crystal with unidirectional domain alignment maintained by an external electric field. Analysis of the data, utilizing trial and error methods followed by least squares refinement, led to the following coordinate parameters: $\delta z_{Ti} = 0.014$, $\delta z_{OI} = -0.023$, and $\delta z_{OII} = -0.014$. These parameters correspond to shifts of 0.06A for Ti, -0.09A for OI, and -0.06A for OII relative to Ba at the origin. This structure is roughly halfway between the two structures reported by Evans. While the above model shows excellent agreement with observed data (R factor slightly less than 3 percent), it is being checked by further measurements at high Bragg angles and by independent observations on a second sample.

Papers Presented

Lackawanna Subsection of ACS

High Energy Particle Bombardment of Solids. G.J. Dienes.

13th Annual Pittsburgh Diffraction Conference

The Crystal Structure of Tetragonal $BaTiO_3$ by Neutron Diffraction. B.C. Frazer, H.R. Danner, and R. Pepinsky.

Experimental Techniques

(5200)

A HIGH PRESSURE PROPORTIONAL COUNTER FOR FAST NEUTRON SPECTROSCOPY. S.D. Bloom, E. Reilly and B.J. Toppel.

A high pressure proportional counter has been built for use as a fast neutron spectrometer. The sensitive cylindrical volume defined by field tubes is 10 cm in diameter by 14 cm long. The counter is normally operated at voltages of 6000 - 8000 volts with pressures of from 6 to 10 atmos. Fillings of argon, helium, and krypton have been successfully used. The use of a graphite liner on the cathode improves the resolution by a factor of three and eliminates the need for counter degassing. The $He^3(n,p)T$ reaction using thermal neutrons yields a resolution of 4.5 percent. The counter has been used to study the $A^{36}(n,\alpha)S^{33}$ reaction and to detect He^3 in normal tank helium.

A COINCIDENCE SORTER FOR SCINTILLATION SPECTROMETERS. L. Grodzins. Rev. Sci. Instr., in press.

A new kind of coincidence sorter has been developed which is proving very useful in disentangling complex decay schemes. The principle of operation is as follows: Two NaI(Tl) crystals and photomultipliers are arranged in a normal coincidence spectrometer with the source between the crystals. The output voltages from the crystals are amplified, stretched and applied to the X and Y axes of an oscilloscope. At the same time, they are sent into a coincidence circuit, the output of which is used to trigger, for a few microseconds, the intensifier of the oscilloscope. Thus, when a coincidence occurs, a dot appears on the oscilloscope face at the X,Y position corresponding to the pulse heights from the two crystals. The patterns produced in this manner are obtained by taking long-time exposures with a Land polaroid camera. The resulting pattern of spots and lines is often sufficient to determine directly the decay scheme of the nucleus in question. The instrument is equivalent, for energy determinations, to about a 75x75 matrix of single channels.

IMPROVING PROPORTIONAL COUNTER RESOLUTION WITH A GRAPHITE CATHODE LINER. S.D. Bloom, E.G. Reilly and B.J. Toppel. Rev. Sci. Instr., in press.

In the course of testing a proportional counter at this Laboratory, it was found that the counter resolution could be improved by about a factor of three by using a

graphite liner on the counter cathode. In one instance the filling from a counter without a liner, which had a resolution of 22 percent, was transferred to a counter with a liner. Without purification, the resolution improved to 12 percent within a few hours. In addition to cleansing the gas itself, the liner will tend to trap impurities which evolve from the counter cathode. These beneficial effects of the graphite to a large extent obviate the need for involved counter degassing prior to assembly.

COSMOTRON DEPARTMENT

Operations

(†)*

The operating period which ended last month was, from the standpoint of steady operation, the most successful so far. Three-shift operation was maintained 5 days a week with few interruptions. The performance of the Van de Graaff injector was notable as it ran nearly 1000 hours without opening the high pressure tank.

For the past month a schedule of shutdowns has been in effect for the purpose of regular maintenance but more particularly to install magnetic shims for the external proton beam. These shims are massive pieces of iron placed in the fringing field of the Cosmotron to alter this field so that the emerging proton beam remains nearly parallel. The forces which result from the magnetic field are considerable and the mechanical problem of supporting the shims in place proved to be difficult. These shims are now in place and the next two weeks will be devoted to producing an intense external beam and bringing it to a focus at various points outside the radiation shield.

The prospect of this external beam has necessitated additional precautions against the hazards of radiation. The control room has been protected by a pile of concrete blocks placed on top of the present shield and a fence has been procured to exclude personnel from the area into which the external proton beam will emerge.

A number of other tasks have been accomplished. Additional space around the south straight section for the K beam setup has been made available by relocating vacuum and water lines. A new frequency control system was installed which has greatly increased the uniformity in the number of protons from one pulse to the next, and has also increased the maximum number of protons available. A stand for the testing of ion sources has been constructed which will permit new ion source designs to be tried without involving the Cosmotron's injection Van de Graaff. Increasing the number of injected protons into the Cosmotron by ion source improvement appears to be one of the most promising ways of increasing the machine's intensity.

There are also omens of trouble. On two occasions, leaks developed which were traced to the rubber blankets covering the vacuum chamber. In both cases these leaks were repaired by the blind application of rubber cement to the area in which the leak was found to be. At present the vacuum system is reasonably tight but future trouble with the rubber blankets may be anticipated.

Additional experimental facilities are being procured. A contract for the construction of a 50-liter per hour hydrogen liquifier has been set as well as one for a moderate size building to house it. Two C-shaped electromagnets with 18 ft by 24 ft pole tips are being designed and the purchase of two pairs of small strong focusing magnets is being arranged through the Berkeley Radiation Laboratory. A 60-kw low voltage M-G set suitable for pulsing the external beams' deflecting magnet has been ordered.

Certain changes in the experimental program are worthy of note. The Columbia cloud chamber group has completed its exposures in the 2.0-Bev π^- beam and is rearranging the chamber for a new experiment. The Harvard cloud chamber group has completed its program for photographing π^- interactions with N_2 and is preparing to study production of π -mesons from collisions between protons of the

*For explanation of this symbol, see Foreword.

external beam with liquid hydrogen. Princeton is setting up a large expansion chamber within a block house to study production of heavy mesons and hyperons in various materials by mesons and protons. The Columbia bubble chamber group has been exposing its chamber to π^- -mesons in the energy range 1.1 to 1.5 Bev in order to study protons in the liquid of the bubble chamber. This is not a complete list of experiments in progress by any means. The ones mentioned were selected because they represent significant changes in the experimental program.

Research

(5210)*

A pressing problem in the physics of heavy unstable particles is the understanding of the relationships between K-mesons which decay in different ways. It is particularly important to know if there is one kind of K-meson which decays in different ways or whether there are different particles. It is known that the masses of the K ($\pi 2$) meson which decays into two π -mesons, the K ($\pi 3$) meson which decays into 3 π -mesons, and the K ($\mu 2$) meson which decays into a μ -meson and a neutrino are the same within narrow limits. If the life times are the same it becomes especially attractive to believe that one particle exists, which has different, competing, decay modes.

A group from Princeton is measuring these life times. A pair of strong focusing quadrupole magnets and a detecting magnet were set up to observe particles emitted from Cu target at an angle of 60° from the incident proton beam. For momenta of about 400 Mev/c a ratio of K-mesons to π -mesons of about 1:500 is observed. The flux, for 6% momentum resolution, is about 0.2 K-mesons/cm² per 10^{10} protons in the circulating beam. The Princeton group selected the K-mesons from protons and π -mesons by knowing the momentum from magnetic field measurements and by selecting the velocity by means of a pair of Cerenkov counters used as a velocity filter. A coincidence Cerenkov counter is designed to accept all particles going as fast as the K-particles while an anticoincidence Cerenkov counter rejects all particles such as π -mesons which have a velocity higher than the K-mesons. Life times were measured by recording the time elapsed between the triggering of the incoming telescope and the decay event. This is accomplished by displaying the pulses on a fast oscilloscope and photographing the trace. Life times of K^+ ($\mu 2$) and K^+ ($\pi 2$) particles were each determined to be about 1.3×10^{-8} sec with an uncertainty of about 10%. The K ($\mu 2$) decays were determined by the detection of the μ -meson in a scintillation counter, the K ($\pi 2$) by using a scintillation counter to detect the shower produced by the π^0 γ -rays in a lead plate.

Further measurements of γ -rays produced downstream from a target exposed to the internal proton beam have been made. These γ -rays are presumed to come from π^0 decays, the π^0 's resulting from the decay of relatively long lived unstable particles. A mean decay length was ascertained. This decay length varies with proton energy in a manner consistent with the assumption that a particle with a life time of about 5×10^{-11} sec is produced in a proton-nucleon collision. The production was measured as a function of proton energy and appears to have a threshold consistent with that of the $p + n \rightarrow \Lambda + K + n$ where n represents a nucleon. However, both the Λ^0 and the ν^0 (K^0) have longer life times than are observed. The charged hyperons $\Sigma^\pm$ have about the correct life time but it is expected that their threshold is higher than that which is observed. Since all the measurements are taken at distances of 5 cm and greater from the target, there is actually a strong observational bias toward longer half-lives such as that of the Λ^0 which is about 3.5×10^{10} sec, and against the short half-life observed.

*For explanation of these numbers, see Foreword.

An interesting event has been observed by the Columbia cloud chamber group. Two Λ^0 particles are observed which appear to come from a 2-Bev π^- interaction in a lead plate. Energies and momenta of the particles observed are consistent with this view. The only somewhat inconsistent feature of the event is long life time of one of the Λ^0 particles. This Λ^0 travels a distance before decaying which determines its life to be about 5 times the usually accepted half-life of the Λ^0 .

In the optical model of π -nucleus interactions, the depth of the potential is related to the real part of the forward scattering amplitude of π -mesons by nucleons. This amplitude is determined causally by the total π -nucleon scattering cross sections at all energies, and has been calculated from these cross sections. These values have been used by the theoretical group here to calculate π -nucleus cross sections. The agreement with experiment is good.

General

Development work on the various AGS components continued. More advanced models of the magnet, rf cavities, linac rf structure, and other components have been designed or built.

After a year-and-a-half study of various linac rf structures, a decision was made to use a modified Alvarez type of structure for the AGS linac. The linac group has now started on the detailed design of this machine.

Studies of electron orbits involving resonance locations and strengths, effects of nonlinear field components, acceleration, phase and frequency control were carried out with the aid of the electron analogue. A wealth of very important information has already been obtained and all indications are that future operations will reveal more information of similar usefulness.

The design of the AGS structures progressed rapidly. Design of the Service Building was completed and bids were requested for its construction. The excavation of the Service Building Area, which was handled under a contract separate from the general construction contract, was started on August 24, 1955. Preliminary design of the tunnel, target area, and linac structures is continuing. As present proposals call for the magnet foundation to be erected on H piles, an elaborate pile testing program was designed and started on 14 piles which have been driven into the ground at the site location.

Electron Analogue

Early in the quarter the study of the resonance locations was finished and a complete resonance plot was made of the area between the 5th and 8th vertical and horizontal integral resonances (see Figure 1). In this study program, variations of n were realized by varying the voltages on the quadrupole lenses. The study showed complete beam losses at integral and sum resonances. Partial losses of intensity were shown to exist at half and quarter resonance locations. These measurements showed that the widths of the resonance bands were in excellent agreement with theoretical predictions.

Observations had shown that the locus of the equilibrium orbit in the analogue was quite wobbly, a fact which contributed to the width of the resonance bands. Consequently, after the basic resonance location studies were finished, attempts were made to straighten out the equilibrium orbit by means of kicker electrodes and thus also reduce the resonance band width. Kickers were energized in groups in such a way as to apply 6th and 7th order harmonic corrections. The results were clear cut as the width of the 6th and 7th integral resonances were reduced by as much as 50 percent.

Once the resonance pattern had been established, experiments were started to study the strength of the various resonances. Exponentially shaped voltage pulses lasting up to 50 μ sec were applied to quadrupole lenses when the machine was operating in the near vicinity of a resonance. The resultant fast change in n would then carry the electron beam through the resonance. It was discovered that, as expected, it was impossible to bring the beam through the integral resonances. However, it was also observed that practically total beam losses occurred every time a sum resonance

*For explanation of these numbers, see Foreword.

Figure 1. Resonance diagram vs. quadrupole voltages data taken from electron analogue July 28, 1955 (with optimum settings of kickers and sextupoles).

crossing was attempted. All other resonances could be traversed with only small or partial beam losses. Fairly heavy beam losses were observed consistently when one-third integral resonances were crossed. Theoretical analysis showed that these losses were due to nonlinear field components introduced by the kicker electrodes. This theory was verified by artificially introducing nonlinear components in the analogue electrostatic field by means of sextupole lenses and also by operating the beam without

kickers. The former case caused heavy beam losses while the latter made possible one-third integral resonance crossings with only about 20 - 30 percent loss of beam intensity.

The resonance studies having been completed, rf was applied and beam bunching, without acceleration, was demonstrated. Subsequent rf experiments made it possible, at the end of the quarter, to accelerate part of the beam up to phase transition energy (about 2.8 Mev). However, only 10 percent of the injected beam could be accelerated to this energy and a thorough overhauling of rf circuits was initiated to increase the beam intensity and to make available the proper degree of control necessary to attempt the phase transition.

Magnet

The magnet program progressed along previously mentioned lines of investigation. The first dynamic magnet model, Model No. 3, which is made of 1-in.-thick low carbon steel lamination, was first utilized to obtain some information about current, voltage, and flux characteristics of the magnet itself. This information was turned over to the power engineering section which will use it to develop a more detailed design of the final AGS magnet power supply.

Field and gradient measurements were made on Model No. 3 under dc conditions and these agreed, as expected, with results previously obtained on Model No. 2, Configuration No. 2. The dynamic measurement instrumentation was then set up at Model No. 3 and dynamic measurements were started. Very soon, B vs I measurements on both the open and closed sectors of the model indicated that the field in these sectors differed when measured at the same point in the excitation cycle. Thorough checks and further careful measurements revealed that this difference was indeed real and that at a given current, the fields in the two sectors varied by as much as 4 percent. This behaviour was not completely unexpected as it was known that heavy eddy currents would be created in this model and that the observed magnetic differences between the model sectors could be explained by these eddy currents. On the basis of this information, the order for Model No. 4, the thin (about .040 in.) lamination model, was altered to include not only an open sector, but also another closed one. Delivery of this model is expected in the near future.

Studies of Model No. 3 were continued with a thorough investigation of remanent field phenomena. After this study dynamic measurements of the gradients as a function of position in the gaps were started and are still in progress.

The steel testing program made steady progress. A new laboratory was set up for these measurements to make it possible to take these permeability measurements without interference from the pulsing magnet models.

Linear Accelerator

Up to this quarter the linear accelerator group has been studying four basic rf structures for possible application to the AGS injector. Three novel structures, "interdigital," "organ pipe," and "resonant cavity," are of the traveling wave type and were developed at this Laboratory. The other structure under consideration is the conventional, standing wave type of Alvarez machine. These investigations have essentially produced the following information: the interdigital system looks very attractive for proton energies up to 10 Mev and should get serious consideration for any future linac which will not exceed this energy. However, at energies higher than 10 Mev, the power requirements of the interdigital system become excessive. Exactly the reverse is the case for the organ pipe system, i.e., its power requirements

at low energies are very high but at energies above 10 Mev the power consumption of the organ pipe system is relatively low. Thus this rf structure should receive careful consideration in future designs of very high energy linacs where the initial high power consumption disadvantages would be overcome by the relatively low power requirements for the remaining part of the machine.

Only the resonant cavity or the Alvarez system remained in consideration for the BNL linac. At this time both systems appear about equally attractive. However, time is becoming an important factor in the considerations. It was the linac group's opinion that at least another six months of modeling and testing would be required to bring the knowledge of the resonant cavities to the stage where detailed design of the machine could begin. Several operating linear accelerators of the Alvarez type are, of course, in existence. And so it was decided to use an Alvarez-like scheme in conjunction with the BNL synchrotron. The studies of the resonant cavity models will continue, but first emphasis will be placed on the detailed design of the linac itself. It is now planned to study several possible modifications of the standard Alvarez machine. Thus, calculations have been started to study the effects produced by introducing ovoid drift tubes. Preliminary analyses seem to indicate that such drift tubes could reduce the length and power requirements of the machine.

A careful study has been made of the injection problems associated with getting protons into the linac. Several accelerators at various energies have been considered. It was concluded that the linac injection energy will be about 750 kev. Both Cockcroft-Walton machines and electrostatic generators are now being considered as linac preaccelerators.

The study of permanent magnet quadrupoles was concluded. Very uniform gradients of as high as 1000 gauss/cm across the 1-in. inside diameter of the magnetic rings seem to be quite feasible. Orbit dynamical calculations of the proton paths in the linac have shown that it would be advantageous to have variable magnetic focusing devices along the complete length of the machine. Consequently, a program has been started to design and develop electromagnetic quadrupoles for this purpose.

The development of a power source for the linac is progressing along two parallel lines. Negotiations are now in progress to have a 5 Mev, 200 Mc klystron developed for this Laboratory. Simultaneously, a power supply is being designed which will use power triodes. For this application EIMAC 3W10000A tubes are now being tested. Construction of the test setup has been finished and as much as 300 kw of pulsed power has been obtained from this tube.

Radiofrequency Cavity

All the ferrite rings for the first model rf cavity were received. The design of the cavity itself has been revised. The principal new features involve the cooling of the ferrite. Previously it had been planned to air-cool this material. However, in the new design, water-cooled copper discs are placed between adjacent ferrite rings. The rf properties of this type of structure were theoretically determined and a model of the new cavity is now being designed. In this connection, experiments were performed to determine the effects of temperature variations on the rf properties of the ferrite. It was shown that, especially at 4.5 Mc, temperature variations strongly affected the Q value of the cavity. As a result of these investigations, it became evident that the temperature of the cavity will have to be limited to 60°C.

The design of the saturating power supply for the model cavity has been completed and this piece of equipment is now under construction. The rf power amplifier is being assembled and most parts of this unit are now in place.

The following abstracts summarize work submitted for journal publication or presentation at scientific meetings by members of the Chemistry Department, including visitors, during the period July 1 - September 30, 1955. The subjects covered lie in the fields of: radiation chemistry; hot atom chemistry; neutron diffraction; mass spectrometry; nuclear chemistry; spectroscopy and theoretical chemistry; and analytical chemistry.

EFFECT OF IODINE ON THE RADIOLYSIS OF BENZENE. R.H. Schuler. Submitted to J. Am. Chem. Soc. Abstract.

The hydrogen yield from the radiolysis of benzene is shown to decrease only slightly upon the addition of high concentrations (>0.1 mole percent) of iodine to the benzene. It is indicated that the hydrogen yield is produced directly as molecular hydrogen without the intervention of hydrogen atoms. The drop in the yield of hydrogen and of C_2 gases observed at high iodine concentrations is attributed to energy transfer processes. The gas production yields observed in this work on gamma radiation are in agreement with previous work with electron beams at much higher intensities.

THE RADIATION-INDUCED DECOMPOSITION OF FERROUS AMMONIUM SULFATE. E.R. Johnson.* Submitted to J. Am. Chem. Soc. Abstract.

Ferrous ammonium sulfate, irradiated with an electron beam and subsequently dissolved in water, shows formation of ferric ion to an extent proportional to the radiation dosage, together with sulfite ion and hydrogen gas. The same quantities of these products were formed on irradiation of hydrated or anhydrous ferrous sulfate, which shows that the hydrogen arises from the water in which the salt is dissolved, and that the presence of water or ammonium ion in the crystal has little influence on the action of radiation.

*Summer visitor (1955) from Stevens Institute of Technology, Hoboken, N.J.

ABSOLUTE MEASUREMENT OF CYCLOTRON BEAM CURRENTS FOR RADIATION-CHEMICAL STUDIES. R.H. Schuler and A.O. Allen. Submitted to Rev. Sci. Instr. Abstract.

Characteristics are described for the collection of cyclotron beams in a conducting medium separated from the accelerator by an insulating window. The measured current can be interpreted in terms of an absolute beam current if charge displacement within the insulator is taken into account. Collection of the beam in this manner is particularly advantageous in a region external to the cyclotron magnetic field where stray currents due to air ionization and secondary electron emission are pronounced. A comparison is made between particle energies determined by the charge-input method and by calorimetry. A simplified arrangement for particle range determination is described.

THE SZILARD-CHALMERS REACTION IN NEUTRON-IRRADIATED POTASSIUM COBALTICYANIDE. H. Rauscher* and G. Harbottle. Abstract of paper presented at the Nuclear and Radiochemistry Symposium, Montreal, Canada, September 1955.

*For explanation of these numbers, see Foreword

Potassium cobalticyanide was chosen for a detailed study of the nature of the Szilard-Chalmers reaction in a crystalline system for several reasons: the compound is easily prepared in a pure, anhydrous, crystalline form; long-lived Co^{60} is formed in good yield in short pile irradiations; the cobalticyanide ion is thermally stable; and the isolation of cobaltous ion from an aqueous solution of the salt is not difficult. It was demonstrated that cobaltous ion and cobalticyanide do not exchange in solution.

A study was made of the effect on the retention of heating the irradiated crystals at various temperatures ("annealing"). The results of this study for annealing temperatures of 76° , 101° and 125° show the presence of fast and slow rate processes. The fast initial rate follows approximately first-order kinetics with a rate constant of about $3 \times 10^{-3} \text{ min}^{-1}$ at 76° . This may be compared with a rate constant of $1 \times 10^{-3} \text{ min}^{-1}$ for cobaltic trisethylenediamine nitrate at the same temperature. The retention versus time curve appears to level off at about 56 percent for annealing at 76° , about 62 percent for annealing at 101° , and about 72 percent at 125° .

The availability of high flux reactors makes the point somewhat academic, but the Szilard-Chalmers process in potassium cobalticyanide also affords a means for the preparation of enriched Co^{60} . By the amyl alcohol-thiocyanate extraction procedure, two pile bombardments (in different locations) of a few grams of material yielded enriched Co^{60} as follows:

(1) A 5-day bombardment near the center of the pile gave 1.42 millicuries, or 1.9 mc/mg of Co.

(2) A 5-day bombardment away from the center of the pile, but in the graphite, gave 1.56 mc, or 5.8 mc/mg of Co.

Since pure Co^{60} is about 320 mc/mg, the richer of these two preparations is about one atom of Co^{60} to 55 atoms of inert cobalt, which indicates a remarkable stability of this salt to radiation decomposition.

*Summer student (1954) from Rensselaer Polytechnic Institute.

NUCLEAR RECOIL AS A MEANS OF FISSION PRODUCT SEPARATION.

R. Wolfgang. Submitted to J. Inorg. and Nuclear Chem. Abstract.

It has been demonstrated that, by use of a suitable heterogeneous system, the nuclear recoil of fission products can be used to effect their complete separation from the parent fissile material. The potentialities of this simple technique are briefly discussed.

A NEUTRON DIFFRACTION DETERMINATION OF THE STRUCTURE OF MANGANESE FERRITE. L.M. Corliss and J.M. Hastings. Abstract of paper submitted for presentation at the Pittsburgh Diffraction Conference, November 1955.

Manganese ferrite has long been assumed to possess the "inverted" spinel structure. This assignment had been based upon lattice parameter systematics and upon generalizations concerning the ionic distribution in ferrimagnetic ferrites. The present neutron diffraction study, based on three independently prepared samples, all having saturation moments of approximately $4.6 \mu_B$, indicates that manganese ferrite is more nearly a "normal" rather than an "inverted" spinel. In all three preparations approximately 80 percent of the "A" sites were occupied by manganese ions.

From the Néel model of relative spin orientation, the coherent magnetic scattering was found to be consistent with the magnetically determined room temperature magnetization. In the case of one preparation, the magnetic scattering was also measured at 4.2°K and found to be in substantial agreement with the saturation magnetization measured at that temperature.

ELECTRON IMPACT STUDIES ON C_2H_5Cl , C_2H_5Br , AND C_2H_5I . A.P. Irsa.
Submitted to J. Chem. Phys. Abstract.

The appearance potentials and mass spectra of some of the ethyl and methyl mono-halides have been studied. The ionization potentials obtained for the parent ethyl halides are $C_2H_5Cl \leq 11.2 \pm 0.2$ ev, $C_2H_5Br \leq 10.7 \pm 0.1$ ev, and $C_2H_5I \leq 9.6 \pm 0.2$ ev. The carbon-halogen bond energies of these ethyl halides as determined from appearance potential data were found to be $(C-Cl) \leq 3.6 \pm 0.2$ ev, $(C-Br) \leq 2.8 \pm 0.1$ ev, and $(C-I) \leq 2.5 \pm 0.2$ ev. Values obtained for the carbon-carbon bond energy of C_2H_5Br and the ionization potential of CH_2Br were 3.6 ev and 9.1 ev, respectively. The ionization potentials of CH_2Cl and CH_2I were estimated as 8.7 ev and 8.4 ev. These values have been used to determine the ionization processes giving rise to $C_2H_5X^+$, $C_2H_5^+$, CH_2X^+ , and HI^+ . The ionization efficiency curves of the negative halogen atoms from the ethyl halides are presented and some of their features discussed.

RECOIL STUDIES OF HIGH ENERGY PROTON REACTIONS IN BISMUTH.

N. Sugarman,* M. Campos** and K. Wielgoz.** Submitted to Phys. Rev. Abstract.

The ranges in bismuth of Sr^{91} and Ba^{130} recoil fragments from bombardment of bismuth with protons of 50 Mev to 2.2 Bev have been measured. The kinetic energies of the fragments have been calculated from the measured ranges and other reported range-energy data for fission fragments. The kinetic energy of the Sr^{91} recoils for all energies, and that of the Ba^{130} recoils up to 450 Mev, can be explained as resulting from high energy fission where most of the mass of the target is divided between two heavy fragments. At 2.2 Bev, the kinetic energy of Ba^{130} is substantially smaller, consistent with a complementary fragment of about 20 mass units.

The energy deposition in the target nucleus for processes leading to Sr^{91} and Ba^{130} was obtained from the ratio of recoils projected forward to those projected backward, and subsidiary calculations involving momentum and energy conservation. The calculated values of the energy deposited are substantially lower than the bombarding proton energies, and even somewhat lower than energy values calculated for production of the "fissioning nucleus" from radiochemical data.

Recoil experiments on spallation products, bismuth, lead and thallium, of masses 198 to 203, from high energy proton bombardment of bismuth, indicate that thallium nuclides formed directly are produced in processes involving alpha particle emission.

*Summer visitor (1953) from the Institute for Nuclear Studies, University of Chicago.

**Institute for Nuclear Studies, University of Chicago.

SPECTRA AND QUANTUM STATES OF THE EUROPIUM ION IN CRYSTALS.

I. ABSORPTION SPECTRUM OF ANHYDROUS EUROPIUM CHLORIDE. E.V. Sayre and S. Freed. Submitted to J. Chem. Phys. Abstract.

Anhydrous europium chloride and single crystals of europium chloride dissolved in a preponderant proportion of isomorphous lanthanum chloride could be prepared so that they were sufficiently free of europous chloride to permit the study of their absorption spectra down to 3900 Å. The crystal structure of these preparations was proved to be UCl_3 type through the use of a trace of praseodymium chloride as an internal indicator. Because this structure is so well substantiated and free of the ambiguity inherent in the structure of hydrated salts, the spectrum of these crystals provides a secure basis for resolving the conflicting interpretations of earlier spectrum analyses. The polarized spectra indicate that lines in the yellow, green and blue visible regions arise from upper states with J values of 0, 1 and 2, as proposed by Joos and Hellwege, rather than J's of 0, 2 and 3, as proposed by Gobrecht.

SPECTRA AND QUANTUM STATES OF THE EUROPIUM ION IN CRYSTALS. II. FLUORESCENCE AND ABSORPTION SPECTRA OF SINGLE CRYSTALS OF EUROPIUM ETHYLSULFATE NONAHYDRATE. E.V. Sayre and S. Freed. Submitted to J. Chem. Phys. Abstract.

From the polarization properties of the fluorescence spectrum of single crystals of europium ethylsulfate nonahydrate, it was possible to determine the multipole character of transitions, the energies and quantum nature of the seven levels of the ground state multiplet of the europium ion, and the group character of the sublevels into which these states are split by the crystal field. Such an analysis was made of all pure, uncoupled electronic transitions in the fluorescence spectrum. The analysis revealed that the rare earth ion is predominantly perturbed by a field of D_{3h} symmetry, which arises from the water molecules of hydration immediately surrounding it. Upon this field is superimposed a weaker one of lower symmetry, C_{3h} , arising from the lattice as a whole. All transitions involving a change of J of one appeared as magnetic dipole radiation. All others appeared as purely forced electric dipole transitions, including one which would have been fully allowed as a magnetic dipole transition.

A similar analysis of the absorption spectrum in the near ultraviolet was only partially successful because of the superposition of the split levels of some of the upper states. It was in accord with the analysis of the fluorescence spectrum and from it was determined the multipole nature of the transitions and the quantum nature of some of the more isolated upper states.

CONCENTRATION EFFECTS ON SOLVENT EXTRACTION COEFFICIENTS OF SOME TRIVALENT METAL HALIDES. J. Saldick.* Submitted to J. Phys. Chem. Abstract.

When trivalent Au, Ga, Tl, In, and Fe halides (MX_3) are extracted into organic solvents from aqueous solutions of the corresponding hydrohalogen acids (HX), the tendency of the (HMX_4) species extracted to dissociate in the organic phase leads to an increased total extractability of the metal at low concentrations, which can be repressed by addition of extractable strong acids. Equations describing this effect are developed.

*Present address: General Electric Co., ANPD, Cincinnati, Ohio.

CO-PRECIPITATION OF RADIUM WITH BARIUM SULFATE. L. Gordon* and K. Rowley. Submitted to J. Am. Chem. Soc. Abstract.

The technique of precipitation from homogeneous solutions was used to determine the nature of co-precipitation of radium with barium sulfate. The distribution of radium between the aqueous and solid phases follows the law of Doerner and Hoskins. The value of λ , the distribution coefficient in the Doerner-Hoskins equation, was found to be constant within experimental error over the range in which the fraction (f) of the barium precipitated was 0.03 to 0.96. Its value is $1.21 + 0.009f$ under the experimental conditions at 90°C ; its value at other temperatures obeys the relationship, $\log_{10}\lambda = 220/(273 + t) - 0.520$, for values of t between 50°C and 90°C .

*Summer visitor (1954 and 1955) from Syracuse University.

REACTOR DEPARTMENT

Operations

(†)*

The reactor operated at an average power level of 22.37 Mw during the last quarter. The maximum power level reached was 24 Mw. During the period, 2,008 Mwd were accumulated.

The research facilities of the reactor continue in capacity use by the program requirements of all the scientific departments as well as for work sponsored by Bell Telephone Laboratories, Inc., Columbia University, Esso Research and Engineering Co., General Electric Company's Research Laboratory and the Knolls Atomic Power Laboratory, the Glenco Corporation, Monsanto Chemical Co., New York University, Nuclear Development Corporation of America, Rensselaer Polytechnic Institute, U.S. Signal Corps, and the Westinghouse Electric Corporation's Atomic Power Division and Research Laboratories.

Enriched Fuel Project

(†)

Actual operation testing of the proposed new fuel element has continued on a limited basis. Procurement of several hundred elements, for testing on a greater scale, is planned during the next six months. Other studies required by this project continue.

Medical Reactor

(6000)*

Process design studies have been completed and a critical assembly experiment is presently under way. Specifications for the instrumentation system are being formulated; a test of components of this system under actual operating conditions has been made.

Isotope Distribution, Irradiation Services, and Special Materials

(†)

The revised brochure, describing BNL services and facilities, has finally gone to press. The demand for radioisotopes and irradiation services continues at a steadily increasing level. During this period, 857 irradiations were carried out for both on-site and off-site users.

The annual Commission survey on our SS materials handling and accountability procedures indicated over-all satisfactory operation. Basic and special quota forecasts for SS materials for 1956 were submitted to the Commission. Inventories and disposal of surplus SS stock and scrap materials have been arranged. Three shipments of irradiated fuel elements were made to ORNL for reprocessing.

Shielding

(4000)

Many reports covering the work in this program are in the process of being revised for declassification. It is hoped that a listing of such documents can be included in the next progress report.

*For explanation of this symbol and these numbers, see Foreword.

The program for measuring the total and scattering cross sections of many elements continues. Results of this work have been submitted for publication.

Meteorology

(†)

Gustiness Analyzer

This device, completed and installed during the last quarter, has operated almost continuously since July 1. Modifications have been incorporated to simplify evaluation of the record, but the essentials have not been changed. Comparison of the 15, 30 and 60 degree vane movements for a large number of hours has proved conclusively that the instrument is capable of distinguishing the Brookhaven gustiness classes reliably. In fact, the desired result can be obtained with only the 15 and 30 degree units in operation. Additional improvements are under consideration to provide a single, direct reading of the gustiness class as the final output of the instrument.

Airborne Filter Samplers

The work on airborne samplers has progressed quite rapidly, and two efficient units are now in operation. After a limited number of tests, the initial, battery-operated model was discarded. It was impossible to obtain a suitable air flow without exceeding the weight limitations, and the use of additional wires from the ground to provide power was cumbersome and impractical. Accordingly, experimentation was begun with model semi-diesel motors as a vacuum source. One development resulted in the use of a portion of the motor intake for the vacuum. This unit gives a flow rate of .05 cfm through a 1-in. diameter Millipore filter and has already provided excellent data during an inversion test. A pump-motor combination was also tried which increases the flow rate by a factor of 10, but is approximately 2 lb heavier.

Oil Fog Tests

Five oil fog field tests were conducted during this quarter. In four of these, densitometers were used to give continuous records of concentration for UNIVAC analysis; the fifth was the first successful airborne operation completed with the new sampler.

Power Spectrum Analysis

The tedious development and correction of the program for UNIVAC processing of power spectra was finally completed in September. Field data are now being readied for the preparation of a large number of spectral studies within the next few weeks.

Submitted for Publication

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*Columbia University.

**General Electric Research Laboratory.

NUCLEAR ENGINEERING DEPARTMENT

During this quarter considerable progress has been made on the LMFR. The in-pile processing loop (Loop B) has been running since the end of May. The results demonstrate first that the xenon produced by fission is almost completely removed from the liquid metal fuel stream in the vapor processing chamber; and second, on the basis of evidence so far obtained the fused salts extract fission products with even better efficiency than the earlier bench experiments would indicate. The other LMFR data on corrosion etc. are equally encouraging.

The Reactor Division of the AEC announced its intention to back a liquid metal fuel reactor experiment as part of its civilian power program. A two-day briefing session on the LMFR has been scheduled for November to acquaint industrial groups with the status of the program and to invite them to participate in the design and construction of a reactor experiment.

Several members of the Department visited the British Atomic Energy Establishment at Harwell following the Geneva Conference. The British expressed increasing interest in the LMFR scheme and a desire to set up a cooperative program with BNL. Some of their engineers and metallurgists will spend a week at Brookhaven in October when consideration will be given to setting up a cooperative program. One way that they could be of considerable help is by constructing and operating a loop in their new experimental reactor, E-443, in which the effect of high neutron fission densities on reactor materials could be tested. They also will send us a type of liquid metal pump which they have been developing which would appear to have considerable promise for use in the LMFR experiment. A joint program of this sort should further the efforts of both countries to achieve a successful liquid metal reactor.

During this period the critical assembly facility for the experimental reactor physics group was completed. A series of critical assemblies for the medical reactor program was started. The initial assemblies were rough mock ups intended only to give information on the safety of operation. Later it is expected to mock up the medical reactor for further tests.

These experiments and the other classified work of the Department on the exponential water lattices, the bromine trifluoride dissolver, and LMFR development are covered in the classified quarterly reports. The unclassified areas of Special Radioisotopes Development, Ultimate Waste Disposal, Fission Product Utilization, and Liquid Metal Heat Transfer are reported below.

Hot Laboratory Operations Division

(†)*

Special Radioisotopes Development and Production

Yttrium-90 -- Work this quarter aimed at finding a simple process for milking Y^{90} from its parent Sr^{90} was shifted to a study of the different rates of electrolytic migration of the strontium and yttrium ions in an agar gel. Since the two ions apparently migrate with different velocities, as would be expected, it should be possible to design a suitable simple system capable of freeing the yttrium of all strontium.

Fluorine-18 -- Fluorine-18 is produced by a (t,n) reaction on oxygen-16 when lithium carbonate is irradiated by neutrons in a reactor, the tritons, of course, coming

*For explanation of this symbol, see Foreword.

from the (n, α) reaction on lithium-6. In the course of devising the process for magnesium-28 production (see below), several alloys of lithium-magnesium were irradiated. At the end of one such irradiation it was noticed that relatively large quantities of fluorine-18 had been produced from an insignificant amount of oxide contamination on the surface. The ratio of fluorine-18 activity to the weight of oxygen present was in this case much higher than had ever been observed before when trying to make fluorine-18 from lithium carbonate.

This indicates simply and conclusively that the neutron self-absorption effect of the lithium is much greater than was realized heretofore. To confirm this, a sample of lithium carbonate having the same external size and shape as the samples previously used was irradiated; this sample, however, was hollow, so that although it had approximately the same outer surface area, its weight was considerably less than normal. The amount of fluorine-18 produced was essentially the same in this case as it would have been if the sample had been solid, which indicates that only an insignificant number of neutrons had been reaching the interior of the sample. By this device of irradiating only thin samples, the specific activity of the fluorine-18 has already been increased by a factor of eight over what was previously available.

One "unit" assaying 9 millicuries was shipped during this quarter.

Magnesium-28 -- Work is continuing on the problem of increasing the specific activity of magnesium-28 obtained from the over-all reaction $\text{Li}^6\text{Mg}^{26}(n, p)\text{Mg}^{28}\text{He}^4$. The large neutron self-shielding effect of the lithium mentioned above applies, of course, equally well in this case, and it has been possible to increase the specific activity of the magnesium-28 by simply irradiating thinner samples. An attempt is being made to determine the optimum thickness of sample.

During this quarter three shipments totaling 153 microcuries of magnesium-28 were made.

Iodine-132 -- During this quarter, nine shipments totaling 1660 millicuries of iodine-132 were sent to New York, Indiana, Tennessee, Virginia, and New Jersey.

Molybdenum-99 -- A suitable process was developed on a tracer scale for producing this isotope. The process will be scaled up as required.

Oxygen-20 -- A search has been started in an attempt to discover the oxygen isotope of mass 20. It is hoped that this "even-even" isotope, if it can be made, might have a half life long enough to make it useful as a radioactive tracer for oxygen, there being no suitable radioisotopes of oxygen at the present time.

(L.G. Stang, Jr., W.D. Tucker, P. Richards, H.O. Banks, Jr., R. Doering, T.H. Mills, and W. Campbell)

Hot Lab Operations

Chemical analyses via emission spectrography have been performed routinely on hot samples since June 10th with highly satisfactory results. The gloved box designed to contain the electrodes of the spectrograph has performed well with no trace of α , β , or γ activities found outside the box.

A new shielded loading and sampling station for the iodine-132 production has been installed, which greatly reduces the radiation exposure to personnel involved in the final phase of the production process.

A special milligram iridium-192 source having an activity of approximately 40 millicuries was prepared for the Biology Department to be used in a model of the gamma-irradiation field exhibited at the Geneva Conference.

The Brookhaven Mechanical Manipulator Model 3 was modified by converting the column rotation from a gear-operated motion to a cable and pulley drive, similar to the other motions. This change not only makes the columns rotate more freely but it also standardizes more of the parts, which thus reduces the cost of future such models. A simple clutch was also installed to permit the distance between the slave and master columns to be varied, which thus permits the operator to work in a more comfortable position than is possible with other type manipulators when it is necessary to manipulate an object close to the inside of the front shielding wall. As a result of these modifications, the new manipulator operates so successfully that the previous model 2 manipulator was rebuilt along the same lines.

Design has been completed and construction started on a new transfer shield which will enable the slugs required for special radioisotope production to be inserted into and removed from the reactor without shutdown of the latter; this will free the radioisotope production program from the reactor shutdown schedule.

At the request of the AEC, an exhibit describing iodine-132, its characteristics, availability, and potential uses was displayed at the recent symposium on Hot Laboratories and Equipment in Washington, D.C.

Design work has been started to convert one of the shielded clean-up rooms in the Hot Lab into a small facility for remote physical handling and materials testing.

The following two abstracts are of papers presented at the Fourth Symposium on Hot Laboratories and Equipment held in Washington, D.C., September 29-30, 1955.

BROOKHAVEN MECHANICAL MANIPULATOR. P. Richards.

A simple and economical manually operated manipulator for use in a bench-type physical handling cell is described. The manipulator travels on rails above the shielding wall and is useful in the remote transfer and handling of objects within the cell. When used in conjunction with either straight or articulated ball-swivel tongs, a great variety of operations can be performed satisfactorily. Information is also given on the cost of materials and labor required in building such a manipulator.

AN ARTICULATED TONGS. L.G. Stang, Jr.

This paper describes the construction and operation of an articulated tongs of the ball-swivel type used for working through a lead brick wall. The tongs resembles a conventional ball-swivel tongs except for the addition of a joint on either side of the ball. When the master handle is rotated about its joint, the slave end rotates in the same manner and to the same extent about its joint. The usual ball-swivel rotation and push-pull motion of the entire tongs are unaffected by the addition of this new rotation. As in the conventional tongs a hydraulic system is used to operate the gripping action of the jaws, and like the conventional tongs, this one may be removed from service without dismantling the wall. Construction is simple, the cost of such a tongs not being greatly different from that of a conventional tongs.

Ultimate Waste Disposal

(4620)*

Pilot plant work on the clay process was suspended during the last quarter because of the need for going to a higher activity level feeds. Arrangements have been made to obtain suitable Purex waste solution from Oak Ridge for further work on the plant.

A more thorough investigation is planned of the magnitude of decontamination factors and volume reduction which may be obtained by use of clay beds, the depth of

*For explanation of these numbers, see Foreword.

which would be representative of full scale plant design. The experiment will involve passing 200 column volumes of a simulated waste solution containing 2 curies of Sr^{90} as a tracer through a series of clay columns with an effective height of 15 feet. Equipment for this run will be assembled in the near future.

The major effort during the previous quarter was spent on the pretreatment of wastes from processing aluminum-uranium and zirconium-uranium alloy fuel elements. The development of equipment for bringing about the decomposition of aluminum nitrate and zirconium and aluminum fluorides to the respective oxides has been of chief interest. Previous investigation has shown that the formation of the oxides and then leaching to remove soluble fission products is entirely consistent with the over-all objective of fixing the fission products in stable solids, i.e., stable oxides or montmorillonite clay. The removal of excessive amounts of multivalent aluminum and zirconium ions is of first importance in the final exchange of fission products cations on the clay. Leaching experiments on the aluminum and zirconium oxides with respect to a number of the fission products were continued. Results have consistently shown that it is possible to recover virtually all of the cesium by leaching aluminum oxide and to separate cesium from aluminum in this manner to a high degree. The recovery of strontium (80 percent) has not been so successful, but considerable improvement in the leaching process is foreseen.

Arrangements have been made to procure a small quantity of high level aluminum nitrate wastes from the Idaho Chemical Processing Plant so that the above process may be tested under more intensive conditions.

Previous work on the design of equipment for conversion of aluminum nitrate and zirconium and aluminum fluorides to the oxides involving the use of a drum dryer (see Quarterly Progress Report, BNL 355) has led to the development of a unit which has several advantages over the drum converter. Among these advantages are better heat transfer and heat economy, more flexibility in residence time, and provision for a much wider range in operating temperatures. Essential features of the unit, which may be classified as a ball kiln, are shown in Figure 1. Liquid waste is fed the first section where the water is evaporated and decomposition of the aluminum takes place.

Figure 1.

The product, which is now in the form of free flowing granules, passes to the next section where final conversion to the oxide occurs at high temperature. The action of the balls serves to keep the product in granular form and aids in the transfer of heat. Quantities of noncondensable gases would be kept to a minimum, and thereby the problem of scrubbing the off-gases would be reduced.

The design of a pilot plant utilizing the ball-kiln principle has been discussed with the Blaw-Knox Co., Buffalo, New York, and present plans look to the building of such a plant at a reasonably early date. No unusual difficulties of operation have been encountered with the small 6-in. kilns shown in Figures 2 and 3.

A number of preliminary experiments have been made to determine the feasibility of sealing radiocesium into quartz glass as a method of manufacturing radioactive sources. This effort is being made informally in cooperation with the Corning Glass works, and one of their standard glass products is being used. The maximum amount of cesium sealed in the glass has been on the order of 150 mg per gram of glass, using reagent grade cesium chloride solutions.

(L.P. Hatch, W. Regan, A. Abriss, R. Domish, E.J. Tuthill)

Fission Products Utilization Project

Polymerization Studies

(4640)

Studies on solid state polymerizations have been pursued and extended to include calcium acrylate and vinyl stearate, both of which have been shown to polymerize readily in a radiation field. Contrary to previous results with acrylamide, the rate of polymerization of vinyl stearate is greatly retarded by the presence of oxygen, being only 1.28 percent per hour in the presence of oxygen and 29.8 percent per hour in its absence, with irradiations being performed at room temperature (20°C) and at an intensity of about 200,000 r/hr. The effect of oxygen on the rate of polymerization of calcium acrylate is currently being investigated.

A comparison of the intrinsic viscosities of polyacrylamides formed by irradiation with cobalt-60 gamma rays (1.2-Mev average energy) and x-rays (80-keV peak voltage) has shown that a lower average molecular weight polymer is obtained by use of the softer energy radiation, although the conversion versus intensity relationship is essentially the same for both energies. These results are tentatively interpreted as being compatible with the theory of "spur" formation along ionization tracks (Magee, Ann. Rev. Nucl. Sci. 3, 171 (1953)).

The publication on solid state polymerization, made in cooperation with Dr. Mesrobian of the Polytechnic Institute of Brooklyn, should be completed in the very near future.

An extensive program of producing graft copolymers of various types has currently arrived at the point where one or more patent applications will soon be submitted. The system most extensively studied has been polystyrene grafted to polyethylene film. The film is immersed in monomer and irradiated. As high as 30 percent by weight of polystyrene can be grafted to polyethylene with as low a dose as 1.75 Mr. An improvement in properties, such as tensile strength and heat deformation temperature, has been noted, and the possibility of improved printing and permeability characteristics is currently being investigated.

Acrylonitrile and 50-50 mixtures of acrylonitrile and styrene have also been grafted to polyethylene and polymethyl methacrylate as the polymer component. Formulation of a unified program to study the effects of radiation on solutions of polymers as a function of concentration, temperature and radiation intensity, and to elucidate some of the fundamental problems in the production of graft copolymers by irradiation of a polymer-monomer system, is currently being undertaken.

The independence of rate of polymerization of an emulsion system on catalyst concentration has been shown to apply to gamma-ray-initiated emulsion polymerizations between intensities of 128,000 and 395,000 r/hr, using a system composed of 1 percent Dupanol G (Lot 465) and 10 percent by volume of styrene at 22°C.

In order to establish that the increased printability of polyethylene film by gamma irradiation is due to surface oxidation, infrared absorption spectra were obtained on a series of films irradiated from 0.5 to 20 Mr. An approximately linear increase in carbonyl content with increasing dosage was observed while no increase in unsaturation was noticed, which thus precludes any improvement due to unsaturation.

As a result of the evaluations by Dr. Eirich of the Polytechnic Institute of Brooklyn, the work on PVP has been temporarily discontinued. The polymer produced by irradiation has no significantly improved properties and, in fact, has the undesirable properties of bad odor upon standing and discoloration due to radiation.

The studies of butadiene polymerization on carbon black surfaces are being further pursued with the intention of comparing the thermal reaction rate with that obtained in a radiation field.

Work on the impregnation of wood has been temporarily halted during the past few months in deference to the work on graft copolymers. It is expected that this work will soon be resumed.

The curing of polyester resins by gamma irradiation has been suspended mainly because of the unfavorable solubility and hardness properties of the cures produced. Although the use of benzoyl peroxide in conjunction with radiation gave a faster cure, an unfavorably high peak isotherm resulted.

The work on solid state polymerizations, butadiene on carbon black, and graft copolymerization is being done in collaboration with Dr. Mesrobian of the Polytechnic Institute of Brooklyn.

(D.S. Ballantine, B. Manowitz, D.J. Metz, A. Glines, P. Colombo)

Radiation Application Engineering

(†)

During the last quarter, Cobalt No. 9 was recharged in the reactor and will be used to replace the source currently being used by Yale University. A standard cobalt-60 source was also inserted in the reactor, together with a special source for Stevens Institute.

Purchase orders and letters of intent for cobalt sources were received from the following:

Cities Service Research and Development Co.	One 2-kilocurie standard source
Radiation Applications, Inc.	Four flat cobalt sources of about 250 curies each
Minnesota Mining and Mfg. Co.	A 200-curie and a 1000-curie small tubular source
Ruskin Research Institute	Two 1-kilocurie standard sources
Columbia University	Four flat cobalt sources*
Quantum, Inc.	One small tubular source

Approximately 800 days of source time were used in the gamma-irradiation facility during the last quarter. Off-site income was about \$12,000.

Considerable time and effort have been spent in the design of a gamma-irradiation cave facility. It is hoped to utilize high level sources in such a cave to facilitate the work of various on-site groups.

*To make up curie deficit due on original source.

An article on the cobalt-60 field irradiation machine appeared in *Nucleonics* 13, No. 7, 42 (1955).
(O.A. Kuhl, R.N. Chapman, E. Elliott)

Liquid Metal Heat Transfer

(4550)

In general, the objective of this work is to investigate local and average heat transfer coefficients and pressure drop characteristics for mercury flowing normal to a bank of tubes.

During the past quarter, the installation of the new test sections, described in the last quarterly report, was completed and the test work started. The initial phase of this program has been to determine the effect of gas entrainment on the heat transfer coefficients. The gas (helium) becomes entrained in the mercury at the pump. Attempts to measure the amounts of gas entrained with gamma-ray densitometer, consisting essentially of a cobalt source and a scintillation counter, have proved unsuccessful. It has been shown with this method, however, that certainly less than 1 percent by volume of gas is present. A gas-collection trap is now going to be installed, in an attempt to measure the gas carry over. Under conditions of gas entrainment, a number of runs have been made to measure the local heat transfer coefficients around the circumference of a tube in the middle of the lattice. It is estimated that the average deviation from the mean, for the tube-average coefficient, was between 5 and 10 percent, whereas for a particular local coefficient the average deviation is estimated to be about 30 percent. Runs will also be made where gas is estimated to be about 30 percent. Additional runs will be made where gas entrainment will be greatly reduced, and, if possible, without gas entrainment.
(C.J. Rickard and O.E. Dwyer)

Publications

The following papers from the Department have been accepted for presentation at the Nuclear Engineering and Science Congress to be held at Cleveland, December 12-16, under the auspices of the Engineers Joint Council.

(4510)

AN INTERNALLY COOLED LIQUID METAL FUEL REACTOR DESIGN. R.J. Teitel. Abstract.

Several new features are described which can be applied to liquid metal fuel reactors. These are intermetallic dispersions of fuel and fertile streams as a core coolant, use of graphite to contain the fuel and fertile stream, "pot-type" construction, and the use of naturally occurring lead of low capture cross section. A preliminary design of a power breeder incorporating these features is given. Values for the size, power, inventory, doubling time, etc. are calculated and appear to compare favorably with other liquid metal fuel reactor designs. Some of the procedures for processing the fuel and breeder blanket for the removal of their respective radiation products are described.

(4510)

THE SMALL LMFR FOR RESEARCH AND SPECIAL POWER APPLICATIONS. J. Chernick. Abstract.

The results of a survey of the nuclear properties and potentialities of small liquid metal fuel reactors are presented. The basic feature of a liquid metal fuel reactor (LMFR) is the fuel which is carried in a liquid metal solution or slurry. Plutonium is discussed as an alternative fuel to the uranium isotopes, lead as an alternative carrier to bismuth, and beryllium as an alternative moderator to graphite. The breeding potentialities of U^{233} - and Pu^{239} -fueled liquid metal systems are detailed.

(4550)

LIQUID BISMUTH AS A FUEL SOLVENT AND HEAT TRANSPORT MEDIUM FOR NUCLEAR REACTORS. O.E. Dwyer, D.H. Gurinsky, and J.R. Weeks. Abstract.

The chief purpose of the present paper is to discuss the qualifications of liquid bismuth as a heat transfer medium in nuclear power reactors and to show how its characteristics influence the design and operation of reactor systems in which it is used. Much of the information to be presented was obtained at the Brookhaven National Laboratory in connection with the development of the LMFR, which is a thermal power breeder reactor for central-power station application. The paper will present a discussion of such factors as pumping-power requirements, metallurgical problems, heat transfer, radioactivity, chemical reactivity, and nuclear considerations. In treating some of these topics, bismuth will be compared with other typical reactor coolants.

(4530)

FUSED-SALT PROCESSING OF LIQUID METAL REACTOR FUELS. R.G. Bauman, L. Hersch, C.J. Raseman, J. Weisman. Abstract.

The oxidation potential of a system used to oxidize and extract fission products selectively from the liquid metal fuel reactor must be carefully controlled. Metal-metal ion "buffer" systems have not yielded the desired oxidative condition, but controlled additions of Bi^{+3} and Mg can be used to obtain the controlled oxidation condition desired at any stage of the fuel processing. This processing scheme is now being tested by an in-pile pilot plant at the Brookhaven reactor.

(4610)

A CONTINUOUS-FLOW PILOT PLANT FOR THE SEPARATION OF BROMINE-FLUORINE COMPOUNDS AND LIGHT END-FISSION-PRODUCT FLUORIDES FROM URANIUM HEXAFLUORIDE. W.R. Page, C.J. Raseman, E.I. Goodman, and C.H. Scarlett. Abstract.

A continuous system of distillation columns was designed and operated to separate tracer-level light end-fission-product fluorides and bromine fluorides from uranium hexafluoride. Decontamination factors were obtained for various elements. Column characteristics such as columns height equivalent to one theoretical plate (HETP) were determined.

(4610)

PROCESS DESIGN FOR FISSION-PRODUCT REMOVAL FROM U-Bi REACTOR FUELS USING FUSED-SALT EXTRACTION. O.E. Dwyer. Abstract.

The liquid metal fuel reactor under development at the Brookhaven National Laboratory uses a fuel which is a solution of U^{233} , Mg, and Zr in liquid bismuth. As it is a power-breeder thermal reactor, high neutron economy is essential, and this calls for low concentrations of those fission products in the fuel which are high neutron capturers. Roughly 45 percent by weight of the fission products can be continuously removed from the fuel by salt extraction with alkali and alkaline-earth fused-salt mixtures. These fission products contain the highly "poisonous" rare earths. This paper will present a discussion of process-design considerations and proposed flow sheets.

(4530)

FRACTIONAL PRECIPITATION PROCESSES FOR LIQUID METAL FUELS. R.J. Teitel. Abstract.

Several liquid metal fuels based on U-Bi, U-Pb-Bi, U-Pb-Sn, and U-Pb-Bi-Sn alloy systems have been proposed for reactor design. Experimental data on the distribution of rare-earth tracers between precipitated uranium intermetallic compounds and their liquid phases are reported and discussed. A complete processing cycle is proposed and tested experimentally for the USn_3 in Pb-Bi-Sn dispersion fuel systems.

(4630)

PROCESSING OF HIGH LEVEL ATOMIC WASTES WITH THE VIEW TO
ULTIMATE DISPOSAL. L.P. Hatch and W. Regan. Abstract.

High level fission-product waste solutions taken directly from the processing of spent uranium fuel elements from atomic reactors usually are not suitable for efficient adsorption of fission products by ion exchange on clay minerals. Separation of the bulk of the nonradioactive ions from the fission products, therefore, is a highly desirable first step. The use of such processes as electrodeionization, high temperature calcination, and distillation to accomplish such separations is discussed with emphasis on the elements of engineering design.

(5141)

TEMPERATURE-DEPENDENT KINETICS OF CIRCULATING-FUEL REACTORS.
J.A. Fleck. Abstract.

The kinetic behavior of circulating-fuel reactors under conditions of constant inlet temperature can be formulated in terms of partial differential equations in time and displacement along the core axis. By means of a Fourier expansion of the flux, these equations can be reduced to a set of integro-differential equations in "delay form" for the Fourier amplitudes. The stability of the equations is examined by studying the conditions for periodicity of the solutions. Conclusions are tested by means of numerical solutions to the partial differential equations.

(4610)

EXTRACTION OF PROTACTINIUM FROM SOLID THORIUM FLUORIDE. R.H.
Wiswall, Jr., R.J. Heus, and F.T. Miles. Abstract.

In connection with a proposed scheme for a thorium fluoride breeder blanket, the removal of protactinium tracer from thorium fluoride powder by treatment with gaseous fluorine was studied experimentally. This paper presents the observed kinetics and analyzes them in terms of a solid state diffusion process accompanied by a slow change in the properties of the solid. The effects on removal rate of conditions of samples, temperature of extraction, and other variables are discussed. The results have a bearing on other possible gas-solid reactions.

(4520)

SOME EFFECTS PRODUCED IN GRAPHITE BY NEUTRON IRRADIATION IN THE
BNL REACTOR. W.L. Kosiba, G.J. Dienes,* and D.H. Gurinsky. Abstract.

The high concentration of lattice defects resulting from neutron bombardment in graphite produces important changes in the physical properties of this material.

The following changes produced in graphite by irradiation in the Brookhaven reactor have been studied: 1) stored energy, 2) physical dimensions, and 3) c axis. These studies were made on samples exposed to an integrated neutron flux of 1.2 to 1.6×10^{20} neutrons/cm². The temperature of exposure varied from 50° to about 130°C.

The results show that 1) the stored energy (heat content) which was released at 200° and 400°C ranged from 0 to 50 cal/g, 2) the physical dimensions increased from 0.09 to 0.18 percent, 3) the c axis of the crystallites increased and this expansion was about nine times as great as the gross physical growth, and 4) the changes in physical properties are more dependent on the temperature of irradiation than on the integrated flux at these levels of exposure. The effect of increasing the temperature of irradiation from 50° to 100°C is to decrease the changes in physical growth and c axis expansion by about a factor of two.

*Member of the Physics Department.

INSTRUMENTATION AND HEALTH PHYSICS DEPARTMENT

Instrumentation Division

Liquid Scintillation Counting

(6570)*

There is some interest here in counting soft beta emitters in a liquid scintillator. W. Bernstein of this Division and R. Steele of Biology have investigated how well a simple counting system will perform. The system consists of a vial of scintillating liquid, a photomultiplier tube, high voltage supply, amplifier and discriminator. The detector assembly is mounted in a refrigerator set at about -5°C . There is a light-tight shield around the detector with a shutter so that the vial may be removed without exposing the tube to light. The high voltage supply is left "on" all the time. The accompanying curves (Figure 1) show the performance of the first counting system; it has been in operation for several weeks.

Figure 1. Performance of liquid scintillation counter. A) C^{14} in benzoic acid with argon flush. B) Same without flush. C) C^{14} in benzoic acid + 5 cc alcohol with flush. D) Same without flush. E) Tritium water + 5 cc alcohol with argon flush. F) Same without flush. G) Total background count. H) Background from phototube only. I) Counting rate of vial filled with alcohol.

At -5°C , thermionic emission from the photo surface is not a problem. Some noise counts are due to K^{40} in the glass. A serious problem is a long-lived phosphorescence of the glass vial after UV irradiation. The glass vial produces many counts which can be flushed by heating the glass. Heating does not appreciably affect the long-lived component. The vial has a volume of 30 cc. The scintillating liquid is

*For explanation of these numbers, see Foreword

3 g/l PBD in xylene. In the case of H₂O soluble samples, 5 cc of ethyl alcohol in 20 cc of scintillator will hold 0.2 cc of H₂O sample.

Scintillation Crystals

(†)*

One 5-in. and two 3-in. diameter NaI(Tl) crystals have been successfully mounted. A flat mosaic of NaI(Tl) crystal chips was made to fit the pickup tube of a closed TV system which will be used for viewing the Cosmotron external beam.

Survey Meter

A portable ionization chamber survey meter with removable plastic chamber cover was described in the first Quarterly Report for 1954 (BNL 289 (S-21)). The three-tube feedback circuit uses a minimum of batteries. Models of this instrument were tested for a year and proved reliable and useful. Bids were invited for construction of a number of these instruments. The contract was awarded to NRD Instruments Co. of St. Louis, Mo. The instruments have been delivered and are very satisfactory.

Ten Channel Printer

(†)

A second multichannel printer has been built for printing the data from up to ten scalars on one electric typewriter (BNL 299 (S-22), page 29). It consists of ten 4-decade accumulators with Ericsson GC10B tubes, a programmer chassis and a modified electric typewriter. Each accumulator chassis may be used in place of the mechanical register on a scalar. The chassis has a switch to select printout time intervals from 2 to 50 min and for resetting after each printout, if desired. The programmer unit scans through the channels and the decades within each channel and causes the data to be printed in ten columns by the typewriter. The signal to each channel is cut off for 6 sec while that channel is being typed. Most of the timing is controlled by a revolving counter-like device with a ten-position switch attached to each of the five number wheels (Photocon Model CC505 telemetering counter) which is driven by a synchronous motor. This counter also serves as a clock. Solenoids were added to a standard electric typewriter in a manner which seems to give reliable performance. The typewriter motor of the previous installation generated interference which was picked up by the counter circuits. It was recently replaced by an induction motor, and the interference is no longer serious.
(S. Rankowitz)

Magnet Power Supply

(†)

A well-regulated supply was built to deliver 0 - 2 amps to a Varian Brothers 12-in. electromagnet (coil resistance about 1200 ohms). A three-phase power line distribution transformer and three-phase, full-wave rectifier constitute the power supply. The reference signal is obtained from a battery-powered potentiometer which may be checked against a standard cell. The difference between reference and shunt voltages is fed to a chopper amplifier. The output of the latter is mixed with the ripple signal which appears across the magnet coil and is fed to the grids of series regulator tubes. The series regulator tubes are not able to dissipate the full power available.

*For explanation of this symbol, see Foreword

A simple servo drives a variac at the input to the power supply in order to maintain the voltage across the series tubes at a reasonable value. There is provision for turning on the circuits in the proper order and for overload protection.

The supply has given satisfactory performance; the field has been maintained constant to better than a part in 30,000.

An EFP-60 fast discriminator was built, similar to that described by Wells in "Millimicrosecond Pulse Techniques," p. 232.

The 1024 channel neutron velocity selector with electrostatic memory is almost constructed. A 100 channel Hutchinson-Scarrott type of pulse height analyzer is also nearing completion.

Health Physics Division

Urinalysis

(†)

Testing of a procedure for analysis of urine samples for radioactive strontium was completed. The method utilized is that developed by Hardy, Fresco and Walford at the Health and Safety Laboratory of the AEC in New York. It gives separate values for the content of radioactive strontium and barium. With a Sr^{90} spike, the chemical recovery of activity was found to be 87-1/2 percent. The loss of counts due to self-absorption by the sample amounted to 20 percent, to give an over-all recovery of 70 percent on a counts-per-minute basis.

Samples are counted for 30 min with a small G-M tube whose background is about 10 cts/min. Counting efficiency for a weightless sample is 37 percent. The minimum amount of strontium activity detectable at the 90 percent confidence level with the above arrangement is 4 dis/min per 24-hr urine sample. The statistical uncertainty in counting a 24-hr sample containing 20 dis/min of strontium (1/10 of the current maximum permissible value) is only 10 percent, by the same 90 percent criterion. Thus, the method has all the sensitivity needed for evaluation and control of internal strontium contamination.

Similar standardization with a radioactive barium spike showed 75 percent recovery of counts per minute. Negligible Ba activity was found in the Sr fraction. In the case of the Sr spike, negligible activity appeared in the Ba fraction. Thus excellent separation of the two activities was achieved. (J. Weiss)

Cosmotron Safety

(†)

Preliminary surveys of the external "pencil beam" of protons now used occasionally at the Cosmotron showed levels of 50 rem/hr just outside the shield, 30 rem/hr just outside the building, and 1 or 2 rem/hr out in the parking lot. The beam is only 1/2 in. x 1/2 in., which is considerably smaller than the ionization chamber used. Thus, a considerable correction factor was necessary, and there is reason to suspect that the observed readings were low because of lack of saturation. Improved instrumentation is needed for measurements of this sort and a small tissue-equivalent chamber is being constructed. Protective barriers are being built to keep personnel from inadvertently getting into this beam.

An external proton beam of large area has also been surveyed, but showed levels of only about 1/10 those noted for the pencil beam. Further increases in intensity of the external beams are anticipated. Despite some improvements in shielding, exposure control at the Cosmotron is becoming more and more difficult as a result of 24-hour-a-day operation, increased machine efficiency and the advent of the high-intensity external proton beams. (M. Beebe)

Fast Neutron Dosimetry

(6560)

A study has been made of the dosage rates in the thermal column on top of the pile when the uranium converter plate is in use. This work, involving simultaneous evaluation of dose rates due to gamma rays, thermal neutrons and fission neutrons, has been done jointly with N. Delihias of the Biology Department.

The method of Hurst has been used to obtain a rough idea of the fast neutron spectrum. Three energy ranges were covered by the use of plutonium, uranium and sulphur threshold detectors which were protected from thermal neutron flux by B¹⁰ shields. For normal conditions of pile operation the observed fluxes were 1.27×10^8 n/cm²/sec in the energy interval 0.1 Mev to 1.5 Mev, 0.87×10^8 n/cm²/sec between 1.5 Mev and 2.5 Mev, and 0.16×10^8 n/cm²/sec above 2.5 Mev. Thermal neutron fluxes were determined with gold foils; they were of the order of 5×10^8 n/cm²/sec, but varied considerably with position in the cavity. An upper limit was set on the gamma ray dose rate by means of a carbon chamber filled with carbon dioxide gas; but only a rough correction of the result, for the contribution of fast neutrons to the dose rate indicated by the chamber, has been possible thus far. For the empty facility, this upper limit amounted to 420 r/hr. (J. Handloser and N. Delihias)

Miscellaneous Projects

(†)

Measurements of radioactive fallout showed greatly reduced values as compared with the preceding quarter. The activity deposited by rain and dust averaged 630 dis/min/m²/day. Daily values varied from below the limit of detectability to a high of 4,050 dis/min/m²/day.

A facility for sandblasting grossly contaminated equipment has been set up at the waste control area and has been used to salvage considerable valuable equipment. Expanded facilities for handling solid wastes and doing reclamation, when there is radioactive contamination, are badly needed. Planning for such expanded facilities is well under way.

Publications

J.D. Chester and J.S. Handloser, Beta-gamma hand and food monitor utilizing 10-digit dekatrons, BNL 2473.

J.S. Handloser and F.B. Oleson, A carbon ionization chamber for gamma-ray measurements in the Brookhaven reactor thermal column, BNL 362 (T-67).

The summer program was very successful this year. Among the visitors there were 24 faculty members and 31 students. The facilities of the Department were taxed by this additional staff but not seriously so. A great deal of excellent work was accomplished.

The Laboratory prepared an exhibit on radiation mutations in plants for the Geneva Conference, and Dr. Shapiro accompanied the exhibit and made many valuable contacts in Geneva.

There have been several changes in the scientific staff during the quarter. Dr. Ralph Singleton left to become Miller Professor of Genetics and Director of the Blandy Farm at the University of Virginia. Dr. Abraham Edelmann left to become Director of the Department of Biology and Medicine of the Nuclear Science and Engineering Corporation. Dr. Harold Smith has joined the staff on a year's leave of absence from Cornell University and will initiate a research program in plant genetics. Dr. Irwin Schwinghamer, from the University of North Dakota, will start work in plant pathology, and Dr. Robert Swanson, from the University of Minnesota, will initiate a program in mammalian physiology. Dr. John Bergeron, from Cornell University, will initiate work in general physiology. Dr. Earl Herr, from Cornell University, has joined the staff as a research associate to work with Dr. D. Koshland. Dr. Yoneo Sagawa has joined the staff as a research associate to work with Dr. Shapiro.

Although the Brookhaven thermal column has been in almost continuous use 24 hours a day, seven days a week, work was falling behind -- largely because of the irradiation of seed and scions in the cooperative program. For this reason it was felt desirable to activate another facility at the reactor. A special cart has been constructed for use in the instrument tunnel under the reactor. In the exposure cavity of the cart, the neutron flux is approximately 4×10^9 $n_{th}/cm^2/sec$. Although the neutrons are not well thermalized, the gamma-ray flux is approximately 350 r/hr which, from a biological point of view, is approximately equivalent to the gamma-ray contamination in the thermal column. The exposure cavity is somewhat larger than that in the thermal column, and thus this new facility increases our radiation facilities by more than a factor of four.

Preliminary Results

The radiation-induced mutation program carried on in cooperation with other laboratories is starting to yield some very interesting results. A variety of wheat has been produced which gives a very high yield and is resistant to wheat rust race 15b, a disease that has caused crop loss in the Middle West of many millions of dollars annually (Myers, University of Minnesota). A variety of rice has been produced with short, strong straw which will withstand wind damage that often devastates the Texas rice crop (Beachell, Rice Experiment Station). A variety of flax has been produced which is resistant to a prevalent flax rust disease (Flor, North Dakota Agricultural Experiment Station). There are now over one hundred such projects in progress, many of which are producing similar results.

*For explanation of these numbers, see Foreword.

Submitted for Publication

REDUCTION IN X-RAY SENSITIVITY BY HYDRATION. R.C. Caldecott.* *Nature* 176, 306 (1955). Abstract.

Numerous investigators have reported that when seeds are soaked there is a parallel increase in their water content and x-ray sensitivity (Å. Gustaffson, *Hereditas* 33, 1 (1947)). These studies have been taken as strong support for the postulate that much radiation injury "indirectly" results from the radiodecomposition and/or ionization of water. Therefore, it was of some concern to us when it was shown that there was actually an inverse relationship between the water content of dormant barley seeds and their x-ray sensitivity (R.S. Caldecott, *Science* 120, 809 (1954); L. Ehrenberg, N. Nybom, *Acta Agr. Scand.* 4, 396 (1954)). For this reason it seemed desirable to reinvestigate the relation between radiosensitivity and the water content of soaked seeds.

In this connection dormant seeds, originally stored over P_2O_5 until they reached weight equilibrium, were soaked at 0° and 22°C for different periods of time and then subjected to x-rays. They were grown for seven days, and their average seedling heights were compared with those of irradiated unsoaked seeds.

From these data it is clear that the sensitivity of seeds to x-rays decreases after one hour of soaking at 22°C. However, after four hours' soaking they are about as sensitive as dry controls. In contrast to this, seeds soaked at 0°C slowly increase in resistance to x-rays until after four hours they reach a point of maximum resistance comparable to that obtained after one hour's soaking at 22°C. They maintain this level of tolerance when the soaking period is extended up to eight hours. However, further soaking results in a gradual increase in sensitivity, and after 24 hours they are about as sensitive to x-rays as the dry control. It is significant that the embryo rapidly absorbs water, and the water content of seeds soaked at both temperatures for one hour equals about 40 percent of their dry weight. After 24 hours' soaking, it only increases to about 60 percent. The corresponding water content of the embryo of the dry control was 4 percent.

Two points seem clear from this study: 1) The x-ray sensitivity of dry seeds can actually be decreased by periods of soaking at both 0° and 22°C. 2) The duration of the reduced sensitivity is related to the temperature of the steeping water and is probably associated with increased physiological activity.

These data suggest that the radiodecomposition of water may play a less significant role in modifying radiosensitivity than it has previously been assigned.

*Present address: U.S. Department of Agriculture, University of Minnesota.

PRELIMINARY REPORT OF X-RAY STUDIES ON THE GOLDEN NEMATODE.

G. Fassuliotis and A.H. Sparrow. *Plant Disease Reporter* 39, 572 (1955). Abstract.

Recent experimental work has shown that ionizing radiations can increase the storage life of potatoes without adversely affecting their texture, taste, or appearance (A.H. Sparrow and E. Christensen, *Nucleonics* 12, No. 8, 16 (1954); L.E. Brownell, J.V. Nehemias, and J.G. Bulmer, *Univ. Mich., Engr. Research Inst. Rept. No. 1943*, 7-23-P, 1954; R.L. Sawyer and S.L. Dallyn, *Am. Potato J.* 32 (4), 141 (1955)). The advent of kilocurie and megacurie radiation sources will make this process commercially feasible within the next few years. As a result of these studies, a program was initiated to study the effects of irradiations on the golden nematode of potatoes, *Heterodera rostochiensis*.

In October 1954 batches of golden nematode cyst material containing approximately 2000 cysts each were washed from infected soil (B.G. Chitwood, U.S. Dept. Agr.

Circ. No. 875, Washington, D.C., 1951) and enclosed in 10-ml plastic vials. They were irradiated with a G.E. Maxitron x-ray machine set at 250 kvp and 30 mamp with 1/4-mm copper and 1-mm aluminum filtration at a distance of 17.5 cm. The dose rate was 1000 r/min. The cysts were treated at room temperature with dosages of 2500, 5000, 10,000, 20,000, 40,000 and 80,000 r. Nonirradiated cysts were used as controls. After treatment, the cysts were removed from the vials and exposed to potato-root leachings in order to obtain free larvae. When the larvae had emerged from the cysts, they were transferred to the roots of growing tomato and potato plants. This was done by removing the root balls from the pots and pouring the larvae from each of the treatments on the roots. Approximately 60 days after the roots were inoculated, the saccate female cysts that had developed were washed free of the roots and soil and examined under the microscope.

Larvae from cysts treated at 2500 and 5000 r seemed to develop normally compared with the unirradiated controls. The newly developed cysts contained viable embryonated eggs. Those cysts which developed after the 10,000-r treatment contained eggs of which approximately one-half were brown in color and obviously dead. After doses of 20,000 r and 40,000 r, the cysts which developed appeared normal upon macroscopic examination of the root balls. Cysts that developed after the 20,000-r treatment contained eggs, all of which were brown and dead, and those developing after the 40,000-r dose (which appeared normal externally) were found to be empty when cut open.

These data indicate that the life cycle of the golden nematode is interrupted by x-rays at dosages of 20,000 r and above. The lowest dose found to inhibit the development of embryonated eggs is comparable to the dose found to inhibit the sprouting of potatoes completely. Although the nematode data were obtained from free cysts, the results indicate that irradiation of tubers infected with the golden nematode will not only inhibit sprouting but will probably also interrupt the life cycle of the parasite, thus eliminating one of the possible routes of spread of the golden nematode. Further tests are now in progress.

THE X-RAY SENSITIVITY OF CUTTINGS OF CREEPING-ROOTED ALFALFA.* Beatrice E. Murray.** Submitted to Can. J. Agr. Sci. Abstract.

A method for the determination of radiosensitivity of alfalfa is presented. Alfalfa stem cuttings were exposed to nine dosage levels of x-radiation, namely, control (no radiation), 500 r, 1000 r, 2000 r, etc., to 7000 r, subsequent to the initiation of root primordia at the base of each cutting. A reduction in the length and number of roots per cutting were the initial manifestations of sensitivity to x-radiation. Complementary information was contributed by axillary bud growth and leaf anomalies. No irradiation effects on root or axillary bud growth were visible in cuttings exposed to the 1000-r level or less. Growth of both roots and axillary buds was inhibited at dosage levels of 5000 r or more. Adventitious stems developed on the roots at the base of cuttings if the rooting portion were shielded from x-radiation.

*This work was performed in cooperation with the Experimental Farms Service, Canada Department of Agriculture, Ottawa, Ontario.

**Research Officer, Dominion Experimental Farm, Swift Current, Saskatchewan.

INDUCTION OF TUMORS BY IONIZING RADIATION ON STEMS, LEAVES AND ROOTS OF AN INTERSPECIFIC "NICOTIANA" HYBRID. A.H. Sparrow and J.E. Gunckel.* Submitted to Proc. Intern. Conf. Radiobiol., Cambridge, England, 1955. Abstract.

It has been known for many years that certain interspecific hybrids of the genus Nicotiana are capable of developing tumor masses of various sizes on leaves, stems

and roots. Since no causative agent has ever been isolated from such tumors, it has been assumed that they are of a genetic nature, caused by some kind of incompatibility produced when certain genome combinations occur. Amphidiploid plants of the hybrid *Nicotiana glauca* x *Langsdorffii*, as well as plants of both parental lines, were exposed to gamma radiation from a cobalt-60 source for various periods of time ranging from 3 weeks to 3 months at dose rates of approximately 15, 25, 50, 100, 200, 300 and 400 r per day. The amphidiploid hybrid normally develops a certain number of tumors in plants which have reached or passed the flowering stage. Tumors in younger plants are rare. In comparison with unirradiated plants of the same age it was found that chronically irradiated plants showed more tumors, a greater number of plants showing tumors at any given date, and an increase in the relative weight of tumor tissue to that of nontumorous tissue. Tumor expression was greatest at the highest dose rate. Data bearing on these points will be presented. No tumors were observed in either of the chronically irradiated parental species. In addition to tumors induced by chronic gamma irradiation, it has also been found that the hybrid plants exposed to acute doses of x-rays also show much greater tumor development than unirradiated control plants. Similarly, plants grown in nutrient solutions containing P^{32} in the form of phosphate also show greatly enhanced tumor formation. In all cases the commonest type of tumors are those observed to originate in the stem. Root tumors are the next most common type, followed by a relatively small number of leaf tumors. At least six clearly distinguishable types of tumors have been observed, and most of these have been grown in sterile culture media. Certain histological and morphological aspects of the various tumor types will be described.

*Rutgers University, New Brunswick, N.J.

TRANSFER OF OXYGEN IN THE GLUTAMINE SYNTHETASE REACTION.*

A. Kowalsky, C. Wytenbach, L. Langer and D.E. Koshland, Jr. Submitted to J. Biol. Chem. Abstract.

The enzyme which catalyzes the formation of glutamine from glutamic acid, adenosine triphosphate, and ammonia was isolated from dried peas. To determine the type of intermediates which might be formed in the reaction, and also to clarify the role of the solvent, the reaction was carried out using O^{18} labeled glutamic acid. An examination of the products and the unreacted glutamic acid revealed that (a) no exchange of the oxygen of glutamic acid with the solvent occurred, (b) the adenosine diphosphate contained essentially no O^{18} , (c) the inorganic phosphate contained O^{18} in amounts corresponding to a stoichiometric transfer of oxygen from acid to phosphate. These results show that the solvent does not enter into the hydrolysis of the adenosine triphosphate and that a phosphorylated intermediate is formed in which the oxygen is covalently bound.

*A preliminary report of this work has been published (Abstracts, Am. Chem. Soc., 127th Meeting, Cincinnati, 27C (1955)). Similar results have been reported by Boyer et al. (Federation Proc. 14, 185 (1955)).

A GAMMA RADIATION PILOT PLANT FACILITY FOR POTATOES. O.A. Kuhl,* A.H. Sparrow and B. Manowitz.* Submitted to Nucleonics. Abstract.

A design of a pilot plant facility for the irradiation of potatoes (or other material) is described. The radiation source (cobalt-60) should provide sufficient gamma radiation to expose about 15 tons of potatoes per day at a dosage of 12,000 r. The whole unit is so designed that it can be mounted on a trailer, and hence it is portable.

Estimated cost of the shield, trailer, and auxiliary equipment should not exceed \$30,000.

*Member of the Nuclear Engineering Department.

THE EFFECTS ON PLANTS OF CHRONIC EXPOSURE TO GAMMA RADIATION FROM RADIOCOBALT.* A.H. Sparrow and J.E. Gunckel.** Submitted to Proc. Intern. Conf. Peaceful Uses of Atomic Energy. Abstract.

Developmental studies of plants after exposure to acute and chronic irradiation reveal a wide range of morphogenetic responses and of cytogenetic changes. A 6-year study of over 100 different species of plants representing 35 families has afforded ample opportunity for the appearance of most of the responses in plants following exposure to ionizing radiation. The effective dosage or dose rate varies greatly in the different species studied. For instance, some species show severe morphogenetic effects with dose rates as low as 25 to 40 r per day after 6 weeks' exposure, whereas other species show little or no effect from exposures as high as 5000 to 6000 r per day. Very few plants so far studied have shown gross morphological changes (excluding mutations) at dose rates below 15 r per day, whereas statistically significant numbers of cytogenetic changes were obtained at dose rates below 1 r per day.

The immediate cytogenetic effect on the irradiated plants included various types of chromosomal aberrations and color changes in both vegetative and floral structures of certain plants. Morphogenetic responses were visibly more severe and more generalized especially in the medium-to-sublethal dose range. These responses ranged from growth inhibition to growth stimulation, depending upon the dose rate and upon the age, physiological condition, and species of plant used. Thus, increased meristematic activity may be expressed in several different abnormal growth forms, including, in the most extreme cases, the induction of large numbers of plant tumors. Representative types of cytogenetic and morphogenetic abnormalities are described, and the probable cause of some of the end results observed are discussed. The abnormal morphological responses observed suggest that profound physiological or biochemical changes are induced. The nature of such changes is largely unknown. Correlation of chromosomal injury and physiological disturbances with the final morphological effects offers interesting fields for further investigation.

Although the use of kilocurie radiation sources in experimental botany is a relatively new development, results already obtained show that such a tool can be very useful in the study of physiological and morphological aspects of normal and abnormal plant growth as well as in theoretical and applied genetics. In addition to these uses there is a practical application for high intensity radiation sources in providing improved storage life in certain vegetables. For example, the radiation-induced inhibition of sprouting in potatoes and onions greatly prolongs their storage life, and with the introduction of megacurie sources, this becomes a commercially feasible process.

*Research carried out in cooperation with Rutgers University.

**Botany Department, Rutgers University, New Brunswick, N.J.

MEDICAL DEPARTMENT

Division of Pathology

Dynamics of Production and Destruction of Formed Elements of the Blood Under Normal and Abnormal Conditions (6300)*

Development work on equipment is progressing satisfactorily. Methods for studying agglutination of platelets by homologous and heterologous platelet antibody have been perfected. Preliminary experiments on influence of heterologous platelet antibodies on platelet production and blood coagulation have been completed. It was of interest that prothrombin utilization bears no relation to the platelet count when a prompt thrombopenia is induced by heterologous platelet antibody. Preliminary studies on platelet labeling with $S^{35}O_4$ and tritium oxide are under way. (E.P. Cronkite and V.P. Bond with G.J. Jacobs, Naval Medical Research Institute, Bethesda, Md.)

Follow-up Studies on Marshallese Exposed to Fall-out Radiation (6300)

The 12-month survey was completed and a report has been submitted to the Division of Biology and Medicine, AEC. All exposed individuals are doing well. Skin lesions have healed with only slight residual scars. The granulocytes had returned to normal but the platelets and lymphocytes, though higher than the 6-month levels, were still below normal. The prognosis for the entire group looks good. Two-year follow-up studies will be performed by the Naval Medical Research Institute. (E.P. Cronkite)

Cancerogenic Action of Local and Graded Doses of Whole-body Irradiation (6210)

To date, rats treated by schedule of combined beta and gamma radiations previously described have developed no lesions at the site of beta radiation. However, the development of mammary tumors continues and is tabulated here for the incidence 210 days after treatment.

<u>γ_1 Series</u>	<u>γ_2 Series</u>	<u>X-Ray + β_2</u>	<u>$\beta_1 + \beta_2$</u>	<u>Controls</u>
$\beta_1 + \gamma_1 - 3/16$	$\beta_2 + \gamma_2 - 4/16$	1/16	0/36	0/18
$\beta_2 + \gamma_1 - 3/16$	$\beta_1 + \gamma_2 - 5/16$			
$\gamma_1 - 2/16$	$\gamma_2 - 4/16$			
Total - 8/48	Total - 13/48	Total - 1/16		
Grand Total - 22/112			Grand Total - 0/54	

(E.P. Cronkite, V.P. Bond and C.J. Shellabarger in collaboration with R.A. Conard, Naval Medical Research Institute)

*For explanation of these numbers, see Foreword.

The Effects of 2-Amino, 5-Nitrothiazole
on Thyroid Function in the Rat

(6300)

It has been reported that 2-amino, 5-nitrothiazole exhibited antigonadotropic properties when fed to fowl. The results of the administration of this compound to rats suggest that 2-amino, 5-nitrothiazole is an antithyroid compound as evidenced by the following observations: rats treated with the compound had lower thyroidal iodine-131 accumulation values and larger thyroid glands than nontreated control rats; the histological findings of thyroid glands from treated rats were consistent with what might be expected after the administration of an antithyroid compound of the thiouracil type.

(C.J. Shellabarger and F.C. Schatzlein)

The Biological Activity of Triiodothyronine,
Triiodothyroacetic Acid, and Thyroxine

(6300)

By use of the goiter-prevention method, the biological activity of triiodothyronine, triiodothyroacetic acid, and thyroxine have been estimated. When the rat was utilized, the activity of the three compounds in decreasing order of potency was: triiodothyronine, thyroxine, and triiodothyroacetic acid. However, when the chick was used as the experimental animal, the order of potency was: thyroxine and triiodothyronine equal, and triiodothyroacetic acid. Experiments are in progress to estimate more precisely the potency of various iodinated compounds in different species.

(C.J. Shellabarger)

Division of Microbiology

(6300)

Astatine (At^{211}) Incorporation into Aromatic
Nuclei Via Diazonium Compounds

A search for methods of incorporating astatine in stable linkage into organic compounds suggests, by analogy with iodine, that aromatic substitution might be best. Therefore, the route via the diazonium salt has been tried and astatine has thus been successfully incorporated into several organic compounds. The evidence for the desired reaction is based primarily on studies of the distribution of radioactivity between aqueous and organic solvents.

Astatine in 0.1 M potassium iodide was added to 2 volumes of cold 0.2 M phenyl diazonium sulfate and warmed to room temperature. Eighty percent of the radioactivity was extracted by toluene even in the presence of sodium hydroxide; whereas, toluene will not extract free astatine from aqueous sodium hydroxide solution. Repetition of the above experiment without "carrier" iodide gave a poorer yield of toluene extractable radioactivity. The presumed reaction is $\text{At}^- + \Phi\text{N}_2^+ \rightarrow \Phi\text{At} + \text{N}_2$. A corresponding experiment with iodine-131 in carrier iodide gave a poorer yield (40 percent) of toluene-soluble radioiodine.

The diazonium salt of p-aminobenzoic acid in 0.3 M solution, produced by the addition of just sufficient sodium nitrite to dissolve a cold crystal suspension of $\text{HOOC}-\Phi-\text{NH}_2 \cdot \text{H}_2\text{SO}_4$ in 10 N H_2SO_4 , was reacted with an equal volume of astatine in 0.1 M potassium iodide. All of the radioactivity was extracted by ether. Evaporation of the ether caused no loss of radioactivity; the radioactivity of the residue was soluble in pH 6.8 phosphate buffer from which it was reprecipitated by the addition of acid. All these properties agree with the presence of p-astatobenzoic acid being

carried by p-iodobenzoic acid which was produced simultaneously in macro-quantities.

As discussed in a previous report (quarterly progress report for July 1-September 30, 1954, BNL 314 (S-23), page 48), astatine binds readily to proteins, but in such a labile way that exchange to other proteins readily occurs under physiological conditions. Now, by means of the diazo reaction, it is possible to bind astatine tightly to serum albumin. An example follows: 0.01 M benzidine in 0.3 N hydrochloric acid was diazotized at 0°C with sodium nitrite and then mixed in the cold with an equal volume of astatine in 10⁻³ M potassium iodide. After a few minutes, this reaction mixture was added to an excess of bovine serum albumin in pH 7 phosphate buffer at room temperature. The resulting diazo coupling of the benzidine bound half of the radioactivity firmly to the protein, since one-half of the radioactivity remained attached to the protein after butanol extraction and also after immune precipitation. Furthermore, all the activity remaining after butanol extraction was precipitated by rabbit anti-serum to bovine albumin. Since in the immune reaction the astatinated albumin was exposed to at least 100 times as much unlabeled protein under essentially physiological conditions, lack of exchange indicates that such tagging should be suitable for physiological studies.

(W.L. Hughes and J. Klinenberg, student guest of the Medical Department from Johns Hopkins University, Baltimore, Md.)

"In vitro" Incorporation of C¹⁴-Labeled Amino Acids by "Trichinella spiralis" Larvae

A series of experiments is being carried on to test the ability of Trichinella larvae to incorporate C¹⁴ under in vitro conditions. The muscle larvae are isolated from host tissues by pepsin digest and cultured in fluid media containing glycine-2-C¹⁴ or dl-alanine-2-C¹⁴. The larvae are later concentrated, washed and lyophilized for carbon-14 analysis.

(R.D. Stoner and L.V. Hanks)

Radiosensitivity of Tissues

Work is continuing in the study of the sensitivity of intraocular transplants to beta irradiation. The study is being extended to compare the sensitivity of the transplants to beta irradiation and gamma irradiation.

(R.D. Stoner)

Papers Presented

THE USE OF RADIOACTIVELY LABELED COMPOUNDS IN STUDY OF METABOLIC INTERRELATIONSHIPS OF HOST AND PARASITIC HELMINTHS. R.D. Stoner and L.V. Hanks. International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, August 8-20, 1955. Abstract.

Trichinella-infected mice were fed C¹⁴-labeled amino acid diets to test the ability of the nematode, Trichinella spiralis, to incorporate labeled compounds from tissues of the host. The experiments indicate that encysted muscle larvae and migrating larvae prior to encystment in skeletal muscle incorporate C¹⁴ from their hosts which were fed diets containing the following C¹⁴-labeled amino acids: glycine-1-C¹⁴, glycine-2-C¹⁴, dl-alanine-1-C¹⁴, and dl-alanine-2-C¹⁴.

A Mechanism for the Fixation of Carbon Dioxide into
the Number-6 Carbon Atom of Uric Acid

The mechanism by which a carbon atom initially present as carbon dioxide may become the number-6 carbon atom of uric acid has been studied. It was found in preliminary experiments that if the δ -carbon atom of δ -aminolevulinic acid was labeled with C^{14} and this material injected into a pigeon, C^{14} appeared in the number-6 carbon atom of uric acid as well as in the ureido carbon atoms (numbers 2 and 8). It appeared that this δ -carbon atom entered uric acid in the number-6 position without first being converted to carbon dioxide. In order to check this conclusion, δ -aminolevulinic acid-5- C^{14} was injected and the radioactivity of the respiratory carbon dioxide was determined during the same period that the pigeon was synthesizing uric acid. It was found that the C^{14} activity of the respiratory carbon dioxide was about one-sixth of the activity of the number-6 position of uric acid. It appears, therefore, that if equilibration occurred among all the carbon dioxide molecules, the δ -carbon atom of δ -aminolevulinic acid was fixed into uric acid without first being oxidized to carbon dioxide. A tentative working mechanism has been postulated.

It is visualized that carbon dioxide first combines with α -ketoglutaric or glutamic acid to form a malonate derivative and the original carboxyl group of the acid is then incorporated into uric acid with the simultaneous regeneration of the acid; the newly formed acid now contains the original carbon dioxide as its carboxyl group. Repetition of the reaction would lead to fixation of the original carbon dioxide into uric acid. It is postulated that δ -aminolevulinic acid is converted into the above derivative and the δ -carbon atom (perhaps converted into an amide) is then utilized for the number-6 position of uric acid. With this mechanism in view, acetyl-L-glutamic acid-1- C^{14} has been synthesized and its metabolic role studied in reference to carbon dioxide and uric acid formation. Both compounds were radioactive, the carbon of the uric acid being 1.5 times more radioactive than the respiratory carbon dioxide. Further conclusions must await the degradation of the isolated uric acid, since the C^{14} activity of the number-6 position alone must be compared with the activity of the respiratory carbon dioxide.

(D. Shemin, guest from the College of Physicians and Surgeons, Columbia University, New York, N.Y.)

The Metabolism of C^{14} -Labeled Tryptophan

The metabolism of tryptophan was studied by injecting tryptophan labeled with C^{14} in the benzenoid nucleus and the alpha carbon atom into rats. Two known metabolites, N-methylnicotinamide and quinolinic acid, were isolated by isotope dilution technique and degraded to show the position of the C^{14} in these molecules. In general, the results confirm the postulated pathway of conversion of tryptophan to pyridine compounds in the rat. The distribution of C^{14} in the tissues was determined in some of these experiments and when excreta, CO_2 and tissue C^{14} were combined, more than 80 percent of the administered dose was accounted for. With both benzenoid and alpha-labeled tryptophan, oxidation to CO_2 was found. Similar experiments with carboxyl-labeled 3-hydroxyanthranilic acid showed that this compound is very rapidly oxidized to CO_2 , which provides an explanation for the relatively poor conversion of this compound to quinolinic acid in the intact animal. The results obtained in these studies

are considered preliminary to more extensive studies of the details of the metabolism of tryptophan in the living animal.

(L.M. Henderson, guest from the University of Illinois, Urbana, Ill., and L.V. Hanks)

A Study of Metabolic Pathways of Carbohydrate Formation in Diabetes by Means of Carbon-14

Studies of the metabolic pathways by which human subjects afflicted with diabetes form glucose have been continued. Two moderately diabetic subjects were fasted and given by mouth 0.5-1.0 g of 1-C¹⁴-ethanol per kilogram of body weight. The blood and urinary glucose were isolated and analyzed for C¹⁴ content and distribution. The general level of C¹⁴ in blood glucose indicated that in one patient about 1/100 as much C¹⁴ was present in total body glucose as had been excreted as CO₂ at 2-1/2 hr and in the other patient about 1/50 as much. Findings from degradation (from fermentation by Leuconostoc mesenteroides) of blood glucose from one patient indicate that, as in the case when 1-C¹⁴-acetate was the precursor, virtually all of the C¹⁴ in glucose is present in the number-3 and -4 carbon atoms of the molecule. Both patients had excreted about 25 percent of the total administered C¹⁴ by the end of 24 hr.

(W.W. Shreeve and M. Conovitz, student from Harvard Medical School, Boston, Mass.)

Observations on Nephrotic Hyperlipemia in Children

The percentages of various lipide components of serum from nephrotic children were determined. Total lipides ranged from 900 to 4475 mg percent (15 analyses) among 4 patients. The mean value was 2915 mg percent. Values of other serum lipides were: total cholesterol, 833 mg percent (370 to 1195); free cholesterol, 250 mg percent (90 to 370); and phosphatide, 490 mg percent (240 to 610).

Changes in serum lipides were observed as a result of administration of albumin to one patient. The levels of all the lipides decreased, with the greatest change in the glyceride fraction.

A second patient was given daily supplements of ethyl linoleate in order to test whether this essential fatty acid had any effect on hyperlipemia. No changes were apparent after 3 weeks. This study is being continued.

(J. James, G.A. Smith, student from Mount Holyoke College, South Hadley, Mass., and L.I. Gidez)

Observations on Nephrotic Hyperlipemia in Rats

A syndrome resembling the nephrotic syndrome of children was induced in weanling rats by daily subcutaneous injections of 6-dimethylamino-9-(3'-deoxy-β-D-ribofuranosyl)-purine ("aminonucleoside" of puromycin). The development of hyperlipemia was followed in these rats and the effect of daily supplements of ethyl linoleate was studied in one-half of these animals. Plasma lipides of all rats sacrificed at the end of 6 days were normal, while the plasma lipides of rats killed after 12 days were greatly elevated. The latter animals had ascites, which was not observed in the animals killed at the end of 6 days. Neither the total lipide nor phosphatide content of the livers of any of the rats differed from normal values, although the percentages of total and free cholesterol were slightly elevated in the animals dispatched at the end of 12 days. At the end of 12 days, the major difference between those animals receiving ethyl linoleate and those receiving no supplement was that the latter group had a greater percentage of arachidonic acid in their plasma and liver lipides.

Examination of microscopic sections (hematoxylin and eosin) from the kidneys of the rats were made. As a preliminary observation, it was noted that the animals killed after 6 days showed no apparent renal lesions, whereas the rats killed after 12 days showed alterations in the glomeruli in all instances. Whether this is a degenerative change in the endothelial and/or epithelial cells, an alteration in basement membrane, or a combination must be settled by further animal study and suitable microscopic preparations utilizing special staining techniques.

(L.I. Gidez, G.A. Smith and J. James)

Papers Presented

THE SOURCE AND STATE OF THE HYDROXYLYSINE OF COLLAGEN. F.M. Sinex and D.D. Van Slyke. *J. Biol. Chem.* 216, 245 (1955). Abstract.

In order to find whether hydroxylysine is formed from lysine in the animal body, young rats were fed for 3 weeks L-lysine uniformly labeled with C^{14} . The rats were then sacrificed, and gelatin was prepared from the skin collagen and hydrolyzed. The basic amino acids were separated from the hydrolysate by precipitation with phosphotungstic acid and then from each other by means of a Dowex 50 ion exchange column. The C^{14} specific activity was the same in the hydroxylysine as in the lysine, and in both of the amino acids the specific activity was the same in the carboxyl group as in the rest of the 6-carbon chain; this would indicate the probability that the uniform C^{14} labeling of the fed lysine was retained. The results indicate that hydroxylysine in the body is formed from lysine. The approximate equality of C^{14} activity in both amino acids indicated the probability that but little hydroxylysine is formed from other sources.

Division of Physiology

State of Tissue Acetylcholinesterase as Studied
by Co^{60} γ -Radiation

(6300)

The pronounced heat sensitivity of Co^{60} γ -irradiated Electrophorus electricus electric organ acetylcholinesterase (as compared to nonirradiated control) has indicated that the enzyme molecules are capable of maintaining hydrolytic activity in spite of suffering partial radiation injury. This in turn was suggestive of the presence of multiple enzymatic sites in a single macromolecule and calculations of the "molecular" weight of such units have substantiated this conclusion. On the basis of inactivation kinetics, the radiosensitive unit weight has been found to be approximately 200,000. Since the molecular weight of eel organ acetylcholinesterase is known to be in the range of 3,000,000, these data imply that this enzyme is a macromolecule composed of 15 independently active centers.

The complete protection of acetylcholinesterase by whole eel organ against indirect effects of irradiation has previously been demonstrated in this laboratory by finding an identical resistance to radiation inactivation in whole and lyophilized tissue. This phenomenon has now been found to apply also to the acetylcholinesterases in human red blood cells and rat brain. Human plasma cholinesterase, however, was found to be more sensitive in the original, wet state than in a dried preparation. Since plasma and eel organ have comparable water contents, a possible explanation for the difference in resistance to indirect irradiation effects might be the particulate localization of the acetylcholinesterase in the latter case.

The inactivation kinetics of lyophilized plasma, r.b.c., and brain cholinesterases were utilized to determine the weights of the radiosensitive, active centers of these

enzymes; these were found to be 200,000, 300,000, and 75,000 respectively.
(G.C. Cotzias and I. Serlin)

Use of P^{32} to Measure the Severity
of β -Ray Skin Lesions

(6210)

Pilot experiments have been carried out to establish the feasibility of measuring the severity of β -ray burns to a rabbit ear by the use of radioactive phosphorus (P^{32}) in a manner similar to that developed for thermal burns (Neil - NMRI Project NM 007081-03.06). Nine exposures with two different β sources have been made and lesions have been obtained which appear to be amenable to measurement by the P^{32} method. Surface counting in vivo is now in progress.
(C.M. Neil)

"In Vitro" Degradation of Iodoalbumin

(6300)

Investigations are being continued on the products of alkaline and enzymatic hydrolysis of iodoalbumin by means of cation and anion exchange columns and paper chromatography.
(H. Sandberg and C.G. Lewallen)

Synthesis of Several Morpholinium Derivatives

(6300)

Several morpholinium derivatives were prepared. These materials have the following general structures:

(O.D. Easterday and D.H. Ives, student from Cornell College, Mt. Vernon, Iowa)

Cation Transport by Human Red Cells "In Vitro"

(6300)

It was previously observed that elevation of blood pH is associated with an initial depression and subsequent progressive increase of (active) K influx until values substantially above those of controls are reached. This progressive increase in K influx appeared to be related to a parallel increase in (active) Na outflux as cell Na progressively increased. This elevation in cell Na is the result of a marked increase in Na influx with increasing pH. The following studies have lent support to this apparent relationship. Choline and tetraethyl ammonium cations, which enter the human red cell very slowly, if at all, were substituted in varying amounts for Na in the suspending medium, isotonicity being maintained. In this way, cell Na could be maintained, lowered, or elevated in accordance with the Na concentration and pH of the medium. An initial depression in K influx was still evident (compared to controls in which similar amounts of quaternary ammonium were substituted for Na, but at physiological pH). Subsequently K influx increased, decreased, or remained unchanged in accordance with the direction of change of cell Na. The ratio K influx/Na outflux remained constant at each pH level throughout the period of measurement. This ratio decreased with increasing pH.

Investigation concerning the effects of alteration in pH and cation composition on cation transport are continuing. A paper summarizing most of this work to date is in preparation.

(E.T. Dunham)

Papers Presented

MICRODIFFUSION OF ACETIC ACID AS AN ASSAY FOR ACETYLCHOLINESTERASE. I. Serlin and G.C. Cotzias. J. Biol. Chem. 215, 263-268 (1955). Abstract.

A simple, direct assay of acetylcholinesterase activity is presented. The procedure consists of a direct titration following microdiffusion of acetic acid from a reaction mixture, the pH of which has been fixed at 3.0. Hydrolysis of the excess, labile substrate is prevented and diffusion of the acetic acid is expedited by addition of the sample to anhydrous sodium sulfate at 4°. The procedure was found suitable for the assay of acetylcholinesterase preparations dilute enough to yield only 0.05 μmole (3 γ) of acetic acid per milliliter per hour.

SOME PHARMACOLOGICAL STUDIES WITH BORON. O.D. Easterday and R.W. Carey. American Society of Pharmacology and Experimental Therapeutics, Iowa City, Iowa, September 5-8, 1955. Abstract of talk.

The preliminary investigation of neutron therapy for treatment of glioblastoma multiforme with boron-10 as the capture element has indicated a need for additional

pharmacological information about boron compounds. Studies concerned with the effect of intravenously administered boron (complexed with and without d-glucose) upon blood pressure, respiration, and the electrocardiogram of dogs were conducted. Standard pharmacological procedure was followed. The blood pressure recordings were made by direct cannulation into the femoral or common carotid artery. The tracings were made by a direct writing manometer. All drugs were administered into the femoral vein. The electrocardiogram tracings from the limb leads were made simultaneously with a Sanborn 4-channel recorder.

Boron produces a transient depressor response followed by an extended pressor response. The respiratory response is a reduction in rate and amplitude. Upon repeated small doses, a tachyphylactic phenomenon appears to be evident. The depressor and pressor phases of boron were not blocked with atropine or dibenamine. The effect, if any, of the complexing agent (d-glucose) was negligible. The acetylcholine and epinephrine responses after boron were enhanced and of increased duration. The electrocardiogram showed various deviations under the influence of boron. Two of the major deviations consisted of T-wave inversion and S-T segment depression. Changes produced in the blood pressure, respiration, and electrocardiogram in overdosage and death will be presented.

THE ACCURACY OF A RADIOPOTASSIUM (STEWART PRINCIPLE) METHOD FOR THE MEASUREMENT OF CARDIAC OUTPUT. H.L. Conn, Jr. J. Appl. Physiol. 7, 542-548 (1955). Abstract.

The accuracy of a radiopotassium method for measurement of cardiac output was determined in dogs by comparison of results with those obtained by the Fick procedure with oxygen. The K^{42} method appears to have no systematic error and a random error of ± 5 percent in normal animals; no systematic error and ± 5 -20 percent random errors under varied experimental conditions. The simplicity of the technique and the advantages accruing from the minimal recirculation of radioactivity are pointed out.

THE TOLERANCE OF LARGE DOSES OF SODIUM BORATE INTRAVENOUSLY BY PATIENTS RECEIVING NEUTRON CAPTURE THERAPY. H.B. Locksley and L.E. Farr. J. Pharm. Exp. Therap. 114, 484-489 (1955). Abstract.

Clinical observations of the effects of intravenously administered borax in doses up to 20 g (2.12 g boron) are reported. Immediate symptoms observed were intense gastro-intestinal stimulation leading to nausea, vomiting, retching, urgent defecation and diarrhea; mild peripheral vascular collapse; mild mental confusion; and a flushed violaceous discoloration of the skin of the face not attributable to respiratory embarrassment. Later symptoms were drowsiness, lethargy, variable degrees of continued gastro-irritability and in a few instances a scarlatiniform rash. These effects usually terminated by the third to fifth day.

No deaths occurred in these patients as a result of this borax administration and a poor general condition of the patient was not found to be an absolute contraindication to boron administration.

Dramamine exerted no significant effect on the early symptoms of nausea and vomiting.

Two successive administrations of 20 g of borax (2.12 g boron) at an interval of two weeks and four successive administrations of the same dose to four patients at an interval of four weeks did not lead to enhanced toxic effects.

Division of Medical PhysicsMedical Research Reactor

(6210)

Much progress has been made in the design of the required shutters and shields by the reactor operations and nuclear engineering groups. For the patient treatment facility a hydraulically operated shutter is planned. For the broad beam facility a neutron filter and a device for producing fast neutrons or gamma rays will be built.

A mock-up of the proposed reactor, but with a square core, has been taken to critical. A cylindrical core like the one which will actually be used will be tested soon. The tests to date confirm the feasibility of using the planned number of fuel elements.

(L.E. Farr, J.S. Robertson, V.P. Bond, E.E. Stickley)

The Effects on Skin of Radiations from the Reactor

(6210)

Some patients undergoing neutron capture therapy for brain tumors have developed skin ulcerations at the site of entry of the thermal neutron beam. Studies with swine were undertaken in an effort to determine the etiology of the lesions. Animals were anesthetized and exposed to the neutron beam for 1/2 hr with one side of the face over the patient treatment port. After this, boron was given intravenously and the opposite side of the face was then exposed for the same period of time. Thus each animal served as its own control. Of the 4 animals treated in this fashion, all showed some degree of skin damage on both sides of the face which usually developed about 10 days after irradiation. In all animals, however, the side receiving boron and thermal neutron irradiation was markedly more damaged. The skin on this side developed severe lesions, with sloughing over the entire port area. All animals developed severe eye lesions on this side, with swelling, closure of the eye and sloughing of the cornea. Although in general the lesions conformed to the area of the treatment port, definite lesions were found outside of the port area. These lesions could not be accounted for by movement of the pig during irradiation, and they did not conform to a vascular pattern. The marked increase in severity of the lesions on the side receiving boron prior to irradiation was borne out by gross and microscopic pathology. It appears definite from these studies that the presence of boron in the skin contributes heavily to the severe skin lesions observed.

Efforts are being made to administer boron at a slow rate directly into the internal carotid of swine. It is hoped that this procedure may actually increase the effective boron concentration in a brain tumor, and at the same time decrease the boron concentration in the skin throughout most of the irradiation period.

(J.S. Robertson, E.P. Cronkite, V.P. Bond, E.E. Stickley)

Calibration of the Slow Neutron Beam by Biological Means

(6210)

Mice have been exposed in the medical facility of the Brookhaven reactor in an effort to determine biologically the dose rate from the reactor beam alone, and from the energy released by injected capture elements such as boron. A dose of 19 μg of B^{10} per gram of mouse was found to approximately double the rem dose rate under the conditions employed; the degree of spleen-thymus weight loss was used as the criterion of effort. The effectiveness of the heavy particles from slow neutron capture by boron relative to gamma radiation (apparent RBE) was found to be approximately 1.4 for this end point.

Additional studies necessary to evaluate the effectiveness of radiations from boron capture in the mouse have been completed or are in progress. These include the depth-flux distribution of thermal neutrons in the mouse under the condition employed, the inter-mouse gamma contribution, the "sink effect" of the mice, control studies with boron and gamma radiation, and the distribution of the injected boron in mouse tissues. Biological end points in mice given boron and thermal neutron irradiation have been extended to include 30-day mortality, and the degree of testis weight loss in the mouse. A markedly shortened survival time has been observed in mice receiving boron and thermal neutron irradiation, compared to mice receiving neutron irradiation alone. An additional capture element, Li, has been used in the mouse irradiated with thermal neutrons. On spleen-thymus weight loss, the effectiveness of the recoil alpha and tritium particles appears to be approximately the same as those from boron. Because of the low percentage of Li^6 in natural lithium, it will be necessary to use enriched lithium to establish this point with certainty.

A cobalt source for animal irradiation, and a controlled-atmosphere mouse exposure unit have been designed, and fabrication is nearing completion. On completion of these units, studies with hypoxia and preprotective agents will be started in mice exposed to different types of radiation. Ehrlich ascites tumor mice have been obtained, and studies on the effectiveness of different radiations on the tumor cells have been initiated. (V.P. Bond, O.D. Easterday, E.E. Stickley and J.S. Robertson)

Gut Permeability Studies

(6210)

Studies of the effect of radiation on the physiology of electrolyte transfer from the lumen of the gut to the blood are being continued. Repeated base line experiments established the reproducibility of the procedure. No effect was noted at 2, 4, and 6 days after irradiation with 300 r of Co^{60} gamma rays. It is planned to concentrate on the first 48 hours after irradiation in future experiments and to use higher doses of irradiation.

(J.S. Robertson, V.P. Bond and E.P. Cronkite)

Mouse Gliomas

(6210)

An attempt was made to study the effects of alpha irradiation on the blood vessels in mouse gliomas. The mice were given the tumor by intracranial injection. At 7 or 8 days after the tumor was given, B^{10} borax was administered intravenously and the mice exposed to a neutron beam. Controls were given the tumor but irradiated without boron. Most of the boron-injected animals died too soon from the effects of radiation on the intestinal tract to be of value. If this project is continued, it is clear that the abdomen must be shielded. The brains were stained with H and E, Mallory's PTAH, Periodic A. Schiff and Biebrick's scarlet dyes for study. Selected brains were frozen and will be examined with a labeled antibody technique. No significant differences were found with use of the dyes.

(N. Bauman, student from New York University College of Medicine, New York, New York, and J.S. Robertson)

The RBE of At^{211} Alpha Particles as Compared to I^{132} Beta Particles in the Rat Thyroid

(6300)

The selective uptake of some halogens by the thyroid was used to compare the effect of alpha and beta particles on mammalian tissue. As alpha emitter At^{211}

(7.3-hr half-life) was used and as beta emitter the iodine isotope I^{132} of comparable half-life (2.3 hr). The 18-hr uptake of I^{131} tracer was used as indication of the destructive effect on the rat thyroid.

A method for the absolute standardization of At^{211} was developed for this project. By dissolving the sample in the liquid scintillator of a scintillation counter, the usual absorption and scattering effects encountered in the standardization of alpha emitters are avoided and 100 percent counting efficiency obtained. Preliminary calculations indicate that the RBE of the alpha particles is about 3.

(J.K. Basson, guest from National Physical Laboratory, Pretoria, South Africa, C.J. Shellabarger, and J.S. Robertson)

Borate Chemistry

(6210)

The $Na_2B_4O_7$ - $\underline{d}$ -glucose - H_2O system is being studied at $37^\circ C$ over a range of concentrations of glucose and borate to determine the optimum ratio of glucose to borate with respect to maximizing the solubility of the borate and to study the complexes formed in this system.

A method for producing B^{10} sodium pentaborate has been developed. The method differs from that for B^{10} sodium tetraborate chiefly in that in the neutralization step relatively less NaOH is used.

(R.F. Straub)

Tissue Equivalent Ionization Chamber

(6300)

The vibrating reed electrometer was found to be too unstable in use with an adequately thin, flexible low noise cable. A temporarily loaned less sensitive vacuum tube electrometer gave indications of being a more suitable instrument. Further studies with such an instrument are in progress.

(R.I. Weller and E.E. Stickley)

Isotope Standards Comparator

(6300)

A program of calibration and standardization studies was instituted.

(R.I. Weller and E.E. Stickley)