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OAK RIDGE MOBILE RADIOISOTOPE LABORATORY

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A mobile radioisotope laboratory was designed by the Special Training Division of the Oak Ridge Institute of Nuclear Studies in 1958, and two such vehicles were constructed for presentation by the United States to the International Atomic Energy Agency. The first laboratory was completed during the summer of 1958, in time for it to be demonstrated at the Second International Conference on the Peaceful Uses of Atomic Energy at Geneva, and to be then transferred officially to the IAEA. The second laboratory was completed subsequently, and delivered in Oak Ridge later that year.

An outgrowth of this activity was the establishment of a program based in Oak Ridge and utilizing a mobile laboratory that would be used on college campuses in the southern area. A new new unit was therefore designed, to be used for this purpose.

The Oak Ridge Mobile Radioisotope Training Laboratory Program is designed to provide faculty members and advanced science majors at undergraduate institutions the opportunity for specialized training in the techniques and applications of radioisotopes. These techniques can be of value to faculty members in their teaching and research activities, and should enable students to become more familiar with this field of atomic energy.

Since the second laboratory constructed for the International Atomic Energy Agency was still in Oak Ridge during the spring

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of 1959 prior to its delivery to the Agency, it was decided to test the effectiveness of this type of course on two small college campuses near Oak Ridge. Because of the proximity, the two colleges chosen were Carson-Newman College at Jefferson City, Tennessee, and Maryville College at Maryville, Tennessee. Preliminary discussions were held with Dr. C. T. Bahner of the Carson-Newman faculty and F. A. Griffitts of the Maryville faculty. Following this, meetings were held with interested members of faculties on the campuses, and it was agreed to attempt the project at these places. It was agreed that Oak Ridge staff members would commute between Oak Ridge and the campus, and also supply a laboratory technician to be in charge of the laboratory truck itself. The course was offered at Carson-Newman March 4-18, 1959 and at Maryville College April 10-27, 1959.

The mobile unit was scheduled for a period of two weeks at each campus. In this period, a well-rounded series of laboratory experiments and lectures were presented, covering the basic counting techniques and applications of radioisotopes in the fields of biology, chemistry, and physics. An organizational visit was made to each college by an ORINS staff member prior to location of the mobile unit on the campus. During this time, an agenda of lectures and experiments was prepared to fit the needs of the college. Every effort was made to arrange a schedule that would allow adequate time for effective presentation of material and, at the same time, cause minimum interference with regularly scheduled classes. All the laboratory experiments were performed in the mobile laboratory, with up to six participants being accommodated at one time. The Institute provided the mobile laboratory and all necessary equipment and supplies at no cost to the college. The college was asked to supply power for the unit and provide classroom space for the lectures.

The pattern of the course at both colleges consisted of a 90-minute lecture each day, with the laboratory sessions scheduled at various times throughout the day to suit the individual schedules of the participants. Each laboratory session had a minimum of two consecutive hours.

The forward portion of the laboratory contains the counting room. There are three identical counting setups which will accommodate six people, working in pairs. Each setup consists of a Geiger counter and a scintillation spectrometer. The Geiger counter is of the end-window type, and is enclosed in a lead shield. The scintillation spectrometer uses a two-inch diameter by two-inch high sodium iodide crystal attached to a two-inch photomultiplier and the usual spectrometer electronic instrumentation. For gas counting, a vibrating-reed electrometer is available. The chemistry laboratory is equipped with three radiochemical fume hoods, radiation monitor, radiation storage vault, air compressor, vacuum pump, analytical balance, centrifuge, and other standard laboratory glassware and chemicals. In addition to the instruments listed above, a spare Geiger counter and scintillation spectrometer, oscilloscope, pulse generator and other test equipment are also contained in the unit.

The course is designed to include predominantly laboratory experience with an adequate amount of lecture material intended to provide the necessary background for understanding the experiments to be conducted. The experiments are intended to present the essential techniques required in many fields, including the basic counting techniques, chemical manipulations, and typical applications. Based on the experience at Carson-Newman and Maryville Colleges, a set of lecture and laboratory experiments have been proposed to be included in subsequent courses. Following is a brief description of lectures and laboratory experiments which will probably be included in the course.

LECTURES

1. *Characterization of Radiation*
   This lecture includes a minimal amount of discussion of alpha and gamma radiation, with greatest attention paid to the problems of beta-ray measurement. The spectrum of beta particles, absorption—including general absorption curves—the techniques of making absorption and self-absorption corrections in the sample are discussed. Backscattering, as a function of the energy of the radiation, and atomic number of backing material are discussed extensively, and a descriptions of the various methods of the experimental determination or range by absorption methods is included. Particular attention is paid to various modifications of the Feather method for detemining range and energy.
2. *Interaction of Radiation with Matter*
   The discussion of the interaction of charged particles covers general problems such as energy conservation, relativity, and the various types of inelastic, elastic, and radiative collisions; the nature and interaction of alpha particles, including their energy distribution, specific ionization features, and their range-energy relations; the problems of straggling; the nature of beta particles and electrons, their energy distribution, and their range-energy relations; and Bremsstrahlung production. The primary interaction processes for electromagnetic radiations are discussed.
3. *Detection of Radiation*
   This topic includes a description of gas-filled detectors, the resultant pulse height versus voltage curves, and a discussion of the utilization of the ionization, proportional and Geiger regions of that curve. Also considered

are scintillation processes, scintillation materials, and photomultipliers.

4. *Instrumentation for Radiation Detectors*
The general problems of selection of instrumentation for specific types of counting are described in this lecture.

5. *Principles of Health Physics*
This lecture includes a rigorous approach to an understanding of the various radiation units. Considerable emphasis is placed on the maximum permissible exposure for professional workers and the general population. The use of instrumentation and methods of keeping the radiation exposure of the laboratory workers to a minimum are included.

6. *Standardization and Assay of Radioactive Materials*
This lecture includes discussion of the standardization of radioactive sources, as illustrated by the problems of commonly used radioisotopes, such as iodine-131 and carbon-14. Also under consideration are the calibration of various types of equipment, such as 4-pi beta counters; the use of a sample standard to calibrate a given source; and gamma-ray standardization.

7. *Nuclear Structure*
This lecture describes the theoretical building-up of nuclei, along with consideration of charge and binding energy, primarily based on the shell model of the nucleus. Consideration of stability and the possibility of nuclear reactions are included, and extensions are made to cosmic nuclear reactions and structure.

8. *Modes of Decay*
This lecture includes the development of the concept of the potential well model of the nucleus, with a description of coulomb barriers, energy levels, and tunneling effect in alpha decay. The mechanisms of nuclear reactions are described, including the formation of the compound nucleus and subsequent particle-emission reactions. The general problems of beta decay and the evidence for the neutrino are described, and electron-capture processes, positron emission, isomeric transitions, and fluorescence and gamma-ray conversions are discussed. Typical decay schemes are described.

9. *Radiochemical Separation Methods*
The use of ion exchange and coprecipitation as a typical radio-chemical technique used for the purification and separation of radioactive material from other radioisotopes or inert materials is described. The nature of ion-exchange resins is considered, as are the advantages of limitations of batch and column-exchange techniques.

Empirical rules of separation are described, and a number of applications of the ion-exchange techniques are discussed.

10. *Biological Applications and Problems*
This lecture provides a survey of a number of biological problems, with particular reference to the techniques and manipulations of the radioactive material. Under discussion are a number of different types of emitters, and a number of different methods of sample preparation, such as wet ashing, liquid measurement, and a thorough treatment of the rationale of tracer work. The approach is such that, while material under discussion is biological, the information and techniques are applicable in a wide variety of scientific fields.

11. *Analytical Applications of Radioisotopes*
The power of the tracer method is probably not shown so clearly in any other application as in isotope dilution. The principles of both direct and inverse dilutions are described, as are the sources of errors, the accuracies obtainable, and the special problems associated with this technique. The importance of the exchange of radioactive materials with stable atoms can not be overestimated. This is of tremendous importance in any tracer problem, and must be particularly considered in biological and medical work. Methods of determining the occurrence and rate of exchange are included, with suggestions as to methods for determination of the possibility of exchange in certain circumstances.

LABORATORY EXPERIMENTS

Determination of Operating Conditions of Various Counters
The object of this experiment is to determine the plateaus and operating voltages of Geiger-Mueller and proportional counters and to determine the precision of counting measurements by statistical evaluation.

Counting Problems: Self-Absorption, Scattering, Statistics
The object of this experiment is to determine some of the characteristics of radiation important to laboratory measurements. The experiment consists of determining self-absorption curves for a series of carbon-14 samples and for a series of cobalt-60 samples, and determining the backscattering effect of radiation for infinitely thick samples of different atomic numbers.

Beta Absorptions: Range and Feather Analysis
This experiment requires the determination of an unknown energy, based on modification of the comparison method of Feather.

Gamma-ray Spectra and Scattering Effects
The object of this experiment is to study scattered radiation from gamma-ray sources; to determine gamma-ray energies by using a scintillation spectrometer; and to assay a sample of unknown disintegration rate by gamma measurement. An absolute assay method by gamma-ray counting with a scintillation spectrometer is used to determine the disintegration rate of either a chromium-51 or a zinc-65 sample.

Preparation of Radioactive Samples for Counting
The object of this experiment is to demonstrate some typical techniques for preparing samples in the radiochemical laboratory. Samples are prepared and counted in triplicate and the activities are compared. Emphasis is laid on laboratory regulations and setting up good housekeeping and waste-disposal procedures. A number of practical "rules of thumb" relative to sample preparation are included.

Assay by Beta and Gamma Counting
The object of this experiment is to demonstrate the use of reference standards to calibrate solutions of iodine-131 by beta counting. The experiment involves the comparison of an NBS sample of known disintegration rate with an aliquot of a solution of iodine-131.

Ion Exchange
The object of this experiment is to demonstrate the use of ion-exchange columns in the separation of radioactive samples from inert material or from other radioactive materials. The experiment consists of using Dowex-1, an ion-exchange resin, and adding a mixture of cobalt-60 radioactive material and inert nickel in a strong HCl solution. The nickel is eluted with 8N HCl, and the effluent is tested for nickel with dimethyglyoxime. When the nickel has been removed, the cobalt is removed with water, and the samples counted. Elution curves are plotted for the materials.

Isotope Dilution
This experiment illustrates the principles of the isotope-dilution method of quantitative analysis. An iron solution of unknown concentration is analyzed by the addition of a known amount of radioactive iron. The iron is precipitated as the hydroxide and dried. The amount of iron in the unknown solution is calculated from the ratio of the specific activity of the added iron and of that of the recovered precipitate.

Coprecipitation
This experiment provides for study of coprecipitation from both the standpoint of its value as a radiochemical-

separations technique and the difficulties it introduces laboratory was something new in the experience of mixing the sample of phosphorus-32 and sulfur-35. Ferric chloride ($FeCl_3$) is added, and is precipitated with ammonium hydroxide. The ferric hydroxide carries much of the phosphorus-32, and most of the sulfur-35 is found in the supernatant solution. The iron is extracted from a solution of hydrochloric acid (HCl) with isopropyl ether and an activity balance is determined for the various supernatant and preciptate fractions for both phosphorus and sulfur activities.

Phosphorus Distribution in Rats

The object of this experiment is to study the phosphorus distribution in a laboratory animal, and to perform wet-ashing and liquid-counting techniques. Phosphorus-32 is injected into a rat, and the animal is killed after a given length of time. (Different pairs of participants allow different circulation times before killing the animal.) Various tissues of the rat are digested in a wet-ashing procedure, and are measured as liquid samples. The specific activities, or percentages of dose localized in various tissues, are reported and compared for the various time intervals.

Activation Analysis

The object of this experiment is to perform a qualitative and quantitative analysis of a sample by measurement of radioactivity produced in the sample by irradiation with slow neutrons. The experiment involves the irradiation of a sample of high cross section and relatively short half life in the Oak Ridge National Laboratory graphite reactor. A different sample is given to each pair of laboratory workers. The identification of the kind of material is carried out by determination of its half life and beta- and gamma-ray energies. An absolute measurement of the amount of activity is made, and the weight of the normal element required to produce that activity is then calculated.

Two of the authors were requested to give firsthand impressions relative to their use of the laboratory on the campus. The following statements represent the viewpoint of the participants in the laboratory course.

The Use of the Mobile Radioisotope Laboratory at Maryville College

The laboratory spent about two weeks in our campus at the suggestion of those in charge at Oak Ridge Institute of Nuclear Studies. This laboratory was something new in the experience of the majors in the Science Division, since it was equipped in a manner, and to an extent, not able to be reached in a college of our type. Indeed, because of the specialized nature of the unit, it would be impractical, not to say too expensive for no more time than students could use it. In other words, the total student-hours in a small college that it would be used would be very few in a twelve-months period. Hence, if such a plan is to be available to students it would have to be on some such basis as this mobile unit provides. For that reason, the idea is good and is a tool of teaching which I think excellent. *To this end I endorse the plan and recommend colleges use it whenever possible.*

The staff which came with it to the Maryville Campus were all experts in the field and did an excellent presentation, not only in the laboratory and classroom, but also in the public relations effect on students and faculty. They could not have done better.

There were generally two on hand at all times. The lectures given by senior scientists were effectively done and well received. Both faculty and students thought well of them. Several students and faculty members outside of the Science Division attended some of the lectures. The lecture given before our entire student body by the Director of the Special Training Division was one of the most effective addresses of the whole year to our student body. For the general good, I recommend this idea.

The "students" taking the course were about half-and-half faculty and students drawn from the area of physics, chemistry, biology and mathematics. About 8 or 9 completed the entire course in class and laboratory.

It was especially interesting because of the new techniques to which they were introduced. The use of the equipment to make measurements, as well as the manner of recording and interpreting data was indeed a constructive piece of study. The overall impression was good—to excellent. I am certain that everyone was glad the course was available. There were no complaints, and no derogatory remarks about the work.

The personnel in charge were most helpful in fitting their schedule to that which could be developed for the students.

The course was one superimposed upon the regular class schedule. The outcome was that since the only students involved were juniors and seniors, they were excused for that time from laboratory work in their major courses. Their schedule "loosened" their program to the extent that they could do the required time in the laboratory. In most cases some such an arrangement will of necessity have to be made. Otherwise, the number of hours required will not be possible.

In general the average student will have to use directly, or indirectly about 5-6 hours a day in one way or another to do the course in the manner best designed for full benefit. In our experience this worked satisfactorily. The students kept full attendance in their other subjects outside the majors.

The presence of the laboratory on the campus was fully explained to the entire student body and faculty. This had a good effect and was an item of interest to all concerned. It is important that such a preparation be made on any campus in advance to achieve the best possible reaction.

It seemed to create a constructive point of view on the campus for by its presence in the center of things it was the subject of considerable comment. Its physical appearance is effective. Many Liberal Arts students visited it, which showed evidence of its value. Faculty members were similarly interested.

In conclusion, for the first time, an object related to the present-day science was added as an extra; and that extra was an effective messenger which, more than you would expect, indicated the impact of the nuclear age on our problems of education.

The Use of the Mobile Radioisotope Laboratory at Carson-Newman College

When we were contacted about the laboratory, we discussed it rather extensively with the personnel of the Special Training Division of Oak Ridge Institute of Nuclear Studies and with our own administration. There was unanimous enthusiasm for the idea, and we could foresee only one major difficulty. This was the problem of fitting the time that would be needed into an already busy schedule. We felt that the advantages were such that this would be only a minor difficulty. After the details had been worked out, we set up a schedule where the lectures were presented in the early afternoon, followed by a laboratory period for about half of the people. We had two faculty members and two students each from our departments of biology, chemistry, and physics taking the course. The ones who were selected to take the course were from the junior class primarily, with only one sophomore. Our thought in this selection was that its impact would be felt by our students for a longer period as a result. The lectures were attended by a large number of students other than the six who were in direct fulltime attendance in the course. For the six who were taking the course, the experiments in the course were substituted for some of the experiments that they would normally have done in the science courses which they were taking at the time. Those people who were unable to take their laboratory work in the late afternoon did their work the following morning. All twelve of the people (six faculty and six students) completed the course. Through the cooperation of Dr. Schipper, who was primarily in charge of the laboratory work, we found it possible to have every student in the physical chemistry course to do two experiments.

The mobile laboratory attracted considerable attention on our campus, and was visited by many of our students and faculty. Its visit was most favorably received by those outside the sciences. The results of the course were better than we had anticipated. This statement is made in the light of our high hopes for the course at its inception. We did encounter the problem of crowded scheduling as we had anticipated, but we felt that this was not a matter of more than slight concern in the overall picture. The difficulty from this source was less than we had anticipated. Our faculty members feel that they benefited greatly from the visit of the mobile laboratory. Following this abbreviated course two of our faculty members attended the full four weeks radioisotope techniques course at ORINS. One of our students expressed student reaction quite well in saying, "The best thing about the visit of the mobile laboratory was the association with its director and staff members. Of course the introduction to the techniques was valuable and important, but the insight into the thinking of the director and his staff was most helpful. Working with new types of equipment and materials explained more the principles of nuclear chemistry than any text book could have."

In retrospect, we would encourage any other small college that has the opportunity to have the mobile laboratory visit its campus. The problem of scheduling is one which must be faced realistically in advance if the maximum benefit from the visit is to be obtained.

CONCLUSION

On the basis of the experience and the reactions of the staff and participants, recommendation was made to the U. S. Atomic Energy Commission that the third unit be constructed and put into operation in the southern region during the fall of 1959. A tentative schedule has been made for colleges to be visited in the 1959-1960 school year.

It would seem that this program would be a most effective approach to the problem of updating colleges in this special field. It appears that its usefulness will be primarily restricted by the limited number of vehicles and the difficulties in locating suitable staff for the lecture presentations.

NEWS OF TENNESSEE SCIENCE

Professor T. M. N. Lewis of the U T department of anthropology will serve as director of the Frank N. McClung Museum when it is built on the U T campus in Knoxville. The building, plus the tract of land on which it will be constructed, are being financed by a $650,000 bequest from the estate of the late Judge and Mrs. John M. Green of Knoxville. The building will be a memorial to Mrs. Green's father. Under terms of the Green wills, the McClung Museum will be "used for display, preservation and study of paintings, works of art, objects of natural history, historical objects, and such other uses and purposes as generally appertain to museums."

Dr. Amos I. Chernoff of the U T Memorial Research Center has received a grant of $23,725 from the National Institute of Health to continue studies of abnormal hemoglobins and myoglobins. At present Dr. Chernoff is engaged in studies of muscle myoglobin of persons suffering from muscular dystrophy, as well as certain other types of hereditary diseases.

Dr. Stanfield Rogers, director of the U T Memorial Research Center, has received a grant of $282,130 from the Public Health Service to further his studies of virus-induced tumors. Dr. Rogers will study the mechanism of action of the Shope papilloma virus.

Dr. A. C. Cole, Professor of Entomology at the University of Tennessee, has received a National Science Foundation grant of $3,700 for a continuation of revisionary studies of the ant genus *Pogonomyrmex*. Dr. Cole has been elected Chairman of the Teaching Section of the Entomological Society of America. Dr. Cole has also been elected President of the North American Section, International Union for the Study of Social Insects.

Dr. Michael D. Coe, Assistant Professor of Anthropology at the University of Tennessee, spent the winter quarter in Costa Rica on an archaeological expedition for the Institute of Andean Research, Inc., of New York City. Dr. Coe found indications that the latest Costa Rican Indians may have developed some industry. In huge shell mounds he found large quantities of murex shells, the mollusk which secretes a purple dye.

Dr. Sidney A. Cohn, associate professor of anatomy at the University of Tennessee Medical Units in Memphis, has been awarded a $39,000 research grant by the Dental Section of the United States Public Health Service. The grant will support studies on the incidence and severity of disease of the supportive tissue of teeth which have lost contact and function due to the extraction of the corresponding teeth in the opposite jaw.

Dr. Roger T. Sherman, assistant professor of surgery at the University of Tennessee College of Medicine at Memphis, has been awarded a $33,000 research grant by the Medical Research and Development Command of the U. S. Army. Dr. Sherman is investigating the response of the body to artificial internal organs constructed from plastic materials.

Dr. Ernest Daigneault, instructor in pharmacology at the U T Medical Units in Memphis, is making a study of yttrium, a derivative of strontium, under a $10,082 research grant from the Atomic Energy Commission. He is investigating methods of making the tissues of the body release to the radio-active element so that it can be safely excreted without damage to the tissues.