A Proposed Work Study Program for Technicians in Radio Pharmacy

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A PROPOSED WORK STUDY PROGRAM FOR

TECHNICIANS IN RADIO PHARMACY

Jerome J. Glass

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment
of the Requirements for the Degree
of Master of Arts.

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LIFE OF THE AUTHOR

Jerome J. Glass was born on Chicago's South Side on April 14, 1926. After attending Sawyer Avenue Grammar School from 1932 to 1940, he went to Gage Park High School from 1940 to 1944. Upon graduation from high school, he went to Roosevelt University from 1946 to 1948. He attended the University of Illinois College of Pharmacy from 1948 to 1952, and received his degree of B.S. in Pharmacy.

He became a Registered Pharmacist in 1952 and was employed in retail pharmacy operations. In 1958, he attended night classes at Foreman Branch of the Chicago Teachers College where he earned sufficient credits in education to begin teaching in Chicago high schools in 1961. While teaching, he also worked as Registered Pharmacist in charge of narcotics at Presbyterian-St. Luke's Hospital.

In 1965, he began attending Loyola University Graduate School, seeking a M.A. in Education - Administration and Supervision. In 1966, he returned to retail pharmacy where he was employed as a store manager until April, 1968. At this date, he went to Wesley Memorial Hospital in the newly created capacity of radio-pharmacist, which he holds today.
TABLE OF CONTENTS

LIFE OF THE AUTHOR........................................ii

CHAPTER I. INTRODUCTION...................................1

II. THE PRACTICE OF RADIO-PHARMACY.......................4

Purchasing - pre-calibration - receiving - storage -
inventory - dispensing - dispensing calculations -
assay - labeling - nuclide generator (kow) - disposal -

III. DETERMINATION OF EDUCATIONAL OBJECTIVES...............21

Raw data #1 - desirable traits - desirable objectives -
medical community - recommended objectives - philosophy
of education - psychology of education - selecting
objectives - final objectives

IV. CURRICULUM GUIDE.........................................30

Concept - content - learning experiences

V. EVALUATION..................................................42

Observation sheet - analysis of observation sheet -
tests - answers

VI. SUMMARY AND CONCLUSION................................56
CHAPTER I

INTRODUCTION

Although the use of radio-isotopes in medical practice has a long history, only recently have they reached the extent of usage that they enjoy today. These isotopes are used in two ways; either in the treatment of disease, therapeutic use, or to help diagnose a disease, diagnostic use.

As a diagnostic tool, some short-lived radio-active materials can be so processed that they will tend to concentrate or localize in specific areas of the human body. When this localization takes place, the person or patient may then be brought in close proximity to highly sophisticated machinery, e.g., the Gamma Camera, which reads the intensity of radiation, or lack of it, in the specific area in question. From this information, a properly trained physician can make a diagnosis concerning certain types of diseases and/or body malfunctions.

The processing of radio-active material for administration into the patient's body is generally identical with the preparation of ordinary pharmaceuticals. Until very recently, this work was being done by chemists essentially on a research basis. As the volume of work increases and the procedures move out of the research laboratories and into a consistant production type of situation, problems in pharmaceutical handling arise, and it is becoming apparent that it takes a pharmacist to produce and

1
handle pharmaceuticals. Basically, the chemist has a problem to solve and will take whatever steps are necessary to effect a solution. The pharmacist is concerned only with the constant production and dispensing of the materials in the best and most highly efficacious form possible. The pharmacist seeks to solve no fundamental problems, but rather endeavors to keep a continuous supply of highly usable material available at all times.

Although this realization is apparent to many of the physicians who act as administrative heads of Departments of Nuclear Medicine in various institutions, very frequently the procurement and training of personnel is a problem in itself, due to a chronic shortage of personnel and their lack of training.

Very little is written about the training, pre-requisites, duties, responsibilities, performance levels and jurisprudence with respect to the radio-pharmacist. Indeed, the only references available were: 1) a press release from the University of Southern California announcing a "Training Program for Specialists in Radio-Pharmaceuticals" under the auspices of the University's College of Pharmacy, and 2) references to the training of radio-pharmacists by a Doctor Beierwaltes.¹ These references were made during a symposium discussion on the Reduction of Radiation Exposure in Nuclear Medicine at Michigan State University on August 7-9, 1967. Doctor Beierwaltes contributed

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a paper to the symposium on training and manpower development. While the formalized training of radio-pharmacists is just beginning little doubt exists about the eventual need for auxiliary help; and, so, the subject of this paper. Since little has been published about the training of radio-pharmacists nothing has been published about the training of radio-pharmacy technicians.

This paper will delineate the areas of responsibility of a radio-pharmacy. It will establish that phase of activity within the radio-pharmacy which would lend itself to auxiliary help, and it will present a teaching procedure to train people for such positions.

Chapter II is a detailed explanation of the fundamental operations carried out in the practice of radio-pharmacy. Chapter III develops the educational objectives of a work-study program for radio-pharmacy technicians; and Chapter IV is a curriculum guide embodying the previously determined educational objectives. An evaluation procedure for student progress is offered in Chapter V, with the summary and conclusion the content of Chapter VI.
CHAPTER II
THE PRACTICE OF RADIO-PHARMACY

When an element, which has the property of radio-activity, is used in the treatment of human beings, whether to diagnose or to treat a disease, it becomes a pharmaceutical. It is just as much a pharmaceutical as any other element which might be used in any one of thousands of compounds regarded by the medical profession as essential to the chemo-therapeutic treatment of human ills. The one distinguishing feature of a radio-pharmaceutical is its radio-activity. This radio-activity gives it its new, unique, and fast emerging utility as a diagnostic tool and as a therapeutic treatment. Elements, compounds, materials or whatever else you choose to name them, must meet the levels of pharmaceutical efficacy required of conventional pharmaceuticals in addition to their radio-activity. To accomplish this requires the services of the one individual expressly trained for such a task, the pharmacist.

In endeavoring to establish the areas of performance and corresponding responsibilities of a radio-pharmacy, it is logical to delineate this relationship. The functions required of a radio-pharmacy with respect to a Department of Nuclear Medicine are identical with those functions required of a hospital pharmacy with respect to a hospital. Specifically, a hospital pharmacy will order, receive, check for content and purity, store, inventory, dispense, compound, manufacture, keep records and dispose of pharmaceutical
products. This is precisely the functions of a radio-pharmacy with the added complication of avoiding the radio-active nature of the pharmaceutical. This would include radio-assay, dose calibration, specialized receiving and disposing procedures, along with added duties in every area of the functioning operation.

The purchase of radio-active materials is unlike most other drug purchases, for it is truly a perishable. Since the material is ordered in terms of millicuries or microcuries (one thousand microcuries is equal to one millicurie, just as one thousand micrograms is equal to one milligram), a concern must be focused on the rate of radio-active decay which is commonly known as the half-life ($T_{1/2}$). This term, half-life, is used to denote that a given radio-active element will lose one-half of its radio-activity in a pre-determined length of time. For purposes of illustration, let us assume that a given quantity of radio-active element $x$ has a half-life of one hour. At the end of one hour, this element has lost one-half of its radio-activity. At the end of the second hour, it does not lose the other half of its radio-activity but rather it loses one-half of the radio-activity that was remaining in the element at the end of the first hour. So that, if the original amount of radio-activity was 24 millicuries, at the end of one hour, it is 12 millicuries, and at the end of the second hour, it would be half of 12 or 6 millicuries, and so on.

Some manufacturers will sell their radio-pharmaceuticals with a certain amount of pre-calibration. This is analogous to receiving a small amount of "free goods". Wherein the ordinary purchase would involve a specific
amount of activity for a certain date, then the manufacturer would set the
date up several days, thus shipping more radio-activity than ordered and more
radio-activity than being charged for. Ordering is done in this manner.
The purchaser orders a specific radio-pharmaceutical and specifies that it
is to have a certain amount of radio-activity (usually in terms of milli-
curies (mCi) at the time it is received.) If, for example, an order of Radio-
Iodine was given that was to have an activity of 5mCi for the first of the
month, the manufacturer may send this same material but with enough radio-
activity so that it is 5mCi on the third of the month, which means that on
the first, there is actually 7mCi of radio-activity. This extra amount of
radio-activity is called a variety of names by the different manufacturers,
but it amounts to the same thing, namely extra radio-activity sent without
cost and used either as a sales promotional inducement or to compensate for
any loss incurred during shipment, such as delivery taking longer than planned
in transit. This can be utilized by the radio-pharmacist to purchase effec-
tively for the best economy.

Receiving radio-pharmaceuticals varies considerably from the receiving
of any other item. Under ordinary circumstances, receiving involves the
acceptance of only properly consigned goods and the non-acceptance of goods
consigned to somewhere else. In the case of radio-pharmaceuticals, this is
ture also, but since the material is radio-active and emits radiation even
through the lead shipping shields and cartons (in most cases), the material
must be given prompt attention and placed in a pre-selected location where
few, if any, people come in close proximity so that they are not exposed
unnecessarily and innocently to radio-activity. Checking can become quite involved. Upon opening the carton, the radio-pharmacist should always maintain a visual inspection. If there is any wetness, or any type of crystalline or dried or powdery material on or near the radio-isotope container, then the shipment itself becomes suspect to damage and perhaps subsequent emission of radiation. One should use tongs, and not hands, in handling such a container. An appropriate monitoring device should be used in order to measure the amount of emanating radio-activity. If everything appears in order, then a wipe of the container should be made, and this wipe measured for any radio-activity it might have picked up. A wipe consists of a small piece of filter paper that is rubbed against or wiped upon the container, the idea being that if there is radio-activity contamination on the surface of the container and invisible to the naked eye, then some of it would be transferred to the filter paper for detection purposes. It is always a good idea to wear disposable plastic gloves whenever handling these radio-active materials. These gloves will not usually block or shield the individual from radiation, but in the event this individual does touch a contaminated object and gets radio-active material on his hands, then mere disposal of the gloves in a proper container (lead-lined) will free him from most, if not all, of this radiation contamination.

Once the shipment is received and properly checked for contamination, it is necessary to ascertain the authenticity of this material with respect to what was ordered. At this time, the techniques of determining radio-chemical purity are not applicable to this paper, but through the use of paper chro-
matography and a multi-channel analyzer, one can determine whether or not his order has been properly filled.

The storage of radio-pharmaceuticals presents some problems. Despite the fact that these materials are encased in carriers or a shield made up of a dense material (usually lead), there is still a part of the radio-activity that will go through the shield and into the surrounding area. This radiation will also ionize the air in its vicinity which then presents a second health problem. The solution commonly used is to place all radio-active pharmaceuticals (except those that must be kept in a refrigerator which has leaded walls) in a fume hood.

By placing good and sufficient lead in the hood to form small structures, and by placing our material in these structures, it is possible to eliminate the two prime cautions of storage. The air circulation of the hood draws out the ionized air and ejects it into the outside atmosphere while replacing it with room air. Assuming that the internal dimensions of the hood are sufficiently large, it presents no real difficulty in building an adequately shielded area out of lead bricks. (These have the same dimensions as common house bricks but are made of solid lead.). They are used to build small structures in the same manner house bricks would be used that would effectively block out any radiation that leaked through the carriers.

Wherever a situation exists that embodies any type of goods, and these goods are kept until they are to be sold, then you have a need for inventory control. Classically, in a retail or wholesale operation, an inventory is taken at specific intervals which may be annually, semi-annually, or even
monthly. By having close count on the amount and type of goods on hand, and by knowing what is likely to be sold, it is possible to buy more goods of various varieties in such a manner as to effect savings on purchases. Larger quantities usually result in less cost per unit and as consumer demands change, so can the buying practices of the individual to correspond with consumer trends. The self-same problem exists in the operation of a radio-pharmacy. How much of each isotope should the pharmacist purchase and when would such purchases best be made? It is easy enough to keep a record of what was used of each isotope and when the quantity of activity seems to be running low, simply order more. This method is crude but it would suffice if the number of radio-pharmaceuticals were small. In a situation where as many as fifteen different radio-pharmaceuticals are used, the ideal system would be a running inventory which would tell at a glance how much of a particular radio-pharmaceutical is on hand in terms of radio-activity. Such a system can be developed merely by this procedure. Upon receipt of an isotope shipment and after it has been properly checked for external contamination and also checked for the level of radio-activity received, (you should receive the amount of activity you ordered), proceed to draw a line of decay on two phase Semi-log graph paper. Use the bottom horizontal line on the graph paper to denote time and the vertical left-hand marginal line to denote activity. Since the newly arrived radio-isotope specified on the label has a definite activity at a specific time (usually a date), set a dot on the interval of the prescribed time and activity. We know the rate of decay for all known radio-isotopes which is very often given in
percentage form. Radio-isotope X will decay y% in a time interval. For example, $^{131}$I will decay down to 91.8% of its original activity in one day. In two days, there will be 84.2% of the original amount of activity remaining. In three days, only 77.3% is left and in four days, the amount of radio-activity of a sample of $^{131}$I is 71.0% of what it was four days previously. Therefore, by plotting several points on the graph using the original amount of activity and decreasing the activity with time according to the known rate of decay, a decay line can be established. Upon removal of an amount of activity at a specific date, extend a straight line downward from the decay line. This perpendicular downward line should be of such length as to represent the amount of radio-activity removed. Then, for subsequent decay, a parallel line to the decay line may be drawn. For each withdrawal, a representative line is dropped, and a parallel decay line is drawn. As an example, note the graph on page 11 as this detailed explanation is presented.

The bottom line is divided into days while the left marginal line has notations with respect to activity. The number 100 represents 100 microcuries (uCi) and the number 1,000 represents 1,000 uCi which is equal to 1 millicurie (mCi). At the top of the page is the isotope, the lot number, and the manufacturer. Now, on March 13th a shipment of 5mCi of I-131 was received and found acceptable. On zero days a dot is placed at the 5000 spot. Since the half-life ($T_{\frac{1}{2}}$) of this isotope is approximately 8 days and since the decay for one $T_{\frac{1}{2}}$ is defined as half the amount of activity present, then at 8 days the 5mCi will have decayed down to 2.5mCi and a dot
Activity in Microcuries

Time in Days

- 3-13-69
- 3-15-69
- 3-17-69
- 3-18-69
- 3-19-69
- 3-20-69
- 3-21-69
- 3-22-69
- 3-23-69
- 3-24-69
- 3-25-69
- 3-26-69
- 3-27-69
- 3-29-69
- 3-31-69

150 uCi
was placed at that intersection. At 16 days or another half-life later, half of the present activity from 8 days would amount to 1.25mCi and a dot was also placed at this intersection. A line connecting these points gives the decay line for the amount of this isotope. On March 7th a withdrawal of 150uCi was made. A perpendicular line representing 150uCi was drawn downward (in this case 1\frac{1}{2} boxes) and a parallel line to the decay line was drawn representing the next day. On March 18th a withdrawal of 150uCi was made again. Again a perpendicular line representing 150uCi and a parallel line to the decay line were drawn. The same procedure holds true for March 19th and 20th. After March 20th there were no more withdrawals until March 24th, so the parallel decay line was merely extended to the graph line representing March 24th. As of March 24th the process resumed and 150uCi were withdrawn each day up to and including March 27th. At each interval a perpendicular line of sufficient length to represent the amount of activity withdrawn was placed on the graph and a parallel decay line to the next day was drawn. At any time during these described 10 days, the amount of radioactivity remaining in the bottle could be readily ascertained by looking at where the graph line is located in relation to the number of days decay. At 200uCi a reorder line was drawn indicating that as the inventory line approaches the operator should consider reordering so that he never runs out of stock.

There are advantages and disadvantages to this system. The chief disadvantage is the time it requires. It must be kept up to date and each withdrawal of radioactive material must be recorded. However, it provides two positive functions: 1) the operator can tell at a glance the amount of activity he
has within the container, and 2) he can in a positive manner ascertain the rate of usage of the material and proceed to buy economically, balancing the usage against decay and purchasing with respect to pre-calibration and quantity. There are no set rules regarding the graph, in that the reorder line may be set at any level the operator wishes or may even be eliminated. The interval of spaces that represent time in variable and can be adjusted to suit the convenience of the operator. The points from which the decay is drawn need not be based on half-life but can be determined using any suitable time interval. Essentially there are three fundamental parts: 1) a decay line, 2) a perpendicular line representing the amount of activity taken out of the container, and 3) a line parallel to the decay line connecting each amount withdrawn.

One of the primary functions of the practice of pharmacy is the act of dispensing medication upon the order of a physician. Accordingly, one of the primary functions of the practice of radio-pharmacy is the act of dispensing the radio-pharmaceuticals upon the order of a physician. While the fundamental goals are the same in both areas, the approaches and requirements to attain these goals are quite different. The customary hospital order for in-patient medication consists essentially of the patient's name, location (room number), the drug requested, the strength of the drug (usually given in terms of weight, volume, or units), and the frequency of administration. The demands upon the radio-pharmacist in this area of dispensing is considerably more complicated. Primarily what he dispenses is a specific amount of radio-activity, which comes from the desired radio-isotope and which itself may be attached to a larger molecule. The duty of the radio-pharmacist
in the dispensing of radio-pharmaceuticals embodies the added condition of radio-activity to those materials. The largest problem lies in his ability to dispense that volume of radio-pharmaceutical which contains the required amount of radio-activity. This problem can be solved if we understand the meaning of radio-assay, which is nothing more than the amount of radio-activity in a milliliter (ml) of liquid. This usually in terms of milli-curies so that the radio-assay is really an expression of radio-activity concentration. If we know how much radio-activity there is in a milliliter of solution and we know how much this isotope decays in a given period of time, then we can calculate the amount of radio-activity remaining in each milliliter, and adjust the amount of material or milliliter of solution to coincide with the amount of activity desired by the physician. Here is an example of how this might be done: Let us say that we have 100mCi of I-131 in a solution of Sodium Iodide. Let us further assume that we have had this solution for a period of three days when a physician's order is received indicating the dispensing of 1.0mCi. The question would be "How much of this solution contains 1mCi at this time?" We know that in three days I-131 will decay so that there is only 71% of its original activity remaining. Taking 71% and converting it to a usable number embodies moving the decimal point two places to the left, that is,.71. Taking this number (.71) and multiplying it by the original assay of 100mCi/ml we would get 100 X .71 = 71mCi/ml at the present time. Then dividing 1.0 by 71 we would get .013 ml of liquid which would have 1.0mCi of activity. There are some instances where the present assay must be determined by division instead of multipli-
cation. Such a condition would be pre-calibration. Up to now we have considered decay only in the past sense wherein the assay was performed at a particular time, and at some later time the remaining radio-activity is determined by the multiplication of the original assay by the decay factor. In those instances where radio-active material is received and the original assay is not for the date received, but for several days ahead, the computation is done by dividing the original assay by the decay factor to get the present assay. For example, a shipment of I-131 is received on the 1st of the month and assayed for the 15th of the month. On the 3rd day of the month it becomes necessary to withdraw a required amount of activity on a physicians request. In order to compute the present assay, which is 12 days in the future instead of the past, divide the original assay by the decay factor instead of multiplying them. Arithmetically for future assayed materials:

\[
\text{Original Assay (mCi)} \div \text{Decay Factor (Numerical equivalent of the \% of activity remaining)} = \text{The present assay}
\]

Using this present assay, it is then possible to continue as previously indicated to determine the necessary volume required for the amount of activity requested. All of the information pertinent to the determination of this volume should be entered on a form so that it would be possible at any time to trace back and determine what the patient received, where it was obtained, and how it was arrived upon. Such a form is shown which contains the following information: Date, weight, isotope used, lot number, assay time, decay (in days, hours, and minutes), original assay, decay factor, present assay, dose requested, milliliters dispensed, signature of dispenser, signature of ad-
ministering physician or technician, and time of administration. A sample of such a form is as follows:

**DOSE CALCULATION SHEET**

<table>
<thead>
<tr>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date ___________________</td>
</tr>
<tr>
<td>Weight __________________</td>
</tr>
<tr>
<td>Perchlorate Yes__________ No__________</td>
</tr>
<tr>
<td>Isotope</td>
</tr>
<tr>
<td>Lot Number</td>
</tr>
<tr>
<td>Assay Time (Date)</td>
</tr>
<tr>
<td>Decay Days Hour(s) Minutes.</td>
</tr>
<tr>
<td>Original Assay mc/ml uc/ml</td>
</tr>
<tr>
<td>Decay Factor</td>
</tr>
<tr>
<td>Present Assay mc/ml uc/ml</td>
</tr>
</tbody>
</table>

Dose: \(\text{mc}(\text{uc})\) ml \(\text{mc}(\text{uc})\) ml

Drawn up by ____________________

Given by ____________________

Time ____________________
Upon withdrawing the proper volume from the vial, the syringe should be placed in a lead shield which consists essentially of a piece of lead pipe with a flat base welded on. Inserting the shield with needle and cover attached to it into the central core of this shield gives good radiation protection and allows for convenience in transportation. In order to reduce the possibility of confusion, a small peelable label with the patient's name should be placed on the outside of the carrier. This carrier containing the injection and the dose calibration sheet should go together with the carrier labeled with the same as that on the dose calibration sheet. This assures that the patient will get the proper dose, and it is analogous to a label put on a container containing ordinary medications which has the name of the patient written on it.

The art of compounding a prescription in conventional pharmacy has its parallel in radio-pharmacy with the process of taking a radio-active atom and attaching it to a larger molecule. This is called labeling. The purpose of labeling is to better localize the radiation energy in a particular area or organ of the body. We know that certain types of molecules have an affinity for specific organs and will deposit in these organs whenever possible. An example of this is the affinity of Iodine for the thyroid gland. If we could make the Iodine radio-active, its deposition in the thyroid gland would make possible the gleaning of a great deal of information; such as the gland's size and shape, the amount of blood it receives, and the presence of non-functioning areas.

Labeling can be done in two fashions: 1) by a chemical reaction wherein
the radio-active atom becomes a part of a molecule which will travel and
deposit (localize) in the part of the body desired, or 2) by physically en-
trapping one or several radio-active atoms in a precipitate. Assuming that
the particle size of this precipitate is sufficiently small so as not to
cause an adverse physiological reaction, these radio-active particles will
deposit in the desired area or organ. This, too, then would become radio-
active. In each case this is the desired situation.

Those reagents used in labeling procedures, especially one which embodies
a chemical reaction, may be purchased on the commercial market in sterile
and pyrogen free form. In those instances where a registered pharmacist is
present, such purchases should not be necessary. The manufacture of reagents
could and should be done in a manner acceptable to the Food and Drug Admin-
istration. All items should be sterile and pyrogen free. Each lot (or batch)
should have a lot number.

Under the heading of manufacturing could be the production of solutions
of selected radio-active elements. For the most part (although not in all
cases) these solutions can be purchased from radio-pharmaceutical suppliers.
Another way of supplying needed radio-activity is through a device called a
radio-nuclide generator. The process is to take a long-lived parent nuclide
which produces by its radio-active decay, a short-lived daughter nuclide,
and arrange this in such a manner that the short-lived daughter nuclide can
be drawn off periodically leaving the long-lived nuclide to continue decaying.
This arrangement is accomplished simply by placing this long-lived parent
nuclide in what is essentially a glass tube open at both ends. The material
may be held in the tube (commonly called a column) by a constriction in the
column's construction coupled by an appropriate filter. By pouring an aqueous solution into the top of the column, it is possible to wash out, by physical or chemical means, the short-lived daughter nuclide. This solution can be treated (sterilized) and used while the longer-lived parent nuclide remains in the column and continues to decay. This type of generator is commonly called a kow, and its operation, although it is primarily an eluting process, is commonly called milking. So milking a kow in this discipline is tantamount to the process of eluting a radio-nuclide generator.

The disposal of unused material and contaminated objects is generally accomplished merely by time. In most cases, these materials and objects are allowed to stay in a secluded room for a prolonged period of time wherein the activity has decayed itself down to what is considered a safe level. At this point, all liquids are disposed of through the sewerage system, and all solids are incinerated.

The practice of radio-pharmacy entails a combination of pharmaceutical and radio-isotope handling procedures. The scope of responsibility of the radio-pharmacy technician must be identical with that of the radio-pharmacist. The demarcation line is that the technician need know only the mechanics of his duties which would enable him to function and be productive. A comprehensive depth of scientific understanding is not necessarily a prerequisite for this type of activity, but a basic sense of scientific essentials is necessary. Primarily, a good grounding in general chemistry, fundamental physics, and mathematics courses, which include besides arithmetic, primary and advanced algebra and geometry should suffice. This
educational background would be minimal but should be adequate, and a technician should be able to advance through daily practice into whatever techniques would be presented to him.

SUMMARY

A radio-pharmacy is, by definition, a pharmacy that handles radio-active material. Its functions are ordering, receiving, checking (for purity and content), storing, inventory, dispensing, labeling (compounding), manufacturing, and disposal.

Ordering is done with pre-calibration in mind. Receiving and checking includes wipes for contamination. Storing encompasses lead storage areas and a system of inventory control. In dispensing, calculations are necessary. Labeling and manufacturing functions are dependent upon the items desired and the procedures to produce them.
CHAPTER III

DETERMINATION OF EDUCATION OBJECTIVES

While it is certainly possible for a person to subjectively decide upon what a student should learn and to what extent, the author chose to follow the method set forth by Ralph W. Tyler in his book, *Basic Principles of Curriculum and Instruction*, University of Chicago Press, 27th Impression, 1967. Here Dr. Tyler indicates that in order to develop a curriculum, several steps are to be followed. He states that initially the objectives of the course of study must be determined. In order to do this, there are several sources which must be taken into account. These are: 1) the students themselves, 2) allied and associative people of the community, 3) the worker's own ideas, and 4) the thoughts of subject specialists. In each case, these people present their own thoughts concerning course objectives, and this information is left for the worker to determine which points, in his opinion, are valid and/or pertinent.

These opinions or objectives are compared with a predetermined philosophy of education and also a predetermined psychology of education. If these objectives agree with the philosophy, then a + mark is assigned. If there is disagreement between the objectives and philosophy of education, then a 0 mark is assigned to it. The same system holds true in comparing the determined objectives with a psychology of education. Those objectives that
have a + in both columns are accepted ultimately as being the course objectives. The learning experiences are then adjusted to give these objectives the three criteria of organization, namely, continuity, sequence, and integration.

This paper considers the instruction of only a single individual at any given time and on a one-to-one basis with the instructor. In this type of condition, the overall view of a classroom situation and a learning situation directed toward a multiple subject level does not apply. By its very nature and its inherent danger to the health of the operator, instruction on the handling and manipulating of radio-active materials should only be done on an individual basis. An identical approach to studying the students themselves as a source of educational objectives cannot be used in this individualized learning situation as with a large group of students who are observed, interviewed, and questioned as a group. Since this is an individualistic approach, a list was drawn up from a subjective viewpoint, listing every trait and characteristic that would supposedly be embodied by the ideal student. This is called Raw Data #1 and consists of the following characteristics: eager, inquisitive, questioning, anxious, enthusiastic, fun-loving, hard-working, corrective, impatient, thoughtful, social, sincere, ambitious, pressured, independent, and aggressive.

From this list, those items that are considered desirable traits are set apart, and, from the point of view of the subjective observation of the learner himself, become part of the desirable objectives. In this case, those traits that would be most conducive to the specialized problems of
radio-pharmacy were judged to be: ambitious, sincere, aggressive, social, inquisitive, hard-working, and thoughtful.

With this second list, called desirable traits, the following desirable objectives were concluded that embodied, in fact or in essence, all of the desirable traits. These desirable objectives are as follows: a fostering of sincerity and ambition, the development of a mastery of the content material, an acquisition of a comprehensive understanding of the absolute necessity of the very highest working standards possible, the encouragement of hard work, accompanied by initiative and thought toward his job, and a comprehension and realization of the dangers involved.

The opinion of the community is also important in curriculum construction, and, in this instance it would be the medical community. Objectives, as listed by allied and associative people, encompasses the thoughts of individuals directly engaged in some area of nuclear medicine activity or radiology. Of the people interviewed, an X-Ray technology student, who spent several weeks in the Department of Nuclear Medicine, thought that the responsibilities of the position, the necessary high degree of accuracy incumbent upon the subject's working habits, neatness of personal appearance and of the working area, and promptness with regard to executing the duties prescribed should be the educational objectives. Miss Brynn Borne, Chief Technician, Department of Nuclear Medicine, Wesley Hospital in Chicago, gave these thoughts as objectives: to understand the fundamental action of the chemicals which the subject is handling, a realization of the meaning of half-life and its effect upon the activity of radio-active materials, to
understand how the radio-pharmaceuticals are produced, and a realization of the dangers involved in working with radio-active materials.

Dr. J. L. Quinn, M.D., Director of the Department of Nuclear Medicine, Wesley Hospital, feels that the course objectives should encompass a cognizance of personal cleanliness, an understanding of sterility techniques and of pyrogen testing, and a working knowledge of the fundamentals of radiation protection. Dr. M. Usher, M.D., Director of the Department of Nuclear Medicine in St. Mary's Hospital and the Jewish General Hospital of Montreal, Canada, feels that this course should instill an awareness of the implications and dangers of radiation, a realization of therapeutic and diagnostic possibilities of nuclear medicine, and an intimate knowledge of the correct dosage of radio-active materials depending upon which radio-pharmaceutical is used and the type of diagnostic scan being sought. Dr. B. Westerman, Ph.D., Radio-Physicist, Wesley Hospital, feels that the educational objectives for instruction of this nature should be to instill a respect for radio-isotopes as potentially dangerous materials from the point of view of both the worker and the patient, to become competent in the ability to carry out the required routines, to be able to control others to the extent that safe procedure is always followed in handling isotopes, and to understand the chemical procedure used in labeling of radio-pharmaceuticals.

From the medical community, there is a variety of thoughts as to what objectives are desirable. A listing of these objectives, irrespective of origin, is as follows: responsibilities of the job, accuracy, neatness, promptness, an understanding of chemical composition of the materials, half-life, how these chemicals are produced and the dangers of working with radio-active materials,
personal cleanliness, sterility techniques, pyrogen testing, radiation protection, an awareness of implications and dangers of radiation, a realization of therapeutic and diagnostic possibilities of nuclear medicine, to instill respect for radio-isotopes, to become competent, to understand radio-labeling procedures, and to assure safe handling procedures.

To understand radio-labeling procedures, it is obvious that a great deal of emphasis is placed upon the physiological dangers involved in the handling and manipulation of radio-isotopes. Also, concern is shown for a positive comprehension of the procedures used in nuclear medicine. Other major points indicated are high personal and professional standards and an elevated level of professional competence. A consensus of the educational objectives recommended by the medical community would be: 1) the development of a knowledge of the dangers inherent with working with radio-active materials, 2) an understanding of the procedures used in nuclear medicine and a comprehension of the part played by the radio-pharmacy, 3) to foster the maintenance of the highest standards possible for personal, environmental, and production cleanliness, and 4) to instill competence with respect to required duties.

Under ordinary circumstances, the thoughts of other subject specialists should be solicited and the objectives that they would put forth should be listed and entered for consideration. However, in this area at this time, there are no known people who practice radio-pharmacy who have experience in the training of technicians for that practice.

The educational philosophy which is used states "that every student be given a comprehensive picture of the subject area, including not only the immediate mechanics of the subject, but any and all corollary and associative
thoughts in order to provide as complete an understanding of the subject as possible." This includes new techniques, new approaches, and new devices. The intent is to give the educational organization continuity, sequence, and integration. Where continuity indicates repetition, sequence indicates a vertical developmental progression that will encompass the repetitive material and go on to a broader and deeper involvement. Integration is in reference to a horizontal interrelationship of other curriculum experiences.

The educational psychology involves the following principles of learning:

Sensorimotor skills which are skills that become automatic in their execution and can be carried out simultaneously with other learned activities without interference.

Associational learning which is facilitated by emphasis of the new to the known. This can be done through review, explanation, classification, surveys, or any other device wherein a correlation can be shown between that which is known and that which the student is to learn.

Conceptual learning specific to this situation involves the perception of many conditions and interrelationships in terms of a common theme to form a concept.

Re-inforcement Theory or Stimulus-Response, championed by E. L. Thorndike and his descendents, who say that the formation of connections or bonds between stimuli and responses is essentially what learning consists of. Experience forms new bonds, and this formation is influenced by intensity, vividness, frequency, mood, and capacity of the subject, situation similarity, and resulting satisfaction or re-inforcement. The following laws of learning
summarize these conditions:

The Law of Effect - When a stimulus and a response connection (which is modifiable) has been made, if it results in satisfaction, this connection is strengthened.

The Law of Exercise - This law consists of two parts:

1) Law of use that asserts that if a modifiable connection between a stimulus and a response is used with greater frequency, then the stronger that connection will be.

2) Law of disuse asserts that if a modifiable connection between a stimulus and a response is not used over a period of time, then there is a weakening of the strength of that connection.

The Law of Readiness - It is satisfying to act when a modifiable connection is ready for such an action, and to act when the modifiable connection is not ready is unsatisfying.

The Principle of Analogy of Assimilation means that when a person has no natural or learned response to a new situation, he will respond in a manner similar to an earlier response to a similar situation.

Following the previously described pattern, at this point, an examination is made in the light of the philosophy and the psychology of education with regard to the two lists of previously evolved desirable objectives. These desirable objectives will be listed, and if it concurs with the philosophy and psychology, a plus (+) sign will be placed under the proper heading. If it does not concur, then a zero (0) sign will be placed in the appropriate heading.
**DESIRABLE OBJECTIVES**

<table>
<thead>
<tr>
<th></th>
<th>Philosophy</th>
<th>Psychology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A fostering of sincerity and ambition</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>The development of a mastery of content material</td>
<td>+</td>
</tr>
<tr>
<td>3.</td>
<td>The acquisition of a comprehensive understanding of the absolute necessity of the highest working standards possible</td>
<td>+</td>
</tr>
<tr>
<td>4.</td>
<td>The encouragement of hard work, accompanied by initiative and thought toward the job</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>A comprehension and realization of the dangers involved</td>
<td>+</td>
</tr>
<tr>
<td>6.</td>
<td>The development of a knowledge of the dangers inherent with working with radio-active materials</td>
<td>+</td>
</tr>
<tr>
<td>7.</td>
<td>An understanding of the procedures used in nuclear medicine and a comprehension of the part played by the radio-pharmacy</td>
<td>+</td>
</tr>
<tr>
<td>8.</td>
<td>To foster the maintenance of the highest standards possible for personal, environmental, and production cleanliness</td>
<td>+</td>
</tr>
<tr>
<td>9.</td>
<td>To instill competence with respect to required duties</td>
<td>0</td>
</tr>
</tbody>
</table>

An inspection of this list shows a degree of repetition. Specifically, items numbered 3 and 8 repeat the idea of high working standards while items numbered 5 and 6 are repetitious of the awareness of the danger involved while working with radio-activity. Those items which were judged to receive a zero (0) mark in either the philosophy or psychology heading, or both, were numbers 1, 4, and 9. In each case, the central theme was a personality or character trait which does not fit into the stated philosophy
and cannot possibly be an educative objective for the purposes of this course. These personality traits should be present and might well be among the prerequisites of a person desiring such training.

Those desirable objectives which have a mark in both columns are:

Mastery of content material
High working standards
Realization of dangers
Understanding the job and its relationship to the entire nuclear medicine operational procedures

The final objectives restated are:

1) To understand the duties of the job and their relationship to the nuclear medicine operational procedures and to be aware of the dangers involved

2) To exercise alertness and possess a mastery of the content material

3) To develop personal skill and a desirable attitude toward the highest level of cleanliness and pharmaceutical efficacy possible

SUMMARY

The educational objectives are determined by asking representative people (in all the groups associated with the content area) for their opinion on what these objectives should be. These opinions are judged for their pertinence and are either discarded or utilized. Those that are utilized are called desirable objectives. A comparison of a philosophy and a psychology of education with these desirable objectives eliminates those that do not fit in this framework. The remaining desirable objectives are then restated and become the educational objectives.
CHAPTER IV

CURRICULUM GUIDE

This curriculum guide related to the development of a new concept in pharmaceutical education is akin in some respects to the old apprentice system of training. It deviates from this in that the apprentice and master educational procedure had no deliberate and internal goal structure. The instructional time was of such length that the assumption is made that the apprentice will meet all practicing situations. The only resemblance here and with the apprentice type training is the individualistic nature of instruction. There the similarity ends, as definitive learning experiences are elucidated, along with the educational conceptual motivation and the content material to be covered. The content of this chapter is designed to be utilized by a professional teacher, not only well-versed in the subject area, but competent in teaching techniques and methods.
CONCEPT
1) Familiarization with and the handling of radio-active material.

CONTENT
Definition of radio-activity
Manipulation of radio-active source

2) It is essential to have a basic understanding of the physics, of radio-activity, and chemistry.

CONTENT
Explanation of:

a) atomic nucleus, protons, neutrons, symbol, atomic number, mass number

b) isotopes -
normal form, stable form, unstable form, bombardment - cyclotron, atomic reactor - fission

c) characteristics of radio-activity, rate of decay, half-life (T\(\frac{1}{2}\)), types of radiation, alpha, beta, gamma
LEARNING EXPERIENCE

1) Take a sample of radio-active material of about 1 millicurie. With tongs, hold the sample approximately 10 feet from the alarm monitor. Slowly, bring the sample towards the monitor instructing the student to watch the gauge's increase in reading. Note the point at which the alarm sounds and the intensity of the alarm. Bring the sample still closer to the monitor noting to the student the increase in alarm intensity as the radio-active sample gets closer in proximity. This serves as a demonstration of radio-activity. Orally assign the student to submit three definitions of radio-activity taken from 3 different sources - dictionary, general encyclopedia, and any scientific authority.

2) Oral explanation of the nucleus of the atom
   Oral explanation of isotopes of elements
   Give reading assignment from pertinent text
   Assign questions from text to be answered

3) Detailed description of learning experience
   Oral explanation of rate of decay (half-life, T_1/2)
   Demonstration of types of radiation:

   Take a radio-active source of each of the three different types of radiation. Place a source and a monitor at a suitable distance from each other (depending upon the activity of the source), and between these, place a shielding substance which will absorb the particular radiation emitting from the source. Then switch shielding substances to demon-
strate their ability or lack of same to block a particular emission.
The three sources should be such that they emit alpha, beta, and gamma rays.
<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>CONTENT</th>
</tr>
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<tbody>
<tr>
<td>4) Since our physical senses do not make us aware of radio-activity, we should know the basic principles of detection devices.</td>
<td>Ionization chamber</td>
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<tr>
<td></td>
<td>Photographic film</td>
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<td></td>
<td>Geiger-Muller tube</td>
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<tr>
<td></td>
<td>Scintillation inter-action</td>
</tr>
<tr>
<td>5) In order to use radio-activity, there must be units and methods of measurement.</td>
<td>Units:</td>
</tr>
<tr>
<td></td>
<td>Curie, millicurie, micro-curie</td>
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<tr>
<td></td>
<td>Methods:</td>
</tr>
<tr>
<td></td>
<td>Scaler, ratemeter, ionization chamber</td>
</tr>
<tr>
<td>6) As there is a danger in the handling of radio-active materials, how can protection be achieved?</td>
<td>Shielding:</td>
</tr>
<tr>
<td></td>
<td>Absorption, beta and gamma rays</td>
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<tr>
<td></td>
<td>Inverse square law</td>
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<td></td>
<td>Time factor</td>
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</tbody>
</table>
LEARNING EXPERIENCE

4) Demonstrate and explain the basic principles of an ionization chamber. With suitable photographic film, demonstrate the ability of radio-activity to expose film. A repetition of the classic key experiment using an X-ray plate would be suitable.

Demonstrate and explain the basic principles of the Geiger-Muller tube.

Explain the basic principle of scintillation interaction.

5) Define and explain:

Curie, Millicurie, Microcurie.

Assign previous readings before making your definition and explanation. In order to encourage self-education, be sure that your definition and explanation is of such nature as to be an adjunct and/or clarification of the readings.

Demonstrate a scaler and a ratemeter and ionization chamber. Explain the differences and show wherein these differences are most useful.

6) Place Gamma and Beta emitting radio-active materials in lead pots or shields of varying thicknesses. With the monitor measure the amount of radio-activity that comes through the lead.

Introduce the inverse square law. Acquaint the students with its calculations and allow for several practice calculations.

Bring to the student's attention that time is an important factor. The less exposure time, the less resultant exposure.
CONCEPT

7) As this is also a pharmacy, there must be a working proficiency in metrology, and an understanding of the metric system of weights and measures.

8) The route of administration of most of the radio-pharmaceuticals is through intravenous injection. Therefore, these materials must be fit for injection in accordance with the standards set by the United States Pharmacopea and the National Formulary.

CONTENT

Weighing and measuring
Use of balances
Systems of weights and measurements

Sterilization:
Steam under pressure - autoclaving
Bacteriological filtration
Aseptic manipulation
Official sterility tests
Thioglycollate medium
Sabouraud medium

9) Parenteral solutions
Pyrogens, sealing, clarity, labeling
LEARNING EXPERIENCE

7) Provide the student with a meter stick and a set of metric weights, a scale, and a balance. Explain the difference between the scale and the balance. Show the metric system of linear measure and of weights. From these evolve the metric system of volumetric measure. Show the student units of the avoirdupois system and provide a conversion table between the two systems.

8) Allow the student to sneeze, cough, or expectorate into a thioglycollate culture media and incubate for 48 hours. Take some of this media and place under a microscope and allow the student to see bacteria from his own body. Take this media and divide into two aliquot portions. Autoclave the first aliquot and observe under the microscope. At the same time explain the principle and requirements for autoclaving. The second aliquot should be put through a bacteriological filter. Observe the filtrate under the microscope. To these two (now sterile) aliquot portions, conduct a transfer to sterile containers. Let one transfer be done using sterile equipment and with sterile techniques. The second transfer is to be done in a non-sterile manner with non-sterile equipment. Incubate these for 48 hours and observe under the microscope. During this procedure, explain and demonstrate proper aseptic techniques in handling and transferring material. Explain the United States Pharmacopeia requirements for sterility testing with respect to autoclaving and thioglycollate and sabouraud media.

9) Give the student suitable reading material covering parenteral solutions.
Emphasis should be placed upon pyrogens, what they are, their effect, and United States Pharmacopea Tests. Demonstrate the sealing of containers and compare clarity between acceptable and non-acceptable solutions. Give explanatory demonstrations on cleaning of apparatus, which includes preparation of glass bottles and rubber caps, labeling, and cleanliness.
<table>
<thead>
<tr>
<th><strong>CONCEPT</strong></th>
<th><strong>CONTENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>10) The handling and dispensing of radio-pharmaceuticals involve a record of decay, the idea of half-life, and the mathematics involved in assay and dosage calculation</td>
<td>Decay graph</td>
</tr>
<tr>
<td></td>
<td>Half-life</td>
</tr>
<tr>
<td>11) Assay of radio-active materials</td>
<td></td>
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<tr>
<td>12) Calculation of dosage</td>
<td></td>
</tr>
</tbody>
</table>
LEARNING EXPERIENCE

10) Take a list of decay factors of a convenient short-lived radio-isotope. From these decay factors, demonstrate how to draw a decay graph. Take a similar list of a different radio-isotope and allow the student to make such a graph. Show how this graph is used to determine the amount of radioactivity of a given sample once an assay has been made. Show the concept of a half-life. Do this by actual measurement of a short-lived radio-isotope while concurrently showing the half-life reading from a newly made graph. Explain how this is useful in activity computations for the present, future, and past.

11) Explain and demonstrate how:
To calculate the assay at the present time

Activity in Mc or uc/volume in ml = Mc/ml

To calculate the assay at a future time period

Assay at present X Decay factor = Future assay for given time period

Commit to memory and be able to use with proficiency

12) In all instances, the material must be previously assayed which would give you the activity at a certain time. If the assay was in the past, then the computation would be:

Original assay in Mc or uc/ml X Decay factor = Present assay

Activity desired/Present assay = Volume to be given

If the assay is for a future date

Future assay/Decay factor = Present assay
Activity desired/Present assay = Volume to be given

The student must commit this to memory and be able to use it with proficiency.
CHAPTER V

EVALUATION

The formulation of educational objectives and the organizing and selecting of learning experiences has been shown. Clearly an evaluation is necessary to indicate the degree that the learning experiences as organized and developed are actually producing the desired results.

Evaluation processes begin with the educational objectives, as ultimately the purpose is to ascertain the degree to which these objectives are being accomplished. The assignment of grades are particularly useless in this situation, as there is no point of reference. A grade per se has no meaning because it would not serve as a medium of comparison to another student, nor would it be indicative of achievement (achievement in this case relates only to performance). It would do little if anything to encourage further growth, and, as this is a one-to-one teaching situation, complete objectivity would be almost impossible. That level of performance which denotes the division between acceptable and non-acceptable is dependent upon the needs of the operating situation. Therefore, this evaluation will be done through the utilization of two tools: the evaluation sheet and frequent short tests.

The observation sheet is to be filled out four times during the course
of instruction, at the beginning and at learning experiences numbered 4, 8, and 12. This would show differences in behavioral patterns associated with the stated educational objectives as the curriculum progresses. It would serve as an indication, not only of student response, but also of the curriculum's ability to produce the desired behavioral changes. The observation sheet is as follows:
OBSERVATION SHEET - To reflect the establishment of the stated objectives

Observation Sheet - Check YES or NO to the following questions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Does the student daydream?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Are the orders filled promptly?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Is a mistake made daily?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Is a mistake made once a week?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Is a mistake made less than once a week?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Is a mistake made very rarely?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Is a mistake never made?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Is attention focused on the task at hand?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Is double checking done routinely?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Is there a place for everything and everything in its place?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Are directions followed precisely?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Are calculations accurate?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Is a given task completed within the range of acceptance or could it have been done better?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Is accuracy as precise as possible?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Is the student neat and clean?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Are mistakes quickly noticed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Are proper safety procedures used?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Does speed increase with practice?</td>
<td></td>
<td></td>
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<tr>
<td>19.</td>
<td>Are difficult or challenging situations welcomed?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>Is thought given to ways of improving the operational procedure?</td>
<td></td>
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</table>
An analysis of the observation sheet shows this breakdown in the light of the educational objectives. For the purposes of this section, the educational objectives are reduced to the following terms: alertness, understanding duties, skill, efficacy, cleanliness, and content. Following each item on the evaluation sheet, the related objective is given.

Does the student daydream? Alertness
Are the orders filled promptly? Understanding duties
Is a mistake made daily? Personal skill
Is a mistake made once a week? Personal skill
Is a mistake made less than once a week? Personal skill
Is a mistake made very rarely? Personal skill
Is a mistake never made? Personal skill
Is attention focused on the task at hand? Alertness
Is double checking done routinely? Pharmaceutical efficacy
Is there a place for everything and everything in its place? Cleanliness
Are directions followed precisely? Understanding duties
Are calculations accurate? Mastery of content
Is a given task completed within the range of acceptance or could it have been done better? Understanding duties
Is accuracy as precise as possible? Personal skill
Is the student neat and clean? Cleanliness
Are mistakes quickly noticed? Alertness
Are proper safety procedures used? Understanding duties
Does speed increase with practice?  

Personal skill

Are difficult or challenging situations welcomed?  

Understanding duties

Is thought given to ways of improving the operational procedure?  

Alertness

A tally shows that there are five observations for understanding duties, four for alertness, three for skill, two for cleanliness, and one each for efficacy and content. Understanding of duties and alertness are fundamental and basic to effective performance. Skill is also very important, but it may take time to develop and is dependent upon the previous two items. Cleanliness becomes academic after a certain point and while it is highly desirable, it is possible to do an acceptable job without a high degree of this item. Efficacy implies a degree of pharmaceutical sophistication which again is desirable but is not necessary, as it is more properly a function of the supervising professional pharmacist. Content with one observation is another matter and will be treated in the following section.

The degree of assimilation of the content material, and the comprehensiveness of understanding is a matter of primary concern. Following is a list of 12 short quizzes, each one corresponding to the similarly numbered learning experience. They should be administered during the learning session following that being quizzed. This will give an indication of the retention abilities of the student and will also tend to avoid the anxiety many students feel with the knowledge of an impending test. A quiz may be given formally or informally. In many instances it might be
given as an oral quiz or in the form of a pleasant interview or conversation. Repetition of a quiz question at another time is definitely in order. These options are at the discretion of the instructor to use in whichever way desired so that he may be able to reach an appraisal of the amount of information learned by the student.

**TESTS - To reflect the assimilation of the content material**

Test #1

1. Give a definition of radio-activity.
   
   Answer - The radiations spontaneously emitted by unstable nuclides

2. Explain a demonstration of radio-activity.
   
   Answer - Fogging of photographic film without exposure to light, with a radio-active source

Test #2

1. Draw and label a simple model of an atom.

   Answer -

   ![Atom Diagram]

   Proton = +
   Neutron = 0
   Electron = -
   2. Define atomic number and mass number.

   Answer - Atomic number is the number of protons in the nucleus of the atom.

   Mass number is the number of protons and neutrons in the nucleus of the atom.
3. What is an isotope?

Answer - One of two or more forms of the same element with the same atomic number but different atomic masses.

Test #3

1. What is half-life (T₁/₂)?

Answer - The time in which one-half of a given number of atoms of a radio-active element disintegrates.

2. Give three types of radiation and explain in general terms what material is necessary to shield against each type.

Answer - Alpha Radiation - a sheet of paper or a few centimeters of air.

Beta Radiation - several thousands of an inch thick aluminum.

Gamma Radiation - very dense materials such as lead and concrete, the thickness of which depends upon the amount of radio-activity it must block.

Test #4

Describe:

1. An ionization chamber

Answer - A closed container with a wire running down its center and insulated from the sides. This is connected to a voltage source where the wire has a positive charge and the container walls have a negative charge. When ions are formed in this
chamber due to radiation, the electron (negatively charged) will migrate to the positively charged wire, while the ion (positively charged) will migrate towards the negatively charged container walls, thus forming a current which can be measured.

2. Scintillation interaction

Answer - Atoms of certain materials (some organic substances and some inorganic crystals) are excited or ionized by the passage of high speed electrons or gamma protons. They emit a very small amount of light. This process is called scintillation.

3. The Geiger-Muller Tube

Answer - This is essentially the same as an ionization chamber except that a high voltage is established between the two terminals. When ionization due to radiation occurs (primary ions) are given energy by the high voltage and this added energy enables them to produce more ions (secondary ion-pairs). This occurs in sufficient numbers so that a single beta particle or gamma proton can be detected.

Test #5

1. Give the difference between a scaler and a ratemeter.

Answer - A scaler is an instrument that gives an actual count of the number of radiations in a given time, while a rate-
meter gives an average rate per unit of time that radiation is received, usually in counts per minute.

2. Define:

Curie
Answer - \(3.7 \times 10^{10}\) Disintegrations per second (37,000,000,000)
(Thirty-seven billion)

Millicurie
Answer - \(3.7 \times 10^7\) Disintegrations per second (37,000,000)
(Thirty-seven million)

Microcurie
Answer - \(3.7 \times 10^4\) Disintegrations per second (37,000)
(Thirty-seven thousand)

Test #6

1. State the inverse square law.

Answer - Radiation intensity from a point source varies inversely as the square of the distance from the source. Example: Doubling the distance from the source decreases the intensity to one-fourth.

2. Give your personal thought about how to protect yourself from radiation using shielding, the inverse square law, and time.

Answer - Protection from radiation using these three principles would best be done by working as much as possible with a dense material between you and the radiation source. Such a material would be lead or concrete. Keep as far
away from the radiation source as possible, and perform your manipulations as quickly as possible.

Test #7

1. What is the difference between a scale and a balance?
   
   Answer - A scale measures the amount of pull the earth exhibits upon an object; this is the weight. A balance measures mass, wherein the unknown object is balanced against a known object.

2. Explain the proper way to use a balance.
   
   Answer - The weights go on the right hand pan, and the unknown goes on the left hand pan. If you wish to weigh out a specific amount, you add unknown until a balance is achieved with the amount you wish to weigh out. If you wish to weigh an unknown, you add weights until a balance is achieved.

3. What is the chief advantage of the metric system?
   
   Answer - All units are diminished or increased by a power of 10.

Test #8

1. What is the United States Pharmacopea requirement for sterilization testing?

   Answer - If the material is autoclaved, it should be subjected to no less than seven (7) days in a Fluid Thioglycollate Culture at 30-32° Centigrade. If the material is sterilized by any other method, it should be subjected to
both the Thioglycollate and the Fluid Sabouraud Culturing. The Fluid Sabouraud Culture should be for no less than ten (10) days at an incubation temperature of 22-25° Centigrade.

2. Where do bacteria come from?
   Answer - Bacteria are omnipresent and are associated primarily in places where air currents and dust particles abound. Those places where the temperature is low have a tendency to be free of bacteria.

3. How do we prove the existence of bacteria?
   Answer - Through bacteriological culturing and microscopic examination, or both

4. How long and at what temperature must we autoclave for sterilization?
   Answer - 121° Centigrade for 20 minutes

5. Give three ways of killing or eliminating bacteria.
   Answer - Bacteriological filtration, steam sterilization (autoclaving), and gas sterilization (ethylene oxide)

Test #9

1. What is the effect of pyrogens on humans?
   Answer - Pyrogens cause a sharp increase in temperature.

2. Explain the two types of pyrogens.
   Answer - a) Bacteriological pyrogens are the by-product of bacterial metabolism and may also include bacterial protein set free in the solution by the lysing of bacteria cells.
b) Chemical pyrogens are trace amounts of chemicals in solution.

3. What is the United States Pharmacopea test for pyrogens?

Answer - Three rabbits are injected with the test material. Three temperature readings are taken on each rabbit at one hour intervals. There must not be a rise in temperature of $0.6^\circ$ Centigrade or more, and the sum of the three readings must not exceed $1.4^\circ$ Centigrade.

4. How do we prepare serum vials for usage?

Answer - Boil them in detergent for 30 minutes. Rinse three times in potable water and three times in distilled water.

5. How do we prepare rubber caps for serum vials for usage?

Answer - Boil them for 15 to 20 minutes in moderate solium hydroxide solution, then boil for 5 to 10 minutes in detergent solution. Wash well in potable, then distilled water. Dry at low to moderate heat.

6. How do we prevent bacterial contamination in drawing doses from a serum vial?

Answer - Swab the rubber stopper with iso-propyl or ethyl alcohol of not less than 70% concentration.

7. What is the action of detergents in cleaning objects?

Answer - The detergents change the surface tension of the water so that the water penetrates better and washes out undesirable materials.
8. In the process of withdrawing sterile material into a sterile syringe, give your thoughts as to where contamination is most likely to occur.

Answer - The injection of non-sterile air into the vial to compensate for the volume of liquid withdrawn.

Test #10

1. What does a decay graph show?

Answer - How much radio-activity has been lost due to decay at various time intervals.

2. Using an imaginary isotope, give the half-life and construct a decay graph.

Answer - The half-life of imaginary isotope x is 5 days.

![Graph showing decay over time with one half-life marked.]
Test #11

1. If a radio-pharmaceutical was assayed several days ago, show how you would calculate the volume necessary to administer any given activity.

Answer - original assay mCi/ml \( \times \) Decay Factor = present assay mCi/ml

\[
\frac{\text{Present assay mCi/ml}}{\text{Activity desired mCi}} = \text{volume in ml}
\]

2. If a radio-pharmaceutical was assayed for several days in advance of your present date, show how you would calculate the volume necessary to administer any given activity.

Answer - \( \frac{\text{Original assay mCi/ml}}{\text{Decay Factor}} \) = present assay mCi/ml

\[
\frac{\text{Present Assay mCi/ml}}{\text{Activity desired mCi}} = \text{volume in ml}
\]

Test #12

1. Show how to calculate the assay at the present time for any given radio-pharmaceutical.

Answer - \( \frac{\text{Activity mCi}}{\text{Volume ml}} \) = Present assay mCi/ml

2. Show how to calculate the assay at a future date for any given radio-pharmaceutical.

Answer - Activity mCi \( \times \) Decay Factor = Future Activity mCi

\[
\frac{\text{Future Activity mCi}}{\text{Volume ml}} = \text{Future assay mCi/ml}
\]
CHAPTER VI

SUMMARY AND CONCLUSION

Radio-pharmacy, as an integral part of the generalized practice of pharmacy, has yet to come of age. Its need is just being recognized, and the distinctive elements of its techniques are now being worked out. Many of these procedures are now standard with conventional pharmaceutical activities, while others are common to the activities of the nuclear chemist and nuclear physicist. In effect radio-pharmacy is a blending of these disciplines, the purpose of which is to provide radio-pharmaceuticals that are fit for human use. This involves the complete handling, processing, and testing of all materials, radio-active or not, that will ultimately find their way to the patient.

The need for auxiliary help becomes apparent when one comprehends the true scope of this responsibility. Whether this help is on a professional level or on the non-professional or technician level depends largely upon the volume of patients and materials being handled by a particular Department of Nuclear Medicine. As professional help is at a premium and its cost might very well be prohibitive, it seems sensible to direct training emphasis for auxiliary help toward the technician. The scope of this training and the direction in which emphasis is placed becomes a part
of the educational objectives of this training program. These objectives are the product of the thoughts of all associated peoples to this technician. These are properly elucidated and brought into focus for their use or elimination as proper educational objectives and those that survive are incorporated as goals of the educational program.

The implementation of these objectives, in accordance with the title of this paper, are to be done in a work-study environment. In a one-to-one situation, due to the inherent danger of handling radio-active materials, this can prove to be ideal. An interwoven series of learning experiences that include not only formalized instruction but informal conversational reinforcement and the accessibility of immediate practice should make learning highly meaningful. These learning experiences encompass not only the elements of content material assigned to them, but endeavor to motivate a conceptual realization that is integrated with the educational objectives.

The degree of achievement of the goals that we have set for our students is reached through two channels: an observation sheet which relates back to the educational objectives and a series of short tests which concentrate on the content material. An analysis of the observation sheet offers an evaluation insight into which objectives are and are not being realized while the short tests can be utilized as an indicator of scholastic ability and scientific aptitude.

Progress is the life and breath of our society. Whether the social sciences or the physical sciences are leading the advance is an academic question. Long overdue is a concerted effort to blend these two areas
of learning into a homogenous outlook toward the solution of our problems. The clean-cut delegation of a subject area into this science or that science may serve well as a means of cataloging the subject, but the subject's use cannot be so restricted as to exclude help from any source.

The day of training for content only must soon end. The idea of taking a skilled person and an unskilled person and let one show the other how to exercise this skill does not produce as an end result a loyal, social minded, reliable worker. It takes an educator to educate, and this education must be as comprehensive as possible in reference to the sphere of activity of the student. This involves the full scope of educational know-how and only then produces the type of skilled person so necessary to our society. This paper shows a blend of the two sciences and hopefully a step toward better co-utilization of each other.
APPROVAL SHEET

The thesis submitted by Jerome J. Glass has been read and approved by the director of the thesis. Furthermore, the final copies have been examined by the director and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

1/16/71 Date

Signature of Adviser