TABLE OF CONTENTS

I. Radiation Safety Responsibilities

The Radiation Safety Program at Williams is under the direction of the Radiation Safety Committee, which receives its authority from the office of the Provost of the College. The Committee is responsible for establishing and maintaining a safety program that will minimize the risks associated with the handling of radioactive materials (RAM), and which will assure full College compliance with all applicable government regulations. Any faculty member wishing to become an authorized user of RAM must first receive the unanimous approval of the Committee. Administrative procedures of the Committee are summarized in Appendix D.

The Radiation Safety Officer is responsible for implementing the Radiation Safety Program as established by the Committee and for providing such services to the authorized users as are necessary to insure both adequate personnel protection and compliance with government regulations. The Safety Officer is available to answer any questions regarding the safe and legal use of RAM that you do not find answered in this handbook. Copies of the Massachusetts Department of Public Health, Radiation Control Program (MRCP)"Rules and Regulations for the Safe Use of Radiation" (105 CMR 120.000), the college licenses, and records of past state inspections are available in the Radiation Safety Officer's office.

A. Authorized Users

Each faculty member wishing to use or supervise the use of RAM must submit and "Application for Authorization to Use Radioactive Materials at Williams College". The application must include details of the faculty member's training and experience and a description of the research to be performed. In general, for authorization to be granted, one must have at least forty hours of training and experience, with at least six hours of formal instruction, on the principles and practice of radiation protection, basic theory of the use and measurement of radioactivity, and the biological effects of radiation.

Authorized users are responsible for enforcement of Committee regulations within their laboratories, and failure to do so can result in loss of their authorizations.

B. Users of radioactive material

Individuals may handle RAM under the supervision of an Authorized User. In general, users of radioactive material are expected to have had at least two hours of formal instruction on the principles and practice of radiation protection, basic theory of the use and measurement of radioactivity, and the biological effects of radiation.

Each individual who handles RAM must register with the Radiation Safety Officer and is responsible for following the regulations contained in this handbook. Individuals may also be required to comply with additional specific regulations established by the Committee, the Radiation Safety Officer, or the Authorized User in whose laboratory they work.

II. Required Procedures

A. Purchase and control of radioactive materials

Only Authorized Users of RAM may purchase or otherwise acquire RAM on the Williams campus. All acquisitions of radioactive materials must be purchased through the committee-designated purchasing agent, usually the Technical Assistant in the Chemistry Department, and must receive the prior approval of the Radiation Safety Officer.

Purchases of RAM are processed in the same manner as regular purchases. All requisitions must clearly indicate that RAM is involved and indicate the radio-nuclide or radio-nuclides and the amount of activity in curies. Authorized Users are responsible for making certain that their orders of RAM will not cause their inventory to exceed the possession limits listed on their authorization. The Radiation Safety Officer reviews all orders to verify that no user's authorization is being exceeded.

Each authorized user is responsible for the ultimate disposition of all RAM purchased through his authorization. No RAM may be transferred to another Authorized User without notifying the Safety Officer. Prior permission of the Safety Officer is required for any transporting or shipping of RAM from the Williams campus to ensure proper packaging, labeling, marking and shipping papers. Any individual, including other faculty members, may use materials purchased by an Authorized User, provided all of the other requirements of this handbook are met (room registration, labelling, etc.). Faculty members planning repeated or extended use of radionuclides should apply for their own authorization and not depend on another faculty member to assume responsibility for their work.

B. Receipt of radioactive materials

All shipments of orders and samples from commercial suppliers of radio-nuclides must be addressed to the purchasing agent. He will normally be responsible for signing out all orders and delivering them to the laboratories or to the Radiation Safety Laboratory (BSC 030) after all necessary surveying and records keeping has been performed. In his absence the Radiation Safety Officer will perform these duties or will notify the laboratories to pick up their orders directly. Each lab, when receiving activity directly from a stockroom, is responsible for logging in, surveying and unpacking the shipment in accordance with instructions detailed in Appendix A.

No radio-nuclides may be brought on campus except through the purchasing agent without the prior permission of the Radiation Safety Officer.

C. Caution signs and labels

1. Labelling of rooms

Each room where radioactive materials are stored or routinely used must display prominently on the outside door "Caution: Radioactive Materials" sign. In addition to caution signs, all rooms should be posted with emergency phone numbers and a listing of the maximum possible radio-nuclide inventory on hand at any one time. The RSO will prepare all signs for posting in cooperation with the authorized user.

2) <u>Labeling of sinks and hood</u>

All sinks and hoods where radio-nuclides are discharged should be clearly labelled with a "Caution: Radioactive Materials" sign, and posted with a form, available from the Safety Officer, on which a record of all discharges must be maintained.

3) <u>Labelling of refrigerators and cabinets</u>

All refrigerators, freezers and cabinets, etc., used for the storage of radioactive materials, must be clearly marked with a Caution: Radioactive Materials" sign. All storage containers must be located in secured laboratories.

4) <u>Labelling of glassware and containers</u>

Each container which holds radioactive materials must have a durable, clearly visible label bearing the radiation warning symbol and the words "Caution: Radioactive Material". These labels should also indicate the contents of the container, giving the nuclide, the amount of activity, and the date. Containers used transiently during laboratory procedures, e.g., pipettes, do not require labelling provided the user is present and the room is properly posted.

Tape appropriate for labelling containers is available from the Radiation Safety Officer. Under no circumstances should the tape be used for any purpose other than for the proper labelling of items as being radioactive. Other caution signs and stickers are also available from the Radiation Safety Officer.

D. <u>Required laboratory procedures for handling radioactive materials</u>

1. All individuals handling radioisotopes are responsible for conducting their work in a manner designed to minimize exposure to ionizing radiation and designed to minimize the potential spread of radioactive contamination.

2. All personnel who might receive as much as 10% of their maximum permissible radiation doses (summarized in Appendix B) are required to wear whole body film badges at all times when handling gamma or X-ray emitting radionuclides, and when handling beta emitters with a maximum energy of greater than 0.5 MeV. Film badges do not effectively record exposures received from low energy beta emitters such as ^{3}H, ^{14}C, ^{35}S and ^{45}Ca, and will not normally be issued to personnel handling only those nuclides. Persons regularly handling more than 1 mCi of ^{32}P must wear ring badges as well as whole body badges. All personnel are entitled to unrestricted access to the results of any monitoring of their radiation exposure, and are entitled to annual summaries of the results of such monitoring.

3. External exposure to ionizing radiation can be kept at a minimum by using proper shielding, by maintaining the maximum possible distance from the radiation source and by minimizing the time spend handling the radionuclides. Shielding requirements differ for different radionuclides depending on the type and energy of the radiation. Prior to any operation involving the handling of radionuclides, individuals should evaluate the hazards involved and plan the operation so as to minimize any exposure to external radiation. The Radiation Safety Officer is available to aid in the solving of any specific shielding problems.

Statutory limits on exposure to ionizing radiation are summarized in Appendix B. All personnel should be aware that, due to the higher susceptibility of rapidly reproducing cells to damage from ionizing radiation, separate standards for exposure have been established for minors and for pregnant women. All women of child-bearing age, who work in laboratories where radioactive materials are handled, are required to read the U.S.Nuclear Regulatory Commission Appendix to Regulatory Guide 8.13, "Possible Health Risks to Children of Women Who are Exposed to Radiation During Pregnancy". All workers should take special care to avoid exposing minors and pregnant women to unnecessary ionizing radiation.

The potential for external exposure is particularly great for users of ^{32}P, since the range of β radiation from this isotope can extend for 20 feet. Thus these individuals should use 1/4" plexiglass shielding around waste and at any other location where mCi amounts of this isotope are found.

4. The greatest potential hazard in radionuclide usage at Williams lies in the possibility of personnel accidentally ingesting or absorbing radionuclides. Almost all internal contamination can be traced to failure of individuals to wear gloves, or to use fume hoods when working with volatile forms of radioactive materials. For this reason, the following requirements have been established to minimize accidental internal exposure.

a) Whenever possible, separate areas should be designated in each laboratory for the use of radioactive materials.

b) No person is permitted to smoke, eat or drink while handling radioactive materials. Furthermore, there will be no storage or use of any food or drink in the vicinity of areas where radioactive materials are being used or stored.

c) All persons handling uncontained radioactive materials must wear rubber or plastic gloves and lab coats at all times. The advantages of glove-wearing are defeated when people wearing contaminated gloves indiscriminately handle uncontaminated objects.

d) The use of eye protection is required in all labs for protection against chemical contamination, and also serves to protect individuals using millicurie amounts of ^{32}P.

e) Absolutely no mouth pipetting of radioactive solutions is permitted.

f) All operations which can give rise to airborne contamination must be performed in fume hoods.

g) Special requirements have been established for the performance of bioassays on individuals handling tritium or radioisotopes of iodine. Users of these radio-nuclides are required to read and fulfill the requirements detailed in Appendix C.

h) Each individual is responsible for the cleanliness of his or her own work areas. Each laboratory is required to perform on a monthly basis whatever surveys and wipe tests are necessary to verify that radioactive contamination is not being spread outside of designated work areas, and record the results. The periodic testing performed by the Radiation Safety Officer is not a substitute for routine monitoring of all work areas in the laboratories performed by individuals fully familiar with the research being conducted. More frequent surveys may be required for individuals using significant amounts of RAM. For instance, users of millicurie amounts of ^{32}P may be required to perform and record daily surveys, and may be surveyed by the RSO (or designated assistant) weekly. Any routine working area where surveys show an exposure level exceeding 2 mR/hr above background must be shielded to reduce the exposure to ALARA level. Any wipe test that shows greater activity than 200 dpm/100 cm^2 above background shall presume contamination. Such areas must be promptly decontaminated (with additional surveys to confirm the effectiveness of the cleanup) and reported to the Radiation Safety Committee. The Committee should also be told of procedures added to prevent repetition of contamination.

E. <u>Handling of radioactive waste</u>

The expense and difficulties in disposal of radioactive waste mandate the minimization of generation of such waste The following general guidelines should be observed.

Regulations permit the disposal of radioactive material as non-radioactive, provided that it has been stored for at least 10 half-lives. Given the relatively short half-lives of ^{32}P and ^{35}S, wastes contaminated with these isotopes should be stored in BSC 030 in appropriate containers for eventual disposal as non-radioactive. The material should be bagged in a <u>regular</u> plastic bag, with no radioactive tape or other warning symbol on it. This bag should then be put into a radioactive waste bag, which does have such warning symbols on it. The overbag should be labelled with the isotope and date, and left in BSC 030. The Radiation Safety Coordinator will monitor radiation levels in BSC 030 with a survey meter and record the results. Before final disposal, the coordinator will monitor the waste in a low background area with a GM type survey meter on the most sensitive scale, and will continue to hold any material for which the reading is greater than twice background. Results will be recorded and filed.

Clearly, storage for disposal after decay is not practical for tritium, nor for ^{14}C, However, both these isotopes may be discharged down the sink, in the quantities <u>normally</u> used at Williams. Most waste consists of gloves and protective matting, which is probably not contaminated but which cannot be monitored for activity. It is in the interests of all users to minimize this waste by using smaller amounts of disposable material (or decontaminating it), and relying more on washing bench tops and reuseable gloves. The following procedure, tested by LSC counting of wash and rinse waters, will remove all contamination: With gloves still on, wash with strong alkaline cleanser and rinse into sink with fresh water. The same procedure can be used for certain small pieces of equipment such as pasteur pipettes, but its efficacy must be checked by LSC counting for any item not previously decontaminated by this method.

Specific guidelines for types of waste follow.

1) <u>Solid waste</u>

Absolutely no contaminated materials can be disposed of in regular waste containers. Special cans for disposing of radioactive waste should be obtained and should be emptied periodically in the waste drums in the Radiation Safety Laboratory (BSC 030). Radioactive warning tape and signs should never be placed in regular waste containers. Empty shipping containers which have been found free of contamination should be disposed of in regular waste, but should be clearly marked "Empty" and should have all radioactive warning symbols crossed out.

The amount of activity and the identity of the nuclide(s) for all materials must be recorded on the drum cards placed on the containers in BSC 030. As noted above, if the material is being held for disposal through decay, this information must also go on the bag inside the drum. The Radiation Safety Coordinator will be responsible for keeping a log of materials disposed of, both by decay and by transport.

2) <u>Gaseous waste</u>

Discharge of radioactive materials through fume hoods is permitted provided the following conditions are met.

a) A careful record of the amount of activity discharged must be maintained. In the absence of accurate measurements of the discharge, a deliberate overestimation should be reported.

b) Concentrations of radionuclides in exhaust air may not exceed limits established in 105CMR120.200.

The Radiation Safety Officer is available to advise as to the proper procedures for such discharges. Calibrated sampling of hood discharges may be required to ensure compliance with the regulations.

3) Liquid waste

Given the limitations of the Williams College license, aqueous radioactive liquids can be discharged down laboratory drains. However, no materials should be discharged down drains unless the materials are readily soluble or dispersible in water. Permission for this type of disposal will be granted by the RSC as part of the review of requests for Authorized User status. Guidelines for maximum concentrations in drain discharges are established in 105CMR120.200. The RSC/RSO will maintain records to show that all disposal is within MRCP limits.

4) Mixed Waste

Liquid waste not permitted to be discharged down the drain because the liquid is considered a hazardous substance is referred to as "mixed waste". At present there is **no** contractor who will handle such waste for us. Therefore, the RSC will not approve procedures that will generate such waste. If, however, the inability to dispose into the sewer system is due solely to the presence of RAM of a type or amount not allowed by MRCP discharge regulations, the liquid should be absorbed with an approved absorbant contained in special bottles (available from the Radiation Safety Officer) and placed with the other radioactive waste.

F. Storage of radioactive materials

No radioactive materials may be left unsecured after working hours. Any storage cabinets or refrigerators in unsecured areas must be kept locked after hours and must be locked during the day when not in use. All containers used for storage should be labelled in accordance with instructions in Section IIC.

G. Transportation of radioactive materials

1) No radioactive materials may be removed from the Williams campus in any manner without the prior consent of the Radiation Safety Officer.

2) No radioactive materials may be transported to any area on campus which has not been previously registered with the Radiation Safety Committee and labelled in accordance with the requirements of Section IIC of this handbook.

3) All materials in transit between registered work areas must be transported and packaged in a manner designed to prevent leakage in the event of any accident, and designed to limit radiation doses to less than 1.0 mRem/hr at a distance of one meter from the container.

You must contact the Radiation Safety Officer for specific advice and approval regarding packaging and transportation methods.

H. Sealed Sources

Sealed sources are also regulated by the college license. Therefore, anyone wishing to bring a sealed source onto the campus must apply for Authorized User status and obtain the permission of the RSC, even if the source is being sold to us under a "general" license. This will ensure that we are not exceeding the possession limits of the license.

In the application for approval, special attention should be given to security of the source (generally a locked room). Student use of such sources, especially in teaching labs, must be carefully pre-planned and supervised to ensure only negligible exposure. Training of students prior to source use and monitoring during use must be documented. An example of a satisfactory protocol is included as Appendix I.

III. Emergency Procedures for Incidents Involving Radioactive Contamination

A. Personal injury with contamination involved

In any accident where both personal injury and radioactive contamination are involved, treatment of the injury has absolute precedence. The following precautions can facilitate medical treatment and minimize the spread of contamination:

1) If possible, remove contaminated clothing at the site of the accident.

2) Inform medical personnel that radioactive contamination is present so that they can take appropriate action. If possible, provide a listing of the suspected contamination.

3) Proceed with notifying proper individuals and with contamination control as detailed in (B) below.

B. General emergency procedures for radioactive spills

1) Notification -- The following personnel should be notified as rapidly as possible in the event of any spill or accidental airborne release of radioactive materials.

a) The authorized user in whose lab the accident has occurred.

b) Thompson Health Center (ext. 2206) -- call immediately if personal injury is involved.

c) The Radiation Safety Officer (Dr. Anne F. Skinner; ext. 2323/2285, or at home, 458-9071).

d) The Radiation Safety Consultant, Jim Tocci (office: 1-413-545-5153; home: 1-413-323-9571).

e) Security (ext. 4444) -- After normal working hours, contact Security for access to the area, if waiting for others will cause a delay.

2) Containment of contamination

a) Volatile liquids or loose powdered activity

i) Evacuate all personnel from the lab immediately, turning off any apparatus which needs constant attention.

ii) Gather personnel and wait immediately outside of the room until help arrives.

iii) Close and lock all entrances to the room. Check the direction of airflow underneath doors, and seal cracks if air is flowing out towards the corridor.

iv) Remove any contaminated lab coats and outer clothing.

b) Non-volatile spills

i) Contain spill as much as possible by covering with absorbant material.

ii) Remove any contaminated lab coats and outer clothing.

iii) Assemble potentially contaminated personnel in one area of lab and monitor for contamination.

iv) Rope off and guard spill area until help arrives.

APPENDIX A

Proper Procedures for Receipt of Radioactive Materials (Beta, Gamma and X-ray Emitters)

Shipments of radioactive materials may have some contamination on the packaging. Orders delivered to laboratories or the Radiation Safety Laboratory by the purchasing agent or the Radiation Safety Officer have already had all of the necessary monitoring completed. This procedure includes the following steps and is designed to minimize contamination from faulty packaging.

1. Carefully check all external labels and packing slips to verify that the package contains your proper order.

2. If the package is labelled with a class I, II or III label, measure the dose rate in contact with the outer package. Surface dose rate limits are as follows: Class I label, 0.5 mR/hr; class II label, 50 mR/hr; class III label, 200 mR/hr. If the rate is greater than that permitted for the label on the package, notify the manufacturer and the Radiation Safety Officer immediately; do not proceed with opening the package. Note that Class III shipments must be inspected within three hours of receipt.

3. Working under a fume hood, remove the packing materials, checking all labels and packing slips for accuracy. If the radiation emitted is detectable on portable survey meters available in the laboratory, check all packaging as it is removed for signs of contamination.

4. Visually inspect the innermost container for signs of leakage.

5. Check the radiation field of the unshielded inner container and make certain that the results are consistent with the packing list results and the expected radio-nuclide.

6. Wet wipe test the inner container and measure for any removable surface contamination. Keep the inner container in any shielding that may have been used during shipment.

7. Record the receipt and the results in your lab's Radiation Safety Logbook.

8. Notify the MRCP and the manufacturer immediately if any contamination is found on the outside packaging, or if more than 0.01 micro-curies (22,000 dpm) per 100 square centimeters is removable from the inner container. Also notify both the MRCP and the supplier if the primary seal on the shipment is broken or otherwise damaged.

9. When checking in shipments, always be careful to use proper shielding to minimize exposure, and remember that contamination on a package may be from any radio-nuclide, not just the one anticipated.

APPENDIX B

Exposure Limits

I. Maximum permissible occupational doses for radiation workers:

Affected Organs	Maximum Rems per calendar quarter	Max. Average Weekly Exposure (millirems)	Max. Avg. Hourly Exp. 40-hr wk (mrems)
1. Whole body; head & trunk; active blood-forming organs; lens of eye, or gonads	1.25	100	2.5
2. Hands and forearms, feet and ankles	12.5	1000	25.0
3. Skin of whole body	12.5	1000	25.0

II. Maximum permissible doses for minors and non-radiation workers:

One-tenth of the values listed in I.

III. Maximum permissible dose to fetus:

0.5 Rem during pregnancy, or an average of 12.5 mRem/week.

NOTE: The Williams College safety program is committed to ALARA, i.e., limiting all exposures to less than 10% of the maximum permitted.

APPENDIX C

Special Requirements for Users of Tritium

Tritium Urinalysis Requirements

All individuals involved in operations which involve the handling at one time of more than 100 millicuries of hydrogen-3 (tritium) in an inorganic uncontained form, or more than 10 millicuries of tritium in an organic uncontained form must have a urinalysis performed on the following day. Individuals handling these amounts of tritium on a regular basis may have urinalyses performed weekly.

APPENDIX D

Administrative Procedures and Responsibilities

A. Responsibilities of the Radiation Safety Committee

1. The Radiation Safety Committee consists of all those members of the academic departments that are actively involved in the use of radioactive materials, the Provost, and the Radiation Safety Officer.

2. The Committee shall meet as necessary, with at least one meeting scheduled each calendar quarter. Records of each Committee meeting will be kept.

3. Each faculty member wishing to supervise the use of radioactive materials (RAM) must first submit an "Application for Authorization to Use Radioactive Materials at Williams College". The application must include details of the faculty member's training and experience, a description of the research to be performed, and a listing of rooms where RAM will be used. The Radiation Safety Officer shall investigate all proposed uses of radioisotopes and report to the Committee prior to consideration of any new application or amendment. The committee's review of each application shall include an evaluation of the faculty members facilities and equipment, and a review of proposed training, records keeping, operating, and emergency procedures. All authorizations will be reviewed and updated at least once every two years, and any proposed change in information included in an Authorized Users Application must have the prior approval of the committee.

4. At each meeting, the Radiation Safety Officer shall report to the Committee on the status of the Radiation Safety Program. Once each year the Committee shall conduct a formal review of the entire program, including a formal evaluation of the training being provided to all laboratory and auxiliary personnel.

B. Responsibilities of the Radiation Safety Officer

The Radiation Safety Officer shall

1. provide the Radiation Safety Committee and individual users with advice and assistance on all matters pertaining to the safe use of radioisotopes.

2. review radioisotope use procedures to determine compliance with Nuclear Regulatory Commission regulations and approved procedures.

3. maintain accurate records of radioisotope inventory, radiation surveys, bioassays, personnel dosimetry, solid waste disposal, leak tests of sealed sources, effluent releases of radioactive material into the samitary sewer system and into the atmosphere, calibration of instruments and any other records necessary for NRC compliance.

4. perform radiation surveys or cause such surveys to be performed, including quarterly routine inspections of all laboratories in which the use of radioactive materials is authorized.

5. calibrate all radiation detection and measurement instruments every six months.

6. investigate accidents and incidents involving the use of radioactive material.

7. collect and dispose of solid wastes containing radioactive material.

8. perform bioassay analysis on researchers as necessary.

9. instruct security personnel as to areas in which radioactive materials are used and stored, and as to emergency response instructions for these areas.

10. recommend the termination of any research operation involving the unsafe use of radioactive material. A violation report will be issued to the appropriate Authorized User at this time by which the user will be required to determine the cause of the unsafe condition(s) and offer corrective action to prevent reoccurance. This report will simultaneously be submitted to the Radiation Safety Committee for review/action.

11. act as secretary to the Radiation Safety Committee.

The Radiation Safety Officer may delegate any of these responsibilities to any qualified technical assistant that he or she feels is suitable, and whose qualifications have been approved by the Radiation Safety Committee.

C. Responsibilities of Authorized Users

Authorized Users of radioactive material (RAM) are responsible to the Radiation Safety Committee for assuring the safe use of RAM in their areas or laboratories. An Authorized User shall

1. comply with and enforce the radiation safety requirements prescribed in this manual, and in the authorization by the Radiation Safety Committee.

2. assure that personnel are properly instructed in safe procedures for working with any RAM in the user's charge.

3. assure that required monitoring devices, protective clothing and equipment, and contamination control methods are used.

4. review in advance all laboratory procedures to be used by personnel in carrying out research work involving RAM for probability of spills, explosion, implosion or fire.

5. assure the integrity of vacuum systems, cryogenic systems, pressure vessels or equipment to be used in conjunction with RAM.

6. assure that any new and/or complex procedures that involve the use of RAM are thoroughly tested in a "dry run" before attempting them with RAM.

7. maintain control of visitors.

8. maintain an up-to-date record or log book showing all receipts and disposals (by any method) of radioisotopes.

9. perform the monthly laboratory inspection and survey, including wipe tests where necessary, and maintain permanent records of the results. Copies of these records are available to the Radiation Safety Officer.

D. Responsibilities of the Individual User

The individual user shall

1. keep user's daily exposures to radiation as low as is reasonably achievable.

2. wear prescribed monitoring devices and protective clothing.

3. use only prescribed or approved techniques and facilities in operations involving the use of radioactive material (RAM).

4. report incidents or accidents involving RAM promptly to the supervisor and the Radiation Safety Officer.

5. post warning signs, label waste containers properly, and otherwise control radiation hazards for which the user is responsible.

6. clean up any contamination generated, using prescribed procedures.

7. keep effluent wastes (i.e., liquids down the sink or airborne releases within or outside of labs) containing RAM below the concentration limits prescribed by NRC 10CRF20, and record each disposal or release.

8. store and handle RAM properly.

9. comply with restrictions on eating, drinking and smoking.

10. comply with all sections of this manual, and with posted NRC regulations.

11. survey the area in which RAM has been used before the end of the day, and ensure that the material will be secured against unauthorized use.

APPENDIX E

Student Use of Radioisotopes in Laboratory Courses

1. For purposes of this section, a "laboratory course" is one which is scheduled as part of a lecture course. Specifically, undergraduate research, although thre is a "course number" attached to it, is not subject to these regulations. Rather, undergraduate researchers are considered "individual users", working under the supervision of an Authorized User.

2. Any faculty member wishing to conduct an experiment involving the use of regulated radioisotopes by students in an undergraduate laboratory course must be an Authorized User of radioisotopes.

3. The faculty member must submit to the Radiation Safety Committee an account of the proposed experiment.

4. For an experiment involving sealed or contained sources to be approved, it must be demonstrated that no individual student can receive from the experiment a whole-body exposure to radiation in excess of 10 mRem, or an exposure to the extremities in excess of 50 mRem.

5. For an experiment to be approved involving the use of radioisotopes which are not in the form of sealed or contained sources, the authorized user must limit the activity to ensure that the dose (TEDE) to students is less than 100 mRem/yr. For such experiments, the faculty member to whom approval to conduct the experiment has been granted must be physically present in the student laboratory area where the experiment is being performed.

6. Students are not required to wear dosimeters when they are working with radioisotopes in undergraduate laboratory courses in experiments that have been approved by the Radiation Safety Committee according to (3) and (4) above.

7. In designing such experiments, emphasis should be placed on educating students as to the hazards involved in the use of radioactive materials and to the proper procedures for handling such materials. Students using radioisotopes in laboratory courses are considered "Users of Radioactive Material", and are required to have at least one hour of formal instruction on principles and practice of radiation protection, basic theory of the use and measurement of radioactivity, and the biological effects of radiation. Consult with the Radiation Safety Officer if help is needed in providing this instruction.

APPENDIX F

Laboratory Rules for the Safe Use of Radioactive Material

1. Wear laboratory coats, or other protective clothing, at all times in areas where radioactive material (RAM) is used.

2. Wear gloves at all times while handling RAM.

3. Monitor hands and clothing for contamination after each procedure or before leaving the area.

4. Do not eat, drink, smoke or apply cosmetics in any area where RAM is stored or used.

5. Wear personnel dosimeters that are assigned to you whenever you are using RAM. These should be worn at chest or waist level.

6. Dispose of radioactive waste only in specially designated receptacles.

7. Never pipette by mouth.

8. Survey areas in which radionuclides have been handled as frequently as necessary during experiments and at the end of the day to minimize the spread of contamination. Decontaminate lab surfaces as necessary.

9. Confine radioactive solutions in covered containers plainly identified and labelled with the name of the compound, radionuclide, date, activity and radiation level if applicable.

10. Always transport RAM in closed secondary containers with absorbent material to prevent spills on floors/stairs/elevators and loss of valuable research material.

APPENDIX G

Emergency Procedures for Incidents Involving Radioactive Material

Minor Spills:

1. NOTIFY persons in the area that a spill has occurred.

2. PREVENT THE SPREAD by covering the spill with absorbent paper.

3. CLEAN UP THE RADIOACTIVE MATERIAL: Using gloves (and, if indicated by the quantity or type of RAM spilled, remote handling tongs), carefully fold the absorbent paper. Insert into a plastic bag and dispose of in the radioactive waste container. Include any other contaminated disposable materials.

4. SURVEY THE ENTIRE AREA INVOLVED with a G.M. Survey Meter. Check the area around the spill, your hands, and clothing for contamination. The window on the meter must be thin enough to measure any radiation emitted by the radionuclide spilled.

5. REPORT the incident to the Radiation Safety Officer.

Major Spills:

1. CLEAR THE AREA, notifying all persons not involved in the spill to vacate the room.

2. PREVENT THE SPREAD by covering the spill with absorbent pads. Do not attempt to clean it up. Confine the movement of all personnel potentially contaminated to prevent the spread. Assemble all potentially involved personnel in an adjacent room for personnel monitoring and decontamination.

3. SHIELD THE SOURCE of radiation if practical (i.e., only if it can be done without further contamination or without significantly increasing your radiation exposure).

4. CLOSE AND LOCK THE ROOM to prevent inadvertent entry by unauthorized personnel.

5. NOTIFY the Radiation Safety Officer immediately.

6. PERSONNEL DECONTAMINATION: Contaminated clothing should be removed and stored for further evaluation by the Radiation Safety Officer. If the spill is on the skin, flush thoroughly and then wash with mild soap and lukewarm water. Contact dose rate on skin should be reduced as far below 1 mRem/hr as possible.

APPENDIX H

Limits for Disposal into Williamstown Sanitary Sewer System

Per B&G records, the annual water usage as of FY02 was 27533 gal (2.5 million liters/month)

Isotope	NRC limit, avg μCi/mo	Max. monthly limit, mCi[1,3]	Comment
H^3	.01 μCi/mL	25000	Note 2
C^{14}	$3x10^{-4}$ μCi/mL	750	Note 2
P^{32}	$9x10^{-5}$ μCi/mL	225	
S^{35}	$1x10^{-3}$ μCi/mL	83	

Note 1: The total amount that can be disposed of via sewerage in a year is 5 Ci for H^3, 1 Ci for C^{14}, and 1 Ci for all other RAM combined.

Note 2: The limits for disposal of $^3H/^{14}C$ LSC vials as non-radioactive waste are 0.05 μCi/g of cocktail medium.

Note 3: Under the college license conditions, we have to ensure that the total disposal complies with a summation of fractional amounts, to limit the total amount of radioactivity released to the sewer system. That fraction will be calculated on a monthly basis, using the formula:

$$\left(\frac{\Delta H^3}{1.8x10^5}\right) + \left(\frac{\Delta C^{14}}{5400}\right) + \left(\frac{\Delta P^{32}}{1620}\right) + \left(\frac{\Delta S^{35}}{6x10^2}\right) = 1$$

To establish compliance with this regulation we will assume the activity of each radionuclide disposed monthly is the actual amount of each radionuclide purchased each month (from monthly RAM inventory reports). This is a “worst case” scenario and past data on RAM purchased and sewer release volume indicate that we easily meet compliance.

APPENDIX I

Sample Protocol for Student Use of Sealed Sources

Radiation Safety in the Physics 301 Lab

In the course of the P301 lab you will do two experiments ("E=mc2: Pair Creation and Annihilation" and "Compton Scattering") in which you will be using radioactive sources. The sources are sealed with epoxy or steel jackets so that direct contact with the radioactive material is not possible. All of the sources are gamma (photon) emitters, any beta radiation (electrons) being shielded by the encapsulation material of the source. The goal of these notes is to inform you about the potential hazards associated with this kind of source and instruct you in proper laboratory procedures. Please read this information carefully. If you have any questions, now or in the lab, do not hesitate to ask the instructor for more information.

Two kinds of effects occur from ionizing radiation: injury to the body tissues of the exposed individual and genetic damage to germ plasm which manifests itself in future generations. It is not possible to avoid exposure to all ionizing radiation: you are constantly being irradiated with cosmic rays, from natural radioactivity in the soil and buildings, and from internal radioactivity in your body.

Radiation doses are measured in Rems (Roengten equivalent man). We will be concerned with millirems (mRem). This unit takes into account the type of radiation and its biological effects. It is proportional to the flux of gamma rays (photons/cm2/sec) with the proportionality factor depending on the energies of the gammas emitted by a particular source. Some approximate dose rates are:

Cosmic rays at sea level: 35mrem/yr at 5000 ft: 60 mRem/yr
Natural radioactivity: 35 to 70 mrem/yr
Internal K40 (in body): 25 mrem/yr

By being aware of the possible exposure and following proper procedures, you should be exposed to a negligible additional dose of radiation in the course of these two experiments. The calculations below indicate how one estimates exposure rates. As an additional safeguard, and to illustrate techniques for working with radiation, you will be issued a personal dosimeter which will measure your actual exposure.

To calculate the dose rate from a particular source, use the following formula:

$$D = (\Gamma \text{ x } C)/r^2$$

Where D is the dose in Rem/hr, Γ is a constant for the particular kind of source, C is the source strength in Curies, and r is the distance from the source in meters. Notice that the dose rate drops off with distance squared. By standing 1 meter from a source instead of 10 cm, you can lower

your dose rate by a factor of 102. For the sources you will be using the factor Γ is:

Co-60 1.3;	Cs-137 0.33;	Ba-133 0.24;
Na-22 1.2;	Co-57 0.09.	

You will be using two types of sources: small calibration sources in the form of plastic buttons and two larger sources housed in lead bricks with a small hole to form a gamma ray beam. Below are estimates of the radiation dose you might receive from these sources.

1. Holding a 1 µC ^{60}Co source in your hand (1cm distance = 10-2 meters):

$$D = 1.3 \text{ x } 10\text{-}6 \text{ x } [1/10^{-2}\}^2 = 0.013 \text{ rem/hr} = 13 \text{ mrem/hr.}$$

Thus if you held this source in your hand for a three hour lab (don't do this!), you would get a dose of about 40 mrem, comparable to the kind of background dose you get in a year (although in this case the exposure would be mostly to your hand rather than the whole body - this is less dangerous than full body exposure since your reproductive organs are not exposed). Standard laboratory practice is to handle this kind of source with your hands, but tongs are provided so that you do not need to incur even this much exposure. For example at 10 cm, you drop your dose by a factor of 100 to a negligible 0.1 mrem/hr.

2. Holding a 10 µC ^{22}Na source by the attached plastic rod at a distance of 5cm:

$$D = 1.2 \text{ x } (10\text{x}10\text{-}6) \text{ x } [1/5\text{x}10^{-2}\}^2 = 0.005 \text{ rem/hr} = 5 \text{ mrem/hr.}$$

If you were to hold the source directly (at 1cm distance) your dose would go up by a factor of 25.

3. The two larger sources you will be using are ^{60}Co and ^{137}Cs. Each source is about 500µC. Since the cobalt source is the more dangerous of the two, we do computations for this one:

At 10 cm from the 500 µC ^{60}Co source:

$$D = 1.3 \text{ x } (500\text{x}10\text{-}6) \text{ x } [1/10\text{x}10^{-2}\}^2 = .065 \text{ rem/hr} = 65 \text{ mrem/hr.}$$

at 1 meter, your dose drops to 0.7 mrem/hr. In the experiment, the source is enclosed in a lead box with a hole to form a beam. These exposure rates would apply only in the beam. Obviously the best protection is to avoid placing yourself in the beam. It would be reasonable to place your hand briefly in the beam while adjusting the detectors. There is no reason to place the rest of your body in the beam and you should avoid doing so.

Shielding effect of the lead box: The shielding effect of lead (or other materials) depends on the energy of the gamma rays involved and, for lead, is a minimum at about 3 MeV photon energy. At this energy 1.1cm of lead is required to attenuate a beam of gamma rays by 50%. Thus a 5cm thick lead brick attenuates the source by:

$$I/I0 = \exp(-0.693\, d/1.1) = \exp(-0.693 \times 5/1.1) = .043$$

where I/I0 is the fraction of the gammas transmitted, d is the thickness of the lead in cm and the factor of .693 arises because we are using half length instead of 1/e length. Thus the presence of a 5cm thick lead shield reduces the radiation dose at a given distance from the source by a factor of 1/0.043 = 23. The 500 µC cobalt source is reduced to a 22µC source (except, of course, in the beam where the full radiation dose is received). If you stand 10 cm from the shielded source your dose rate is .043 x 65mRem/hr = 2.8 mRem/hr. By moving back to one meter, you can reduce your dose to a tiny 10-2 x 2.8 mRem = 0.03 mRem/hr.

Based on these calculations we can arrive at some procedures to follow in the lab:

1. Keep your distance from all sources. When you are not actively manipulating the sources, step back.

2. Minimize your exposure to the direct beam from the two larger sources. There is no reason to place any part of your body other than your hands in the direct beam, so avoid doing so.

3. Place extra sources behind lead shielding when not in use.

4. Never open the lead shielding around the larger ^{60}Co and ^{137}Cs sources
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5. Although the sources are sealed, there may be trace amounts of radioactive material on the sources or the lead bricks. Wash your hands thoroughly when leaving lab. Do not eat or drink in the lab. Also lead is poisonous, so wash thoroughly after touching the lead bricks.

6. If you have any questions about safety, stop and consult the instructor.

Appendix J

Incidents Requiring Notification to MRCP

The MRCP requires licensees to notify the agency within four hours of an event that could result in release into the environment of quantities greater than MRCP limits, or radiation exposure to researchers greater than certain limits. The quantities of RAM at the College are sufficiently low that no scenario requiring a four-hour notification seems possible (the limit for P-32 is 50 curies!).

The agency also requires notification within 24 hours of certain less drastic events. Most, again, would involve quantities of RAM in excess of our possession. However, one has no quantity limit, and therefore could be a reality for the College at some time. This is "unplanned medical treatment, at a medical facility, of a person with spreadable contamination on their clothing or body".

The most probable scenario is that a worker, student or supervisor, is found injured in an area where RAM is in use (see list below) and is unable to assist in determining the cause of the accident (due to shock, or loss of consciousness). In such a case, the presence of contamination would have to be assumed unless evidence to the contrary can be found, and medical personnel either at the College Infirmary or at any hospital might be the ones doing the reporting to the MRCP. To clarify the procedures in such a case, the following chain of command has been constructed. Medical or Security personnel should attempt to contact the following people:

1. The supervisor of the laboratory in question

2. Dr. Anne Skinner, Radiation Safety Officer, x2323/2285, 458-9071

3. Mr. Jim Tocci, Radiation Safety Consultant, 1-413-545-5153 (work) or 1-413-323-9571 (office).

4. Any member of the radiation safety committee

If any of the above people can be reached, it will be their responsibility to determine the presence or absence of contamination, and if contamination is present, to notify the MRCP.

It is essential, however, to recognize that in no case should medical treatment be delayed or withheld for fear of contamination. To repeat, the amounts of RAM maintained at **any** location on campus are too small to present any threat to human health and safety. No precautions beyond those normal to protect against other medical hazards are needed.

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APPENDIX K

Procedures For the Use of ^{125}I

Introduction

Iodine is very volatile. Uptake by inhalation, skin absorption, or ingestion will result in approximately 30% of total uptake being delivered to the thyroid and remaining there with an effective half-life of 32 days. The result is that one can experience large doses (30 Rem/yr) to the thyroid from continuous uptake of very small quantities (50 nCi.wk). All experiments involving carrier-free iodine must be performed in a glovebox fitted into a hood and equipped with a recirculating charcoal filter (without such a filter, MRCP release limits cannot be met). Note that NaI solutions are unstable at cold temperatures; freezing can result in volatilization of iodine. Also, acidic solutions can release volatile iodine. Labelled (or bound) iodinated RAM does not present a volatility problem but must still be regarded as a potential contaminant through ingestion or skin absorption.

Experimental Procedures

1. Place all equipment and solutions needed for the experiment in the secondary chamber of the glove box before beginning the procedure.

2. Turn the activated charcoal re-circulating filter on.

3. Seal the secondary chamber door.

4. Move all necessary materials into the primary chamber.

5. Seal primary chamber door.

6. When the iodination procedure is complete, wait at least five minutes before opening the door from the primary chamber. This allows enough time for any volatile iodine to be absorbed by the filter.

7. Every item entering the glovebox is to be considered contaminated until proved otherwise, and no items are to be removed from the glove box without wipe testing and decontamination (if needed). Decontamination must be done for any item showing 200 dpm/100 cm^2 above background and should be performed in the secondary chamber. All containers removed from the primary chamber must be tightly covered (parafilm is satisfactory).

8. Any equipment containing iodinated materials must be placed in secondary containment (e.g. a tightly-covered plastic or styrofoam box) for transport from the iodination facility to the researcher's lab.

Monitoring of Exhaust

The airflow rate of the hood surrounding the glove box must be checked at least every six months using standard instruments. During an iodination procedure, the exhaust air must be sampled with a charcoal filter/calibrated sample pump. The filter will then be analyzed in an NaI detector/SCA unit calibrated with an NIST traceable standard to determine the concentration of ^{125}I released during the experiment. A calculation must be done after every procedure, and the results kept, to ensure that the release of ^{125}I does not exceed the concentration limits provided in Table II, Column I of Appendix B, 10CFR Part 20.

Handling of Waste

Solid radioactive waste should be placed in a double plastic bag inside the glove box. After the experiment is complete, this waste should be transferred to the solid waste barrel for this isotope. Liquid waste should be placed in the plastic jug in the glove box, containing saturated sodium thiosulfate solution (this keeps any unbound iodine reduced). When the jug is full, it should be emptied by authorized personnel only, into the designated hood drain sink, and refilled with fresh thiosulfate solution.

Medical Surveillance

Approximately 48 hours after the experiment has been performed, the researcher must report for a routine thyroid monitoring with a Ludlum Model 3 survey meter with a Model 44-3 Gamma Scintillation Probe (or an equivalent meter) to determine iodine uptake, if any. In case of continuous use of mCi quantities, thyroid scans must be done weekly. Any individual whose thyroid indicates the presence of more than 20 nanocuries (0.020 microcuries) will be subject to a further evaluation. Results of these tests are available to individual researchers upon request.

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Tocci, Jim, "Radiation Exposure from P-32 in the Life Science Research Lab", from the UMass Safety Bulletin (copy available in the Radiation Safety Office).