NRC FORM 313 (1-84) 10 CFR 30, 32, 33, 34, 35 and 40

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED BY OMB 3150-0120
Expires 5-31-87

APPLICATION FOR MATERIAL LICENSE

INSTRUCTIONS: SEE THE APPROPRIATE LICENSE APPLICATION GUIDE FOR DETAILED INSTRUCTIONS FOR COMPLETING APPLICATION. SEND TWO COPIES OF THE ENTIRE COMPLETED APPLICATION TO THE NRC OFFICE SPECIFIED BELOW.

FEDERAL AGENCIES FILE APPLICATIONS WITH:

U.S. NUCLEAR REGULATORY COMMISSION
DIVISION OF FUEL CYCLE AND MATERIAL SAFETY, NMSS
WASHINGTON, DC 20555

ALL OTHER PERSONS FILE APPLICATIONS AS FOLLOWS, IF YOU ARE LOCATED IN:

CONNECTICUT, DELAWARE, DISTRICT OF COLUMBIA, MAINE, MARYLAND, MASSACHUSETTS, NEW JERSEY, NEW YORK, PENNSYLVANIA, RHODE ISLAND, OR VERMONT, SEND APPLICATIONS TO:

U.S. NUCLEAR REGULATORY COMMISSION, REGION I
NUCLEAR MATERIAL SECTION B
631 PARK AVENUE
KING OF PRUSSIA, PA 19406

ALABAMA, FLORIDA, GEORGIA, KENTUCKY, MISSISSIPPI, NORTH CAROLINA, PUERTO RICO, SOUTH CAROLINA, TENNESSEE, VIRGINIA, VIRGIN ISLANDS, OR WEST VIRGINIA, SEND APPLICATIONS TO:

U.S. NUCLEAR REGULATORY COMMISSION, REGION II
MATERIAL RADIATION PROTECTION SECTION
101 MARIETTA STREET, SUITE 2900
ATLANTA, GA 30323

IF YOU ARE LOCATED IN:

ILLINOIS, INDIANA, IOWA, MICHIGAN, MINNESOTA, MISSOURI, OHIO, OR WISCONSIN, SEND APPLICATIONS TO:

U.S. NUCLEAR REGULATORY COMMISSION, REGION III
MATERIALS LICENSING SECTION
799 ROOSEVELT ROAD
GLEN ELLYN, IL 60137

ARKANSAS, COLORADO, IDAHO, KANSAS, LOUISIANA, MONTANA, NEBRASKA, NEW MEXICO, NORTH DAKOTA, OKLAHOMA, SOUTH DAKOTA, TEXAS, UTAH, OR WYOMING, SEND APPLICATIONS TO:

U.S. NUCLEAR REGULATORY COMMISSION, REGION IV
MATERIAL RADIATION PROTECTION SECTION
611 RYAN PLAZA DRIVE, SUITE 1000
ARLINGTON, TX 76011

ALASKA, ARIZONA, CALIFORNIA, HAWAII, NEVADA, OREGON, WASHINGTON, AND U.S. TERRITORIES AND POSSESSIONS IN THE PACIFIC, SEND APPLICATIONS TO:

U.S. NUCLEAR REGULATORY COMMISSION, REGION V
MATERIAL RADIATION PROTECTION SECTION
1450 MARIA LANE, SUITE 210
WALNUT CREEK, CA 94596

PERSONS LOCATED IN AGREEMENT STATES SEND APPLICATIONS TO THE U.S. NUCLEAR REGULATORY COMMISSION ONLY IF THEY WISH TO POSSESS AND USE LICENSED MATERIAL IN STATES SUBJECT TO U.S. NUCLEAR REGULATORY COMMISSION JURISDICTION.

1. THIS IS AN APPLICATION FOR *(Check appropriate item)*

- [ ] A. NEW LICENSE
- [ ] B. AMENDMENT TO LICENSE NUMBER ______
- [x] C. RENEWAL OF LICENSE NUMBER #20-00642-07

2. NAME AND MAILING ADDRESS OF APPLICANT *(Include Zip Code)*

Boston College
Chestnut Hill, MA
02167

3. ADDRESS(ES) WHERE LICENSED MATERIAL WILL BE USED OR POSSESSED

Boston College
Chestnut Hill, MA
02167

4. NAME OF PERSON TO BE CONTACTED ABOUT THIS APPLICATION: Prof. George Goldsmith

TELEPHONE NUMBER: (617) 552-3592

SUBMIT ITEMS 5 THROUGH 11 ON 8½ x 11" PAPER. THE TYPE AND SCOPE OF INFORMATION TO BE PROVIDED IS DESCRIBED IN THE LICENSE APPLICATION GUIDE.

5. RADIOACTIVE MATERIAL
a. Element and mass number; b. chemical and/or physical form; and c. maximum amount which will be possessed at any one time.

6. PURPOSE(S) FOR WHICH LICENSED MATERIAL WILL BE USED.

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING AND EXPERIENCE.

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS.

9. FACILITIES AND EQUIPMENT.

10. RADIATION SAFETY PROGRAM.

11. WASTE MANAGEMENT.

12. LICENSEE FEES *(See 10 CFR 170 and Section 170.31)*
FEE CATEGORY: NA
AMOUNT ENCLOSED: $

13. CERTIFICATION. *(Must be completed by applicant)* THE APPLICANT UNDERSTANDS THAT ALL STATEMENTS AND REPRESENTATIONS MADE IN THIS APPLICATION ARE BINDING UPON THE APPLICANT.

THE APPLICANT AND ANY OFFICIAL EXECUTING THIS CERTIFICATION ON BEHALF OF THE APPLICANT, NAMED IN ITEM 2, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH TITLE 10, CODE OF FEDERAL REGULATIONS, PARTS 30, 32, 33, 34, 35, AND 40 AND THAT ALL INFORMATION CONTAINED HEREIN, IS TRUE AND CORRECT TO THE BEST OF THEIR KNOWLEDGE AND BELIEF.

WARNING: 18 U.S.C. SECTION 1001 ACT OF JUNE 25, 1948, 62 STAT. 749 MAKES IT A CRIMINAL OFFENSE TO MAKE A WILLFULLY FALSE STATEMENT OR REPRESENTATION TO ANY DEPARTMENT OR AGENCY OF THE UNITED STATES AS TO ANY MATTER WITHIN ITS JURISDICTION.

SIGNATURE—CERTIFYING OFFICER	TYPED/PRINTED NAME	TITLE	DATE
George J. Goldsmith	Prof. George Goldsmith	Associate Prof., Physics	10/31/84

14. VOLUNTARY ECONOMIC DATA

a. ANNUAL RECEIPTS

- [ ] < $250K
- [ ] $250K – 500K
- [ ] $500K – 750K
- [ ] $750K – 1M
- [ ] $1M – 3.5M
- [ ] $3.5M – 7M
- [ ] $7M – 10M
- [ ] > $10M

b. NUMBER OF EMPLOYEES *(Total for entire facility excluding outside contractors)*

c. NUMBER OF BEDS

d. WOULD YOU BE WILLING TO FURNISH COST INFORMATION *(dollar and/or staff hours)* ON THE ECONOMIC IMPACT OF CURRENT NRC REGULATIONS OR ANY FUTURE PROPOSED NRC REGULATIONS THAT MAY AFFECT YOU? *(NRC regulations permit it to protect confidential commercial or financial—proprietary—information furnished to the agency in confidence)*

- [ ] YES
- [ ] NO

FOR NRC USE ONLY

TYPE OF FEE	FEE LOG	FEE CATEGORY	COMMENTS	APPROVED BY
Renewal	Nov 5 I	EX 3A 1K	1984 NOV -3 PM 2:08 RECEIVED-REGION 1 NOV 0 2 1984	Frances Brown
AMOUNT RECEIVED	CHECK NUMBER		170.11(a)(4) - confirmed	DATE
No fee due				11/7/84

8803150047 851107
REG1 LIC30
20-00642-07 DCD

"OFFICIAL RECORD COPY" ML10003090

FEE EXEMPT

Answer to Question #5

A. Any byproduct material with Atomic Nos. 3 through 83, inclusive, in any chemical and/or physical form up to a maximum of 50 millicuries of each byproduct material with Atomic Nos. 3 through 83, inclusive.

B. Hydrogen-3 in any chemical or physical form up to a maximum of 500 millicuries.

C. Molydenum-99 in any chemical or physical form up to a maximum of 200 millicuries.

D. Technetium-99m in any chemical or physical form up to a maximum of 200 millicuries.

E. Technetium 99 in any chemical or physical form up to a maximum of 250 millicuries.

F. Carbon-14 in any chemical or physical form up to a maximum of 250 millicuries.

G. Hydrogen-3 in form of accelerator targets up to a maximum of 20 curies.

H. Iodine-125 in form of a foil source up to a maximum of 10 millicuries.

I. Polonium-210 in any chemical or physical form up to a maximum of 100 microcuries.

J. Carbon-14 in the form of a self luminous light source up to a maximum of 20 millicuries.

K. Californium-252 electroplated onto a Pt foil up to a maximum of 65 millicuries.

L. Plutonium-239 encapsulated as Pu-Be neutron sources up to a maximum of 48 grams.

M. Plutonium-239 in the form of plated alpha sources up to a maximum of 0.05 microcurie.

N. Americium-241 in the form of plated alpha sources up to a maximum of 0.2 microcurie.

Answer to Question #6

Laboratory research including animal studies and teaching and training of students.

Answer to Question #7. (Please see attachment).

Answer to Question #8.

Not Applicable.

Answer to Question #9. (Please see attachment).

Answer to Question #10 and #11 (Included in attached document "The Use of Radioactive Byproducts Materials at Boston College" and its supplementary material).

Answer to Question #7

RADIOACTIVE BYPRODUCTS CONTROL AND SAFETY SUPERVISION
1984-1985

Executive Vice President
(Dr. Frank Campenella)

Campus Safety Officer
(Mr. Russel Kelly)

Radiation Safety Officer (RSO)
(Prof. George Goldsmith)

Radiation Safety Committee

Biology	Chemistry	Physics	Administration
C. Stachow	M. Clarke	G. Goldsmith	M. McHugh
A. Annunziato	E. Kantrowitz	R. Hon (Geophysics)	

Radiation Survey Assistant: M. Pinheiro

Committee responsibilities:

(1) Establish and/or approve safety procedures and guides for radioactive isotope use.

(2) Approve proposals for initiating isotope uses prior to purchase or acquisition of isotopes.

(3) Review cases of infringement of guidelines and procedures.

(4) Meet at least once each academic semester.

(5) Other responsibilities as may develop in accordance with Nuclear Regulatory Commission regulations.

RSO responsibilities:

(1) Assure overall compliance with federal and in-house guidelines and regulations.

(2) Conduct and/or supervise: periodic safety evaluations (testing, etc.), education programs, distribution and maintenance of monitoring systems (film badges, counters, etc.); provision of bio-assays upon request; establish and/or approve receipt, distribution, storage and disposal systems; establish and/or approve keeping systems as required internally and by law.

Qualifications of Radiation Safety Committee Members

Prof. George J. Goldsmith PhD (Chmn.)
Associate Professor, Physics
Training:
Principles Purdue Univ. 8yrs. (on the job and formal training)
Standardization Purdue Univ. -- 1 yr (on job)
Biological Effects Purdue Univ. 1 yr (on job and formal)

Prof. Rudolph Hon, PhD
Assistant Professor, Geology
Training:
Principles MIT 4yrs. (on the job and formal training)
Standardization MIT 4yrs. (on the job and formal training)
Biological Effects MIT (on the job and formal training)

Prof. Chester Stachow, PhD.
Associate Professor, Biology
Training:
Principles Univ. of Manitoba 5yrs. (on the job and formal training)
Standardization Univ. of Manitoba & Cell Biology Research Institute Ottawa 3yrs. (on the job training)
Biological Effects Cell Biology Research Institute Ottawa & Boston College 10yrs. (on the job)

Prof. Michael J. Clarke, PhD.
Associate Professor, Chemistry
Training:
Principles Catholic Univ. & Stanford Univ. 2 courses (formal training)
Standardization Stanford Univ. 1 month (on the job)
Biological Effects Stanford Univ. 2 months (on the job)

Prof. Francis McCaffrey, PhD.
Associate Professor, Physics
Training:
Principles Army Mechanics & Materials Research Center 4 yrs. (on the job training)
Standardization none
Biological Effects AMMRC 4yrs. (on the job)

Prof. Anthony Annunziato. PhD.
Assistant Professor, Biology
Training:
Principles Univ. of Massachusetts, Amherst 5yrs. (on the job and formal training)
Standardization Univ. of Massachusetts 5yrs. (on the job and formal)
Biological Effects Univ. of Massachusetts 5yrs. (on the job and formal)

Prof. Evan Kantrowitz, PhD.
Associate Professor, Chemistry
Training:
Principles Harvard, one course plus 10 years work experience
Biological Effects Harvard, one course

Note: All of the persons mentioned above have had at least 5 years beyond their formal doctoral work in on-the-job experience measuring, and manipulating radioactive substnces at Boston College.

Answer to Question #9 (Part 1)

Facilities and Equipment

Biology. Ground floor of Higgins Hall (constructed 1966)

Rm. 110 - Lecture Lab complex - Used for Lectures in Summer Institute in Radiation Biology.

Rm. 114 - Animal Room - Used for animals involved in radiation and radioisotope tracer studies only.

Rm. 116 - Radiation Counting Room - Location of all nuclear detection equipment.

Rm. 118 - General Utility Room - Autoclave, balance, refrigerator, etc., can also be used as photographic dark room.

Rm. 115 - Radioisotope Handling Room - Injection of isotopes, preparation of samples, Storage of isotopes, etc.

Rm. 123 - Faculty member-graduate student research lab.

Rm. 125 - Faculty member office.

Consult building plan submitted with AEC-313 on December 20, 1967 for A73 Renewal.

Chemistry.

Air Sampling Equipment.

Cascade impactor, Unico, 5 stage	2
Cascade impactor, Andersen, 7 stage	1
Air Sampler, Bendix, portable, 10-20 cfm	2
Air Sampler, Staplex, Model TF1A	2
Air Sampler, Hivol	1
Air Sampler, Hurricane	1
Coulter Particle Counter, w/ 30um, 70um and 100 um apertures, w/ RIDL 52-58 discriminating amplifier. Used with ND-128	1
Low Temperature Asher, Tracerlab, LTA 600	1

Physics. ("all sealed source usage.")

Note: In general undergraduates do not handle isotope material except in the form of sealed sources. The undergraduate program is geared entirely to low-level sealed sources or to the use of our plutonium-beryllium howitzer which is covered under a separate license.

Physics (continued)

Use of radioactive isotopes occurs in the following spaces:

Higgins Room 467 Advanced Undergraduate Laboratory -- A large laboratory room with an a-proved hood and a large variety of measuring and monitoring instruments.

Higgins Room 463 Low level source storage and instrument storage.

Higgins Room 460 Undergraduate measurements laboratory.

Higgins Room B64 Isotope Storage Room (see letter dated 1/26/66)

Higgins Room 168 Mossbauer Laboratory (sealed Sources Only).

The DEpartment of Physics shares a building with the Biology Department which has a much more extensive radioisotope program. It is common practice to share instruments and facilities when required. (See jprevious individual license #200064202.

Answer to Question #9 (Part 2)

Monitoring, Measuring and Survey Instruments

Instrument	# on hand	radiation	use
Ge Mod 4sn11a3 Rad Monitor	1		mon
Pocket Dosimeters	18	g,x	mon
Ge(Li) Detectors, with cryostats and Tennelec preamps	3		mea
NaI(Tl) Detector, CI-1405 Isotopes, Inc.	3		mea
Surface Particle Detectors (alpha particle spectroscopy) Nuclear Diodes SL5-20-10 Nuclear Diodes SL5-50-21 (w/low noise preamplifier Tennelec 100B & - power supply Tennelec 900.) & vacuum chamber	2		mea
X-Ray Spectrometer, w/ Baird Atomic preamp CS-210 and Baird Atomic single channel spectrometer BA-530	1		mea
PROPORTIONAL DETECTOR	4	b,a	mea
SCINTILLATION DETECTOR	2	g	mea
SCINTILLATION (deep well)	3	g	mea
VICTOREEN METER	3	X-ray	mea
LIQUID SCINTILLATION	2	a,b	mea
Tracerlab SC-81 Spectrometer	1	g	mea
Tracerlab P20D Scintillation Detector	4	g	mea
CE BPA7 B-10 Neutron Counters	2	n	mea
Picker GM Mod 600010	7	g,g	mea & sur
RCL Neutron Counter 10514	2	n	mea & sur
NUCLEAR CHICAGO UNILUX II	1	b	all

Question #9 CFR30. NRC 313 Boston College

Instrument	#on hand	radiation	use
Beckman LS-1800 Liquid Scintillation Counter	1	b,g	all
Multichannel Spectr. Nuclear Data	1	g,a,b	all
Auto. Proportional Counter Nuclear Chicago	1	a,b,g	all
Baird-Atomic Windowless Flow Counters	2	a,b	mea,sur
Tracerlab Ratemeter	1		mea
Welch Thoron Ion Chambers	8	a	mea
Lauritsen Electrometers	3	a,b,g	mea
Tracerlab SC-18 Windowless Counter	3	a,b	meas
MI2714 Fast Neutron Survey Meter	1	n	sur

Scalers
(There are approximately 50 scalers of various sorts used in teaching, measurement and monitoring. Included in this group are three Tracerlab single channel gamma spectrometers)

Survey Meters
Geiger Counter General Purpose Survey Meters: a) 3 Victoreen Thyac III, b) 1 Technical Associates PUG-1, c) 1 Victoreen x-ray Minimonitor II, d) 1 Reactor Experiment Dig/Rate Exposure Ratemeter). Items (b) and (c) were factory calibrated 7/84. The other instruments are subject to periodic calibration checks using our calibration sources.

Coincidence and Miscellaneous
There are located in various laboratories throughout the campus a wide variety of coincidence measuring equipment, pulse generators, oscillosocopes, amplifiers, power supplies, photomultiplier tubes, geiger counters, scintillation crystals, silicon barrier layer detectors, CdTe detectors, ionization chambers, etc., the accumulation of many years of radiotracer studies, and nuclear physics measurement and instruction.

Calibration Sources
Victoreen 06-021 Multidosimeter Calibrator
Isotope Products Am-241 #12042 0.1171 microcurie alpha standard
Isotope Products Beta Calibration Source Set # 200-1 C-14, Tc-99, Pb-210, Pm-147, Sr-90
Isotope Products Gamma Calibration Set #290 Ba-133, Cd-109, Co-57, Cs-137, Mn-54, Na-22

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A. GOVERNMENT REGULATIONS AND STANDARDS:

1. The use of Radioactive byproduct materials (yielded in or made radioactive through nuclear reactions involving plutonium, U-233, or U-253 reactants) is governed by licenses issued by the United States Nuclear Regulatory Commission.

2. All licenses of the Nuclear Regulatory commission are required to conform to the standards for protection against radiation hazards established by the Nuclear Regulatory Commission (published as Title 10, Chapter 1, part 20 - Nuclear Regulatory Commission, Rules and Regulations, "Standards for Protection Against Radiation"). Copies of these regulations may be examined at the Office of Campus Safety and Security, Boston College, or may be obtained from the academic department offices.

3. All persons using, possessing, receiving, or in any way handling materials, instruments or machines which emit ionizing radiation in the Commonwealth of Massachusetts are also subject to rules and regulations issued by the Massachusetts Department of Public Health, except as may be specifically exempted. Copies of these are available from:

   The Department of Public Health
   Division of Sanitary Engineering
   State House
   Boston, Massachusetts

   Copies may also be examined at the Office of Campus Safety and Security.

4. Users at Boston College are collectively governed by license application filed with the Nuclear Regulatory Commission under Nuclear Regulatory Commission Regulatory Guide - Title 10, Chapter 2, "Guidance for Academic Institutions Applying for Specific Byproduct Material Licenses."

5. In accordance with the guides and regulations referred to above, academic institutions are required as condition of license to operate a radiation safety program.

Boston College's license application and a description of its radiation safety program are available from the following sources:

1. Departmental representatives to the Radiation Safety Committee;

2. Academic departmental offices;

3. Office of Campus Safety and Security.

B. ADMINISTRATION OF THE RADIATION SAFETY PROGRAM AT BOSTON COLLEGE:

Under the terms of the academic institution license, the government guides and regulations applicable to the use, possession, handling or transportation of radioisotopes on campus by University staff are enforced by a Radiation Safety Committee. The Committee will meet at least once a semester to review operations regarding radioisotopes at Boston College, and will report its activities and findings to the Radiation Safety Officer.

1. Committee Membership: The Radiation Safety Committee consists of representatives from all University units wherein radioisotopes are used, the Radiation Safety Officer, an academic administrator (ex officio), and the Director of Campus Safety and Security (ex officio).

2. Committee Authorities: The Radiation Safety Committee will have the authority to:

   a. Establish, approve and/or review overall safety procedures and those for individual users;

   b. Approve new proposals for radioisotope users, and uses, prior to purchase or acquisition of radioisotope materials;

   c. Review and investigate cases of infringement of guidelines and procedures;

   d. Suspend authorization for use of isotopes.

   The Radiation Safety Committee and its members will be available to users as sources of advisement, and for procedures involving radiation safety.

3. Radiation Safety Officer:

   a. The Radiation Safety Officer will report on the status of radiation safety to the University official responsible for overall University compliance with Federal and state safety regulations (the Director of Campus Safety and Security).

b. The Radiation Safety Officer will be an ex officio member of the Radiation Safety Committee except that he/she may also serve on the Committee as a departmental representative.

c. The Radiation Safety Officer may recommend suspension of any operations involving radioactive materials where hazards or violations exist. Operations may resume only after review and approval by the Radiation Safety Committee.

d. The Radiation Safety Officer, as directed by the Radiation Safety Committee, will coordinate or supervise: periodic safety evaluations and tests; provision of bioassays; establishment of systems and procedures for receipt, distribution storage and disposal of radioactive materials; establishment of internal record-keeping systems and procedures as required by law.

e. The Radiation Safety Officer shall conduct a review of the total Boston College radiation safety program at least once each year. The purpose of the review will be to examine the program to determine the level of compliance, and to detect areas in which modification of established procedures may be desirable.

C. RADIATION EXPOSURE: CONTROL AND PERSONNEL LIMITS:

1. Definition of areas, labelling and signs: Federal and State regulations define the following area definitions and special control features:

a. Unrestricted areas are areas in which a person continually present receives less than 2 mrem in any 1 hour or 100 mrem in any 7 consecutive days to any portion of the body. Control measures for exposure from external radiation are not required.

b. Restricted areas are areas where radiation levels are above those cited as maximum allowable for unrestricted areas. Access to restricted areas must be controlled by the individual users of radioisotopes employed in the areas with the following criteria to be met:

No individual over 18 years of age will receive in one quarter year, from any radiation source, an occupational dose in excess of the following:

- Whole body; head and trunk; active blood-forming organs;	1 1/4 rem
- Hands and forearms; feet and ankles	18 3/4 rem
- Skin of whole body	7 1/2 rem

Persons under 18 years of age are limited to maximum exposures of 1/10th of the above levels.

Non-occupational exposures are limited to maximum levels of 0.5 rem/year.

Higher exposures must meet special government regulations under the direct supervision of the Radiation Safety Officer.

2. Personnel Monitoring: Personnel monitoring devices are required by law, and records must be kept if any individual receives, or is liable to receive, a dose in any calendar quarter in excess of 25% of the above values (5% for persons under 18).

3. Airborne Contamination Limits: Airborne radioactivity concentration limits to prevent overexposure of any organs as a result of breathing contaminated air are summarized for common radioisotopes (concentrations are in microCuries/cc) in Table 1 of the Appendix.

4. Posting of Signs and Labels: Government regulations specify the following signs and conditions:

   a. "CAUTION RADIATION AREA" (Sign) - Required for areas where a major part of the body can receive an hourly dose of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirem. For sealed sources, if the level at 12 inches from the source container surface is not in excess of 5 millirem/hour, a sign is not required.

   b. "CAUTION RADIOACTIVE MATERIALS" (Sign) - Required in areas/rooms in which radioactive materials are used or stored in an amount exceeding quantities listed in Table 2, Column (a), of the Appendix.

   c. "CAUTION RADIOACTIVE MATERIAL" (Label) - Required on any container used to transport, store or use radioactive materials in quantities greater than specified in Table 2, column (b), of the Appendix. Labels will also state

quantities, kinds of materials, and dates of measurement of quantities.

d. "DANGER, HIGH RADIATION AREA" (Signs are required for any area where a major part of the body may receive in excess of 100 millirem in one hour.

Signs are also required for airborne radioactivity areas (consult the Radiation Safety Officer for specific conditions). Signs should not be used when they are not required.

D. APPLICATION PROCEDURES AND AUTHORIZATION FOR USE OF RADIOISOTOPES:

1. No person may use, or bring into an official part of the Boston College campus, radioisotopes in any amount without notification of the Radiation Safety Officer, or the departmental representative in the case of quantities not requiring a specific license or sold to the general public, or without approval of the Radiation Safety Committee in the case of quantities which do not require a specific license.

2. Authorization for the use of radioisotopes is given to designated individuals, known as Principal Investigators (also referred to below as "users"), who will be held responsible for the safe and proper use, storage and disposal of all radioisotopes under their jurisdiction.

3. Applications for the initial use, or modification of existing authorizations, of radioisotopes must be submitted in written proposal form to the Radiation Safety Officer who will forward the proposal with comments and recommendations to the Radiation Safety Committee. Written proposals should include such information as:

   a. Names of Principal Investigators who will supervise individual laboratory/program safety procedures;

   b. Specific isotopes and maximum quantities involved;

   c. Chemical and/or physical form;

   d. Purpose and nature of proposed use, with citation of specific operations that may effect contamination and/or exposure (e.g., grinding, evaporations, etc.);

   e. Training and experience of supervisory and other persons

handling materials;

f. Training provided technicians;

g. Monitoring instrumentation available on site, or available for use if not on site (location);

h. Storage and disposal methods specific to type of material or individual academic departments;

i. Other information as may be required by government regulations or recommended by the Radiation Safety Officer.

4. Proposals will be distributed to each member of the Radiation Safety Committee for review and comment. Except where vetoed or modified by the Committee, the recommendations made on each proposal by the Radiation Safety Officer will determine the authorization and conditions of use of radioisotopes by individual users.

5. Authorization for use will be effective for a specified time period--covering specified radioisotopes and their quantities. University purchasing offices will honor only those requests from Principal Investigators whose names appear on the list of authorized users received from the Radiation Safety Officer.

6. At least once each semester, the Radiation Safety Committee will offer a training course for Housekeeping, Security, and other support personnel. This course will include: basic information about radiation from radioactive substances and their hazards; rules and regulations concerning the use of radioactive substances; management of accidents and spills; and emergency procedures.

Further, the Director of Security and the head of Housekeeping will receive each year a notice from the Radiation Safety Committee containing a reminder of the current rules and procedures.

It will be the responsibility of operators of individual laboratories to see to the proper instruction of new personnel who join the facility between training sessions.

All new personnel must be reported to the Radiation Safety Officer for certification prior to assuming their duties.

E. USER RESPONSIBILITIES AND DUTIES:

Users of radioisotopes are individually accountable for compliance with government regulations, and in-house conditions of use regarding the radioisotopes in their possession.

1. General user responsibilities and duties are to:

   a. See that all persons who work with the radioisotopes authorized for the user are properly trained, and/or indoctrinated in safe working habits.

   b. Avoid unnecessary exposure, either to themselves or to others under their supervision.

   c. Maintain up-to-date logs of receipt and disposal of radioisotopes in their possession; their use in research, waste disposal, transfer, and storage. These records must be available for inspection and/or use by the Radiation Safety Officer at all times.

   d. Maintain an up-to-date inventory of radioisotopes on hand, and insure that current quantities do not exceed authorized maximum levels.

   e. Post on-site, in each authorized location under direct supervision, rules, conditions and/or instructions regarding the use of authorized radioisotopes.

   f. Insure the convenient availability of a survey meter to monitor personnel exposure and surface contamination (tritium excepted).

   g. Attend to necessary monitoring tasks (leak tests, etc.), as noted in this policy and procedure, and any additional monitoring tasks that should be directed by the Radiation Safety Officer or Radiation Safety Committee.

2. It is the responsibility of each Principal Investigator to communicate to the Radiation Safety Officer in writing: the name(s) and duties of women who are pregnant and who work with radioisotopes under the control of the user.

F. ORDERING, DELIVERY, HANDLING AND STORAGE OF RADIOISOTOPES:

1. Ordering Materials: Authorized users will submit all orders for radioisotopes to the person designated as Academic Purchasing Officer for the department. Prior to processing the order, the purchasing officer will review that user's current inventory of radioisotopes on hand to assure that maximum allowable quantities for that user will not be exceeded by the new order.

2. Delivery of Materials: All radioisotopes must be delivered to the Biology Department stockroom, B-18, to be leak tested prior to delivery to the addressee. No delivery can be made without a signed statement of receipt from the purchasing officer, the department receiving clerk, or the user who originated the order.

   Packages which show measureable contamination above background upon wipe testing should be decontaminated and then stored for 24 hours prior to retesting for surface contamination.

   Packages are to be opened according to the procedure described in Appendix 3.

3. Handling of Materials:

   a. Each user is responsible for the availability of proper equipment (laboratory handling equipment, shielding, hoods), protective clothing (gloves, coveralls, shoe cover, etc.) prior to the start of work involving quantities of radioisotopes which may be hazardous to health.

   b. Whenever possible, all work should be done in trays lined with absorbent materials to avoid contamination of permanent laboratory bench tops.

   c. All persons working in areas where radioisotopes are contained or used must "wash up" before eating, smoking or leaving work. Hand and shoe counts will be taken at the completion of daily operations.

   d. Eating, storing or preparing food is forbidden in areas where unsealed radioactive sources are located or worked on. Smoking is also prohibited in these locations.

   e. Radioactive liquids will not be mouth pipetted.

4. Storage of Materials:

   a. Materials requiring a "Radioactive Materials" label will be stored only in areas which provide protection against fire, explosion and flooding. Such areas must be approved by government agency or by the Radiation Safety Officer. They are to be kept locked and under the supervision of Radiation Safety Officer-authorized departmental staff.

   b. Materials will be stored in suitable containers and direct radiation from the containers will not create a "Radiation Area." Appropriate shielding should be provided to insure this condition.

   c. Prolonged storage of source radioisotopes in individual user laboratories in excess of normal research needs is prohibited.

   d. Area signs must be posted and containers of materials properly labelled.

   e. The Radiation Safety Officer must be informed of any significant interdepartmental transfer.

   A log of inflow and disposal of materials will be maintained for each non-user storage area designating dates, laboratory origins, levels and nature of radioisotopes.

G. WASTES: STORAGE AND DISPOSAL:

Radioactive wastes must be stored only in restricted areas approved by the Radiation Safety Committee.

1. Liquid Wastes:

   a. Liquid wastes must be neutralized (pH7±1) prior to placement in the waste container. Volatile wastes will be transported in sealed containers.

   b. Each user laboratory will maintain and post its system for disposing of liquid wastes. Logs must be kept of disposal operations (see F.4.).

c. Liquid wastes may be sink-disposed within the limits of Table 3 (see Appendix) provided the wastes are readily soluble or dispersible in water. Sink disposal must be accompanied by repetitive flushings with water.

2. Solid Wastes:

a. Each user will be informed of the procedure for transporting solid waste from the user laboratory to a central dumping and disposal point. This operation will be supervised by a designated employee.

b. Disposal of solid wastes will be via commercial vendor.

c. An up-to-date log must be maintained of the inflow and collection by vendor of solid wastes from the user dumping area. Such inflow information as laboratory of origin, nature, and quantity will be kept; outflow will be recorded as approximate upper limits discharged to the commercial vendor.

H. CONTAMINATION AND SPILLS:

1. Table tops, floors, and all exposed surfaces should be cleaned immediately after a spill. These and work areas should also be monitored before and after work with radioactive materials.

2. The maximum limits suggested for fixed contamination on hands, body surfaces, personnel clothing and shoes are:

Alpha activity - 100 d/m per 100 cm^2
Beta-gamma activity - 0.1 mrad/hr at 2cm

3. All significant spills must be reported to the Radiation Safety Officer or by the departmental representative to the Radiation Safety Committee, who in turn will inform the Radiation Safety Officer. Each user is responsible for reporting and prompt clean up of spills. A survey must be made after each spill to verify the removal of radioactive material. All contaminated clean up equipment should be disposed of in approved fashion as required for the disposal of solid wastes.

I. EMERGENCY PROCEDURES:

Minor Spills:

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

2. PREVENT THE SPREAD: Cover the spill with absorbent paper.

3. CLEAN UP: Use disposable gloves and remote handling tongs. Carefully fold the absorbent paper and pad. Insert into a plastic bag and dispose of in the radioactive waste container. Also insert into the plastic bag all other contaminated materials such as disposable gloves

4. SURVEY: With a low-range, thin-window G-M survey meter, check the area around the spill, hands, and clothing for contamination.

5. REPORT: Report incident to the Radiation Safety Officer.

Major Spills:

1. CLEAR THE AREA: Notify all persons not involved in the spill to vacate the room.

2. PREVENT THE SPREAD: Cover the spill with absorbent pads, but do not attempt to clean it up. Confine the movement of all personnel potentially contaminated to prevent the spread.

3. SHIELD THE SOURCE: If possible, the spill should be shielded, but only if it can be done without further contamination or without significantly increasing your radiation exposure.

4. CLOSE THE ROOM: Leave the room and lock the door(s) to prevent entry.

5. CALL FOR HELP: Notify the Radiation Safety Officer immediately.

6. PERSONNEL CONTAMINATION: 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.

J. ACCIDENT REPORTS:

All accidents involving possible individual or area contamination must be reported immediately to the Radiation Safety Officer or by the departmental representative to the Radiation Safety committee, who in turn will inform the Radiation Safety Officer.

K. TERMINATION OF WORK WITH RADIOISOTOPES:

The Radiation Safety Officer, or the departmental representative to the Radiation Safety Committee, must be informed prior to the termination of any use of radioisotopes. Areas which are planned to be returned to general, unrestricted use, must be surveyed by the Radiation Safety Officer beforehand.

TABLE 1

AIRBORNE CONTAMINATION LIMITS FOR COMMON RADIOISOTOPES

Isotope	MicroCurie/ml
C-14	$1x10^{-7}$
H-3	$2x10^{-7}$
S-35	$9x10^{-9}$
I-131	$1x10^{-10}$
I-125	$8x10^{-11}$
P-32	$2x10^{-9}$
Ca-45	$1x10^{-9}$
Na-24	$5x10^{-9}$
K-42	$4x10^{-9}$
Cr-51	$8x10^{-8}$
CL-36	$8x10^{-10}$

TABLE 2

MINIMUM QUANTITIES (LEVELS) OF SELECTED RADICISOTOPES REQUIRING SIGNS AND LABELS

Isotope	(a) Signs on rooms* MicroCuries	(b) Labels** MicroCuries
C-14	1,000	100
H-3 (HTO, $H_3$20)	10,000	1,000
Ca-45	100	10
Co-60	10	1
Cr-36	100	10
Cr-51	10,000	1,000
Cs-37, Ba-137	100	10
Cu-64, Fe-55	1,000	100
Fe-59	100	10
I-131	100	10
I-125	10	1
K-42, Na-24, P-32	100	10
S-35	1,000	100
Sr-90	1	0.1

*Signs are not required on rooms in cases where radioisotopes will be in them for less than 8 hours provided that (1) the materials are constantly attended by an individual who will take necessary precautions to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations; (2) the room is under the authorized user's control.

**Daily permissible sink disposal limits.

TABLE 3

MAXIMUM CONCENTRATIONS OF SELECTED RADIOISOTOPES PERMISSIBLE FOR SINK DISPOSAL (SOLUABLE FORMS ONLY)

Isotope	MicroCurie/ml
C-14	$2x10^{-2}$
H-3	$1x10^{-1}$
Ba-13	$5x10^{-3}$
Ca-45	$3x10^{-4}$
Co-60	$1x10^{-3}$
Cl-36	$2x10^{-3}$
Cr-51	$5x10^{-2}$
Cs-137	$4x10^{-4}$
Cu-64	$1x10^{-2}$
Fe-55	$2x10^{-2}$
Fe-59	$2x10^{-3}$
I-125	$4x10^{-5}$
I-131	$6x10^{-5}$
K-42	$9x10^{-3}$
Na-24	$6x10^{-3}$
P-32	$5x10^{-4}$
S-35	$2x10^{-3}$
Sr-90	$1x10^{-5}$

*U.S. Nuclear Regulatory Commission, Rules and Regulations (Title 10, Chapter 1, part 20.3)

APPENDIX I

BIOASSAY PROGRAM

Bioassays will be employed to evaluate the exposure levels of individuals working with I-125, I-131, and H-3. The basic procedures to be followed are as outlined in Regulatory Guide 8.20: Applications of Bioassay for I-125 and I-131 (April, 1978) and Guidelines for Bioassay Requirements for Tritium (NRC, Div. Fuel cycle & mat. Safety. Oct. 18, 1977 - AB/REA).

The major features of the bicassay programs are as follows:

A. For users of I-125 or I-131:

I. Any individual who will be using unsealed sources of I-125 or I-131 in excess of 99 $_N$Ci must notify the departmental Radiation Safety Officer.

II. a. Those individuals who will be using these isotopes repeatededly (more than once per two week period) will be monitored regularly following baseline measurements.

b. Those individuals who will be infrequent users (less than once every two weeks) will be required to submit to bioassay within 72 hours of last isotope use.

c. Note: Depending upon the nature of I-125 or I-131 use, it may be necessary for all individuals frequenting the laboratory to be assayed as in a or b above (consult the Radiation Safety Committee for determination of such need).

III. Individuals who show activity greater than 0.12 $_N$Ci I-125 or 0.04 $_N$Ci I-131 will be prohibited from conducting further studies employing the isotope in question until further notified by the Radiation Safety Committee.

IV. a. Individuals who show a positive bioassay (see III above, will be required to have repeated bioassays as determined by the Radiation Safety Committee until acceptable limits are resumed.

b. Any laboratory whose personnel show a positive bioassay (see III above) will be specifically monitored and its procedures will be reviewed and evaluated by the

Radiation Safety Committee to determine if potential hazards exist.

B. For users of H-3:

I. Any individual who will be using unsealed sources of H-3 in excess of 1 mCi must notify the departmental radiation safety officer.

II. a. Individuals who will be using H-3 repeatedly will be required to submit urine samples regularly for evaluation.

b. Individuals who will be using H-3 infrequently will be required to submit a urine sample within 1 week of last H-3 use.

c. Note: The nature of H-3 use may require that any individual frequenting the laboratory similarly submit urine samples (consult Radiation Safety Committee for determination of such need).

III. Individuals who show H-3 activity greater than 5 μCi/l will be prevented from continuing studies employing H-3 and will not be allowed to resume until notified by the Radiation Safety Committee.

IV. Individuals who show a positive bioassay, and the laboratories whose personnel show a positive bioassay, will be subject to procedures as described in A.IV a and b above.

APPENDIX II

RADIATION SAFETY COMMITTEE

All laboratories will be classified according to the following schedule.

A. Classification of Laboratory Areas:

Radionuclide Group **	SURVEY FREQUENCY CATEGORY LOW	MEDIUM	HIGH
1	Less than 10 uCi	10 uCi to 1 mCi	Greater than 1 mCi
2	Less than 1 mCi	1 mCi to 100 mCi	Greater than 100 mCi
3	Less than 100 mCi	100 mCi to 10 Ci	Greater than 10 Ci
4	Less than 10 Ci	10 Ci to 1000 Ci	Greater than 1000 Ci

Proportional fractions are to be used for more than one isotope.

Modifying Factors	Factors
Simple storage	x 100
Very simple wet operations (e.g. preparation of aliquots of stock solutions)	x 10
Normal chemical operations (e.g. analysis, simple chemical preparations)	x 1
Complex wet operations (e.g. multiple operations, or operations with complex glass aparatus)	x 0.1
Simple dry operations (e.g. manipulation of powders) and work with volatile radioactive compounds	x 0.1
Exposure of non-occupational persons	x 0.1
Dry and dusty operation (e.g. grinding)	x 0.01

The object is to determine how often to survey the laboratory. To do this, multiply the activity range under LOW, MEDUIM, and HIGH survey frequency by the appropriate Modifying Factor to construct a new set of mCi ranges for LOW, MEDIUM, and HIGH survey frequency.

EXAMPLE: A lab in which 10 mCi of Group II radionuclide is used in normal chemical operations should be surveyed on a MEDIUM frequency. However, if only simple storage is done, then a LOW frequency is adequate (Less than 1mCix100=Less than 100mCi new LOW range). But if a dry grinding operation is done, a HIGH frequency is required (Greater than 100mCix0.01=Greater than 1mCi new HIGH range).

** Patterned after the Recommendation of the International Commission on Radiological Protection-Report of Committee V; Pergamon Press, New York, N.Y. (1965).

B. Methods and Frequency for Conducting Surveys:

Low Level Areas - Not less than once per month.

Medium Level Areas - Not less than once per week.

High Level Areas - Not less than once per normal working day.

C. Method of Survey: Routine surveys should be carried out in two parts to determine both radiation levels and removable contamination levels.

I. Radiation Levels: Monitoring area with a radiation survey meter sufficiently sensitive to detect 0.1 mR/h. The results of this survey should be recorded on a standard form which should show:

a. Location, date, and type of equipment used.

b. Identification of person conducting the survey

c. Sketch of area surveyed, identifying relevant features such as active storage areas, active waste areas, etc.

d. Measured exposure rates, keyed to location on sketch (point out rates that require corrective action).

e. Corrective action taken in the case of excessive exposure rates, reduced exposure rates after corrective action, and any appropriate comments.

II. Contamination Levels: A series of wipe tests should be taken in all areas where activity is handled in unsealed form. The location of wipe tests should be indicated on the above mentioned survey form and should be chosen for maximum probability of contamination.

Floors, particularly adjacent to doorways, and door and drawer handles should also be wipe tested frequently. Care should be taken that cross contamination does not occur.

An end window GM or gas flow proportional counter normally may be used for assaying beta emitters at or above C-14 energies; low energy beta emitters will require liquid scintillation counting.

A gamma-scintillation counter (example: NaI well counter), should be used for pure gamma emitters. Make sure that the analyzer threshold is set below the lowest gamma energy used in the lab (usually I-125).

Record a background count of 5-10 minutes using the same counting conditions used with the wipes.

In the case of wipes contaminated with gamma emitters, the radionuclide can be identified from successive counts with different analyzer settings if the settings have been calibrated with known energy standards.

Acceptable Limits:

a. Radiation Limits (Whole body only):

   1. Non-controlled area: Personnel must not receive more than 2 mR in any one hour, or more than 100 mR in 7 consecutive days, or more than 500 mR in any one year.

   2. Controlled area: If an area is controlled for purposes of radiation protection, then an investigator's total exposure must be less than 1.25 Rem/13 wks. (there are certain conditions where up to 3 Rem/le wks. is allowed, but this exposure level cannot be continued routinely). On a basis of 40 hours/wk exposure, the maximum exposure rate would have to be less than 2,5 mR/h. In practice, the radiation levels should be kept as low as is practicabl, and always below applicable limits.

b. An individual wipe test should routinely cover approximately 100-150 cm^2. Ideally, any contamination more than a few DPM above background should be cleaned up; however, a more usual level for B-y at which cleanup is initiated is about 200 DPM. At approximately 1000 DPM

a Contamination Zone should be established until the contamination is removed.

Contamination levels may also be estimated with a survey meter. As a rough rule of thumb, establish a Contamination Zone if readings are greater than 100 CPM for Group I and II radionuclides and greater than 1000 CPM for Groups III and IV radionuclides when measured with a thin window GM meter. Of course, this particular instrument will not detect low energy beta emitters such as tritium.

APPENDIX III

PROCEDURES FOR SAFELY OPENING PACKAGES CONTAINING RADIOACTIVE MATERIAL

1. Visually inspect package for any sign of damage (e.g., wetness, crushed). If damage is noted, stop procedure and notify Radiation Safety Officer.

2. Measure exposure rate at 3 feet from package surface and record. If greater than 10 mR/hr, stop procedure and notify Radiation Safety Officer.

3. Measure surface exposure rate and record. If greater than 200 mR/hr, stop procedure and notify Radiation Safety Officer.

4. Put on gloves.

5. Open the outer package (following manufacturer's directions, if supplied) and remove packing slip. Open inner package to verify contents (compare requisition, packing slip, and label on bottle), and check integrity of final source container (inspecting for breakage of seals or vials, loss of liquid, discoloration of packaging material). Check also that shipment does not exceed possession limits.

6. Wipe external surface of final source container with moistened cotton swab or filter paper held with forceps; assay and record.

7. Monitor the packing material and packages for contamination before discarding.

   a. If contaminated, treat as radioactive waste.

   b. If not contaminated, obliterate radiation labels before discarding in regular trash.

In all of the above procedures, take wipe tests with a paper towel, check wipes with a thin-end-window GM survey meter, and take precaution against the spread of contamination as necessary.

APPENDIX IV

IN VIVO LABELLING STUDIES

1. In vivo labelling experiments are to be conducted only by individuals whose protocols have been approved by both the University Committee on the Care and Use of Animals (UACC), to ensure adherence to guidelines for the humane treatment of animals during the course of the experiments, and the University Radiation Safety Committee (RSC) to ensure proper isotope handling and monitoring.

2. All such studies are to be conducted in the facilities of room H114 which are designed for this purpose.

3. All cages and other materials for use in these in vivo labelling studies will be kept in room H114 and its environs and shall be used exclusively for such studies, i.e. these cages and other materials will not be used for routine animal housing, maintenance, or experimentation.

4. At the conclusion of the in vivo labelling experiment (irrespective of duration) the following procedures must be followed:

   a. All bedding materials must be suitable disposed of as contaminated solid waste;

   b. All cages and areas used in the study must be thoroughly cleaned by the investigator;

   c. All such cages and areas must be monitored carefully to ascertain that they are free of any detectable radioactive contaminants;

   d. All carcasses must be disposed of as outlined in the regulations.*

5. The direct responsibility for overseeing and manipulating the organisms carrying radioisotopes (and the cages and other materials) during the in vito experiments rests with the investigator personally--subject to the advisements and directives of the Director of Animal Facilities and the UACC with regards to animal well-being. No individual who has not been specifically approved by the RSC for direct use of radioisotopes will be involved with the animals or materials used in any in vito labelling experiment.

* Not specifically outlined--e.g., garbage grinder, dilution tank, etc.

APPENDIX V

GENERAL RULES FOR THE SAFE USE OF RADIOACTIVE MATERIAL

1. Wear laboratory coats or other protective clothing at all times in areas where radioactive materials are used.

2. Wear disposable gloves at all times while handling radioactive materials.

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

4. Use syringe shields for preparation of patient doses and administration to patients except in circumstances such as pediatric cases when their use would compromise the patient's well-being.

5. Do not eat, drink, smoke, or apply cosmetics in any area where radioactive material is stored or used.

6. Assay each patient dose in the dose calibrator prior to administration. Do not use any doses that differ from the prescribed dose by more than 10%.

7. Wear personnel monitoring devices (film badge of TLD) at all times while in areas where radioactive materials are used or stored. These devices should be worn at chest or waist level.

8. Wear TLD finger badges during elution of generator and preparation, assay, and injection of radiopharmaceuticals.

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

10. Never pipette by mouth.

11. Survey generator, kit preparation, and injection areas for contamination after each procedure or at the end of the day. Decontaminate if necessary.

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

13. Always transport radioactive materials in shielding containers.

APPENDIX VI

METHODS FOR CALCULATION OF (X- AND GAMMA-RAY) SURVEY METERS, INCLUDING PROCEDURES, STANDARDS AND FREQUENCY

A. Calibration of survey meters shall be performed with radionuclide sources.

1. The sources shall be approximate point sources.

2. The source activities shall be traceable within 5% accuracy to the U.S. National Bureau of Standards (NBS) calibrations.

3. The frequency shall be at least annually and after servicing.

4. Each scale of the instrument shall be calibrated at least at two points such that (a) one point is in each half of the scale and (b) the two points are separated by 35-50% of full scale.

5. The exposure rate measured by the instrument shall differ from the true exposure rate by less than 10% of full scale (read appropriate section of the instrument manual to determine how to make necessary adjustments to bring instrument into calibration). Readings within ±20% will be considered acceptable if a calibration chart or graph is prepared and attached to the instrument.

Note: Sources of Cs-137, Ra-226, or Co-60 are appropriate for use in calibrations. The activity of the calibration standard should be sufficient to calibrate the survey meters on all ranges, or at least up to 1 R/hr on the higher-range instruments. If there are higher ranges, they should at least be checked for operation and approximately correct response to radiation.

B. A reference check source of long half-life, e.g., Cs-137 or Ra D and E, shall also be read at the time of the above calibration. The readings shall be taken with the check source placed in specific geometry relative to the detector. A reading of the reference check source should be taken:

1. Before each use and also after each survey to ensure that the instrument was operational during the survey;

2. After each maintenance and/or battery change;

3. At least quarterly.

If any reading with the same geometry is not within ±20% of the reading measured immediately after calibration, the instrument should be recalibrated (see item A).

C. The instrument must be calibrated at lower energies if its response is energy dependent and it is to be used to measure in the Xe-133 or Tc-99m energy ranges.

This calibration may be done either:

1. As in item A above with calibrated standards of radionuclides at or near the desired energies; or

2. As a relative intercomparison with an energy-independent instrument and uncalibrated radionuclides.

D. Records of the above items A, B-2, B-3, and C must be maintained.

E. Use of Inverse Square Law and Radioactive Decay Law:

1. A calibrated source will have a calibration certificate giving its output at a given distance measured on a specified date by the manufacturer or NBS.

   a. The Inverse Square Law may be used with any point source to calculate the exposure rate at other distances.

   b. The Radioactive Decay Law may be used to calculate the output at other times after the specified date.

2. <u>Inverse Square Law</u>:

   S (R_1) (R_2)

   * - - P_1

   \- - - - - - P_2

   Exposure rate at P_2:

   $R2 = [(P_1)^2/(P_2)^2](R_1)$

   Where:

   S is the point source

R_1 and R_2 are in the same units (mR/hr or R/hr)

P_1 and P_2 are in the same units (centimeters, meters, feet, etc.)

3. Radioactive Decay Law:

Exposure rate t units of time after specified calibration date

$$R_t = R_o \times e - [0.693/T_{\frac{1}{2}} \times t]$$

where

R_o and R_t are in the units mR/hr or R/hr

R_o is exposure rate on specified calibration date

R_t is exposure rate t units of time later

$T_{\frac{1}{2}}$ and t are in the same units (years, months, days, etc.)

$T_{\frac{1}{2}}$ is radionuclide half-life

t is the number of units of time elapsed between calibration and present time

4. Example: Source output is given by calibration certificate as 100 mR/hr at 1 foot on March 10, 1975. Radionuclide half-life is 5.27 years.

Question: What is the output at 3 feet on March 10, 1977 (2.0 years)?

a. Output at 1 foot, 2.0 years after calibration date:

$$R = 100 \text{ mR/hr} \times e - (0.693 \times 2.0 / 5.3)$$

$$= 100 \times 0.77 - 77 \text{ mR/hr at 1 foot on March 10, 1977}$$

b. Output at 3 feet, 2.0 years after calibration date:

$$R_3 \text{ feet} = [(1 \text{ foot})^2/(3 \text{ feet})^2] \times 77 \text{ mR/hr}$$

$$= 1/9 \times 77 - 8.6 \text{ mR/hr at}$$

3 feet, 2.0 years after calibration.

Check appropriate items:

_____ 1. Survey instruments will be calibrated at least annually and following repair.

_____ 2. Calibration will be performed at two points on each scale.

The two points will be approximately 1/3 or 2/3 of full scale. A survey instrument may be considered properly calibrated when the instrument readings are within ±10% of the calculated or known values for each point checked. Readings within ±20% are considered acceptable if a calibration chart or graph is prepared and attached to the instrument.

3. Survey instruments will be calibrated

_____ a. By the manufacturer

_____ b. At the licensee's facility

(1) Calibration source

Manufacturer's name ______________________

Model no. ______________________

Activity in millicuries

Accuracy ______________________

Traceability to primary standard __________

_____ (2) The calibration procedures in Section I of Appendix D will be used

or

_____ (3) The step-by-step procedures, including radiation safety procedures, are attached.

_____ c. By a consultant or outside firm

(1) Name ____________________

(2) Location ____________________

(3) Procedures and sources:

________ have been approved by NRC and are on file in License No.____________________

________ are attached.

Safety Guidelines for Radioisotope Users

(Biology Dept.)

1. All radioisotopes entering the Biology Dept. must be leak tested before final delivery to the receiving laboratory.

2. Any working stock of a radioactive by-product actually stored in an individual laboratory must be stored with adequate regard for appropriate safety measures, such as shielding, e.g. lead shields for all gamma and x-ray sources. All such isotope by-products are to be accurately and clearly labelled.

3. While working with any isotope, each investigator must
   a) minimize exposure time - working at maximal effective distance and the shortest possible time,
   b) use appropriate safety measures - gloves, absorbant matting, mechanical pipettors, shielding, monitoring devices (Geiger Counter and Radiation Monitoring Badge, especially for strong beta, gamma, and x-ray sources, e.g. ^{32}P, ^{125}I, ^{131}I), etc.

4. All work areas are to be monitored for contamination after each assay, e.g. wipe test for ^{3}H and ^{14}C. (Each laboratory is subject to periodic inspection by the Departmental Radiation Safety Committee).

5. Each laboratory is required to keep accurate records of all isotope use and disposal. A separate logging of liquid and solid waste disposal will be required at the location of the waste barrel or sink located in Higgins 115. Copies of all records are to be periodically submitted for central recording to Olga Anderson.

6. Spills resulting in contamination are to be reported to the Departmental Radiation Safety Committee for later confirmation of decontamination. Such areas are to be blocked off until decontamination is accomplished. Each investigator is expected to be familiar with procedures and have available suitable materials to deal with any possible contaminations resulting from the isotopes being used.

7. No individual will be allowed to work with radioactive by-products before having undergone suitable orientation - Radiation Biology courses (Bi 710), direct instruction by the laboratory's principal investigator, or both.

8. Each member of the department is required to be familiar with and adhere to these guidelines and any other guidelines or regulations as may be

promulgated by the Dept. Radiation Safety Committee, the University Radiation Safety Committee, the Nuclear Regulatory Commission, or other duly authorized governing body.

Chemistry Department

General Safety Instructions for the Use of Radioactive Materials

1. General

The quantities of radioactive materials within the laboratory are to be kept to an absolute minimum, consistent with research requirements. In general, liquid sources, as received from the vendor will be 1 millicurie or less. Typically, such a source, unshielded, will deliver a dose at one meter distance of a few tenths to one millirad per hour depending on the energy characteristics and branching ratios of the gammas. Graduate students will work with levels of the order of one microcurie or less in their research projects. Students in the radiochemistry course will work with levels of a nanocurie (10^{-9}) or less.

Film badges and pocket dosimeters are available and must be worn during operations involving receipt, handling, storage or removal from storage, of radioactive materials in the following categories:

a. Isotopes in packaged form received from the vendor.

b. Neutron activated samples.

All graduate students involved in handling radioactive materials are required to familiarize themselves with the principles and procedures of radioactive monitoring. Many practical details are to be found in the Los Alamos Handbook of Radiation Monitoring LA-1835, and Radiation Safety and Control, Oak Ridge National Laboratory Handbook, especially in the appendices. Incoming radioisotopes will be handled under the direct supervision of the Department representatives to the Radiation Safety Committee.

Two types of beta-gamma survey meters are used: The Baird Atomic 420 portable GM survey meter is more sensitive but less quantitative than the Tracerlab Cutie Pie, portable survey meter SU-1B. Thus, the Baird Atomic Monitor with the probe shielded will usually give a higher reading than the Cutie Pie in the shielded mode.

Prior to use these instruments are checked against a scaled 1 millicurie Cs-137 source at a distance of 1 foot. This source has been derivatively calibrated against an NBS 2 microcurie source. You should observe about 3.5 millirad per hour per millicurie for the Cs-137 source on the Cutie Pie with aperture closed, at a distance of one foot. However, the response is energy dependent. For a source having an energy close to Co-60, 1.17-1.33 meV, a perfectly functioning survey meter would read about 13.4 millirad/hour at one foot. [For the present purpose rads and roentgens may be considered interconvertible].

Be sure to record your film badge number, pocket dosimeter number, and date of issue. The pocket dosimeter should be charged and reset

to zero before use. All information should be logged in the appropriate laboratory record book.

Since the research in our laboratory primarily involves quantitating radioactivity in rains, air particulates, soils and plants, it is essential that you pay the most scrupulous attention to controlling even the smallest quantities of extraneous radioactive materials. A few picocuries (one picocurie is 2.2 disintegrations per minute) of contamination can invalidate time-consuming measurements of environmental samples on the Ge(Li) detector and low background counters. If ever contamination is suspected it is important to determine its intensity and identity immediately. For this purpose our 30 cc Ge(Li) detector is invaluable. A portion of suspected material, carefully wrapped to avoid contaminating the sample recess of the Ge(Li) detector, can immediately be characterized as to its gamma ray content by taking a 1024 channel spectrum at 1.5 keV per channel.

Note that a millicurie is 2.2×10^9 disintegrations per minute. Thus, a few parts in a billion contamination can render our environmental research inoperative, particularly if the isotope in question is one we are assaying in the natural environment, e.g., Ce-144, Zr-95, Cs-137, Mn-54, Ru-106.

For suspected alpha particle contamination the alpha particle spectrometer can be used to identify the source, via the energy of the alpha particles. However, a special sample preparation is needed to give unambiguous results, involving mounting the samples in thin plates. Procedures are available for this purpose.

2. Receipt, Handling and Storage of Radioisotopes

All radioisotopes, as received from the vendor, or in the form of neutron-irradiated capsules from MIT, Lowell or URI in a lead pig, will be taken to the isotope processing and storage laboratory in the basement of Devlin Hall (B-22). The packages are monitored with the Cutie Pie, at the surface, and at one meter, and the data are recorded in the log book; Release data from health physics people at reactor, can also be used.

Persons removing radioisotopes from containers must wear surgical rubber gloves. When unpacked, the isotopes are placed in the lead-lined safe provided for the purpose in the isotope storage area. When the safe is closed the top and front surfaces of the safe are monitored and the radiation level and date are entered on sheets affixed to the top and front of the safe.

Neutron-irradiated capsules will be removed, using forceps, one at a time, and the radiation level at one foot measured. Most of the early time radiation will be due to 15 hour Na-24 (1.8 mr/hr per millicurie at one meter) or 19.8 mr/hr per millicurie at one foot). Each capsule is held securely by the tongs and flushed with a steady stream of water to remove any possible surface contamination that may have been introduced by handling. The samples are dried by placing on tissues. After cleaning, capsules are placed in a polyethylene bag and returned to the pig for storage, until taken to the counting room.

3. Preparation of Radioactive Samples, or Source Dilutions

All radioactive sample preparation, including dilution of isotopes as received from the vendor, will be done in the isotopes preparation and storage area. As an extra precaution to reduce radiation levels in the working area, operations should be performed in the stainless steel hood behind a two inch lead brick shield. All pipettes or micro-pipettes used in dispensing radioactive solutions shall be clearly labelled, and restricted to processing a single batch of given isotope. An abundant source of Kimwipes should be available to catch droplets of radioactive solution and to wipe off outer surfaces of pipettes. Surgical gloves should be worn during these operations. Pipettes should be placed only on clean Kimwipe surfaces which in turn are supported by Saran-wrap or other suitable material. At the conclusion of the operation these wastes are gathered up and placed in the dry waste disposal container. Volumetric flasks containing the diluted activity will be properly labelled as to isotope identification, concentration (microcuries per ml), date of preparation, and chemical form of the solution, for example, 1 N HCl. Volumetric flasks containing radionuclide solutions will be placed in polyethylene trays or beakers to minimize the possibility of contamination should breakage occur.

4. Inadvertent Spills

Attempt to confine the movement of liquids by throwing down paper towels or other absorbent materials. Then cordon off the area. Report any spills of radioactive materials immediately to the departmental representative to the Radiation Safety Committee. Do not attempt to clean up the spill yourself without supervision. This precaution is necessary to avoid indiscriminate low level contamination of laboratory premises.

The affected area is washed with a sponge and decontaminating solution (for example, a 2% solution of Count-Off), wearing rubber gloves. Decontaminating solutions, after use are flushed down stainless steel sinks provided in each radiochemical working area. Following cleanup the affected surfaces, and the sink should be checked with a sensitive laboratory monitor with beta window open (Baird Atomic 420). Discard the sponge and other contaminated articles in polyethylene containers provided.

5. Disposal of Radioisotopes

A. By Dilution. Ordinary low level wastes can be disposed of by dilution, i.e., by flushing down stainless steel sinks into the sewage system, in accordance with provisions of paragraph 20.303, Part 20, "Standards for Protection Against Radiation", Title 10, CFR.

b. By Decay. Certain of the radioisotopes encountered in neutron activation samples (15 hr Na-24, Sm-153, La-140, Br-82, Sb-122) are short-lived. Because irradiation times are short and the quantities irradiated are usually 10 mg or less, quantities of long-lived isotopes in excess of 1 nanocurie are rarely, if ever produced. Most samples of neutron activated substances are retained for at least two years to permit accurate assay of long-lived Eu-152 and Cs-134. Disposal of neutron irradiation capsules can be achieved by curring open the capsule, dissolving the residual contents in HCl and flushing the diluted radioactivity into the sewage system. [A pooled group of 150 neutron activation capsules 2 years after irradiation registered about .15 mr/hr net at 4 inches on the Baird Atomic 420 survey meter]. Only one by-product isotope obtained in liquid form, Cs-137 is sufficiently long-lived to fail this criterion. Others, such as one year Ru-106, 285 day Ce-144, 65 day Zr-95, 310 day Mn-54, and 60.4 day Sb-124 are usually obtained in quantities sufficient to last for a year or more. The 1 millicurie Cs-137 now on hand will satisfy contemplated research needs for this isotope for the next ten years.

6a. Rules for the Radiochemical Laboratory

1. You will be working in a low level radiochemical laboratory. The most active sealed radioactive source you will handle will be 1 microcurie (2.2×10^6 disintegrations per minute). On occasion you will be working with radioactive solutions. These will be prepared by the instructor and will generally not exceed 1000 disintegrations per minute (approximately one-half a nanocurie). With the sensitive instruments

at our disposal the use of higher levels of activity is quite unnecessary, and further might jeopardize the ability to carry on environmental radioactivity research in our laboratories, where we routinely measure picocurie (10^{-12}) levels.

2. Despite the low levels of radioactivity with which you will work, and the emphasis on low level assay techniques, in some cases you will be expected to follow rules and procedures which would apply if you were engaged in working with much higher levels.

a. To avoid inhalation or ingestion of radioisotopes no smoking or eating in the laboratory areas will be permitted.

b. For instructional purposes, you will wear pocket dosimeters while working with radioisotopes. You are responsible for recording the dosimeter reading in your notebook before and after the work interval, with appropriate time notations. See the instructor to obtain access to the dosimeter charger.

c. Always work on a stainless steel surface covered with Kimpak or similar removable sheeting. Place pipettes and stirring rods on proper receptacle or in plastic trays provided.

d. Never pipette by mouth. Use the autopipetter. Carefully wipe off outer droplets or adhering liquid with Kimwipe and place in the foot-operated disposal receptacle. Always wear rubber gloves when pipetting radioactive solutions.

e. Place all glassware, test tubes, etc. used in the radiochemical operation in the marked box provided. It is important to keep this glassware segregated so that it will not be used in ultra-low level procedures.

f. Before centrifuging carefully balance the test tube holder and test tube with a tare, using the dual pan balance. This is important because an unbalanced centrifuge may lead to breakage and spillage. Always check test tubes for cracks before using and make sure rubber pad is properly seated in the test tube holder. Discard suspected test tubes. Polyethylene tubes should be checked with water prior to use for possible leakage. If you hear a crack of a "ping" shut off the centrifuge immediately. <u>Do not attempt to remove the shattered tube.</u> Call the instructor.

g. A drop of aerosol added to the centrifuge tube will assist in cleanly decanting the supernatant solution after centrifugation.

h. Waste solutions may be poured down the stainless steel sinks unless instructions are issued to the contrary. Be careful to avoid

spattering. Gently flush with a stream of water after decanting radioactive solutions into the drain. [This is an accepted procedure for the low levels of radioactivity with which we are dealing. Dilution by the sewage system will reduce the levels of the isotope far below the maximum permissible concentrations allowed for drinking water].

i. Scavenging precipitates should be dissolved in a little HCl or HNO_3 before being flushed into the sink.

j. The stainless steel filter tower used for mounting precipitates is kept immersed in concentrated HNO_3 between uses. After filtering your precipitate a few particles of precipitate may adhere to the filter tower, particularly around the edges where the tower seats on the filter support. Use your chemical sense to decide on the appropriate reagent to dissolve this deposit, or consult your instructor. For example, MoO_3 is dissolved by NH_4OH, $BaCO_3$ by dilute acid, etc. After dissolving the precipitate, wash well with tap water and then immerse in concentrated HNO_3 until used again.

k. Exercise great care with the drying and desiccation steps performed on the filtered precipitate. Place the sample on a watch glass and cover with another watch glass in transporting it to the drying oven or desiccator. A well-mounted precipitate should be firm and non-powdery. After weighing the sample, it is mounted on a brass planchet, carefully center the filter circle with your tweezers, and place another sheet of mylar on top of the sample. In dry air the mylar may develop an electrostatic charge which may disturb, and even scatter the precipitate. Hence it is a good practice to breathe lightly on the mylar before bringing it down on the sample surface. Affix the aluminum retaining ring and trim the excess mylar with a scalpel. Affix a circular label to the bottom of the planchet with the following information: Isotope, time of precipitation, chemical yield, sample thickness in mg/cm^2, chemical form of the precipitate, and your initials. If an accident occurs and precipitate is spilled call the laboratory instructor immediately.

After you have finished your experiment clean up your experimental area and wash all glassware with the decontaminating and detergent solutions provided. Check your area with the low level laboratory monitor (Baird Atomic 420), with beta window open. Report any unusual response of the monitor to your instructor. [A level three times background would be considered unusual]. Place cleaned and dried glassware in the designated polyethylene tray.

6b. Counting Room Rules and Procedures

1. No uncovered sample shall ever be allowed in the counting room!

2. The background counting rates of all operating instruments are routinely recorded. Usually when not in use background measurements are being taken. If you are the last experimenter at a given instrument, it is your responsibility to place the instrument on background, with appropriate notations in the record book, unless informed to the contrary by the instructor. Similarly, if you interrupt a background measurement when you begin your experiment, shut the counter off, noting the time on the master laboratory clock, and record the data before proceeding. If you note any statistically valid increase in background over the norm bring immediately to the attention of the instructor. A high background may signify instrument malfunction, contamination, or careless disposition of a radioactive source near the counter.

3. Standard sealed sources (Baird Atomic standard set CT-200) are provided for recording standard factors (see below) and for counter calibrations. The gamma ray sources are each approximately 1 microcurie. They are imbedded in polyethylene plastic disks which fit snugly into the sample holder. Handle the sources carefully. They are quite rugged, but severe crushing may rupture them. Report any damage of the source to the instructor.

4. Beta ray sources are weaker than the gamma ray sources, about .02-.03 microcuries. They are covered with a sheet of aluminum foil. Handle carefully and take care to avoid puncturing the foil cover. These beta ray sources, although mounted on one inch planchets similar to our standard brass planchet mount, are not appropriate for the determination of precise beta counting efficiencies for the isotopes in question. Since they are essentially weightless point sources, covered with a thin aluminum sheet, their scattering, backscattering and self-absorption characteristics are quite different than those exhibited by precipitated samples of the same isotope, approximately 7 mg/cm^2 thick, mounted on brass and covered with .15 mg/cm^2 mylar.

5. Standard factors are obtained for each proportional beta counter or gamma ray detector by measuring a standard source in fixed geometry, to a suitable number of counts, 50,000 or more. The counting rate of the standard source is divided into a fixed arbitrary number close to the counting rate of the source. This number is obtained from the instructor. The resulting quantity is called the "standard factor". It is applied as a multiplicative factor to net counting rates to normalize counting efficiency on a given instrument from day to day, or from instrument-to-instrument of a given type.

6. Keep radioactive sources while not in use in the boxes provided for them, and return the boxes to their designated place. Be certain that

radioactive sources or samples are not allowed to lie around use. A sample storage cabinet is provided for radiochemical planchet-mounted samples.

7. Report any evidence of contamination, or unusual component in a gamma ray spectrum to the instructor. This is a low level laboratory and we want to keep it that way.

6c. Training and Instruction of Students Prior to Handling and Use of Byproduct Material in Laboratory

1. Students enrolled in the nuclear and radiochemistry course (Chem 576) receive a survey of essential principles and facts prior to performing laboratory experiments. Usually two weeks of lectures covering the following topics periments:

a. Equations of radioactive decay and growth, and statistical aspects of counting.

b. Interaction of radiation with matter.

c. Radiation detection and measurements.

d. Basic techniques in nuclear and radiochemistry.

Subsequent lectures, using as a framework "Nuclear and Radiochemistry" by Friedlander, Kennedy & Miller, 2nd Edition, J. Wiley., supplemented by the teacher's lecture notes and pertinent portions of the Los Alamos Handbook of Radiation Monitoring LA-1835, go more deeply into these and other topics.

The course outline reads: "The theory and practice of radiochemistry, including a review of radiochemical techniques and their applications. Emphasis is placed on using nuclear and radiochemical methods in the solutions of problems relating to the environment."

Because the emphasis is on environmental chemistry applications, most of the experiments, following the usual counter calibrations, etc., stress the use of sophisticated gamma and alpha ray spectroscopy, and low level radiochemical analysis and beta counting techniques. Thus, the student does beta and gamma ray analysis of natural radioactive decay products collected by dry filtration of laboratory air; performs radiochemical analysis of Sr-90 and Cs-137 resulting from radioactive fallout in oak leaves; examines the radial distribution of U-238 and Th-232 and their daughter products in radial sections of deep sea Mn nodules. One neutron activation analysis of a natural sample, vegetation

ash or air particulate sample is conducted. [For this purpose 10 mg of ash are irradiated for 8 hours at $2x10^{13}$ neutrons/cm^2/sec at the MIT reactor in a sealed polyethylene capsule.] Analysis is conducted non-destructively by high resolution Ge(Li) spectroscopy such diverse natural samples as rocks, for their U, Th and K content; rains, for their content of fissi^n products from atmospheric nuclear explosions; soils and vegetation ash, for natural and bomb-produced radionuclides from the environment.

2. Graduate students engaged in isotope work are directly under the supervision of the principal investigator, Prof. Irving J. Russell. Graduate students (two to three in number) will have taken the course in nuclear and radiochemistry in addition to advanced courses in nuclear chemistry and nuclear physics. Our research (see item 11) is restricted to levels of approximately 1 microcurie or less in any given application.

7. Methods, Frequency and Standards Used in Radiation Detection Instrument and Dosimeter Calibrations

a. Gamma ray spectrometers.

The primary standardization of the Ge(Li) gamma ray detectors is via a 1.96 microcurie Cs-137 source obtained from the National Bureau of Standards (Dec. '68). A set of Baird Atomic gamma ray sources is also available. A number of other gamma ray emitters are available from our neutron activation work covering a wide range of gamma ray energies. We use gamma ray energies and intensities reported by Gunnink et. al.[Lawrence Radiation Laboratory Report UCID-15439, Jan. 69] to obtain a relative gamma ray efficiency versus energy curve over the range .06-3.0 meV. This curve is normalized at the Cs-137 point (662 keV). This curve applies to a standard planchet counting geometry. Factors for other geometries or other modes of sample preparation are easily obtained by relative counting methods. The gamma ray standardization is checked very frequently since these instruments are used routinely in our research as well as for instructional purposes. Any NaI (Tl) detectors used may be calibrated by comparative counting.

b. Beta ray proportional counters.

Our standard technique for quantifying beta ray emitters on proportional counters is to mount a 7.0 mg/cm^2 precipitate sample on Whatman #42, backed by a one inch diameter brass planchet (saturation thickness). The sample is covered with mylar film (.15-.20 mg/cm^2). If the sample thickness is different from 7.0 mg/cm^2 correction is made to 7.0 mg/cm^2 by use of a curve which relates relative counting rate of the isotope in question, at a given geometry, to the thickness of the sample.

A large body of work in our laboratory over the years has established

the counting efficiency, defined at 7.0 mg/cm^2, in relation to the maximum beta energy of pure beta emitters. Minor corrections can be applied for gamma ray contributions, beta spectral shape and the nature of the precipitate. For complex beta emitters, given a knowledge of the decay scheme, an effective efficiency can be calculated. When the relative efficiency curve has been obtained for a given counter, the entire procedure is put on an absolute basis by measuring one or more calibrated sources, appropriately mounted. We have used NBS standard Cs-137 and Sr-90 sources for this purpose. This technique enables one to assay a wide variety of non-routine beta emitters with confidence that the counting efficiency can be determined to from 5-10% accuracy. A given source of Cs-137 can, in turn, be used to insure that the beta and gamma ray systems are properly intercalibrated.

c. Solid state alpha spectroscopy. The solid state alpha spectrometry system is calibrated by the specific activity method, using a microbalance for weighing, and accurately weighed milligram quantities of U-233 and U-235, which are dissolved and diluted quantitatively to an appropriate level. Thin electrodeposits on stainless steel are prepared for counting.

d. Survey meters and dosimeters. The beta-gamma Baird Atomic 420 Survey meter with attached source is a reproducible instrument when functioning with sound batteries. It is well known that instruments of this type may give a poor measure of absorbed dose because of radiation type and energy sensitivity unless detailed correction factors are applied. The Tracerlab Portable Survey Meter SU-1B is a more reliable but less sensitive instrument for gamma ray assay. A 1 millicurie source of Cs-137 obtained from New England Nuclear has been calibrated derivatively against the NBS 2 millicurie standard by the aliquot method. This 1 millicurie source is used to check the response of the Baird 420E and Tracerlab SU-1B whenever isotope shipments are received, or when monitoring activities are indicated. The Baird Atomic monitor exhibits a reading of 7.5 ±.5 mr/hr per millicurie at one foot distance.

The pocket dosimeters are zeroed with the dosimeter charger each time before use. Approximately once each quarter they are checked by overnight exposures at a distance of one foot from the 1 millicurie Cs-137 source. Results ±15% of the expected readings are obtained.

Chemistry: Supplement I

Safety Instructions for the Laboratory Use of Tc-99

Professor M. Clarke

1. Safety Precautions, Permission, Personal Monitoring

Laboratory workers are not to handle Tc-99 without the expressed permission of Dr. Clarke. Normally experiments will involve the use of no more than 50 mg of pure Tc-99. However, quantities up to 0.25g of pure Tc may be stored in a desiccator and handled carefully with lucite or glass shields and plastic gloves. Quantities in excess of 0.25g of pure Tc will be handled only in the basement radiation laboratory. Other experiments will take place only in specified areas of D-304 and D-212.

When handling Tc-99 a lab coat and film badge must be worn. When available, a pocket dosimeter will give a more immediate indication of dose. A finger film badge will give a better indication of the dose to the hands.

2. Experiment Levels

Most experiments will not involve more than 50 mg of pure technetium (94 mg of ammonium pertechnetate). Normal laboratory glassware provides sufficient protection against the 0.29 Mev betarays emitted by this isotope. Tc-99 has a half life of 2.1×10^5 years and an activity of 17 mCi/g (9.1 mCi/g of NH_4TcO_4). There are no gamma rays emitted but the action of the beta rays on glass produces a bremstrahlung of weak x-rays, which are largely absorbed in a distance of 30 cm of air. Solutions also attenuate the x-rays, so that they are normally not a problem. TcO_2 and Tc_2O7 are known to be slightly volatile and quantities of these as solids or aqueous solutions should be handled in a fume hood.

The technetium should be kept localized in posted areas. Synthetic work is to be done on large fiberglass trays covered with absorbant pads or towels. Evaporations should be done on a hot plate covered with aluminum foil (or on a teflon covered hot plate). Evaporating solutions should also be covered with aluminum foil to prevent splattering.

New shipments of Tc will normally be received as NH_4TcO_4, divided into 1 gram quantities and stored in the safe in the basement radiation lab. These should be recrystallized before use.

3. Surveying and Monitoring of Lab Area

When working with relatively large quantities of Tc in the basement radiation lab, monitor the area using a "Cuti-Pie" or GM counter imme-

diately after use. Wipe-down any contaminated areas with a decontamination solution. All areas where Tc is used should be checked by wipe-test at least every other week. The results of the wipe-tests are to be recorded in the Tc-Ru log book.

4. Spills and Safety Cleanup

Spills should normally be confined to the trays, where they can be easily wiped up with absorbant towels. If not confined in this manner the spill should be confined as much as possible with towels or other absorbant materials. Cordon off the area with report of any spills of radioactive materials to Dr. Clarke, Dr. Russell or a designated assistant.

The affected area should be washed with a sponge and decontaminating solution (for example a 2% solution of Count-Off), wearing rubber gloves. Decontaminating solutions, after use are flushed down stainless steel sinks provided in the basement lab, D-212 or D-309. Following cleanup, the affected surfaces and the sink should be checked with a sensitive laboratory monitor (Baird Atomic Model 420) with beta window open. Discard the sponge and other contaminated articles in polyethylene containers provided.

5. Handling Procedures, Transport, Labelling

Radioactive materials containing Tc-99 may be moved between posted areas in sealed glass containers. Quantities in excess of 0.25 g of Tc (0.47 g of NH_4TcO_4) are not to be moved out of the basement radiation lab.

All containers containing Tc-99 compounds will be labelled with the usual magenta and yellow radiation marker. Vials should be labelled with the radiation warning symbol, the date the compound was stored, the name or code number of the compound and the designation "Tc-99". Desiccators should display the radiation warning symbol.

All areas where radioactive materials are handled are designated with a yellow-magenta radiation warning sign. These areas now include: the basement radiation lab, D212, D-304 and D-309. Each area contains a receptacle for low-level wastes, such as paper towels, etc.

6. Decontamination of Laboratory Equipment

Contaminated glassware is to be rinsed, soaked in a decontaminating solution and then washed in the normal manner. (Note: rubber gloves

are always to be worn when washing contaminated glassware.) This glassware will often be radioactive at a low level and should always be placed in a plastic basin labelled with radiation warning symbol.

7. Film Badges, Area Monitoring

All personnel will wear a film badge, which can be obtained from Dr. Russell. These are to be turned in monthly and you will be notified of any radiation dose received above background. Pocket dosimeters may also be available to give you an immediate indication of any dose received. Record these results in your laboratory notebook, a record of the total dose.

Working areas are to be monitored with the Tracerlab Cutie Pie or the Baird Atomic 420 GM meter. You will be instructed in the use of these.

8. Waste Disposal

Low-level wastes are to be placed in the designated receptacles. Solutions containing Tc-99 may be disposed of via the drain system using one of the stainless steel sinks in D-309. D-212 or the basement lab, when the total amount does not exceed 100uCi/day and does not produce a sewage concentration greater than 0.01 uCi/ml. Aqueous solutions in excess of these limits will be combined with cement or plaster of paris and disposed of as solid wastes. Solid materials that cannot be washed cleaned are to be placed in the designated receptacle in the basement lab for commercial disposal.

9. Log Maintenance: Receipt, Use and Disposal of Material

When quantities of Tc are removed from the safe, they should be logged in the Tc-Ru log book. Quantities taken for individual experiments should be noted in the researchers' laboratory notebook and summed up, accounted for the logged in the Tc-Ru log book when the next large quantity is taken. Notebook records should be kept for any materials which are disposed. Whenever a compound is transferred to another institution the amount, compound, and date should be noted in the Tc-Ru log book.

New shipments of Tc-99 from Oak Ridge or New England nuclear should be recorded in the log book as to date, amount, activity and shippers reference number. The Shipper's Certification should be retained in the log book, the duplicate given to Dr. Russell and a xerox copy to Dr. Clarke.

I have read and understood the above instructions and have a copy available for my personal use.

Name	Date
1.____________________	_______________
2.____________________	_______________
3.____________________	_______________

Chemistry: Supplement II

Carbon-14 and Tritium (H^3)

Professor M. Clarke

Carbon-14 is a Beta emitter with a half-life of 5730 years. The average beta energy is 0.050 MeV. From a safety point of view this isotope is relatively safe. The range of the beta in air is one foot, and 0.029 cm in unit density material. Tritium (H^3) on the other hand has only a 12.3 year half-life with a beta energy of 0.006 MeV. At this energy, an average H^3 would only have a 0.02 foot range in air. The beta from H^3 does not penetrate the skin.

Handling and Safety Procedures for C^{14} and H^3

The use of Carbon-14 and tritium labelled compounds will be strictly limited to trained personnel. Room warning signs will be displayed in areas in which the quantity of material is greater than 1 mCi for C^{14} and 10 mCi for H^3. Storage of the material will be confined to appropriately designed areas. An inventory of the amount of radioactive material held will be available for inspection.

All work with C^{14} and H^3 will be carried out in designated areas. Work will be confined to the hood as much as possible. Glassware will be decontaminated by soaking for 24 hours in Count-off (New England Nuclear) before washing. Residual radioactivity on glassware and in all areas will be checked by wipes. In addition, wipes will be carried out at the conclusion of a particular experiment with the results of the wipe tests being recorded directly in the researcher's notebook. Monthly wipes of the whole area will be carried out to check for contamination.

Liquid waste will be disposed of via the drain system only when the total amount does not exceed 100 uCi/day, and does not produce a sewage concentration greater than 0.01 uCi/ml. Aqueous solutions in excess of these limits will be conbined with cement and disposed of as solid waste. Disposable equipment, towels and scintillatory vials with C^{14} and H^3 over recommended levels will be disposed of by commercial means.

Chemistry: Supplement III

Instructions for Handling ^{14}C

Professor E. Kantrowitz - Biochemistry - Devlin 214

Whenever radioactive materials are being used for biochemical experiments the following rules must be followed:

1. No matter what levels of radioactive are being used, take precautions as if the material was very radioactive. It's better to be overcautious than not cautious enough.

2. Disposable gloves are to be used at all times. In addition, disposable plastic backed absorbant pads are to be placed under all experimental setups.

3. Any disposable equipment contaminated is to be placed in plastic bags. When the plastic bags are full, they are to be sealed and placed in the radioactive waste barrel.

4. Used scintillation vials should be stored in trays until they are disposed of in the radioactive waste barrel.

5. All glassware contaminated will be decontaminated by first rinsing 2-3 times with tap water, followed by a 24 hour soak in Count-off (20 ml/ liter) before normal washing. Residual radioactivity on glassware is to be checked by wipes after washing.

6. At the conclusion of a particular experiment, contamination should be checked for by wipes. The results of the wipes should be recorded directly into your notebook (just as if it were experimental data).

7. All radioactive work should be confined to the hood if possible. If this is not possible then the radioactive materials should be localized in a designated area (Any area covered by absorbant pads is a designated area).

8. All containers, vials, bottles, etc. that have radioactive material in them should be indicated as such with a standard radioactive label.

9. No one should disturb any materials on an absorbant pad without first talking with the person conducting the experiment.

10. If wipes show a contamination (more than x2 background) the area should be decontaminated by washing with Countoff on disposable towels. Decontamination should continue until wipes are negative.

11. No experiments are authorized in which more than 20 uCi of material are used. Consult Dr. Kantrowitz before proceeding with these experiments.

12. No food or drink is allowed in any area where radioactive materials are being used.

Physics Department

Advanced Laboratories

REGULATIONS AND PROCEDURES FOR EXPERIMENTS WITH RADIOACTIVE MATERIALS

Professor G. Goldsmith

Professor R. Becker

General Rules

1. Wear pocket ionization chambers during all laboratory periods and keep a record of the readings. Avoid jarring them.

2. Do not use the mouth for pipetting and do not put it in contact with any other apparatus in the laboratory.

3. Do not smoke or eat in the laboratory.

4. Use the fume hood in all cases where radioactive material may be lost by volatilization, by dusting, or by spraying or spattering. Work with closed containers wherever possible.

5. Meter all radioactive samples and determine the safe working distance before beginning to work with them.

6. Avoid handling samples in such a way that any radioactive material can be transferred to the hands or other parts of the body.

7. Plan your work carefully to minimize any danger of spilling radioactive material. When dealing with unsealed sources, work over absorbant paper so that if slight losses occur they can be contained and disposed of.

8. Do not put uncovered samples in counter shields if it is avoidable. Take unusual precautions to avoid contaminating the counter shields.

9. If radioactive material should happen to be accidentally spilled, commence taking requisite steps IMMEDIATELY and report it at once to the person in charge of the laboratory. SEE BELOW FOR PROCEDURES.

10. Meter your working space at the beginning of the working period and again at the end.

11. Dispose of all radioactive waste in containers provided especially for the purpose--NEVER DOWN THE SINK OR INTO WASTEBASKETS!

Spills REPORT ALL SPILLS AT ONCE TO THE LABORATORY SUPERVISOR

1. Should radioactive material be spilled on your clothing, take immediate measures to remove either the contamination or the clothing.

2. For spills in general, first spread several layers of absorbant paper over the spill area in order to contain the spill. Then, determine with a survey meter the extent of the area which is above tolerance and the extent of the actual spill. Mark off the area with chalk or crayon. Then proceed as with a normal chemical spill, taking precautions to avoid spreading the activity. After thoroughly cleaning the area, check it for residual contamination by a wipe test and continue decontamination procedures until the test shows background or near background activity.

Physics Department

Advanced Laboratories

REGULATIONS COVERING THE HANDLING, SURVEYING AND STORAGE OF SEALED SOURCES

Professor G. Goldsmith

Professor R. Becker

1. Storage

a) All sealed sources are to be stored in closed metal containers, appropriately labelled and locked in the cabinet marked "RADIOACTIVE SOURCES".

b) Authorized persons may obtain the key to this cabinet in the departmental office or from Professor Goldsmith.

c) Only the following persons may authorize the use of sealed sources:

G. J. Goldsmith, Ph.D.
R. L. Becker, Ph.D
J. H. Kinnier, S. J.

2. Leak Testing

a) Leak testing of all sealed sources is to be performed under the supervision of the above-named persons at intervals not to exceed six months according to the method detailed below. In addition to these regularly scheduled tests, similar tests will be made before and after each series of laboratory experiments employing the sources and upon evidence of possible damage to them.

b) A standard wipe test will be performed on the external surfaces of each source, using moistened Whatman 40 filter paper. Upon drying, the wipes will be counted in a windowless flow counter, (Tracerlab SC16) or thin-window proportional counter (Tracerlab SC59 or equivalent) or by a scintillation detector (Tracerlab P-20DQA or equivalent) capable of detecting 0.001 microcurie of the appropriate activity. A permanent log of leak-test results is to be kept in the departmental offices.

3. Procedures in event of leakage (actual or suspected).

1. Immediately exclude all unauthorized persons from the area, unless they have become contaminated.

2. Scrub hands with soap and water, dry throughly, and put on protective gloves.

3. Put source and removable contaminated items in pyrex glassware in glove box using tongs or other remate handlers.

4. Test the area (persons if necessary) for contamination by standard wipe test or approximate survey meter.

5. Decontaminate wherever the tests indicate that it is necessary.

6. Dispose of contaminated wipes and other materials in appropriate container.

THE SOURCE ITSELF

7. Inside the glove box, wipe test the exterior of the source and of other suspected items.

8. If not contaminated, return to ordinary storage.

9. If contaminated, remove contamination by careful wiping or other approved method and then check for further leakage if none is found, return the source to storage.

10. If repairs are required and can be carried out easily, make these in the glove box and check the source carefully for integrity.

11. It is more likely that the source cannot be repaired safely, in which case seal it in a tightly covered jar, and either dispose of it in the active waste container, or pack it for return to the manufacturer (following the manufacturer's instructions for such events).

REPORT ALL ACCIDENTS AND CASES OF LEAKAGE TO THE DEPARTMENTAL OFFICE AND TO THE PERSON IN CHARGE OF THE LABORATORY. MAKE A WRITTEN REPORT OF THE PROCEDURES CARRIED OUT AND THE TESTS MADE.