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1 EMERGENCY INFORMATION

In case of an emergency, call the University of Kansas Medical Center (KUMC) Police Department for assistance.

Dial 911 from any campus land-line telephone and you will be connected to the KUMC Police 911 service.

If calling from a mobile phone, **dial 913-588-5030** to reach the KUMC Police 911 Services. Dialing 911 from a cell phone will connect you to other community 911 Services and will delay emergency services response to your emergency.

If you must call 911 Services due to an emergency involving radioactive materials be able to provide the following information:

- Type of Emergency
- Your Name
- Location
- Radionuclide involved and activity, if known
- Call-back phone number

The following table provides guidance for emergency incidents involving radioactive materials:

Incident	Procedure	Contact
Radioactive Spills	<ol style="list-style-type: none"> 1. Notify all other persons in the room. 2. Confine the spill. 3. If liquid, place absorbent paper on the spill. 4. If powder, lay a damp cloth or paper on the spill. 5. Call the KUMC Environment, Health & Safety Office or 911 Services. 6. Do not allow other persons who were in the room to leave the area. 7. If clothing is grossly contaminated, discard outer clothing at once into a bag or other container which can be isolated for proper disposition. 8. If the skin is contaminated, flush thoroughly with tepid running water. 	Environment, Health & Safety Office Monday – Friday 8:00 AM – 4:30 PM Ext. 8-1081 or 913-588-1081 After Hours, Weekends, and Holidays Call KUMC Police from a campus phone: 911 using a cell phone: 913-588-5030
Air Contamination	<ol style="list-style-type: none"> 1. Notify all other persons to vacate the room immediately. 2. Turn off the air circulation devices. 3. Seal the room by closing all doors and windows. 4. Vacate the room. 5. Call the KUMC Environment, Health & Safety Office or 911 Services. 6. Post the room and prevent opening the room until qualified persons can evaluate the hazard and give instructions. 	
Unexpectedly High Dose Rate Levels	If an unexpectedly high radiation dose rate is measured or suspected, call Environment, Health & Safety Office or 911 Services.	
Loss of Sources	<ol style="list-style-type: none"> 1. Report the loss or theft of any radiation-producing machine or radiation source IMMEDIATELY to the Environment, Health & Safety Office. 2. If the laboratory has been burglarized, contact KUMC Police IMMEDIATELY. Do not disturb the scene. 	

2 SCOPE

The University of Kansas Medical Center Radiation Safety Manual details the policies and regulations applicable to the handling of radioactive materials and radiation-producing equipment at the University of Kansas Medical Center.

The policies and regulations stated in this Radiation Safety Manual are incorporated into the University's Radioactive Materials License.

Failure by University personnel to observe these policies and regulations may result in citations, fines and/or removal of the University's Radioactive Materials License by state or Federal agencies.

Failure to follow applicable rules and regulations by Authorized Users and Radiation Workers may result in warnings and/or other actions, which could include the removal of authorization to use radioactive materials, by the Radiation Safety Committee (RSC) or by the Environment, Health & Safety Office.

3 PURPOSE

This Radiation Safety Manual is designed to be a practical guide for the ordering, possession, use and disposal of radioactive material and radiation-producing equipment at KUMC.

It cannot cover every contingency or question. Detailed information on the regulations and policies may be obtained from the Environment, Health & Safety Office at 913-588-1081.

4 RESPONSIBILITIES

4.1 United States Nuclear Regulatory Commission

The possession and use of radioactive materials in the United States is governed by strict regulatory controls. The primary regulatory authority for most types and uses of radioactive materials is the federal Nuclear Regulatory Commission (NRC). The Nuclear Regulatory Commission has entered into an agreement with the State of Kansas to transfer the regulation of reactor-produced radionuclides to the authority of the Kansas Department of Health and Environment, Bureau of Environmental Health. As part of the agreement process, Kansas must adopt and enforce regulations comparable to those found in Title 10 of the Code of Federal Regulations (CFR).

4.2 Kansas Department of Health and Environment

The Kansas Department of Health and Environment (KDHE) Bureau of Environmental Health is responsible for implementing and enforcing the Kansas Radiation Protection regulations.

In most situations, the types and maximum quantities of radioactive materials possessed, the manner in which they may be used, and the individuals authorized to use radioactive materials are stipulated in the form of a "specific" license from KDHE. However, for certain institutions, such as KUMC, that routinely use large quantities of numerous types of

radioactive materials, the exact quantities of materials and details of use may not be specified in the license. Instead, the license grants KUMC the authority and responsibility for setting the specific requirements for radioactive material use within its facilities. This type of license, termed a “broad scope” license, governs most uses of radioactive material at the University of Kansas Medical Center.

KUMC is subject to periodic inspection by the Kansas Department of Health and Environment to ensure that all radioactive material license requirements are being met.

4.3 University of Kansas Medical Center

It is the policy of the University of Kansas Medical Center to control and facilitate the use of radioactive materials and radiation-producing devices on campus for purposes of research and teaching.

The University is committed to ensuring that the use of these materials and devices are in compliance with regulatory requirements and that any resulting radiation exposures are “As Low As is Reasonably Achievable” (ALARA).

The University has established specific administrative entities with responsibilities for controlling the use of radioactive material and radiation-producing devices on campus.

The KUMC Radioactive Materials License is contingent upon the existence of a Radiation Safety Committee (RSC), appointed by the Associate Vice Chancellor for Compliance.

4.4 Radiation Safety Committee

The Radiation Safety Committee (RSC) is the administrative body responsible for the safe handling of radioactive materials within KUMC.

The Radiation Safety Committee membership includes the Radiation Safety Officer; a representative of university management; and faculty and professional staff experienced in handling radionuclides, the use of radiation-producing devices, and the practice of radiation protection or those who have a desire to institute safe practices in regard to radiation. The Radiation Safety Committee meets at least quarterly and its responsibilities include, but are not limited to:

1. Assuring that any Authorized User using radioactive material is qualified by training and experience to safely use the proposed radionuclide, has the facilities to handle the materials safely and proposes a use which is safe for all concerned.
2. Assuring observance of all radiation safety standards established by the Radiation Safety Committee and Kansas Department of Health and Environment.
3. Assuring that records are kept of the receipt, storage, use, transfer, and ultimate disposal of all radioactive materials used at KUMC.
4. Assuring that records are kept of the radiation exposure monitoring of personnel and areas involved in the use of radioactive material.
5. Recommending modifications to operating or maintenance procedures.
6. Reviewing and making recommendations in advance of construction for new buildings or alterations/remodeling of existing buildings for laboratories and rooms in which the use and storage of radioactive materials or radiation-producing devices is contemplated

to ensure proper ventilation, air flow rates, filtration in properly designed fume hoods, shielding, construction material, furniture and finishes.

7. Delegating to the Radiation Safety Officer the authority to review, grant or deny temporary authorizations for use of radioactive materials and radiation-producing devices during the interim between Radiation Safety Committee meetings. Such authorizations are subject to final approval or denial by the Radiation Safety Committee.

It is the Radiation Safety Committee's policy to encourage and promote the safe handling of radiation at KUMC. To this end, the KUMC Radiation Safety Program has been designed to help Authorized Users with any problems that may arise from the use of radiation. The Radiation Safety Program relieves the individual Authorized User the time-consuming work of obtaining an individual state license, interpreting radiation regulations and keeping extensive records. The Radiation Safety Program provides the Radiation Worker with most of the services necessary for compliance with the state radiation safety standards. The Authorized User is ultimately responsible for radiation safety.

The Radiation Safety Committee also has the responsibility for controlling the use of radiation-producing equipment, e.g., x-ray machines, electron microscopes, etc. Persons desiring to use radiation-producing equipment must be deemed qualified to use and operate such equipment by the Radiation Safety Committee.

4.5 Environment, Health & Safety Office and Radiation Safety Officer

The business of the Radiation Safety Committee is administered through the Radiation Safety Officer (RSO) and the Environment, Health & Safety Office.

The Radiation Safety Officer and the Environment, Health & Safety Office will have the responsibility for ensuring adherence to requirements issued or subscribed to by the Radiation Safety Committee and will advise and assist the Radiation Safety Committee with regard to compliance with the applicable regulations of KDHE, local agencies, and all similar codes and regulations.

The Radiation Safety Officer's responsibilities include, but are not limited to:

1. Implementing the organization, administration and management of the Radiation Safety Program.
2. Interpreting regulations that govern the use of sources of ionizing radiation and disseminating information on radiation safety.
3. Developing and keeping current a radiation safety manual.
4. Developing, supervising and maintaining all radiation protection programs.
5. Coordinating the dosimetry service, maintaining personnel exposure records and giving timely notification of unexpected exposures to the exposed individuals.
6. Reviewing requests for procurement of radionuclides.
7. Maintaining an inventory of all radioactive materials.
8. Supervising the radioactive waste disposal program.
9. Maintaining radionuclide disposal records.
10. Instructing employees and students on proper procedures for handling radioactive materials, exposure precautions, protective devices and applicable portions of KDHE regulations.

11. Ensuring that leak tests on radioactive sealed sources are completed as required.
12. Ensuring that portable monitoring and surveying equipment are calibrated as required.
13. Verifying and reporting to appropriate authorities any reportable radiation incidents and overexposure events as defined in KDHE regulations.

The Radiation Safety Officer and the Environment, Health & Safety Office have been given authority by the Radiation Safety Committee to require cessation of any project where an unsafe practice involving radiation is occurring or where a practice in violation of established regulations is observed until a review by the Radiation Safety Committee can be made.

4.6 Authorized Users

Those faculty members or others granted authorization by the Radiation Safety Committee as Authorized Users of radioactive material are responsible for the safe use of radionuclides and radiation sources by workers under their supervision.

Responsibilities of an Authorized User include but are not limited to:

1. Ensuring compliance with the KDHE and KUMC rules and regulations regarding radioactive material and radiation-producing devices.
2. Ensuring that the instruction of employees and students has been accomplished as outlined in this Manual.
3. Ensuring that radiation workers wear personal dosimeters as necessary, are included in any bioassay monitoring as necessary, and follow the requirements for preventing and monitoring for personal contamination.
4. Ensuring that, in any posted Radioactive Materials or Radiation Area, workers or visitors in the lab do not eat, drink, prepare, store or transport food or drinks in the lab; and do not use tobacco products or apply cosmetics in the lab.
5. Ensuring proper planning of an experiment or procedure and ensuring that adequate safety precautions are observed.
6. Maintaining required records of receipt, use, storage, and disposal of all radionuclides.
7. Maintaining records of laboratory surveys conducted by the Authorized User or radiation workers.
8. Submitting a periodic inventory of radionuclides as specified by the Radiation Safety Committee.
9. Maintaining radionuclides under proper security when the laboratory is vacant.
10. Completing annual training related to radiation use or safety and ensuring that all radiation workers listed on the permit complete their annual radiation safety training.
11. Reporting immediately to the Radiation Safety Officer any theft or loss of radionuclides or major accidents involving radionuclides.
12. Reporting immediately to the Radiation Safety Officer any incidents of personnel skin contamination.
13. Ensuring that areas where spills of radionuclides have occurred are decontaminated to acceptable levels and informing the Radiation Safety Officer of actions taken.
14. Communicating to the Radiation Safety Officer all pertinent information impacting the authorization (e.g., change in facility, deletion or addition of personnel, changes in project, etc.).
15. Informing the EHS office of the presence of any new radiation survey equipment so that they may be added to the schedule for routine calibration.

16. Answering communications from the Radiation Safety Committee or Radiation Safety Officer in a timely manner.

4.7 Authorized User On Sabbatical or other Extended Leave

During the time that an Authorized User is on sabbatical or other extended leave, an alternate or secondary Authorized User can be responsible for the day-to-day operations with approval by the Radiation Safety Committee. Authorized Users planning an extended leave should inform the RSO.

If the Authorized User has a laboratory worker with extensive experience with radioactive materials, the AU may delegate responsibility for performance of periodic (usually monthly) Inventories, "Area Radiation and Contamination Surveys," and other routine tasks associated with Radioactive Materials Permits. This is particularly necessary in the event that the AU is unexpectedly absent (due to an illness, for example) during the times that these tasks are due. This does not relieve the AU of the primary responsibility for the performance of these tasks so care should be taken when determining the individual who will be delegated this responsibility.

4.8 Radiation Worker

A Radiation Worker is a person who works with radioactive materials or radiation-producing equipment as an Authorized User or under the supervision of an Authorized User.

Radiation Workers must comply with KUMC polices and government regulations including, but not limited to, the following:

1. In any posted Radioactive Materials or Radiation Area, do not eat, drink, prepare, store or transport food or drinks in the lab and do not use tobacco products or apply cosmetics in the lab.
2. If required by Radiation Safety Committee conditions, survey hands, shoes, body, and clothing for radioactivity before leaving the laboratory.
3. Check work areas for contamination and conduct decontamination procedures as necessary.
4. Report immediately to the Authorized User and Radiation Safety Officer the details of major spills or other accidents, losses or theft of radioactive materials, any known violations of KDHE regulations or KUMC license requirements, and any incidents in which personnel received unnecessary exposure to radiation or radioactive materials.
5. Wear personnel dosimeters, as required, and comply with the rules concerning those dosimeters.
6. Report immediately to the Authorized User and Radiation Safety Officer any incidents of personnel skin contamination.
7. Use recommended or required protective measures, such as protective clothing, respiratory protection, remote pipetting devices, ventilated glove box or hood and shielding.
8. Keep personal exposure to radiation As Low As Reasonably Achievable (ALARA) utilizing time, distance, shielding, and source reduction principles.
9. Follow the protective rules for preventing contamination.
10. Participate in the bioassay program as required.
11. Dispose of radioactive wastes in proper containers and maintain disposal records.

12. Maintain security of radionuclides both while in use and in storage.
13. Complete annual training related to radiation use and radiation safety.
14. Inform EHS if any radiation badges need to be discontinued

5 GENERAL POLICIES AND PROCEDURES

5.1 General Procedures and Requirements for Working with Radioactive Materials

The RSC may require the use of special equipment or devices that are necessary to ensure the safe use of radionuclides in a given situation. This includes special shielding, handling tools or tongs, alarms and warning devices, sampling equipment and other such apparatus.

Glassware and utensils used for a project involving radioactive material shall be properly labeled and should be cleaned and maintained in the work area to be used in future projects of the same nature. If contamination of the equipment cannot be determined, it is advisable to dispose of it rather than risk ruining a sensitive experiment.

Clothing will often provide a protective barrier when handling unsealed sources. For this reason, long pants and closed-toed shoes are required in laboratories where radioactive materials are used. Laboratory coats should also be worn in areas where radioactive material is used and should be removed before leaving the area.

Disposable gloves must be worn at all times when using unsealed materials and should be changed frequently to avoid contaminating areas and equipment.

When unsealed radioactive compounds that may penetrate gloves and skin are used, especially tritiated water, two pairs of gloves should be worn, and these should be changed frequently. Gloves must be removed each time you leave the designated work area.

Use low density shielding such as Lucite or Plexiglas to shield high-energy betas such as those from P-32. Do not use lead as the primary shield for beta-emitters such as P-32, S-35, C-14, etc., thereby avoiding the production of bremsstrahlung x-rays.

Use lead shielding for gamma and x-rays.

6 Authorization to Perform Research Involving Radiation

Any research at the University of Kansas Medical Center that involves the use of radioactive material or a radiation-producing device must be specifically authorized by the University of Kansas Medical Center's Radiation Safety Committee coordinated through the KUMC Environment, Health & Safety Office.

Approval of human subject research involving the use of radioactive material and/or radiation-producing devices conducted at the University of Kansas Hospital must be approved by the University of Kansas Hospital Radiation Safety Committee. Similarly, approval of human subject research involving the use of radioactive material and/or radiation-producing devices conducted at the University of Kansas Medical Center must be approved by the University of Kansas Medical Center Radiation Safety Committee.

The KUMC Environment, Health & Safety Office will coordinate the review process between the hospital's Radiation Safety Committee and the KUMC Research Institute, Human Subjects Committee and/or the Principle Investigator.

The KUMC Radiation Safety Committee has voted to accept the review and approval of the hospital's Radiation Safety Committee as adequate review and approval of these research projects and grants approval and authorization to proceed based on The KU Hospital's Radiation Safety Committee approval.

6.1 Obtaining Permission (Authority) to Possess and Use Radioactive Materials

Before an individual can possess and use radioactive materials, the individual must become an approved Authorized User of radioactive materials. To be an Authorized User at KUMC, the individual must ordinarily be a faculty member (teaching associate or higher). However, a person other than a faculty member may be authorized at the discretion of the Radiation Safety Committee. The process of becoming an Authorized User begins when the interested individual completes and submits the "Application for Authorization to Possess and Use Radioactive Materials" found on the EHS website.

As part of this application, the individual must supply evidence of past training and/or knowledge of radiation safety by providing evidence of passing a radiation safety class at another institution.

If the individual does not have evidence of prior training and/or knowledge of radiation safety, the individual will have to complete the following:

- Supply evidence of experience commensurate with the planned use of radioactive materials (approval to use radioactive material will not be granted based on work experience alone) and;
- Meet the Radiation Safety Training Requirements for an Authorized User described in section 7 of this manual.

6.1.1 Application for Authorization to Possess and Use Radioactive Material

To become an Authorized User, an individual must complete and submit the "Application for Authorization to Possess and Use Radioactive Materials" form.

This form requires the applicant to provide all the information necessary for the Radiation Safety Committee to review in order to approve the request and name the individual as an Authorized User and to issue the individual a radioactive materials use permit.

The form requires the following information:

- Required Personal Information, including Social Security Number. The Social Security Number is required by the federal government for all individuals granted permission to order, possess, use and dispose of radioactive material.

- Proposed Radioisotope Usage, including chemical compound, unit activity and maximum activity in the lab at one time
- Radiation Safety Training History of Applicant
- Radiation Protection required to be used in lab while working with these compounds
- Experience working with radiation
- Identification of personnel under applicant's supervision that will be working with the radioactive material
- Additional information such as description of the storage area, procedures to ensure security, process descriptions, and any special handling that may be required
- Acknowledgement of Responsibilities
- Department Chairperson Approval
The Chair of the applicant's department must sign the application. This signature indicates that the Chair will share responsibility for assuring that all work is performed in compliance with KUMC policies and government regulations and assume responsibility for final disposition of all radionuclides remaining in an Authorized User's inventory if that Authorized User leaves KUMC without disposing of all radioactive materials.
- Diagram of Entire Laboratory Area
A diagram, electronic copy preferred, of the entire laboratory area should indicate where the radioactive material will be used, stored, where waste materials will be staged, location of hoods, sinks, benches, windows, doors and equipment.

6.1.2 Approval to Possess and Use Radioactive Material

The Radiation Safety Officer will complete the initial review of the application and grant conditional approval if the request falls within the limits and authority of the KUMC Radioactive Materials License.

The Radiation Safety Officer will present the conditionally approved request to the Radiation Safety Committee for final approval. The Radiation Safety Officer has been granted the authority by the RSC to approve one use of radioactive material while the permit is in "conditionally approved" status.

Approval for Authorization to Possess and Use Radioactive Materials is issued to the applicant. Once approved, the Authorized User will be issued a Radioactive Materials Use Permit based on the information presented. Any changes in the information presented will need to be communicated to the Radiation Safety Officer as an amendment to the permit.

6.1.3 Amending Radioactive Materials Use Permit

Authorized Users are required to keep all aspects of their radioactive materials use permit accurate and up to date. Any changes to any of the information contained in the Permit should be communicated to the Radiation Safety Officer. Changes become effective after approval by the Radiation Safety Officer. Possible amendments include:

6.1.3.1 Adding or deleting Areas or Personnel from the Radioactive Materials Use Permit

To add an area, schedule a meeting with the Radiation Safety Officer to review the layout of radioactive work areas. To remove an area, contact the Radiation Safety Officer and make arrangements for a final survey of the room after all radioactive material and radioactive waste materials have been removed from the room.

To add personnel, contact the Radiation Safety Officer to verify that all Radiation Safety Training requirements have been met. To remove personnel, contact the Radiation Safety Officer.

6.1.3.2 Adding a Chemical Compound

To add a compound, contact the Radiation Safety Officer. Changes could include a different

- Radionuclide
- Chemical Compound or Physical Form
- Desired possession limit

The description for this type of amendment should include a detailed description of the handling procedures, waste production, and storage requirements if they differ from what is currently listed in the permit.

6.1.3.3 Add or Amend a Protocol

Contact the Radiation Safety Officer prior to any significant changes in how radioactive materials will be handled. This may include changes to protocols, procedures, radioactive waste handling, etc.

6.2 Radiation Project Approval

6.2.1 General Information

The project for which radionuclide use is requested shall be reviewed for feasibility based on the applicant's training and experience with the radionuclides for the project. It is the responsibility of the Radiation Safety Committee to determine whether a project presents a radiological hazard to the person performing the experiment, to the people working around the experiment, or to the general population.

The project application should furnish information outlining the laboratory procedures which involve the use of radioactive material, the amount of waste stored in the lab, a statement outlining the objective of the experiment, and a statement explaining why a specific isotope and quantity is needed.

In addition to the above, the protocol should demonstrate a need for radioactive material. In some instances, the chemical compound of labeled material being disposed presents a much greater hazard to persons than the radioactivity present. If the type of material being used presents a non-radiological hazard (e.g., virulent, carcinogenic, pathogenic, explosive, etc.), procedures outlining how the material is to be handled must be included in the project protocol.

6.2.2 Animal and In-vitro Projects

Any project involving the use of radioactive materials or radiation-producing devices with animals or in-vitro must be reviewed and approved by the KUMC Environment, Health & Safety Office and may also require Radiation Safety Committee approval. The applicant should provide adequate detail for the RSC to evaluate the radiation safety for the project and must include the project protocol.

6.2.3 Human Use Projects

The “Application for Use of Radiation in Research Involving Human Subjects” must be completed and returned to the KUMC Environment, Health & Safety Office for review. For human research, the project must have approval from the Human Subjects Committee and either the KUMC Radiation Safety Committee or The KU Hospital Radiation Safety Committee.

The Human Subjects Committee will not grant final approval until notified that the project has received Radiation Safety Committee approval. Radiation Safety Committee approval does not authorize use in humans until the HSC approval is finalized.

6.3 Renewal of a Radioactive Material Permit

Every two years, radioactive material permits will be evaluated for renewal. Prior to the expiration date of the present authorization, the Authorized User shall complete and submit a request for renewal of the user’s radioactive Materials Use Permit. The request should indicate any changes in personnel, facility, project, and radionuclides. Renewals are reviewed by the Radiation Safety Officer and the Radiation Safety Committee on the same criteria as original applications for authorization.

A renewal request received by the Radiation Safety Officer prior to the permit’s expiration date will be considered as being in a “timely renewal” status. The Authorized User may continue radiation use until approval/disapproval by the Radiation Safety Committee.

If the renewal is not received prior to expiration, the permit may be terminated and any radioactive material may be confiscated.

6.4 Termination of a Radioactive Material Permit

In the event that a Radioactive Materials Permit is no longer required because the Authorized User no longer wishes to use radioactive materials or the Authorized User is leaving the University, the Authorized User must complete the following steps:

1. Notify the Radiation Safety Officer in writing documenting the request to close the Radioactive Materials Use Permit, the reason for discontinuing the Permit, and the date the Permit needs to be closed. If the Authorized User is leaving campus, indicate the final day on campus.
2. Make arrangements with the Radiation Safety Officer for final disposition of all radioactive materials in the inventory. This may be done by transferring to another Authorized User on campus, shipping to an off-campus location, or disposing of the materials as radioactive waste.
3. The Radiation Safety Officer and the Authorized User will ensure that a laboratory survey is conducted and any contamination that is found is cleaned by the

Authorized User before leaving the lab. The Authorized User will submit a final survey report to the Radiation Safety Officer.

4. The Radiation Safety Officer will also terminate or transfer all appropriate personnel monitoring activities.

7 TRAINING AND EXPERIENCE REQUIREMENTS

7.1 AUTHORIZED USER

An Authorized User at the University of Kansas Medical Center must have training and experience commensurate with the level of work proposed and must comply with at least one of the following training requirements:

Supply evidence of passing a radiation safety class at another institution; or

- Pass a written examination given by the KUMC Environment, Health & Safety Office; or
- Pass the Radiation Safety class given by the KUMC Environment, Health & Safety Office;

If an applicant feels that the Authorized User training requirements should be waived, the applicant may make a formal request for such to the Radiation Safety Committee. The Radiation Safety Committee will review the request and decide whether the applicant adequately demonstrates competence in using radioactive material. If the Radiation Safety Committee rules in favor of the request, the class or exam will not be required. If the Radiation Safety Committee decides that the applicant does not adequately demonstrate competence in using radioactive material, the class or exam must be taken.

7.2 OTHER RADIATION WORKERS

All Radiation Workers (laboratory personnel) must comply with at least one of the following training requirements:

- Provide evidence of passing a radiation safety class at another institution; or
- Pass the Radiation Safety course for laboratory personnel given by the KUMC Environment, Health & Safety Office. The course may be taken on a self-study basis. Persons completing the requirements in this manner are responsible for passing all exams.

If a person feels that these requirements should be waived, a formal request for a waiver along with reason(s) for requesting the waiver must be submitted to the Radiation Safety Officer. The Radiation Safety Officer will review the waiver request and decide if the person satisfies the basic requirements for handling radioisotopes.

7.3 ANNUAL TRAINING

All personnel working with radioactive materials or radiation must complete annual radiation safety refresher training. The annual training may be completed on-line or by attending a radiation safety training class presented by the Environment, Health & Safety Office.

8 POSTING AND LABELING

8.1 POSTING REQUIREMENTS

In general, all radiation signs must have the radiation tri-blade symbol and appropriate wording in magenta, purple, or black on a yellow background. These signs are available from the Environment, Health & Safety Office. The following specific requirements are given for posting areas where radioactive material is used or stored:

8.1.1 Notice to Employees Form (Form RH-3)

A copy of the State of Kansas Form RH-3, "Notice to Employees," must be posted in a sufficient number of places to be observed by radiation workers on the way to or from work. It is recommended that it be posted in at least one authorized radionuclide laboratory listed in a given Authorized User's permit. If the Authorized User has authorized radionuclide labs on more than one floor of a building or in more than one building, a "Notice to Employees" should be posted in each of those general areas.

8.1.2 "Caution – Radioactive Materials"

This posting is used if radioactive materials are used or stored within an area.

8.1.3 "Caution – Radiation Area"

This posting is used if an individual could receive a dose equivalent of five mrem in any one hour at 30 centimeters from the radiation source or from the surface of any shielding or other material that the radiation penetrates.

8.1.4 "Caution (or Danger) – High Radiation Area"

This posting is used if an individual could receive a dose equivalent in excess of 100 mrem in one hour at 30 centimeters from the radiation source or from the surface of any shielding or other material that the radiation penetrates.

8.1.5 "Caution (or Danger) – X-Ray"

This posting is used if an area has a permanently installed x-ray machine (e.g., x-ray diffraction units).

8.2 LABELING REQUIREMENTS

Any container or storage unit (e.g., a refrigerator, freezer, cabinet or drawer) that contains radioactive materials must be labeled with a radioactivity warning label. A radioactive isotope container label must also include the name of the isotope and a reference date.

All equipment in contact with radioactive materials (e.g., beakers, pipettes, etc.) should be labeled with a radioactive label to indicate the possible presence of radioactivity or radioactive contamination.

Equipment which contains radioactive material on a temporary basis and will not be constantly attended (e.g., centrifuges) should be labeled with "radioactive" tape either permanently or during the time it actually contains the radioactive material.

Equipment that is routinely used for radioactive work and is known to be contaminated (e.g., incubator) should be permanently labeled with a “Caution – Radioactive Materials” label. Information such as the radionuclide, location of the contamination, and specific precautions to follow should be included on the label (e.g., “S-35 contamination on the inside of the incubator. Wear gloves at all times”).

The KUMC Environment, Health & Safety Office has available tape marked with the standard radiation symbol, radioactive warning signs for posting work areas, labeled 20-gallon drums, boxes, plastic liners, and plastic jugs.

9 CALIBRATION AND LEAK TESTING

9.1 CALIBRATION OF PORTABLE AND MEASURING INSTRUMENTS

Monitoring equipment and instruments used for laboratory surveys and dose measurements must be calibrated annually and following repairs.

When a survey meter is taken out of service, it should be tagged and labeled “Out of Service” with the date that it was removed from service. The survey meter will need to be re-calibrated before being returned to service. The Environment, Health & Safety Office monitors the calibration status of all survey instruments on campus. Inform the Environment, Health & Safety Office when the survey meter is taken out of or returned to service or repaired.

If purchasing a new instrument, notify the Environment, Health & Safety Office so that it may be included in the inventory listing of all radiation detection instruments. The Environment, Health & Safety Office tracks the annual calibration dates for all survey meters on campus and will arrange for the annual calibrations to be completed.

9.2 LEAK TESTING OF SEALED SOURCES

Sealed sources must be leak tested at six month intervals, or as stated in the conditions of the KUMC Radioactive Materials License, to detect any failure in containment. The Environment, Health and Safety Office is responsible for ensuring the leak tests are conducted and for maintaining the test records.

A leak test is not required for the following sealed sources (KDHE K. A. R. 28-35-216a):

- Sources containing only radioactive material as a gas
- Sources containing 100 μCi or less of beta or gamma-emitting material
- Sources containing 10 μCi or less of alpha-emitting material
- Sources stored, not being used, and are identified as being in storage (in which case they still must be inventoried every 6 months)
- Seeds of Ir-192 encased in nylon ribbon
- Sources with half-lives of less than 30 days
- Sources containing only H-3

The leak test for generally licensed materials must be arranged by the person who purchased the material (e.g., Ni-63 sources for gas chromatography). Arrangements may

be made with the KUMC Environment, Health & Safety Office staff to ensure these tests are performed.

If the leak test reveals the presence of 0.005 μCi or more of removable contamination, the sealed source must be immediately withdrawn from use until it is repaired or replaced.

9.3 LABORATORY SURVEYS

The KUMC Radioactive Materials License requires that periodic laboratory surveys for radioactive contamination be conducted. The survey results will assist in identifying possible problems in radioisotope handling procedures. New radioactive materials users or individuals unfamiliar with performing routine surveys should contact the Environment Health & Safety office for guidance.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix S at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

Each laboratory which has radioactive materials in its inventory must complete, at a minimum, a monthly survey. A survey is not required when all radioactive materials and radioactive waste have been removed from the laboratory. However, a survey is still required if the Authorized User has radioactive waste or other radioactive materials present in the laboratory – even if these radioactive materials have decayed to essentially zero activity.

Reports indicating the results of the surveys must be sent to the Environment, Health and Safety Office. The laboratory and the Environment, Health & Safety Office should maintain copies of the survey.

The Environment, Health & Safety Office will provide a standard Area Contamination and Radiation Survey form for use in performing routine surveys of laboratories and other areas. The second page of this form (not intended to be turned in) provides practical guidance for users performing the survey.

If a liquid scintillation counter is used to assay the radioactive samples in your research, then this is a reasonable instrument to use to assay the survey samples. Wipe each section with a filter paper, place each filter paper in its own counting vial, add scintillation fluid, shake and count the vial. The background swipe should be treated in the same way.

If a gamma counter is used to assay the radioactivity of your research samples, then use the same counter to count the swipes and use a survey meter such as a Geiger-Muller counter to survey for radiation levels. It is recommended that a survey meter with an audible signal be used for this type of survey. The audible signal has a faster response and it allows the surveyor to watch the area being surveyed instead of the survey meter. The probe should be moved slowly above the work area (1/2 inch above), and the meter

response monitored for a signal increase. This type of survey is recommended for high-energy beta and gamma sources. It is strongly recommended that the work area be monitored each time radioactive materials are used.

If contamination is found (>220 dpm/100 cm²), the area must be cleaned and resurveyed. Notify the Environment, Health & Safety Office that contamination has been discovered. Repeat the cleaning process until the contamination is as low as reasonably achievable and below 220 dpm/100cm².

Periodic surveys may be conducted on a random, unannounced basis by the Environment, Health & Safety Office to monitor radioactive material handling practices.

9.4 DOCUMENTATION PROCEDURES

9.4.1 Laboratory Surveys Records

All survey results, either positive or negative, must be noted along with the background reading and date of monitoring and must also indicate areas that were monitored, e.g. marked on a map. Send a copy to the KUMC Environment, Health & Safety Office and keep a copy for your files.

9.4.2 Radioisotope Usage, Disposal and Inventory Records

The records of radioisotope utilization, disposal, and inventory must be maintained by the laboratory. Records should be organized in such a way that they are self-explanatory and inspection-ready. Records may be inspected by the Environment, Health & Safety Office and by KDHE or other regulatory agencies at any time.

10 PERSONNEL MONITORING

10.1 RADIATION PROTECTION

The users of ionizing radiation must keep exposure to themselves and those around them As Low As is Reasonably Achievable (ALARA). There are several factors that can be manipulated to reduce exposure to radiation:

- Increase distance from the source of radiation
- Increase shielding between you and the source of radiation
- Decrease time exposed to radiation
- Decrease the source's activity – use only the activity needed
- Use compounds that are less volatile and less readily absorbed through the skin

10.2 RADIATION MONITORING

The maximum permissible doses established by KDHE for radiation workers are summarized in the following table:

Exposed Part of Body	Abbreviation	Limit (mrem)	Time Period
Whole Body (Deep Dose Equivalent)	DDE	5,000	Annually
Lens of the Eye (Lens Dose Equivalent)	LDE	15,000	Annually
Skin (Shallow Dose Equivalent – Whole Body)	SDE-WB	50,000	Annually
Extremity (Shallow Dose Equivalent – Maximum Extremity)	SDE-ME	50,000	Annually
Total Organ Dose Equivalent	TODE	50,000	Annually
Fetus of a Declared Pregnant Woman	DPW	500	Gestation period

NOTE:

- Minors (individuals under 18 years old) are limited to 10% of these values.
- Extremities include hands, elbows, and arms below the elbows, and feet, knees and legs below the knee.
- A declared pregnant woman is limited to 500 mrem for the entire gestation period unless she has already received 500 mrem since conception. In this case, she is allowed 50 mrem for the remainder of the pregnancy.
- The Total Effective Dose Equivalent (TEDE) is the sum of all internal and external exposures.
- Weighting factors (W_T) are used in calculating the effective dose equivalent. A weighting factor for an organ or tissue is the proportion of risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. The values for the weighting factors are summarized below:

ORGAN DOSE WEIGHTING FACTORS	
Organ or Tissue	W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30*
Whole Body	1.00

* 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

State regulations require that any individual who is likely to receive 10% of any applicable limit must be provided with a monitoring device.

Although most individuals who work with radioactive materials or radiation-emitting equipment at KUMC never approach values that require personnel monitoring, KUMC will provide monitoring at the request of a worker.

Badges are processed by a vendor who holds current accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Bureau of

Standards. The type of badge (quarterly or monthly, extremity, second whole body) provided depends upon the individual's department and the type of radiation exposure.

10.3 ALARA (As Low As is Reasonably Achievable)

Even though current occupational exposure limits keep the risk of injury to personnel very low, our operating philosophy is to keep occupational exposures as far below specified limits as is reasonably achievable. This philosophy, emphasized in federal regulations and referred to as ALARA, means that each work procedure that will result in a radiation dose should be subject to scrutiny and that methods to reduce the dose should be identified. For this purpose, KUMC established specific guidelines to initiate notification and investigation procedures. They shall be initiated for any deep dose equivalent levels above 50 mrem per month, or any shallow dose equivalent above 100 mrem per month. However, for personnel being trained in radiology the notification and investigation procedure will be initiated for deep dose or shallow dose equivalent exposures above 400 mrem per month.

10.4 ENROLLMENT IN THE RADIATION MONITORING PROGRAM

To enroll in the radiation monitoring program contact the Environment, Health & Safety Office during normal working hours, Monday through Friday, to complete the necessary paperwork to obtain a badge.

Once the paperwork has been submitted, you will be issued a badge and entered into the routine monitoring program. Badges will be collected either monthly or quarterly. Except as indicated in this manual, reports of badge analyses are not routinely distributed to users. However, any individual enrolled in the radiation monitoring program may review and/or be given a written report detailing the results of analysis of the person's badges upon written request for such information from the Environment, Health & Safety Office.

10.5 ENROLLMENT IN THE FETAL MONITORING PROGRAM

Any woman considering becoming pregnant or discovering that she is pregnant should consider declaring her pregnancy with the Environment, Health and Safety Office who will counsel her on the advantages and disadvantages of declaring her pregnancy. If, after this discussion, she wishes to declare her pregnancy and voluntarily enroll in the Fetal Monitoring Program, she will be provided with a "Declaration of Pregnancy for Laboratory Workers" form.

The Radiation Safety Officer will use the information provided on this form to calculate the dose received from the date of conception until the date of declaration. Exposure limits for the duration of the pregnancy will be set at that time. A declared pregnant woman is limited to 500 mrem for the entire gestation period unless she has already received 500 mrem since conception. In this case, she will be allowed 50 mrem for the remainder of the pregnancy. A copy of the completed Declaration of Pregnancy for Laboratory Workers form and a fetal monitoring badge will be provided to the Declared Pregnant Woman as soon as practical.

The fetal monitoring badge is to be worn at the waist versus the standard whole body badge that is worn at the collar or chest. If a lead apron is utilized, the fetal badge is worn under the apron and the whole body badge outside the apron at the collar.

The exposure levels obtained from the fetal monitoring badges will be monitored throughout the pregnancy by the Environment, Health & Safety Office. Should the fetal ALARA limit be exceeded, the Declared Pregnant Woman will receive immediate notification.

The Declared Pregnant Woman should inform the Environment, Health & Safety Office when the fetal monitoring is no longer required.

10.6 BIOASSAYS

If analysis of a bioassay sample indicates a positive result, the EHS office will follow the recommendations of NUREG/CR-4884 “Interpretations of Bioassay Measurements” for the particular radionuclide of interest.

10.6.1 I-125 and I-131

The use of I-125 or I-131 may require a thyroid bioassay. A thyroid bioassay is simply a measurement of the iodine activity in the thyroid gland. This activity is representative of the amount of iodine inhaled, ingested or absorbed through the skin.

U. S. Nuclear Regulatory Commission Regulatory Guide 8.20 provides guidance for conditions under which a bioassay is necessary. The following table was adapted from that Regulatory Guide and may be used to determine if a thyroid bioassay is necessary. For example, if a worker is performing an iodination with greater than 1 mCi of volatile iodine in a fume hood, a bioassay would be required. All workers handling radioiodine at or exceeding the limits specified in the table, or sufficiently close to the process that intake is possible, must participate in the bioassay program.

All workers handling radioactive iodine or sufficiently close to the process so that intake is possible (e. g., within a few meters and in the same room as the worker handling the material) should participate in bioassay programs which will include baseline, routine and termination measurements – as described in Reg. Guide 8.20.

When radioactive iodine is handled routinely, bioassays must be completed between 6 and 72 hours following work with radioiodine in excess of levels specified in the following table. When work is on an infrequent basis (less frequently than every 2 weeks), bioassay should be performed within 10 days of the end of the work period during which radioactive iodine was handled.

Operations involving the routine use of I-125 or I-131 in an open room or bench will be discouraged. Whenever practicable, sealed bottles or containers holding more than 0.1 mCi or more of I-125 or I-131 should be opened, at least initially, within hoods having adequate face velocities.

Amount of Activity Handled for which a Bioassay will be Necessary ^a for I-125 or I-131

Type of Operation	Activity Handled in Unsealed Form Making Bioassay Necessary ^b	
	Volatile Forms	Non-volatile Forms
Open room or bench	0.1 mCi	1.0 mCi
Fume hood	1.0 mCi	10.0 mCi
Glove box	10.0 mCi	100.0 mCi

^a These quantities apply to both the single quantity handled at any one time or integrated as the total amount of activity introduced into a process over any three (3) month period.

^b Quantities may be considered the cumulative amount in process handled by a worker during a 3-month period (e.g., the total quantity introduced into a chemical or physical process over a 3-month period, or on one or more occasions in that period, by opening stock reagent containers from which radioactive iodine may escape). Quantities in the right-hand column may be used when it can be shown that activity in process is always chemical-bound and processed in such a manner that I-125 or I-131 will remain in non-volatile form and diluted to concentrations less than 0.1 mCi/mg of non-volatile agent. Capsules (such as gelatin capsules given to patients for diagnostic tests) may be considered to contain the radioiodine in non-free form, and bioassay would not be necessary unless a capsule were inadvertently opened (e.g., dropped or crushed). However, certain compounds where radioiodine is normally bound are known to release radioiodine when the material is in process, and the left-hand column may then be applicable. In those laboratories working only with I-125 in radioimmunoassay (RIA) kits, the quantities of I-125 are very small and in less volatile forms. Thus, bioassay requirements may be judged from the right-hand column. In operations where reagent containers are opened indoors for simple operations such as pouring liquid solutions, the above table does not apply. Bioassays should be performed whenever an individual employee handles in open form (e.g., an open bottle or container) of more than 50 mCi of I-125 or I-131 at any one time.

10.6.2 H-3 (Tritium)

U. S. Nuclear Regulatory Commission Regulatory Guide 8.32 provides guidance for conditions under which a bioassay is necessary. The table below was adapted from that Regulatory Guide and should be used to determine when routine bioassay sampling is necessary. Routine Bioassay sampling should be performed when quantities processed by an individual at any one time or the total amount processed per month exceed those for the forms of tritium shown in the following table.

Special bioassay sampling (non-routine) should also be performed when an employee comes into skin contact with, ingests, or absorbs into the body through cuts, abrasions, or accidental (hypodermic) injection tritiated compounds.

All workers involved in the processing of tritium under conditions specified above (or in the environs of the process) must participate in the bioassay program. The Authorized User is responsible for implementing the H-3 bioassay procedures for those workers under his/her supervision, and for training those workers in the requirements of the KUMC's bioassay program. This includes reinforcing the need for workers to contact the Environment, Health & Safety office when any accidental contact with tritiated

compounds occurs (as described in the previous paragraph). The Authorized User in coordination with the Environment, Health & Safety office must determine the frequency for bioassays and schedule worker's participation. The Radiation Safety Officer will report any positive bioassay results to the individual and the Authorized User.

For routine bioassay sampling, a sample of at least 40 ml of urine must be taken within 72 hours following entry of an individual into an area where operations require bioassay and then every two (2) weeks thereafter, as long as the individual is working with the levels of tritium indicated in the table below. When work with tritium is on an infrequent basis (less frequently than every 2 weeks), bioassays should be performed within 10 days of the end of the work period during which tritium was handled.

For special bioassay sampling, a sample of at least 40 ml of urine must be taken within 72 hours following the event, and a similar volume must be taken as a follow-up sample seven to fourteen days later.

Amount of Activity^a Handled for which a Bioassay will be Necessary For Tritium

Types of Operation ^a	HTO ^b and Other Tritiated Compounds (Including Nucleotide Precursors)	Tritium (HT or T ₂) ^c Gas in Sealed Process Vessels ^d
Processes in open room or bench with possible escape of tritium from process vessels.	0.1 Ci	100 Ci
Processes with possible escape of tritium carried out within a fume hood of adequate design, face velocity, and performance reliability	1 Ci	1,000 Ci

^a Quantities (<10 kg) of substances containing tritium that are present during operations may be considered to be either the amount processed by an individual at any one time (when accidental intake is more likely) or the amount of activity that entered into the process (throughout) during any one month (when routine handling of repeated batches is the more likely source of exposure).

^b HTO is a symbol for a water molecule in which a tritium atom (T) is present in place of a normal hydrogen atom (H).

^c A molecule of hydrogen gas contains two hydrogen atoms. Either one of these atoms may be replaced with T to form HT, or two T atoms may combine to form T₂ gas.

^d This assumes that adequate air monitoring has established that there is no tritium leakage or that no significant amount of tritium gas can be converted to HTO before intake.

10.6.3 Other Radionuclides

Bioassay requirements will be determined by the RSO on a case-by-case basis if the quantity of other radionuclides used in a month is greater than 10 mCi.

11 CONTROL OF RADIOACTIVE MATERIAL

11.1 PROCEDURES FOR ORDERING RADIOACTIVE MATERIALS

11.1.1 Requisition Number

Each order of radioactive material must be approved by the Environment, Health & Safety Office before it can be ordered. The Environment, Health & Safety Office will verify that the requesting user is authorized to possess and use the requested material and will ensure the amount ordered will not exceed the Authorized User's possession limit for the isotope requested. The Environment, Health & Safety Office will issue a "Requisition Number" for each approved order.

The Environment, Health & Safety Office must be informed of any and all radioactive materials that are to be sent to or have been received by anyone from off-campus sources. This includes free samples or calibration standards provided by vendors.

All radioactive materials shipped to or delivered to the University of Kansas Medical Center must be checked in through the Environment, Health & Safety "Hot Room." After being checked in, the appropriate party will be contacted to pick up the materials.

11.1.2 Special Cases

Occasionally a researcher will need to try a labeled chemical that the researcher is not authorized for in order to ascertain the feasibility of using it in a study. Usually only one order will be approved for "Evaluation" if the chemical form/radionuclide is similar to an existing project protocol. If the Authoree decides to continue use, an amendment must be approved by the Environment, Health & Safety Office before the next order.

11.1.3 Free Items From Manufacturers

The Authoree must inform the Environment, Health & Safety Office when any such material is expected and must provide the following information:

- Manufacturer's name
- Isotope
- Chemical compound
- Activity

As with all radioactive material, the material must be checked in through the Environment, Health & Safety "Hot Room."

11.1.4 Inventory Number (Also Referred To As "Package ID")

This number, assigned by the Environment, Health & Safety Office when the package is checked in, will be used to track the radioactive material during its presence on the KUMC campus.

11.1.5 Safe Opening of Packages of Radioactive Materials

Packages of radioactive materials shipped to the University will be delivered to the University's receiving dock. Certain types of packages are required by regulations to have certain initial checks performed within three hours of their arrival on campus or

within three hours after the start of the next work day for packages received after hours, on weekends or holidays. The Environment, Health & Safety Office will ensure that all of these initial checks will be performed within that time limit. This includes inspecting for signs of damage and surveying for removable contamination. In general, these surveys will be conducted in the Environment, Health & Safety Office's "Hot Room."

11.2 RECORDKEEPING

Each Authorized User must keep copies of all records of receipt, utilization, disposal, and inventory of radioactive material as well as records of radiation and contamination monitoring. Contact the KUMC Environment, Health & Safety Office prior to disposal of any of these types of records.

11.3 INVENTORY

An inventory of radioisotopes must be maintained. This inventory must indicate receipt and disposal for all radioactive material possessed or disposed.

The inventory is maintained by reviewing, adjusting and signing the computer-generated inventory sheet sent to the Authorized User periodically (usually monthly). The Authorized User must ensure that the inventory is correct by conducting a visual verification that all items on the inventory are in the laboratory and that all radioactive materials in the laboratory are included on the inventory report.

The Authorized User is responsible for maintaining a copy of the completed inventory report and for submitting a copy to the Environment, Health & Safety Office. These reports comprise records of cumulative use and disposal of radioactive material that each Authorized User is required to maintain for inspection by the State of Kansas.

11.4 MAINTAINING SECURITY OF RADIOACTIVE MATERIALS:

Authorized Users and lab personnel must maintain immediate control and constant surveillance of radioactive materials or they must secure the materials against unauthorized removal.

Authorized Users should review systems for key control, locking of rooms, and internal transfers of radioactive materials, to assure that they are effective enough to prevent unauthorized removal of the material.

Radioactive materials shall not be stored in unlocked refrigerators or freezers which are located in hallways or other unsecured areas.

11.5 TRANSFER OF RADIOACTIVE MATERIAL

Any transportation of radioactive materials must comply with the appropriate state of Kansas Department of Health and Environment, federal Department of Transportation, and any other applicable regulations as to the amount of material shipped, shielding, and labeling. Shipments of radioactive material will be processed by the Environment, Health & Safety Office to ensure that the person or facility is authorized to possess the material.

11.5.1 Transfers within KUMC

Transfers within KUMC may be made to Authorized Users who have Radiation Safety Committee authorization to possess the material being transferred.

Before transferring radioactive material, check with the KUMC Environment, Health & Safety Office to ensure that the person receiving the material is authorized by the Radiation Safety Committee to possess that particular isotope, chemical compound and activity.

11.5.2 Transfers outside of the University of Kansas Medical Center

Transfers outside of KUMC may be made if the steps outlined below are followed:

- Obtain written verification from the appropriate authority that the person to whom the transfer is to be made has an agreement State or NRC license which authorizes them to possess the material. The verification must be submitted to the Radiation Safety Officer before shipment can be made.
- Prepare the material in a leak-proof container and affix a label with full information as to isotope, activity, and reference date. Bring the material and, if possible, the shipping container in which the material was originally received to the Environment, Health & Safety Office.
- The Radiation Safety officer or other trained individual will ship the package.

12 PROCEDURES FOR HANDLING RADIOACTIVE MATERIAL SAFELY

12.1 PERSONNEL SAFETY RULES FOR POSTED RADIOACTIVE MATERIALS AREAS

- Do not drink, eat, apply cosmetics or use tobacco products in these areas..
- Do not store or dispose of food or beverages in these areas.
- Limit the use of personal items in these areas.
- Wear appropriate apparel to prevent skin contamination.
- Wash hands often.
- NEVER pipette radioactive liquids by mouth.
- Keep work area free of equipment not needed in the procedure.
- Properly label containers to inform other workers of radioactive hazards. Where space is available, this labeling should include as much information as possible, for example: assay date, radionuclide, activity, and chemical compound.
- Use minimum material and time, but maximum distance and shielding.
- Dispose of radioactive waste separately from normal waste, and in specified radioactive waste containers.
- Follow standard disposal procedures.
- Keep accurate records of receipt, monitoring, usage, and disposal.
- If you are assigned a dosimeter, wear it in the same location on the body consistently, and wear it whenever you are in an area where radiation hazards might exist.

- Monitor the project with suitable radiation detecting instruments. Monitor hands and feet at least daily when unsealed radioactive materials are in use.
- If a spill is suspected, avoid spreading contamination by isolating the area. Notify the KUMC Environment, Health & Safety Office of every spill. Follow the spill procedures as outlined in Section 1.
- Radioactive materials are to be used only in those facilities that have been approved by the Radiation Safety Officer and the Radiation Safety Committee. Work areas should be designated for handling radioactive materials and these areas should have surfaces that are easily cleaned or replaced.
- Work with unsealed sources must be done on absorbent paper with impermeable backing. All work with volatile materials must be conducted in a laboratory fume hood.

13 USE OF RADIOACTIVE MATERIALS WITH ANIMALS

The Radiation Safety Committee grants approval for radioactive material usage involving live animals. However, final approval for such studies comes from the Institutional Animal Care and Use Committee (IACUC) and must be obtained before the project can begin.

When radionuclides are administered to animals, it is the responsibility of the Authorized User to establish protocols that prevent contaminating other animals, workers, experiments and areas. The rooms, cages, equipment and associated materials in contact with the animals shall be regarded and treated as contaminated until determined otherwise.

All potentially contaminated materials shall be marked with the following information:

- The standard radiation symbol
- The Authorized User name, contact person and phone number
- The radioisotope used
- The activity used
- The date the radioisotope was administered
- Any special instructions
- Project termination date

This information shall remain posted on equipment, materials and other potentially contaminated areas until they are deemed “clean.”

14 RADIOACTIVE WASTE DISPOSAL

14.1 TYPES OF RADIOACTIVE WASTE

Radioactive waste can be in the form of solids or liquids. It can also be composed of many components: liquid scintillation wastes, animal carcasses, sharps, mixed wastes (i.e., having both a radioactive and a chemical hazard), etc. Finally, it can include different radioisotopes. In general, each type of waste should be collected in separate container, for example, solid and liquid wastes must be segregated. EHS can provide further guidance on waste segregation beyond what is provided in this section.

14.1.1 Solid Waste

Definition:

Absorbent paper, glassware, gloves etc. that are contaminated must be disposed of as solid waste.

Packaging

Prior to transfer to an EHS waste processing area, dry, solid waste should be packaged in radiation-labeled containers supplied by the Environment, Health & Safety office. The containers must be lined with a thick plastic bag prior to depositing the solid waste. The bag and the container must be closed securely.

Solid waste that is wet with residual liquid must be segregated from dry waste and packaged in a drum or box that is double-lined with thick plastic bags. Be sure that the label indicates the presence of wet, solid waste.

NOTE: Lead shipping containers (commonly referred to as “pigs”) are not to be mixed with solid waste.

14.1.2 Liquid Waste

Definition

Liquid waste at KUMC comes in three forms:

Liquid waste which is collected in containers for pick up and disposal by the Environment, Health & Safety office (who can supply one-gallon plastic bottles).

The liquid waste must be stored in a chemically-compatible bottle with the “Caution – Radioactive Material” label that the Environment, Health & Safety Office provides. Do not overfill the bottle. Ensure the bottle has at least one inch of empty space.

Liquid waste which can be disposed of via the sanitary sewer with written permission from the Radiation Safety Officer. On a monthly basis, all releases of liquid radioactive waste to the sanitary sewer must be reported to the Environment, Health & Safety office on the inventory report form. Liquid waste eligible for sewer disposal must meet the following criteria:

- It must have a pH between 5.5 and 10.5. The generator has the responsibility for adjusting the pH of the waste. The Environment, Health & Safety Office may have neutralizing material available if required. Activity in the bottle can be determined by records or by analyzing a sample from the bottle. Ensure the contents are adequately mixed prior to sampling.
- It must not contain any chemicals classified as a hazardous waste by EPA due to characteristics such as corrosivity, reactivity, ignitability, and toxicity or due to being a specifically listed waste.
- If a non-hazardous chemical is present, it must be readily dispersed in water.
- Local ordinance must not prohibit its disposal via the sanitary sewer system.

For further information regarding these criteria contact the Environment, Health & Safety Office.

Liquid waste that is considered a mixed-waste composed of EPA-regulated chemical waste and radioactivity. Due to the high cost of disposing of mixed-waste, Authorized Users are strongly encouraged to eliminate the generation of mixed-waste if at all possible. Mixed-waste that is collected by the KUMC Environment, Health & Safety Office for disposal must have the major chemical constituents and their concentrations (in percent) identified in addition to isotope and activity information.

Activity in the bottle can be determined from records or by analyzing a sample from the bottle. Ensure the contents are adequately mixed prior to sampling.

NOTE: According to hazardous waste satellite accumulation area regulations, a full container may be in a laboratory no more than three days and only one full container per waste stream is allowed in a laboratory at any time.

14.1.3 Liquid Scintillation Waste

Deregulated vs. Regulated Liquid Scintillation

Deregulated liquid scintillation waste contains H-3 or C-14 with a concentration that is less than 0.05 $\mu\text{Ci/gm}$.

Regulated liquid scintillation waste contains H-3 or C-14 with a concentration that is greater than 0.05 $\mu\text{Ci/gm}$ or any other radionuclide in any concentration (K. A. R. 28-35-223a).

All LSC waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods.

NOTE: liquid scintillation vials waste containing Fe-55 must be kept separate from all other radionuclides.

Packaging

Bulk glass and plastic liquid scintillation vials may be disposed of in a twenty-gallon drum, double-lined with thick plastic bags. This drum should contain only liquid scintillation vials. Do not place any other waste material in this container. Alternatively, the vials may be collected in flats. The flats do not need to be taped together.

14.1.4 Animal (Biological) Waste

Disposal of animals which contain radioactive materials must be coordinated with the Environment, Health & Safety Office. A radioactive waste record should be completed. Animal or biological waste must be placed in a double plastic bag and marked with the following:

- Authorized User's name
- Standard radiation symbol
- Date of disposal
- Radioisotope

- Amount of material to be disposed of (total μCi and $\mu\text{Ci/gm}$)
- Activity reference date

14.1.5 Sharps

All needles and other sharp items that are contaminated with radioactive materials must be placed in rigid, puncture-proof containers. These containers must not be disposed of in the other solid radioactive waste containers but must be collected in separate containers to eventually be collected by EHS for disposal.

14.2 SEGREGATION OF WASTE

In accordance with waste minimization practices, KUMC has a procedure to decay waste in storage.

Except on the rare occasions when a user is given written permission by the EHS office for an alternate segregation method, the laboratories must segregate solid and liquid waste into separate disposal containers as follows:

- Waste with a half-life of 30 days or less (e.g., P-32)
- Waste with a half-life greater than 30 days but less than or equal to 61 days (e.g., I-125)
- Waste with a half-life greater than 61 days but less than 90 days (e.g., S-35)
- Waste with a half-life greater than or equal to 90 days (e.g., H-3, C-14)

As much as possible, radiation workers should segregate all waste by isotope.

14.3 LABELING OF WASTE

All radioactive waste must be labeled as “Radioactive Material.” The packages must also be labeled with:

- Standard radiation symbol
- Radioisotope(s) in the package
- Amount of material (μCi) in the package
- Reference or assay date
- Authorized User’s name
- Chemical compound (if liquid waste, list all chemicals in container)

14.4 STORAGE OF WASTE

Radioactive waste, like all radioactive materials, must be secured to prevent unauthorized removal. Please keep in mind that it has been found that sometimes even conspicuously marked packages/boxes are at risk of being removed by persons who do not realize that the waste cannot be treated as ordinary trash.

The waste storage must be in an area where the exposure to personnel is minimal. If the waste presents an external radiation hazard, shielding must be used to prevent unnecessary exposure.

Volatile radioactive material must be stored in a fume hood.

14.5 DISPOSAL OF RADIOACTIVE WASTE

Radioactive waste will be picked up from the laboratories by the Environment, Health & Safety office upon request (currently by calling 588-1081, emailing EHS@kumc.edu, or by filling out the Chemical Waste Pick-Up form and specifying that radioactive waste is to be picked up). Never leave radioactive waste unattended.

14.6 DISPOSAL RECORDS

When radioactive material is turned over to the Environment, Health & Safety Office for disposal every column of the Disposal Record must be completed.

- Name of Isotope: The symbol and number of the radioisotope to be disposed of.
- Calculated Activity of Isotope: The activity of the radioactive waste to be disposed of. Specify units e.g., μCi .
- Date Activity Calculated: The date on which the reported activity is accurate.
- Chemical /Physical Form: Indicate the chemical (e.g., toluene, xylene, methanol) or physical (e.g., paper, pipette tips, wet solid waste, etc.) form of the waste making special note of carcinogens, toxins, poisons, biohazards, and/or flammables.

15 IN THE EVENT OF A NON-COMPLIANCE

15.1 CORRECTIVE ACTIONS

The Radiation Safety Officer will implement corrective actions when evidence of non-compliance with the requirements of the radiation safety program is noted. Corrective actions will be documented by the Environment, Health & Safety Office and communicated to the Radiation Safety Committee. Corrective actions could include a wide variety of responses up to and including the termination of an Authorized User's ability to possess and use radioactive materials.

15.2 DISCIPLINARY ACTIONS

Progressive disciplinary steps will be taken to address repetitive problems encountered with the use of radioactive materials by an individual or specific laboratory.

16 RADIATION-PRODUCING DEVICES

Radiation safety from x-ray-producing equipment is the responsibility of the Radiation Safety Committee. Before any purchase or receipt on the KUMC campus of radiation-producing equipment, the KUMC Environment, Health & Safety (EHS) Office must be advised so that conformity with the State laws may be checked, and so that the EHS office can coordinate the initial radiation survey with the users.

The EHS office is required to notify the Kansas Dept. of Health and Environment within 30 days of an x-ray device being removed from service (due to inoperability or transfer to another facility) or being placed in service (due to repair, purchase, or other means). Therefore, owners of this equipment must inform the EHS office as soon as possible of any change in status. EHS should also be involved in coordination of disposal of any radiation-producing devices.

The requirements and information below are written to fulfill this obligation of the users of x-ray producing equipment.

16.1 REGISTRATION OF IONIZING RADIATION-PRODUCING DEVICES

16.1.1 Type of Equipment

Registration of any machine capable of producing ionizing radiation must be accomplished within thirty (30) days of acquisition with the KUMC Environment, Health & Safety Office and the Kansas Department of Health and Environment.

Items to be registered include:

- Medical and dental x-ray machines, including fluoroscopes
- X-ray diffraction units
- Electron microscopes
- Particle accelerators
- Any equipment which may produce potentially hazardous ionizing radiation.

Registration information shall include the following:

- Type of equipment
- Manufacturer
- Model number
- Serial number
- Maximum kVp
- Maximum mA
- Location

16.1.2 Users of Ionizing Radiation-Producing Equipment (like x-ray devices)

Persons operating radiation-producing equipment for research purposes must have the approval of the Radiation Safety Officer before using such equipment. Permission to use radiation-producing equipment is granted after the person desiring to use the equipment demonstrates competence in its safe use.

16.1.3 Protection of Personnel

16.1.3.1 General

General protective actions for personnel should include the following:

- Environment, Health & Safety Office personnel must check walls, ceilings, and floors to ensure that ALARA principles are being implemented and personnel in adjacent areas are not being unreasonably exposed to ionizing radiation.
- To protect the operator during exposures, the control panel should be in a shielded area.
- The Environment, Health & Safety Office will review the workload to determine if personnel using the equipment should wear dosimeters.
- Should malfunction of the machine be suspected, discontinue its use, label it conspicuously “Danger, Do Not Use” until it has been checked and approved by a qualified person, and inform the KUMC Environment, Health & Safety Office. The EHS office is required to notify the Kansas Dept. of Health and Environment within 30 days of an x-ray device being removed from service.

- For monitoring any suspected radiation leakage, call the KUMC Environment, Health & Safety Office.

16.1.3.2 Fluoroscopy

General protective actions for personnel using fluoroscopy should include:

- Shielding of at least 0.25 mm of lead should be used between the subject and all individuals in the room. If any part of the whole body will be in the primary beam, 0.5 mm of lead equivalent shielding must be worn. If any part of the hands or forearms will be in the primary beam for any length of time, EHS strongly encourages the user to wear radiation-monitoring ring badges.
- Persons not needed in performing the examination should stand as far as possible from the x-ray tube and target.
- The primary beam should be collimated to the minimum area needed for the procedure. This will reduce operator exposures.

16.1.3.3 New Construction

Department chairpersons must submit a written statement as to whether or not sources of radiation will be used in the instructional or research laboratories of any new building. Upon receipt of this statement, the KUMC Environment, Health & Safety Office will consult with and advise the building committee on matters pertaining to the use of sources of radiation. Its recommendations will be submitted in writing to the Radiation Safety Committee and copies sent to the chairperson of the department involved.

Prior to being approved and sent out for bid, plans and specifications of a new building, including laboratory furniture, must be sent to the Radiation Safety Officer. These will be reviewed and recommendations made for any necessary changes. When these plans are satisfactory, approval will be indicated. No changes in these approved plans and specifications that pertain to the use of sources of radiation may be implemented until they have been resubmitted to the Radiation Safety Officer and approved.

17 NON-IONIZING RADIATION

Use of Class 3b and 4 lasers for research purposes (not including human subjects research) shall be approved by the Radiation Safety Committee.

For general safety precautions and institutional policies, contact the KUMC Environment, Health & Safety Office.

18 GLOSSARY:

A-number	A number that is the sum of the number of protons and the number of neutrons in an atom
Absorbed dose	The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The units of absorbed dose are the rad and the Gray (Gy). 1 rad equals 0.01 Gy
Absorption	The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.
Activity	The rate of disintegration, transformation or decay of radioactive material. Activity is expressed in the SI unit of Becquerel (Bq) or in the special unit of curie (Ci), or the multiples of either unit, or disintegrations or transformations per unit of time as follows: (1) One Becquerel (Bq) equals one disintegration or transformation per second (dps or tps); and (2) One Curie (Ci) equals 3.7E+10 disintegrations or transformations per second (dps or tps). One curie also equals 3.7E+10 Becquerel (Bq).
Acute Exposure	The absorption of a relatively large amount of radiation (or intake of radioactive material) over a short period of time.
Agreement State	Any state in which the U.S. Nuclear Regulatory Commission has entered into an effective agreement concerning the licensing of by-product material. Kansas is an agreement state and regulates the safe uses of radiation and by-product material within its boundary.
Airborne radioactive material	Radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases.
ALARA	Means "As Low As Reasonably is Achievable". See definition below.
Alpha Particle (α)	A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Annual Limit on Intake (ALI)	The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. The ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rem (0.05 Sv) or a committed dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue.
As Low As is Reasonably Achievable (ALARA)	Means that every reasonable effort has been made to maintain exposures as far below the dose limits specified in regulations as is practical, consistent with the purpose for which the licensed or registered activity is undertaken, taking the following into account: (1) the state of technology, (2) the economics of improvements in relations to the state of the technology, (3) the economics of improvements in relation to benefits to public health and safety and to other societal and socioeconomic considerations; and (4) the economics of improvements with respect to the utilization of nuclear energy and licensed or registered sources of radiation in the public interest.
Attenuation	The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.
Authorized User (AU or Authoree)	An individual who is identified as an authorized user on a license issued by the KDHE for the use of radioactive material or an individual who is designated by a registered facility as a user of ionizing radiation-producing devices. At KUMC this is usually a faculty member (or other designated person) who has been approved by the Radiation Safety Committee for the possession and use of radioactive materials.
Background Radiation	The radiation from cosmic sources; naturally occurring radioactive materials, including radon, except for those radioactive materials that are a decay product of source materials or special nuclear material; and global fallout as it exists in the environment from the testing of nuclear explosive devices. The term "background radiation" shall not include radiation from radioactive materials regulated by KDHE.
Becquerel (Bq)	The SI unit of activity. One Becquerel = 1 disintegration per second (dps) or transformation per second (tps).
Beta Particle (β)	Charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Bioassay	The determination of kinds, quantities or concentrations, and in some cases, the locations of radioactive material in the human body. This may be done by direct measurement (in-vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.
Body Burden	The amount of radioactive material which, if deposited in the total body, will produce the maximum permissible dose rate to the critical organ.
Bremsstrahlung	Electromagnetic (x-ray) radiation produced by the deposition of the energy from charged particles in matter. It is usually associated with energetic beta emitters (e.g., P-32), x-ray machines and linear accelerators.
Calibration	Determination of either of the following: The response or reading of an instrument relative to a series of known radiation values over the range of the instrument; or the strength of a source of radiation relative to a standard.
CFR	Code of Federal Regulations
Chronic Exposure	The absorption of radiation (or intake of radioactive materials) over a long period of time (e.g., over a lifetime).
Collective dose	The sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.
Contamination, Radioactive	Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be a source of excessive exposure to personnel or the validity of an experiment or a procedure.
Committed Dose Equivalent (CDE)	The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50 year period following the intake. (units = Sievert or Rem))
Committed Effective Dose Equivalent (CEDE)	The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues (units = Sievert- or Rem))
Cpm	Counts per minute

Critical Organ	The organ or tissue that when irradiated will result in the greatest hazard to the health of the individual or the individual's descendents.
Curie (Ci)	<p>Unit of activity. One Curie (Ci) is the quantity of radioactive material that decays at the rate of 3.7×10^{10} transformations per second (tps).</p> <p>One Curie = 3.7×10^{10} Becquerels = 2.22×10^{12} disintegrations per minute.</p> <p>Commonly used submultiples of the Curie are the millicurie and the microcurie. One millicurie (mCi) = 0.001 Curie = 3.7×10^7 tps. One microcurie (μCi) = 0.000001 Curie = 3.7×10^4 tps.</p>
Daughter Products	Isotopes that are formed by the radioactive decay of some other isotope. For example, in the case of Radium-226, there are ten successive daughter products, ending in the stable isotope Lead-206
Decay, Radioactive	A process whereby the nucleus spontaneously lowers its energy with the emission of radiation.
Declared Pregnant Woman (DPW)	A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception or of delivery. The written declaration shall remain in effect until the declared pregnant woman withdraws the declaration in writing or is no longer pregnant.
Deep Dose Equivalent (DDE)	The dose equivalent to a tissue depth of 1 cm (1000 mg/cm^2); applies to external whole body exposure,
Department of Transportation (DOT)	A government agency responsible for promoting the safe transportation of hazardous materials
Derived Air Concentration (DAC)	The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI.
Disintegration	See Decay, radioactive
Dose	A generic term that means the absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, total organ dose equivalent, total organ dose equivalent, or total effective dose equivalent. For our purposes, "radiation dose" shall be considered an equivalent term.

Dose Rate	The radiation dose delivered per unit of time. For example, measured in Gy/hr or rad/hr
Dosimeter	A portable device for measuring and registering the total accumulated exposure to ionizing radiation (see Dosimetry and Radiation Monitoring Device). Also referred to as an exposure monitoring badge
Dosimetry	The theory and application of the principles and technique involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made (e.g., radiation monitoring devices).
Dpm	Disintegrations per minute
Dose Equivalent	The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).
Effective Dose Equivalent (EDE)	The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.
Efficiency	The percent of total activity present for a given nuclide detected by the radiation detection instrument being used. It is calculated by the following formula $((\text{cpm} - \text{background})/\text{dpm})(100\%) = \text{efficiency}$
External Dose	That portion of the dose equivalent received from radiation sources outside the body.
Extremity	Hand, elbow, arm below the elbow, foot, knee, or leg below the knee.
Geiger–Müller (G-M) meter	Radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.
Gray (Gy)	SI unit of absorbed dose. One gray is equal to an absorbed dose of one joule per kilogram. One gray is also equal to 100 rads.

Half-Life, Effective	Time required for a radioactive nuclide in a system to be diminished by 50% as a result of the combined action of radioactive decay and biological elimination.
Half-Life, Radioactive	Time required for a radioactive substance to lose 50% of its activity by decay. Each radionuclide has a unique half-life.
Half-Value Layer	The thickness of any specified material used as shielding necessary to reduce the intensity of an x-ray or gamma ray beam to one-half (1/2) its original value.
Health Physics	A term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects (e.g., ionizing radiation).
High Radiation Area	An area accessible to individuals in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1mSv) in 1 hour at 30 cm from the radiation sources or from any surface that the radiation penetrates
Hot Spot	The region in a radiation/contamination area in which the level of radiation/contamination is noticeably greater than in neighboring regions in the area.
Inverse Square Law	The intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example, if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at 100 inches.
Ion	An atom that has too many or too few electrons resulting in a positive or negative charge, causing it to be chemically active; a free electron or other charged subatomic particle.
Ionizing Radiation	Alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other particles or electromagnetic radiation capable of producing ions.
Isotopes	Nuclides having the same number of protons in their nuclei and hence having the same atomic number, but differing in the number of neutrons, and therefore differing in the mass number. Almost identical chemical properties exist between isotopes of a particular element.
Kansas Department of Health and Environment (KDHE)	A regulatory agency which oversees compliance with radioactive material licenses in Kansas.

Labeled Compound	A compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition, this compound or its fragments may be followed through physical, chemical, or biological processes.
Lens of the Eye Dose Equivalent (LDE)	A calculated dose to the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm (300 mg/cm ²).
Licensed or Registered Material	Radioactive material received, possessed, used, transferred or disposed of under a general or specific license or registration issued by KDHE.
Limits	The permissible upper bounds of radiation exposures, contamination or releases.
LSC	Liquid scintillation cocktail or liquid scintillation counter
Microcurie (μCi)	A one-millionth part of a curie (0.000001 Ci). See Curie.
Millicurie (mCi)	A one-thousandth of a curie (0.001 Ci). See Curie.
MilliRoentgen (mR)	A one-thousandth of a Roentgen (0.001 R). See Roentgen.
Minor	An individual less than 18 years of age.
MPC	Maximum permissible concentration
Natural Radiation	Ionizing radiation, not from man-made sources arising from radioactive material. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of natural radiation vary with location, weather patterns, and time to some degree.
NCRP	National Council on Radiation Protection and Measurements
Neutron	Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral in a free state.
Nonstochastic Effects	These are health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect.
NRC	Nuclear Regulatory Commission

Nuclide	A type of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.
Occupational Dose	The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.
OSL	Optically Stimulated Luminescence
Photon	A quantum of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are photons.
Pig	A container (usually lead) used to ship or store radioactive materials. The thick walls protect the person handling the container from radiation.
Proton	An elementary nuclear particle with a positive electric charge located in the nucleus of an atom
Quality Factor	The modifying factor that is used to derive dose equivalent from absorbed dose.
Rad	Unit of absorbed dose. One rad is equal to one-hundredth of a joule per kilogram of material or the absorption of 100 ergs/gram of material. One millirad (mrad) equals 0.001 rad.
Radiation Area	An area accessible to individuals in which there exists radiation at such levels that, at 30 centimeters from the source of the radiation or any surface that the radiations penetrates, an individual could receive a dose equivalent in excess of five millirems in one hour.
Radiation Monitoring Device	A device designed to be worn by a single individual for the assessment of dose equivalent such as Luxel badges, film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, or personal air sampling devices. See Dosimeter and Dosimetry.
Radiation Worker	An individual who uses radioactive material under the licensee's control. Individuals must be trained and have passed a radiation safety examination prior to beginning work with radioactive materials.

Radioisotope	A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.
Radiography	The making of shadow images on photographic film or other radiation detector by the action of ionizing radiation.
Radio sensitivity	The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation.
Rem	The special unit of any of the quantities expressed as dose equivalent. One millirem (mrem) equals 0.001 rem.
Restricted Area	An area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.
Roentgen (R)	The special unit of radiation exposure
RSC	Radiation Safety Committee
RSO	Radiation Safety Officer
Scintillation Counter	A counter in which light flashes produced in a scintillator are converted into electric pulses by a photomultiplier tube; usually used to detect ionizing radiation.
Sealed Source	Any radioactive material that is permanently encased in a capsule designed to prevent the leakage or escape of the radioactive material.
Shallow Dose Equivalent - Whole Body or Maximum Extremity.(SDE-WB, SDE-ME)	The external exposure of the skin of the whole body or the maximum extremity. It is taken as the dose equivalent at a tissue depth of 0.007 cm (7 mg/cm ²) averaged over an area of 1 square centimeter.
Shielding Material	Any material which is used to absorb radiation and thus effectively reduce the intensity of radiation and in some cases eliminates it. Examples of commonly used shielding material are lab coats, gloves, lead, concrete, aluminum, water, and plastic
SI	The abbreviation for the international system of units.

Smear or Swipe Test	A procedure in which a swab (e.g., filter paper or cotton-tipped applicator) is rubbed on a surface and measured to determine if the surface is contaminated with removable radioactive material.
Stochastic Effects	Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.
Survey	An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive materials and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.
TLD	Thermoluminescent dosimeter
Total Effect Dose Equivalent (TEDE)	The sum of the deep dose equivalent (for external exposures) and the committed effect dose equivalent (for internal exposures).
Unrestricted Area	An area to which access is neither limited nor controlled by the licensee.
Very High Radiation Area	An area accessible to individuals in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at one meter from a source of radiation or from any surface that the radiation penetrates.
Whole Body	For the purposes of external exposure, head, trunk, arms above the elbow, and legs above the knee.
X-rays	Penetrating electromagnetic radiation having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra nuclear part of the atom as X-rays.
Z-number	The number of protons in the nucleus of an atom.

19 RADIATION UNITS AND CONVERSIONS

The following table provides information on various measurement units and conversions:

Quantity	Special Units	International Units (SI)	Equivalencies
Activity	Curie (Ci)	Becquerel (Bq)	1 Bq = 1 dps 1 Ci = 3.7×10^{10} dps
Absorbed Dose	Rad (Rad)	Gray (Gy)	1 Gy = 100 Rad 1 Rad = 0.01 Gy
Dose Equivalent	Rem (rem)	Sievert (Sv)	1 Sv = 100 rem 1 rem = 0.01 Sv
Exposure	Roentgen (R)	Coulomb/kg (C/kg)	1R = 2.58×10^{-4} C/kg

20 RADIONUCLIDE INFORMATION

20.1 Hydrogen-3 (Tritium or H-3)

- I. Physical Data
 - a. Maximum Beta Energy = 0.018 MeV (100%)
 - b. Maximum Range in Air = 4.7 mm (~0.19 inches)
 - c. Half-Life = 12.28 years
- II. Radiation Protection Procedures
 - a. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - b. Volatile chemical compounds should be handled in a certified fume hood.
 - c. Use lab coats and disposable gloves.
 - d. Regularly monitor and replace gloves as needed.
 - e. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - f. Select gloves appropriate for chemicals being handled.
- III. Shielding Requirements: None needed
- IV. Contamination Surveys
 - a. A removable contamination survey is the only method to monitor for H-3 contamination. This type of survey is performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
 - b. The contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds this level should be decontaminated and re-surveyed until the analysis shows levels below this value.
- V. Bioassay Requirements: See section 10.7.2 for Bioassay requirements.
- VI. Biological Distribution: H-3 (tritium) does not present an external exposure hazard because the low-energy betas emitted cannot penetrate the outer dead layer of skin. The critical organ for tritium uptake is the whole body water. Three to four hours after intake, tritiated water is uniformly distributed in all body water. On average, tritiated water is eliminated with a ten-day biological half-life. Elimination rates may be increased by increasing water intake.

VII. Waste Disposal

- a. Solid: Isolate waste from other nuclides in clearly labeled containers, except H-3 waste may be combined with C-14 waste since both have relatively long half-lives.
- b. Liquid:
 - a. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - b. Sewer disposals must be reported to EHS on a monthly basis.
- c. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods

VIII. Survey Meters: No portable survey meter is required for work with H-3.

- IX. Survey Frequency: The survey frequency for your H-3 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of H-3 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

- X. Personnel Monitoring: Whole body and extremity ring badges will not detect H-3 and are therefore not required for work with H-3. (The OSL whole body dosimeter's lower limit of detection for beta particles is 150 keV; the TLD ring dosimeter's lower limit of detection for beta particles is 200 keV.)
- XI. Decay Table: Not provided due to the long half-life of H-3

20.2 Carbon-14 (C-14)

- I. Physical Data
 - a. Maximum Beta Energy = 0.156 MeV (100%)
 - b. Approximate Maximum Range in Air = 22 cm (~8.6 inches); in plastic = 0.5 mm (~0.02 inches)
 - c. Half-Life = 5,730 years
- II. Radiation Protection Procedures
 - a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.
 - b. Shielding Requirements: None needed.
- III. Contamination Surveys
 - a. Two types of surveys may be used to monitor C-14 contamination.
 - i. A direct survey using a thin window Geiger-Muller detector or thin crystal sodium iodide detector to monitor work surfaces after use.
 - ii. A removable contamination survey performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
 - b. The contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis that exceeds this level should be decontaminated and re-surveyed until the analysis shows levels below this value.
- IV. Bioassay Requirements: May be required for work with > 10 mCi of C-14 (see also section 10.7.3).
- V. Biological Distribution: C-14 does not present a significant external exposure hazard because the low-energy betas emitted barely penetrate the horny outer layer of skin. The critical organ for uptake of many C-14 labeled carbonates is the bone. The critical organ for uptake of other compounds is the fat. Most C-14 labeled compounds are rapidly metabolized and the radionuclide is exhaled as C-14O₂. Some compounds and their metabolites are eliminated via the urine. Biological half-lives vary from a few minutes to 35 days – 10 days being a conservative value for most compounds.
- VI. Waste Disposal

- a. Solid: Isolate waste from other nuclides in clearly labeled containers. C-14 waste may be combined with H-3 waste since both have relatively long half-lives.
- b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. Sewer disposals must be reported to EHS on a monthly basis
 - iii. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods

VII. Survey Meters

- a. A survey meter may be required for work with C-14
- b. A thin window Geiger-Muller tube is necessary to detect C-14. These are typically approximately 10% efficient for C-14.

VIII. Survey Frequency: The survey frequency for your C-14 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of C-14 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

XII. Personnel Monitoring: Whole body badges and extremity ring badges will not detect the majority of the beta energies associated with C-14, and therefore are not required for work with C-14. (The OSL whole body dosimeter's lower limit of detection for beta particles is 150 keV; the TLD ring dosimeter's lower limit of detection for beta particles is 200 keV.)

IX. Decay Table: No decay table is provided due to the long half-life of C-14.

20.3 Phosphorus-32 (P-32)

- I. Physical Data
 - a. Maximum Beta Energy = 1.71 MeV
 - b. Approximate Maximum Range in Air = 3 meters (~10 feet)
 - c. Approximate Maximum Range in Water or Plastic = 0.75 cm (~0.3 inches)
 - d. Dose rate at one centimeter from an unshielded, 1 mCi point source of P-32 = approximately 200 Rads/hour.
 - e. Half-Life = 14.29 days

- II. Radiation Protection Procedures
 - a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.

 - b. Shielding Requirements
 - i. Handle millicurie or greater quantities behind Lucite or similar material of approximately 0.5 inches thick. Do not use lead as a shielding material when working with P-32. Using lead as a shielding material will actually increase the hazard due to generation of x-rays emitted when high-energy charged particles (like the beta particles emitted by P-32) suffer rapid deceleration. This occurs most readily when the charged particle passes through a material with a high atomic number (like lead) and is known as Bremsstrahlung production of x-rays.
 - ii. Store millicurie or greater quantities of waste behind Lucite-type (or equivalent) shields of approximately 0.5 inches thick and attach 1/8 to 1/4 inches of lead to outside of Lucite.

- III. Contamination Surveys
 - a. Two types of surveys may be used to monitor P-32 contamination.
 - i. A direct survey using a thin window Geiger-Muller detector or thin crystal sodium iodide detector to monitor work surfaces after use.
 - ii. A removable contamination survey performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.

 - b. The contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds this level should be decontaminated and re-surveyed until the analysis shows levels below this value.

- IV. Bioassay Requirements: May be required for work with > 10 mCi of P-32 (see also section 10.7.3).

V. Biological Distribution: The bone is the critical organ for intake of transportable compounds of P-32. Phosphorus metabolism is complex; 30% is rapidly eliminated from the body, 40% possesses a 19-day biological half-life, and the remaining 30% is reduced by radioactive decay. The lung and lower large intestine are the critical organs for inhalation and ingestion, respectively, of non-transportable P-32 compounds. Externally, the high energy beta emissions can present a substantial skin hazard.

VI. Waste Disposal

- a. Solid: Isolate waste from other nuclides in clearly labeled containers.
- b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. Sewer disposals must be reported to EHS on a monthly basis.
- c. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods.

VII. Survey Meters

- a. A survey meter is required for work with P-32
- b. A thin window Geiger-Muller tube or thin window crystal sodium iodide detector is necessary to detect P-32.

VIII. Survey Frequency: The survey frequency for your P-32 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of P-32 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

IX. Personnel Monitoring

- a. Whole body badges are required when any individual will receive or is likely to receive in one year an occupational dose to the whole body of 500 mrem.
- b. Extremity ring badges are recommended, particularly for work with multi-millicurie amounts of P-32.

X. Decay Table (P-32 Half-Life = 14.29 days)

Days	0	1	2	3	4	5	6	7	8	9
0	1.000	0.953	0.908	0.865	0.824	0.785	0.747	0.712	0.678	0.646
10	0.616	0.587	0.559	0.532	0.507	0.483	0.460	0.438	0.418	0.398
20	0.379	0.361	0.344	0.328	0.312	0.297	0.283	0.270	0.257	0.245
30	0.233	0.222	0.212	0.202	0.192	0.183	0.174	0.166	0.158	0.151
40	0.144	0.137	0.130	0.124	0.118	0.113	0.107	0.102	0.097	0.093
50	0.088	0.084	0.080	0.076	0.073	0.069	0.066	0.063	0.060	0.057
60	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.037	0.035
70	0.034	0.032	0.030	0.029	0.028	0.026	0.025	0.024	0.023	0.022
80	0.021	0.020	0.019	0.018	0.017	0.016	0.015	0.015	0.014	0.013
90	0.013	0.012	0.012	0.011	0.010	0.010	0.009	0.009	0.009	0.008

20.4 Sulphur-35 (S-35)

- I. Physical Data
 - a. Beta Max = 0.167 MeV
 - b. Approximate Maximum Range in Air = 24 cm (~9.5 in); in plastic = 0.1 cm (~0.05 in)
 - c. Half-Life = 87.4 days
- II. Radiation Protection Procedures
 - a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.
 - b. Shielding Requirements: None needed
- III. Contamination Surveys
 - a. Two types of surveys may be used to monitor S-35 contamination.
 - i. A direct survey using a thin window Geiger-Muller detector or thin crystal sodium iodide detector should be used to monitor work surfaces after use.
 - ii. A removable contamination survey performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
 - b. The removable contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds the action level must be decontaminated and re-surveyed until the analysis shows levels below this value.
- IV. Bioassay Requirements: May be required for work with > 10 mCi of S-35 (see also section 10.7.3).
- V. Biological Distribution: Millicurie quantities of S-35 do not present a significant external exposure hazard since the low energy emissions barely penetrate the horny outer skin layer. The critical organ for S-35 is the whole body. The elimination rate of S-35 depends on the chemical compound. Most S-35 labeled compounds are eliminated via the urine. The physical half-life of 87.4 days is a conservative biological half-life.

- VI. Waste Disposal
 - a. Solid: Isolate waste from other nuclides in clearly labeled containers.
 - b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. Sewer disposals must be reported to EHS on a monthly basis.
 - c. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods

VII. Survey Meters: A thin-window Geiger-Muller survey meter may be required for work with S-35.

VIII. Survey Frequency: The survey frequency for your S-35 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of S-35 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

XIII. Personnel Monitoring: Whole body badges and extremity ring badges will not detect the beta energies associated with S-35, and therefore are not required for work with S-35. (The OSL whole body dosimeter's lower limit of detection for beta particles is 150 keV; the TLD ring dosimeter's lower limit of detection for beta particles is 200 keV.)

IX. Decay Table (S-35 Half-Life = 87.4 days)

Days	0	3	6	9	12	15	18	21	24	27
0	1.000	0.976	0.954	0.931	0.909	0.888	0.867	0.847	0.827	0.807
30	0.788	0.770	0.752	0.734	0.717	0.700	0.684	0.667	0.652	0.636
60	0.621	0.607	0.593	0.579	0.565	0.552	0.539	0.526	0.514	0.502
90	0.490	0.478	0.467	0.456	0.445	0.435	0.425	0.415	0.405	0.396
120	0.386	0.377	0.368	0.360	0.351	0.343	0.335	0.327	0.319	0.312
150	0.305	0.297	0.290	0.284	0.277	0.270	0.264	0.258	0.252	0.246
180	0.240	0.234	0.229	0.224	0.218	0.213	0.208	0.203	0.198	0.194
210	0.189	0.185	0.180	0.176	0.172	0.168	0.164	0.160	0.156	0.153
240	0.149	0.146	0.142	0.139	0.136	0.132	0.129	0.126	0.123	0.120
270	0.118	0.115	0.112	0.110	0.107	0.104	0.102	0.100	0.097	0.095
300	0.093	0.091	0.088	0.086	0.084	0.082	0.080	0.079	0.077	0.075
330	0.073	0.071	0.070	0.068	0.066	0.065	0.063	0.062	0.060	0.059
360	0.058	0.056	0.055	0.054	0.052	0.051	0.050	0.049	0.048	0.047

20.5 Iodine-125 (I-125)

I. Physical Data

- a. Gamma = 0.035 MeV
- b. K_a x-rays = 0.027 MeV
- c. K_b x-rays = 0.031 MeV
- d. Half-Life = 60.14 days
- e. Half value layer for lead shielding = 0.02 mm (~0.001 inches) [Note: the half value layer is the amount of shielding to reduce the intensity of an x-ray or gamma ray beam to one-half of its original value]

II. Radiation Protection Procedures

- a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.
- b. Shielding Requirements
 - i. Handle millicurie or greater quantities behind lead shields approximately 3 mm (1/8 inch) thick.
 - ii. Store millicurie or greater quantities of waste behind lead shields approximately 3 mm (1/8 inches) thick.

III. Surface Contamination Surveys

- a. Two types of surveys may be used to monitor I-125 contamination.
 - i. A direct survey using a thin window Geiger-Muller detector or thin crystal sodium iodide detector should be used to monitor work surfaces after use.
 - ii. A removable contamination survey performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
- b. The removable contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds the action level must be decontaminated and re-surveyed until the analysis shows levels below this value.

- IV. Bioassay Requirements: See section 10.7.2 of this Radiation Safety Manual for Bioassay requirements.
- V. Biological Distribution: The thyroid is the critical organ for an internal I-125 uptake. Individual uptake and metabolism vary over a wide range. The thyroid may be assumed to accumulate 30% of soluble radioiodine uptake and retain the iodine with a 138 day biological half-life. Radioiodine in the body can be assumed to be eliminated via the urine.
- VI. Waste Disposal
- a. Solid: Isolate waste from other nuclides in clearly labeled containers.
 - b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. Sewer disposals must be reported to EHS on a monthly basis.
 - c. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods.
- VII. Survey Meters
- a. A survey meter is required for work with I-125.
 - b. For I-125, a thin window crystal sodium iodide detector is more efficient than a Geiger-Muller detector.
- VIII. Survey Frequency: The survey frequency for your I-125 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of I-125 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

- IX. Personnel Monitoring
- a. Whole body badges are required when any individual will receive or is likely to receive in one year an occupational dose to the whole body of 500 mrem. The OSL whole body badges are capable of detecting photon (gamma or x-ray) energies as low as 5 keV
 - b. Extremity ring badges are recommended for work with multi-Curie quantities of I-125. The TLD extremity ring badges are capable of detecting photon (gamma or x-ray) energies as low as 15 keV.

X. Decay Table (I-125 Half-Life = 60.14 days)

Days	0	2	4	6	8	10	12	14	16	18
0	1.000	0.977	0.955	0.933	0.912	0.891	0.871	0.851	0.831	0.812
20	0.794	0.776	0.758	0.741	0.724	0.707	0.691	0.675	0.660	0.645
40	0.630	0.616	0.602	0.588	0.574	0.561	0.548	0.536	0.524	0.512
60	0.500	0.489	0.477	0.467	0.456	0.445	0.435	0.425	0.416	0.406
80	0.397	0.388	0.379	0.370	0.362	0.354	0.345	0.338	0.330	0.322
100	0.315	0.308	0.301	0.294	0.287	0.281	0.274	0.268	0.262	0.256
120	0.250	0.244	0.239	0.233	0.228	0.223	0.218	0.213	0.208	0.203
140	0.198	0.194	0.189	0.185	0.181	0.177	0.173	0.169	0.165	0.161
160	0.157	0.154	0.150	0.147	0.144	0.140	0.137	0.134	0.131	0.128
180	0.125	0.122	0.119	0.117	0.114	0.111	0.109	0.106	0.104	0.102
200	0.099	0.097	0.095	0.093	0.090	0.088	0.086	0.084	0.082	0.081
220	0.079	0.077	0.075	0.073	0.072	0.070	0.069	0.067	0.065	0.064

20.5 Calcium-45 (Ca-45)

- I. Physical Data
 - a. Beta Max = 0.257 MeV
 - b. Approximate Maximum Range in Air = 70 cm (~27.5 in); in plastic = 0.05 cm (~0.02 in)
 - c. Half-Life = 162.7 days
- II. Radiation Protection Procedures
 - a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As is Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.
 - b. Shielding Requirements: Shielding provided by the container is adequate.
- III. Surface Contamination Surveys
 - a. Two types of surveys may be used to monitor Ca-45 contamination.
 - i. A direct survey using a thin window Geiger-Muller detector or thin crystal sodium iodide detector should be used to monitor work surfaces after use.
 - ii. A removable contamination survey performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
 - b. The removable contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds the action level must be decontaminated and re-surveyed until the analysis shows levels below this value.
- IV. Bioassay Requirements: May be required for work with > 10 mCi of Ca-45 (see also section 10.7.3)
- V. Biological Distribution: Millicurie quantities of Ca-45 do not present a significant external exposure hazard because the low energy betas emitted barely penetrate the horny outer skin layer. The critical organ for Ca-45 uptake is the bone. The metabolism of Ca-45 is complex. The majority of Ca-45 is deposited in the bone and is retained with a long biological half-life. A smaller fraction is rapidly eliminated. Ca-45 is initially eliminated via the urine but eventually half the radionuclide is eliminated via the feces.

- VI. Waste Disposal
 - a. Solid: Isolate waste from other nuclides in clearly labeled containers.
 - b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. Sewer disposals must be reported to EHS on a monthly basis.
 - c. LSC waste: This waste should be picked up by the Environment, Health & Safety office for disposal unless prior approval has been granted for other disposal methods.

VII. Survey Meter: A thin-window Geiger-Muller survey meter is required for work with this isotope (Ca-45).

VIII. Survey Frequency: The survey frequency for your Ca-45 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of Ca-45 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

- IX. Personnel Monitoring
 - a. Whole body badges are required when any individual will receive or is likely to receive in one year an occupational dose to the whole body of 500 mrem. However, the average beta energy for Ca-45 is 1/3 of the maximum beta energy, or 85.7 keV – this is well below the detection capability of the OSL whole body dosimeters; their lower limit of detection for beta particles is 150 keV.
 - b. Extremity ring badges are not recommended for work with Ca-45. The TLD ring dosimeters lower limit of detection for beta particles is 200 keV.

X. Decay Table (Ca-45 Half-Life = 162.7 days)

Days	0	5	10	15	20	25	30	35	40	45
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0	1.000	0.979	0.958	0.938	0.918	0.899	0.880	0.861	0.843	0.826
50	0.808	0.791	0.774	0.758	0.742	0.726	0.711	0.696	0.682	0.667
100	0.653	0.639	0.626	0.613	0.600	0.587	0.575	0.563	0.551	0.539
150	0.528	0.517	0.506	0.495	0.485	0.474	0.464	0.455	0.445	0.436
200	0.427	0.418	0.409	0.400	0.392	0.383	0.375	0.367	0.360	0.352
250	0.345	0.337	0.330	0.323	0.317	0.310	0.303	0.297	0.291	0.285
300	0.279	0.273	0.267	0.261	0.256	0.250	0.245	0.240	0.235	0.230
350	0.225	0.220	0.216	0.211	0.207	0.202	0.198	0.194	0.190	0.186
400	0.182	0.178	0.174	0.171	0.167	0.164	0.160	0.157	0.153	0.150
450	0.147	0.144	0.141	0.138	0.135	0.132	0.129	0.127	0.124	0.121
500	0.119	0.116	0.114	0.111	0.109	0.107	0.105	0.102	0.100	0.098
550	0.096	0.094	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.079

20.6 Iron-55 (Fe-55)

- I. Physical Data
 - a. X-Rays (very low energy, < 7 keV) and Auger Electrons (very low energy, < 5 keV)
 - b. Approximate Maximum Range in Air = 1.5 mm (0.06 inches)
 - c. Half-Life = 2.7 years
- II. Radiation Protection Procedures
 - a. Special Equipment or Procedures
 - i. Use transfer pipettes, spill trays, and absorbent coverings to confine contamination.
 - ii. Volatile chemical compounds should be handled in a certified fume hood.
 - iii. Use lab coats and disposable gloves.
 - iv. Regularly monitor and replace gloves as needed.
 - v. Regularly monitor and promptly decontaminate work surfaces to contain contamination and maintain exposures As Low As Reasonably Achievable.
 - vi. Select gloves appropriate for chemicals being handled.
 - b. Shielding Requirements: None required
- III. Surface Contamination Surveys
 - a. A removable contamination survey is the only method to monitor for Fe-55 contamination. This type of survey is performed by rubbing swipes (e.g., filter papers or cotton-tipped applicators) over the surfaces of the work areas and then using a liquid scintillation counter to analyze the swipes.
 - b. The contamination action level is 220 dpm per 100 cm² of work surface for swipe surveys. Any area whose analysis exceeds this level should be decontaminated and re-surveyed until the analysis shows levels below this value.
- IV. Bioassay Requirements: May be required for work with > 10 mCi of Fe-55 (see also section 10.7.3)
- V. Biological Distribution: The lower large intestine is the critical organ for ingestion of Fe-55 compounds. The spleen and the lungs are the critical organs for inhalation of soluble and insoluble Fe-55 compounds, respectively. One or two percent of an uptake of Fe-55 is eliminated via urine during the first 24 hours.
- VI. Waste Disposal
 - a. Solid: Isolate waste from other nuclides in clearly labeled containers.
 - b. Liquid
 - i. Material may be discharged in the sanitary sewer ONLY if prior Environment, Health & Safety Office approval has been granted, **and** if it is readily soluble or dispersible in water, **and** if it is not an EPA-regulated waste.
 - ii. The total quantity of Fe-55 that can be disposed of in any one day will be determined by the Environment, Health & Safety Office.
 - iii. Sewer disposals must be reported to EHS on a monthly basis.

- c. LSC waste: All Fe-55 liquid scintillation waste must be kept separate from all other liquid scintillation waste and must be disposed of through the Environment, Health & Safety Office.

VII. Survey Meters: No portable survey meter is required for work with Fe-55.

- XI. Survey Frequency: The survey frequency for your Fe-55 use will be determined with the Radiation Safety Officer. Typically the survey frequency for a user of Fe-55 is monthly. However, weekly or daily surveys may be necessary if you are using higher quantities and/or your experiment can easily cause contamination.

Laboratory surveys for radiation and contamination will be conducted according to NUREG 1556, Volume 7, Appendix Q at a frequency based on the quantity and type of radioactive material used. Daily, weekly, or monthly survey frequency may be appropriate depending upon the radionuclide, quantity, and handling methods. Quarterly contamination surveys for unrestricted areas are needed to document that contamination is not being transferred out of the restricted areas.

- VIII. Personnel Monitoring: None required. The OSL whole body badge's lower limit of detection for beta particles or Auger electrons is 150 keV; the TLD ring dosimeter's lower limit of detection is 200 keV, therefore they are incapable of recording the beta or electron exposure from Fe-55. Similarly, the OSL whole body badges are capable of detecting photon (gamma or x-ray) energies as low as 5 keV and the TLD extremity ring badges are capable of detecting photon (gamma or x-ray) energies as low as 15 keV. This makes them very inefficient and inaccurate for detecting Fe-55 x-rays.

- IX. Decay Table: No decay table is provided due to the long half-life of Fe-55.

20.7 CALCULATING DECAY

Formula: $A = A_0 e^{(-0.693t/T)}$

Definition of Terms:

A = Activity

A_0 = Original Activity

T = Half-life of nuclide

t = time

Example:

A researcher obtains 5.0 mCi of P-32 (half-life = 14.3 days).

How much activity will remain after 10 days?

Given: $A_0 = 5.0$ mCi

t = 10 days

T = 14.3 days

A = 3.1 mCi

20.8 RADIONUCLIDE LABORATORY CLASSIFICATION

The purpose of this Section is to present criteria acceptable to the Radiation Safety Committee for various operations that cover a wide range of types, quantities, and forms of radioactive material. The information in Tables 1, 2, 3, and 4 are guidelines to be followed. The faculty member who applies for Authorization to Use Radioactive Materials should represent, by the applications, that facilities and equipment safeguards present in the work place are consistent with these guidelines. The Radiation Safety Officer will evaluate the application, facilities, and equipment.

Laboratory hazard classification is based on three (3) factors:

1. Relative radiotoxicity of nuclides in use
2. Maximum amounts of activity stored or used in the area
3. Type of use in terms of relative hazard of the handling procedures.

Table 1

In Table 1, commonly used radionuclides are classified as to their relative radiotoxicity in relation to internal dose (reference: NUREG -1556, Table S.4, Isotope Groups). The hazard of a radioisotope depends on the effective half-life of the nuclide in the body or organ, the type and energy of the emitted radiation, the physical and chemical compound of the material, and the organ of maximum concentration. The Radiation Safety Officer has information for radionuclides not listed.

Table 1: Hazard Group Classification (for some selected radionuclides – see NUREG-1556, Appendix S for a full listing)

Very High	High	Moderate	Low
Pb-210 Ra-226 Cf-252	Ca-45 Ag-110m I-125 I-125 I-131 Cs-137	C-14 S-35 P-32 P-33 Cr-51 Fe-55 Co-57 Fe-59 Zn-65 Rb-86 Cd-109	H-3 Tc-99m

Table 2

For normal usage, laboratories are classified according to the total activity of the various classes of nuclides present in the lab. The top of table 2 gives the three laboratory classifications based on the radioisotope hazard group and activity present (reference: NUREG -1556, Tables S.2 Classification of Laboratories, S.3 Survey Frequency Category Modifiers, and S.4, Isotope Groups). In cases where more than one nuclide is being used in a laboratory, the classification will be determined by summing the constituent nuclides.

Table 2: Classification of Laboratories, Maximum Permissible Activities, and Survey Frequency

Radioisotope Hazard Group (Table 1)	Low Level Laboratory (mCi)	Medium Level Laboratory (mCi)	High Level Laboratory (mCi)
Very High	< 0.010	0.010 to 1	> 1
High	< 1	1 to 100	> 100
Moderate	< 100	100 to 10,000	> 10,000
Low	< 10,000	10,000 to 1,000,000	> 1,000,000
Typical Survey Frequency and Type			
Personal Contamination and Specific Area Surveys	Daily, prior to leaving the area when radioactive materials are handled		
Radiation Safety, Contamination, and Radiation Level General Area Surveys (performed by users and/or by EHS)	Semiannually	Quarterly	Monthly

Table 3

The survey frequency for a given laboratory type may be increased or decreased according to certain modifying factors (reference: NUREG -1556, Table S.3 Survey Frequency Category Modifiers). With high accident risk operations, the survey frequency is increased. For a simple, relatively safe operation, the survey frequency in a given classification type may be decreased. As a guide, the modifying factors in Table 3 are used to determine the amount by which the survey frequency should be increased or decreased. Table 3 may also be used to determine if a laboratory's facilities are appropriate for the types and quantities of radioactive materials requested.

Table 3: Modifying Factors

Storage (stock solutions)	100
Very simple wet operations	10
Normal chemical operations	1
Complex wet operations with risk of spills	0.1
Simple dry operations	0.1
Dry and dusty operations	0.01
Radiopharmaceutical preparation/injection/administration	0.01

Brodsky, A., CRC Handbook of Radiation Measurement and Protection: Vol. II., CRC Press. 1982.

Shleien, Bernard, Radiation Safety Manual for Users of Radioisotopes in Research and Academic Institutions, Nuclear Lectern Associates, Olney, Maryland. 1987.

Table 4: Recommendations for Various Levels of Laboratories

Table 4 indicates recommendations for the design, equipment, facilities, and protective clothing specifications recommended for each laboratory type. In designing new areas, the researcher should consult the Radiation Safety Officer to discuss requirements for a particular facility.

Design, Equipment, and Clothing	Low Level Laboratory	Medium Level Laboratory	High Level Laboratory
Required Equipment and Facilities	<ul style="list-style-type: none"> No special facilities or equipment 	<ul style="list-style-type: none"> Fume hoods and/or glove boxes Decontamination supplies - Dosimetry Appropriate survey meter 	<ul style="list-style-type: none"> Fume hoods and/or glove boxes Special decontamination facilities Change room Dosimetry Appropriate survey meter - Air monitor (if appropriate)
Required Protective Clothing	<ul style="list-style-type: none"> Lab coat Protective Gloves 	<ul style="list-style-type: none"> Lab coat Protective Gloves Shoe covers recommended 	<ul style="list-style-type: none"> Coveralls, protective gloves, shoe covers, head cover (respirator)
Floors	<ul style="list-style-type: none"> Smooth, nonabsorbent 	<ul style="list-style-type: none"> Smooth, nonporous, easily removable, protective under layer, no cracks 	<ul style="list-style-type: none"> Smooth, nonporous, easily removable, protective under layer, no cracks
Walls	<ul style="list-style-type: none"> Painted, smooth 	<ul style="list-style-type: none"> Smooth, nonporous, strippable if possible 	<ul style="list-style-type: none"> Smooth, nonporous, strippable if possible
Work Surface	<ul style="list-style-type: none"> Smooth, sealed coating -Cover with absorbent paper 	<ul style="list-style-type: none"> Smooth, nonabsorbent - Removable covering (absorbent paper) 	<ul style="list-style-type: none"> Smooth, nonabsorbent - Removable covering (absorbent paper)
Ventilation	<ul style="list-style-type: none"> Any 	<ul style="list-style-type: none"> Room under net negative pressure Filter recommended 	<ul style="list-style-type: none"> No recirculated air Charcoal and/or HEPA filters in exhaust Room under net negative pressure
Hood	<ul style="list-style-type: none"> Any ducting Flow Rate: 100 linear feet per minute 	<ul style="list-style-type: none"> "Radiochemical hood" singularly ducted from hood to roof Filter required Flow rate: 100+ linear feet per minute 	<ul style="list-style-type: none"> "Radiochemical hood" singularly ducted from hood to roof Filter required Flow rate: 100+ linear feet per minute
Other	<ul style="list-style-type: none"> Portable, localized shielding as needed 	<ul style="list-style-type: none"> Consider built-in shields, special handling 	<ul style="list-style-type: none"> Consider built-in shields, special handling