Cyclotrons & Radiochemistry

David Stout PhD

Topics

- **Cyclotrons:** How to accelerate protons
- **Cyclotrons:** Targetry, making radioactive atoms
- **Radiochemistry:** Half-life limitations, Chemistry in a box
- **Safety:** Radioactive, chemical, electrical, mechanical issues
- **Operational Consideration:** logs, stack monitoring, usage, transfer records, access & personnel
- **Visual Tour:** Installation & systems

Topics

- **Cyclotrons:** How to accelerate protons
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- **Visual Tour:** Installation & systems

Access

- Access to all spaces requires a CNSI photo ID card
- Entry authorization granted for cyclotron and imaging areas following review of this training material AND a facility tour with one of the lab supervisors (David, Jeff or Waldy)
- Entry authorization for vivarium comes from DLAM only after meeting all vivarium requirements
- Appropriate clothing always required, no exposed skin below the waist, closed shoes
- Lab coat and ID badge required for all spaces

Reporting Problems

If there are any problems, report them to the imaging center staff and your faculty member.

Contact information is also on fire diamond cards on each door.

Technology Center Oversight:

David Stout	x72646	dstout@mednet.ucla.edu

Cyclotron/Radiochemistry Area:

Jeffrey Collins	x33220	JeffreyCollins@mednet.ucla.edu

Imaging Area:

Waldemar Ladno	x42224	wladno@mednet.ucla.edu
Darin Williams	x42224	DarinWilliams@mednet.ucla.edu

Emergency Contact Numbers

- DLAM: Vivarium Facility Emergency contact pager at 98714. For problems related to animal health, please page either the on-call veterinary technician (pager 94513) or the on-call veterinarian (pager 96545) for assistance
- ARC Phone: (310) 206-6308 email: OARO@research.ucla.edu
- EHS (RSO & Biosafety): Phone: (310) 82**5-5689** | Fax: (310) 82**5-7076** | EH&S Hotline: (310) 82**5-9797**
- Occupational Health: Occupational Health Facility - Westwood 10833 Le Conte Ave, Room 67-120 CHS Los Angeles, CA 90095 **(310) 825-6771** Mon - Fri 7:00 am - 4:30 pm

Glove Use

- Gloves are only for immediate handling of chemicals, radiation and animals
- Gloves cannot be worn outside the room where you put them on, no gloves in hallways or touching door handles
- Glove cannot touch doors, cabinets, computers, pens, notebooks, or be on hands in your pockets
- Consider anything touched by a glove to be potentially hazardous; don't touch anything others would handle while not wearing gloves

Radiation Safety:

You should know to answer these questions:

- What is ALARA?
- How is radiation stored in the lab, wastes?
- What are the hazards of the isotope you use?
- Where do you get information about radiation use and policies?
- What training is required, initial and ongoing?
- How is radioactive material labeled?
- What do you do in an emergency?
- How do you use radioactivity monitoring equipment?
- What techniques do you use to reduce exposure?

Personnel Requirements

- Must have lab coat used only for radioactive work
- Must wear film badge and finger rings
- No exposed skin below the waist, closed shoes
- Wear gloves only when handling radiation, remove all other times. **No gloves on in hallways and they should never touch doors, pens, meters, drawers or keyboards**. If a glove is needed to hold something for transport, use secondary containment.
- Always have a meter on and check yourself, your surroundings and your work area before, during and after your work
- Notify others in your work area of radiation use

Personnel

- All personnel working in the cyclotron area must be radiation workers and trained in appropriate use and monitoring of radioactive materials
- Safety training is mandatory, both for initial training and as an ongoing program
- People must know what to do in the event of an accident, who to notify and how to properly document actions
- Only licensed operators are allowed to operate the cyclotron according to the UCLA-CA radiation license agreement

Radiochemistry Hazards

- Primary hazard is radiation; up to 4 Ci may be present
- Secondary hazard is chemical exposure to reagents
- Mechanical hazards: hot cell doors, tripping hazards, heavy equipment
- May be electrical hazards from switches, power supplies, cables
- Gas tanks must be secured, heavy, potential missile if valve is sheared
- Proper monitoring equipment required for radiation
- Stack monitoring must be observed to note radiation releases
- Know where first aide kits and eye wash stations are located
- Do not work alone

Internal versus External Exposure

- Internal exposure from ingested or implanted activity is much more damaging than external sources because of short distance, long exposure time and no shielding.
- PET isotopes have both charged particle beta exposure (positron) and gamma radiation.
- Positron dose is all deposited locally (<1 mm), and causes more damage since it is an ionizing charged particle.
- Gamma radiation causes exposure to a much larger area and is harder to shield. Others in the room may be subject to exposure.
- No food or drink allowed to minimize risk of internal exposure

Things NOT to have in the Lab

- No Drink
- No Food or gum
- Don't Smoke
- No cosmetics

Annual Radiation Dose Limits

Population	Whole Body	Extremity
Radiation Workers	5 rem/yr	50 rem/yr
General Public	0.5 rem/yr	5 rem/yr

UCLA requires action if whole body dose exceeds 1.25 R/yr

Radiation Dose Notifications

	ALARA I	ALARA II	ALARA III
Whole Body	100 mrem	300 mrem	500 mrem
Extremity	100 mrem	1000 mrem	5000 mrem

If you reach any of these alarm levels, immediately notify your supervisor. There may be ways to reduce your exposure that should be considered.

Radiation Warning Signs

Cyclotron Vault

Radiochemistry Room
QC Lab
PET/CT Imaging Area
Radiolabeling Lab
Dose drawing room

Warning Indicators

Negative pressure indicator

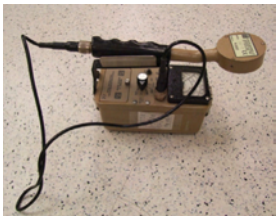
Safety Diamond with emergency contact numbers

Doors are labeled with safety information, including the fire diamond and radioactivity warning.

Vivarium doors have a negative pressure indicator, where a red ping pong ball is visible if pressure is not correct.

Radiation Meters

Exposure meter: Activity level mR



Pancake Meter Activity: yes/no

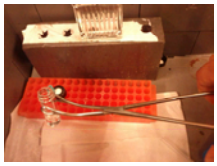
Use meters to survey for activity. Always have a pancake meter on when using activity to survey your gloves. Use exposure meter to measure activity field strength.

Meter Operation Check

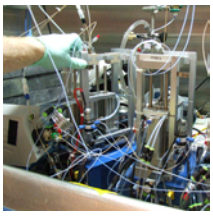
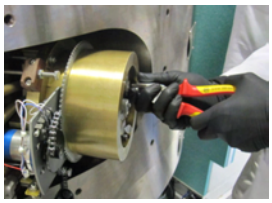
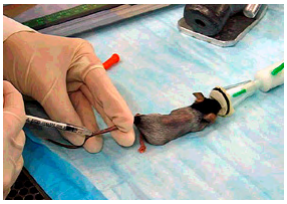
- Always have a GM meter on when working with radiation
- Turn meters OFF when not in use
- Operation/Battery check with each use
- Annual calibration

Measures to Reduce Personnel Dose

- ALARA: As Low As Reasonably Achievable
- Time, Distance, and Shielding
- Plan your experiments!
- Laboratory Technique
- Administrative and Procedural Controls



Minimize Time: Practice

- Practice what you plan to do first, without radioactivity if at all possible
- Measure radioactivity field first, decide how much time a quick fix requires and estimate your exposure before going into the hot cell
- If exposure is unavoidable (servicing hot parts), walk through the process first to know exactly what you need and how to do it, review SOPs
- Sometimes experiments need to fail, do not take unnecessary dose and risks for something that can be tried again later

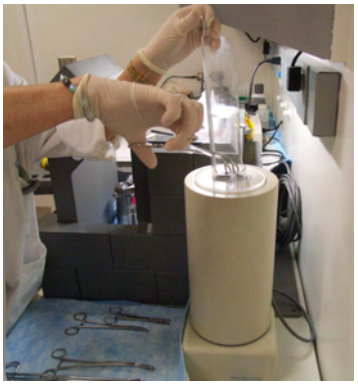
Radiation Safety – Handling Activity

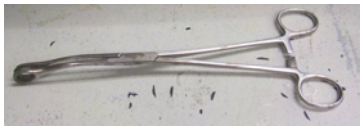
- Wear gloves, lab coast, film and ring badges
- Use remote handling devices whenever possible
- Notify others in the room if activity will be outside of shielding
- Minimize time of exposure; think about how and what you will do first
- Handling >200 mCi is unsafe; use remote tools
- Opening hot cells when high amounts of activity are present is unsafe, leave door closed. Consider remote actions and plan ahead
- Shield locally when possible, reduces shielding required
- Use portable personal dose meters
- Beta particles (positrons) have very limited range but do much more damage compared to gamma radiation (511 keV). Keep yourself from direct contact with liquids containing radiation.

Personal Protective Gear - PPG

- Lab coats must be worn and not removed from the area if performing radiochemistry, a coat rack is located in the cyclotron area
- Radiation and ID badges are required, but do not leave them in radiation areas when you are not there
- If using solvents or liquid reagents, safety glasses or shields are required
- Legs and feet must be covered; no exposed skin
- Use proper gloves for handling reagents
- Volatile reagents must be handled in fume or chemistry hood
- Reagent bottles must be stored in proper containment; do not leave lying around, especially on the island

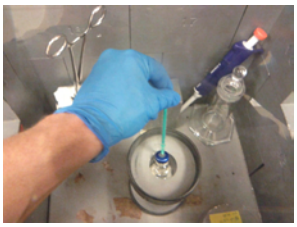
Radiation Safety – Handling Activity





- Use remote handling tools; tongs, forceps etc.
- Avoid having any contact at all with liquids or uncovering activity. Positrons will travel and annihilate in your skin and give a much higher dose.
- Use short time, distance and shielding wherever possible

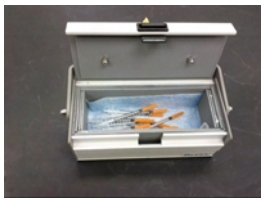
Dose Drawing Procedure



- Before drawing a dose, read the Cyclotron Log Form posted on minicell to find out how much activity is present in the vial; the activity is delivered to a volume of ~1.2mL
- Determine what volume you need to withdraw from the vial in order to obtain the amount of activity required for your experiment
- Working behind the lead block, remove the lid of the pig and insert a 1.5”-2” needle to the bottom of the vial and pull the syringe
- Dispense the activity to another vial, if sealed use a vent to avoid spray
- Assay your vial and record the activity and time on the F-18 Crump Cyclotron Log Form

Transport of Vials and Syringes

- Syringes should not be transported unless they are sealed with a capped needle; do not carry a syringe that has a sharp point exposed! Use a syringe shield for a radioactive syringe
- If transporting multiple radioactive syringes use a shielded box on a cart
- Radioactive vials must be transported in a shielded lead pig container. If activity level is high use the shipping box on the dolly to transport the dose.



Storing Radioactive Waste

- Radioactive waste can be stored in the bottom middle mini-cell
- Use sharps container for glass (eg. capillary tubes) and needles, labeled beaker for solvents, and garbage bin for solid waste.
- Garbage will be removed the following morning after activity has decayed; sharps bin swapped when ¾ full
- Please remove reusable items such as Eppendorf holders, glass syringes, and Wheaton vials once decayed
- To determine if waste is decayed and ready to be removed from the cell use a contamination meter to check background level; if material is still above background leave it in for another day

Radioactive Trash

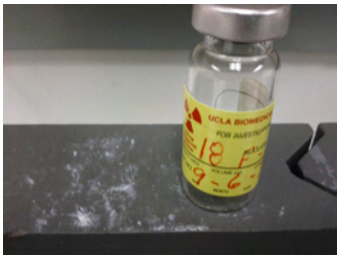
Images above are unacceptable ways to store chemicals, gloves, syringes and needles.

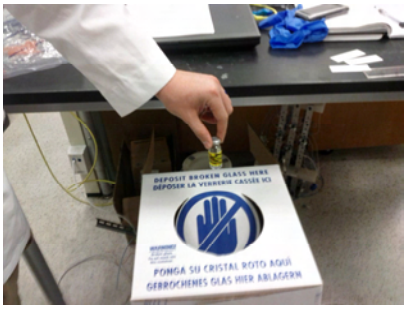
These conditions violate lab safety and radiation safety requirements.

Radioactive Trash

Images above show proper tagging and bagging of wastes, separation of materials and secondary containment for liquids

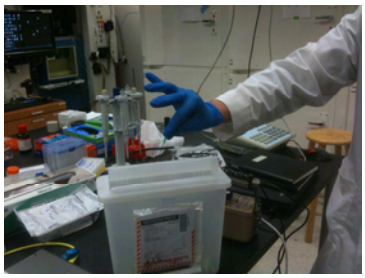
Labeling Radioactive Vials





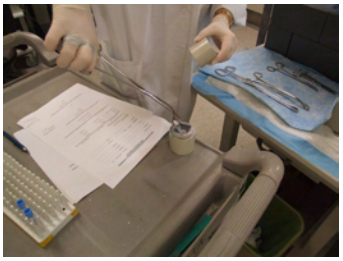
- Vials that contain radioactive material must be labeled if they are to be removed from a hotcell
- Two labels are necessary: an inner label on the vial itself that specifies the nuclide and date, and an outer label placed on the shield container which specifies the nuclide, amount of activity, time, and date.
- When material has decayed, deface the label and dispose of vial in either a sharps container or glass waste box.

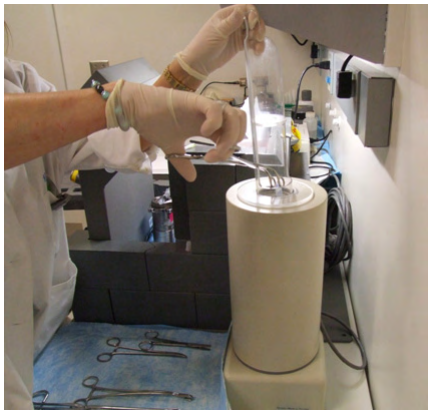
Sharps



- Dispose of all needles in sharps containers
- Do NOT recap needles when disposing of them; this can create a violation on our inspections
- Do not leave needles lying around on counters
- If you need to recap (as necessary for filling syringes for transport) use a recapping tool

Distance



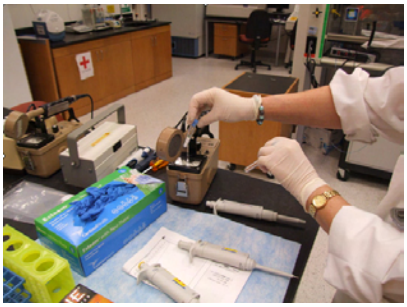


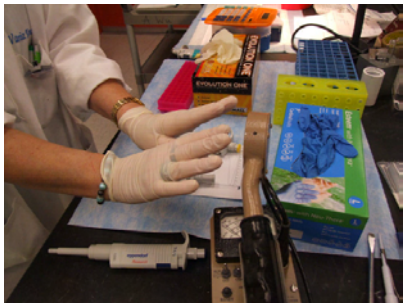
Substantial hand dose reduction by using tongs to hold sources

Distance

In the imaging center, distance is used to reduce exposure
For most mouse work, 2 meters results in no measureable exposure
Sources are kept away from high traffic areas

Proper Technique





Check samples and equipment for contamination
Check hands frequently, immediately remove gloves if contaminated
Do not touch the meter or it may become contaminated
Survey the area **BEFORE** and AFTER use, make sure area is clean

PET Shielding: Tenth Value Layers

Radionuclide	TVL* (mm) for Lead
Fluorine-18 or any PET isotope	13.7
Gallium-67	4.7
Indium-111	2.2
Technetium-99m	0.9
Thallium-201	0.9

*** TVL = thickness of material required to absorb 90% of photons**

How much lead?

- 13.7 mm (1/2 inch) stops 90%
- 1 inch stops 99%
- 2 inches stops 99.99% < this is usually enough
- 7 cm (2.75 inches) of lead surrounds each hot cell, which is sufficient for >4Ci

Note that our lead bricks are mostly 2x4x8 inches, so the thinnest dimension is sufficient.

X-ray Aprons -- No Protection at 511 KeV

The "lead" aprons used in diagnostic radiology have about 0.5 mm lead equivalent.

Usually tin, not lead.

These afford significant protection at energies under 120 KeV, but are nearly useless against annihilation photons.

Scatter can actually increase dose.

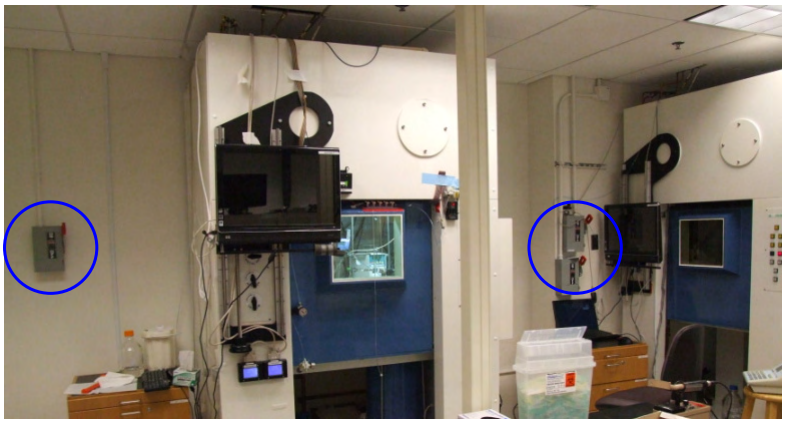
100 KeV: Transmission = 4.3 %

511 KeV: Transmission = 91.0 %

Iodine Special Requirements

- Must use fume hood with Plexiglas mini-hood for all work with any possibility of releasing free iodine.
- Thyroid testing within 4 days required when using over 1 mCi
- Once Iodine is chemically reacted to a bound form, then it can be used outside of the mini-hood.

Emergency Electrical Shut-Off



In case of emergency, power to the hot cells can be shut off at nearby breakers

Emergency Electrical Shut-Off

Hot cell 4 shut-off location

Emergency Electrical Shut-Off

In case of emergency, power to the cyclotron can be stopped from several locations in the vault, radiochemistry lab and control room.

Using this button may damage the cyclotron and should only be used in case of emergencies.

Accident Response

- Contain if possible, evacuate if necessary
- Notify area occupants and faculty
- Call 911 if needed
- Monitor exposure, do not track contamination to other areas
- Mark off effected areas
- Know location of and how to use spill kits, first aid kits and decontamination supplies
- Know proper chemical and radiation disposal or holding requirements
- Report, document, take all necessary and appropriate actions
- Do not step in water if cyclotron is operational, shock hazard
- Use emergency kill switch only if computer remote shutdown is not possible

What to do in case of radioactivity spill

- Notify everyone in the area
- Make sure people are safe and not tracking activity around the area
- Obtain the exposure meter located near the fire suppression system in the hot lab doorway
- Measure the field and determine where activity is located
- Mark off area. Wipe up any obvious activity only if necessary, otherwise wait for it to decay (assuming F-18)
- Notify Jeff Collins or David Stout, or if not available, notify Darin Williams, Arion Chatziioannou or one of the other Crump faculty
- If a person is contaminated, wash affected area in sick. Use shaving cream for fingers and skin, Windex for shoes
- Activity levels must be below 3X background to be considered safe

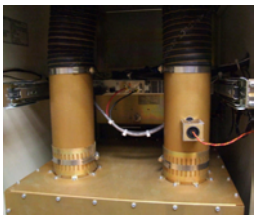
Safe Cyclotron Operations

- Only licensed trained personnel can operate the cyclotron.
- A pre and post initialization checklist is used to ensure operating parameters are within specifications.
- During operation, the cyclotron must be attended at all times.
- Operators must know what to do in case of failure, who to notify, what steps to take and how to document actions.
- After bombardment is complete, the operator must ensure the safe and appropriate delivery is made, along with notification to anyone in the radiochemistry area.
- Once activity has been delivered, the cyclotron should be shut down and the chilled water booster turned off.
- Minimize distractions, pay attention to what is happening.

Cyclotron Servicing

- There are very sensitive parts which can be easily damaged if handled improperly. Only trained cyclotron engineers should open and work inside the tank.
- Ensure targets are unloaded of any radioactive materials, power is off and electrical components are grounded.
- If the tank is opened, moisture is the enemy. First vent the tank by filling with nitrogen.
- Avoid touching any surfaces as it contaminates; wear gloves.
- Mechanical, electrical and radioactive safety protocols must be observed. Parts of the cyclotron and shielding are permanently activated, mainly around the target carousel.

Cyclotron Hazards



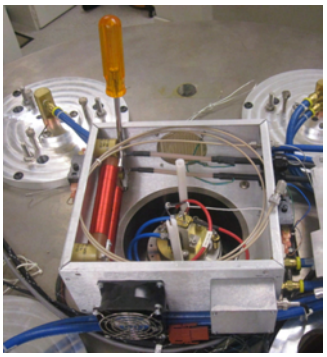
Burn Hazard, pipes over 220C

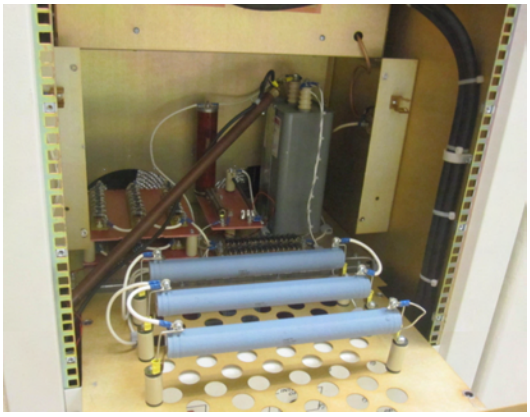
- **Chemical hazards** are present from cleaning solvents, oils and hydraulic fluids. These may also be flammable.
- **Burn hazards** exist with RF system and diffusion pumps. Various solenoid valves may also be very hot.

Cyclotron Hazards

Electrical Safety Issues:

- Electrical fields are present that could easily kill.
- Numerous safety protections are present; do not override interlocks or remove covers without knowledge, grounding sticks and other people present.
- Even when turned off, capacitance can leave behind dangerous electrical charges capable of serious injury



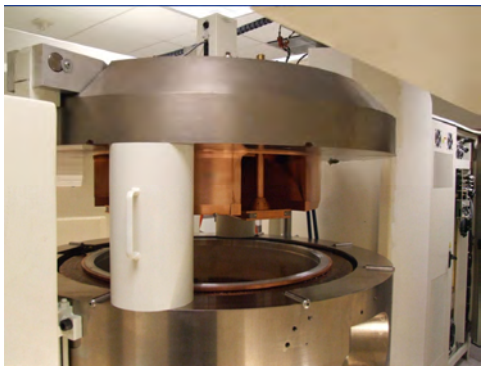


Electrical Safety Issues:

- Residual electrical capacitance can be lethal
- Left image above shows use of a screwdriver to short out the ion source leads to prevent shock
- Right image above shows proper used of a grounding bar to discharge the high voltage anode power supply

Cyclotron Hazards

Safety Cans required to hold up cyclotron top



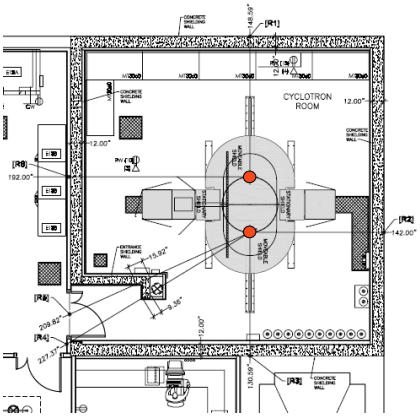
Mechanical injury is possible from:

- Hitting the shields (typically with your head)
- Crushing during shield closure
- Failure of hydraulics if safety cans are not in place
- Parts that are heavy and require servicing: pumps, lead bricks, etc.

Cyclotron Hazards

Site planning map of radiation field

● marks location of target carousels



Radiation Fields:

- Beam when cyclotron is operating, lethal radiation levels >500 REM
- Target contents: F-18, C-11, N-13, O-15
- Target foils
- Activated components in the tank and target carousel
- Activated areas in shielding, mainly near target carousel

What to do in case of target failure

- For a all targets, the DPs will automatically shut down and butterfly valves close due to pressure drop
- Activity will be mostly contained inside tank
- Note failure in cyclotron log and observe stack monitoring readout for any release
- Notify chemists and imaging personnel
- Wait for target contents to decay before attempting to clean and repair

What to do in case of water leak

- Ensure cyclotron is powered off, including any pumps and electrical equipment
- Shut off water source, most likely makeup water for the chilled water system
- Several drains are located under the cyclotron, in pits and under the main tank.
- If drains are plugged, vacuum up water with shop vac and get a plumber to clear the lines

Safety Equipment

Emergency shower and spill kit located in cyclotron entryway

A second spill kit is located in the imaging center

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- **Operational Considerations:** logs, stack monitoring, usage, transfer records, access & personnel
- **Visual Tour:** Installation & systems

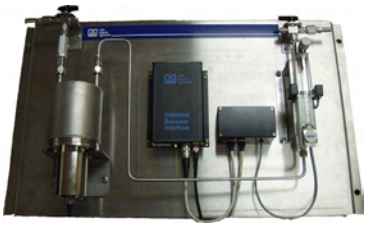
Cyclotron Operations

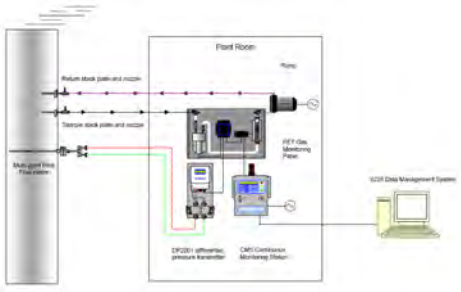
- A pre and post initialization checklist must be gone through before operating the cyclotron.
- Personnel ideally should not be in the vault during bombardment. While it is safe to be in the vault, radiation fields are elevated above background.
- The cyclotron operator must work carefully and without interruptions or distractions. Operations require careful attention to detail.
- All cyclotron operations must be attended; someone must be present at all times. Frequent checking of the status is required.
- Operators must know what to do in case of systems failure.

Logging Usage

- Required for radiation license, billing & usage records
- Track performance over time, determine when servicing is required
- Help to establish a reasonable budget
- Cyclotron software records several metrics regarding component usage and remaining service life

Stack Monitoring





- Measures radiation emissions from the cyclotron air exhaust duct
- Air sampling probe looks for positrons on a solid state detector
- Gamma probe for radiation field at cyclotron vault doorway
- Required for regulatory monitoring and reporting
- Helpful for monitoring chemistry failures & synthesis progress

Stack Monitoring

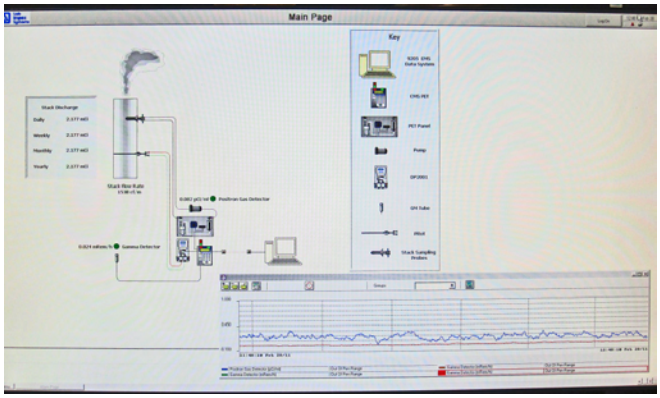
Located in the cyclotron control room

Consists of both a gamma radiation counter near the vault door and an air sampler in the HVAC ductwork

Set to alarm if activity is detected above emission limits

Dual display, with a second display located over the minicells so chemists can observe any releases

Stack Monitoring



Software creates records required by state license for radiation use.

Display is useful to observe small emissions normal for chemistry, helps with feedback that reactions are proceeding as expected.

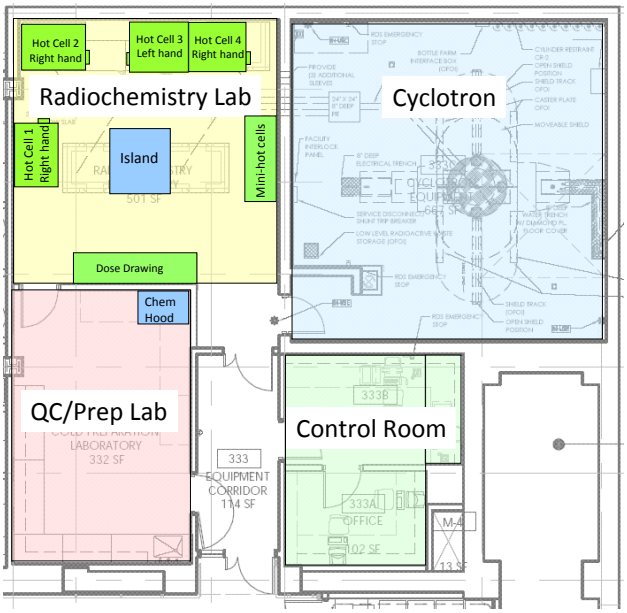
Transfer Records

Usage Lists

Time	mCi	Name	Lab	Charge
9:30	20	Sam	MVD	
10:00	100	Wei-Yu	CS	

- By law, all radiation produced must be tracked from creation to decay.
- Any product produced and shipped out of the facility must be logged and transferred only to an approved radiation license
- Activity, volume, solvent and time are all important metrics
- Monthly reports due to Radiation Safety Office
- Data is entered manually into the cyclotron run record in MIDAS for report generation

Radiochemistry & Cyclotron Area



Radiochemistry

Shared working environment…be courteous!

- High radiation levels may be present
- No chemical storage on island
- No dispensing volatile reagents in the open, use hot cells or fume hood
- Survey meters must be on during radiation use, turn off at night
- Use exposure meter to make informed decision about entering hot cells
- Only cyclotron operators can operate dose delivery system
- Inform others working in the room what you are doing
- Observe stack monitoring to help gauge chemistry process

QC Lab

- Radiation limit <1 mCi
- Only trained people can use the glove box
- Fume hood is for dispensing volatile solvents, not for experiments
- Flammables cabinet storage conditions must meet chemical safety requirements
- Chemicals must be labeled properly with open date, lab ID
- Use gloves to handle chemicals, nothing else; no gloves touching cabinets, doors, computers, etc.
- Equipment is shared by multiple users; please book use of HPLC and GC on the white board or online

Cyclotron Vault

- Only cyclotron operators should enter this area
- High radiation levels may be present
- High voltage area
- Sensitive equipment; only trained individuals with certificates can operate.
- No equipment is to be removed from this area.
- Please feel free to ask for a tour to learn more about the cyclotron

Cyclotron Control Room

- No radiation or chemicals in this area
- Food and drinks are allowed
- Only cyclotron operators can use the cyclotron computer.
- Stack monitoring computer is only for that purpose, no browsing.
- Audible stack alarm coming from this area is an indicator that it may not be safe to conduct chemistry experiments.
- **If you hear the alarm please verify with supervisor that it is safe to work in the area**

If you have a question...

Ask for help, ignorance can be cured

Make suggestions if you see something that could be improved

Accidents happen and we need to acknowledge and learn from them. Do not try to hide mistakes

This facility exists for you to use, so make sure things are working well for everyone

Follow the University, state and federal requirements; this is not an option

Be nice to people, it helps