Radon Emanation at Cryogenic Temperatures

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PNNL
Radon is a problematic background

- Ra decay daughter
- Highly mobile, diffuse throughout detector
- Can plate out on surfaces

- An issue for next generation low-energy neutrino, dark matter and neutrinoless double beta decay experiments

Radon chain leading to:
- $(\alpha, \gamma)$ (~15 MeV)
- $(\alpha, n)$
- $\alpha$

e.g. DUNE
Radon Emanation Measurements

Try to maximize transfer efficiencies at each stage

Sample → Emanation Chamber → Radon Trap → Liquid Nitrogen → Detector
Radon Emanation Measurements

Try to maximize transfer efficiencies at each stage

- Take advantage of PNNL ultralow background proportional counters to count radon
- Use ultrapure electroformed copper

PNNL Emanation Bench

System as constructed at PNNL

Work by Ray Bunker and Dan Jardin (SCGSR)
PNNL Emanation Bench

- Calibration with radon source sample using alphas

- Count radon rate using Po-214 alpha peak
  - 0.1 background events/per day in $^{214}$Po ROI
  - $<100 \mu$Bq background rate
Emanation in materials and cold

- Total radon emanation is the sum of two distinct components:
  - Recoil induced emanation
  - Bulk diffusion
- Different materials contain varying rates of both processes

- At cold temperatures, the diffusion term is suppressed
- However, in liquids the recoil term is enhanced
  
  e.g. Sebastian Lindemann; Hardy Simgen; Grzegorz Zuzel, Behaviour of 222Rn/222Rn at cryogenic temperatures

- What are the rates in cryogenic liquids?
Simulation of Emanation in Cryogenic Liquids

- In vacuum or gases surface effects can lower the radon emanation rates
  - Emitted radon can return to the material it came from
- This effect is suppressed in liquid
  - Denser liquid stops radon more easily before it returns to the material it came from
Simulation of Emanation in Cryogenic Liquids

• Have created a Monte Carlo model to estimate the surface-shape contribution to emanation

• Consists of:
  ▪ 2D geometric model of surfaces dependent of measured ‘roughness parameters’
  ▪ SRIM based simulation of average propagation depths through materials
    ✓ Argon and stainless steel so far

Work by Aaron Hellinger and Brianne Hackett


Chris Jackson
Simulation in Cryogenic Liquids

- Preliminary simulation results show a factor two difference in emanation rates between emanation into liquid and gas at cryogenic temperatures.
- This does not include the effect of diffusion, going from room temperature to cryogenic temperatures.
Cryogenic Liquid Radon Emanation Measurement Bench

- Testing is underway of system to validate these results
- Designed to maintain stable 1-liter liquid argon radon emanation volume using cold head (1-week timescales)
- Liquid argon then boiled off through dry ice (above argon freezing point, below radon freezing point) filled radon trap
- Control/monitoring system testing completed, leak tests ongoing, first cool down in next weeks
- System can be upgraded for larger emanation chambers

Work by Gabe Ortega
Radiopurity.org

• Recent development:
  ▪ Search improvements
    ✓ Search all, summary Information
    ✓ New synonym capability (e.g. Cu/copper)
    ✓ New published/unpublished data flag
    ✓ New unit conversion
  ▪ Guided data entry page
  ▪ Data update feature
• Backend Development:
  ▪ New modern MongoDB database, replacing deprecated CouchDB tools
  ▪ New python-based toolkit for access and large dataset upload
  ▪ Improved data security, database changes tracked and versioned
  ▪ Improvements to website uptime
  ▪ Containerized deployment

• Visit the site: [www.radiopurity.org](http://www.radiopurity.org)
• Feedback? Data to share? radiopurity@snolab.org

Poster at this conference
Conclusions

• Radon emanation is a key problem for low background physics experiments such as low-energy neutrino measurements, dark matter searches and neutrinoless double beta decay

• Measurement capability constructed at PNNL:
  ▪ Comparable to best sensitivity in the world
  ▪ Use ultralow background proportional counter capability

• Temperature and emanation media (gas/liquid) can affect emanation rates

• SRIM-based simulation developed to evaluate surface roughness effects on emanation

• Cryogenic liquid radon emanation capability being tested to validate this model and evaluate emanation rates for next-generation noble liquid experiments in realistic conditions.
Thank you

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