Measurement of PTFE Outgassing for the XENON1t Experiment

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XENON
&
THE SEARCH FOR DARK MATTER
The XENON Experiment

• Direct search for Dark Matter
  • What is Dark Matter?
  • Why do we believe it exists?
WIMPs

- Weakly Interacting Massive Particles
- Most popular theorized DM candidate
- Lightest Supersymmetric Particle (stable): sneutrino, gravitino, axino and neutralino.
Gran Sasso National Lab

1. Cosmic radiation bombards our planet constantly. Rock shields the experiment from many of these particles.

2. Weakly Interacting Massive Particles (WIMPs) can pass through the Earth to reach the Xenon100 detector.

3. A WIMP can interact with liquid xenon to produce an initial flash of light, detected by photomultipliers, and free electrons.

4. An electric field draws the free electrons to the anode at the top of the tank.

5. The electrons move from liquid xenon creating another flash of light the photomultipliers can detect. The relative brightness of the two flashes reveals the type of particle that caused the signal.

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XENON Principle

- WIMP → LXe
- Photons produced: scintillation, S1
- Electrons produced
- Interact with GXe
- Second scintillation, S2

BUT WAIT!

O₂
THE SCIENCE OF OUTGASSING
Outgassing

Two main dependencies:

Time: Outgassing ↓ Time ↑
Temperature: Outgassing ↑ Temp. ↑
Cylinder that houses xenon made of PTFE (Teflon).

Other materials:
- Kapton cables
- PMTs
- Stainless steel
...shown to outgas much less than PTFE, also less surface area in contact with xenon.
Project Aim

- Determine the temperature and time dependences of the outgassing of oxygen in PTFE
- Especially important since XENON is upgrading its size:
  - A larger detector means more materials and more outgassing.
Throughput method

Outgassing = Conductance * Pressure
Improvements to system

- Installed new ADC
- Streamlined all outputs and deliver to MySQL database
- Created aluminum piece to create better contact of sensor with sample
PROCEDURE
Procedure: taking measurements

• Close bypass valve
Bypass valve

LN2 from bottle

Al Plate

GN2 to air

Bypass

RGA

8"
Procedure: taking measurements

• Close bypass valve
• Wait for the pressure to equilibrate and use asymptote fitter to find the final pressure
Procedure: taking measurements

• Close bypass valve
• Wait for the pressure to equilibrate to find the final pressure
• Run residual gas analyzer (RGA)
• Normalize the pressure of oxygen using the total pressure from the pressure gauge
Close bypass
Start RGA
Stop RGA & Open bypass

Graph showing pressure in Torr over time from 2018/07/20 15:19 to 2018/07/20 18:19.
PTFE TESTING
Time Dependence

Key takeaways:

- Stable within 100 hours
- Significantly higher than background outgassing

\[ a + b \times e^{-x/\tau} \]
TEMPERATURE TESTING
Procedure

• Cool to -20°C
• Start the relay power to begin pumping liquid nitrogen into the sample chamber
• Wait 2 hours
• Unplug the relay (to limit pressure fluctuations)
• Take RGA scan
• Repeat for -60 °C, -80 °C and -100 °C.
Temperature Dependence

Two warning signs:
1. Pressure spikes
Two warning signs:
1. Pressure spikes
2. HUGE variation in outgassing rates

ERROR IN METHOD
Liquid nitrogen (-196 °C)

Pressure sensor

-80°C
Liquid nitrogen (-196 °C)

Artificially low pressure

Pressure sensor

-80°C
Room temperature

Pressure sensor
Measurement of PTFE Outgassing in XENON1t
Temperature Dependence: new method

First cool, and then take RGA scans as it warms!
Temperature Dependence: new method

Key takeaways:

Exponential fit:
Outgassing rate [Torr * l/s] = 3.86e-14 * exp(0.023 * Temp(C))

Much less variation than previously thought

Very close to background at low temperatures
A remaining problem: ambient temperature fluctuations
Conclusions

• Solid data for background and time-dependent measurements
• Discovered flaw in previously-used method for cooling
• Promising final results: exponential temperature dependence, and, at low temperatures, the outgassing rates are close to background
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