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Molecular sieve vacuum swing adsorption purification and radon reduction system for gaseous dark matter and rare-event detectors

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In the field of directional dark matter experiments, SF_6 has emerged as an ideal target gas. A critical challenge with this gas, and with other proposed gases, is the effective removal of contaminant gases. This includes radon which produces unwanted background events, but also common pollutants such as water, oxygen, and nitrogen, which can capture ionisation electrons, resulting in loss of detector gas gain over time. We present here a novel molecular sieve (MS) based gas recycling system for the simultaneous removal of both radon and common pollutants from SF_6. The apparatus has the additional benefit of minimising gas required in experiments and utilises a Vacuum Swing Adsorption (VSA) technique for continuous, long-term operation. The gas system's capabilities were tested with a 100 L low-pressure SF_6 Time Projection Chamber (TPC) detector. For the first time, we present a newly developed low-radioactive MS type 5 Å. This material was found to emanate radon at 98% less per radon captured compared to commercial counterparts, the lowest known MS emanation at the time of writing. Consequently, the radon activity in the TPC detector was reduced, with an upper limit of less than 7.2 mBq at a 95% confidence level (C.L.). Incorporation of MS types 3 Å and 4 Å to absorb common pollutants was found successfully to mitigate against gain deterioration while recycling the target gas.

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