An economical laboratory-scale system for purifying 3He

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Introduction: For more than a decade, researchers have been studying hyperpolarized ^{3}He as a contrast agent for lung imaging. Promising results from a number of groups suggest that it has the potential to become an important modality for the early detection and diagnosis of lung diseases such as emphysema. However, that potential is clouded by concerns that the global supply of ^{3}He is not sufficient to allow widespread adoption of ^{3}He MR imaging. These concerns would be eliminated by a demonstration that after imaging, ^{3}He can be captured, purified, and repolarized. A proof-of-principle experiment has been performed to show that helium can be purified in a simple apparatus.

Materials and Methods: A molecular sorption vacuum pump (Varian VacSorb) contains a "molecular sieve" which is cooled by liquid nitrogen. The Van der Walls interaction between the sieve material and gas molecules traps the gas in the sieve, and the pump is capable of reducing the pressure of atmospheric gases from 1 bar to below 1 torr with proper preparation. However the pump is essentially incapable of pumping a few inert gases such as helium. This weakness is an advantage in the present application.

The apparatus is shown in Figure 1. The sorption pump (part S in Fig. 1) was attached to a simple gas manifold (part M) which could be isolated from it by a manual valve (part V). The manifold was evacuated by the sorption pump, and then mixtures of helium and room air were metered into the manifold using a 1.5 L syringe. The syringe was filled either entirely with room air or with between 10% and 25% ^{4}He by volume. The total cost of the manifold and sorption pump was less than $3,000.

Two gas samples were extracted from the manifold into tedlar sampling bags. The first sample (A) was not purified. Before it was collected, the isolation valve (V) was closed to prevent the sorption pump (S) acting upon the gas in the manifold. A volume of 900 mL air and 260 mL of helium was injected into the evacuated manifold. Sample A was then collected. Next, the isolation valve (V) was opened and a total of 26.19 L of room air and 2.91 L of helium was injected into the manifold. Another sample (B) was then collected from the manifold. Two more sample bags (C and D) were filled directly from the ^{4}He supply tank in the same lab. Samples A and C were collected at approximately the same time, and samples B and D were also collected approximately simultaneously.

The four samples were transported for testing with a MIGET by MMIMS system (Oscillogy, LLC, Folsom, PA). This system is designed such that the electron multiplier signal is linearly proportional to the partial pressure of a gas in the sample. The ^{4}He signal from the samples was compared to the zero offset and the signal from 100% ^{4}He. These quantities were calibrated using, respectively, samples of room air and gas from a ^{4}He tank, both from the testing facility.

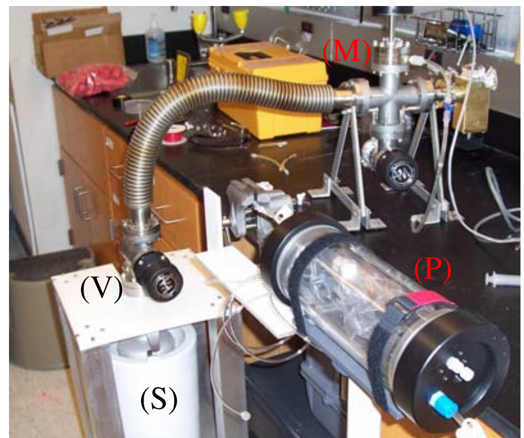

Figure 1. The system for helium purification. (S) Sorption pump. (V) Isolation valve. (M) Manifold with ports for pressure measurement and for injecting and extracting gas. (P) Gas extractor. The cylinder contains a tedlar bag; the volume around the bag can be evacuated to draw gas into the bag or pressurized to push gas out of the bag.

Results and Discussion: The measured helium fractions are shown in Table 1. The results are within 10% of expectations for the "calibrated" samples (pure helium or 22% helium). The initial helium concentration of 10% is approximately what we expect to obtain by capturing exhaled gas from the human and animal subjects in our ^{3}He imaging studies. A more detailed understanding of the performance of the purifier will require installation of gas measurement equipment (e.g. a residual gas analyzer) directly onto the purification system.

Conclusion and Future Directions: A simple technique, using equipment costing less than $3,000, has been shown to allow for the purification of helium from a concentration of 10% to a concentration greater than 85%. The accuracy of these measurements will be improved with additional equipment. It may be necessary to pass the helium from the stage demonstrated in this work through another cryogenic stage (25 K or less) to obtain ^{3}He with purity adequate for polarizing. The ^{3}He will be repolarized for use in animal studies, resulting in significant cost savings in the long term.

Sample	Comments	Purity (fraction)
A	mixture of 22% He, 78% air	0.26 ± 0.01
B	purified from 10% He, 90% air	0.88 ± 0.02
C	sample from pure He supply	0.96 ± 0.02
D	sample from pure He supply	0.95 ± 0.02

Table 1. Results of calibration samples (A,C,D) were consistent with expectations; the sample B result shows the apparatus has been used successfully to significantly enrich helium.

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