Adsorption Characteristics of Isoflurane in Porous Materials

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Introduction: There has been increasing interest in the emissions and associated environmental impact of volatile anesthetic gases.[1] Activated charcoal has been the immediate material of choice for many product designs trying to capture these gases,[2] however there exists a large variety of other porous materials that may pose superior capacity, adsorption kinetics, or direct material cost savings. Naturally occurring porous frameworks beyond activated charcoal are abundant, notably a wide variety of aluminosilicates, silicates, and alumina-oxides. These materials typically have a narrower range of pore sizes, enabling more selective adsorption uses.[3] To explore these materials as an alternative to activated charcoal for adsorbing volatile anesthetic gases, we tested several of these frameworks in the presence of isoflurane and characterized each of these materials on a variety of adsorption properties indicative of the potential as an anesthetic adsorbent.

Methods: An adsorption column was developed consisting of a 10 cm long glass bed reactor with internal radius of 1.25 cm. Ports were placed at both the inlet and outlet. Pellets of porous material were then packed into the column, including activated charcoal (Oxpure 1220C-75, Oxbow Activated Carbon, West Palm Beach, FL), a variety of silica gels (Silica gel-214426, technical grade 40 & Silica gel-S7500 Type II, Sigma-Aldrich, St. Louis, MO), zeolites (3Å molecular sieve-208582 & 13X molecular sieve-208639, Sigma-Aldrich, St. Louis, MO), and an aluminum oxide (Aluminum oxide-414069, Sigma-Aldrich, St. Louis, MO). Isoflurane (Piramal Healthcare Limited, Andhra Pradesh, India) was then introduced at 2 MAC in room air at a flow rate of 5 liters/minute, confirmed with a screen pneumotachograph (VT-Plus Gas Flow Analyzer, Fluke Corp., Everett, WA). The sampling ports were used to monitor, via infrared absorption (CapnoMAC Ultima, Datex-Ohmeda, Helsinki, Finland), the rate of isoflurane absorption through the column, also known as a breakthrough curve. To determine the amount of isoflurane absorbed into the particle, the porous materials were weighed before and after exposure to the anesthetic gas. The percent mass adsorbed in comparison to the mass of the material was also calculated. Finally, the time to breakpoint, specifically the time at which 0.05% of the inlet concentration is detected at the outlet, was determined.

Results and Discussion: The adsorption capacities and breakpoint times of isoflurane in porous materials are summarized in Table 1. The range of adsorption capacities varied greatly, with 3Å molecular sieves containing a negligible amount of isoflurane, while activated charcoal and the 13x molecular sieve absorbing over a third of their initial mass in isoflurane. As expected, the breakpoint times largely correlated to the adsorption capacities of the materials (Figure 1). Looking more closely at the breakthrough curves, the steep slope of activated charcoal is indicative of favorable rate kinetics for rapid and complete adsorption. While the 13X molecular sieves may have a higher adsorption capacity for a given volume, the slow rate kinetics yields a less-than-ideal material when used in practical applications.

Table 1: Adsorption characteristics of tested porous materials

Material	Initial Material Mass (g)	Isoflurane Adsorbed (g)	Percent Mass Absorbed (%)	Time to Breakpoint (sec)
3Å Molecular Sieve	39.3	0.4	1.0	5.3

Aluminum Oxide	39.6	4	10.1	92.4
Silica Gel Type II	38.0	9.4	24.7	202.4
13X Molecular Sieve	33	12.1	36.7	226.1
Silica Gel Grade 40	37.0	11.4	30.8	421.2
Activated Charcoal	21.6	9.8	45.4	970.0

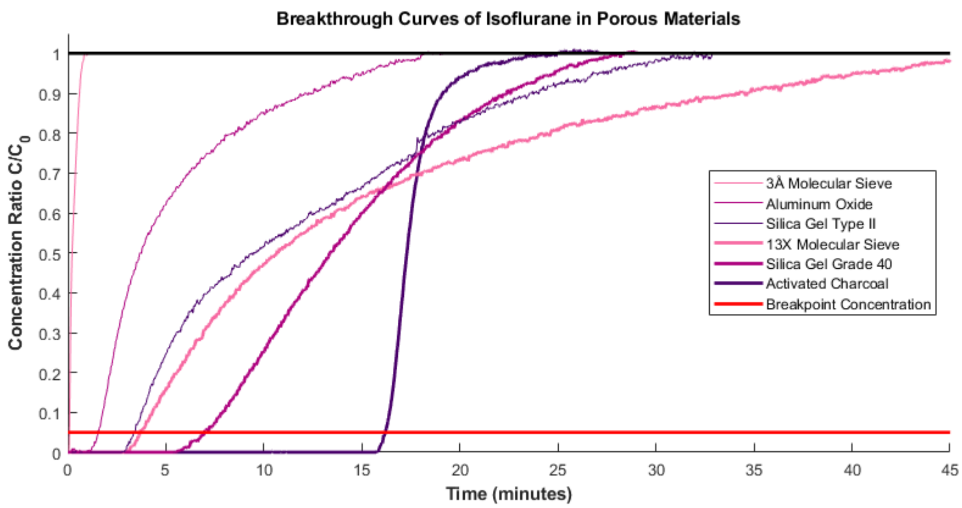

Figure 1 – Breakthrough curves of isoflurane at a concentration of 2 MAC at flow rates of 5 liters/minute, in a variety of porous materials in a packed bed at 25°C, with a bed length of 10 cm and radius of 1.25 cm. The time to breakpoint was determined with the outlet concentration reached 0.05% of the inlet concentration.

References: 1. Eckelman, M. J. & Sherman, J. D. Estimated Global Disease Burden From US Health Care Sector Greenhouse Gas Emissions. *Am. J. Public Health* e1–e3 (2017). doi:10.2105/AJPH.2017.303846

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