What is Technegas?

W M Burch PhD
Visiting Fellow, John Curtin School of Medical Research
Australian National University (1976 - 2008)
email: wburch@optusnet.com.au

Technegas is a cluster of nano-sized (~35nm) pure carbon platelets of hexagonal shape fully encapsulating pure Technetium metal crystals. Thus each particle only presents a pure carbon surface to the external environment. They are stable up to about 500°C, and being pure carbon, are extremely repellent of water vapour, i.e. are hydrophobic. The small size and hydrophobic property together confirm ideal characteristics for gas-like behaviour on inhalation into the lungs.

Electron microscope photograph of a Technegas particle ~35nm across.

It is important to understand the physical transport mechanisms of a gas, to appreciate just how effective is Technegas as a lung imaging agent. "Brownian" motion, first observed in microscopic particles, 'pollen' floating on a liquid surface, is demonstrating the random collision between molecules and particles, creating diffusion of the particles across the surface. The same diffusion mechanism applies in 3 dimensions in the gas phase, leading to a rapid establishment of uniformity for an introduced gas. Where the introduced matter is a micro-aerosol, the diffusion is much slower because of the relative mass differences of gas molecules and particles. Overriding the diffusion mechanism is any 'convective' or directional flow of the gas and during inhalation, this is many orders of magnitude greater than the diffusion velocity. Thus on inhalation, laminar flow is created down the bronchial tree, and other than sites of turbulence where partial obstruction and disruption of flow exists, the convective flow vector keeps the particles away from the bronchial walls. Only when the inhalation is stopped and the breath held, does diffusion take over and transport the particles to the vessel wall, where because of the surfactant properties of the mucus on the wall surface, they adhere. This is precisely why the inhalation technique for Technegas is so important. It should consist of a slow deep inhalation followed by a 3-5s breath-hold before exhalation. Failure to observe this will reduce the efficiency of deposition in the lungs.

Principle of formation of Technegas

The Technegas generator is essentially a miniature high temperature furnace in which the heating element is also the source of graphite vapour which ultimately coats the Technetium metal. The heating element is made from 100% pure spectroscopic graphite whose electrical and mechanical specifications match the requirements of the machine. It is a 6mm square section rod 50mm long, machined to form a crucible in the centre section such that it can hold a liquid volume of 0.14mL. This hollowed and thinned section also provides the high resistive portion of the rod, which becomes the hottest section when electric current is passed through it. The rod is held under spring tension between two high current electrodes. The entire assembly is mounted as a drawer section sliding into the lower chamber of a 6L vessel, and electrically powered from an automatic process-controller.

The crucible is first filled with liquid Sodium Pertechnetate in normal physiological saline, which in most instances contains enough activity [260-370MBq or 7-10mCi] for a single patient administration. The drawer section is then closed and the automatic process takes over, gently blowing pure argon gas over the top of the crucible while warming it to 70°C. This is known as the "simmer" cycle, and takes 6 minutes, during which time the liquid in the crucible dries out and the whole chamber is purged with pure argon, replacing all the original air and water vapour. At the conclusion of this preparation phase, the machine is activated via the control panel "start" button, and the crucible temperature rises to 2550°C by resistively heating it with about 4.5kW of power within 0.75s and holds that value ±50°C for 15s through a feedback servo from an optical sensor before switching off. This fills the 6L chamber with Technegas ready for immediate use via inhalation by the patient.

For operational convenience, the machine allows a 10 minute window in which the Technegas may be administered to the patient, and this is generally accomplished in 2-3 breaths, depending on many variables related mainly to the technique of administration.

It was always somewhat counter-intuitive that Technetium metal should suddenly volatilise a little way above its melting temperature (2157°C) when its boiling point is 4165°C. Also, although graphite has a steep partial pressure profile with temperature in the 2-3000°C range, some 6 orders of magnitude, predominantly releasing Carbon as C-C-C triplets, it still did not explain the sudden "lifting off" and Technegas

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production. There is good evidence now to suggest that the sudden lift-off is caused by the striking of an alternating current (AC) arc from the intense thermionic plasma inside the crucible, and that it is this arc that ablates the technetium and carbon simultaneously. About 10 cm above the crucible we have observed a 'co-condensation zone' where it is surmised the Tc atoms coalesce and crystallise forming the nuclei for coating by the carbon triplet 'vapour' into purely 6 member graphitic planes. No evidence for 5 member rings has been found in Technegas, although prominent among the small mass of unlabelled carbon particles also present is a wide spectrum of "Fullerenes". When Technegas was discovered initially, an association with the newly described "Bucky Balls" was seen to be a not unreasonable structure to postulate – hence the Company logo. It took some years of careful laboratory work by Prof. Tim Senden and Rod Browitt to unravel the final structure and its explanation. A more complete discussion may be found at our University website: http//jcsmr.anu.edu.au/technegas.

Cautions on argon use

Pure argon is critical for proper Technegas production, as is the integrity of all the gas lines to and within the machine. Traces of oxygen as low as 0.1% will produce at least some Pertechnegas, effectively a soluble oxide of 99mTc that converts to Pertechnetate in the lung. Pertechnegas is finding an application in various lung permeability studies, as it is absorbed rapidly through the lung directly into the blood stream. The level of Pertechnegas formed rises rapidly to near 100% above 0.5% oxygen content. Note that the use of ultra-pure argon shipped in aluminium cylinders is not advised. The aluminium forms a microscopic oxide coating on the inside of the cylinder when it is made. Some of this is aerosolised when the cylinder is filled, remains suspended in the gas and leads to Pertechnegas formation. It is not detected by the gas cylinder suppliers in their QC process, as they only look for pure gas contamination.