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# Securing molybdenum-99 supply

**The molybdenum isotope molybdenum-99 and its decay cousin technetium-99m are extremely helpful and widely used in medical procedures, for example in the diagnosis of cancer. Current production methods for $^{99}$Mo are in question because of aging reactors and the use of weapons-grade uranium. Fortunately, some new methods for producing $^{99}$Mo are under development and show great promise. If they are successful, molybdenum can continue to play its life-saving role.**

Recent articles in MolyReview discussed the basic components of the molybdenum atom (January 2012 issue) and the extreme importance of the $^{99}$Mo isotope for medical use (July 2010 issue). Atoms are composed of a nucleus, made of positively charged protons and uncharged neutrons, surrounded by negatively charged electrons. In a neutral atom, the number of electrons and protons is the same, and this number is called the atomic number of the element, which for molybdenum is 42. However, atoms of the same element can have different numbers of neutrons in their nuclei. These are called isotopes of the element. There are 33 known isotopes of molybdenum, but only six are stable – the others decaying radioactively.

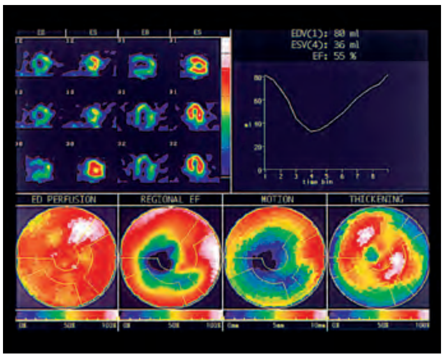
The $^{99}$Mo isotope, with 42 protons and 57 neutrons, is uniquely suited for use in medical diagnostic procedures. It is radio-active with a half-life of about 2.75 days, meaning that half the atoms, on average, decay in that time. It decays to technetium-99m ($^{99m}$Tc), the metastable isotope of technetium, the element to the right of Mo in the periodic table. The short half-life of $^{99}$Mo is ideal, as it is sufficiently stable to be transported to its place of use, while its radioactivity is short lived.

The $^{99m}$Tc isotope is the one used in medical procedures. It decays with a half-life of only six hours, emitting a 140 keV gamma ray, similar in energy to that from X-ray machines. The radiation is thus detectable using standard “gamma cameras”. This short half-life means that the medical procedure can happen rapidly and the radioactivity will leave the patient quickly.

$^{99m}$Tc can be chemically bound to different pharmacological agents that concentrate the isotope in different parts of the body, for example the heart, brain, and kidneys, among others. The gamma rays from the decaying $^{99m}$Tc atoms produce a picture of the target area, which is vital for the diagnosis of different medical conditions. $^{99m}$ Tc is the most widely used medical isotope with over 55,000 procedures performed every day in the US alone.

The problem is that a few aging reactors are producing nearly all the world’s supply of $^{99}$Mo, and they use highly enriched (weapons-grade) uranium (HEU) in the process. So there is an intense effort by governments and private companies to find alternative methods of producing $^{99}$Mo to secure its supply, and to reduce the use of HEU and the risk of proliferation.

One of the newer methods is similar to the traditional, but uses low enriched uranium (LEU) in the reactor. Unlike HEU, LEU cannot be used to make nuclear weapons. The SAFARI-1 reactor in South Africa, for example, has operated using LEU fuel since June 2009 and other operators have followed suit, or are working on similar ways to reduce the use of HEU in the world.




Technetium-99m is used as tracer in diagnostic procedures to visualize organs. Here blood was labelled with $^{99m}$Tc. The scans are showing blood uptake by the heart muscle (red-adequate, blue-inadequate). © Zephyr/SPL

Two of the newer processes under development do not use a reactor or enriched uranium at all. These methods use a particle accelerator. For one process, the Government of Canada awarded \$15 million in 2011 to the Canadian Light Source, a 2.9 GeV electron accelerator facility. They are investigating the production of $^{99}$Mo by bombarding another molybdenum isotope, $^{100}$Mo, with high-energy gamma rays. In a similar effort, the US Government has awarded a \$22.2 million matching grant to Northstar Medical Radioisotopes to build a multiple linear accelerator complex to make $^{99}$Mo, also from $^{100}$Mo. Northstar believes it could be producing 50% of the US need for $^{99}$Mo by the end of 2014.

For the second process, the University of Wisconsin received a \$20 million grant for the design of an accelerator-based neutron generator. In this route, the neutrons would strike a sub-critical solution of uranium, producing the desired $^{99}$Mo isotope.

It is hoped that one or both of these methods will provide a reliable source of the much needed molybdenum isotope in the near future. This would maintain our vital supplies of $^{99}$ Mo without the use of weapons-grade uranium.
(Tom Ferguson)