Canadian Nuclear Society

Smoke detectors and americium-241 fact sheet

www.cns-snc.ca/ecc/cnsecc.html

$^{241}_{95}Am$

For more than 25 years, Canadians have used ionization-chamber-based smoke detectors to warn them of possible fires in their homes. Most of these detectors use a small quantity (approximately 0.25 µg) of americium-241 (^{241}Am) in the form of americium dioxide (AmO_2). This small quantity of ^{241}Am corresponds to 30 kilobecquerels (kBq) of radioactive material. The alpha radiation emitted by the ^{241}Am ionizes oxygen and nitrogen in the air in the sensing chamber. The electric potential from a battery causes a small current to flow. Smoke particles (or aerosols, or mists from the bathroom shower) that enter the chamber absorb alpha particles. This reduces the ionization of the air, and hence reduces the electric current in the chamber. The reduction in the current is detected by an electronic circuit and the alarm is triggered.

Am-241 emits both alpha radiation and low-energy gamma rays. The alpha particles are absorbed within the detector, while most of the gamma rays escape.

Americium has atomic number 95 and an average atomic mass of 243. Metallic americium is a silvery metal, which tarnishes slowly in air and is soluble in acid. There are no stable isotopes of americium, and hence it is extremely scarce in nature. The first sample of americium was produced by bombarding plutonium with neutrons in a nuclear reactor at the University of Chicago. The discovery of element number 95 was announced on an American children's radio program called “Quiz Kids” in November 1945 by Glenn Seaborg, a chemist who worked on the Manhattan Project and co-discovered 10 elements, including plutonium.

The name americium, chosen by Seaborg in honour of the continent where it was discovered, was given to the new element in 1946. Of its 13 isotopes, Am-243 is the most stable, with a half-life of over 7500 years, although ^{241}Am, with a half-life of 470 years, was the first isotope to be isolated. (After one half-life, half of the original quantity of a radioactive isotope would have decayed, and half would remain.)

Source

Plutonium-241 (Pu-241), which forms about 12% of the one percent plutonium content of typical spent fuel from a light-water power reactor, has a half-life of 14 years, decaying to ^{241}Am through beta emission. (These proportions are different in a CANDU® heavy water reactor.) ^{241}Pu is formed in any nuclear reactor by neutron capture starting from uranium-238 (U-238). The steps are:

^{238}U + neutron => ^{239}U,
^{239}U by beta decay => ^{239}Np, Np - neptunium
^{239}Np by beta decay =>^{239}Pu,
^{239}Pu + neutron => ^{240}Pu,
^{240}Pu + neutron => ^{241}Pu.

The ^{241}Pu decays (emitting a beta particle) both in the reactor and subsequently to form Am-241.

It is of interest (and some significance in recycling spent fuel) that if too much ^{241}Am builds up in plutonium separated from spent fuel, it cannot readily be used for mixed oxide (MOX) fuel because it is too radioactive for handling in the normal MOX plant. For instance, the British Nuclear Fuels Limited facility at Sellafield, UK, could handle plutonium with up to 3% ^{241}Am, hence up to 6 years old (higher concentrations would need additional measures to control the dose received by workers).

Hazards

The radiation dose to the occupants of a house from a domestic smoke detector is very small, very much less than that from natural background radiation due to cosmic rays, naturally occurring radioactive elements such as potassium, or radon. The small amount of radioactive material that is used in these detectors is not considered to be a health hazard. When smoke detectors using americium were first introduced, they were labelled as requiring return to the supplier or shipment to the (then) Atomic Energy Control Board for disposal in Canada. This requirement was later withdrawn, although some jurisdictions (e.g., Australia) require special disposal. There is probably some "spent fuel waste" in your local land fill in the guise of defunct smoke detectors.

^{241}Am is a potentially hazardous isotope, decaying by both alpha activity and gamma emissions. If it enters the body in a chemically available form, it would concentrate in the skeleton. However, swallowing the radioactive material from a smoke detector would not lead to significant internal absorption of ^{241}Am. Since the dioxide is insoluble, it will pass through the digestive tract, without delivering a significant radiation dose. Inhaling AmO_2 as dust particles could lead to it residing in the lungs. Alpha particle emitters present a biological hazard when inside the body, since the alpha particles are absorbed in a small volume near the source, increasing the risk of cell damage that may result in cancer. The low-energy gamma rays are less hazardous as they interact over a larger volume.

^{241}Am decays to an isotope of neptunium (^{237}Np), emitting an alpha particle with an energy of approximately 5.5 MeV and gamma rays, with the majority having an energy of 60 keV. ^{237}Np has a half-life of 2.14 million years, and also decays by alpha emission (4.9 MeV). Because of its long half-life, ^{237}Np is less hazardous than ^{241}Am. (Very rarely, ^{241}Am undergoes spontaneous fission.)

Cost

Americium dioxide was first offered for sale by the US Atomic Energy Commission in 1962 and the price of $1500 US per gram has remained virtually unchanged to the present day. Since one gram of americium dioxide provides enough active material for more than 4000000 smoke detectors, the AmO_2 accounts for less than 0.1% of the retail price of a smoke detector.

Other uses

Americium (in combination with beryllium) is also used as a neutron source in non-destructive testing of machinery and equipment, and as a thickness gauge in the glass industry. However, its most common application is as an ionization source in smoke detectors, and most of the several kilograms of americium made each year is used in this way.

Alternative Smoke Detectors

Photoelectric smoke detectors sense smoke in the air by detecting changes in the transmission of light due to absorption and scattering by smoke particles. For specific types of fires, one detector type may perform better than the other, but both are considered to be effective, in general. Some manufacturers offer smoke detectors that use both technologies.

References

Via the world wide web: The Uranium Institute, London, UK
Uranium Information Centre Limited, Melbourne, Australia
Ontario Fire Safety Council
Handbook of Physics and Chemistry, 60th Edition, Chemical Rubber Company, 1979.