Poisonous polonium

Eric Ansoborlo considers the disproportionate potency of polonium compared with its relative scarcity on Earth.

Polonium is the 84th entry in the periodic table and is a natural radioelement present in the environment at extremely low concentrations. The discovery of polonium was published[1] by Pierre and Marie Curie in July 1898. It was the first element discovered using their newly developed radiochemical separation method, where each product isolated from primary pitchblende ore was detected using an electrometer constructed by Pierre. They cautiously wrote "we believe that the substance we recovered from pitchblende contains a heretofore unknown metal, similar to bismuth in its analytical properties. If the existence of this new metal is confirmed, we propose that it be named polonium in honour of the native land of one of us."

This discovery led to the first controversy[2] in radiochemistry, in this case between the Curies and a number of German scientists — including Willy Marckwald and Friedrich Giesel — who thought that this new element was nothing other than 'inducedly activated bismuth'. In 1901 Marckwald isolated, using a different method, what turned out to be the same 'new substance' and provisionally renamed it radiotellurium. For several years, controversy over both the identity of the material and its location in the periodic table continued, and it was only in 1910 that Marie Curie and André-Louis Debierne unequivocally identified, by a spark spectrum technique, 0.1 mg polonium in 2 mg of separated sulfide residue. In 1911 Marie Curie received the Nobel Prize in Chemistry for the discoveries of both polonium and radium.

Polonium has 41 isotopes, with masses ranging from 187 to 227. The predominant naturally occurring isotope is ^{210}Po, which is a radioactive decay product in the natural uranium decay series. Nowadays the two main methods for producing significant quantities (that is, a few milligrams) of ^{210}Po are to neutron-irradiate a ^{209}Bi target in a nuclear reactor, or to bombard a ^{209}Bi target

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with a 37 MeV beam of alpha particles. Isotope ^{210}Po is almost exclusively an alpha emitter with a half-life of 138.4 days. Consequently, it is both highly radioactive and highly toxic[3]. Because of its radiotoxicity, the fact that it volatilizes at low temperature (~50 °C) and that it sticks rather avidly to glass, it is difficult to handle, and therefore its chemistry remains only poorly known[4].

Belonging to the chalcogenide family of the periodic table, along with oxygen, sulfur, selenium and tellurium, polonium can also be compared to bismuth, its neighbour to the left in the periodic table. Of several oxidation states (-II, +II, +IV and +VI), the tetravalent Po(IV) is the most stable in aqueous solution, and this gives rise to its most important chemical property: its tendency to hydrolyse and form colloids of $Po(OH)_4$, in analogy with most tetravalent elements. It also forms soluble salts with chlorides, acetates, nitrates and other inorganic anions, but precipitates with sulfides, and this is the property that was originally exploited by the Curies in separating and identifying it. With organic ligands, however, the coordination chemistry of Po(IV) is much more complicated and leads to mixed oxide and hydroxide complexes.

Elemental ^{210}Po has a few specific uses, such as studying the effects of alpha particles and for the calibration of radiation detectors. It is also a concentrated source of heat, and small neutron sources can be prepared by mixing it with beryllium. It is perhaps most widely known, though, as a rare but highly toxic poison that targets the liver[3] and also affects the bone marrow, gastrointestinal and central nervous systems. The lethal dose for humans is estimated to be fewer than 10 μg, and its radiotoxicity was demonstrated soon after its discovery, when the accidental release of polonium from a distillation vessel in the Curie lab caused the death of a technician.

More recently, Alexander Litvinenko, a former member of the Russian security services, was thought to have been poisoned[5] with ^{210}Po-contaminated tea in 2006, and the involvement of polonium has been suggested in Yasser Arafat's death. Polonium is over 10,000 times more toxic than hydrogen cyanide and, alongside the botulinum toxin, it is one of the most toxic substances known. In soils, ^{210}Po is absorbed by clay minerals and organic matter. In particular, it is known to accumulate in tobacco plants, which results in a surprisingly significant presence of polonium in cigarettes. Not good news for smokers then, considering that only a few studies have been carried out into treatments for polonium poisoning, with thiol-based chelating agents the only recommended ones thus far. ❐

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Tl Pb Bi **Po** At Rn Fr Ra Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md