

# Polonium-210: Factfile\*

The element polonium was first discovered by Mme. Curie in 1898 while seeking the cause of radioactivity of pitchblende (uranium ore). The element is named after Poland, Mme Curie's native country. There are now 35 known radioactive isotopes of the element polonium – there are no stable isotopes. Polonium-210 (Po-210) is a naturally occurring radioactive material. Although it decays to stable lead-206, it is constantly being produced in nature from the decay of uranium-238 – the main component of uranium in the earth. Due to this “equilibrium”, the concentration of Po-210 in nature is approximately 75 µg of Po-210 for every ton of uranium-238. In terms activity, this corresponds to  $1.2 \times 10^{10}$  disintegrations per second or  $1.2 \times 10^{10}$  Bq (1 Becquerel, Bq = 1 disintegration per second).

<b>Po 208</b> 2.898 a α 5.1152... ε γ (292; 571...) g	<b>Po 209</b> 102 a α 4.881... ε γ (895; 261; 263...)	<b>Po 210</b> 138.38 d α 5.30438... γ (803); σ < 0.0005 + < 0.030; σ <sub>n,α</sub> 0.002; σ <sub>f</sub> < 0.1	<b>Po 211</b> 25.2 s 0.516 s α 7.275; 8.883... γ 570; 1064... t <sub>γ</sub> α 7.450... γ (898; 570...)
<b>Bi 207</b> 31.55 a ε β <sup>+</sup> ... γ 570; 1064; 1770...	<b>Bi 208</b> 3.68 · 10 <sup>5</sup> a ε γ 2615	<b>Bi 209</b> 100 σ 0.011 + 0.023 σ <sub>n,α</sub> < 3E-7	<b>Bi 210</b> 3.0 · 10 <sup>6</sup> a 5.013 d α 4.946; 4.908... γ 266; 904... σ 0.054 β <sup>-</sup> 1.2 α 4.649; 4.886 γ (305; 266)
<b>Pb 206</b> 24.1 σ 0.027	<b>Pb 207</b> 22.1 σ 0.61	<b>Pb 208</b> 52.4 σ 0.00023 σ <sub>n,α</sub> < 8E-6	<b>Pb 209</b> 3.253 h β <sup>-</sup> 0.6 no γ

Fig.1: Extract from the Karlsruhe Nuclide Chart [1] showing the basic nuclear data of polonium-210. The nuclide can be produced by neutron irradiation of bismuth-209 in a nuclear reactor (see text).

The most important basic nuclear data are summarised in the Po-210 “box” of the Karlsruhe Nuclide Chart shown in fig. 1. Po-210 is an alpha emitter with a half-life of 138 days. The alpha particle energy is 5.30438 MeV. It emits a gamma photon with energy 803 keV with a low emission probability (the low emission probability of less than 1% is indicated by the brackets surrounding the energy in fig. 1 i.e. (803)). The capture (n,γ) cross section for thermal neutrons is  $\sigma < 0.0005$  barn to the metastable state Po-211m and  $\sigma < 0.030$  barn to the ground state Po-211. The (n,α) cross section for thermal neutrons is  $\sigma = 0.002$  barn. The fission cross section for thermal neutrons is less than 0.1 barn. Due to its short half-life, the specific activity (activity per unit mass) of Po-210 is very high:  $1.7 \times 10^{14}$  Bq/g. The resulting isotopic power (energy released per second by its decay) is 140 Watt per gram. Additional data can be obtained from the Nucleonica database\*.

Po-210 is highly radiotoxic. The radiotoxicity (as opposed to chemical toxicity) of a substance refers to its potential capacity to cause damage to living tissue due to its radioactive emissions. To establish the radiation dose due to exposure to Po-210, one must differentiate between external exposure and internal exposure. Since Po-210 is mainly an alpha emitter, the main damage is from internal exposure either by ingestion or by inhalation. Once in the blood stream, polonium disperses through the entire body giving rise to a whole-body radiation dose which kills or damages organs, tissues and cells. To determine the biological hazard, the so-called *effective dose coefficients* should be used. These relate the biological hazard (measured in Sievert, Sv) to the amount of intake (in Becquerel, Bq) of the radionuclide.

Effective dose coefficients for intake of Po-210 (ICRP 72)	
Effective dose coefficient for ingestion	Effective dose coefficient for inhalation
$1.2 \times 10^{-6}$ Sv/Bq	$4.3 \times 10^{-6}$ Sv/Bq

To obtain the dose from intake of Po-210 from ingestion of this material, the amount of intake (in Bq) is multiplied by the effective dose coefficient for ingestion. For a mass of Po-210 of 0.1  $\mu\text{g}$  (corresponding to an activity of  $1.7 \times 10^7$  Bq), the dose is given by:  $1.7 \times 10^7$  Bq  $\times$   $1.2 \times 10^{-6}$  Sv/Bq = 20 Sv or 200 Sv/ $\mu\text{g}$ . This is a very high dose. To put this into perspective, a radiation dose of 5 Sv received over a short period will cause death in 50% of cases within 30 days (Lethal Dose, LD 50/30).

Mr. Alexander Litvinenko, a former Russian dissident who died on November 23, 2006, is believed to be the first person to have died from acute polonium poisoning. In 1956 Irène Joliot-Curie, whose parents first isolated polonium, died from leukaemia. This was attributed to chronic poisoning following the explosion of a sealed capsule containing polonium a decade earlier.

From the Nucleonica database, the emission probability of the 803 keV gamma photons is  $1.1 \times 10^{-5}$ . This implies that approximately one gamma photon is emitted for every 100,000 disintegrations. The gamma dose rate resulting from irradiation of tissue from a 0.1  $\mu\text{g}$  Po-210 source is however much less than  $1 \mu\text{Sv/h}$  (the tenth value shield thickness in tissue is approximately 30 cm).

Po-210 can be produced by irradiating natural bismuth (Bi-209) by neutrons in a nuclear reactor. Through the capture of a neutron, with capture cross section 0.023 barn (see fig. 1), Bi-210 is produced in its ground state and this in turn decays to Po-210. Currently, approximately 100 grams of Po-210 are produced annually.

Po-210 is also present in cigarettes. The actual mechanism by which the polonium arises in tobacco leaves is still disputed. It can arise through the decay of radon gas in the air directly onto the tobacco leaves or directly from the uptake of radioactive decay products of uranium in the earth in the roots of the plant. As cigarette burn, the radioactive polonium on the surface volatilizes and enter the lungs through inhalation. It has been claimed that radioactive polonium-210 is responsible for more than 90% of all smoking related lung cancers.

Polonium-210 is also used as a source of alpha emitters in research. When combined with beryllium, it can provide a powerful source of neutrons through ( $\alpha, n$ ) reactions. It can be used as a neutron trigger in nuclear weapons.

## The Nucleonica Team

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\* all results obtained above have been calculated with Nucleonica (see [www.nucleonica.net](http://www.nucleonica.net))

[1] [Karlsruher Nuklidkarte](#), J. Magill, G. Pfennig, J. Galy, 7<sup>th</sup> Edition, 2006 ISBN 92-79-02175-3.