Journal of Physics Special Topics

An undergraduate physics journal

Group A3 4 Pripyat in my Pocket - Thoriated Tungsten

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October 30, 2024

Abstract

In this paper we discuss just how radioactive thoriated tungsten is. By calculating dose rates for tradespeople, we discover exposure rates of 0.614 mSv per year. This doesn't quite compare to the irradiated town of Pripyat, where exposure levels for 'safe' visitor tours work out to be 17.52mSv per year. However, questions for future papers are exposed when the issue of airborne dust is proposed.

Introduction

Tungsten inert gas (TIG) welding uses a sharpened tungsten electrode to facilitate an electric arc for the purpose of welding. As tungsten has a higher melting point than most common metals, it stays solid during the process to provide a stable form of welding. The electrodes are small, often carried in a person's pocket. The most common tungsten electrode in use contains the radioactive element Thorium-232, as an oxide at 2 % concentration. It decays into Radium-228, releasing α radiation in the process.[1] By examining the radioactivity of Thorium-232, we will demonstrate if this practice is safe or if millions of trades-people worldwide carry a miniature version of the famously irradiated town, Pripyat.

Radiation Testing and Evaluation

Thorium-232 has a range of decay energies, but by taking a weighted average, a value of 3998.03 keV can be used for the α particles.[4] From this, the activity can be determined using the simple equation,

$$A = \lambda N, \tag{1}$$

where A is activity in Becquerels (Bq), λ is a decay constant and N is the number of particles. To achieve this we first must determine the amount of Thorium in an electrode (a cylinder, length 200mm by 2.4mm DIA). With the molecular weight of Thorium in Thorium Oxide (ThO_2, 264.04 mol)[3] being 87.88% we can calculate the volume of thorium in the electrode,

$$V_t = (\pi r^2 h) \cdot 2\% \cdot 87.88\%, \tag{2}$$

as the density of Thorium-232 is 11.7 g/cm^3[3], we can further calculate the number of particles present with the mass of Th in the electrode, it's molecular mass, all multiplied by Avogadro's number,

$$N_t = \frac{M_t}{M_m} N_A, \tag{3}$$

giving us a value of $(4.83 \cdot 10^{19})$ Th atoms. As the decay constant is related to the half-life of a substance ($t_{1/2}$ of Th being $4.415 \cdot 10^{17}$s)[3] by,

$$\lambda = \frac{\ln(2)}{t_{1/2}}, \tag{4}$$

we get a value of $(1.57 \cdot 10^{-18})$ for λ. Finally, by plugging these into the activity equation we get an activity of 75.81 Bq. The question then logically becomes, is this activity rate dangerous? To answer that we start with the fact that α particles cannot penetrate skin, nevermind the multiple layers of clothing or metal toolbox casing. [6] But assuming that the α particles do get to the skin, what damage will they potentially cause?

The answer is, not very much. Radiation exposure and it's dangers use a complicated system of absorbed dose (A_b in Grays, Gy, Joules per Kg) and effective dose in Sieverts (Sv), which includes radiation/tissue weighting factors (W_R and W_t) that depend on the radiation type and organ sensitivity to such (in this case the skin only). Due to the small size of the electrodes, we can approximate the exposed mass of tissue to be about 0.5kg. By converting the known energy of each α particle to joules ($6.41 \cdot 10^{-13}$ J), multiplying it by the Bq, and the number of seconds in a year (again assuming this sort of exposure time) we get $1.53 \cdot 10^{-3} J$ which translates to $3.07 \cdot 10^{-3}$ Gy for our 0.5kg case. Finally we can calculate the yearly effective dose[7],

$$E_{ff} = A_b W_R W_T, \quad (5)$$

Which in the case of our specific example, equates to 0.614 mSv, far below the maximum safe exposure rate of 20 mSv in the UK.[8] This yearly level is also far below what visitors to Pripyat receive. While areas of the city are still highly radioactive, typical exposure rates are 1-2 μSv per hour[9], which equates to about 17.52 mSv per year, still below the UK's recommended exposure rate. It is worth noting that a lot of this exposure is in form of more penetrating gamma-rays.

Conclusion

In conclusion, we can say with a fair degree of certainty that the radiation risk to millions of workers is negligible. Carrying tungsten electrodes is far less harmful than even the safest of Pripyat guided tours. But there is a catch, tungsten electrodes must be sharpened to a point for welding and Thorium is inevitably released in to the air. A question for a future paper, how dangerous is this dust?

References

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