Teaching Nuclear Radiation and the Poisoning of Alexander Litvinenko

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The recent international story about the death of the former KGB agent Alexander Litvinenko has more than just a few wondering about radiation poisoning and the sinister sounding polonium-210. I was preparing to begin a nuclear radiation unit the Monday after Thanksgiving 2006. As it turned out, Litvinenko died Thanksgiving Day after a short and terrible three-week illness. Having the story continue to unfold throughout the next two weeks of the new unit provided a daily opportunity for students to see the relevance of what we were doing in class. My students were able to have meaningful and informed conversations with their peers and parents over an important international event. They even began to feel a bit like authorities themselves when listening to experts respond to media questions about polonium-210 and nuclear radiation in general. This paper discusses some of the ways that the story of Litvinenko was used while presenting the topic of nuclear radiation.

On the first day of the unit, approximately 10% of students in each of four physics classes indicated they had heard the name Alexander Litvinenko. I found a five-minute video available from the Frontline Club[1] in which Litvinenko accuses Russian President Putin of being responsible for the Oct. 7, 2006, murder of Anna Politkovskaya (a Russian journalist critical of the Kremlin). While students watched the video, I had each of them handle a sealed envelope, holding it for several seconds before passing it along. At the end of the video, I told each class that this man had died an agonizing death after falling ill Nov. 1. The cause of death was radiation poisoning from the isotope polonium-210. I then opened the envelope in each class to show them that they had each just handled a polonium-210 source. Of course there was immediate interest in what they just handled. Some students questioned the safety of the activity; others wondered how I was able to obtain the isotope. It was the perfect opportunity to talk about the relative penetration of alpha, beta, and gamma radiation into matter. It became clear how simultaneously "safe" and dangerous an alpha emitter like polonium-210 can be. They understood that the envelope was fully adequate to stop the alpha radiation, but that this made the alpha particles far more dangerous than beta or gamma radiation inside the body, since any energy from alpha emission would be completely absorbed by the body. It was then obvious to them how deadly the polonium-210 is if ingested and also how the person who poisoned Litvinenko could easily transport it without detection and with little risk of self-poisoning.

The story also played into a discussion activity. I indicated that, when fresh, my polonium-210 source had 0.1 μCi of activity. Making the quick conversion to decays per second by using 1 Curie (Ci) = 3.7×10^{10} Becquerels (decays per second), students were amazed to find that a source so small had at one point been emitting 3700 alpha particles per second. To put this into perspective, we decided to estimate the activity of the polonium-210 in the body of Litvinenko. One source[2] suggested that observed effects could have been caused by as little as one microgram of

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polonium-210. Students then calculated the activity using $A = \lambda N$, where N = the number of radioactive nuclei and $\lambda = \dfrac{\ln 2}{half\text{-}life}$.

The half-life of polonium-210 is 138.38 days (1.1956×10^7 s):

$$A = \lambda N = \left(\frac{\ln 2}{1.1956\times10^{7}\,\mathrm{s}}\right)\left(1\times10^{-6}\,\mathrm{g\ Po}\cdot\frac{6.023\times10^{23}}{210\mathrm{g\ Po}}\right)$$
$$= 1.66\times10^{8}\,\mathrm{Bq} = 4.49\ \mathrm{mCi}\ .$$

This is approximately 45,000 times more radioactive than the classroom source, giving students an appreciation for how high the level of poisoning was in the system of Litvinenko and a sense of how small in mass a radioactive isotope can be and still be exceptionally dangerous.

When half-life was presented, I once again used the polonium-210 to discuss the topic conceptually. My classroom Geiger counter easily indicates the activity of a polonium-210 source dated October 2005, but a similar source dated September 2003 can't be distinguished from background radiation. A 138-day half-life means that I have to buy a new polonium-210 source every couple of years. After two years, more than five half-lives have gone by and only about 2.5% of the activity remains. While students can easily make a chart showing the amount of radioactive isotope remaining after any whole number of half-lives, and thereby verify this small amount remaining, this tangible demonstration of the evidence of half-life has been the most effective I've used. Another issue that students have with half-life is the misconception that the decay of the isotope results in the disappearance of the atom rather than its transmutation into another. Students asked, for example, if Litvinenko was getting "lighter" with each decay. That led to a discussion of transmutation equations and a solid understanding on the students' part that the polonium-210 was slowly changing into lead-206 by alpha emission:

$${}^{210}_{84}\mathrm{Po} \rightarrow {}^{206}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{He}\ .$$

The use of the Alexander Litvinenko story in presenting nuclear radiation made a strong impact not only on the interest my students had in the topic, but also in the ultimate depth of understanding they gained. Just recently (six months after I first discussed Litvinenko's polonium-210 poisoning with my high school physics classes), I used the same approach to introduce the topic of nuclear radiation to a conceptual physics course I teach at a Sonoma State University. This time there was even more impact because the news story was still prominent in the international media and a greater portion of my students were familiar with the Litvinenko story. I have been reminded again of the importance in making the physics we teach relevant and of the great value of finding applications of what we teach outside of the physics lab.

References

1. http://www.thefrontlineclub.com.
2. http://news.bbc.co.uk/2/hi/science/nature/6190144.stm.

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