Radioactivity : Homework task

News Item on 24th November 2006: Radiation tests after spy death

Tests are set to be carried out on members of the public who may have come into contact with Russian ex-spy Alexander Litvinenko.

Officers are examining material taken various scenes

His death has been linked to the presence of a "major dose" of radioactive polonium-210 in his body. Radioactive traces were found at a London hotel and sushi bar he visited on 1 November. Tests are for those who may have been in contact with him. Cobra, the UK's civil contingencies committee, has discussed the case. Anyone who was in the Itsu restaurant, or who was in the Pine Bar of the Millennium Hotel on 1 November has been urged to contact NHS Direct on 0845 4647. An HPA spokeswoman said: "We expect that we are going to do [urine] tests and we expect that they are going to be negative and we have no reason to think customers are at risk."

Mr Litvinenko's condition deteriorated rapidly in hospital

Meanwhile, chief medical officer Sir Liam Donaldson has issued advice to GPs and hospitals on the risks and clinical implications of exposure to Polonium-210. Managing Director of Itsu, Clive Schlee, said in a statement: "I have not had a single report from our staff or our customers of any illness related in any way to the events of 1 November." He also stressed that the only Itsu affected is the branch at 167 Piccadilly and their interest was confined to those who visited the restaurant on 1 November. BBC home affairs correspondent Andy Tighe said various sites are being regarded as crime scenes.

Officers are also interviewing witnesses in an attempt to find out who Mr Litvinenko met around the time he fell ill. Tests are also being carried out at the two London hospitals where Mr Litvinenko had been treated, University College and the Barnet General, the Health Protection Agency said.

No post-mortem examination yet on Mr Litvinenko

A post-mortem examination on Mr Litvinenko has not yet been held. The delay is believed to be over concerns about the health implications for those present at the examination. Medical experts had previously expressed differing opinions over substances that could have possibly led to his death. Initial reports that he was given the heavy metal thallium gave way to other theories including radiation poisoning. Friends have said Mr Litvinenko was poisoned because of his criticism of Russia. Police searches are taking place at Mr Litvinenko's house in north London, where radioactive traces were discovered, and other places he had been.

TIMELINE

1 Nov - Alexander Litvinenko meets two Russian men at a London hotel and then meets Italian academic Mario Scaramella at a sushi bar in Piccadilly. Hours later he falls ill and is admitted to Barnet General Hospital
17 Nov - Mr Litvinenko is transferred to UCH
19 Nov - Reports say Mr Litvinenko is poisoned with thallium
21 Nov - A toxicologist says he may have been poisoned with "radioactive thallium"
22 Nov - Mr Litvinenko's condition deteriorates overnight. Thallium and radiation ruled out
23 Nov - The ex-spy dies in intensive care
24 Nov - His death is linked to radioactive polonium-210

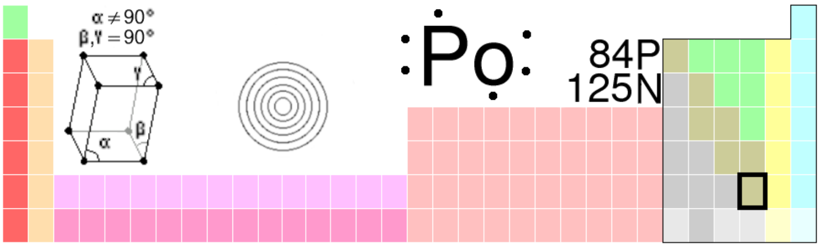
In a statement dictated before he died at University College Hospital on Thursday, the 43-year-old accused Russian President Vladimir Putin of involvement in his death. Mr Litvinenko had recently been investigating the murder of his friend, Russian journalist Anna Politkovskaya, another critic of the Putin government. Mr Putin's spokesman Dmitry Peskov reiterated the Kremlin's earlier dismissal of allegations of involvement in the poisoning as "sheer nonsense". Mr Putin himself has said Mr Litvinenko's death was a tragedy, but he saw no "definitive proof" it was a "violent death".

Police have been examining two meetings Mr Litvinenko had on 1 November - one at a London hotel with a former KGB agent and another man, and a rendezvous with Italian security consultant Mario Scaramella, at a sushi restaurant in London's West End. Mr Litvinenko, who was granted asylum in the UK in 2000 after complaining of persecution in Russia, fell ill later that day.

Extracts from BBC news reports were used in the composition of this assignment - LOJ – November 25th 2006

Physics in the news – some background to help you understand it

Poisoning by polonium (specifically the polonium-210 isotope) is believed to have caused the death of Alexander Litvinenko, a dissident former Russian KGB spy, on 2006-11-23. Traces of polonium were found in several locations he had visited shortly before becoming ill. Litvinenko on his deathbed blamed his death on deliberate poisoning by the FSB (the successor organization to the KGB) and ultimately Russian President Vladimir Putin but the exact source of the poisoning has not been established.



Polonium (atomic number 82) is a rare radioactive metalloid, and occurs naturally in uranium ores. Polonium is a solid but dissolves readily in dilute acids. It is only slightly soluble in alkalis.

Polonium has been studied for possible use in heating spacecraft. It exists as a number of isotopes.

Polonium was discovered by Marie Curie and her husband Pierre Curie in 1897 and was later named after Marie's home land of Poland (Latin: *Polonia*). Poland at the time was under Russian, Prussian and Austrian domination, and not recognized as an independent country. It was Marie's hope that naming the element after her home land would add notoriety to its plight. Polonium may be the first element named to highlight a political controversy.

This element was the first one discovered by the Curies while they were investigating the cause of radioactivity in pitchblende (a Uranium ore). The pitchblende, after removal of uranium and radium, was more radioactive than both radium and uranium put together! This spurred them on to find the element responsible for this.

Occurrence

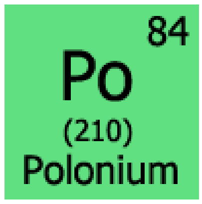
A very rare element in nature, polonium is found in uranium ores at about 100 micrograms per metric ton ($1{:}10^{10}$) - to find 1 mg of Polonium you would need refine 10,000 kg of Uranium ore. In 1934 an experiment showed that when natural ^{209}Bi is bombarded with neutrons, ^{210}Bi, which is the parent of polonium, was created. Polonium may now be made in milligram amounts in this procedure which uses high neutron fluxes found in nuclear reactors.

Polonium is so exceedingly rare that only about 100 grams is believed to be produced each year.

Isotopes

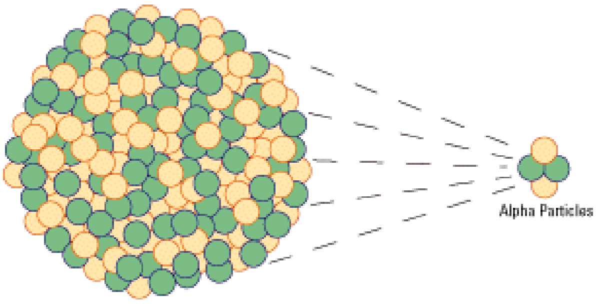
Polonium has 25 known isotopes all of which are radioactive. It has more isotopes than any other element. They have atomic masses that range from 194 u to 218 u. ^{210}Po is the most widely available. ^{209}Po (half-life 103 years) and ^{208}Po (half-life 2.9 years) can be made through the alpha, proton, or deuteron bombardment of lead or bismuth in a cyclotron. However these isotopes are expensive to produce.

Polonium-210



This isotope of polonium is an alpha emitter that has a half-life of 138 days. A milligram of ^{210}Po emits as many alpha particles as 5 grams of radium because it has a shorter half life. A great deal of energy is released by its decay with a half a gram quickly reaching a temperature above 750 K. A few curies (gigabecquerels) of ^{210}Po emit a blue glow which is caused by excitation of surrounding air. A single gram of ^{210}Po generates energy at the rate of 150 watts. Since nearly all alpha radiation can be easily stopped by ordinary containers and upon hitting its surface releases its energy, ^{210}Po has been used as a lightweight heat source to power thermoelectric cells in artificial satellites. A ^{210}Po heat source was also used in each of the Lunokhod rovers deployed on the surface of the Moon, to keep their internal components warm during the lunar nights.

Precautions when handling it



Polonium 210 Atom

Polonium is a highly radioactive and toxic element and is very difficult to handle. Even in milligram or microgram quantities, handling polonium-210 is extremely dangerous, requiring specialized equipment and strict handling procedures. Alpha particles emitted by polonium material when absorbed by the body and will damage organic tissue in a highly localized concentration very near to the source as alpha particles are highly ionizing and have low penetration power.

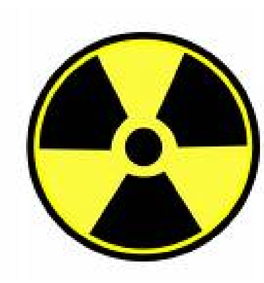
The maximum allowable body burden for ingested polonium is only 1100 becquerels (0.03 microcurie), which is equivalent to a particle weighing only 6.8×10^{-12} grammes (0.0000000000067g). Weight for weight polonium is approximately 2.5×10^{11} times as toxic as hydrogen cyanide.

Polonium has been found in tobacco smoke from tobacco leaves as a contaminant and in uranium ores.

Use as a poison

The amount of material required to produce a lethal dose of 10 Sieverts would be only 0.12 micrograms (1.17×10^{-7}g). The **biological half-life is 50 to 30 days in humans**. Biological half life is the time taken for the activity of the sample within the body to halve. It is always less than the radioactive property of half life as it not only happens because the radioactive nuclei have decayed but also because the body loses some of the radioactive nuclei by natural expulsion of material in sweat, urine, faeces, tears etc.

When ingested or inhaled, polonium starts attacking organs and **can cause irreversible damage to the kidneys, liver and spleen**. It would also make its victim's **hair fall out**. There is **no antidote**, and handling it in a laboratory requires special equipment. But to be fatal, it must be swallowed, breathed in or injected; the alpha particles it produces cannot penetrate the skin. So it could theoretically be carried safely in a glass vial or paper envelope and sprinkled into food or drink by a killer willing to take the chance that he did not accidentally breathe it in or swallow it.



Polonium 210 does its damage by **emitting alpha particles**, which have enough energy to tear apart the genetic machinery of cells (DNA), killing them outright or causing them to mutate into tumour-producing forms. Alpha-emitters are not picked up by normal radiation-detection devices, a British expert said, so it would be relatively easy to take across a border.

Extracts from BBC news reports were used in the composition of this assignment - LOJ – November 25th 2006

The radioactive particles — essentially tiny bits of polonium — disperse through the body emitting alpha particles as they go. First they destroy fast-growing cells, such as those in bone marrow, blood, hair and the digestive tract. So symptoms would include hair loss, inability to make blood cells and gastrointestinal distress.

Polonium is available **commercially on special order** from the Oak Ridge National Laboratory, Tennessee. It can only be produced in large enough concentrations to use as a poison from nuclear establishments.

Questions (20 marks)

1. Write the nuclear symbol for polonium 210 – nuclear symbols indicate which isotope we are dealing with

$$^{210}_{84}Po$$

2. How many neutrons are in the nucleus of polonium 210?

210-84 = 126

3. How many protons are in the nucleus of polonium 210?

84

4. What type of radioactive particle is emitted by polonium? (symbol for it and its name please)

An alpha particle - $^{4}_{2}\alpha$

(2 marks)

$3d^{10}4s^2$	$4s^24p^1$	$4s^24p^2$	$4s^24p^3$	$4s^24p^4$	$4s^24p^5$	$4s^24p^6$
48 Cd $4d^{10}5s^2$	49 In $5s^25p^1$	50 Sn $5s^25p^2$	51 Sb $5s^25p^3$	52 Te $5s^25p^4$	53 I $5s^25p^5$	54 Xe $5s^25p^6$
80 Hg $5d^{10}6s^2$	81 Tl $6s^26p^1$	82 Pb $6s^26p^2$	83 Bi $6s^26p^3$	84 Po $6s^26p^4$	85 At $6s^26p^5$	86 Rn $6s^26p^6$

5. Write out the nuclear equation showing the decay that would take place within a polonium nucleus. (Use the section of the periodic table given on the right to work out the symbol for the daughter nucleus).

(3 marks)

$$^{210}_{84}Po \longrightarrow {}^{4}_{2}\alpha + {}^{206}_{82}Pb$$

6. News reports are saying that careful handling of polonium is not a threat to careful handlers but it is deadly as a poison if administered as such. Explain why this is true as fully as you can.

Alpha sources are **not dangerous outside the body** as they **cannot penetrate** through the skin to reach sensitive organs but if **ingested it is very dangerous** as alpha particles have **low penetrating power** which involves very **concentrated damage** due to **intense ionisation** in a small locality. This is made worse by the relatively short half life of Polonium which means that a small sample will have a high activity. (4 marks)

7. News reports are saying that this poisoning was arranged by people in powerful positions with government connections not just people with money. Why would they say that?

Polonium is difficult to get hold of. Polonium is available commercially on special order from the Oak Ridge National Laboratory, Tennessee. It can only be produced in large enough concentrations to use as a poison from nuclear establishments. It will therefore be expensive and you would have to fill in a form saying what you needed it for.

(2 marks)

8. News reports say that a post mortem has yet to be carefully carried out. Explain why anyone present at the post mortem might be at risk because of the nature of the poisoning that is suspected and list precautions you would expect to be put in place and the reasoning behind this.

His body fluids would contain polonium and at a post mortem cutting etc. would cause tiny specs of body fluids to become airborne – anyone breathing them in would then take polonium into their own bodies. It would therefore be necessary to wear masks/breathing apparatus and body suits. After the PM the instruments used would have to be carefully washed or disposed of and the room and suits thoroughly cleaned. (3 marks)

9. 'Biological half life is the time taken for the activity of the sample within the body to halve.' Explain what is meant by the physical half life of a radioactive isotope as opposed to the biological half life.

The physical half life of a radioisotope is the time taken for half of the nuclei of that radioactive isotope in a sample to decay. That time is not affected by the physical conditions that the isotope is subjected to. (1 mark)

10. Name the other form of nuclear radiation you would expect to be given out by Polonium 210 and explain why it would be given out in addition to the principal form of radiation.

Gamma rays would also be given out. These are given out when a nucleus adjusts to a lower energy state after ejecting particles. When the alpha particle leaves the other nucleons have to adjust their position within the nucleus to fill up the gap – this involves a change in energy level. (2 marks)