Part 1: Nuclear safety

Having watched the video that outlines how a physicist working with radioactive materials exercises strict safety procedures to minimise exposure to radiation poisoning, answer the following questions.

1. What are three fundamental principles that handlers of radioactive materials need to consider when dealing with radioactive substances?

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2. List all safety precautions the physicist took while handling the radioactive isotope.

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3. List any actions of the physicist that might be considered to be unsafe handling of radioisotopes.

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4. List as many ways as possible that you consider the physicist could improve her procedures to make the handling even safer.

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5. Would handling procedures for dealing with alpha emitters need to be different from handling gamma emitters? Explain.

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6. Design a coloured label that could be fixed to the door of a school laboratory where radioisotopes are stored.

Part 2: Radioisotopes in medicine

- Read the following article from World Nuclear Association Information Paper (January 2008). *Radioisotopes in medicine*. Retrieved July 4, 2008, from http://world-nuclear.org/info/inf55.html, and answer questions that follow.

Introduction

There are several ways of using radioactivity in medicine. These include diagnosis of disease, external source cancer treatment and internal source cancer treatment. Each use is carefully designed for the patient and disease. In diagnosis, just enough radioactivity is given to the patient so that it can be detected and used to visualise or look at the function of the organ or tissue without causing damage; external and internal source radiation is limited to specific areas of the disease to minimise the effect on normal healthy cells and tissue.

Rapidly dividing cells are particularly sensitive to damage by radiation. For this reason, some cancerous growths can be controlled or eliminated by irradiating the area containing the growth. External irradiation can be carried out using a gamma beam from a radioactive cobalt–60 source, though in developed countries much more versatile linear accelerators are now being used. Linear accelerators deliver a uniform dose of high energy x-rays to a specific region of the patient's tumour. Internal radiotherapy is done by administering or seeding a small radiation source, usually a gamma or beta emitter, in the target area.

Every organ in our bodies acts differently from a chemical point of view. Doctors and chemists have identified a number of chemicals that are absorbed by specific organs. The thyroid, for example, takes up iodine, the brain consumes quantities of glucose, and so on. With this knowledge, radiopharmacists are able to attach various radioisotopes to biologically active substances. Once a radioactive form of one of these substances enters the body, it is incorporated into the normal biological processes and excreted in the usual ways.

Iodine-131 is commonly used to treat thyroid cancer, and is probably one of the most successful cancer treatments. Iodine-131 is also used to treat non-malignant thyroid disorders. In the head and breast, iridium-192 implants are used. They are produced in wire form and are introduced through a catheter to the target area. After administering the correct dose, the implant wire is removed to shielded storage. This brachytherapy (short-range) procedure gives less overall radiation to the body, is more localised to target the tumour and is cost effective.

Diagnostic radiopharmaceuticals

The amount of the radiopharmaceutical given to a patient for diagnostic purposes is just sufficient to obtain the required information before its decay. The radiation dose received is considered medically insignificant. The patient experiences no discomfort during the test and after a short time there is no trace that the test was ever done. The non-invasive nature of this technology, together with the ability to observe an organ functioning from outside the body, makes this technique a powerful diagnostic tool.

A radioisotope used for diagnosis must emit gamma rays of sufficient energy to escape from the body and have a half-life short enough for it to decay completely soon after imaging is completed.

The radioisotope most widely used in medicine is technetium-99m, employed in some 80% of all nuclear medical procedures. It is an isotope of the artificially-produced element technetium and has almost ideal characteristics for a nuclear medical scan.

- Its half-life of six hours is long enough to image or examine a metabolic process yet short enough to minimise the radiation dose to the patient.

- Technetium-99m decays by a process called isomeric decay which emits gamma rays and low energy electrons. Since there is no high energy beta emission the radiation dose to the patient is low.
- The low energy gamma rays it emits easily escape the human body and are accurately detected by a gamma camera. Once again the radiation dose to the patient is minimised.
- The chemistry of technetium is versatile. It can form tracers by being incorporated into a range of biologically-active substances to ensure that it concentrates in the tissue or organ of interest.

Technetium generators, comprising a lead pot enclosing a glass tube containing the radioisotope, are supplied to hospitals from the nuclear reactor where the isotopes are made. They contain molybdenum-99, with a half-life of 66 hours, which progressively decays to technetium-99m. The Tc-99m is washed out of the lead pot by saline solution when it is required. After approximately two weeks the generator is returned for recharging.

Therapeutic radiopharmaceuticals

For some medical conditions, it is useful to destroy or weaken malfunctioning cells using radiation. The radioisotope that generates the radiation can be localised in the required organ in the same way it is used for diagnosis: through a radioactive element following its usual biological path, or using elements attached to a suitable biological compound. In most cases, it is beta radiation that causes the destruction of the damaged cells. This is radiotherapy. Short-range radiotherapy is known as brachytherapy, and this is becoming the main method of treatment. Radioisotopes can also be implanted using surgical methods to localise the effects.

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Questions

7. What type of radiation (alpha, beta or gamma) does polonium-210 emit? What evidence from the article supports your answer? (See the section *Radioisotope poisons*)

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8. Why is cobalt used for external radiotherapy instead of alpha radiation?

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9. How does brachytherapy differ from external irradiation?

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10. When using diagnostic radiopharmaceuticals why is there no trace of a radiation dose given to a patient a short time after the procedure?

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11. Technetium-99m is widely used in medicine. Its half-life is about six hours. How can it be produced in the Eastern states of Australia and still be used effectively in Western Australia many days later?

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12. Why are the half-lives of isotopes used in diagnosis and treatment of people relatively short (a matter of days, rather than weeks or years)?

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13. What is the difference between a therapeutic and a diagnostic radioisotope?

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14. Technetium–99m (Tc-99m) decays to produce gamma rays and low energy electrons that can be detected by a gamma camera. Explain what gamma rays are.

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15. In this article, is Tc-99m being used for diagnostic or therapeutic purposes? Explain.

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16. Iodine-125 with a half-life of 60 days is widely used in cancer brachytherapy (prostate and brain). If iodine-125 is administered to a patient to treat prostate cancer how long will it take (approximately) for I-125 activity to reduce to one eighth of its original activity?

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Part 3: Research questions

17. What is the meaning of metastatic?

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18. The article refers to radiation 'destroying' or 'weakening' cells. Describe effects of radiation on living cells and how they are killed by it.

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19. Consult references to write a paragraph on one of the Curie family. Choose either Pierre, Marie or Irene. All three worked with radioactive materials and were pioneers in the development of radioisotopes for use in medicine.

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