Written Exam, Radiation Protection, Dosimetry, and Detectors (SH2603), January 14, 2008

Allowed aids: pocket calculator.

The tables you need is handed out together with this exam
To pass the exam, you need at least 6 points from Section A, **and** at least 4 points from Section B (also for Fx).

Grading is determined by the total number of points:
A:20-22, B:18-19.5, C:15-17.5, D:13-14.5, E:11-12.5, Fx:10-10.5, F:0-9.5

Halv-points (0.5 etc) can be rewarded for partially correct answers

Motivate your answers by calculations and text. Write clearly.

Make your own, reasonable assumptions, when necessary. It should be clear from your text what assumptions you make.

Good Luck!

Section A

1. A ^{235}U nucleus in a nuclear reactor absorbs a slow neutron. The nucleus then fissions, creating two new nuclides: ^{93}Rb and ^{140}Cs. Three neutrons are emitted in the process. Using the mass differences, calculate the energy release in this particular fission event (give the answer in MeV). [1 p]

2. What is the range, in water, of the most energetic electrons emitted from a ^{90}Sr+^{90}Y source? [1 p]

3. Two scientists are doing work in the nuclear physics laboratory. They are studying the isotope ^{203}Hg, using a plastic scintillator to detect electrons that are emitted from the radioactive source. The scientists see a continous energy spectrum from zero up to about 210 keV. But at 193 keV they see a sharp peak, indicating a discrete energy of the electrons. Which process in the radioactive source is responsible for this sharp peak in the electron energy spectrum? Name the process and explain what happens in the process. [1 p]

4. A 1 mCi closed ^{18}F source is used in a hospital. Will any photons be emitted from the source or not? Explain. [1 p]

5. In a laboratory, a strong Co-60 source (100 mCi) is kept inside a safe-box with lead walls (5 cm thickness) to limit the gamma radiation exposure of the staff working in the lab. But when the dosimeters are checked it turns out that the dose is still too high. It is decided to reduce the gamma intensity from the box by a factor of 100. The solution is to increase the lead wall thickness of the safe-box. How thick must the new walls be? [1 p]

6. The gamma radiation from a closed Cs-137 source is analysed using a small NaI scintillator detector. A sharp peak (the photo-peak) is visible at 662 keV. At lower energies there is a continous distribution of detected energies, starting near zero and reaching almost all the way up to the photo peak energy. Explain the origin of this continous distribution of energies (draw a picture if you like). [1 p]

7. Some radioctive elements can be used as heating devices due to self-absorption of ionising radiation. Assuming that we could produce the radioisotope ^{210}Po in large quantities. Then we could assemble a polonium-210 pile with the same mass as a typical (3GW$_{th}$) nuclear reactor (100 tons). What is the thermal power of the ^{210}Po pile? [1 p]

8. What is the difference between the **absorbed dose** and the **dose equivalent**? [1 p]

9. A child (30 kg) opens a smoke detector and swallowes the 1μCi ^{241}Am source. Assuming that the source dissolves and distributes over the whole body, what is the effective dose over 24 hours? [1 p]

10. What is the dose limit, i.e. the highest allowed effective dose from ionising radiation (as recommended by the ICRP as well as the Swedish authorities) for a person working with radioctivity in the nuclear industry? [1 p]

Section B

1. The human body contains approximately 2 grams of potassium per kilogram. Assuming that ^{40}K is the only contribution to radioactivity in the body, calculate you own body activity [1 p]. Making reasonable approximations, calculate the effective dose that you will get from your own radioactivity during one year [2 p].

2. In accident scenarious (such as after the Chernobyl accident), helicopters are sometimes flown over areas with radioactive material. To reduce the dose to the personnel in the helicopter, we could mount some protective plate (lifted by the helicopter) that reduces the gamma intensity from the ground by absorption. Choose the material that is best suited for such a protective plate. Motivate your answer well [1p]. (Note that the helicopter have a limited lifting capacity (e.g. one ton), so that it is not only the gamma absorption that matters, but also the mass of the plate.)

   In the Chernobyl accident, many radioactive isotopes were released in a radioactive cloud, escaping the reactor buildning. Two important isotopes in this scenario are the fission products I-133 and Cs-137. Just before the accident the core contained 4 times more Cs-137 than I-133. Which of the two radioisotopes represented the highest activity in the radioactive cloud immidiately after the accident [1 p]? How long time after the accident did it take before the two activities were equal? [1 p]

3. When transporting a very strong cesium-137 source (1000 Ci), there is a car accident on a bridge over a lake. The radioactive source drops out of its large container and falls down in the lake, ending up on the bottom of the lake at a depth of 10 meters. The empty container also also drops into the lake, ending up a few meters from the source.

   A diver is sent by the authorities to retrieve the source. The diver uses a two meter long manipulator rod in order to keep some distance to the source. Working underwater, she is able to put the source back into the container, so that it can be safely removed later on. The diver's work moving the source with the rod is difficult and takes ten minutes. Calculate the effective dose that the diver receives. [3 p]

4. A Bi-209 sample is put inside a nuclear reactor to irridiate it with a high intensity of thermal neutrons. After a few days, the sample is removed from the reactor. One week later the sample is analysed by various detector systems, i.e a germanium detector for gamma spectroscopy, a plastic scintillator for beta spectroscopy, and a silicon detector for alpha spectroscopy. Explain the nuclear processes that takes place in the sample. Should we expect any gamma photons. If so, from which nuclide? At which energ(y/ies)? Should we expect any beta electrons? If so, from which nuclide? At which energ(y/ies)? Should we expect any alpha particles? If so, from which nuclide? At which energ(y/ies)? [2 p].

   The sample is then stored for 10 years. It is then analysed chemically. Which elements do we expect to find in the sample? [1 p]