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Los Alamos NATIONAL LABORATORY

DOE Radiological Triage Program
Analyst Open Book Exam 2021

Name:________________________________ Date:____________________

The following questions test your knowledge relevant to the DOE Radiological Triage program. There is no time limit, and you may use any reference materials or software you like. You may discuss with other analysts but please show your own work. Spectra are provided in electronic form. There are 10 questions and up to 1 point of extra credit is available. A score of 80% is required to pass. Please send your answers in any convenient form to Mercer@LANL.gov.

Question 1: A curator for the Museum of Natural History was approached about purchasing a large piece of californium from a supplier in India. See attached image, *Californium Report.jpg*

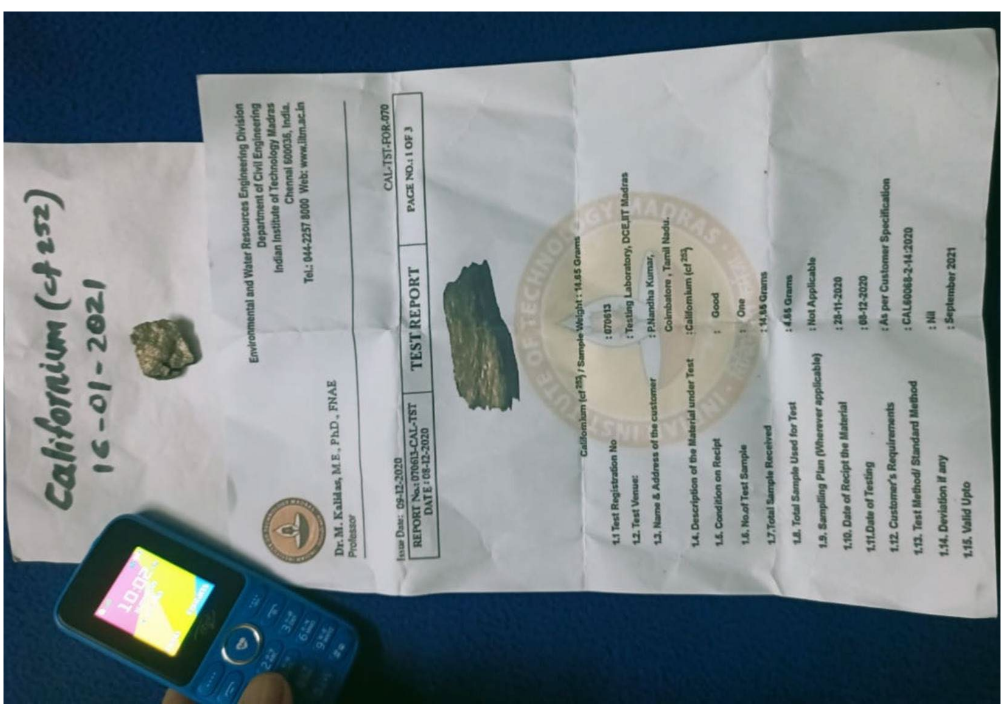
(1a) Does this seem to be a legitimate sample or a hoax? Please explain.

For questions b, c, and d, assume that the sample is actually 10.0 g of pure Cf-252.

(1b) What is the neutron output (in neutrons/second) of such a sample?

(1c) What is the equivalent neutron dose rate (in rem/hr) at 1 meter?

(1d) If a museum patron examined this sample for 10 minutes at a distance of 1 foot with no intervening shielding, would the neuron dose be greater than, or less than, an LD50 dose?

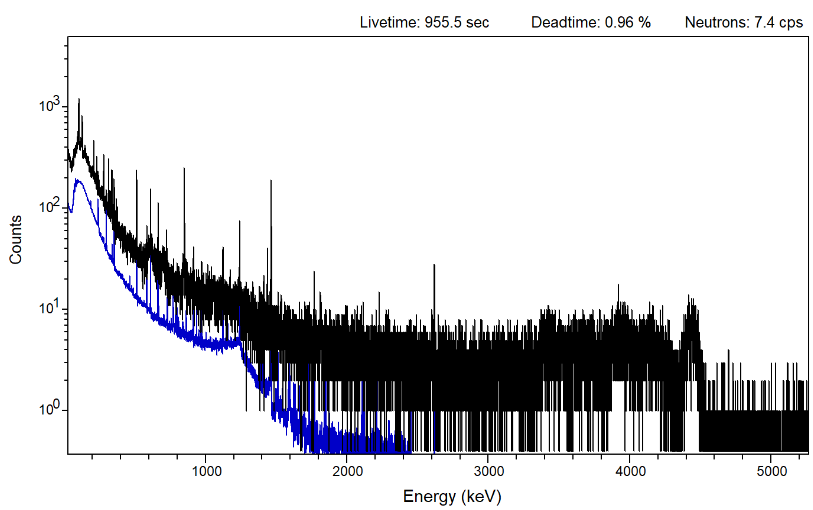


Question 2: The spectrum *Neutron Source.SPE* is collected from a source used for soil moisture measurements. The source was from a 1970's style Troxler gauge (pictured) but has been removed and placed in a stainless steel container. A background spectrum is also available.

(2a) What reaction(s) and/or phenomena produce(s) the structure between 3300 and 4500 keV? (0.4 points)

(2b) What neutron activation and/or neutron scatter lines can you identify? You will earn 0.1 points for each line correctly identified (0.3 points for the main problem, and up to 0.4 points of extra credit for additional lines identified).

(2c) Stainless steel contains up to 20% chromium. Is a statistically significant signature of the neutron activation product Cr-51 visible? What is a possible explanation for the low (or zero) amount of Cr-51 observed? (0.3 points)



Question 3: The spectrum from the previous question was collected using a Detective-X at a distance of 100 cm. You may assume that steel is the only attenuating material.

(3a) Estimate the thickness of the steel container wall (0.4 points).

(3b) Estimate the quantities of Am-241, Am-243, and Np-237. Assume that all curium and neptunium isotopes were chemically removed when the source was manufactured (0.6 points).

Extra Credit: By comparing the Am-241 and Np-237 lines, what can you infer about the time between the chemical separation and the measurement date? (up to 0.2 points)

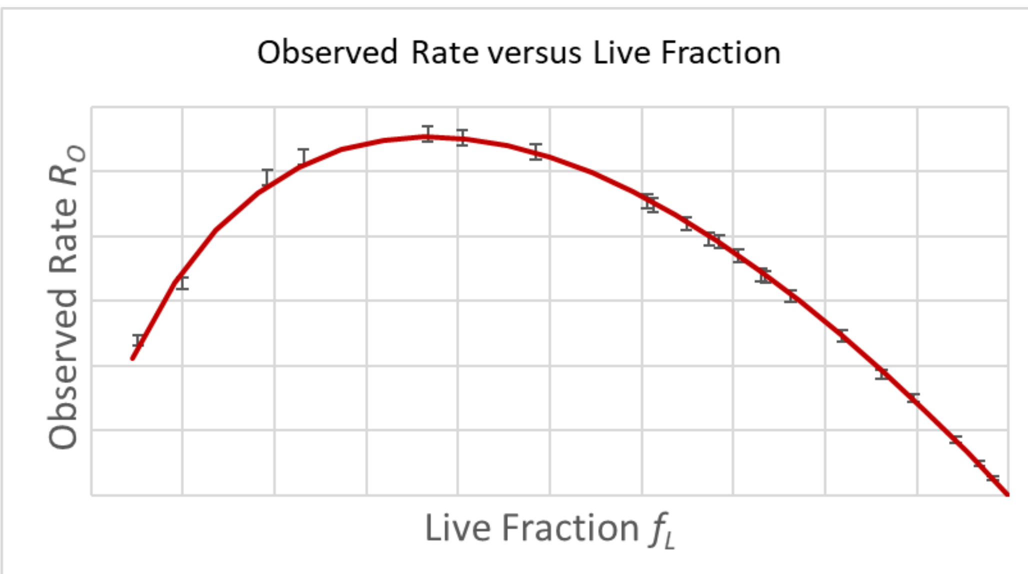
Question 4: The dead time constant “τ” of a detector is defined as the minimum time interval by which two consecutive pulses must be separated in order to be recorded as two different events, typically 10-30 microseconds. To a reasonable approximation, the observed count rate R_O, the input rate R_I, and the live fraction f_L are related as

$$f_L = \frac{R_O}{R_I} = e^{-R_I \tau}$$

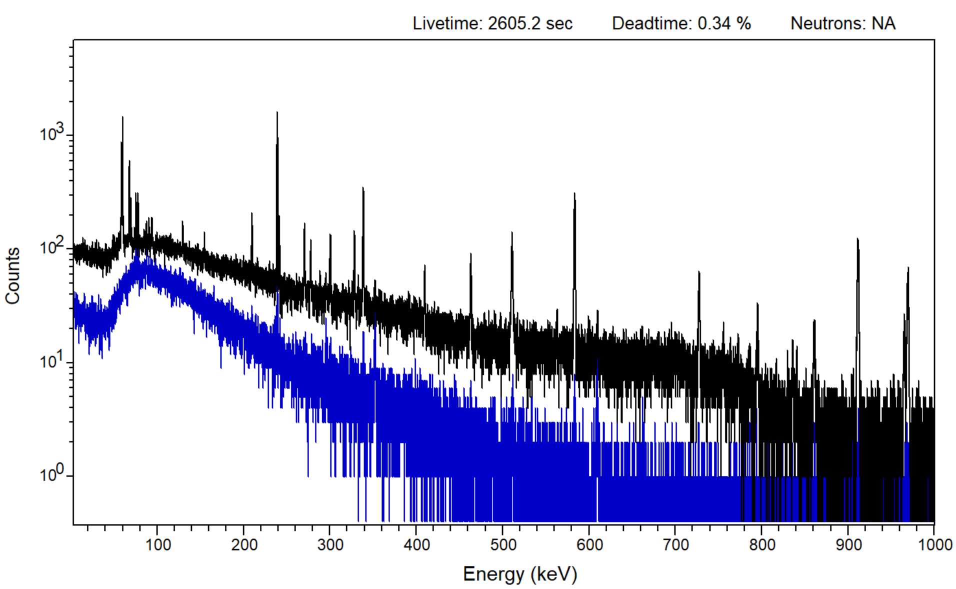
so

$$R_O = -\frac{1}{\tau} f_L \ln(f_L)$$

For what live fraction f_L is the observed rate R_O maximized? Note that this is independent of τ. What is the corresponding dead fraction $f_D = 1 - f_L$?



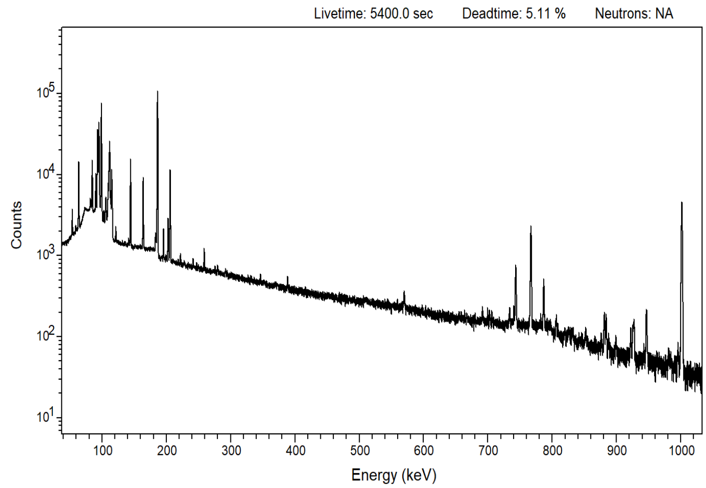
Question 5: This spectrum was collected from either <u>lantern mantles</u> or <u>welding rods</u> made with natural thorium. Which one is it? What feature(s) did you use to discriminate? The detector is a 2.5-inch × 1.5-inch planar HPGe with a Pb-Cd collimator and Be window. See *Thorium.CNF* and *Thorium Background.CNF*



Black=foreground, blue=background.

Question 6: The spectrum *Pellet.P3t* was collected from a low-enriched uranium fuel pellet. The spectrum is collected with the pellet nearly in contact with the face of the detector. Also see *40pct_SpecSheet.pdf.* The goal is to determine the enrichment (U-235/Total U mass ratio).

Pellet is in a plastic holder centered on the detector face, separated from detector by 1 mm of plastic.

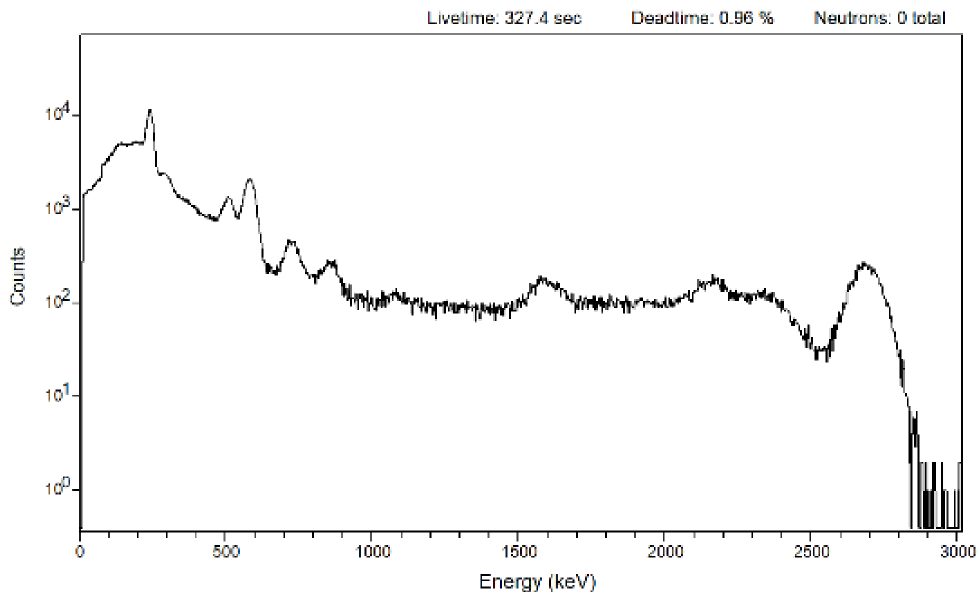


(6a) What is the calculated enrichment presuming chemical separation occurred more than 2 years ago?

(6b) What is the calculated enrichment presuming chemical separation on 01 July 2021?

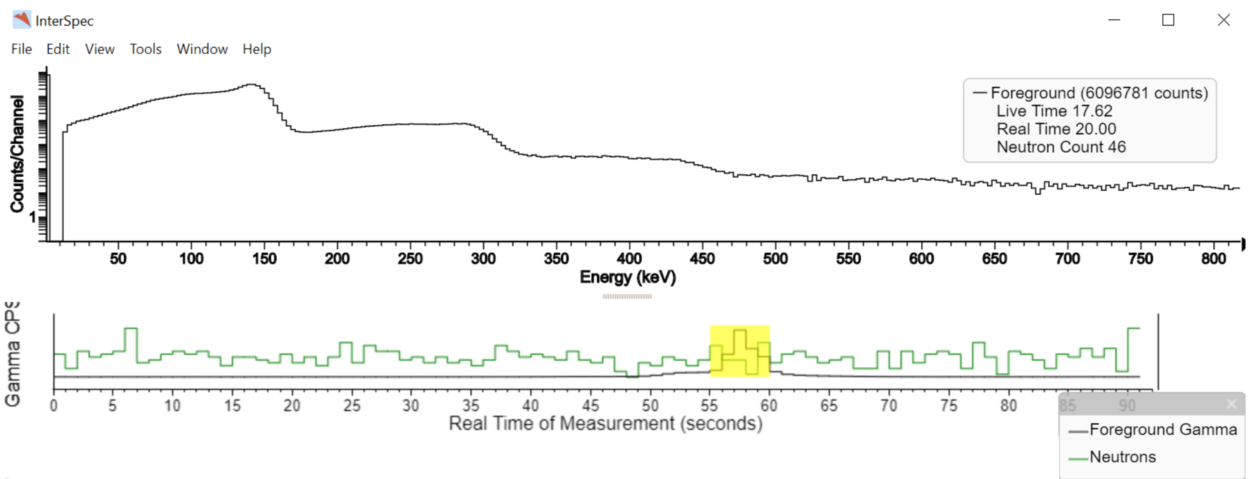
(6c) What is the U-234/U-235 mass ratio? Does the presumed time since chemical separation affect this ratio?

Question 7: This radionuclide was once involved in tests for therapy of tuberculosis and ankylosing spondylitis, but was discontinued following a high rate of side effects. There is renewed interest in the form of coated calcium carbonate microparticles. Identify this alpha-emitting radionuclide, visible in the spectrum *Brachytherapy.n42,* courtesy of LSS.



Question 8: The file *Portal.n42* contains a time series of spectra from a Radiation Solutions Model RS-705 spectroscopic portal monitor, which has four 2-inch × 4-inch × 16-inch NaI detectors and two Li-6 "Silverside" neutron modules that are linked together. Spectra are recorded once every second while a person walks through the portal. Spectra are available in a linear format (3 keV/channel, "LinEnCal") and also in a format with variable channel width ("CmpEnCal").

What common medical radionuclide do you observe?



Question 9: Domestic intelligence causes the FBI to investigate a warehouse (40 m deep × 10 m wide). An external gamma/neutron survey identified a broad gamma hotspot on a loading dock, centered on the roll-up door and 1 meter above the dock. Near/far gamma dose rates reported by an IdentiFinder were measured:

Contact with door = 30 uR/hr

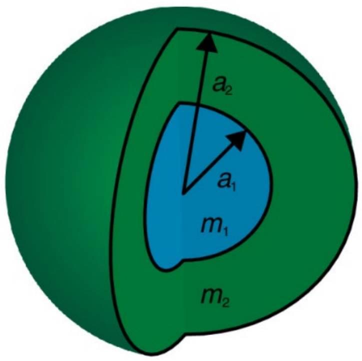
2.5 meters from door = 15 uR/hr

No gamma background values reported.

No elevated neutron hotspot.

The FBI has made a time-urgent operational decision to enter the warehouse without further gamma/neutron diagnostics. Advise the FBI on what to expect for the radiological source location and what factors and limitations may affect that result. (For full credit, provide an estimated source location, plus list three factors that may affect the accuracy of the result.)

Question 10: Consider a nominal solid 1-kilogram sphere of WGPu shielded by a shell of depleted uranium. The DU shell is designed to reduce detectability of the plutonium signature. Detailed material and measurement properties are given below:



WGPu: Delta phase metal, Ga 0.60%, Pu-236 1.5E-8%, Pu-238 1.5E-2%, Pu-239 92.9%, Pu-240 6.0%, Pu-241 0.50%, Pu-242 1.0E-2%, age 20 years, m_1=1.0 kg, a_1=24.7 mm.

DU: metal, U-234 1.5E-3%, U-235 0.2%, U-238 99.8%, age 20 years, m_2 and a_2 are not unspecified.

1800-second (real time) measurement using a Detective EX-100 and 1.0 meter detector-to-source distance, measured at the Albuquerque airport.

(10a) What is the minimum thickness (a_2-a_1) of the DU shell necessary so that the 413.7 keV gamma ray will not be observable in the spectrum? Specify the criterion used; full credit given for any reasonable approach and answer.

(10b) With the shell thickness you determined, are any other gamma rays from plutonium visible?

(10c) With the shell thickness you determined, are any gamma rays from americium visible?

(10d) With the shell thickness you determined, what is the estimated neutron leakage (n/s)?

Extra Credit: The spectrum *SX_Closed.CHN* was collected using a small coaxial HPGe from an aqueous Pu sample that has been freshly separated via solvent extraction.

(a) Identify the gamma ray lines at 88.0 and 558.6 keV (0.2 points)

(b) What is the mass ratio of Am-241 to total Pu? (0.2 points)