HAZARDS OF SOME ISOTOPES IN SPENT FUEL COMPARED TO THE HAZARD OF URANIUM ORE

Directions: Use the graph entitled *Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore* to answer the questions below.

Part I

1. Identify the isotopes. (If necessary, refer to the periodic table of the elements.)

^{90}Sr	*Strontium-90*	^{241}Am	*Americium-241*	^{137}Cs	*Cesium-137*
^{238}Pu	*Plutonium-238*	^{240}Pu	*Plutonium-240*	^{239}Pu	*Plutonium-239*
^{237}Np	*Neptunium-237*	^{229}Th	*Thorium-229*	^{210}Pb	*Lead-210*

2. Identify the information on each axis.

X axis (horizontal):

The x axis uses a logarithmic scale (exponential notation) to represent the years of spent fuel storage. How many years are represented by each of the following:

10^{-1}	*0.1*	1	*1*	10	*10*	10^{2}	*100*	10^{3}	*1,000*
10^{4}	*10,000*	10^{5}	*100,000*	10^{6}	*1,000,000*	10^{7}	*10,000,000*		

Y axis (vertical):

Relative hazard is one of many ways to compare the potential hazards of radioactive elements. The y axis measures the "relative hazard" of each isotope compared to the hazard of uranium ore, which is naturally radioactive. Although all the isotopes in spent fuel are not shown, the hazard from all isotopes present in spent fuel, considered as a whole, is shown as "Total."

Like the x axis, the y axis is a logarithmic scale. From the relative hazard list given below, insert the correct term in sentences a-f.

one tenth	one hundredth	ten times
one hundred times	one thousand times	ten thousand times

a. A substance located at 0.01 represents (*one hundredth*) the hazard of uranium ore.

b. A substance located at 0.1 represents (*one tenth*) the hazard of uranium ore.

c. A substance located at 10 represents (*10 times*) the hazard of uranium ore.

d. A substance located at 100 represents (*100 times*) the hazard of uranium ore.

e. A substance located at 1,000 represents (*1,000 times*) the hazard of uranium ore.

f. A substance located at 10,000 represents (*10,000 times*) the hazard of uranium ore.

Part II

1. When spent fuel is first placed in storage, what is the hazard of the isotopes in the spent fuel in comparison to the hazard of uranium ore?

   Sr-90 between *100* and *1,000* times (more? less?) hazardous than uranium ore

   Cs-137 between *10* and *100* times (more? less?) hazardous than uranium ore

   Pu-238 between *10* and *100* times (more? less?) hazardous than uranium ore

   Am-241 between *1* and *10* times (more? less?) hazardous than uranium ore

   Pu-240 between *1* and *10* times (more? less?) hazardous than uranium ore

   Pu-239 between *1* and *10* times (more? less?) hazardous than uranium ore

   Np-237 between *1/10* and *1* times (more? less?) hazardous than uranium ore

2. Between what years does each of the following isotopes reach the level of hazard of uranium ore? (The first answer is done as an example.)

Element	**Storage Time (Exponential Notation)**	**Storage Time (Years)**
Sr-90	*Between 10^2 and 10^3 years*	*Between 100 and 1,000*
Am-241	*Between 10^3 and 10^4 years*	*Between 1,000 and 10,000*
Cs-137	*Between 10^2 and 10^3 years*	*Between 100 and 1,000*
Pu-238	*Between 10^2 and 10^3 years*	*Between 100 and 1,000*
Pu-239	*Between 10^4 and 10^5 years*	*Between 10,000 and 100,000*
Pu-240	*Between 10^4 and 10^5 years*	*Between 10,000 and 100,000*
Np-237 (first)	*Between 10^2 and 10^3 years*	*Between 100 and 1,000*
Np-237 (second)	*Between 10^6 and 10^7 years*	*Between 100 and 1,000*

Between what years does the hazard of the spent fuel considered as a whole reach the level of hazard of uranium ore?

Total	*Between 10^6 and 10^7 years*	*Between 1,000,000 and 10,000,000*

3. Does the relative hazard for an isotope decrease over the long term? Explain.

(Yes. Radioactive isotopes undergo radioactive decay. As a result, they become less hazardous over long term.)

4. Does the relative hazard for an isotope always decrease over shorter time periods? Explain your answer.

(Over shorter periods of time, the hazard represented by a given isotope may actually increase rather than decrease. This is because the amount of that isotope present in spent fuel may increase because it is created as a product of decay when another isotope in the spent fuel decays.)

5. When the spent fuel is first placed in storage, the relative hazard of neptunium-237 is (less?) than that of uranium ore. After 10^3 years, the hazard has (increased?). Then at about 10^6 years, it (decreases?) to that of uranium ore and continues to (decrease?). Explain how this is possible.

(The increase is the result of radioactive decay of another isotope. Neptunium-237 is a decay product of plutonioum.)

6. Look at the graphs of relative hazard for Th-229 and Pb-210. Notice that their graphs do not even begin until approximately 10,000 years. Where do you think these isotopes come from? How hazardous are they compared to uranium-238?

(Th-229 and and Pb-210 result from decay of other isotopes present in spent fuel. They present less hazard than U-238.)

7. In the graph, the hazard for uranium ore is shown as a constant for comparative purposes. In reality, the hazard for uranium changes over time. Do you think the hazard for uranium would increase or decrease over time? Why?

(Uranium will undergo radioactive decay because it is a radioisotope. As a result of decay, it will become less hazardous.)

8. The canister in which spent fuel will be stored is being designed to provide isolation for a minimum of 300 years. The repository itself must provide isolation of spent fuel from the accessible environment for 10,000 years. Using the information in the graph, explain why 300 years and 10,000 years are reasonable periods of time.

(After about 300 years, isotopes with most intense levels of radioactivity will have decayed so that they present about the same relative hazard as uranium ore. By 10,000 years, isotopes in spent fuel will present about the same hazard as naturally occuring uranium ore that is part of our natural environment.)

Part III

1. The period of time represented on the x axis is very long. To get some perspective of exactly how long, a timeline is shown below that goes back in time. Put the following items on the timeline in the appropriate place by making a tick mark and labeling it. The first item is done as an example. (If necessary, refer back to Part I for the conversions from exponential notations.)

   a. Average lifespan of US citizen—70-72 years

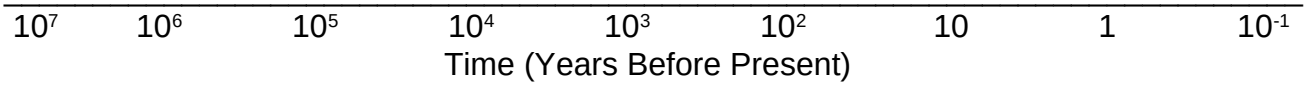
   b. The oldest known living plant (in 1990), a bristle cone pine, which is growing in the Sierra Nevada Mountain, sprouts in the area of the Nevada/California border—4,900 years ago

   c. End of last Ice Age—10,000 years ago

   d. Meteor strikes Arizona and creates Meteor Crater—150,000 years ago

   e. Beginning of last Ice Age—2,500,000 years ago

   f. Earliest primate hominid remains deposited—5,000,000 years ago



2. Despite the length of time represented above, it is not very long in comparison to time spans used to describe the whole history of the Earth. To illustrate this point, several other important dates that geologists have established are given below. What are those dates in years?

   a. Years since the last dinosaurs died: 6.5×10^7 = *65,000,000*

   b. Years since the formation of the Earth: 4.6×10^9 = *4,600,000,000*

   c. How many years elapsed between the formation of the Earth and the end of the dinosaurs?
   4,535,000,000

   d. How many years elapsed between the formation of the Earth and the beginning of the last Ice Age? *4,597,500,000*

   e. How many years elapsed between the end of the dinosaurs and the beginning of the last Ice Age? *64,990,000*

Across the top of the graph entitled "Relative Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore" are tick marks. Label them to match the timeline for time before the present. Then add points along the top to represent the correct location for items a through f in question 1. This will help you to understand the length of time for storage of spent fuel that is represented by the graph.

Then answer the questions on the next page.

3. Suppose you live in St. Louis and have a time machine and decide to check the figures on this graph. You travel back in time 10^4 years ago. Would you need to take a coat? Why or why not?

(You would need a coat because the last Ice Age would just be ending.)

4. Then you travel into the future. After 5,100 years of travel, a little longer than the length of time the bristle cone pine has lived, you stop to think about the spent fuel in storage.

a. What is the relative hazard of strontium-90 when you check it compared to what its hazard was in the present?
(The relative hazard of strontium-90 will have decreased to the same level as uranium ore before 1,000 years have passed. By 5,100 it will present much less hazard than uranium ore.)

b. What is the relative hazard of Americium-241 in comparison to the hazard of uranium ore? Has the relative hazard changed at all during the 5,100 years? Why or why not?
(Americium-241 will have increased in hazard. There will be more of this isotope present because it is a decay product.)

c. At 5,100 years, what isotopes are still more hazardous than the standard for uranium ore? (Use abbreviations.)
(Am-241, Np-237, Pu-239, Pu-240 will all present more hazard than uranium ore at 5,100 years.)

d. How does the hazard of all the isotopes considered as a whole (i.e., Total) compare to the hazard of uranium ore?
(The total hazard is greater than that presented by uranium ore at 5,100 years.)

e. Why are the decay rates shown important in planning for disposal of spent fuel?
(The hazard of radioactive materials decreases over time. The decay rates tell how long the materials will remain hazardous in comparison to naturally occurring uranium ore. This permits planning for disposal.)

HAZARDS OF SOME ISOTOPES IN SPENT FUEL COMPARED TO THE HAZARD OF URANIUM ORE