Name: ______________________________ Date: ______________

NUMB3RS Activity: A Matter of Half-Life and Death

A truck hauling radioactive waste is hijacked on its way to New Mexico. The FBI is called in to consider the possibility that the hijackers intend to use the radioactive material to make a "dirty bomb." A dirty bomb, also called a Radiological Dispersal Device (RDD), uses conventional explosives like dynamite, to spread radioactive material over a large area. Charlie and Larry discuss the properties of the material and its impact if used to make a bomb.

The material on the hijacked truck is Caesium-137 (Cs-137, or ^{137}Cs) – a radioactive isotope usually formed by nuclear fission, such as is used to produce nuclear power. It is the principal radiation source at the site of the Chernobyl disaster, which occurred in Russia in 1986. Its half-life is 30.23 years, where a half-life is the amount of time for half of the nuclei of the substance to decay.

Charlie and Larry estimate that the amount of pure ^{137}Cs on the truck is about 500 grams. If made into a dirty bomb, there is enough to contaminate an area of nearly 30 km^2. For ^{137}Cs's decay, use the model $y = a(.5)^{(x/h)}$, in which *a* represents the initial amount, *h* is the length of a half-life in a specified time unit, *x* is the time, and *y* is the resulting amount. Enter the equation on your Y= screen (using *x*). Use the WINDOW shown to draw the GRAPH of the first half-life. Note that after one half-life, exactly half of the original ^{137}Cs remains.

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WINDOW
 Xmin=0
 Xmax=30.23
 Xscl=1
 Ymin=0
 Ymax=500
 Yscl=10
 Xres=1
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Now examine the table of values for this function. Use 2nd [TBLSET] with TblStart =0, and ΔTbl=10. Use 2nd [TABLE] to view the table as at the right. Experiment with different values of TblStart and ΔTbl, as well as the WINDOW for the graph, then switch between the graph and table to answer the following questions (express answers to #2 and #3 to the nearest hundredth of a year, consistent with the way that the half-life of ^{137}Cs is given):

X	Y1
0	500
10	397.55
20	316.09
30	251.32
40	199.83
50	158.88
60	126.33

X=0

1. How much of the original 500 g of ^{137}Cs will remain after exactly 50 years?
2. How long will it take so that 10% (to the nearest gram) of the original 500 g remains?
3. Suppose the "safe" amount in this sample of radioactive waste is 1.0 gram. How many years does this take for this amount to remain?

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In 1984, a hospital in Goiânia, Brazil was abandoned. One of the items left behind was a small canister of ^{137}Cs (originally made in 1971), used for radiation therapy. In 1987, two people found and managed to damage the canister, exposing themselves and many others to the radiation. As a result, four people, including a child, died; another 20 were hospitalized. Nearly 250 people received measurable doses of radioactivity. The incident is considered one of the worst accidents ever involving the mishandling of radioactive material. (For the details of the "Goiânia Accident," see "Extensions".)

The *biological* half-life of ^{137}Cs after ingestion is approximately 100 days (the time required for half the amount of radiation to leave the body).

4. Modify your equation from above to determine how long a person would have to survive (to the nearest whole day) following exposure such that 10% (to the nearest whole percent) of the radiation remains (use 1 as the initial amount).

Radioactivity is measure in *becquerels* (Bq) and represents the decay of one nucleus per second. The canister in Brazil contained 74 TBq (T - "tera", or 10^{12}) in 1971.

5. Using the half-life of ^{137}Cs (not the biological half-life), how much radioactivity was in the canister when it was abandoned in 1984?

6. How much radioactivity was there when it was found in 1987?

7. How much radioactivity is there now (2006)?

A *joule* (J) is approximately the amount of energy needed to lift 1kg of mass to a height of 10cm. The unit used to measure *absorbed dose* of radiation is the *gray* (Gy). It is defined as 1 J/kg, or the amount of energy absorbed by one kilogram of matter. Grays are used to measure physical effects (like burns) from radiation exposure. A similar unit, called a *sievert* (Sv), has the same definition but is used to measure the biological effects on different tissues (like cancer in muscles or bones).

The dose rate of the Goiânia canister at a distance of one meter was 4.56 Gy/hr.

8. There is a good chance (>95%) of surviving a dose of less than 3 Gy, thereby making it a "safe" dose. What is the maximum time of "safe" exposure?

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