

Name: \_\_\_\_\_

Period: \_\_\_\_\_ Date: \_\_\_\_\_



**BADDEST CLASS ON CAMPUS**

**RADIOACTIVE DECAY IN THE CLOSET**

**20 pts, Due: Nov 9**

**NOTE:** *You will need a copy of the old Tsokos book to complete this lab. Make sure you pick one up!!!*

**SITUATION:** A student brought a water pistol to school to harass a friend who constantly falls asleep in math class. When he attempts to use it, a first-year math teacher overreacts and orders a school-wide lockdown. When we get the word, we dutifully cram ourselves into the storage room. Ross, however, forgets the lockdown instructions given at the beginning of the year and fails to bring his snacks with him. Within 15 minutes of the start of the lockdown, Ross exceeds his maximum time of 23 minutes between snacks and starts opening jars in the closet. One of the jars he opens contains radioactive samples that emits beta particles and two that emit alpha particles. The lockdown ends up taking two hours and 15 minutes to complete.

Your job is to test the samples and determine if the 2-hour exposure was harmful using the chart provided on the class website. The teacher will use a Vernier radiation detection probe to make a 2-minute count of the sample emissions. Copy the data, extrapolate the 2-minute data to a 2-hour exposure, convert the exposure to Sieverts (old Tsokos pg. 712-715), and compare to the chart posted on the class website. Use the total effects of exposure to all three samples.

**DATA COLLECTION:**

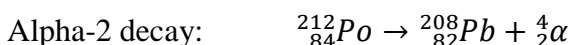
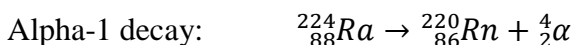
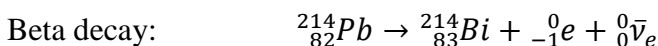
**Radiation Data:**

Time (s)	Beta (count)	Alpha-1 (count)	Alpha-2 (count)
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
110			
120			
<b>TOTAL</b>			

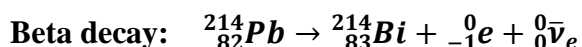
## PART A:

**Note:** From this point forward, do not round any numbers or apply the rules for significant figures. The amounts we are dealing with are very small and all decimal places count. For calculations, use all the numbers your calculator provides.

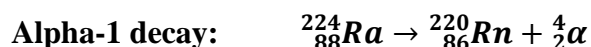
Further investigation has revealed that the following reactions were producing the decays:



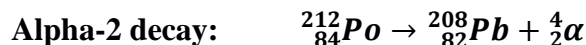
- Use the website <http://www.wolframalpha.com> to find the atomic masses of each component in each reaction (**except, use the following value for mass of an electron,  $m_e = 5.48603 \times 10^{-4}$** ). **Do not round off!!!**
- Compute the mass defect of each decay
- Convert the defect to eV and then to Joules.  $1 \text{ u} = 931.5 \text{ MeV}$ ,  $1 \text{ eV} = 1.602177 \times 10^{-19} \text{ J}$
- Show your work here or on a separate sheet, preferably an Excel Spreadsheet.



Component	Atomic Mass (u)
${}^{214}_{82}\text{Pb}$	
${}^{214}_{83}\text{Bi}$	
${}^0_{-1}\text{e}$	
Mass Defect (u)	
Mass Defect (eV)	
Mass Defect (J)	



Component	Atomic Mass (u)
${}^{224}_{88}\text{Ra}$	
${}^{220}_{86}\text{Rn}$	
${}^4_2\alpha$	
Mass Defect (u)	
Mass Defect (eV)	
Mass Defect (J)	



Component	Atomic Mass (u)
${}^{212}_{84}\text{Po}$	
${}^{208}_{82}\text{Pb}$	
${}^4_2\alpha$	
Mass Defect (u)	
Mass Defect (eV)	
Mass Defect (J)	

## **PART B:**

Assumptions:

- For the above decays, all of the mass defect is converted into kinetic energy of the products of the decay.
- For the alpha decays, disregard the fact that alpha particles are always emitted at discrete energy levels. Instead, make an estimation of the alpha particle's energy using conservation of momentum and conservation of energy.
- Assume momentum and kinetic energy are conserved for each reaction.
- Assume any potential energy is negligible.
- Assume the energy/momentum of the neutrino is negligible.

*Show the derivations for the equations used to determine the kinetic energy of the beta particle released in the above decay as sample equations for all three reactions. Compute kinetic energy for the three particles in the decays and write the values in the tables provided on the next page. This constitutes the energy per particle for each decay. If your work doesn't take up at least all of this page, you are doing something wrong. Record your calculations in the tables on the next page.*

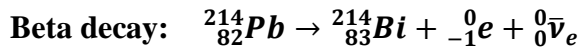
$$\text{Conservation of Momentum: } m_1 v_1 + m_2 v_2 = m_1' v_1' + m_2' v_2'$$

$$\text{Conservation of Energy: } \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1' v_1'^2 + m_2' v_2'^2$$

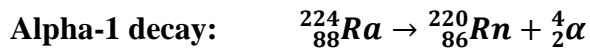
$$v_1 - v_2 = v_2' - v_1'$$

## SUMMARY OF PARTS A AND B:

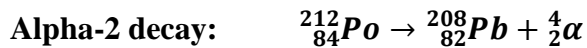
Transfer the atomic mass and mass defect from Part A, and the kinetic energy of the particle specified from Part B in the tables below.



Component	Atomic Mass (u)
${}_{83}^{214}\text{Bi}$	
${}_{-1}^0e$	
Mass Defect (J)	
$KE_e$	



Component	Atomic Mass (u)
${}_{86}^{220}\text{Rn}$	
${}_2^4\alpha$	
Mass Defect (J)	
$KE_\alpha$	



Component	Atomic Mass (u)
${}_{82}^{208}\text{Pb}$	
${}_2^4\alpha$	
Mass Defect (J)	
$KE_\alpha$	

## PART C:

Read Page 712-715 (Option I-3) in the old Tsokos textbook. We will now calculate the total energy exposure, the absorbed dose, and the dose equivalent. Once we have this number in Sieverts, we can find a comparison to see if our exposure was deadly or not – assuming we live long enough to finish our calculations. Be careful and conscientious in your work – our lives may depend on it!

- List the total number of particles counted (number of decays) for each of our three samples in the 2-minute count.
- Find the total number of decays for each sample by multiplying our two-minute count by 60 minutes.
- Fill in the information for energy per decay (KE) as calculated above.
- Calculate the total energy emitted by multiplying the energy per decay by the total number of decays.
- Fill in your best estimate for your body mass in kg.
- Damage done by radiation is dependent on body mass. If a large person and a small person are both exposed to the same dose of radiation, the smaller person would have more damage to tissue because the smaller person has fewer cells which means greater exposure per cell. The *absorbed dose* is defined as the amount of energy absorbed per unit mass. Assuming all the emitted radiation was absorbed, calculate and write down your absorbed dose.
- Different types of radiation produce different levels of damage to tissue. To find the *dose equivalent*, we multiply the absorbed dose by a dimensionless quality factor. Find the quality factors for the two different types of radiation on page 713 in your book and put them into the table below. Then calculate your dose equivalent. The units for dose equivalent is J/kg, but the name Sievert (Sv) is used to distinguish it from other forms of radiation exposure.
- Now find the total dose equivalent by adding the three individual values together.
- Now write your answer in terms of micro-Sieverts ( $\mu\text{Sv}$ ).

Value	Beta	Alpha-1	Alpha-2
Number counted (2 min)			
Total count (2 hr)			
Energy per decay (J)			
Total energy emitted (J)			
Body mass (kg)			
Absorbed dose (J/kg)			
Quality factor			
Dose equivalent (Sv)			
Total dose equivalent (Sv)			
Total dose equivalent ( $\mu\text{Sv}$ )			

## **ANALYSIS:**

1. Compare your value to the chart given on the webpage. Are we all going to die a horrific death due to radiation poisoning? If so, what is your best estimate of the number of days we have left? \_\_\_\_\_  
\_\_\_\_\_
2. Based on the chart, what activity is our exposure most comparable to? \_\_\_\_\_  
\_\_\_\_\_
3. Roughly how long would we have to be locked up in the closet to receive the same radiation exposure as you would during a dental x-ray? \_\_\_\_\_  
\_\_\_\_\_
4. If we were locked together in a closet for that long, would radiation really be your chief concern? If not, explain what would be. \_\_\_\_\_  
\_\_\_\_\_

**Room For Improvement:** Write any suggestions for improving this lab below.