

Physics 232 Exam III

Apr. 25, 2008

Soc. Sec # _____ Name _____

1. In a particular sample of mica, the ratio of a certain isotope of strontium to a certain isotope of rhobidium is found to be 0.05. Assume that all of this isotope of strontium is due to the decay of the rhobidium. The decay constant for rhobidium is $4.33 \times 10^{-19} yr^{-1}$.

- (a) **What is the lifetime of the rhobidium isotope?**

The lifetime is given by

$$t_{\frac{1}{2}} = \frac{0.693}{\lambda} = \frac{0.693}{4.33 \times 10^{-19}} = 1.60 \times 10^{18} \text{ yrs}$$

- (b) **How old is the sample?**

This is a radioactive decay problem with

$$N = N_0 e^{-\lambda t}$$

where λ is the decay constant. The decay constant in terms of the half-life is given by

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{1.6 \times 10^{18}} = 4.33 \times 10^{-19} yr^{-1}$$

The current number of rhobidium nuclei that we have left in terms of its original quantity is given by

$$N_r = N_{r0} e^{-\lambda t}$$

At the current moment, we also have to have that the number of strontium nuclei plus the number of rhobidium nuclei equals the original number of rhobidium nuclei.

$$N_s + N_r = N_{r0}$$

But we also have that

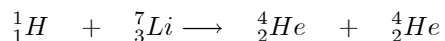
$$N_s = 0.05N_r$$

Then

$$\begin{aligned} 0.05N_r + N_r &= N_{r0} \\ \frac{N_r}{N_{r0}} &= \frac{1}{1.05} = 0.952 \end{aligned}$$

$$\begin{aligned} \frac{N_r}{N_{r0}} &= 0.952 = e^{-\lambda t} \\ -\lambda t &= \ln(0.952) = -0.0488 \\ t &= \frac{0.0488}{4.33 \times 10^{-19}} = 1.127 \times 10^{17} \text{ years} \end{aligned}$$

2. The first nuclear reaction utilizing particle accelerators was performed by Cockcroft and Walton. Accelerated protons were used to bombard lithium nuclei, producing the following reaction.



Since the masses of the particles involved in the reaction were well known, these results were used to obtain an early proof of the Einstein mass-energy relation. Calculate the Q value of the reaction. The atomic masses to use are

$$\begin{aligned} {}^1_1H &= 1.0078 u \\ {}^4_2He &= 4.0026 u \\ {}^7_3Li &= 7.0160 u \\ u &= 1.6605 \times 10^{-27} kg \end{aligned}$$

The Q value is given by

$$Q = (m_A + m_B - m_C - m_D)c^2$$

where A and B represent the initial particles and C and D represent the final particles. We then have

$$\begin{aligned} Q &= (1.0078 + 7.0160 - 4.0026 - 4.0026)(1.6605 \times 10^{-27})(3 \times 10^8)^2 \\ &= 2.780 \times 10^{-12} \text{ joules} \\ &= 17.37 \text{ MeV} \end{aligned}$$

3. Electrons of energy 12.2 eV are fired at hydrogen atoms in a gas discharge tube. Some or all of the electron's energy maybe transferred to the hydrogen atom.

- (a) How many lines will be "seen" in the hydrogen spectrum?

The ground state energy of hydrogen is -13.6eV . To find the highest level that the hydrogen's electron can be raised to we add the energy of the incoming electron to the ground state energy to get

$$E_{\max} = -13.6 + 12.2 = -1.4 \text{ eV}$$

We now use the energy level formula to solve for the max n.

$$\begin{aligned} E_n &= -\frac{13.6}{n^2} \\ -1.4 &= -\frac{13.6}{n^2} \\ n^2 &= 9.71 \\ n &= 3.11 \end{aligned}$$

but since n has to be an integer the max level that the hydrogen's electron can get to is $n = 3$. we can therefore have the following transitions

$$\begin{aligned} 3 &\longrightarrow 2 \\ 3 &\longrightarrow 1 \\ 2 &\longrightarrow 1 \end{aligned}$$

We therefore have 3 transitions

- (b) Between what levels are these transitions?

See a)

- (c) What are the various wavelengths?

We start from

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

Then ΔE is given by

$$\Delta E = -\frac{13.6}{n_f^2} + \frac{13.6}{n_i^2} = -13.6 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

We then use

$$\begin{aligned} \Delta E &= hf = \frac{hc}{\lambda} = 13.6 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \\ \lambda &= \frac{hc}{13.6(1.6 \times 10^{-19})} \left(\frac{n_f^2 n_i^2}{n_i^2 - n_f^2} \right) = 9.135 \times 10^{-8} \left(\frac{n_f^2 - n_i^2}{n_f^2 n_i^2} \right) \end{aligned}$$

We dropped the minus because we need the energy of the photon that is emitted and not the change in energy of the hydrogen atom.

For the transition $3 \longrightarrow 2$ we then have

$$\lambda_{3 \longrightarrow 2} = 9.135 \times 10^{-8} \left(\frac{(9)(4)}{9-4} \right) = 6.577 \times 10^{-7} \text{ m} = 657.7 \text{ nm}$$

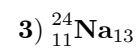
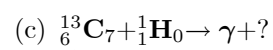
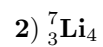
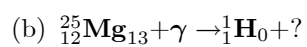
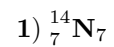
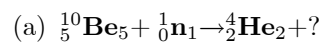
For the transition $3 \longrightarrow 1$ we then have

$$\lambda_{3 \longrightarrow 1} = 9.135 \times 10^{-8} \left(\frac{(9)(1)}{9-1} \right) = 1.028 \times 10^{-7} \text{ m} = 102.8 \text{ nm}$$

For the transition $2 \longrightarrow 1$ we then have

$$\lambda_{2 \longrightarrow 1} = 9.135 \times 10^{-8} \left(\frac{(4)(1)}{4-1} \right) = 1.218 \times 10^{-7} \text{ m} = 121.8 \text{ nm}$$

4. Complete the following reactions or questions with the appropriate answers.



a) - 2

b) - 3

c) - 1