1. An experiment is carried out in which alpha (α) particles of initial kinetic energy 5.0 MeV are fired at a piece of gold foil. The proton number of gold is 79. Determine the distance of closest approach of an alpha (α) particle to a gold nucleus. **[4.6 x 10^{-14} m]** 5

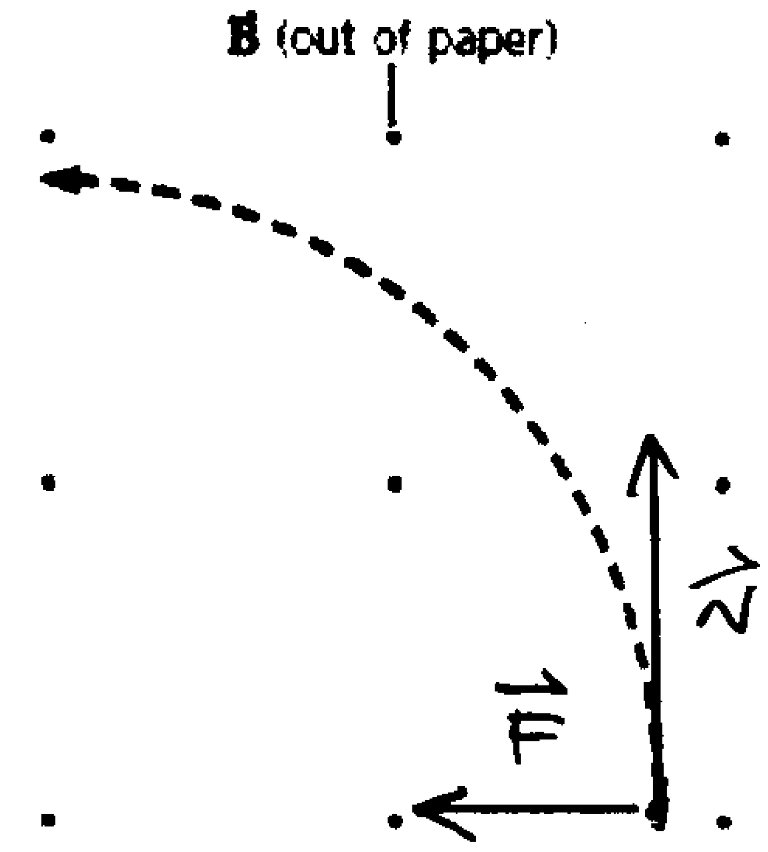
α $\vec{v}$ → Au

2e Ze

$$E = \frac{kq_1q_2}{r} = \frac{k(2e)(Ze)}{d} = KE = 5.0\,\text{MeV} = 8.0\times10^{-13}\,\text{J}$$

$$\Rightarrow d = \frac{2ke^2Z}{KE} = \frac{2(8.99\times10^{9})(1.6\times10^{-19})^2(79)}{8.0\times10^{-13}} = \boxed{4.5\times10^{-14}\,\text{m}}$$

2. A charged particle enters a uniform magnetic field and follows the circular path shown.



a) Is the particle positively or negatively charged? Why?

NEGATIVE SINCE BY THE RHR THE $\vec{F}_B$ GOES OUT THE BACK OF THE HAND, BY DEFINITION.

b) The particle's speed is 140 m/s, the magnitude of the magnetic field is 0.48 T, and the radius of the path is 960 m. Determine the mass of the particle, given that its charge has a magnitude of 8.2 x 10^{-4} C. **[2.7 x 10^{-3} kg]**

$$r = \frac{mv}{qB} \Rightarrow m = \frac{rqB}{v} = \frac{(960)(8.2\times10^{-4})(0.48)}{140} = \boxed{2.7\times10^{-3}\,\text{kg}}$$

(from $\vec{F}_c = \vec{F}_B$)

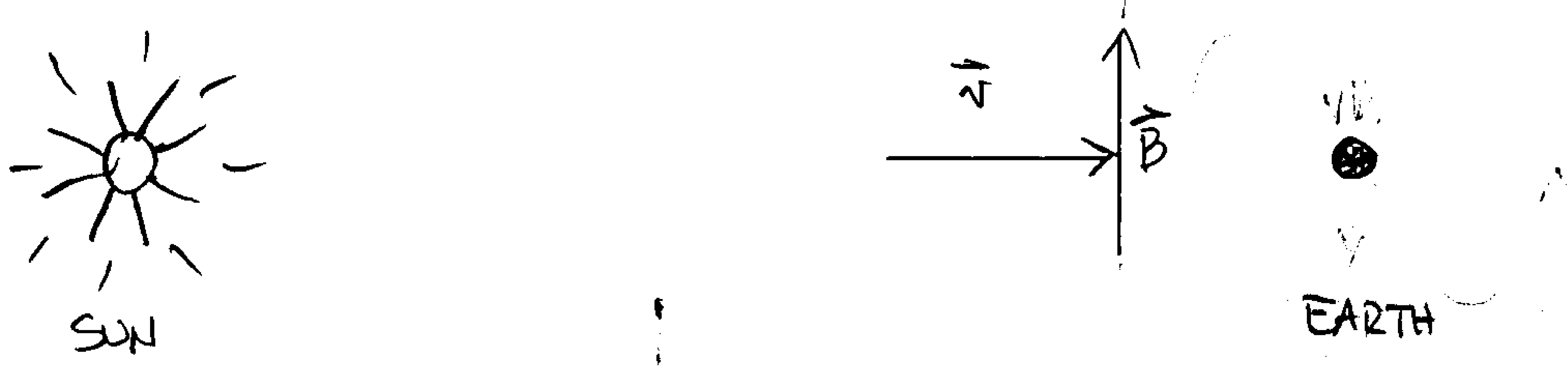
3. The solar wind is a thin, hot gas given off by the sun. Charged particles in this gas enter the magnetic field of the earth and can experience a magnetic force. Suppose that a charged particle traveling with a speed of 9.0 x 10^{6} m/s encounters the earth's magnetic field at an altitude where the field has a magnitude of 1.2 x 10^{-7} T. Assuming that the particle's velocity is perpendicular to the magnetic field, find the radius of the circular path on which the particle would move if it were

a) an electron **[4.3 x 10^{2} m]**

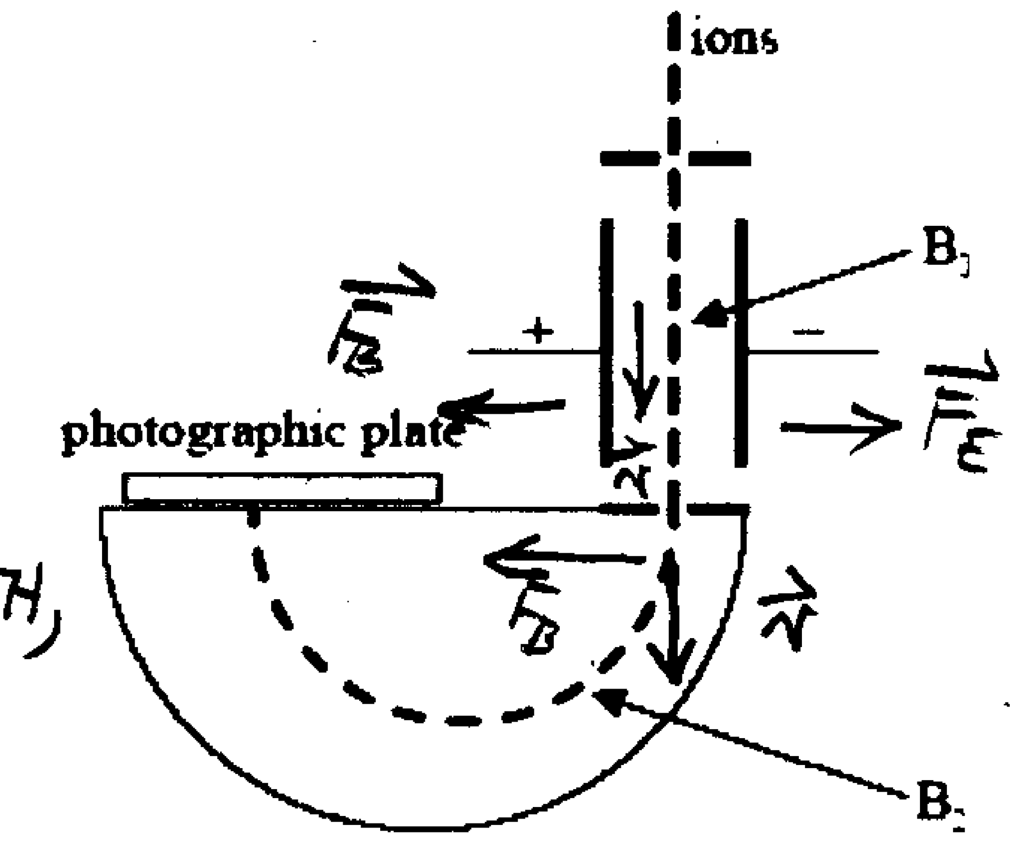
$$r = \frac{mv}{qB} = \frac{(9.11\times10^{-31})(9.0\times10^{6})}{(1.6\times10^{-19})(1.2\times10^{-7})} = 427\,\text{m} = \boxed{4.3\times10^{2}\,\text{m}}$$

b) a proton **[7.8 x 10^{5} m]**

$$r = \frac{mv}{qB} = \frac{(1.67\times10^{-27})(9.0\times10^{6})}{(1.6\times10^{-19})(1.2\times10^{-7})} = 782813\,\text{m} = \boxed{7.8\times10^{5}\,\text{m}}$$



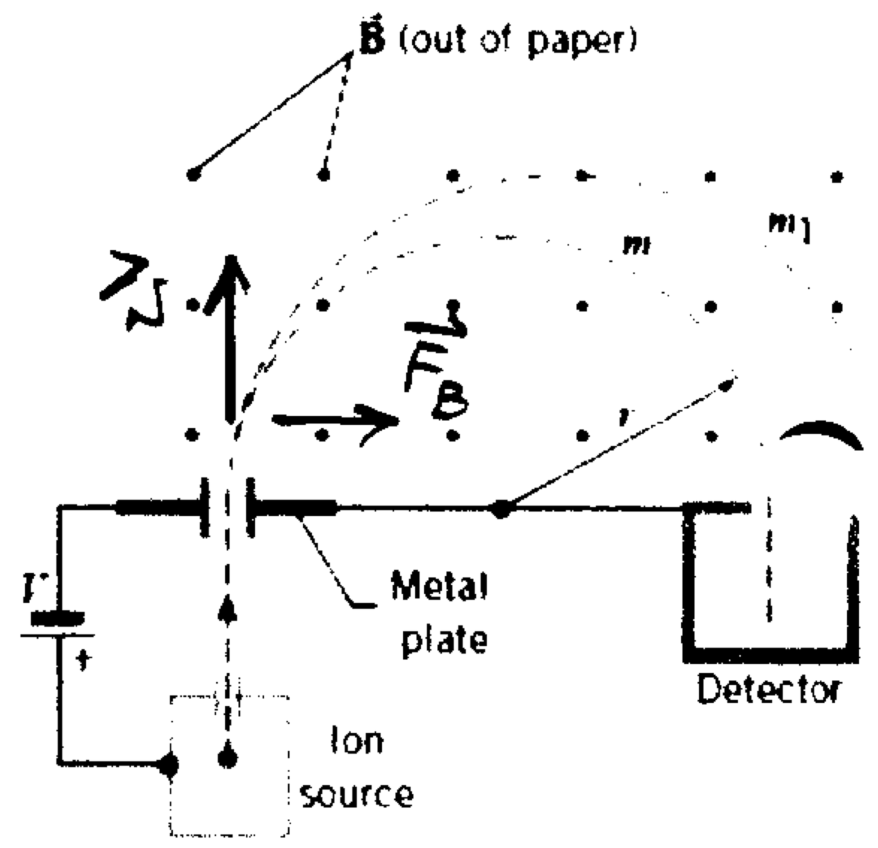
4. The diagram is a schematic representation of the Bainbridge mass spectrometer. Positive ions are injected between the plates of the speed selector. Describe the direction of the magnetic fields B_1 and B_2 and explain your answers fully. **[both fields out of the page]**



SINCE THE MOVING PARTICLES ARE (+), THEY WILL BE DEFLECTED TO THE RIGHT IN THE $\vec{E}$-FIELD BETWEEN THE PLATES. TO MAINTAIN A STRAIGHT PATH, F_B MUST ACT TO THE LEFT TO OPPOSE $\vec{F}_E$. BY THE RHR, $\vec{B}$ IS <u>OUT OF THE PAGE.</u>

WHEN MOVING IN A CIRCULAR PATH, $\vec{F}_B$ MUST BE ACTING INITIALLY TO THE LEFT. AGAIN BY THE RHR, $\vec{B}_2$ MUST BE <u>OUT OF THE PAGE.</u>

* **5.** When beryllium-7 ions pass through a mass spectrometer, a uniform magnetic field of 0.283 T curves their path directly to the center of the detector as shown. For the same accelerating potential difference, what magnetic field should be used to send beryllium-10 ions to the same location in the detector? Both types of ions are singly ionized. $(q = +e)$



$F_c = F_B \Rightarrow B = \frac{mv}{rq} = \frac{m}{rq}\left(\frac{2qV}{m}\right)^{1/2} = \left(\frac{2Vm}{q}\right)^{1/2}\frac{1}{r}$

$\frac{mv^2}{r} = qvB$

LET $B_7 = \vec{B}$-field for Beryllium 7 ions
$B_{10} = \vec{B}$-field for Beryllium 10 ions.

$KE = EPE$

$\frac{1}{2}mv^2 = qV$

$v = \left(\frac{2qV}{m}\right)^{1/2}$

Same r, but m changes. So, determine what B_{10} will give the same r as B_7 but with different masses.

mass Be-7: 1.17×10^{-26} kg
Mass Be-10: 1.67×10^{-26} kg

$\frac{B_{10}}{B_7} = \left(\frac{m_{10}}{m_7}\right)^{1/2} \Rightarrow B_{10} = B_7\left(\frac{m_{10}}{m_7}\right)^{1/2} = \boxed{0.338\ T}$

6. Two isotopes of carbon, carbon-12 and carbon-13, have masses of 19.93 x 10^{-27} kg and 21.59 x 10^{-27} kg, respectively. These two isotopes are singly ionized (+*e*) and each is given a speed of 6.667 x 10^5 m/s. The ions then enter the bending region of a mass spectrometer where the magnetic field is 0.8500 T. Determine the spatial separation between the two isotopes after they have traveled through a half-circle. **[1.63 x 10^{-2} m]**

$r_{12} = \frac{mv}{qB} = \frac{(19.93\times10^{-27})(6.667\times10^5)}{(1.6\times10^{-19})(0.8500)} = 9.77\times10^{-2}$ m.

$r_{10} = \frac{(21.59\times10^{-27})(6.667\times10^5)}{(1.6\times10^{-19})(0.8500)} = 1.058\times10^{-1}$ m.

$\frac{1}{2}$ a circle is the diameter, so; $2r_{10} - 2r_{12} = 2(1.058\times10^{-1}) - 2(9.77\times10^{-2})$

$= \boxed{0.0163\ m}$

7. The activity of a freshly prepared sample of bismuth-212 is 2.80 × 10^{13} Bq. After 80.0 minutes the activity is 1.13 × 10^{13} Bq. Determine the half-life of bismuth-212. **[61.1 min]**

Activity $= \frac{\Delta N}{\Delta t} = 2.80\times10^{-13}$ decays·s^{-1}

To find k: $A = A_0 e^{-kt} \Rightarrow \ln(A) = \ln(A_0) - kt$

$k = \frac{\ln(A) - \ln(A_0)}{t} = \frac{-\ln(1.13\times10^{13}) + \ln(2.80\times10^{13})}{(80.0)(60)}$

$k = 1.89\times10^{-4}$

So, $t_{1/2} = \frac{0.693}{k} = \frac{0.693}{1.89\times10^{-4}} = 3666.7\text{s} = \boxed{61.1\ \text{min}}$

8. A radioactive emitter I - 132 has a half-life of 2.3 hours. Calculate the mass needed initially to produce an activity of 6 kBq. **[1.58×10^{-14} g]**

EACH I-132 NUCLEUS HAS MASS OF: $(132)(1.67\times10^{-27}) = 2.20\times10^{-25}$ kg $= 2.20\times10^{-22}$ g.

$\frac{N}{N_0} = \frac{A}{A_0} \Rightarrow N_0 = \frac{NA_0}{A} = \frac{NA_0}{kN} = \frac{A_0}{k}$

since $t_{1/2} = \frac{0.693}{k}$, $k = 8.37\times10^{-5}$ $\quad N_0 = \frac{A_0}{k} = \frac{6\times10^3}{8.37\times10^{-5}} = (7.17\times10^7)(2.20\times10^{-22}$ g nuclei$^{-1}) = \boxed{1.58\times10^{-14}\text{ g.}}$

9. Initially the number of atoms in a radioactive element X is 2.000×10^{21}. Its half-life is 4 hours.

a) Calculate the number of atoms which have disintegrated in 6 hours. **[1.292×10^{21}]**

$t_{1/2} = \frac{0.693}{k} \Rightarrow k = \frac{0.693}{4(3600)} = 4.81\times10^{-5}$

$N = N_0 e^{-kt} = (2.000\times10^{21})(e^{-(4.81\times10^{-5})(21600)}) = 7.08\times10^{20}$; $N_0 - N = \boxed{1.292\times10^{21}}$

If the energy liberated per decay is 3.0×10^{-13} J, find

b) the total energy liberated. **[390×10^6 J]**

$\frac{3.0\times10^{-13}\text{ J}}{1\text{ decay}} \times \frac{1.292\times10^{21}\text{ decays}}{1} = \boxed{3.9\times10^8\text{ J}}$

c) the average power developed. **[18×10^3 W]**

$P = \frac{\Delta E}{\Delta t} = \frac{3.9\times10^8\text{ J}}{21600\text{ s}} = \boxed{1.8\times10^4\text{ W}}$

11. Radium-222 disintegrates initially at a rate of 5.00 kBq. If the decay constant is 2.00×10^{-6} s^{-1},

a) determine the half-life. **[4 days]**

$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{2.00\times10^{-6}} = 346{,}500\text{ s} = 5775\text{ min} = 96.25\text{ hr} = \boxed{4\text{ days}}$

b) calculate the initial mass of the element. **[9.25×10^{-13} g]**

EACH Ra-222 nucleus has a mass of $222(1.67\times10^{-27}\text{ kg})$
$= 3.71\times10^{-25}$ kg $= 3.71\times10^{-22}$ g.

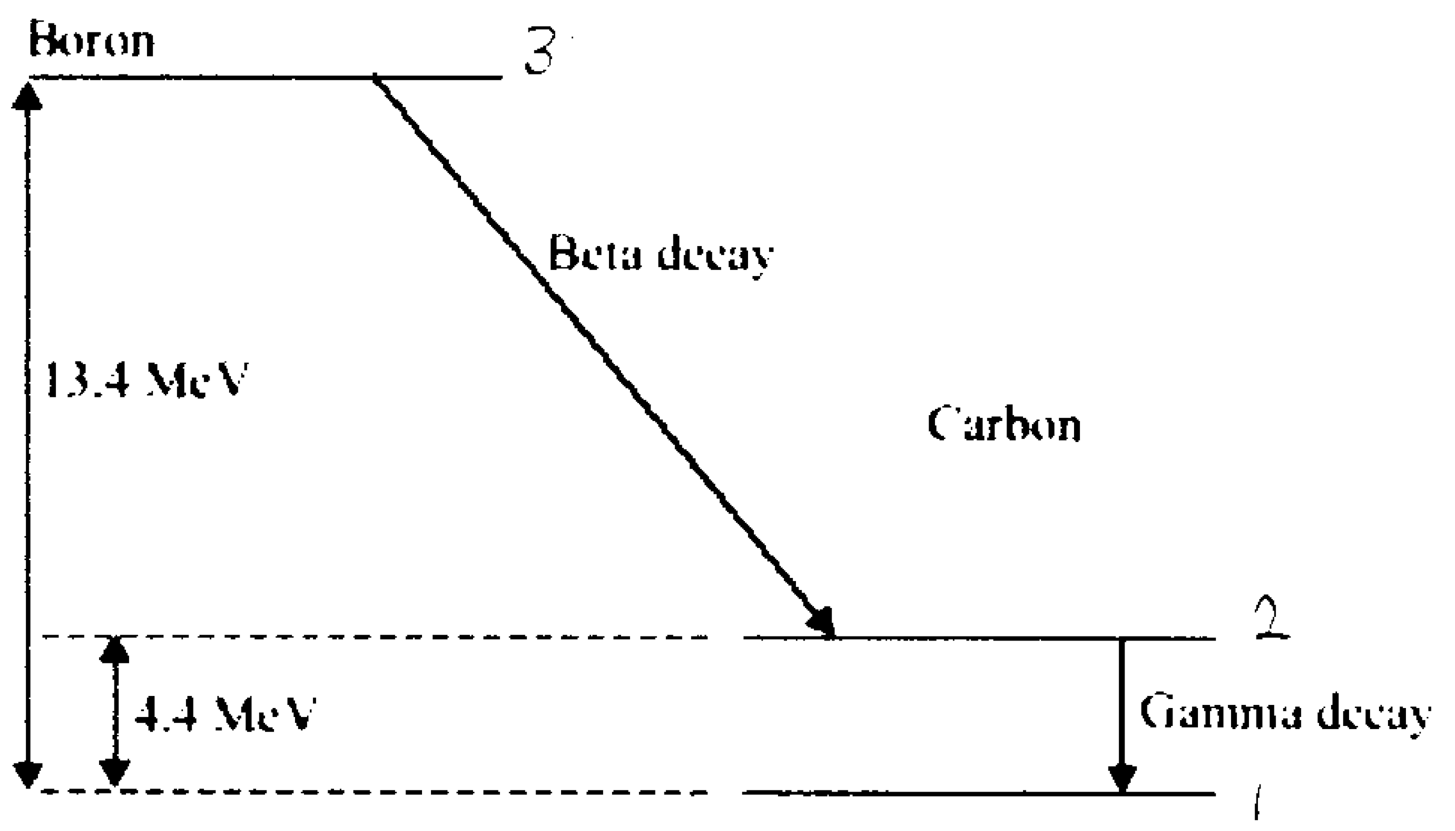
Since $\frac{N}{N_0} = e^{-kt} = \frac{A}{A_0}$; $\frac{N}{N_0} = \frac{A}{A_0}$

then $N_0 = \frac{NA_0}{A} = \frac{NA_0}{kN} = \frac{A_0}{k} = \frac{(5.00\times10^3)}{(2.00\times10^{-6})} = 2.50\times10^9$ nuclei.

$(3.71\times10^{-22}\text{ g nuclei}^{-1})(2.50\times10^9\text{ nuclei}) = \boxed{9.28\times10^{-13}\text{ g}}$

$N = N_0 e^{-kt}$

12. The diagram shows some of the nuclear energy levels of the boron isotope $^{12}_{5}B$ and the carbon isotope $^{12}_{6}C$. Differences in energy between the levels are indicated on the diagram. A particular beta decay of boron and a gamma decay of carbon are marked on the diagram.



a) Calculate the wavelength of the photon emitted in the gamma decay. **[2.8×10^{-13} m]**

$$\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(4.4\times10^{6})(1.6\times10^{-19})}$$

$$= \boxed{2.8\times10^{-13}\,m}$$

b) Calculate the maximum kinetic energy of the electron emitted in the beta decay indicated. **[9.0 MeV]**

$$\Delta E = KE = E_3 - E_2$$

$$= (13.4 - 4.4)\times10^{6}\,eV$$

$$= \boxed{9.0\,MeV}$$

c) Explain why the electrons emitted in the indicated beta decay of boron do not always have the kinetic energy calculated in (b).

A NEUTRINO IS ALSO PRODUCED IN β DECAY;
THEREFORE THE 9.0 MeV ENERGY IS SHARED BETWEEN 2 PARTICLES (the neutrino and the β particle).