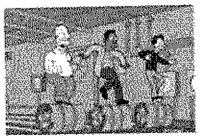
04/07/2019



P30 Unit D UA pt B: Nuclear Physics

Name: Key!

Date: ~~8~~ Jan 9/2020

1. The four fundamental forces are listed below. Place the names of particles which are affected by each force on the line next to the force. **(0.5 marks each)**

Gravitational Force: (Any particle with mass, energy or momentum)

Weak Nuclear Force: protons, neutrons, quarks, electrons, neutrinos

Electromagnetic Force: (Any particle with charge)

Strong Nuclear Force: protons, neutrons, quarks

Particles: proton, electron, neutron, beta positive, beta negative, alpha, quarks, neutrino.

2. Write decay reactions for each of the following transmutations. Show all sub-atomic particles produced: **(1 mark each)**

a) An atom of $^{226}_{88}Ra$ transmutes to $^{222}_{86}Rn$: $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}\alpha$

b) Uranium-235 decays into thorium-231 (Th-231): $^{235}_{92}U \rightarrow ^{231}_{90}Th + ^{4}_{2}\alpha$

c) $^{239}_{92}U$ decays to $^{239}_{93}Np$ which decays to $^{239}_{94}Pu$: $^{239}_{92}U \rightarrow ^{239}_{93}Np + ^{0}_{-1}\beta + ^{0}_{0}\bar{\nu} \rightarrow ^{239}_{94}Pu + ^{0}_{-1}\beta + ^{0}_{0}\bar{\nu}$

d) Carbon-11 decays beta-positive. $^{11}_{6}C \rightarrow ^{11}_{5}B + ^{0}_{+1}\beta + ^{0}_{0}\nu$

3. The diagram shows a type of radioactive decay, where the black spheres represent protons and the white spheres represent neutrons.

+ $^{0}_{-1}?\beta + ^{0}_{0}\bar{\nu}$

Name and give the notation for the type of particle that is emitted during this reaction. **(1 mark)**

4. A student was given the following reactions to complete:

a. $^{12}_{6}C + ^{1}_{1}H \rightarrow \underline{^{13}_{7}N} + \gamma$

b. $^{1}_{0}n + ^{235}_{92}U \rightarrow ^{121}_{53}I + \underline{^{112}_{39}Y} + 3^{1}_{0}n$

c. $^{27}_{13}Al + ^{4}_{2}He \rightarrow \underline{^{30}_{14}Si} + ^{1}_{1}H$

In the blank spaces, place the notation that will complete the reaction. **(1 mark each)**

Use the following table to answer the next question.

Table 1: Atomic Masses of Selected Isotopes

hydrogen	H	1.007825	magnesium-24	Mg	23.985042
neutron	n^0	1.008665	silicon-28	Si	27.976927
deuterium	H (or D)	2.014102	potassium-40	K	39.963998
tritium	H (or T)	3.016049	calcium-40	Ca	39.962591
helium-3	He	3.016029	cobalt-60	Co	59.993817
helium-4	He	4.002603	cesium-140	Cs	139.905439
boron-12	B	12.003510	barium-141	Ba	140.914412
carbon-12	C	12.000000	lead-208	Pb	207.976652
nitrogen-16	N	16.006102	radon-222	Rn	222.017578
oxygen-16	O	15.994915	radium-226	Ra	226.025410
neon-20	Ne	19.992440	thorium-230	Th	230.033134
neon-22	Ne	21.991385	thorium-234	Th	234.043601
sodium-22	Na	21.994436	uranium-235	U	235.043930
sodium-23	Na	22.989769	uranium-238	U	238.050788

*Additional Information: 1 u = 1.660539 x 10^{-27} kg, 1 u = 931.4941 MeV

5. a) Determine the mass defect (in kg and u) and binding energy (in joules and MeV) of the neon-22 atom. **(0.190845 u, 3.16906 x 10^{-28} kg, 2.85215 x 10^{-11} J, 177.771 MeV)**

$\Delta m = 10(1.007825u) + 12(1.008665u) - 21.991385u = 0.190845u$

$0.190845u \times 1.660539\times10^{-27}$ kg

$\Delta m = 3.16905565\times10^{-28}$ kg

b) Write the process for the alpha decay of radium-226. **(2 marks)**

c) Estimate the kinetic energy (in J and MeV) of the alpha particle from question b. **(7.81466258 x 10^{-13} J, 4.87078265 MeV) (2 marks)**

See last page

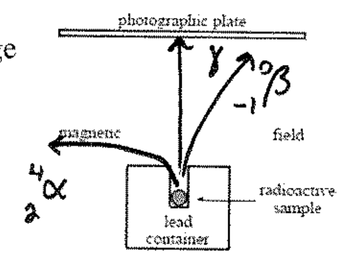
d) Using the isotopes above, give one pair that could undergo beta negative decay and calculate the maximum total kinetic energy released in this reaction. **(2 marks)**

6. The reaction below shows artificial transmutation of uranium-235. Fill in the boxes to complete the reaction. **(1 mark)**

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + ^{1}_{0}n + ^{1}_{0}n + ^{1}_{0}n$$

7. The diagram shows a radioactive sample in a lead container. The sample radiates through a magnetic field that is directed into the page perpendicular to the plane of the page.

On the diagram, show the deflection of the radiation of three major decay products due to the magnetic field, identify them, and show their electric charge. **(2 marks)**



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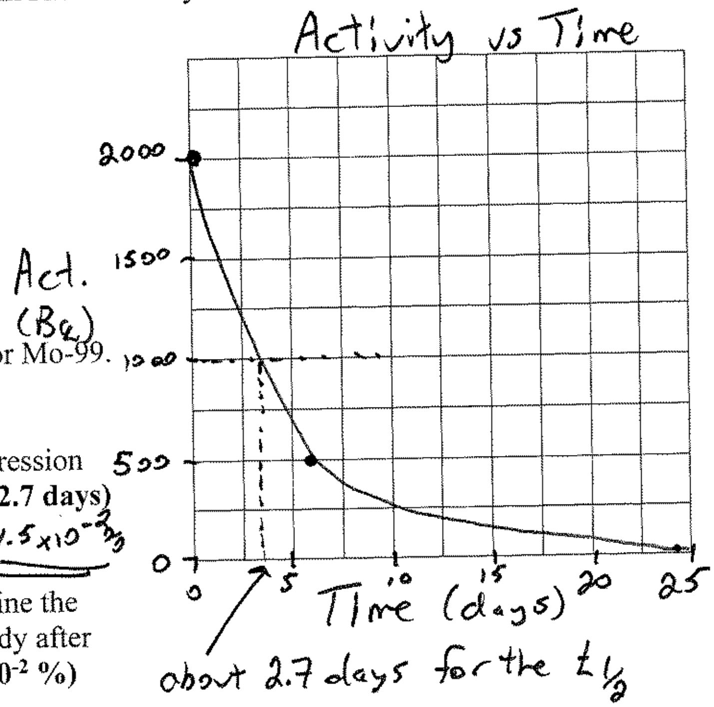
8. Chalk River Laboratories in Ontario provides about two-thirds of the world's medical radioactive isotopes. The isotopes are used to treat diseases and for diagnostic purposes in the body. A common isotope produced at Chalk River is Molybdenum-99. A decay chart of this radioisotope is shown below:

Activity (Bq)	Time (days)
2000	0.0
428.6	6.00
91.86	12.0
19.69	18.0
4.219	24.0



a) Construct a graph of activity vs. time for Mo-99. **(1 mark)**

b) Using your graph or an appropriate regression method, estimate the half-life of Mo-99. **(2.7 days)** **(1 mark)** $N = (100\%)(\frac{1}{2})^{30/2.7} = 4.5\times10^{-2}\%$

c) Using your answer from part b, determine the percentage of Mo-99 left in a patient's body after one month (30 days). **(1 mark) (~ 4.5 x 10^{-2} %)**

9. Complete the following nuclear reactions. Identify them as Nuclear Fission or Nuclear Fusion.

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U \rightarrow ^{90}_{38}Sr + ^{A}_{Z}\mathbf{X} + 2^{1}_{0}n$ $\quad ^{144}_{54}Xe$ fission

$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{A}_{Z}\mathbf{X} + ^{1}_{0}n$ $\quad ^{4}_{2}He$ fusion.

10. What conditions are required for a fission reaction to occur? What conditions are required for a fusion reaction to occur? Fission → neutron hits large nucleus. Fusion → high heat + pressure of hydrogen isotopes.

11. Write the general equation for a beta negative and beta positive decay, starting with either a proton or neutron, using quark notation.

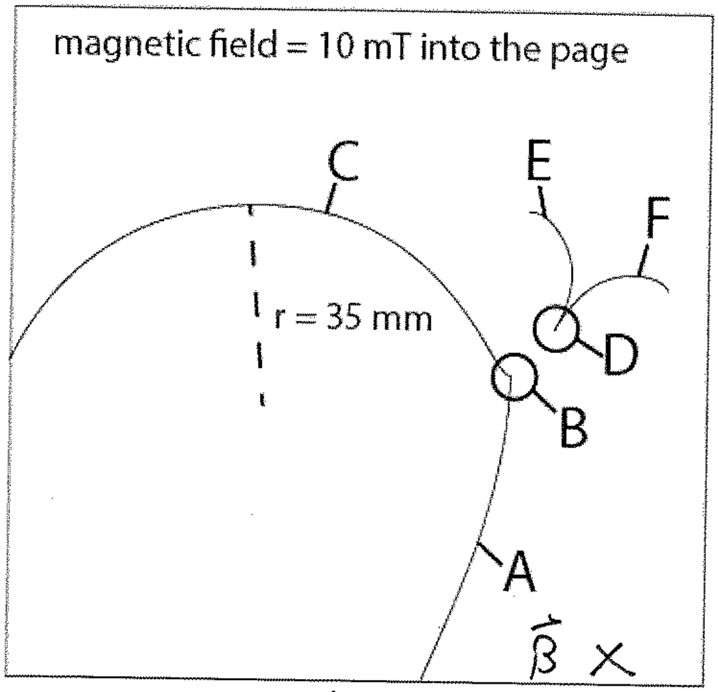
Beta-neg → $^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}\beta + ^{0}_{0}\bar{\nu}$

udd → uud

Beta-pos → $^{1}_{1}p \rightarrow ^{1}_{0}n + ^{0}_{+1}\beta + ^{0}_{0}\nu$

uud → udd

Use the following information to answer the next question.



12. The cloud chamber above shows several particle interactions. The chamber is placed in a constant magnetic field of 10 mT, directed into the page.

a) Determine the nature of the charge of the particle making track A. Positive (3rd RHR)

b) Describe the event occurring at point B. Which two physics principals from your data sheet are used to explain this track shape? The positive decays to another positive and a neutral particle. Conservation of charges conservation of momentum.

c) Compare and contrast the momentum and nature of charge of the particle making track C to the particle making track A. The particles have the same charge, but A has more momentum (larger radius).

d) Calculate the charge to mass ratio of the particle making track C. The particle has a speed of 4.0 x 10^6 m/s. $\frac{q}{m} = \frac{v}{Br} = \frac{4\times10^6 \text{ m/s}}{(0.01\text{T})(0.035\text{m})} = 1.14\times10^{10}$ C/kg

e) What is occurring in the space between point B and D?

A neutral particle, as no track is made.

f) Name the event occurring at point D.

Pair production

g) What is the relationship between particles making tracks E and F?

They are anti particles.

5. a.) Mass defect = $^{22}_{10}Ne \rightarrow 10\ ^{1}_{1}p + 12\ ^{1}_{0}n$

$\Delta m = 19.992440u - [10(1.007825u) + 12(1.008665u)]$

$\Delta m = 0.190845u$

* Note: a proton is a hydrogen nucleus! So use the mass of H for the proton!

$\Delta m = 0.190845u \times 1.660539 \times 10^{-27} kg = 3.16905565 \times 10^{-28} kg$

$\Delta E = mc^2 = (3.16905565 \times 10^{-28} kg)(3 \times 10^8 m/s)^2 = 2.85215 \times 10^{-11} J$

↑ I used $E = mc^2$ since I had the mass in kg.

$\Delta E = 0.190845u \times 931.4941 \frac{MeV}{u} = 0.190845u$

↗ I multiplied by the conversion factor given in the question.

b. $^{226}_{88}Ra \rightarrow ^{4}_{2}\alpha + ^{222}_{86}Rn$

c.) Note: the E_K of the alpha is equal to the binding energy.

$\Delta m = 226.025410u - [222.017578u + 4.002603u]$

$= 0.005229u$

$\Delta E = 0.005229u \times 931.4941 \frac{MeV}{u} = 4.87078265\ MeV$

d.) In beta negative decay, the number of protons in the daughter must increase by 1 from the parent. Also, the mass number of parent & daughter are equal.

So, a pair like:

$^{23}_{10}Ne \rightarrow ^{23}_{11}Na + ^{0}_{-1}\beta + ^{0}_{0}\bar{\nu}$

(also potassium-40 calcium-40)

would work.