Exam nuclear and particle physics, FYSA01

Mass values and other data are found after ex. 7

5.

A reliable energy source during long space flights can be in the form of radioactive material. One nuclide that has been used is $^{238}_{94}Pu$ which decays by α-decay. The half life is 87.7 years.

a) write out the decay formula and calculate the Q-value (2p)

b)How many kilograms of the nuclide is needed to provide the initial power 5kW. We assume that all energy released in the decay contributes to the power. If you have not solved 5a, you may guess a reasonable Q-value. The daughter nuclide has so long half life that you can neglect its decay as a contributor to the power. (2p)

c) After how long time has the power changed from 5kW to 4kW? (1p)

6.

By the discovery of the J/ψ meson the existence of the c-quark was proven.

a) J/ψ can decay in many ways. One is:

$J/\psi \rightarrow \mu^+ + \mu^-$

Calculate the total energy, momentum and kinetic energy for each of the two muons. The J/ψ can be regarded to decay at rest in the laboratory system. (2p)

b) All of these decays violate one or more conservation laws. Which laws? Show that you have checked them all.

(i) $\pi^+ \rightarrow e^- + \gamma$

(ii) $n \rightarrow e^- + e^+ + \nu_e$

(iii) $p \rightarrow \pi^+ + \pi^-$ (2p)

(iv) $\mu^- \rightarrow e^- + \nu_e + \nu_\mu$

(v) $K^+ \rightarrow \pi^+ + \pi^- + \pi^0$ (weak interaction)

c) Discuss qualitatively how energy and momentum of the muons in 6a, become different if the decay is instead from a J/ψ in motion. (1p)

7.

a) Calculate the binding energy of ${}_{8}^{16}O$. (1p)

b) Weizäckers semiempirical mass formula describes how the binding energy (BE) depend on the mass number (A). The first 3 terms look like this:

$BE = k_1A - k_2A^{2/3} - k_3 Z(Z-1)A^{-1/3} + \ldots\ldots$

k_1, k_2 and k_3 are empirical constants.

i What do we call the three terms? (1p)

Ii Which term explains why light nuclei have low BE per nucleon. Explain. (1p)

iii Which term explains why the BE per nucleon gets lower for heavy nuclei. Explain. (1p)

c) Rewrite the formula so that it is explicitly shown how the BE depends on the nuclear radius. (1p)

Viktigaste elementarpartiklar

Grupp	Namn	Partikel	Antipartikel	Massa (MeV/c^2)	Paritet Spinn	Isotopiskt spinn	Särhet	Medellivstid (s)	Vanligaste sönderfall
Baryoner	Ω-hyperon	Ω^-	$\bar{\Omega}^+$	1672	$3/2^+$	0	−3	$1.3 \cdot 10^{-10}$	$\Xi^0\pi^-, \Xi^-\pi^0, \Lambda^0\underline{K}^-$
	Ξ-hyperon	Ξ^-	$\bar{\Xi}^+$	1321	$1/2^+$	1/2	−2	$1.7 \cdot 10^{-10}$	$\Lambda^0\pi^-$
		Ξ^0	$\bar{\Xi}^0$	1315	$1/2^+$		−2	$3.0 \cdot 10^{-10}$	$\Lambda^0\pi^0$
	Σ-hyperon	Σ^-	$\bar{\Sigma}^+$	1197	$1/2^+$		−1	$1.6 \cdot 10^{-10}$	$n\pi^-$
		Σ^0	$\bar{\Sigma}^0$	1192	$1/2^+$	1	−1	$< 1.0 \cdot 10^{-14}$	$\Lambda^0\gamma$
		Σ^+	$\bar{\Sigma}^-$	1189	$1/2^+$		−1	$0.8 \cdot 10^{-10}$	$p\pi^0, n\pi^+$
	Λ-hyperon	Λ^0	$\bar{\Lambda}^0$	1116	$1/2^+$	0	−1	$2.5 \cdot 10^{-10}$	$p\pi^-, n\pi^0$
	neutron	n	$\bar{n}$	940	$1/2^+$	1/2	0	$1.0 \cdot 10^{3}$	$e^-\bar{\upsilon}_e$
	proton	p	$\bar{p}$	938	$1/2^+$		0	∞	
Mesoner	η-meson	η^0	η^0	549	0^-	0	0	$< 10^{-22}$	$\gamma\gamma, 3\pi^0, \pi^+\pi^-\pi^0$
	K-meson	$\underline{K}^0$	$\bar{K}_0$	498	0^-	1/2	1	$0.9 \cdot 10^{-10}(\underline{K}_1^0)$	$\pi^+\pi^-, \pi^0\pi^0$
								$5.4 \cdot 10^{-4}(\underline{K}_2^0)$	$3\pi^0, \pi^+\pi^-\pi^0, \pi\mu\upsilon$
		$\underline{K}^+$	$\underline{K}^-$	494	0^-		1	$1.2 \cdot 10^{-8}$	$\mu^+\upsilon_\mu, \pi^+\pi^0, \pi^+\pi^+\pi^-$
	π-meson	π^+	π^-	140	0^-	1	0	$2.6 \cdot 10^{-8}$	$\mu^+\upsilon_\mu$
		π^0	π^0	135	0^-		0	$0.9 \cdot 10^{-16}$	$\gamma\gamma$
Leptoner	myon	μ^-	μ^+	106	1/2			$2.2 \cdot 10^{-6}$	$e^-\upsilon_e\upsilon_\mu$
	elektron	e^-	e^+	0.51	1/2			∞	
	neutrino	υ_μ	$\bar{\upsilon}_\mu$	0	1/2				
		υ_e	$\bar{\upsilon}_e$	0	1/2				
Foton	foton	γ		0	1		0		

Några massor: ***Some masses:***

$m_n = 939.57\ MeV/c^2$; $m_p = 938.27\ MeV/c^2$; $m_e = 0.511\ MeV/c^2$;
$m_{K^-} = 493.7\ MeV/c^2$; $m_{\pi^\circ} = 135.0\ MeV/c^2$; $m_{\pi+} = 139.6\ MeV/c^2$;
$m_{\mu+} = 105.7\ MeV/c^2$; $m(J/\Psi) = 3096.6\ MeV/c^2$;
$m({}^1H) = 1.007825u$; $m({}^4He) = 4.002603u$; $m({}_{8}^{16}O) = 15.994914u$;
$m({}_{92}^{234}U) = 234.040952u$; $m({}_{94}^{238}Pu) = 238.049559u$; $m({}_{92}^{238}U) = 238.050788u$;
$m({}_{93}^{238}Np) = 238.050946u$; $m({}_{95}^{238}Am) = 238.051980u$

Namn..... persnr.....
8.

8. English
Ten multiple choice questions. A question can have several correct alternatives irrespective of the way it is formulated.

8.1 What is the quark content of the neutral π-mesonen (Q=0, B=0, S=0)? The u-quark has the charge +2/3 and the d-quark has charge -1/3. Both quarks have baryon number +1/3.

a) $u\bar{u}$ b) udd c) $d\bar{d}$ d) ud

8.2 A nuclear reaction in which energy is released is called ?

a) compton scattering b) inelastic c) exothermal d) endotherm

8.3 In what way does the activity change in a radioactive sample by heating it up?

a) increases b) it varies d) it decreases d) it doesn't change

8.4 Which of the four fundamental interactions is responsible for holding nuclei together?

a) weak b) electromagnetic c) gravitation d) strong

8.5 How does one adjust the power of a light water reactor so that one gets constant power although the amount of ^{235}U goes down with time?

a) reduce pressure b) insert control rods c) add moderator water d) pull out control rods

8.6 What is true about different isotopes of an element?

a) same A b) same Z c) same N d) same number of electrons

8.7 Elementary particles are classified in two groups depending on their mode of interaction. The groups are:

a) hadrons/leptons b) mesons/baryons c) hadrons/mesons d) hadrons/baryons

8.8 Which 10cm thick material would be best to protect against gamma radiation

a) carbon b) heavy water c) water d) lead

8.9 From a radioactive sample one measured an activity after 3hrs that was a factor 8 lower than the original. What was the half life?

a) 0.5 hour b) 1 hour c) 1.5 hour d) 2 hour

8.10 β^--decay is characterized by?

a) discrete electron energies b) Z changes c) A changes d) continuous electron energies

Answers (of course not available at the exam):

5a. $^{238}Pu \rightarrow {}^{234}U + {}^{4}He$
Q=5.59MeV

5b. 8800gram

5c. 28.2 år

6a. Shared equally because the mass is the same
Ekin =1442.6MeV
Etot = 1548.3MeV
P=1544.6MeV/c

6c. i Q och Le
ii B och Le
iii B och Q
iv Le
v Q

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7 a BE=127.6MeV
7b i volume. Surface and coulomb
ii surface
iii Coulomb

7c $BE = k_v R^3 - k_y R^2 - k_c Z(Z-1)R^{-1} + \ldots\ldots$

8.1 a,c
8.2 c
8.3 d
8.4 d
8.5 d
8.6 b,d
8.7 a
8.8 d
8.9 b
8.10 b,d