Exam in nuclear and particle physics, FYSA01

Some masses and data that you may need can be found after problem 7 and 8.

5.

Medical examinations with a so called PET-camera use radioactive nuclides which decay by β^+-decay. ^{15}O is often used since one can study how oxygen is transported in e.g. the brain. Some questions around this:

a. Write the formula for the ^{15}O decay. (1)

b. Calculate the Q-value for the decay. (1)

c. How many grams of ^{15}O must be inhaled (we assume that the intake is momentary in one breath and that all ^{15}O inhaled stays in the body) so that we, immediately after the inhalation will have a total activity from ^{15}O in the body equal to 10^9 Bq. The half life for ^{15}O is 122 seconds. The answer is a very small fraction of a gram. (2)

d. How long time does it take until the activity from ^{15}O has dropped to a harmless 1000Bq. (1)

6.

The reaction below is one of the importan fusion reactions in the sun.

$p + p \rightarrow d + e^+ + \nu_e$

d is a deuterium nucleus i.e. the nucleus of the hydrogen isotope ^2H.

a. Calculate the Q-value for the reaction. (1)

b. How many grams of ^1H must undergo fusion per second to produce 500MW (MegaWatt) of power (comparable to a fission reactor). You can assume that all energy, represented by the Q-value contributes to the power. If you have not managed to obtain a reasonable Q-value in part a, you may assign a reasonable value. (1)

c. In addition to the energy represented by the Q-value, the reaction above can give rise to further transformation of potential energy (mass) to kinetic energy. How? (1)

d. Draw a diagram which shows how the binding energy per nucleon varies with the mass number. Mark and discuss the features of the curve that you think are important. Explain how the curve is important for exothermal fusion reactions in the sun. (2)

7.

a. The Ξ -baryon has the following properties. Q = -1, S = -2 och B = 1. Determine the quark content. The u, d and s quarks are characterized by

	Q	B	S
u	2/3	1/3	0
d	-1/3	1/3	0
s	-1/3	1/3	-1

(1)

b. Ξ^- decaus most likely as:

$\Xi^- \rightarrow \Lambda^\circ + \pi^-$

Calculate the momenta and kinetic energies of the daughter particles provided that the decay is from a mother particle at rest in the laboratory frame. (2)

c. Determine which decays are allowed? For the ones not allowed you shall tell which conservation laws are broken. If a decay is allowed under certain circumstances this shall be mentioned. (2)

i. $p \rightarrow n + e^+ + \nu_e$

ii. $\pi^+ \rightarrow e^+ + \gamma$

iii. $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$

iv. $\pi^\circ \rightarrow \mu^- + \nu_e + e^-$

v. $n \rightarrow \pi^+ + \pi^-$

Some masses:

m_n=939.57 MeV/c^2 ; m_p= 938.27 MeV/c^2; m_e=0.511 MeV/c^2 ;

m_{Λ°= 1115.7 MeV/c^2; m_{π^-} = 139.6 MeV/c^2; m_{Ξ^-} =1321.3 MeV/c^2

m(^{1}H)=1.007825u; m(^{2}H)=2.014102u; m(^{4}He)=4.002603u;

m(^{16}O)= 15.994915u; m(^{12}C)= 12.000000u; m(^{11}C)= 11.011434u;

m(^{15}N)= 15.000109u; m(^{15}O)= 15.003066u; m(^{15}F)= 15.018010u;

Some proton numbers:

O : 8; N : 7; C : 6; F : 9

Namn.. persnr..

8. 10 multiple choice questions. 0.5 points per question. A question can have several correct answers regardless of the wording (singular or plural) in the text.

8.1. Why do we have decay with α emission but not with proton emission.

a) the proton is too light b) the proton has too small charge
c) the α-is loosely bound d) the α-particle has high binding energy per nucleon

8.2. Vhihc of the 4 fundamental forces makes it possible to accelerate protons?

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

8.3. Short half life for a nuclide means (compared with one with long half life)?
a) it has lower decay constant b) the activity for a given number of atoms is higher
c) the activity for a given number of atoms is lower d) it has higher decay constant

8.4. What is the purpose with the moderator water in a fission reactor?

a) protects the uranium fuel against air b) slows down neutrons to thermal velocities
c) absorbs the released energy d) transports the released energy out from the reactor.

8.5. Fission fragment are radioactive. What is the most likely way for them to decay.:

a) α b) neutron c) β^+ d) β^-

8.6. in nuclear reactions the mass number A must be conserved. This is a special case of a more general conservation rule. Which?

a) Baryon number b) charge c) energy d) mass

8.7. A π^+ meson has an average life time of 26ns before decay. What can you conclude about the interaction responsible for the decay.

a) strong b) weak c) coulomb d) hadronic

8.8. The long live time of the π^+ meson makes it fly rather long distance before decay. It often travels with a velocity close to c. Actually there is a wellknown (at least to some) relativistic effect which changes the average flight length before decay as observed in the laboratory. What is the result of this effect?

a) longer flight length b) shorter flight length
c) the flight length changes sign d) the flight length becomes infinite

8.9. The area of a nucleus is proportional to some power of the mass number area=const·A^x. what is x.
a) 1 b) 2 c) 1/3 d) 2/3

8.10. In teh magnetic field of a mass spectrometer we register the circular motion of ^{12}C och ^{36}Ar. Both have the charge +e and both have the same velocity. What can be said about the radius of the circle for ^{36}Ar relative to the radius for ^{12}C. We make the assumption that m(^{A}X) $\approx$ Au.

a) 3 times smaller b)both have the same radius c) 3 times larger d) 9 times larger

Viktigaste elementarpartiklar

Grupp	Namn	Partikel	Antipartikel	Massa (MeV/c^2)	Paritet Spinn	Isotopiskt spinn	Särhet	Medellivstid (s)	Vanligaste sönderfall
Baryoner	Ω-hyperon	Ω^-	$\overline{\Omega}^+$	1672	$3/2^+$	0	−3	$1.3 \cdot 10^{-10}$	$\Xi^0\pi^-, \Xi^-\pi^0, \Lambda^0 K^-$
	Ξ-hyperon	Ξ^-	$\overline{\Xi}^+$	1321	$1/2^+$	1/2	−2	$1.7 \cdot 10^{-10}$	$\Lambda^0\pi^-$
		Ξ^0	$\overline{\Xi}^0$	1315	$1/2^+$		−2	$3.0 \cdot 10^{-10}$	$\Lambda^0\pi^0$
	Σ-hyperon	Σ^-	$\overline{\Sigma}^+$	1197	$1/2^+$	1	−1	$1.6 \cdot 10^{-10}$	$n\pi^-$
		Σ^0	$\overline{\Sigma}^0$	1192	$1/2^+$		−1	$< 1.0 \cdot 10^{-14}$	$\Lambda^0\gamma$
		Σ^+	$\overline{\Sigma}^-$	1189	$1/2^+$		−1	$0.8 \cdot 10^{-10}$	$p\pi^0, n\pi^+$
	Λ-hyperon	Λ^0	$\overline{\Lambda}^0$	1116	$1/2^+$	0	−1	$2.5 \cdot 10^{-10}$	$p\pi^-, n\pi^0$
	neutron	n	$\overline{n}$	940	$1/2^+$	1/2	0	$1.0 \cdot 10^3$	$e^-\overline{\nu}_e$
	proton	p	$\overline{p}$	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	K^0	$\overline{K}_0$	498	0^-	1/2	1	$0.9 \cdot 10^{-10} (K_1^0)$	$\pi^+\pi^-, \pi^0\pi^0$
								$5.4 \cdot 10^{-4} (K_2^0)$	$3\pi^0, \pi^+\pi^-\pi^0, \pi\mu\nu$
		K^+	K^-	494	0^-		1	$1.2 \cdot 10^{-8}$	$\mu^+\nu_\mu, \pi^+\pi^0, \pi^+\pi^+\pi^-$
	π-meson	π^+	π^-	140	0^-	1	0	$2.6 \cdot 10^{-8}$	$\mu^+\nu_\mu$
		π^0	π^0	135	0^-		0	$0.9 \cdot 10^{-16}$	$\gamma\gamma$
Leptoner	myon	μ^-	μ^+	106	1/2			$2.2 \cdot 10^{-6}$	$e^-\nu_e\nu_\mu$
	elektron	e^-	e^+	0.51	1/2			∞	
	neutrino	ν_μ	$\overline{\nu}_\mu$	0	1/2				
		ν_e	$\overline{\nu}_e$	0	1/2				
Foton	foton	γ		0	1		0		

Answers (not available in the real exam):

5a. $^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$
5b Q=1.73MeV
5c. $4.4 \cdot 10^{-12}$ gram
5d. 2432s

6a. Q=0.42MeV
6b 25mg
6c. $e+e^-$ aniihilation

7a dss
7b $p_\Lambda = p_\pi = 139 MeV/c$; $E_{k\,\Lambda} = 8.6 MeV$; $E_{k\pi} = 57.4 MeV$
7c i E
ii Le
iii reactionen OK
iv Q,Le,Lμ
v B

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