STRUCTURE OF MATTER – Midterm Exam 2

April 11, 2022

Without explanation or calculation steps no points will be awarded to a sub-problem even if the answer is correct!

1 – Baryons: Consider the charmed baryon with quark content usc and which decays into $p + K^- + \pi^+$.

The quark composition of π^+ is $u\bar{d}$ and of K^- it is $s\bar{u}$.

a) Determine the hypercharge and the azimuthal isospin of this baryon. Explain your answer. [2 pnt]

b) Verify whether conservation laws for charge and baryon number are respected. Explain your answer. [2 pnt]

c) What is the approximate time scale of the decay? Explain your answer. [3 pnt]

d) Which force carrier is most likely to be involved in this decay? Explain your answer. [3 pnt]

2 – Color and Symmetry: Consider a Δ^{2+} baryon (quark content uuu)

a) What is the color of the Δ^{2+} baryon, explain your answer. [2 pnt]

b) What is the color hypercharge of the Δ^{2+} baryon, explain your answer. [2 pnts]

3 - Mesons consisting out of the following quarks: $u, d, \bar{u}, and\ \bar{d}$

a) What is the quark composition of ρ^- mesons. Explain your answer. [1 pnts]

b) ρ^- mesons are the second lightest mesons of these mesons. What are the J value and parity of ρ^- mesons? Explain your answer [3 pnts].

c) Derive whether ρ^- mesons are or are not eigenstates of the charge conjugation operator? [2 pnts]

4 – Nuclear sizes, decay and stability

a) The unstable dysprosium isotope $^{150}_{66}$Dy decays via either α decay to gadolinium (Gd) or via β^+ decay to terbium (Tb). Give the complete formula for each of the two decay reactions. [3 pnts]

b) For a specific Sn isotope (Z=50) one finds the charge density to be 0.058 (e/fm^3). Determine the mass number of this Sn isotope, explain your answer [3 pnts]

c) For A=149 one calculates with the liquid drop model that Z=62 and N=87 is most stable ($^{149}_{62}$Sm). How does the ratio between neutrons and protons change if one would neglect either the Coulomb term or the "δ" term in the liquid drop model (hint: no lengthy calculations needed). [4 pnts]

$$B(N,Z) = aA - bA^{\frac{2}{3}} - \frac{dZ^2}{A^{\frac{1}{3}}} - s\frac{(N-Z)^2}{A} - \frac{\delta}{A^{\frac{1}{2}}}$$

a=	15.8	δ=	11.2	odd-odd
b=	18.3		0	even-odd
d=	0.71		-11.2	even-even
s=	23.2	all parameters are in MeV		

5 – Nuclear shell model and hyperfine levels.

Use the generic sequence of nuclear shell filling:

1s, 1p, 1d, 2s, 1f, 2p, 1g, 2d, 1h....

a) Why are all even-even nuclei 0^+ nuclei? Motivate/explain your answer. [3 pnts]

b) What is the nuclear spin and parity of $^{123}_{51}$Sb. Explain your answer. [4 pnts]

c) The ground term of Sb is of ^{4}S character. Determine the hyperfine levels (F values) associated with the ground term of Sb. Explain your answer. [3 pnts]