

STRUCTURE OF MATTER – Midterm Exam 2

April 6, 2023

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

1 – Consider charmed baryons with quark content usc and dsc .

- Use hypercharge and azimuthal isospin to show that usc and dsc form an isospin $1/2$ multiplet. Explain your answer. [3 pts]
- The usc baryon decays into $p + K^- + \pi^+$. (the quark composition of π^+ is $u\bar{d}$ and of K^- it is $s\bar{u}$.) What is the approximate time scale of the decay? Explain your answer. [3 pts]
- Which force carrier is most likely to be involved in this decay? Explain your answer. [2 pt]

2 – Consider a Ω^- baryon which consist of three s quarks

- What is the color of the Ω^- baryon, explain your answer. [1 pt]
- What is the Y^C value of the Ω^- baryon, explain your answer. [2 pts]

3 – D mesons

- What is the quark composition of D^+ mesons, select quarks from the following set of quarks: $c, d, \bar{c},$ and \bar{d} . Explain your answer. [1 pts]
- D^+ mesons are the lightest mesons of the D mesons. What are the J value and parity of D^+ mesons? Explain your answer [3 pts].
- What are the leptonic decay products if a D^+ would decay to second generation leptons? Explain your answer. [2 pts]
- Derive whether D^+ mesons are or are not eigenstates of the \hat{C} operator? [2 pts]

4 – Nuclear sizes, decay and stability

- a) The unstable dysprosium isotope $^{150}_{66}\text{Dy}$ 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) Of a $^{120}_{50}\text{Sn}$ isotope with a 3 to 2 neutron-to-proton ratio, determine its nuclear charge density in (e/fm³). Explain your answer [2 pnts]
- c) For A=149 one calculates with the liquid drop model that Z=62 and N=87 is most stable. How does for A=149 the ratio between neutrons and protons change if one would neglect the Coulomb term in the liquid drop model (hint: no lengthy calculations needed). [2 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	$\delta = \begin{cases} 11.2 \\ 0 \\ -11.2 \end{cases}$	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 $^{121}_{51}\text{Sb}$. Explain your answer. [4 pnts]
- c) The electronic ground term of Sb is of ⁴S character. Determine the hyperfine levels (F values) associated with the ground term of Sb. Explain your answer. [2 pnts]