Fall Term 2006

22.02 Introduction to APPLIED NUCLEAR PHYSICS

Problem Set #9

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1. Krane, problems 10.5, 10.6
2. Krane, problems 9.3, 9.6, 9.9, 9.11
3. This is the story of ${}^{99m}Tc$, an amazing itotope that produces only gamma rays for diagnostic purposes in nuclear medicine. The "m" in exponent means metastable since it has half life of 6 hours. Long enough to be injected into patient and utilized. Short enough that radiation intensity is high. This metastable state has spin/parity, $\frac{1}{2}^-$, and decays by gamma emission to its ground state with, $\frac{9}{2}^+$. First a couple questions about the gamma decay.
   - Explain the $\frac{9}{2}^+$ ground state using the shell model.
   - Give the expected mode of gamma decay, i.e. multipolarity and electric/magnetic nature.
   - Estimate lifetime for transition based on Weisskopf formulas. Don't expect to get that close to 6 hours (remember how approximate those formulas are).

Now lets understand how this isotope is produced. Start with ${}^{98}Mo$ produced as a fission product (also produced in accelerators). This is bombarded with neutrons to produce, ${}^{99}Mo$, with spin/parity of $\frac{1}{2}^+$. Compare this to shell model prediction and try to explain how the $\frac{1}{2}^+$ spin comes about. ${}^{99m}Tc$ is produced by a beta decay from ${}^{99}Mo$. Can you explain why this results in the metastable state with $\frac{1}{2}^-$, rather than the ground state with, $\frac{9}{2}^+$? It turns out that ${}^{99m}Tc$ can be separated chemically from the ${}^{99}Mo$ that produced it and this pure gamma emitter is then what is used in applications.