Physics 457 Problem Set 8

Due in Class, April 1, 2005 (Friday) – No joke!
Note: There will be no class on March 27.
There will be a make–up class on April 1, 2005, at 10:00 in room 4404

1. Use the shell model to predict the spins and parities of the ground states of ^{14}N, ^{15}N and ^{17}O. Be sure to identify both the closed shell and valence nucleon shells.

2. Use the shell model to predict the spins and parities of the first excited states of ^{13}C and ^{17}O.

3. Predict the magnetic moment of the ground state of ^{13}C.

4. The doubly magic nucleus ^{56}Ni is unstable ($t_{1/2} = 6$ days), and the most stable nucleus is ^{56}Fe with no magic numbers. Explain this in terms of nuclear models and nuclear forces.

5. ^{239}Pu is produced by neutron capture on ^{238}U followed by two $\beta -$ decays. ^{239}Pu decays by α emission. Calculate the α binding energy and KE of the α–particle for ^{239}Pu decay.

6. Estimate the α–decay lifetime of ^{239}Pu.

Explanation of Table (cont.)

Column 3, Mass Excess, Δ:

Mass excesses, M–A, are given in MeV with $\Delta(^{12}C)=0$, by definition. For isomers the values are obtained by adding the excitation energy to the Δ(g.s.) values. Wherever the excitation energy is not known, the mass excess for the next lower isomer (or g.s.) is given. The values are given to the accuracy determined by uncertainty in Δ(g.s.) (maximum of three figures after the decimal). The uncertainty is ≤9 in the last significant figure. An appended "s" denotes that the value is obtained from systematics.

Column 4, T½, Γ or Abundance:

The half–life and the abundance (in **bold face**) are shown followed by their units ("%" symbol in the case of abundance) which are followed by the uncertainty, in *italics*,in the last significant figure. For example, 8.1 s *10* means 8.1±1.0 s. For some very short–lived nuclei, level widths rather than half–lives are given. There also, the width is followed by units (*e.g.*, eV, keV, or MeV) which are followed by the uncertainty in *italics*, if known. As stated above when a limit or an approximate value is given it is based on systematics, mostly from [8].

For $2\beta^-$ and 2ε decay only the lowest value of their several limits (*e.g.*, for 0ν or 2ν, etc.) is given.

If a new measurement of T½ has since become available it is presented in place of the evaluated value in ENSDF.

Explanation of Table (cont.)

Column 5, Decay Mode:

Decay modes are given in decreasing strength from left to right, followed by the percentage branching, if known ("w" indicates a weak branch). The percentage branching is omitted where there is no competing mode of decay or no other mode has been observed. A "?" indicates an expected but not observed mode of decay[8]. The various modes of decay are given below:

$\beta-$	β^- decay
ε	ε (electron capture), or $\varepsilon+\beta^+$, or β^+ decay
IT	isomeric transition (through γ or conver–sion–electron decay)
n, p, α, ...	neutron, proton, alpha, ... decay
SF	spontaneous fission
$2\beta-$, 3α, ...	double β^- decay ($\beta^-\beta^-$), decay through emission of 3 α's, ...
$\beta-$n, $\beta-$p, $\beta-\alpha$, ...	delayed n, p, α, ... emission following β^- decay
εp, $\varepsilon\alpha$, εSF, ...	delayed p, α, SF, ... decay following ε or β^+ decay

Nuclear Wallet Cards

Isotope Z El A		Jπ	Δ (MeV)	T½, Γ, or Abundance	Decay Mode
91 Pa	229	(5/2+)	29.890	1.50 d *5*	ε 99.52%, α 0.48%
	230	(2−)	32.167	17.4 d *5*	ε 91.6%, β− 8.4%, α 3.2×10^{-3}%
	231	3/2−	33.421	32760 y *110*	α, Ne 13×10^{-10}%, SF < 2×10^{-11}%
	232	(2−)	35.939	1.31 d *2*	β−, ε 3.0×10^{-3}%
	233	3/2−	37.484	26.967 d *2*	β−
	234	4+	40.336	6.70 h *5*	β−
	234m	(0−)	40.410	1.17 m *3*	β− 99.84%, IT 0.16%
	235	(3/2−)	42.32	24.5 m *2*	β−
	236	1(−)	45.3	9.1 m *1*	β−
	237	(1/2+)	47.6	8.7 m *2*	β−
	238	(3−)	50.76	2.3 m *1*	β−, SF < 2.6×10^{-6}%
	239	(1/2+)	53.2s	106 m *30*	β−
	240		56.8s	≈2 m	β− ?
92 U	218	0+	21.88s	1.5 ms *+73−7*	α
	219	(9/2+)	23.21	42 μs *+34−13*	α
	220	0+	23.0s	≈60 ns	α?, ε?
	221		24.5s	≈0.7 μs	α?, ε?
	222	0+	24.3s	1.0 μs *+10−4*	α
	223	(7/2+)	25.82	55 μs *10*	α
	224	0+	25.70	0.9 ms *3*	α
	225		27.37	60 ms *10*	α
	226	0+	27.33	0.35 s *15*	α
	227	(3/2+)	29.01	1.1 m *1*	α
	228	0+	29.22	9.1 m *2*	α > 95%, ε < 5%
	229	(3/2+)	31.201	58 m *3*	ε ≈ 80%, α ≈ 20%
	230	0+	31.603	20.8 d	α, SF < 1×10^{-10}%
	231	(5/2−)	33.803	4.2 d *1*	ε
	231	(3/2+,5/2+)	33.803	4.2 d *1*	α ≈ 4×10^{-3}%
	232	0+	34.602	68.9 y *4*	α, Ne 9×10^{-10}%, SF < 1×10^{-12}%
	233	5/2+	36.913	1.592×10^{5} y *2*	α, SF < 6×10^{-11}%, Ne 7×10^{-11}%
	234	0+	38.141	2.455×10^{5} y *6* **0.0054% *5***	α, SF 1.6×10^{-9}%, Mg 1×10^{-11}%, Ne 9×10^{-12}%
	235	7/2−	40.914	703.8×10^{6} y *5* **0.7204% *6***	α, SF 7.0×10^{-9}%, Ne 8×10^{-10}%
	235m	1/2+	40.914	≈25 m	IT
	236	0+	42.441	2.342×10^{7} y *3*	α, SF 9.4×10^{-8}%, ^{30}Mg
	237	1/2+	45.386	6.75 d *1*	β−
	238	0+	47.304	4.468×10^{9} y *3* **99.2742% *10***	α, SF 5.4×10^{-5}%
	239	5/2+	50.569	23.45 m *2*	β−
	240	0+	52.709	14.1 h *1*	β−
	241		56.2s	≈5 m	β− ?
	242	0+	58.6s	16.8 m *5*	β−
93 Np	225	(9/2−)	31.58	>2 μs	α

Nuclear Wallet Cards

Isotope Z El A	Jπ	Δ (MeV)	T½, Γ, or Abundance	Decay Mode
93 Np 226		32.72s	35 ms *10*	α
227		32.56	0.51 s *6*	α
228		33.7s	61.4 s *14*	ε 60%, α 40%
229		33.76	4.0 m *2*	α > 50%, ε < 50%
230		35.22	4.6 m *3*	ε ≤ 97%, α ≥ 3%
231	(5/2)	35.61	48.8 m *2*	ε 98%, α 2%
232	(4+)	37.4s	14.7 m *3*	ε
233	(5/2+)	37.94	36.2 m *1*	ε, α ≤ 1.0×10^{-3}%
234	(0+)	39.950	4.4 d *1*	ε
235	5/2+	41.038	396.1 d *12*	ε, α 2.6×10^{-3}%
236	(6–)	43.37	154×10^{3} y *6*	ε 87.3%, β– 12.5%, α 0.16%
236m	1	43.43	22.5 h *4*	ε 52%, β– 48%
237	5/2+	44.868	2.144×10^{6} y *7*	α, SF ≤ 2×10^{-10}%
238	2+	47.451	2.117 d *2*	β–
239	5/2+	49.305	2.3565 d *4*	β–
240	1(+)	52.32	7.22 m *2*	β– 99.89%
240	(5+)	52.32	61.9 m *2*	β–
241	(5/2+)	54.26	13.9 m *2*	β–
242m	(1+)	57.4s	2.2 m *2*	β–
242m	(6)	57.4s	5.5 m *1*	β–
243	(5/2–)	59.87s	1.85 m *15*	β–
244	(7–)	63.2s	2.29 m *16*	β–
94 Pu 228	0+	36.07	≈0.2 s	α
229	(3/2+)	37.39	>2 μs	α
230	0+	36.93	≈200 s	α ≤ 100%
231	(3/2+)	38.4s	8.6 m *5*	ε 90%, α 10%
232	0+	38.36	34.1 m *7*	ε 80%, α 20%
233		40.04	20.9 m *4*	ε 99.88%, α 0.12%
234	0+	40.338	8.8 h *1*	ε ≈ 94%, α ≈ 6%
235	(5/2+)	42.18	25.3 m *5*	ε, α 2.7×10^{-3}%
236	0+	42.894	2.858 y *8*	α, SF 1.9×10^{-7}%
237	7/2–	45.088	45.2 d *1*	ε, α 4.2×10^{-3}%
237m	1/2+	45.234	0.18 s *2*	IT
238	0+	46.159	87.7 y *3*	α, SF 1.8×10^{-7}%
239	1/2+	48.583	24110 y *30*	α, SF 3×10^{-10}%
240	0+	50.121	6564 y *11*	α, SF 5.7×10^{-6}%
241	5/2+	52.951	14.290 y *6*	β–, α 2.5×10^{-3}%, SF > $2.\times10^{-14}$%
242	0+	54.713	3.733×10^{5} y *12*	α, SF 5.5×10^{-4}%
243	7/2+	57.750	4.956 h *3*	β–
244	0+	59.800	8.00×10^{7} y *9*	α 99.88%, SF 0.12%
245	(9/2–)	63.10	10.5 h *1*	β–
246	0+	65.39	10.84 d *2*	β–
247		69.0s	2.27 d *23*	β–
95 Am 231		42.4s	≈10 s	ε?, α?
232		43.4s	79 s *2*	ε ≈ 98%, α ≈ 2%
233		43.3s	≈2 m	ε?, α?
234		44.5s	2.32 m *8*	ε 99.96%, α 0.04%
235		44.7s	15 ms *5*	ε
236		46.2s	4.4 m *8*	ε
237	5/2(–)	46.55	73.0 m *10*	ε 99.98%, α 0.03%