UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2005

TITLE OF THE PAPER: NUCLEAR PHYSICS

COURSE NUMBER: P442

TIME ALLOWED: THREE HOURS

INSTRUCTIONS: **CHOOSE AND ATTEMPT ANY FOUR QUESTIONS. EACH QUESTION CARRIES 25 MARKS.**

THE PAPER CONSISTS OF SEVEN PAGES INCLUDING THIS ONE. DATA SHEETS ARE ALSO INCLUDED.

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

Question 1

a) A sample of gold is exposed to a neutron beam of constant intensity such that 10^{10} neutrons per second are absorbed in the reaction

$$^{197}Au + n \rightarrow {}^{198}Au + \gamma$$

The nuclide ^{198}Au undergoes β^- - decay to ^{198}Hg with a mean life of 3.89 days.

(i) Show the decay scheme. (3 marks)

(ii) How many atoms of ^{198}Au will be present after six days of irradication? (11 marks)

(iii) How many atoms of ^{198}Hg will be present at that time, assuming that the ^{198}Hg is unaffected by the neutron beam? (6 marks)

(iv) What is the equilibrium number of ^{198}Au atoms? (5 marks)

Question 2

a) What is the mechanical potential energy of an electron at the centre of a gold nucleus (Z=79, A=197) given that the nucleus is a uniformly charged sphere of radius $R=1.2\ A^{1/3}$ fm? Consider the cases when the observer is outside and inside the sphere. (15 marks)

b) Estimate the radius of the first Bohr orbit of a μ - meson about

(i) a proton (5 marks)

(ii) a ^{12}C nucleus (5 marks)

Question 3

a) Explain the terms in the semi-empirical mass formula

$$M(Z, A) = ZM_H + NM_n - a_V A + a_S A^{2/3} + a_C Z^2/A^{1/3} + a_{asym}(A-2Z)^2/A$$

$$\pm a/A^{1/3}$$ (15 marks)

b) Show for large A and Z that the energy released when a nucleus (Z,A) emits an α- particle is given by

$$Q = -4a_V + 8a_S/3A^{1/3} + 4a_C Z(1-Z/3A)/A^{1/3} - 4a_{asym}(N-Z)^2/A^2 + B(2,4)$$

where B (2,4) is the binding energy of the α-particle, 28.30 MeV.

(10 marks)

Question 4

a) (i) Explain why naturally occuring nuclei of mass number $A < 60$ are not α-unstable. (4 marks)

(ii) With neglect of nuclear spins, and for Coulomb potential barriers large compared with the α- particle energy, the dependence of the meanlife τ of an α-unstable nucleus on the charge Z and α-particle velocity v is represented by

$$\tau \propto \exp(4\pi Ze^2/4\pi\epsilon_0\hbar v)$$

Discuss the basic assumptions made in the derivation of this expression. (4 marks)

b) In the decay

$$^{138}U \rightarrow {}^{234}Th + \alpha$$

the emission of α-particles of energy 4.195, 4.147, 4.038 MeV is observed. Use the formula in (a) (ii) above to estimate the relative strength of these lines.

(i) What are the most probable spin-parity assignments for the states of ^{234}Th produced in this reaction? (9 marks)

(ii) State briefly why consideration of the spins of the states of ^{234}Th would change your estimates of the relative line strengths. (8 marks)

Question 5

a) Compute the Q-values for the reactions

$$d + d \rightarrow n + {}^{3}_{2}He$$

$$d + t \rightarrow n + \alpha$$

given mass defect of the neutron = 0.008 665 u
mass defect of deuterium atom =0.014 102 u
mass defect of tritrium atom = 0.016 050 u
mass defect of helium - 3 atom = 0.016 030 u
mass defect of helium - 4 atom = 0.002 603 u

(8 marks)

b) What are the maximum energies (in the laboratory) of neutrons that can be produced using 4 MeV deuterons incident on stationary targets of deuterium and of tritium? Use non- relatiristic kinematics and assume nuclear masses are

A x 931.5 MeV /c^2

in the transformation, but use the Q- values from (a) above. (17 marks)

Question 6

a) (i) Assuming that the wavefunction

$$u(r) = r\psi(r) = Ce$$

is valid for the deutron from r=0 to r=∞ obtain the value of the normalization constant C.

(ii) If $\alpha=0.232fm^{-1}$, find the probability that the separation of the two two particles in the deutron exceeds a value of 2fm

(iii) Find the average distance of interaction for this wavefunction.

b) (i) For the two-body system the radial Schrodinger wave equation is given as

$$\frac{d^2}{dr^2}u_\ell + \frac{2m}{\hbar}[E-V-\frac{\ell(\ell+1)\hbar^2}{2mr^2}]u_\ell = 0 \qquad 6.1$$

where ℓ is orbital angular momentum. The last term in the square bracket is called the centrifugal potential.Sketch the behaviour of this potential and state its importance.

(ii) To simplify the derivation it is usual to assume the s-state for the deutron wave function. Discuss this assumption in relation to the fact that the observed deutron spin is 1.

CONSTANTS

Speed of light	c	2.99792458×10^{8} m/s
Charge of electron	e	1.602189×10^{-19} C
Boltzmann constant	k	1.38066×10^{-23} J/K
		8.6174×10^{-5} eV/K
Planck's constant	h	6.62618×10^{-34} J · s
		4.13570×10^{-15} eV · s
	$\hbar = h/2\pi$	1.054589×10^{-34} J · s
		6.58217×10^{-16} eV · s
Gravitational constant	G	6.6726×10^{-11} N · m^2/kg^2
Avogadro's number	N_A	6.022045×10^{23} mole^{-1}
Universal gas constant	R	8.3144 J/mole · K
Stefan-Boltzmann constant	σ	5.6703×10^{-8} W/m^2 · K^4
Rydberg constant	R_∞	1.0973732×10^{7} m^{-1}
Hydrogen ionization energy		13.60580 eV
Bohr radius	a_0	5.291771×10^{-11} m
Bohr magneton	μ_B	9.27408×10^{-24} J/T
		5.78838×10^{-5} eV/T
Nuclear magneton	μ_N	5.05084×10^{-27} J/T
		3.15245×10^{-8} eV/T
Fine structure constant	α	1/137.0360
	hc	1239.853 MeV · fm
	$\hbar c$	197.329 MeV · fm
	$e^2/4\pi\epsilon_0$	1.439976 MeV · fm

PARTICLE REST MASSES

	u	MeV/c^2
Electron	5.485803×10^{-4}	0.511003
Proton	1.00727647	938.280
Neutron	1.00866501	939.573
Deuteron	2.01355321	1875.628
Alpha	4.00150618	3727.409
$\pi^{\pm}$	0.1498300	139.5669
π^0	0.1448999	134.9745
μ	0.1134292	105.6595

CONVERSION FACTORS

1 eV = 1.602189×10^{-19} J

1 u = 931.502 MeV/c^2
= 1.660566×10^{-27} kg

1 b = 10^{-28} m^2

1 Ci = 3.7×10^{10} decays/s

PERIODIC TABLE OF THE ELEMENTS

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.70	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (97)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.33	57–71 Rare Earths	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89–103 Acti-nides	104 Rf (257)	105 Ha	106 (263)	107	108	109									

Rare Earths (Lanthanides)	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinides	89 Ac (227)	90 Th 232.04	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

For each element, the bottom line gives either the atomic mass or (in parentheses, for radioactive elements) the mass number of the most stable isotope.

TABLE OF NUCLEAR PROPERTIES

The following table shows some properties of a selection of isotopes. For each element only the stable and relatively long-lived radioactive isotopes are included. Ground-state atomic masses and spin-parity assignments are shown for all isotopes; uncertain spin-parity assignments are in parentheses. Abundances are given for stable isotopes, and for radioactive isotopes the half-life and principal decay mode are shown (ε—electron capture, possibly including positron emission; β^-—negative beta decay; α—alpha decay; f—spontaneous fission). The masses are those of the corresponding neutral atoms and were taken from the 1983 atomic mass evaluation: A. H. Wapstra and G. Audi, *Nucl. Phys.* **A432**, 1 (1985). In the half-life entries, My = 10^6 y. Uncertainties in the masses are typically 10^{-5} u (10^{-4} u for some cases far from stability); uncertainties in the abundances and half-lives are typically at or below the level of the last digit tabulated.

	Z	A	Atomic mass (u)	I^π	*Abundance* or Half-life
H	1	1	1.007825	$\frac{1}{2}^+$	*99.985%*
		2	2.014102	1^+	*0.015%*
		3	3.016049	$\frac{1}{2}^+$	12.3 y (β^-)
He	2	3	3.016029	$\frac{1}{2}^+$	*1.38 × 10⁻⁴%*
		4	4.002603	0^+	*99.99986%*
Li	3	6	6.015121	1^+	*7.5%*
		7	7.016003	$\frac{3}{2}^-$	*92.5%*
		8	8.022486	2^+	0.84 s (β^-)
Be	4	7	7.016928	$\frac{3}{2}^-$	53.3 d (ε)
		8	8.005305	0^+	0.07 *fs* (α)
		9	9.012182	$\frac{3}{2}^-$	*100 %*
		10	10.013534	0^+	1.6 My (β^-)
		11	11.021658	$\frac{1}{2}^+$	13.8 s (β^-)
B	5	8	8.024606	2^+	0.77 s (ε)
		9	9.013329	$\frac{3}{2}^-$	0.85 as (α)
		10	10.012937	3^+	*19.8%*
		11	11.009305	$\frac{3}{2}^-$	*80.2%*
		12	12.014353	1^+	20.4 ms (β^-)
		13	13.017780	$\frac{3}{2}^-$	17.4 ms (β^-)
C	6	9	9.031039	$\frac{3}{2}^-$	0.13 s (ε)
		10	10.016856	0^+	19.2 s (ε)
		11	11.011433	$\frac{3}{2}^-$	20.4 m (ε)
		12	12.000000	0^+	*98.89%*
		13	13.003355	$\frac{1}{2}^-$	*1.11%*
		14	14.003242	0^+	5730 y (β^-)
		15	15.010599	$\frac{1}{2}^+$	2.45 s (β^-)
N	7	12	12.018613	1^+	11 ms (ε)
		13	13.005739	$\frac{1}{2}^-$	9.96 m (ε)
		14	14.003074	1^+	*99.63%*
		15	15.000109	$\frac{1}{2}^-$	*0.366%*
		16	16.006100	2^-	7.13 s (β^-)

	Z	A	Atomic mass (u)	I^π	*Abundance* or Half-life
		17	17.008450	$\frac{1}{2}^-$	4.17 s (β^-)
		18	18.014081	1^-	0.63 s (β^-)
O	8	14	14.008595	0^+	71 s (ε)
		15	15.003065	$\frac{1}{2}^-$	122 s (ε)
		16	15.994915	0^+	*99.76%*
		17	16.999131	$\frac{5}{2}^+$	*0.038%*
		18	17.999160	0^+	*0.204%*
		19	19.003577	$\frac{5}{2}^+$	26.9 s (β^-)
		20	20.004076	0^+	13.5 s (β^-)
F	9	17	17.002095	$\frac{5}{2}^+$	64.5 s (ε)
		18	18.000937	1^+	110 m (ε)
		19	18.998403	$\frac{1}{2}^+$	*100 %*
		20	19.999981	2^+	11 s (β^-)
		21	20.999948	$\frac{5}{2}^+$	4.3 s (β^-)
		22	22.003030	$(3,4)^+$	4.2 s (β^-)
		23	23.003600	$(\frac{3}{2},\frac{5}{2})^+$	2.2 s (β^-)
Ne	10	17	17.017690	$\frac{1}{2}^-$	0.11 s (ε)
		18	18.005710	0^+	1.7 s (ε)
		19	19.001880	$\frac{1}{2}^+$	17.3 s (ε)
		20	19.992436	0^+	*90.51%*
		21	20.993843	$\frac{3}{2}^+$	*0.27%*
		22	21.991383	0^+	*9.22%*
		23	22.994465	$\frac{5}{2}^+$	37.6 s (β^-)
		24	23.993613	0^+	3.4 m (β^-)
		25	24.997690	$(\frac{1}{2},\frac{3}{2})^+$	0.60 s (β^-)
Na	11	20	20.007344	2^+	0.45 s (ε)
		21	20.997651	$\frac{3}{2}^+$	22.5 s (ε)
		22	21.994434	3^+	2.60 y (ε)
		23	22.989768	$\frac{3}{2}^+$	*100 %*
		24	23.990961	4^+	15.0 h (β^-)
		25	24.989953	$\frac{5}{2}^+$	60 s (β^-)
		26	25.992586	3^+	1.1 s (β^-)
		27	26.993940	$\frac{5}{2}^+$	0.30 s (β^-)
Mg	12	21	21.011716	$(\frac{1}{2},\frac{3}{2})^+$	0.123 s (ε)
		22	21.999574	0^+	3.86 s (ε)
		23	22.994124	$\frac{3}{2}^+$	11.3 s (ε)
		24	23.985042	0^+	*78.99%*
		25	24.985837	$\frac{5}{2}^+$	*10.00%*
		26	25.982594	0^+	*11.01%*
		27	26.984341	$\frac{1}{2}^+$	9.46 m (β^-)
		28	27.983877	0^+	21.0 h (β^-)
		29	28.988480	$\frac{3}{2}^+$	1.4 s (β^-)
Al	13	24	23.999941	4^+	2.07 s (ε)
		25	24.990429	$\frac{5}{2}^+$	7.18 s (ε)
		26	25.986892	5^+	0.72 My (ε)
		27	26.981539	$\frac{5}{2}^+$	*100 %*
		28	27.981910	3^+	2.24 m (β^-)
		29	28.980446	$\frac{5}{2}^+$	6.6 m (β^-)
		30	29.982940	3^+	3.7 s (β^-)
Si	14	26	25.992330	0^+	2.21 s (ε)
		27	26.986704	$\frac{5}{2}^+$	4.13 s (ε)
		28	27.976927	0^+	*92.23%*
		29	28.976495	$\frac{1}{2}^+$	*4.67%*
		30	29.973770	0^+	*3.10%*
		31	30.975362	$\frac{3}{2}^+$	2.62 h (β^-)
		32	31.974148	0^+	105 y (β^-)
		33	32.997920	$(\frac{3}{2}^+)$	6.2 s (β^-)
P	15	29	28.981803	$\frac{1}{2}^+$	4.1 s (ε)
		30	29.978307	1^+	2.50 m (ε)
		31	30.973762	$\frac{1}{2}^+$	*100 %*
		32	31.973907	1^+	14.3 d (β^-)
		33	32.971725	$\frac{1}{2}^+$	25.3 d (β^-)
		34	33.973636	1^+	12.4 s (β^-)
S	16	30	29.984903	0^+	1.2 s (ε)
		31	30.979554	$\frac{1}{2}^+$	2.6 s (ε)
		32	31.972071	0^+	*95.02%*
		33	32.971458	$\frac{3}{2}^+$	*0.75%*
		34	33.967867	0^+	*4.21%*
		35	34.969032	$\frac{3}{2}^+$	87.4 d (β^-)
		36	35.967081	0^+	*0.017%*
		37	36.971126	$\frac{7}{2}^-$	5.0 m (β^-)
		38	37.971162	0^+	170 m (β^-)
Cl	17	33	32.977452	$\frac{3}{2}^+$	2.51 s (ε)
		34	33.973763	0^+	1.53 s (ε)
		35	34.968853	$\frac{3}{2}^+$	*75.77%*
		36	35.968307	2^+	0.30 My (β^-)
		37	36.965903	$\frac{3}{2}^+$	*24.23%*
		38	37.968011	2^-	37.3 m (β^-)
		39	38.968005	$\frac{3}{2}^+$	56 m (β^-)
		40	39.970440	2^-	1.35 m (β^-)
		41	40.970590	$(\frac{1}{2},\frac{3}{2})^+$	31 s (β^-)
Ar	18	34	33.980269	0^+	0.844 s (ε)
		35	34.975256	$\frac{3}{2}^+$	1.78 s (ε)
		36	35.967546	0^+	*0.337%*
		37	36.966776	$\frac{3}{2}^+$	35.0 d (ε)
		38	37.962732	0^+	*0.063%*
		39	38.964314	$\frac{7}{2}^-$	269 y (β^-)
		40	39.962384	0^+	*99.60%*
		41	40.964501	$\frac{7}{2}^-$	1.83 h (β^-)

	Z	A	Atomic mass (u)	I^π	*Abundance* or Half-life
		42	41.963050	0^+	33 y (β^-)
		43	42.965670		5.4 m (β^-)
		44	43.965365	0^+	11.9 m (β^-)
K	19	37	36.973377	$\frac{3}{2}^+$	1.23 s (ε)
		38	37.969080	3^+	7.61 m (ε)
		39	38.963707	$\frac{3}{2}^+$	*93.26%*
		40	39.963999	4^-	1.28 Gy (β^-)
		41	40.961825	$\frac{3}{2}^+$	*6.73%*
		42	41.962402	2^-	12.4 h (β^-)
		43	42.960717	$\frac{3}{2}^-$	22.3 h (β^-)
		44	43.961560	2^-	22.1 m (β^-)
		45	44.960696	$\frac{3}{2}^+$	17 m (β^-)
		46	45.961976	(2^-)	115 s (β^-)
		47	46.961677	$\frac{1}{2}^+$	17.5 s (β^-)
Ca	20	38	37.976318	0^+	0.44 s (ε)
		39	38.970718	$\frac{3}{2}^+$	0.86 s (ε)
		40	39.962591	0^+	*96.94%*
		41	40.962278	$\frac{7}{2}^-$	0.10 My (ε)
		42	41.958618	0^+	*0.647%*
		43	42.958766	$\frac{7}{2}^-$	*0.135%*
		44	43.955481	0^+	*2.09%*
		45	44.956185	$\frac{7}{2}^-$	165 d (β^-)
		46	45.953689	0^+	*0.0035%*
		47	46.954543	$\frac{7}{2}^-$	4.54 d (β^-)
		48	47.952533	0^+	*0.187%*
		49	48.955672	$\frac{3}{2}^-$	8.72 m (β^-)
		50	49.957519	0^+	14 s (β^-)
Sc	21	42	41.965514	0^+	0.68 s (ε)
		43	42.961150	$\frac{7}{2}^-$	3.89 h (ε)
		44	43.959404	2^+	3.93 h (ε)
		45	44.955910	$\frac{7}{2}^-$	*100 %*
		46	45.955170	4^+	83.8 d (β^-)
		47	46.952409	$\frac{7}{2}^-$	3.35 d (β^-)
		48	47.952235	6^+	43.7 h (β^-)
		49	48.950022	$\frac{7}{2}^-$	57.0 m (β^-)
		50	49.952186	5^+	1.71 m (β^-)
Ti	22	43	42.968523	$\frac{7}{2}^-$	0.51 s (ε)
		44	43.959690	0^+	54 y (ε)
		45	44.958124	$\frac{7}{2}^-$	3.09 h (ε)
		46	45.952629	0^+	*8.2%*
		47	46.951764	$\frac{5}{2}^-$	*7.4%*
		48	47.947947	0^+	*73.7%*
		49	48.947871	$\frac{7}{2}^-$	*5.4%*
		50	49.944792	0^+	*5.2%*
		51	50.946616	$\frac{3}{2}^-$	5.80 m (β^-)
		52	51.946898	0^+	1.7 m (β^-)
		53	52.949730	$(\frac{3}{2})^-$	33 s (β^-)
V	23	46	45.960198	0^+	0.42 s (ε)
		47	46.954906	$\frac{3}{2}^-$	32.6 m (ε)
		48	47.952257	4^+	16.0 d (ε)
		49	48.948517	$\frac{7}{2}^-$	330 d (ε)
		50	49.947161	6^+	*0.250%*
		51	50.943962	$\frac{7}{2}^-$	*99.750%*
		52	51.944778	3^+	3.76 m (β^-)
		53	52.944340	$\frac{7}{2}^-$	1.6 m (β^-)
		54	53.946442	$(3,4,5)^+$	50 s (β^-)
Cr	24	46	45.968360	0^+	0.26 s (ε)
		47	46.962905	$\frac{3}{2}^-$	0.51 s (ε)
		48	47.954033	0^+	21.6 h (ε)
		49	48.951338	$\frac{5}{2}^-$	41.9 m (ε)
		50	49.946046	0^+	*4.35%*
		51	50.944768	$\frac{7}{2}^-$	27.7 d (ε)
		52	51.940510	0^+	*83.79%*
		53	52.940651	$\frac{3}{2}^-$	*9.50%*
		54	53.938882	0^+	*2.36%*
		55	54.940842	$\frac{3}{2}^-$	3.50 m (β^-)
		56	55.940643		5.9 m (β^-)
Mn	25	50	49.954240	0^+	0.28 s (ε)
		51	50.948213	$\frac{5}{2}^-$	46.2 m (ε)
		52	51.945568	6^+	5.59 d (ε)
		53	52.941291	$\frac{7}{2}^-$	3.7 My (ε)
		54	53.940361	3^+	312 d (ε)
		55	54.938047	$\frac{5}{2}^-$	*100 %*
		56	55.938907	3^+	2.58 h (β^-)
		57	56.938285	$\frac{5}{2}^-$	1.6 m (β^-)
		58	57.940060	3^+	65 s (β^-)
Fe	26	51	50.956825	$(\frac{5}{2})^-$	0.25 s (ε)
		52	51.948114	0^+	8.27 h (ε)
		53	52.945310	$\frac{7}{2}^-$	8.51 m (ε)
		54	53.939613	0^+	*5.8%*
		55	54.938296	$\frac{3}{2}^-$	2.7 y (ε)
		56	55.934939	0^+	*91.8%*
		57	56.935396	$\frac{1}{2}^-$	*2.15%*
		58	57.933277	0^+	*0.29%*
		59	58.934877	$\frac{3}{2}^-$	44.6 d (β^-)
		60	59.934078	0^+	1.5 My (β^-)
		61	60.936748	$(\frac{3}{2},\frac{5}{2})^-$	6.0 m (β^-)
		62	61.936773	0^+	68 s (β^-)
Co	27	54	53.948460	0^+	0.19 s (ε)

	Z	A	Atomic mass (u)	J^π	*Abundance* or Half-life
		55	54.942001	$\frac{7}{2}^-$	17.5 h (ε)
		56	55.939841	4^+	78.8 d (ε)
		57	56.936294	$\frac{7}{2}^-$	271 d (ε)
		58	57.935755	2^+	70.8 d (ε)
		59	58.933198	$\frac{7}{2}^-$	*100 %*
		60	59.933820	5^+	5.27 y (β^-)
		61	60.932478	$\frac{7}{2}^-$	1.65 h (β^-)
		62	61.934060	2^+	1.5 m (β^-)
		63	62.933614	$(\frac{7}{2})^-$	27.5 s (β^-)
Ni	28	55	54.951336	$\frac{7}{2}^-$	0.19 s (ε)
		56	55.942134	0^+	6.10 d (ε)
		57	56.939799	$\frac{3}{2}^-$	36.0 h (ε)
		58	57.935346	0^+	*68.3%*
		59	58.934349	$\frac{3}{2}^-$	0.075 My (ε)
		60	59.930788	0^+	*26.1%*
		61	60.931058	$\frac{3}{2}^-$	*1.13%*
		62	61.928346	0^+	*3.59%*
		63	62.929670	$\frac{1}{2}^-$	100 y (β^-)
		64	63.927968	0^+	*0.91%*
		65	64.930086	$\frac{5}{2}^-$	2.52 h (β^-)
		66	65.929116	0^+	54.8 h (β^-)
		67	66.931570	?	21 s (β^-)
Cu	29	59	58.939503	$\frac{3}{2}^-$	82 s (ε)
		60	59.937366	2^+	23.4 m (ε)
		61	60.933461	$\frac{3}{2}^-$	3.41 h (ε)
		62	61.932586	1^+	9.73 m (ε)
		63	62.929599	$\frac{3}{2}^-$	*69.2%*
		64	63.292766	1^+	12.7 h (ε)
		65	64.927793	$\frac{3}{2}^-$	*30.8%*
		66	65.928872	1^+	5.10 m (β^-)
		67	66.927747	$\frac{3}{2}^-$	61.9 h (β^-)
		68	67.929620	1^+	31 s (β^-)
Zn	30	61	60.939514	$\frac{3}{2}^-$	89 s (ε)
		62	61.934332	0^+	9.2 h (ε)
		63	62.933214	$\frac{3}{2}^-$	38.1 m (ε)
		64	63.929145	0^+	*48.6%*
		65	64.929243	$\frac{5}{2}^-$	244 d (ε)
		66	65.926035	0^+	*27.9%*
		67	66.927129	$\frac{5}{2}^-$	*4.10%*
		68	67.924846	0^+	*18.8%*
		69	68.926552	$\frac{1}{2}^-$	56 m (β^-)
		70	69.925325	0^+	*0.62%*
		71	70.927727	$\frac{1}{2}^-$	2.4 m (β^-)
		72	71.926856	0^+	46.5 h (β^-)
		73	72.929780	$(\frac{3}{2})^-$	24 s (β^-)

	Z	A	Atomic mass (u)	J^π	*Abundance* or Half-life
Ga	31	64	63.936836	0^+	2.6 m (ε)
		65	64.932738	$\frac{3}{2}^-$	15.2 m (ε)
		66	65.931590	0^+	9.4 h (ε)
		67	66.928204	$\frac{3}{2}^-$	78.3 h (ε)
		68	67.927982	1^+	68.1 m (ε)
		69	68.925580	$\frac{3}{2}^-$	*60.1%*
		70	69.926028	1^+	21.1 m (β^-)
		71	70.924701	$\frac{3}{2}^-$	*39.9%*
		72	71.926365	3^-	14.1 h (β^-)
		73	72.925169	$\frac{3}{2}^-$	4.87 h (β^-)
		74	73.926940	$(4)^-$	8.1 m (β^-)
		75	74.926499	$\frac{3}{2}^-$	2.1 m (β^-)
Ge	32	66	65.933847	0^+	2.3 h (ε)
		67	66.932737	$(\frac{1}{2})^-$	19.0 m (ε)
		68	67.928096	0^+	271 d (ε)
		69	68.927969	$\frac{5}{2}^-$	39.0 h (ε)
		70	69.924250	0^+	*20.5%*
		71	70.924954	$\frac{1}{2}^-$	11.2 d (ε)
		72	71.922079	0^+	*27.4%*
		73	72.923463	$\frac{9}{2}^+$	*7.8%*
		74	73.921177	0^+	*36.5%*
		75	74.922858	$\frac{1}{2}^-$	82.8 m (β^-)
		76	75.921402	0^+	*7.8%*
		77	76.923548	$\frac{7}{2}^+$	11.3 h (β^-)
		78	77.922853	0^+	1.45 h (β^-)
		79	78.925360	$(\frac{1}{2})^-$	19 s (β^-)
As	33	70	69.930929	4^+	53 m (ε)
		71	70.927114	$\frac{5}{2}^-$	61 h (ε)
		72	71.926755	2^-	26.0 h (ε)
		73	72.923827	$\frac{3}{2}^-$	80.3 d (ε)
		74	73.923928	2^-	17.8 d (ε)
		75	74.921594	$\frac{3}{2}^-$	*100 %*
		76	75.922393	2^-	26.3 h (β^-)
		77	76.920646	$\frac{3}{2}^-$	38.8 h (β^-)
		78	77.921830	(2^-)	91 m (β^-)
		79	78.920946	$\frac{3}{2}^-$	9.0 m (β^-)
Se	34	71	70.932270	$\frac{5}{2}^-$	4.7 m (ε)
		72	71.927110	0^+	8.4 d (ε)
		73	72.926768	$\frac{9}{2}^+$	7.1 h (ε)
		74	73.922475	0^+	*0.87%*
		75	74.922522	$\frac{5}{2}^+$	119.8 d (ε)
		76	75.919212	0^+	*9.0%*
		77	76.919913	$\frac{1}{2}^-$	*7.6%*
		78	77.917308	0^+	*23.5%*
		79	78.918498	$\frac{7}{2}^+$	< 0.065 My (β^-)

Z	A	Atomic mass (u)	I^π	Abundance or Half-life
	80	79.916520	0^+	*49.8%*
	81	80.917991	$(\frac{1}{2})^-$	18.5 m (β^-)
	82	81.916698	0^+	*9.2%*
	83	82.919117	$(\frac{9}{2})^+$	22.5 m (β^-)
	84	83.918463	0^+	3.3 m (β^-)
Br	35 76	75.924528	1^-	16.1 h (ε)
	77	76.921378	$\frac{3}{2}^-$	57.0 h (ε)
	78	77.921144	1^+	6.46 m (ε)
	79	78.918336	$\frac{3}{2}^-$	*50.69%*
	80	79.918528	1^+	17.6 m (β^-)
	81	80.916289	$\frac{3}{2}^-$	*49.31%*
	82	81.916802	5^-	35.3 h (β^-)
	83	82.915179	$(\frac{3}{2})^-$	2.39 h (β^-)
	84	83.916503	2^-	31.8 m (β^-)
	85	84.915612	$(\frac{3}{2})^-$	2.9 m (β^-)
Kr	36 75	74.931029	?	4.3 m (ε)
	76	75.925959	0^+	14.8 h (ε)
	77	76.924610	$\frac{3}{2}^+$	75 m (ε)
	78	77.920396	0^+	*0.356%*
	79	78.920084	$\frac{1}{2}^-$	35.0 h (ε)
	80	79.916380	0^+	*2.27%*
	81	80.916590	$\frac{7}{2}^+$	0.21 My (ε)
	82	81.913482	0^+	*11.6%*
	83	82.914135	$\frac{9}{2}^+$	*11.5%*
	84	83.911507	0^+	*57.0%*
	85	84.912531	$\frac{9}{2}^+$	10.7 y (β^-)
	86	85.910616	0^+	*17.3%*
	87	86.913360	$\frac{5}{2}^+$	76 m (β^-)
	88	87.914453	0^+	2.84 h (β^-)
	89	88.917640	$(\frac{3}{2})^+$	3.18 m (β^-)
Rb	37 82	81.918195	1^+	1.25 m (ε)
	83	82.915144	$\frac{5}{2}^-$	86.2 d (ε)
	84	83.914390	2^-	32.9 d (ε)
	85	84.911794	$\frac{5}{2}^-$	*72.17%*
	86	85.911172	2^-	18.8 d (β^-)
	87	86.909187	$\frac{3}{2}^-$	*27.83%*
	88	87.911326	2^-	17.8 m (β^-)
	89	88.912278	$(\frac{3}{2})^-$	15.2 m (β^-)
	90	89.914811	(1^-)	153 s (β^-)
Sr	38 81	80.923270	$(\frac{1}{2}^-)$	22 m (ε)
	82	81.918414	0^+	25.0 d (ε)
	83	82.917566	$\frac{7}{2}^+$	32.4 d (ε)
	84	83.913430	0^+	*0.56%*
	85	84.912937	$\frac{9}{2}^+$	64.8 d (ε)
	86	85.909267	0^+	*9.8%*
	87	86.908884	$\frac{9}{2}^+$	*7.0%*
	88	87.905619	0^+	*82.6%*
	89	88.907450	$\frac{5}{2}^+$	50.5 d (β^-)
	90	89.907738	0^+	28.8 y (β^-)
	91	90.910187	$(\frac{5}{2})^+$	9.5 h (β^-)
	92	91.910944	0^+	2.7 h (β^-)
	93	92.913987	$(\frac{7}{2}^+)$	7.4 m (β^-)
Y	39 84	83.920310	(5^-)	39 m (ε)
	85	84.916437	$(\frac{1}{2})^-$	2.7 h (ε)
	86	85.914893	4^-	14.7 h (ε)
	87	86.910882	$\frac{1}{2}^-$	80.3 h (ε)
	88	87.909508	4^-	106.6 d (ε)
	89	88.905849	$\frac{1}{2}^-$	*100 %*
	90	89.907152	2^-	64.1 h (β^-)
	91	90.907303	$\frac{1}{2}^-$	58.5 d (β^-)
	92	91.908917	2^-	3.54 h (β^-)
	93	92.909571	$\frac{1}{2}^-$	10.2 h (β^-)
	94	93.911597	2^-	18.7 m (β^-)
Zr	40 87	86.914817	$(\frac{9}{2}^+)$	1.6 h (ε)
	88	87.910225	0^+	83.4 d (ε)
	89	88.908890	$\frac{9}{2}^+$	78.4 h (ε)
	90	89.904703	0^+	*51.5%*
	91	90.905644	$\frac{5}{2}^+$	*11.2%*
	92	91.905039	0^+	*17.1%*
	93	92.906474	$\frac{5}{2}^+$	1.5 My (β^-)
	94	93.906315	0^+	*17.4%*
	95	94.908042	$\frac{5}{2}^+$	64.0 d (β^-)
	96	95.908275	0^+	*2.80%*
	97	96.910950	$\frac{1}{2}^+$	16.9 h (β^-)
	98	97.912735	0^+	31 s (β^-)
Nb	41 89	88.913449	$(\frac{1}{2})^-$	2.0 h (ε)
	90	89.911263	8^+	14.6 h (ε)
	91	90.906991	$(\frac{9}{2})^+$	700 y (ε)
	92	91.907192	$(7)^+$	35 My (ε)
	93	92.906377	$\frac{9}{2}^+$	*100 %*
	94	93.907281	6^+	0.020 My (β^-)
	95	94.906835	$\frac{9}{2}^+$	35.0 d (β^-)
	96	95.908100	6^+	23.4 h (β^-)
	97	96.908097	$\frac{9}{2}^+$	72 m (β^-)
Mo	42 90	89.913933	0^+	5.67 h (ε)
	91	90.911755	$\frac{9}{2}^+$	15.5 m (ε)
	92	91.906808	0^+	*14.8%*
	93	92.906813	$\frac{5}{2}^+$	3500 y (ε)
	94	93.905085	0^+	*9.3%*
	95	94.905841	$\frac{5}{2}^+$	*15.9%*

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	96	95.904679	0^+	*16.7%*
	97	96.906021	$\frac{5}{2}^+$	*9.6%*
	98	97.905407	0^+	*24.1%*
	99	98.907711	$\frac{1}{2}^+$	66.0 h (β^-)
	100	99.907477	0^+	*9.6%*
	101	100.910345	$\frac{1}{2}^+$	14.6 m (β^-)
Tc	43 94	93.909654	7^+	293 m (ε)
	95	94.907657	$\frac{9}{2}^+$	20.0 h (ε)
	96	95.907870	7^+	4.3 d (ε)
	97	96.906364	$\frac{9}{2}^+$	2.6 My (ε)
	98	97.907215	$(6)^+$	4.2 My (β^-)
	99	98.906254	$\frac{9}{2}^+$	0.214 My (β^-)
	100	99.907657	1^+	15.8 s (β^-)
Ru	44 94	93.911361	0^+	52 m (ε)
	95	94.910414	$\frac{5}{2}^+$	1.65 h (ε)
	96	95.907599	0^+	*5.5%*
	97	96.907556	$\frac{5}{2}^+$	2.88 d (ε)
	98	97.905287	0^+	*1.86%*
	99	98.905939	$\frac{5}{2}^+$	*12.7%*
	100	99.904219	0^+	*12.6%*
	101	100.905582	$\frac{5}{2}^+$	*17.0%*
	102	101.904348	0^+	*31.6%*
	103	102.906323	$\frac{3}{2}^+$	39.4 d (β^-)
	104	103.905424	0^+	*18.7%*
	105	104.907744	$\frac{5}{2}^+$	4.44 h (β^-)
	106	105.907321	0^+	372 d (β^-)
	107	106.910130	$(\frac{1}{2}^+)$	3.8 m (β^-)
Rh	45 98	97.910716	$(2)^+$	8.7 m (ε)
	99	98.908192	$(\frac{1}{2}^-)$	16.1 d (ε)
	100	99.908116	1^-	20.8 h (ε)
	101	100.906159	$\frac{1}{2}^-$	3.3 y (ε)
	102	101.906814	6^+	2.9 y (ε)
	103	102.905500	$\frac{1}{2}^-$	*100 %*
	104	103.906651	1^+	42.3 s (β^-)
	105	104.905686	$\frac{7}{2}^+$	35.4 h (β^-)
	106	105.907279	1^+	29.8 s (β^-)
Pd	46 99	98.911763	$(\frac{5}{2}^+)$	21.4 m (ε)
	100	99.908527	0^+	3.6 d (ε)
	101	100.908287	$\frac{5}{2}^+$	8.5 h (ε)
	102	101.905634	0^+	*1.0%*
	103	102.906114	$\frac{5}{2}^+$	17.0 d (ε)
	104	103.904029	0^+	*11.0%*
	105	104.905079	$\frac{5}{2}^+$	*22.2%*
	106	105.903478	0^+	*27.3%*
	107	106.905127	$\frac{5}{2}^+$	6.5 My (β^-)
	108	107.903895	0^+	*26.7%*
	109	108.905954	$\frac{5}{2}^+$	13.4 h (β^-)
	110	109.905167	0^+	*11.8%*
	111	110.907660	$\frac{5}{2}^+$	23.1m (β^-)
	112	111.907323	0^+	21.0 h (β^-)
Ag	47 103	102.908980	$\frac{7}{2}^+$	65.7 m (ε)
	104	103.908623	5^+	69.2 m (ε)
	105	104.906520	$\frac{1}{2}^-$	41.3 d (ε)
	106	105.906662	1^+	24.0 m (ε)
	107	106.905092	$\frac{1}{2}^-$	*51.83%*
	108	107.905952	1^+	2.4 m (β^-)
	109	108.904756	$\frac{1}{2}^-$	*48.17%*
	110	109.906111	1^+	24.4 s (β^-)
	111	110.905295	$\frac{1}{2}^-$	7.45 d (β^-)
	112	111.907010	2^-	3.14 h (β^-)
Cd	48 104	103.909851	0^+	58 m (ε)
	105	104.909459	$\frac{5}{2}^+$	56.0 m (ε)
	106	105.906461	0^+	*1.25%*
	107	106.906613	$\frac{5}{2}^+$	6.50 h (ε)
	108	107.904176	0^+	*0.89%*
	109	108.904953	$\frac{5}{2}^+$	463 d (ε)
	110	109.903005	0^+	*12.5%*
	111	110.904182	$\frac{1}{2}^+$	*12.8%*
	112	111.902757	0^+	*24.1%*
	113	112.904400	$\frac{1}{2}^+$	*12.2%*
	114	113.903357	0^+	*28.7%*
	115	114.905430	$\frac{1}{2}^+$	53.4 h (β^-)
	116	115.904755	0^+	*7.5%*
	117	116.907228	$\frac{1}{2}^+$	2.4 h (β^-)
	118	117.911700	0^+	50.3 m (β^-)
In	49 110	109.907230	2^+	69.1 m (ε)
	111	110.905109	$\frac{9}{2}^+$	2.83 d (ε)
	112	111.905536	1^+	14.4 m (ε)
	113	112.904061	$\frac{9}{2}^+$	*4.3%*
	114	113.904916	1^+	71.9 s (β^-)
	115	114.903882	$\frac{9}{2}^+$	*95.7%*
	116	115.905264	1^+	14.1 s (β^-)
	117	116.904517	$\frac{9}{2}^+$	43.8 m (β^-)
Sn	50 109	108.911294	$\frac{5}{2}^+$	18.0 m (ε)
	110	109.907858	0^+	4.1 h (ε)
	111	110.907741	$\frac{7}{2}^+$	35 m (ε)
	112	111.904826	0^+	*1.01%*
	113	112.905176	$\frac{1}{2}^+$	115.1 d (ε)
	114	113.902784	0^+	*0.67%*
	115	114.903348	$\frac{1}{2}^+$	*0.38%*

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		116	115.901747	0^+	*14.6%*
		117	116.902956	$\frac{1}{2}^+$	*7.75%*
		118	117.901609	0^+	*24.3%*
		119	118.903311	$\frac{1}{2}^+$	*8.6%*
		120	119.902199	0^+	*32.4%*
		121	120.904239	$\frac{3}{2}^+$	27.1 h (β^-)
		122	121.903440	0^+	*4.56%*
		123	122.905722	$\frac{11}{2}^-$	129 d (β^-)
		124	123.905274	0^+	*5.64%*
		125	124.907785	$\frac{11}{2}^-$	9.62 d (β^-)
		126	125.907654	0^+	0.1 My (β^-)
		127	126.910355	$(\frac{11}{2}^-)$	2.1 h (β^-)
Sb	51	118	117.905534	1^+	3.6 m (ε)
		119	118.903948	$\frac{5}{2}^+$	38.0 h (ε)
		120	119.905077	1^+	15.8 m (ε)
		121	120.903821	$\frac{5}{2}^+$	*57.3%*
		122	121.905179	2^-	2.70 d (β^-)
		123	122.904216	$\frac{7}{2}^+$	*42.7%*
		124	123.905938	3^-	60.2 d (β^-)
		125	124.905252	$\frac{7}{2}^+$	2.7 y (β^-)
		126	125.907250	8^-	12.4 d (β^-)
		127	126.906919	$\frac{7}{2}^+$	3.85 d (β^-)
Te	52	117	116.908630	$\frac{1}{2}^+$	62 m (ε)
		118	117.905908	0^+	6.00 d (ε)
		119	118.906411	$\frac{1}{2}^+$	16.0 h (ε)
		120	119.904048	0^+	*0.091%*
		121	120.904947	$\frac{1}{2}^+$	16.8 d (ε)
		122	121.903050	0^+	*2.5%*
		123	122.904271	$\frac{1}{2}^+$	*0.89%*
		124	123.902818	0^+	*4.6%*
		125	124.904429	$\frac{1}{2}^+$	*7.0%*
		126	125.903310	0^+	*18.7%*
		127	126.905221	$\frac{3}{2}^+$	9.4 h (β^-)
		128	127.904463	0^+	*31.7%*
		129	128.906594	$\frac{3}{2}^+$	69 m (β^-)
		130	129.906229	0^+	*34.5%*
		131	130.908528	$\frac{3}{2}^+$	25.0 m (β^-)
		132	131.908517	0^+	78.2 h (β^-)
		133	132.910910	$(\frac{3}{2}^+)$	12.5 m (β^-)
I	53	123	122.905594	$\frac{5}{2}^+$	13.2 h (ε)
		124	123.906207	2^-	4.18 d (ε)
		125	124.904620	$\frac{5}{2}^+$	60.2 d (ε)
		126	125.905624	2^-	13.0 d (ε)
		127	126.904473	$\frac{5}{2}^+$	*100 %*
		128	127.905810	1^+	25.0 m (β^-)
		129	128.904986	$\frac{7}{2}^+$	16 My (β^-)
		130	129.906713	5^+	12.4 h (β^-)
		131	130.906114	$\frac{7}{2}^+$	8.04 d (β^-)
		132	131.907987	4^+	2.30 h (β^-)
Xe	54	121	120.911450	$(\frac{5}{2}^+)$	40.1 m (ε)
		122	121.908170	0^+	20.1 h (ε)
		123	122.908469	$(\frac{1}{2}^+)$	2.08 h (ε)
		124	123.905894	0^+	*0.096%*
		125	124.906397	$(\frac{1}{2})^+$	17 h (ε)
		126	125.904281	0^+	*0.090%*
		127	126.905182	$(\frac{1}{2}^+)$	36.4 d (ε)
		128	127.903531	0^+	*1.92%*
		129	128.904780	$\frac{1}{2}^+$	*26.4%*
		130	129.903509	0^+	*4.1%*
		131	130.905072	$\frac{3}{2}^+$	*21.2%*
		132	131.904144	0^+	*26.9%*
		133	132.905888	$\frac{3}{2}^+$	5.25 d (β^-)
		134	133.905395	0^+	*10.4%*
		135	134.907130	$\frac{3}{2}^+$	9.1 h (β^-)
		136	135.907214	0^+	*8.9%*
		137	136.911557	$\frac{7}{2}^-$	3.82 m (β^-)
Cs	55	130	129.906753	1^+	29.2 m (ε)
		131	130.905444	$\frac{5}{2}^+$	9.69 d (ε)
		132	131.906431	2^-	6.47 d (ε)
		133	132.905429	$\frac{7}{2}^+$	*100 %*
		134	133.906696	4^+	2.06 y (β^-)
		135	134.905885	$\frac{7}{2}^+$	3 My (β^-)
		136	135.907289	5^+	13.1 d (β^-)
		137	136.907073	$\frac{7}{2}^+$	30.2 y (β^-)
		138	137.911004	3^-	32.2 m (β^-)
Ba	56	127	126.911130	$(\frac{1}{2}^+)$	12.7 m (ε)
		128	127.908237	0^+	2.43 d (ε)
		129	128.908642	$\frac{1}{2}^+$	2.2 h (ε)
		130	129.906282	0^+	*0.106%*
		131	130.906902	$\frac{1}{2}^+$	12.0 d (ε)
		132	131.905042	0^+	*0.101%*
		133	132.905988	$\frac{1}{2}^+$	10.7 y (ε)
		134	133.904486	0^+	*2.42%*
		135	134.905665	$\frac{3}{2}^+$	*6.59%*
		136	135.904553	0^+	*7.85%*
		137	136.905812	$\frac{3}{2}^+$	*11.2%*
		138	137.905232	0^+	*71.7%*
		139	138.908826	$\frac{7}{2}^-$	82.9 m (β^-)
		140	139.910581	0^+	12.7 d (β^-)
		141	140.914363	$\frac{3}{2}^-$	18.3 m (β^-)

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La	57	135	134.906953	$\frac{5}{2}^+$	19.5 h (ε)
		136	135.907630	1^+	9.87 m (ε)
		137	136.906460	$\frac{7}{2}^+$	0.06 My (ε)
		138	137.907105	5^+	*0.089%*
		139	138.906347	$\frac{7}{2}^+$	*99.911%*
		140	139.909471	3^-	40.3 h (β^-)
		141	140.910896	$\frac{7}{2}^+$	3.90 h (β^-)
		142	141.914090	2^-	91.1 m (β^-)
Ce	58	133	132.911360	$\frac{1}{2}^+$	5.4 h (ε)
		134	133.908890	0^+	76 h (ε)
		135	134.909117	$\frac{1}{2}^+$	17.6 h (ε)
		136	135.907140	0^+	*0.190%*
		137	136.907780	$\frac{3}{2}^+$	9.0 h (ε)
		138	137.905985	0^+	*0.254%*
		139	138.906631	$\frac{3}{2}^+$	137.2 d (ε)
		140	139.905433	0^+	*88.5%*
		141	140.908271	$\frac{7}{2}^-$	32.5 d (β^-)
		142	141.909241	0^+	*11.1%*
		143	142.912383	$\frac{3}{2}^-$	33.0 h (β^-)
		144	143.913643	0^+	284 d (β^-)
		145	144.917230	$\frac{5}{2}^+$	2.98 m (β^-)
Pr	59	138	137.910748	1^+	1.45 m (ε)
		139	138.908917	$\frac{5}{2}^+$	4.4 h (ε)
		140	139.909071	1^+	3.39 m (ε)
		141	140.907647	$\frac{5}{2}^+$	*100 %*
		142	141.910039	2^-	19.2 h (β^-)
		143	142.910814	$\frac{7}{2}^+$	13.6 d (β^-)
		144	143.913301	0^-	17.3 m (β^-)
Nd	60	139	138.911920	$\frac{1}{2}^+$	29.7 m (ε)
		140	139.909306	0^+	3.37 d (ε)
		141	140.909594	$\frac{3}{2}^+$	2.5 h (ε)
		142	141.907719	0^+	*27.2%*
		143	142.909810	$\frac{7}{2}^-$	*12.2%*
		144	143.910083	0^+	*23.8%*
		145	144.912570	$\frac{7}{2}^-$	*8.3%*
		146	145.913113	0^+	*17.2%*
		147	146.916097	$\frac{5}{2}^-$	11.0 d (β^-)
		148	147.916889	0^+	*5.7%*
		149	148.920145	$\frac{5}{2}^-$	1.73 h (β^-)
		150	149.920887	0^+	*5.6%*
		151	150.923825	$(\frac{1}{2}^+)$	12.4 m (β^-)
		152	151.924680	0^+	11.4 m (β^-)
Pm	61	142	141.912970	1^+	40.5 s (ε)
		143	142.910930	$\frac{5}{2}^+$	265 d (ε)
		144	143.912588	5^-	349 d (ε)
		145	144.912743	$\frac{5}{2}^+$	17.7 y (ε)
		146	145.914708	3^-	5.5 y (ε)
		147	146.915135	$\frac{7}{2}^+$	2.62 y (β^-)
		148	147.917473	1^-	5.37 d (β^-)
		149	148.918332	$\frac{7}{2}^+$	53.1 h (β^-)
		150	149.920981	(1^-)	2.68 h (β^-)
Sm	62	142	141.915206	0^+	72.5 m (ε)
		143	142.914626	$\frac{3}{2}^+$	8.83 m (ε)
		144	143.911998	0^+	*3.1%*
		145	144.913409	$\frac{7}{2}^-$	340 d (ε)
		146	145.913053	0^+	103 My (α)
		147	146.914894	$\frac{7}{2}^-$	*15.1%*
		148	147.914819	0^+	*11.3%*
		149	148.917180	$\frac{7}{2}^-$	*13.9%*
		150	149.917273	0^+	*7.4%*
		151	150.919929	$\frac{5}{2}^-$	90 y (β^-)
		152	151.919728	0^+	*26.6%*
		153	152.922094	$\frac{3}{2}^+$	46.8 h (β^-)
		154	153.922205	0^+	*22.6%*
		155	154.924636	$\frac{3}{2}^-$	22.4 m (β^-)
Eu	63	148	147.918125	5^-	54.5 d (ε)
		149	148.917926	$\frac{5}{2}^+$	93.1 d (ε)
		150	149.919702	0^-	36 y (ε)
		151	150.919847	$\frac{5}{2}^+$	*47.9%*
		152	151.921742	3^-	13 y (ε)
		153	152.921225	$\frac{5}{2}^+$	*52.1%*
		154	153.922975	3^-	8.5 y (β^-)
		155	154.922889	$\frac{5}{2}^+$	4.9 y (β^-)
		156	155.924752	0^+	15 d (β^-)
		157	156.925418	$\frac{5}{2}^+$	15 h (β^-)
Gd	64	149	148.919344	$\frac{7}{2}^-$	9.4 d (ε)
		150	149.918662	0^+	1.8 My (α)
		151	150.920346	$\frac{7}{2}^-$	120 d (ε)
		152	151.919786	0^+	*0.20%*
		153	152.921745	$\frac{3}{2}^-$	242 d (ε)
		154	153.920861	0^+	*2.1%*
		155	154.922618	$\frac{3}{2}^-$	*14.8%*
		156	155.922118	0^+	*20.6%*
		157	156.923956	$\frac{3}{2}^-$	*15.7%*
		158	157.924099	0^+	*24.8%*
		159	158.926384	$\frac{3}{2}^-$	18.6 h (β^-)
		160	159.927049	0^+	*21.8%*
		161	160.929664	$\frac{3}{2}^-$	3.7 m (β^-)
Tb	65	156	155.924742	3^-	5.34 d (ε)
		157	156.924023	$\frac{3}{2}^+$	150 y (ε)

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		158	157.925411	3^-	150 y (ε)
		159	158.925342	$\frac{3}{2}^+$	*100 %*
		160	159.927163	3^-	72.1 d (β^-)
		161	160.927566	$\frac{3}{2}^+$	6.90 d (β^-)
		162	161.929510	1^+	7.76 m (β^-)
Dy	66	153	152.925769	$\frac{7}{2}^-$	6.4 h (ε)
		154	153.924429	0^+	3 My (α)
		155	154.925747	$\frac{3}{2}^-$	10.0 h (ε)
		156	155.924277	0^+	*0.057%*
		157	156.925460	$\frac{1}{2}^-$	8.1 h (ε)
		158	157.924403	0^+	*0.100 %*
		159	158.925735	$\frac{3}{2}^-$	144.4 d (ε)
		160	159.925193	0^+	*2.3%*
		161	160.926930	$\frac{5}{2}^+$	*19.90%*
		162	161.926795	0^+	*25.5%*
		163	162.928728	$\frac{5}{2}^-$	*24.9%*
		164	163.929171	0^+	*28.1%*
		165	164.931700	$\frac{7}{2}^+$	2.33 h (β^-)
		166	165.932803	0^+	81.6 h (β^-)
Ho	67	162	161.929092	1^+	15 m (ε)
		163	162.928731	$(\frac{7}{2})^-$	33 y (ε)
		164	163.930285	1^+	29.0 m (ε)
		165	164.930319	$\frac{7}{2}^-$	*100 %*
		166	165.932281	0^-	26.8 h (β^-)
		167	166.933127	$(\frac{7}{2}^-)$	3.1 h (β^-)
Er	68	160	159.929080	0^+	28.6 h (ε)
		161	160.929996	$\frac{3}{2}^-$	3.24 h (ε)
		162	161.928775	0^+	*0.14%*
		163	162.930030	$\frac{5}{2}^-$	75.1 m (ε)
		164	163.929198	0^+	*1.56%*
		165	164.930723	$\frac{5}{2}^-$	10.4 h (ε)
		166	165.930290	0^+	*33.4%*
		167	166.932046	$\frac{7}{2}^+$	*22.9%*
		168	167.932368	0^+	*27.1%*
		169	168.934588	$\frac{1}{2}^-$	9.40 d (β^-)
		170	169.935461	0^+	*14.9%*
		171	170.938027	$\frac{1}{2}^-$	7.52 h (β^-)
		172	171.939353	0^+	49.3 h (β^-)
Tm	69	166	165.933561	2^+	7.70 h (ε)
		167	166.932848	$\frac{1}{2}^+$	9.25 d (ε)
		168	167.934170	3^+	93.1 d (ε)
		169	168.934212	$\frac{1}{2}^+$	*100 %*
		170	169.935798	1^-	128.6 d (β^-)
		171	170.936427	$\frac{1}{2}^+$	1.92 y (β^-)
		172	171.938397	2^-	63.6 h (β^-)
Yb	70	166	165.933875	0^+	56.7 h (ε)
		167	166.934946	$\frac{5}{2}^-$	17.5 m (ε)
		168	167.933894	0^+	*0.135%*
		169	168.935186	$\frac{7}{2}^+$	32.0 d (ε)
		170	169.934759	0^+	*3.1%*
		171	170.936323	$\frac{1}{2}^-$	*14.4%*
		172	171.936378	0^+	*21.9%*
		173	172.938208	$\frac{5}{2}^-$	*16.2%*
		174	173.938859	0^+	*31.6%*
		175	174.941273	$\frac{7}{2}^-$	4.19 d (β^-)
		176	175.942564	0^+	*12.6%*
		177	176.945253	$\frac{9}{2}^+$	1.9 h (β^-)
		178	177.946639	0^+	74 m (β^-)
Lu	71	172	171.939085	(4^-)	6.70 d (ε)
		173	172.938929	$\frac{7}{2}^+$	1.37 y (ε)
		174	173.940336	1^-	3.3 y (ε)
		175	174.940770	$\frac{7}{2}^+$	*97.39%*
		176	175.942679	7^-	*2.61%*
		177	176.943752	$\frac{7}{2}^+$	6.71 d (β^-)
		178	177.945963	1^+	28.4 m (β^-)
Hf	72	171	170.940490	$(\frac{7}{2}^+)$	12.1 h (ε)
		172	171.939460	0^+	1.87 y (ε)
		173	172.940650	$\frac{1}{2}^-$	24.0 h (ε)
		174	173.940044	0^+	*0.16%*
		175	174.941507	$\frac{5}{2}^-$	70 d (ε)
		176	175.941406	0^+	*5.2%*
		177	176.943217	$\frac{7}{2}^-$	*18.6%*
		178	177.943696	0^+	*27.1%*
		179	178.945812	$\frac{9}{2}^+$	*13.7%*
		180	179.946546	0^+	*35.2%*
		181	180.949096	$\frac{1}{2}^-$	42.4 d (β^-)
		182	181.950550	0^+	9 My (β^-)
		183	182.953530	$(\frac{3}{2}^-)$	64 m (β^-)
Ta	73	178	177.945750	1^+	9.31 m (ε)
		179	178.945930	$(\frac{7}{2}^+)$	665 d (ε)
		180	179.947462	1^+	*0.0123%*
		181	180.947992	$\frac{7}{2}^+$	*99.9877%*
		182	181.950149	3^-	115 d (β^-)
		183	182.951369	$\frac{7}{2}^+$	5.1 d (β^-)
W	74	178	177.945840	0^+	21.5 d (ε)
		179	178.947067	$(\frac{7}{2}^-)$	38 m (ε)
		180	179.946701	0^+	*0.13%*
		181	180.948192	$\frac{9}{2}^+$	121 d (ε)
		182	181.948202	0^+	*26.3%*
		183	182.950220	$\frac{1}{2}^-$	*14.3%*

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		184	183.950928	0^+	*30.7%*
		185	184.953416	$\frac{3}{2}^-$	75.1 d (β^-)
		186	185.954357	0^+	*28.6%*
		187	186.957153	$\frac{3}{2}^-$	23.9 h (β^-)
		188	187.958480	0^+	69.4 d (β^-)
Re	75	182	181.951210	2^+	12.7 h (ε)
		183	182.950817	$(\frac{5}{2})^+$	71 d (ε)
		184	183.952530	3^-	38 d (ε)
		185	184.952951	$\frac{5}{2}^+$	*37.40%*
		186	185.954984	1^-	90.6 h (β^-)
		187	186.955744	$\frac{5}{2}^+$	*62.60%*
		188	187.958106	1^-	16.9 h (β^-)
		189	188.959219	$(\frac{5}{2})^+$	24.3 h (β^-)
Os	76	182	181.952120	0^+	21.5 h (ε)
		183	182.953290	$(\frac{9}{2})^+$	13.0 h (ε)
		184	183.952488	0^+	*0.018%*
		185	184.954041	$\frac{1}{2}^-$	93.6 d (ε)
		186	185.953830	0^+	*1.6%*
		187	186.955741	$\frac{1}{2}^-$	*1.6%*
		188	187.955830	0^+	*13.3%*
		189	188.958137	$\frac{3}{2}^-$	*16.1%*
		190	189.958436	0^+	*26.4%*
		191	190.960920	$\frac{9}{2}^-$	15.4 d (β^-)
		192	191.961467	0^+	*41.0%*
		193	192.964138	$\frac{1}{2}^-$	30.6 h (β^-)
		194	193.965173	0^+	6.0 y (β^-)
Ir	77	188	187.958830	(2^-)	41.5 h (ε)
		189	188.958712	$\frac{3}{2}^+$	13.1 d (ε)
		190	189.960580	(4^+)	11.8 d (ε)
		191	190.960584	$\frac{3}{2}^+$	*37.3%*
		192	191.962580	4^-	74.2 d (β^-)
		193	192.962917	$\frac{3}{2}^+$	*62.7%*
		194	193.965069	1^-	19.2 h (β^-)
		195	194.965966	$(\frac{3}{2}^+)$	2.8 h (β^-)
Pt	78	187	186.960470	$\frac{3}{2}^-$	2.35 h (ε)
		188	187.959386	0^+	10.2 d (ε)
		189	188.960817	$\frac{3}{2}^-$	10.9 h (ε)
		190	189.959917	0^+	*0.013%*
		191	190.961665	$\frac{3}{2}^-$	2.9 d (ε)
		192	191.961019	0^+	*0.78%*
		193	192.962977	$(\frac{1}{2}^-)$	50 y (ε)
		194	193.962655	0^+	*32.9%*
		195	194.964766	$\frac{1}{2}^-$	*33.8%*
		196	195.964926	0^+	*25.3%*
		197	196.967315	$\frac{1}{2}^-$	18.3 h (β^-)
		198	197.967869	0^+	*7.2%*
		199	198.970552	$(\frac{1}{2}^-)$	30.8 m (β^-)
		200	199.971417	0^+	12.5 h (β^-)
Au	79	194	193.965348	1^-	39.5 h (ε)
		195	194.965013	$\frac{3}{2}^+$	186 d (ε)
		196	195.966544	2^-	6.18 d (ε)
		197	196.966543	$\frac{3}{2}^+$	*100 %*
		198	197.968217	2^-	2.696 d (β^-)
		199	198.968740	$\frac{3}{2}^+$	3.14 d (β^-)
		200	199.970670	1^-	48.4 m (β^-)
Hg	80	193	192.966560	$\frac{3}{2}^-$	3.8 h (ε)
		194	193.965391	0^+	520 y (ε)
		195	194.966640	$\frac{1}{2}^-$	9.5 h (ε)
		196	195.965807	0^+	*0.15%*
		197	196.967187	$\frac{1}{2}^-$	64.1 h (ε)
		198	197.966743	0^+	*10.0%*
		199	198.968254	$\frac{1}{2}^-$	*16.8%*
		200	199.968300	0^+	*23.1%*
		201	200.970277	$\frac{3}{2}^-$	*13.2%*
		202	201.970617	0^+	*29.8%*
		203	202.972848	$\frac{5}{2}^-$	46.6 d (β^-)
		204	203.973467	0^+	*6.9%*
		205	204.976047	$\frac{1}{2}^-$	5.2 m (β^-)
Tl	81	200	199.970934	2^-	26.1 h (ε)
		201	200.970794	$\frac{1}{2}^+$	73 h (ε)
		202	201.972085	2^-	12.2 d (ε)
		203	202.972320	$\frac{1}{2}^+$	*29.5%*
		204	203.973839	2^-	3.77 y (β^-)
		205	204.974401	$\frac{1}{2}^+$	*70.5%*
		206	205.976084	0^-	4.20 m (β^-)
Pb	82	201	200.972830	$\frac{5}{2}^-$	9.3 h (ε)
		202	201.972134	0^+	0.05 My (ε)
		203	202.973365	$\frac{5}{2}^-$	51.9 h (ε)
		204	203.973020	0^+	*1.42%*
		205	204.974458	$\frac{5}{2}^-$	15 My (ε)
		206	205.974440	0^+	*24.1%*
		207	206.975872	$\frac{1}{2}^-$	*22.1%*
		208	207.976627	0^+	*52.3%*
		209	208.981065	$\frac{9}{2}^+$	3.25 h (β^-)
		210	209.984163	0^+	22.3 y (β^-)
		211	210.988735	$(\frac{9}{2}^+)$	36.1 m (β^-)
		212	211.991871	0^+	10.6 h (β^-)
Bi	83	206	205.978478	6^+	6.24 d (ε)
		207	206.978446	$\frac{9}{2}^-$	32 y (ε)

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		208	207.979717	(5^+)	0.368 My (ε)
		209	208.980374	$\frac{9}{2}^-$	*100 %*
		210	209.984095	1^-	5.01 d (β^-)
		211	210.987255	$\frac{9}{2}^-$	2.15 m (α)
		212	211.991255	1^-	60.6 m (β^-)
Po	84	206	205.980456	0^+	8.8 d (ε)
		207	206.981570	$\frac{5}{2}^-$	5.8 h (ε)
		208	207.981222	0^+	2.90 y (α)
		209	208.982404	$\frac{1}{2}^-$	102 y (α)
		210	209.982848	0^+	138.4 d (α)
		211	210.986627	$\frac{9}{2}^+$	0.52 s (α)
At	85	208	207.986510	6^+	1.63 h (ε)
		209	208.986149	$\frac{9}{2}^-$	5.4 h (ε)
		210	209.987126	5^+	8.3 h (ε)
		211	210.987469	$\frac{9}{2}^-$	7.21 h (ε)
		212	211.990725	(1^-)	0.31 s (α)
		213	212.992911	$\frac{9}{2}^-$	0.11 μs (α)
Rn	86	207	206.990690	$\frac{5}{2}^-$	9.3 m (ε)
		210	209.989669	0^+	2.4 h (α)
		211	210.990576	$\frac{1}{2}^-$	14.6 h (ε)
		212	211.990697	0^+	24 m (α)
		218	218.005580	0^+	35 ms (α)
		222	222.017571	0^+	3.82 d (α)
		224		0^+	107 m (β^-)
Fr	87	209	208.995870	$\frac{9}{2}^-$	50 s (α)
		212	211.996130	5^+	20 m (ε)
		215	215.000310	$\frac{9}{2}^-$	0.12 μs (α)
		220	220.012293	1	27.4 s (α)
		223	223.019733	$(\frac{3}{2})$	21.8 m (β^-)
Ra	88	222	222.015353	0^+	38 s (α)
		223	223.018501	$\frac{1}{2}^+$	11.4 d (α)
		224	224.020186	0^+	3.66 d (α)
		225	225.023604	$(\frac{3}{2})^+$	14.8 d (β^-)
		226	226.025403	0^+	1602 y (α)
		227	227.029171	$(\frac{3}{2}^+)$	42 m (β^-)
Ac	89	224	224.021685	(0^-)	2.9 h (ε)
		225	225.023205	$(\frac{3}{2}^-)$	10.0 d (α)
		226	226.026084	(1^-)	29 h (β^-)
		227	227.027750	$\frac{3}{2}^-$	21.77 y (β^-)
		228	228.031015	(3^+)	6.1 h (β^-)
Th	90	228	228.028715	0^+	1.91 y (α)
		229	229.031755	$\frac{5}{2}^+$	7300 y (α)
		230	230.033128	0^+	75,400 y (α)
		231	231.036299	$\frac{5}{2}^+$	25.52 h (β^-)
		232	232.038051	0^+	*100 %*
		233	233.041577	$(\frac{1}{2}^+)$	22.3 m (β^-)
Pa	91	229	229.032073	$(\frac{5}{2}^+)$	1.4 d (ε)
		230	230.034527	(2^-)	17.7 d (ε)
		231	231.035880	$\frac{3}{2}^-$	32,800 y (α)
		232	232.038565	(2^-)	1.31 d (β^-)
		233	233.040243	$\frac{3}{2}^-$	27.0 d (β^-)
U	92	233	233.039628	$\frac{5}{2}^+$	0.1592 My (α)
		234	234.040947	0^+	0.245 My (α)
		235	235.043924	$\frac{7}{2}^-$	*0.720%*
		236	236.045563	0^+	23.42 My (α)
		237	237.048725	$\frac{1}{2}^+$	6.75 d (β^-)
		238	238.050785	0^+	*99.275%*
		239	239.054290	$\frac{5}{2}^+$	23.5 m (β^-)
Np	93	236	236.046550	(6^-)	0.11 My (ε)
		237	237.048168	$\frac{5}{2}^+$	2.14 My (α)
		238	238.050941	2^+	2.117 d (β^-)
		239	239.052933	$\frac{5}{2}^+$	2.36 d (β^-)
Pu	94	237	237.048401	$\frac{7}{2}^-$	45.3 d (ε)
		238	238.049555	0^+	87.74 y (α)
		239	239.052158	$\frac{1}{2}^+$	24,100 y (α)
		240	240.053808	0^+	6570 y (α)
		241	241.056846	$\frac{5}{2}^+$	14.4 y (β^-)
		242	242.058737	0^+	0.376 My (α)
		243	243.061998	$\frac{7}{2}^+$	4.96 h (β^-)
Am	95	240	240.055278	(3^-)	50.9 h (ε)
		241	241.056824	$\frac{5}{2}^-$	433 y (α)
		242	242.059542	1^-	16.0 h (β^-)
		243	243.061375	$\frac{5}{2}^-$	7370 y (α)
		244	244.064279	(6^-)	10.1 h (β^-)
Cm	96	246	246.067218	0^+	4700 y (α)
		247	247.070347	$\frac{9}{2}^-$	16 My (α)
		248	248.072343	0^+	0.34 My (α)
		249	249.075948	$\frac{1}{2}^+$	64 m (β^-)
Bk	97	246	246.068720	2^-	1.8 d (ε)
		247	247.070300	$(\frac{3}{2}^-)$	1380 y (α)
Cf	98	251	251.079580	$\frac{1}{2}^+$	898 y (α)
		252	252.081621	0^+	2.64 y (α)
Es	99	252	252.082944	$(4^+, 5^-)$	472 d (α)
		253	253.084818	$\frac{7}{2}^+$	20.5 d (α)