Excess neutron shell model of Nuclei

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Abstract

Review of the periodic table and existing research on isotopes of the various elements of the periodic table is conducted and the attempt is made here to visualize the process of element formation.

The role of Neutron in element formation is investigated and found to be vital for existence of elements . In the new light, the new model of nucleus is proposed which explains the stability of the nuclei and reason for multiple stable isotopes of elements.

Review of the Periodic Table

The inspection of the periodic table of elements reveal an interesting fact that for all elements other than Hydrogen, for element to be stable, number of Neutrons are always greater or equal, to the number of Protons in the nucleus. The periodic table is analyzed with respect to the abundance in nature for the elements.

The fusion of Hydrogen to produce Helium can be envisioned as follows:

$$1H + 1H + 1H + 1H \rightarrow 2H + 2N + 2e+ \qquad (1)$$

where 2e+ later annihilating to produce additional gamma radiation.

Since tremendous force is needed to keep four protons together during the formation of helium and emit 2 positrons, it is unlikely. The mass of neutron is more than the mass of proton and this fact alone negates the likeliness of the above scenario.

In another scenario, the formation of helium may be envisioned as four neutrons coming close together to form a stable nuclei of Helium as follows:

$$4N \rightarrow 2N + 2P + 2e \qquad (2)$$

Here the mass of Neutron is higher than the Proton. The Neutron releases electron to form proton. Also justifies the reason for the Proton to be lighter than the Neutron.

Thus it is assumed that

1) Neutrons are the building blocks for elements in nature.

2) In the elements , other than hydrogen, neutron and proton form a pair (np) and keeps distinct identity.

3) Excess neutrons stay at the center of the nuclei but keeps their distinct identity.

Using the above assumption the periodic table is analyzed by finding excess neutrons for all stable isotopes of elements as follows:

Excess neutrons = Atomic mass – 2P where P is the number of Protons for the element.

The relative abundance of Isotopes is obtained from the research papers and wikipedia and is included in the Table 1, 2 ,3. The relative abundance is indicative of the preferred state for the element (nuclei) in nature.

The following facts are found as a result of analysis:

For Odd atomic number nuclei :

a) Abundance of isotope is close to 100% when excess neutrons are odd count.
b) If the excess neutron count is even, the isotope is radio active.
c) Majority elements have only one Isotope.
d) Only Potassium has three isotopes, the one with 2 excess neutron is radio active with 0.001 relative abundance.

For Even atomic number nuclei:

a) Elements He, C, O, Ne, Mg, Si, S are close to one in abundance with no excess neutron and maximum three isotopes
b) Element Be has one excess neutron and one isotope, 100% abundance.
c) All other higher elements require four or more excess neutrons for the element to be abundant in nature and has up to 10 stable isotopes.
d) Element Ca is exception with 0 excess neutron and 97% abundance. However it is unstable with >E+21 a Half life.

Atomic number 43 (Tc) and 61 (Pm) has no stable isotopes in nature.

Thus from the above analysis, it looks like that all nuclei, stable or otherwise, prefers to keep at least one neutron at the center of the nuclei from its excess count. The remaining excess neutrons stay very close to the center keeping its own identity. The other neutrons pair up with each proton and stay close together to the proton (like heavy hydrogen) but maintains its separate identity.

The nature prefers, for more complex nucleus, more neutrons than protons and creates a delicate balance to form a stable nuclei.

This balance of forces is so critical that in case of element F (the stable isotope is with 9 proton and 10 neutrons) The isotope 18F with 9 Protons and 9 Neutrons, with in 20 minutes decays and forms 18O which is stable with 8 protons and 10 Neutrons and gives up a e+ positron to convert proton to neutron and e+ and e- reaction produces Gama radiation.

Equation $18F \rightarrow 18O + e+$

Thus the existence of Neutron is vital to the existence of the universe itself, because without neutron, elements may not have been possible and hence the intelligence as we know today.

Structure of Neutron

The fact that Gravitational binding forces (Fg) of masses in the nucleus needs to be more than the destructive electromagnetic forces (Fem) created by the electrically positive environment of the nucleus, ($Fem < Fg$) excess neutrons are required in the nuclei. However, even at the center of the nucleus neutrons keep their distinct identity, rather than lumping together to form one heavy neutron. Therefore, neutron can not be just a fuzzy mass but a well defined structure able to hold induced charges with precise demarcation of boundary with an insulating layer, more like a free standing capacitor. Which suggests that at least three particles with two sets of characteristics are required to create a neutron. For our model here, that has to be two particles capable of holding charges and one particle which provides insulation between these particles, similar to that of dielectric layer in the capacitor. Thus in this postulated model the neutron looks and behaves neutral for all practical purposes. However, within nuclei keeps separate and distinct identity and does not combine with other neutrons to form a one central heavy body.

The proposal here defers from the model independent analysis predicting the structure having negative charge on the surface, Positive charge in the next lower level and than neutral mass. My model suggests that neutron is a free standing charged capacitor. This helps in keeping the distance between excess neutron in the nuclei. Otherwise there is nothing stopping these neutrons from lumping together to form a mini neutron star with in the nuclei. This model of Neutron is justified from the known fact that Neutron is heavier than Proton.

For elements other than Hydrogen, the nuclei becomes a chaotic environment. For Example, in case of 4He, two protons require their space and wants to be separate from each other as far as possible, and two neutrons are caught between the two protons as shown in figure 1. From the reference frame of protons it is envisioned that Neutrons spin on its axis at very high rotational speed. One clockwise and other anticlockwise.

Model of nuclei:

A new model of nuclei is proposed as shown in the figure 3. A spherical shell of excess neutrons with one neutron at the center of the shell surrounded by paired proton neutron (pn) shell.

For the stable nuclei system the electromagnetic forces needs to be balanced and gravitational forces maximized. From the example of 4He above, it is envisioned that elements are built, in this model, by Heavy Hydrogen nuclei (pn) as a building block and just enough excess neutrons to provide needed gravitational force for stability.

Energy levels (orbitals) in pn outer shell follows the similar shell structure of electrons, with K,L,M,N,O being primary shell and s, p, d, f, g sub shells with similar total charge particle capacity. However for excess neutron shell it differs, where a single neutron stays at the center of the nuclei when in excess. The energy level for that central neutron in this model is called “Foundation neutron” (Fn).

The Table 4 shows the placement of neutrons in each shell.

Nuclei Stability Analysis using above model

For Odd atomic number nuclei:

In the 'p-n shell' the outermost pair has no symmetry, however the excess neutron shell is symmetrical for all odd atomic number elements giving the stability and abundance. Referring to table 2 and table 4 , isotopes, with one excess neutron, has relative abundance in nature of 1 or close to 1, The excess neutron takes the place of Fn. The isotopes with 2 excess neutrons are all radio active which can be attributed to the asymmetry of neutron in unfilled K shell, which can hold up to 2 neutrons. When the K shell is completely filled as in the case of 41K, the nuclei is stable. Table 2 outlines isotopes and abundance for majority of elements, all follow the same principle and model fits perfectly with the exception of 14N with atomic number 7. Iodine has 21 excess neutrons, as we see in table 4, the outer most excess neutron shell is symmetrical, making it stable. All other elements follows.

For Even atomic number nuclei:

The stability is obtained from the pn shell. However, excess neutron shell becomes asymmetric and depending on which sub shell, there is a room for additional excess neutrons and hence exhibits many stable isotopes with relative abundance. Theoretical probability calculation may prove this fact.

Instability and radio activity in heavy elements:

The neutron proton (np) pair in nuclei has capability to grow indefinitely. However as the heavier elements are built the inner excess neutron shell is large enough to interact with lower np shells, thus giving instability to the nuclei. e.g. for 238U there are 148 total neutrons and 54 excess neutrons. A nuclei with 111 excess neutron will completely fill up the O shell. All elements after 209Bi are radio active, this shows that interaction of neutrons form excess neutron shell(inner shell) with pn shell is destructive when the N shell is half filled. Thus there is a upper limit to the size of the inner excess neutron shell and this may be the reason for non existence of super heavy stable elements in nature.

Conclusion:

This proposed model of nuclei, explains the stability and relative abundance of the nuclei. The nuclei(except for H and He) in this model is a shell with in a shell, where an innermost shell structure is formed with excess neutrons with one Fundamental foundation neutron (Fn) and the rest arranged in shell structure. Protons, form pair with neutron and form shell enclosing this excess neutron shell as shown in figure 3. The stability of the nuclei is a direct result of symmetrical placement of neutrons in the outer most shell of excess neutron shell. The same shell is responsible for many stable isotopes in even atomic number nuclei. The additional isotopes are possible if the outer shell of excess neutron shell holds odd number of neutrons. The nature of neutron is postulated here, the proof of which depends on future experiments.

References:

1) Numerous Scientists' and scholars' exhausting work in development of periodic table, investigation of Isotopes is utilized and due credits are given. The list is too large to print here, but due credits are mentally given to all scientists.

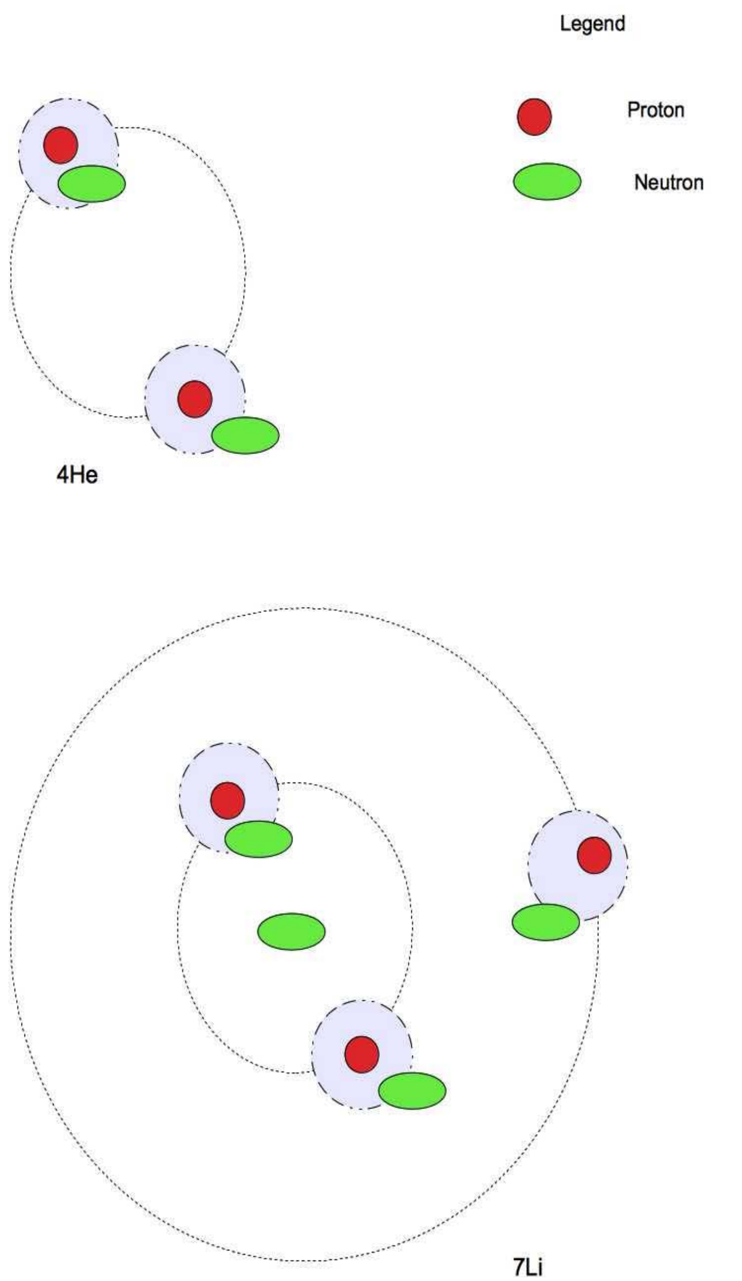

Figure 1

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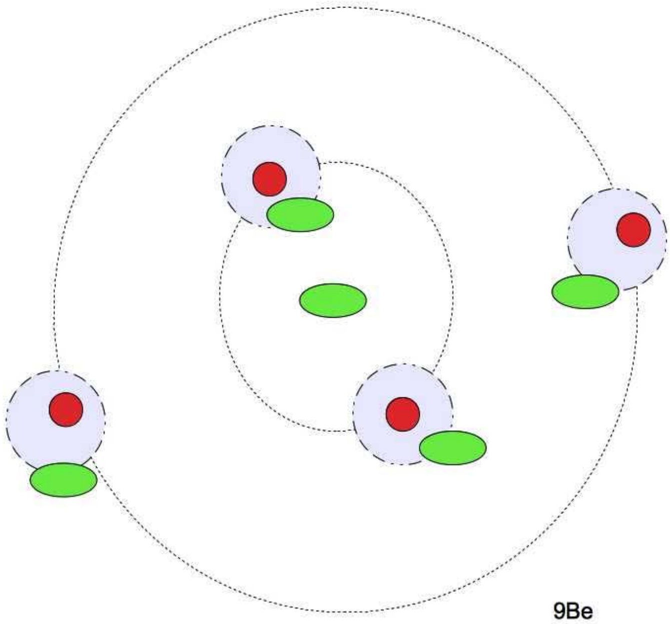

Figure 2

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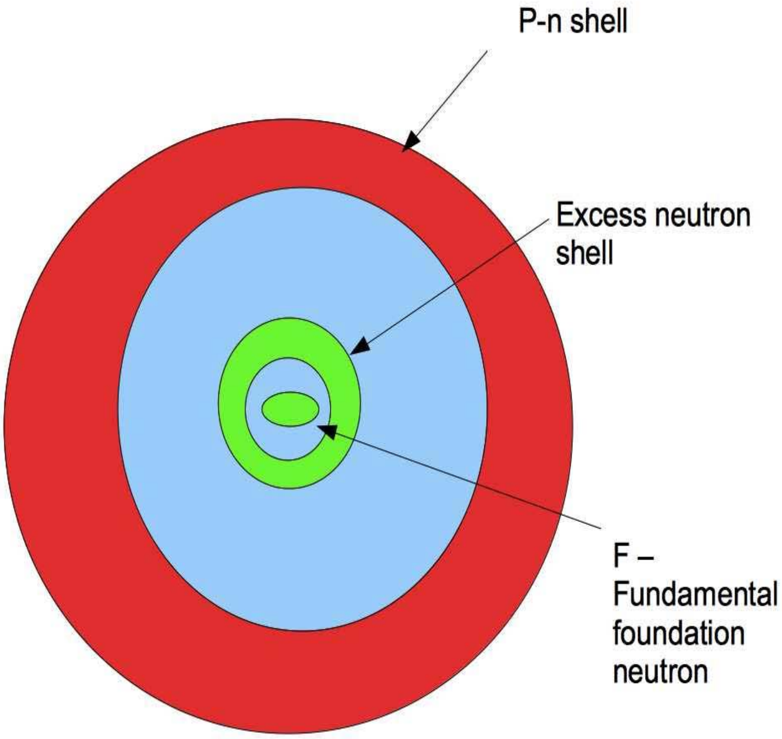

Figure 3

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Table of stable nuclei
Table 1

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
1H	1	0	-1	0.9999	2	
2H	1	1	0	0.0001		
3He	2	1	-1	0.0000	2	
4He	2	2	0	1.0000		
6Li	3	3	0	0.0759	2	
7Li	3	4	1	0.9241		
9Be	4	5	1	1.0000	1	
10B	5	5	0	0.1990	2	
11B	5	6	1	0.8010		
12C	6	6	0	0.9893	2	
13C	6	7	1	0.0107		
14N	7	7	0	0.9936	2	
15N	7	8	1	0.0036		
16O	8	8	0	0.9976	3	
17O	8	9	1	0.0004		
18O	8	10	2	0.0021		
19F	9	10	1	1.0000	1	
20Ne	10	10	0	0.9048	3	
21Ne	10	11	1	0.0027		
22Ne	10	12	2	0.0925		

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
23Na	11	12	1	1.0000	1	
24Mg	12	12	0	0.7899	3	
25Mg	12	13	1	0.1000		
26Mg	12	14	2	0.1101		
27Al	13	14	1	1.0000	1	
28Si	14	14	0	0.9222	3	
29si 30si	14 14	15 16	1 2	0.0469 0.0309		
31P	15	16	1	1.0000	1	
32S	16	16	0	0.9493	4	
33S	16	17	1	0.0076		
34S	16	18	2	0.0429		
36S	16	20	4	0.0002		
35Cl	17	18	1	0.7576	2	
37Cl	17	20	2	0.2424		
36Ar 38Ar	18 18	18 20	0 2	0.0033 0.0006	3	
40Ar	18	22	4	0.9960		
39K	19	20	1	0.9326	3	
40K	19	21	2	0.0001		E+9 a
41K	19	22	3	0.0673		

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
40Ca	20	20	0	0.9694		>E+21 a
42Ca	20	22	2	0.0065		
43Ca	20	23	3	0.0014		
44Ca	20	24	4	0.0209		
46Ca	20	26	6	0.0000		>E+15 a
48Ca	20	28	8	0.0000		
45Sc	21	24	3	1.0000	1	
46Ti	22	24	2	0.0825	5	
47Ti	22	25	3	0.0744		
48Ti	22	26	4	0.7372		
49Ti	22	27	5	0.0541		
50Ti	22	28	6	0.0518		
50V	23	27	4	0.0025	2	E+17 a
51V	23	28	5	0.9975		
50Cr	24	26	2	0.0435	5	>E+18 a
52Cr	24	28	4	0.8379		
53Cr	24	29	5	0.0950		
54Cr	24	30	6	0.0237		
55Mn	25	30	5	1.0000	1	
54Fe	26	28	2	0.0585	5	>E+22 a
56Fe	26	32	6	0.9175		
57Fe	26	33	7	0.0212		
58Fe	26	34	8	0.0028		
59Co	27	32	5	1.0000	1	

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
58Ni	28	30	2	0.6808		E+18 a
60Ni	28	32	4	0.2622		
61Ni	28	33	5	0.0114		
62Ni	28	34	6	0.0363		
64Ni	28	38	10	0.0093		
63Cu	29	34	5	0.6915	2	
65Cu	29	36	7	0.3085		
64Zn	30	34	4	0.4827		>E+18 a
66Zn 67Zn	30 30	36 37	6 7	0.2798 0.0410		
68Zn	30	38	8	0.1902		
70Zn	30	40	10	0.0063		>E+16 a
69Ga	31	38	7	0.6011	2	
71Ga	31	40	9	0.3989		
70Ge	32	38	6	0.2038	5	
72Ge	32	40	8	0.2731		
73Ge	32	41	9	0.0776		
74Ge	32	42	10	0.3672		
76Ge	32	44	12	0.0783		E+21 a
75As	33	42	9	1.0000	1	
74Se	34	40	6	0.0089	6	
76Se	34	42	8	0.0937		
77Se	34	43	9	0.0763		
78Se	34	44	10	0.2377		
80Se	34	46	12	0.4961		

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
82Se	34	46	14	0.0873		>E+18 a
79Br	35	44	9	0.5069	2	
81Br	35	46	11	0.4931		
80Kr	36	44	8	0.0036	6	>E
82Kr	36	46	10	0.0229		
83Kr	36	47	11	0.1159		
84Kr	36	48	12	0.1150		
85Kr	36	49	13	0.5699		
86Kr	36	50	14	0.1728		
85Rb	37	48	11	0.7217	2	
87Rb	37	50	13	0.2783		E+10 a
84Sr	38	46	8	0.0056	4	
86Sr	38	48	10	0.0986		
87Sr	38	49	11	0.0700		
88Sr	38	50	12	0.8258		
89Y	39	50	11	1.0000	1	
90Zr	40	50	10	0.5145	5	
91Zr 92Zr	40 40	51 53	11 12	0.1122 0.1715		
94Zr	40	54	14	0.1738		>E+17 a
96Zr	40	56	16	0.0280		
93Nb	41	52	11	1.0000	1	
92Mo	42	50	8	0.1477	7	E+18 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
94Mo	42	52	10	0.0923		
95Mo	42	53	11	0.1590		
96Mo	42	54	12	0.1668		
97Mo	42	55	13	0.0956		
98Mo	42	56	14	0.2419		E+12 a
100Mo	42	58	16	0.0967		E+18 a
Tc	43			0.0000		
96Ru	44	52	8	0.0554	7	>E+15 a
98Ru	44	54	10	0.0187		
99Ru	44	55	11	0.0000		
100Ru	44	56	12	0.1260		
101Ru	44	57	13	0.1706		
102Ru	44	58	14	0.3155		
104Ru	44	60	16	0.1862	?	
103Rh	45	58	13	1.0000	1	
102Pd	46	56	10	0.0102	6	
104Pd	46	58	12	0.1114		
105Pd	46	59	13	0.2233		
106Pd	46	60	14	0.2733		
108Pd	46	62	16	0.2646		
110Pd	46	64	18	0.1172		>E15 a
107Ag	47	60	13	0.5184	2	
109Ag	47	62	15	0.4816		
106Cd	48	58	10	0.0125	6	>E+18 a
108Cd	48	60	12	0.0089		>E+15 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
110Cd	48	62	14	0.1249		
111Cd	48	63	15	0.1280		
112Cd	48	64	16	0.2413		
113Cd	48	65	17	0.1222		E+15 a
114Cd	48	66	18	0.2873		E+18 a
116Cd	48	68	20	0.0749		E+19 a
113In	49	64	15	0.0429	2	
115In	49	66	17	0.9571		E+14a
112Sn 114Sn	50 50	62 64	12 14	0.0097 0.0066	10	
115Sn	50	65	15	0.0034		
116Sn	50	66	16	0.1454		
117Sn	50	67	17	0.0768		
118Sn	50	68	18	0.2422		
119Sn	50	69	19	0.0859		
120Sn	50	70	20	0.3258		
122Sn	50	72	22	0.0463		
124Sn	50	74	24	0.0579		>E+15 a
121Sb	51	70	19	0.5721	2	
123Sb	51	72	21	0.4279		
120Te	52	68	16	0.0009	8	>E+16 a
122Te	52	70	18	0.0255		
123Te	52	71	19	0.0089		>E+12 a
124Te	52	72	20	0.0474		
125Te	52	73	21	0.0707		
126Te	52	74	22	0.1884		
128Te	52	76	24	0.3174		>E+24 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
130Te	52	78	26	0.3408		>E+18 a
127I	53	74	21	1.0000	1	
124Xe	54	70	16	0.0010	9	>E15+a
126Xe	54	72	18	0.0009		
128Xe	54	74	20	0.0191		
129Xe	54	75	21	0.2640		
130Xe	54	76	22	0.0407		
131Xe	54	77	23	0.2123		
132Xe	54	78	24	0.2691		
134Xe	54	80	26	0.1044		>E+15 a
136Xe	54	82	28	0.0886		>E+21 a
133Cs	55	78	23	1.0000	1	
130Ba	56	74	18	0.0011	7	>E+21 a
132Ba	56	76	20	0.0010		>E+18 a
134Ba	56	78	22	0.0242		
135Ba	56	79	23	0.0659		
136Ba	56	80	24	0.0785		
137Ba	56	81	25	0.1123		
138Ba	56	82	26	0.7170		
138La	57	81	24	0.0009	2	E+11 a
139La	57	82	25	0.9991		
136Ce	58	78	20	0.0019	4	>E + 15 a
138Ce	58	80	22	0.0025		>E +12 a
140Ce	58	82	24	0.8845		
142Ce	58	84	26	0.1111		>E +15 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
141Pr	59	82	23	1.0000	1	
142Nd	60	82	22	0.2720	7	
143Nd	60	83	23	0.1220		
144Nd	60	84	24	0.2380		E+15 a
145Nd	60	85	25	0.0830		
146Nd	60	86	26	0.1720		
148Nd	60	88	28	0.0570		>E+18 a
150Nd	60	90	30	0.0560		E+18 a
Pm	61			0.0000		
144Sm	62	82	20	0.0307	7	
147Sm	62	85	23	0.1499		E+11 a
148Sm	62	86	24	0.1124		E+15 a
149Sm	62	87	25	0.1382		> E+15 a
150Sm	62	88	26	0.0738		
152Sm	62	90	28	0.2675		
154Sm	62	92	30	0.2275		
151Eu	63	88	25	0.4781	2	E+18 a
153Eu	63	90	27	0.5219		
152Gd 154Gd	64 64	88 90	24 26	0.0020 0.0218	7	E+14 a
155Gd	64	91	27	0.1480		
156Gd	64	92	28	0.2047		
157Gd	64	93	29	0.1565		
158Gd	64	94	30	0.2484		
160Gd	64	96	32	0.2186		Halflife E+20 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
159Tb	65	94	29	1.0000	1	
156Dy	66	90	24	0.0006	7	Half life E+18 a
158Dy	66	92	26	0.0010		
160Dy	66	94	28	0.0233		
161Dy	66	95	29	0.1889		
162Dy	66	96	30	0.2548		
163Dy	66	97	31	0.2490		
164Dy	66	98	32	0.2826		
165Ho	67	98	31	1.0000	1	
162Er	68	94	26	0.0014	6	Halflife E+12 a
164Er	68	96	28	0.0160		
166Er	68	98	30	0.3350		
167Er	68	99	31	0.2287		
168Er	68	100	32	0.2698		
170Er	68	102	34	0.1491		Hallife E+15 a
169Tm	69	100	31	1.0000	1	
168Yb	70	98	28	0.0013	7	halflife E+12
170Yb	70	100	30	0.0304		
171Yb	70	101	31	0.1428		
172Yb	70	102	32	0.2183		
173Yb	70	103	33	0.1613		
174Yb	70	104	34	0.3183		
176Yb	70	106	36	0.1276		Halflife E+15 a
175Lu	71	104	33	0.9741	2	
176Lu	71	105	34	0.0259		half life E+9 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
174Hf	72	102	30	0.0016	6	
176Hf	72	104	32	0.0526		
177Hf	72	105	33	0.1860		
178Hf	72	106	34	0.2728		
179Hf	72	107	35	0.1362		
180Hf	72	108	36	0.3508		
180Ta	73	107	34	0.0001	2	Half life e+15 a
181Ta	73	108	35	0.9999		
180W	74	106	32	0.0012	5	long half life
182W	74	108	34	0.2650		
183W	74	109	35	0.1431		
184W	74	110	36	0.3064		
186W	74	112	38	0.2843		
185Re	75	110	35	0.0374	2	
187Re	75	112	37	0.6260		Half life E+9 a
184Os	76	108	32	0.0002	7	
186Os	76	110	34	0.0159		
187Os	76	111	35	0.0196		
188Os	76	112	36	0.1324		
189Os	76	113	37	0.1615		
190Os	76	114	38	0.2626		
192Os	76	116	40	0.4078		

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
191Ir	77	114	37	0.3730	2	
193Ir	77	116	39	0.6270		
190Pt	78	112	34	0.0001	6	
192Pt	78	114	36	0.0078		
194Pt	78	116	38	0.3297		
195Pt	78	117	39	0.3383		
196Pt	78	118	40	0.2524		
198Pt	78	120	42	0.0716		
197Au	79	118	39	1.0000	1	
196Hg	80	116	36	0.0015	7	
198Hg	80	118	38	0.0997		
199Hg	80	119	39	0.1687		
200Hg	80	120	40	0.2310		
201Hg	80	121	41	0.1318		
202Hg	80	122	42	0.2986		
204Hg	80	124	44	0.0687		
205Tl	81	124	43	1.0000	1	
204Pb	82	122	40	0.0140	4	
206Pb	82	124	42	0.2410		
207Pb	82	125	43	0.2210		
208Pb	82	126	44	0.5240		
209Bi	83	126	43	1.0000	1	
Po	84			0.0000		All Radio active

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
At	85			0.0000		
Rn	86			0.0000		
Fr	87			0.0000		
Ra	88			0.0000		
Ac	89			0.0000		
232Th	90	142	52	1.0000	1	
231Pa	91	140	49	1.0000	1	
233U	92	141	49	0.0000	5	
234U	92	142	50	0.0001		
235U	92	143	51	0.0072		
236U	92	144	52	0.0000		
238U	92	146	54	0.9927		

Table of Odd number stable nuclei
Table 2

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
1H	1	0	-1	1	2	
2H	1	1	0	0		
6Li	3	3	0	0.08	2	
7Li	3	4	1	0.92		
10B	5	5	0	0.2	2	
11B	5	6	1	0.8		
14N	7	7	0	0.99	2	
15N	7	8	1	0		
19F	9	10	1	1	1	
23Na	11	12	1	1	1	
27Al	13	14	1	1	1	
31P	15	16	1	1	1	
35Cl	17	18	1	0.76	2	
37Cl	17	20	2	0.24		
39K	19	20	1	0.93	3	
40K	19	21	2	0		E+9 a
41K	19	22	3	0.07		
45Sc	21	24	3	1	1	
50V	23	27	4	0	2	E+17 a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
51V	23	28	5	1		
55Mn	25	30	5	1	1	
59Co	27	32	5	1	1	
63Cu	29	34	5	0.69	2	
65Cu	29	36	7	0.31		
69Ga	31	38	7	0.6	2	
71Ga	31	40	9	0.4		
75As	33	42	9	1	1	
79Br	35	44	9	0.51	2	
81Br	35	46	11	0.49		
85Rb	37	48	11	0.72	2	
87Rb	37	50	13	0.28		E+10 a
89Y	39	50	11	1	1	
93Nb	41	52	11	1	1	
103Rh	45	58	13	1	1	
107Ag	47	60	13	0.52	2	
109Ag	47	62	15	0.48		
113In	49	64	15	0.04	2	
115In	49	66	17	0.96		E+14a

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
121Sb	51	70	19	0.57	2	
123Sb	51	72	21	0.43		
127I	53	74	21	1	1	
133Cs	55	78	23	1	1	
138La	57	81	24	0	2	E+11 a
139La	57	82	25	1		
141Pr	59	82	23	1	1	
151Eu	63	88	25	0.48	2	E+18 a
153Eu	63	90	27	0.52		
159Tb	65	94	29	1	1	
165Ho	67	98	31	1	1	
169Tm	69	100	31	1	1	
175Lu 176Lu	71 71	104 105	33 34	0.97 0.03	2	 half life E+9 a
180Ta	73	107	34	0	2	Half life e+15 a
181Ta	73	108	35	1		
185Re	75	110	35	0.04	2	
187Re	75	112	37	0.63		Half life E+9 a
191Ir	77	114	37	0.37	2	
193Ir	77	116	39	0.63		

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
197Au	79	118	39	1	1	
205Tl	81	124	43	1	1	
209Bi	83	126	43	1	1	
232Th	90	142	52	1	1	
231Pa	91	140	49	1	1	

Table of Noble stable nuclei
Table 3

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
3He	2	1	-1	0	2	
4He	2	2	0	1		
20Ne	10	10	0	0.9	3	
21Ne	10	11	1	0		
22Ne	10	12	2	0.09		
36Ar	18	18	0	0	3	
38Ar	18	20	2	0		
40Ar	18	22	4	1		
80Kr	36	44	8	0	6	>E
82Kr	36	46	10	0.02		
83Kr	36	47	11	0.12		
84Kr	36	48	12	0.12		
85Kr	36	49	13	0.57		
86Kr	36	50	14	0.17		
124Xe	54	70	16	0	9	>E15+a
126Xe	54	72	18	0		
128Xe	54	74	20	0.02		
129Xe	54	75	21	0.26		
130Xe	54	76	22	0.04		
131Xe	54	77	23	0.21		
132Xe	54	78	24	0.27		
134Xe	54	80	26	0.1		>E+15 a
136Xe	54	82	28	0.09		>E+21

Excess Neutrons and energy levels
Table 4

Excess Neutron	Shell	F	K 2 max	L 8 max		M 18 max			N 32 max			
	Sub shell	0 1	s 2	s 2	p 6	s 2	p 6	d 10	s 2	p 6	d 10	f 14
1		1										
2		1	1									
3		1	2									
4		1	2	1								
5		1	2	2								
6		1	2	2	1							
7		1	2	2	2							
8		1	2	2	3							
9		1	2	2	4							
10		1	2	2	5							
11		1	2	2	6							
12		1	2	2	6	1						
13		1	2	2	6	2						
14		1	2	2	6	2	1					
15		1	2	2	6	2	2					
16		1	2	2	6	2	3					
17		1	2	2	6	2	4					
18		1	2	2	6	2	5					
19		1	2	2	6	2	6					
20		1	2	2	6	2	6	1				
21		1	2	2	6	2	6	2				
22		1	2	2	6	2	6	3				
23		1	2	2	6	2	6	4				
24		1	2	2	6	2	6	5				
25		1	2	2	6	2	6	6				
26		1	2	2	6	2	6	7				

Excess Neutron	Shell	F	K 2 max	L 8 max		M 18 max			N 32 max			
	Sub shell	0 1	s 2	s 2	p 6	s 2	p 6	d 10	s 2	p 6	d 10	f 14
27		1	2	2	6	2	6	8				
28		1	2	2	6	2	6	9				
29		1	2	2	6	2	6	10				
30		1	2	2	6	2	6	10	1			
31		1	2	2	6	2	6	10	2			
32		1	2	2	6	2	6	10	2	1		
33		1	2	2	6	2	6	10	2	2		
34		1	2	2	6	2	6	10	2	3		
35		1	2	2	6	2	6	10	2	4		
36		1	2	2	6	2	6	10	2	5		
37		1	2	2	6	2	6	10	2	6		
38		1	2	2	6	2	6	10	2	6	1	
39		1	2	2	6	2	6	10	2	6	2	
40		1	2	2	6	2	6	10	2	6	3	
41		1	2	2	6	2	6	10	2	6	4	
42		1	2	2	6	2	6	10	2	6	5	
43		1	2	2	6	2	6	10	2	6	6	
44		1	2	2	6	2	6	10	2	6	7	
45		1	2	2	6	2	6	10	2	6	8	
46		1	2	2	6	2	6	10	2	6	9	
47		1	2	2	6	2	6	10	2	6	10	
48		1	2	2	6	2	6	10	2	6	10	1
49		1	2	2	6	2	6	10	2	6	10	2
50		1	2	2	6	2	6	10	2	6	10	3
51		1	2	2	6	2	6	10	2	6	10	4
52		1	2	2	6	2	6	10	2	6	10	5
53		1	2	2	6	2	6	10	2	6	10	6
54		1	2	2	6	2	6	10	2	6	10	7

Excess Neutron	Shell	F	K 2 max	L 8 max		M 18 max			N 32 max			
	Sub shell	0 1	s 2	s 2	p 6	s 2	p 6	d 10	s 2	p 6	d 10	f 14
55		1	2	2	6	2	6	10	2	6	10	8
56		1	2	2	6	2	6	10	2	6	10	9
57		1	2	2	6	2	6	10	2	6	10	10
58		1	2	2	6	2	6	10	2	6	10	11
59		1	2	2	6	2	6	10	2	6	10	12
60		1	2	2	6	2	6	10	2	6	10	13
61		1	2	2	6	2	6	10	2	6	10	14

Table of elements with no stable nuclei
Table 5

Element	Z(p)	N(n)	n – p	abundance	stable isotopes	Comment
Tc	43			0		
Pm	61			0		
Po	84			0		All Radio active
At	85			0		
Rn	86			0		
Fr	87			0		
Ra	88			0		
Ac	89			0		