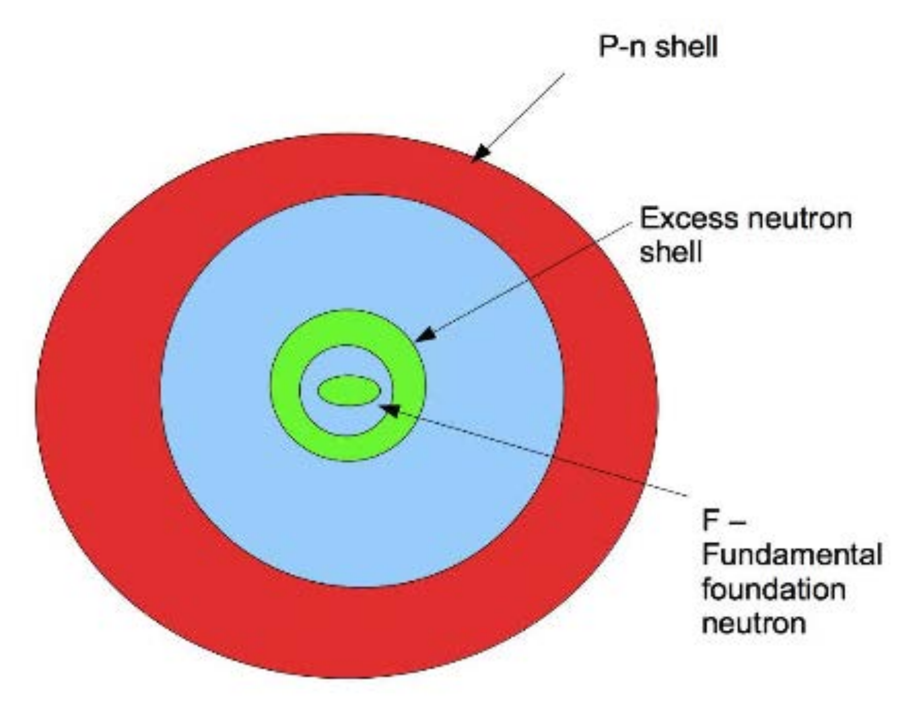
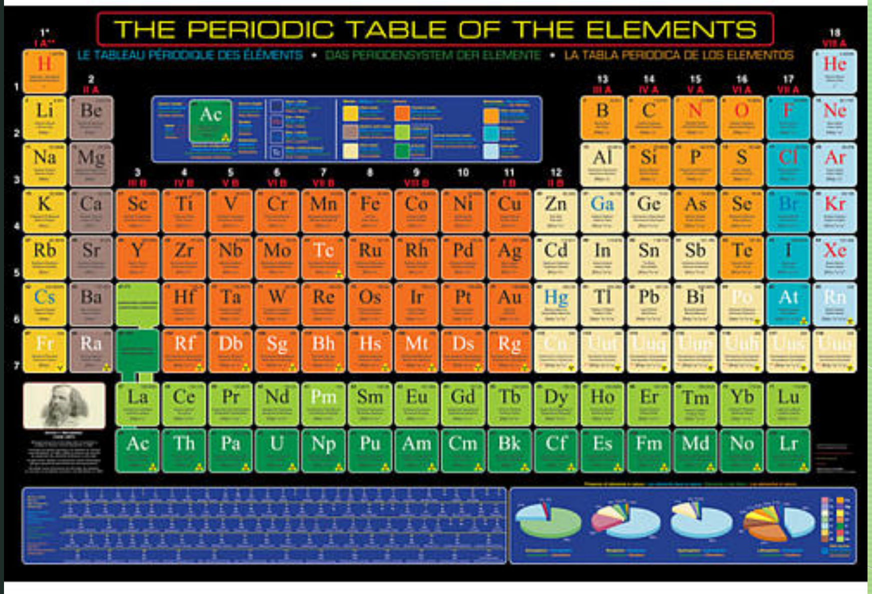
Excess Neutron Shell Model of Nuclei

- Bhagirath Joshi



Analysis of Periodic Table



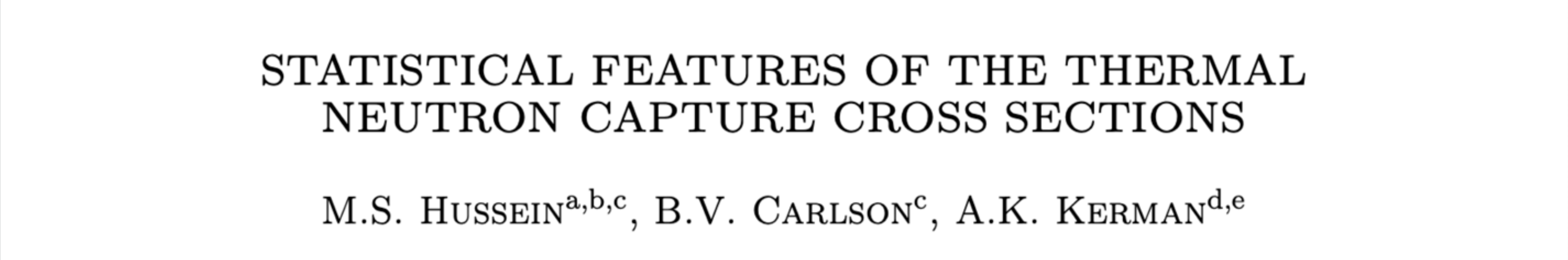
THE PERIODIC TABLE OF THE ELEMENTS

LE TABLEAU PÉRIODIQUE DES ÉLÉMENTS • DAS PERIODENSYSTEM DER ELEMENTE • LA TABLA PERIODICA DE LOS ELEMENTOS

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo

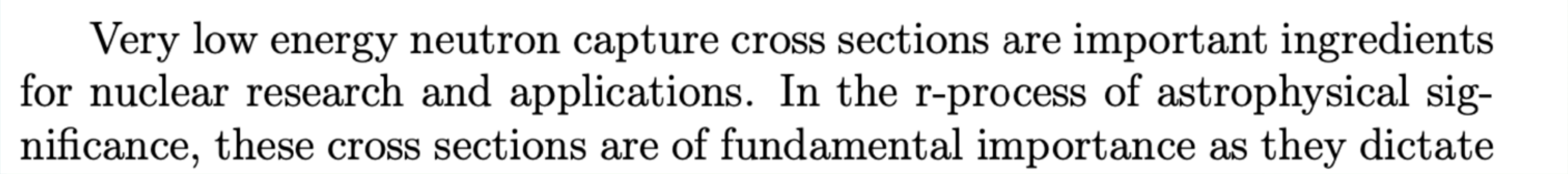
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

- 80 Stable elements
- Tc z=43 unstable!
- Pm z = 61 unstable!
- Even the stable elements can be made unstable by introducing a Neutron or removing it.
- No H isotope with 100 neutrons !!!!

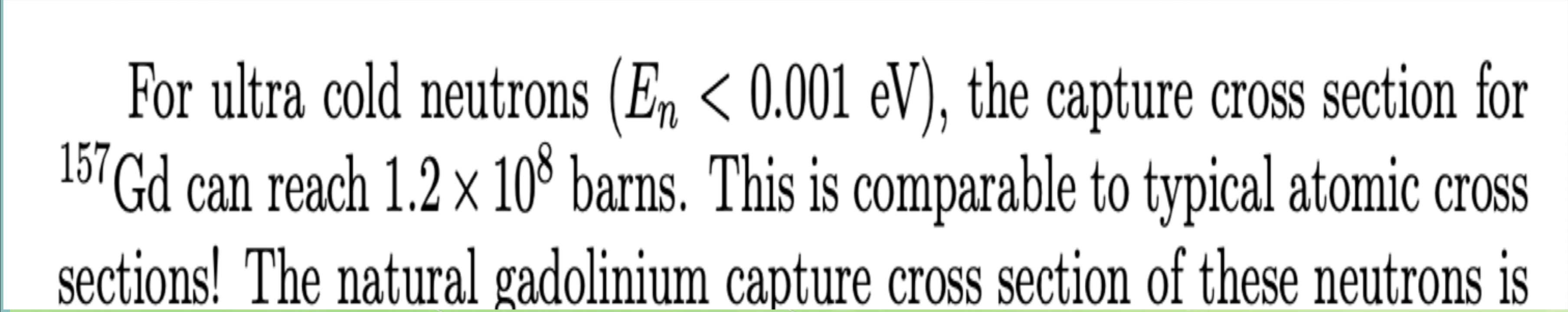


STATISTICAL FEATURES OF THE THERMAL NEUTRON CAPTURE CROSS SECTIONS

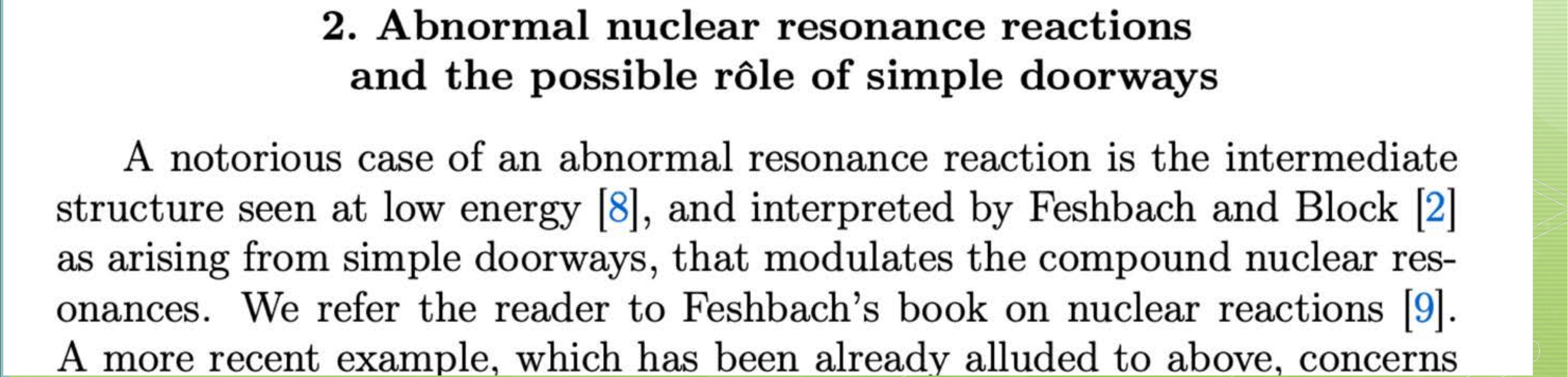
M.S. HUSSEIN[a,b,c], B.V. CARLSON[c], A.K. KERMAN[d,e]



Very low energy neutron capture cross sections are important ingredients for nuclear research and applications. In the r-process of astrophysical significance, these cross sections are of fundamental importance as they dictate



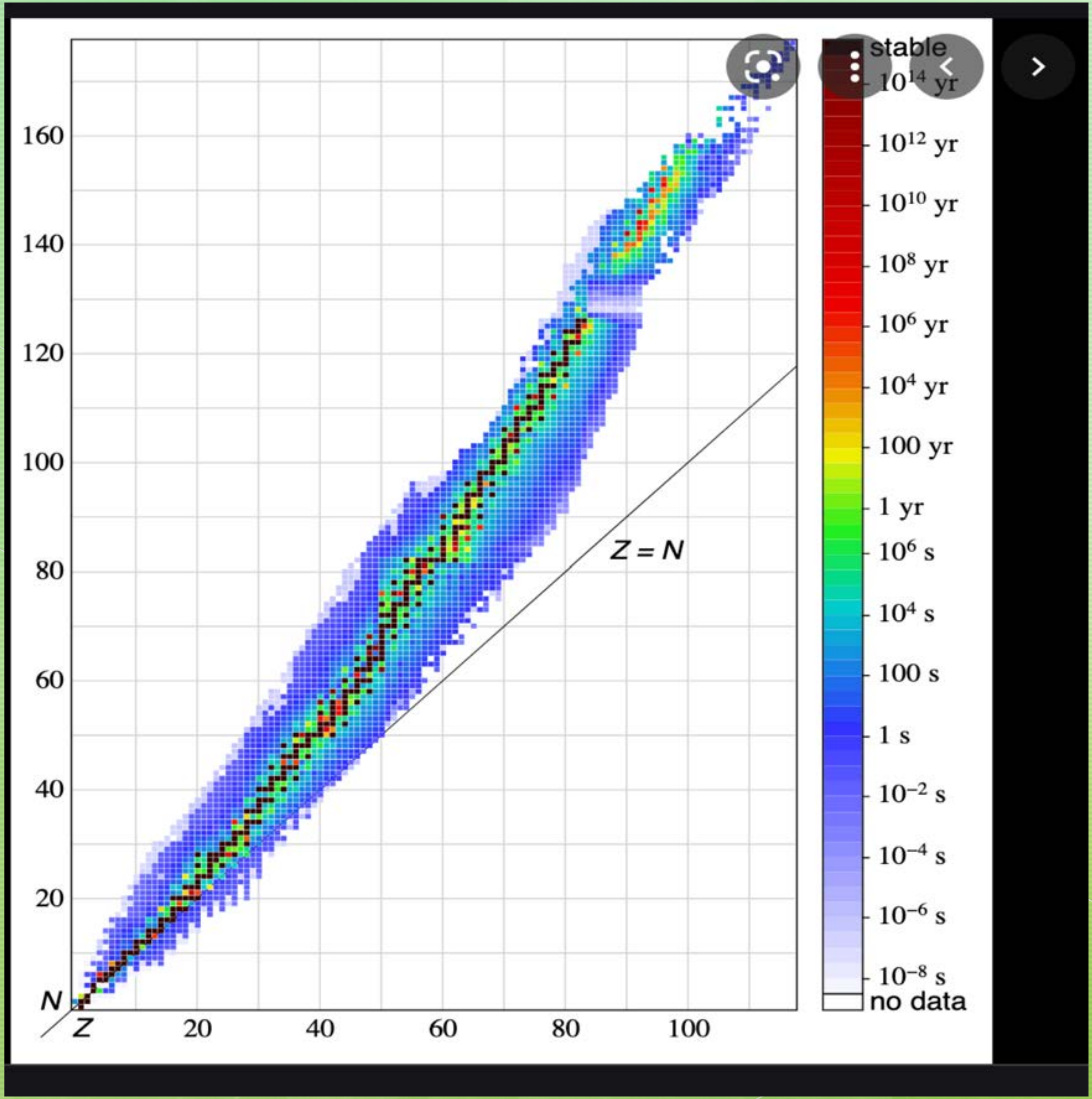
For ultra cold neutrons ($E_n < 0.001$ eV), the capture cross section for ^{157}Gd can reach 1.2×10^8 barns. This is comparable to typical atomic cross sections! The natural gadolinium capture cross section of these neutrons is



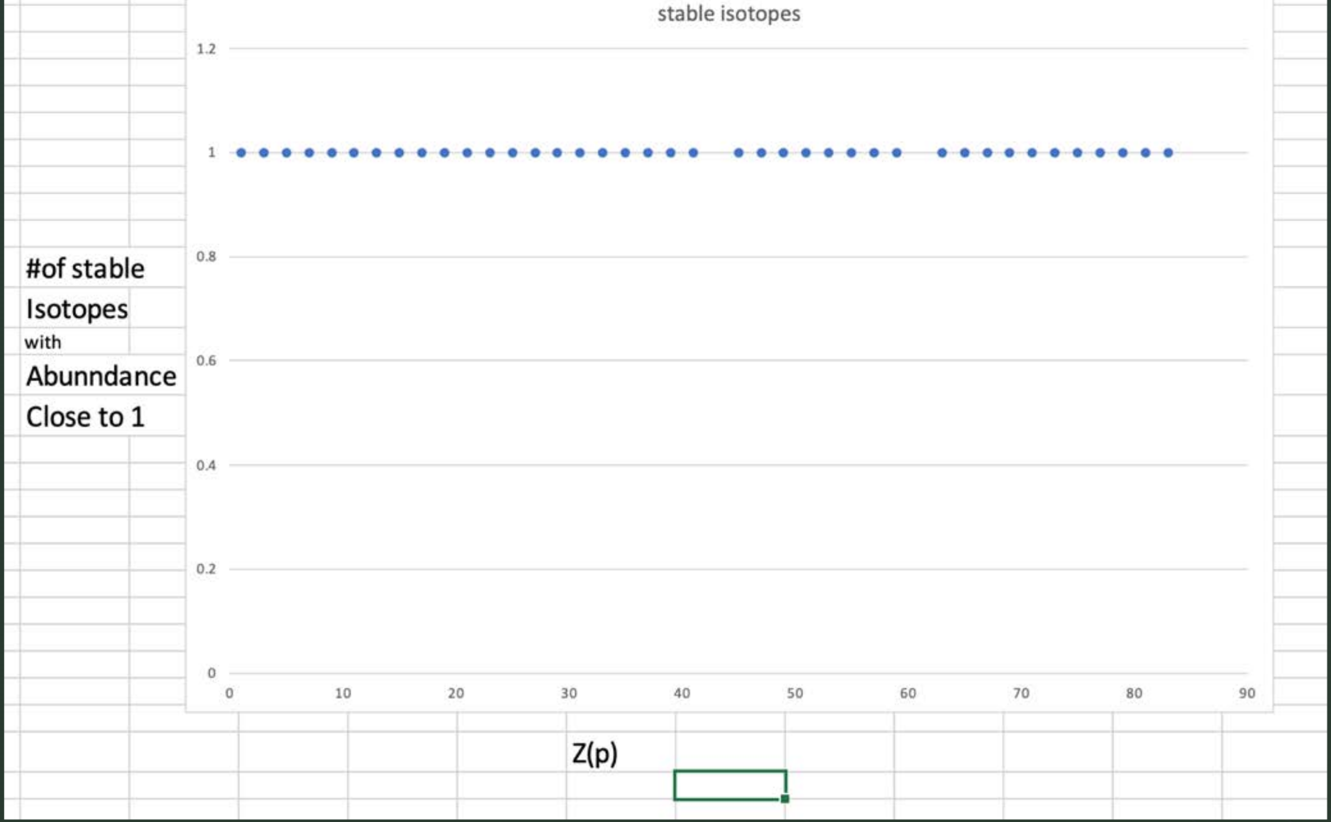
2. Abnormal nuclear resonance reactions and the possible rôle of simple doorways

A notorious case of an abnormal resonance reaction is the intermediate structure seen at low energy [8], and interpreted by Feshbach and Block [2] as arising from simple doorways, that modulates the compound nuclear resonances. We refer the reader to Feshbach's book on nuclear reactions [9]. A more recent example, which has been already alluded to above, concerns

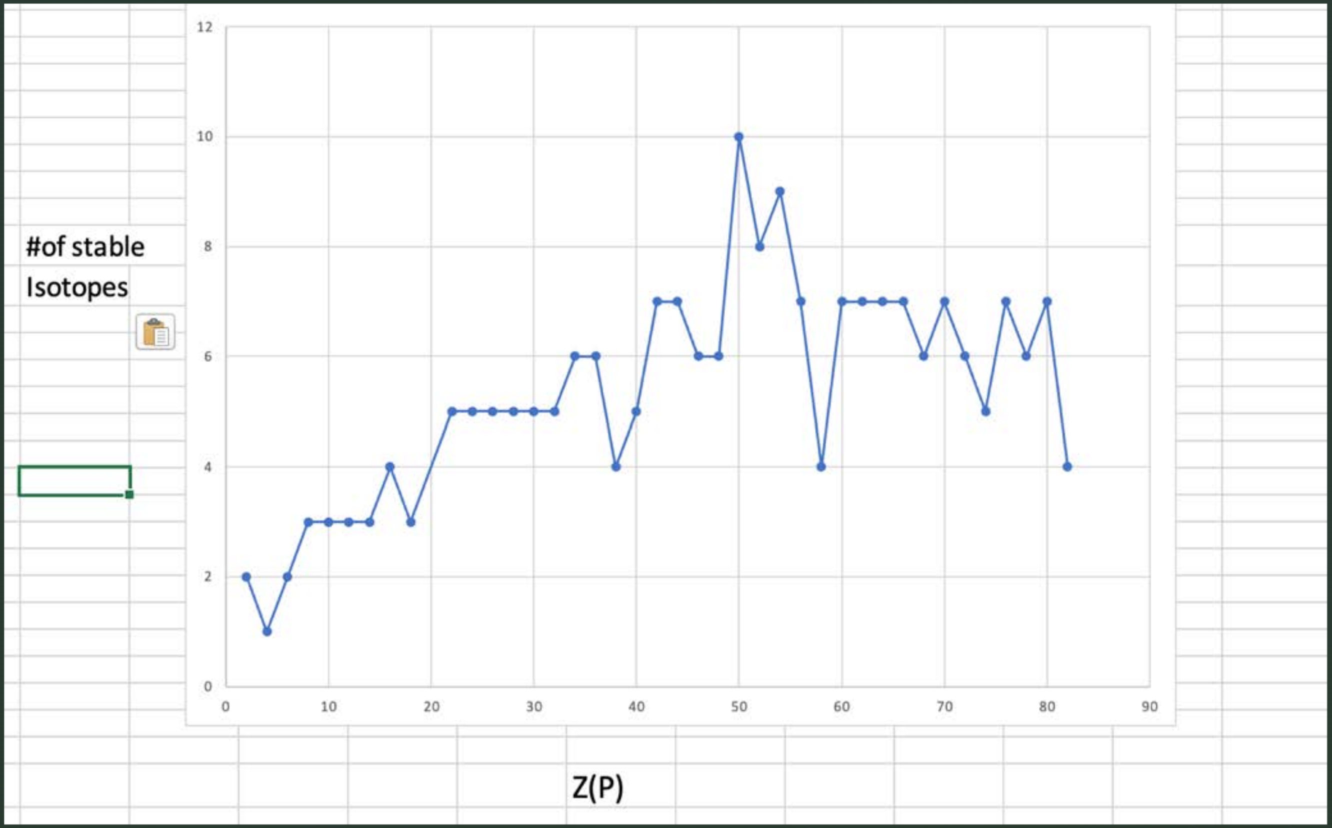
Traditional plot



Odd Z elemets vs #of stable Isotopes



Even Z elements
Stable Isotopes



Neutron's distinct identity within the nuclei

- If neutrons are really neutral than All neutrons in the nuclei should combine and form one heavy neutron But in reality
- All neutrons stand up and want to get counted
- What gives separate identity in the reference frame of Nuclei?

Preferential states and abundance in Nature

- Nature prefers stable systems
- Probability → Abundance
- The most abundant isotope of Element in nature represents the preferred state of that Nuclei
- WHAT MAKES THE ISOTOPE STABLE?

Relation between Abundance and Preferred state

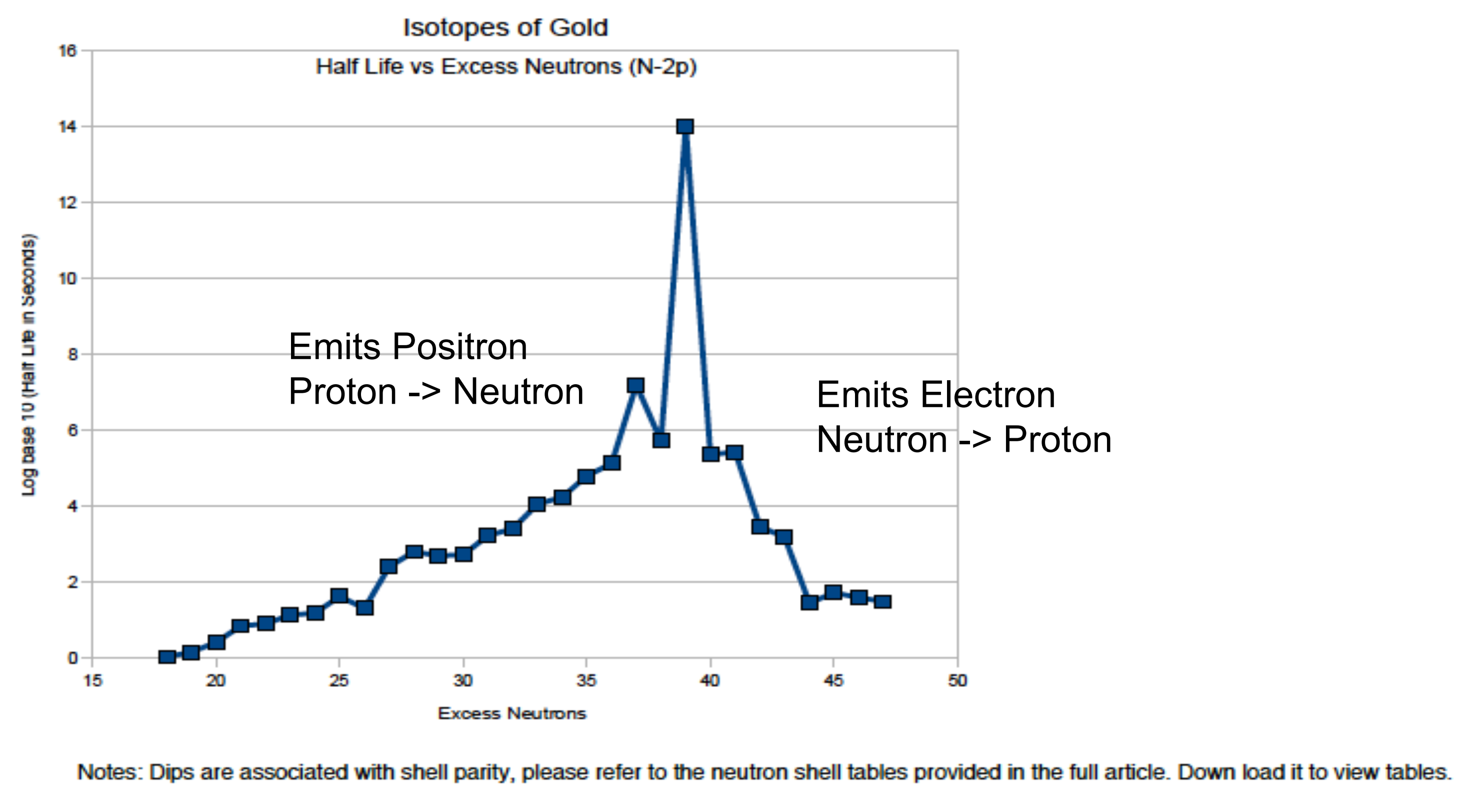
- Element may have many isotopes but it has upper limit
- Only handful of isotopes of element are non radioactive

Out of all the possibilities only some states are preferred

Stable Isotopes of Au, Pt, Hg and It's Abundance

Element	Z(p)	N(n)	n – p Unpaired excess neutrons	n-p/Z(p)	Relative abundance	stable isotopes
190Pt	78	112	34	0.44	0	6
192Pt	78	114	36	0.46	0.01	
194Pt	78	116	38	0.49	0.33	
195Pt	78	117	39	0.5	0.34	
196Pt	78	118	40	0.51	0.25	
198Pt	78	120	42	0.54	0.07	
197Au	79	118	39	0.49	1	1
196Hg	80	116	36	0.45	0	7
198Hg	80	118	38	0.48	0.1	
199Hg	80	119	39	0.49	0.17	
200Hg	80	120	40	0.5	0.23	
201Hg	80	121	41	0.51	0.13	
202Hg	80	122	42	0.53	0.3	
204Hg	80	124	44	0.55	0.07	

Instability Of Nuclei



Emits Positron
Proton -> Neutron

Emits Electron
Neutron -> Proton

Notes: Dips are associated with shell parity, please refer to the neutron shell tables provided in the full article. Down load it to view tables.

43Tc and 61Pm

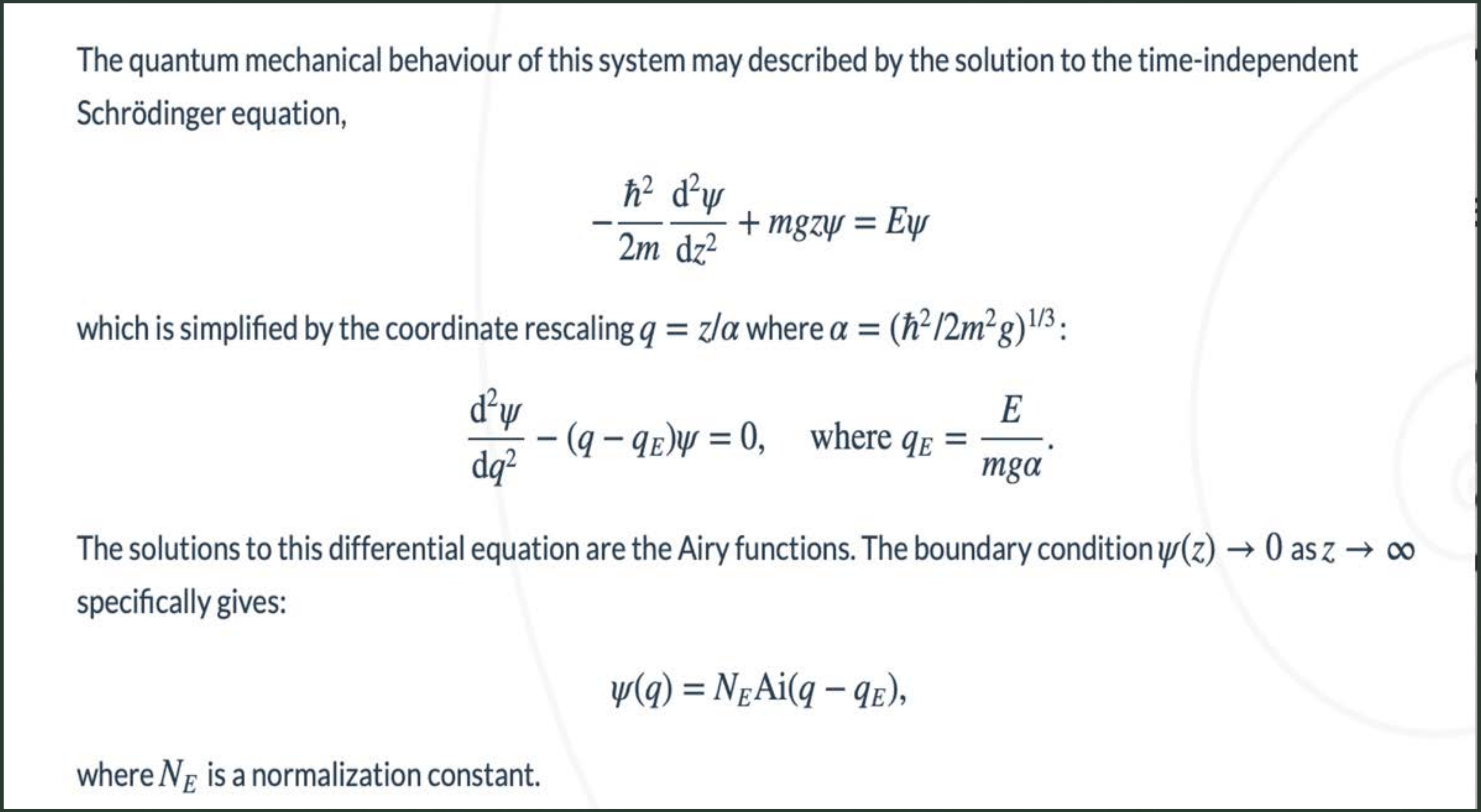
- No stable isotopes ,None found in Nature .
- Radioactive isotopes ..

  byproduct of Nuclear Reactor waste

The longest surviving Isotopes have

- For Tc excess N 11,12,13
- For Pm excess N 23, 24, 25

A Quantum Particle in a gravitational field



The quantum mechanical behaviour of this system may described by the solution to the time-independent Schrödinger equation,

$$-\frac{\hbar^2}{2m}\frac{\mathrm{d}^2\psi}{\mathrm{d}z^2} + mgz\psi = E\psi$$

which is simplified by the coordinate rescaling $q = z/\alpha$ where $\alpha = (\hbar^2/2m^2g)^{1/3}$:

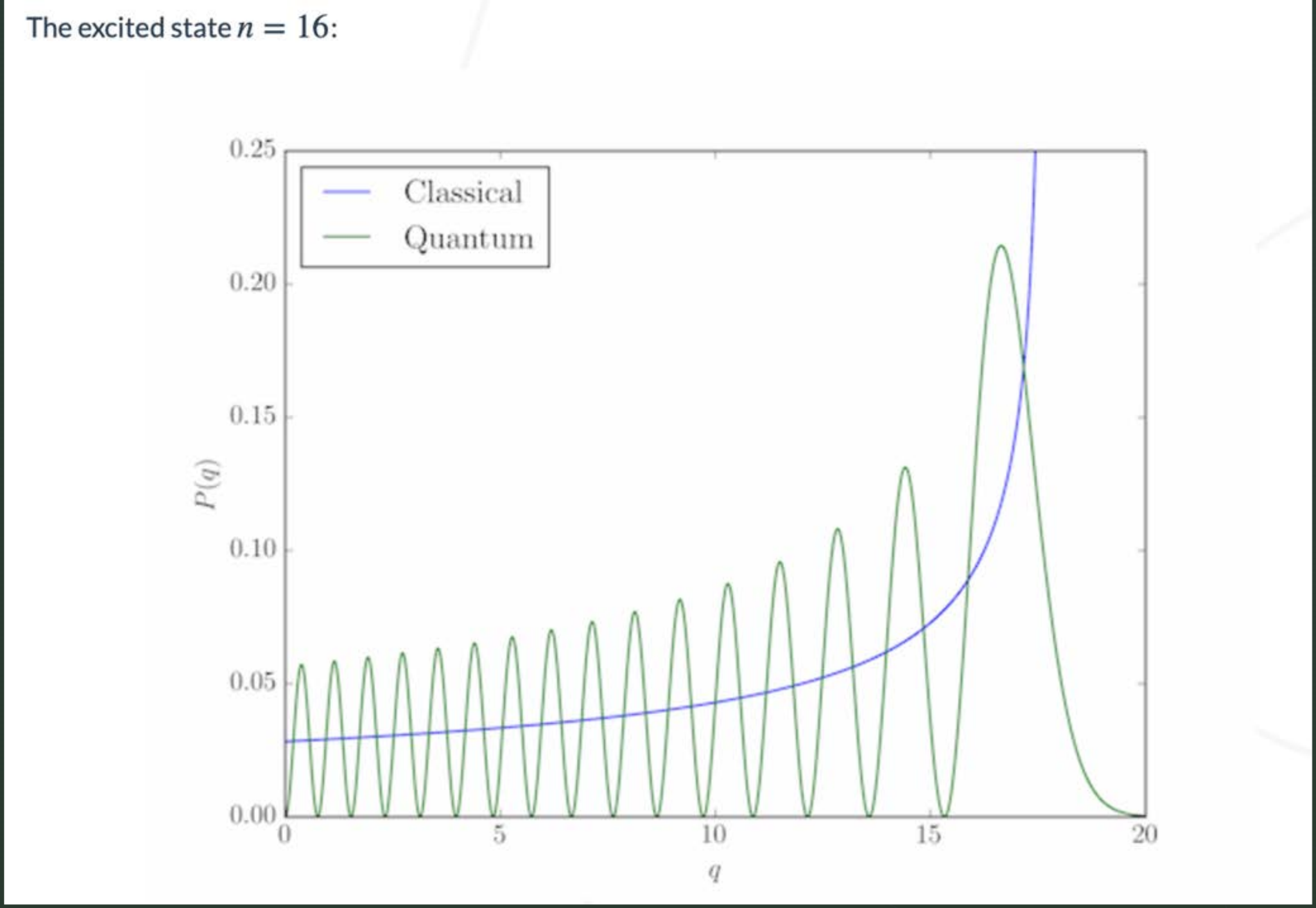
$$\frac{\mathrm{d}^2\psi}{\mathrm{d}q^2} - (q - q_E)\psi = 0, \quad \text{where } q_E = \frac{E}{mg\alpha}.$$

The solutions to this differential equation are the Airy functions. The boundary condition $\psi(z) \to 0$ as $z \to \infty$ specifically gives:

$$\psi(q) = N_E \mathrm{Ai}(q - q_E),$$

where N_E is a normalization constant.

Solution for n= 16

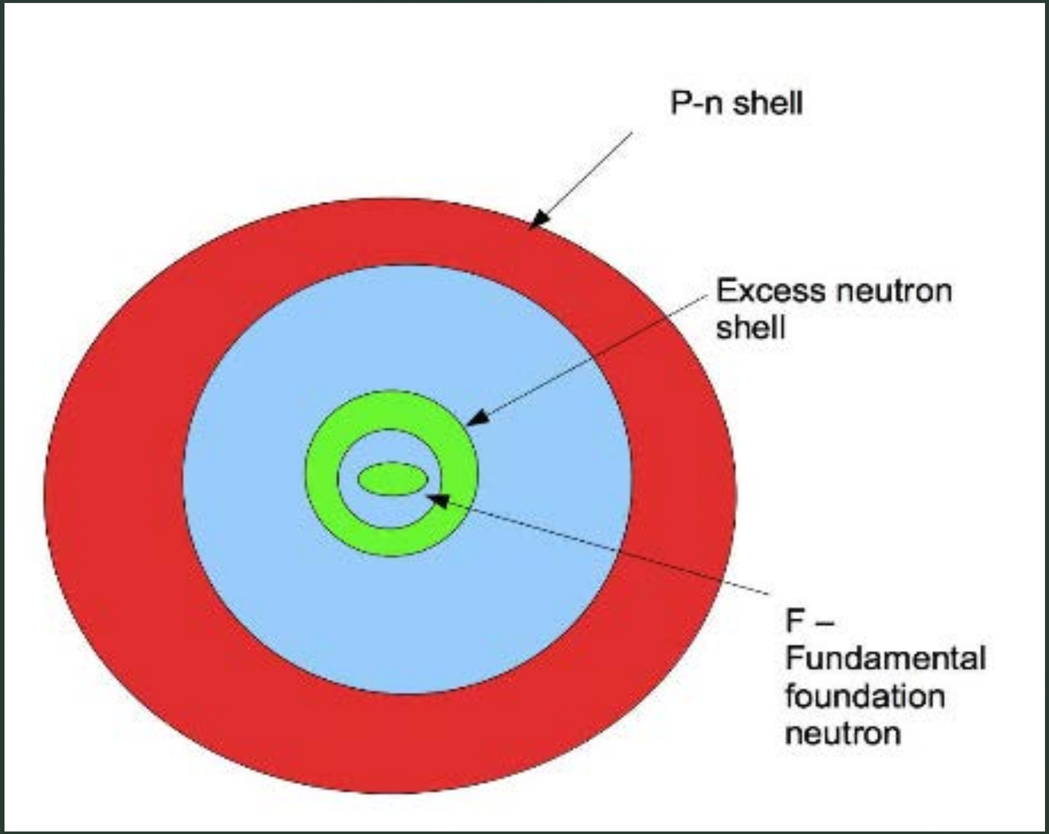


The excited state $n = 16$:

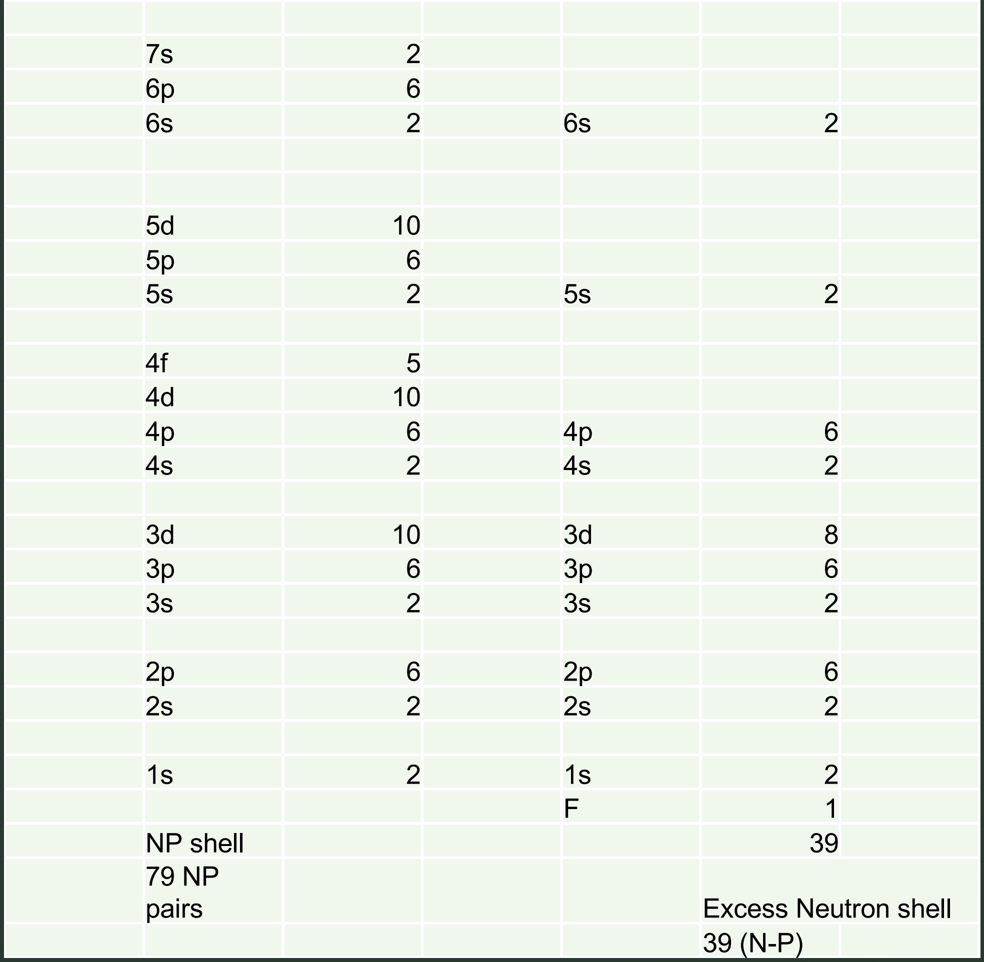
Energy levels of Neutron Shell

Excess Neutron Shell	Shell										
	F	K	L		M			N			
		s	s	p	s	p	d	s	p	d	f
	1	2	2	6	2	6	10	2	6	10	14

Excess Neutron Shell model of Nuclei

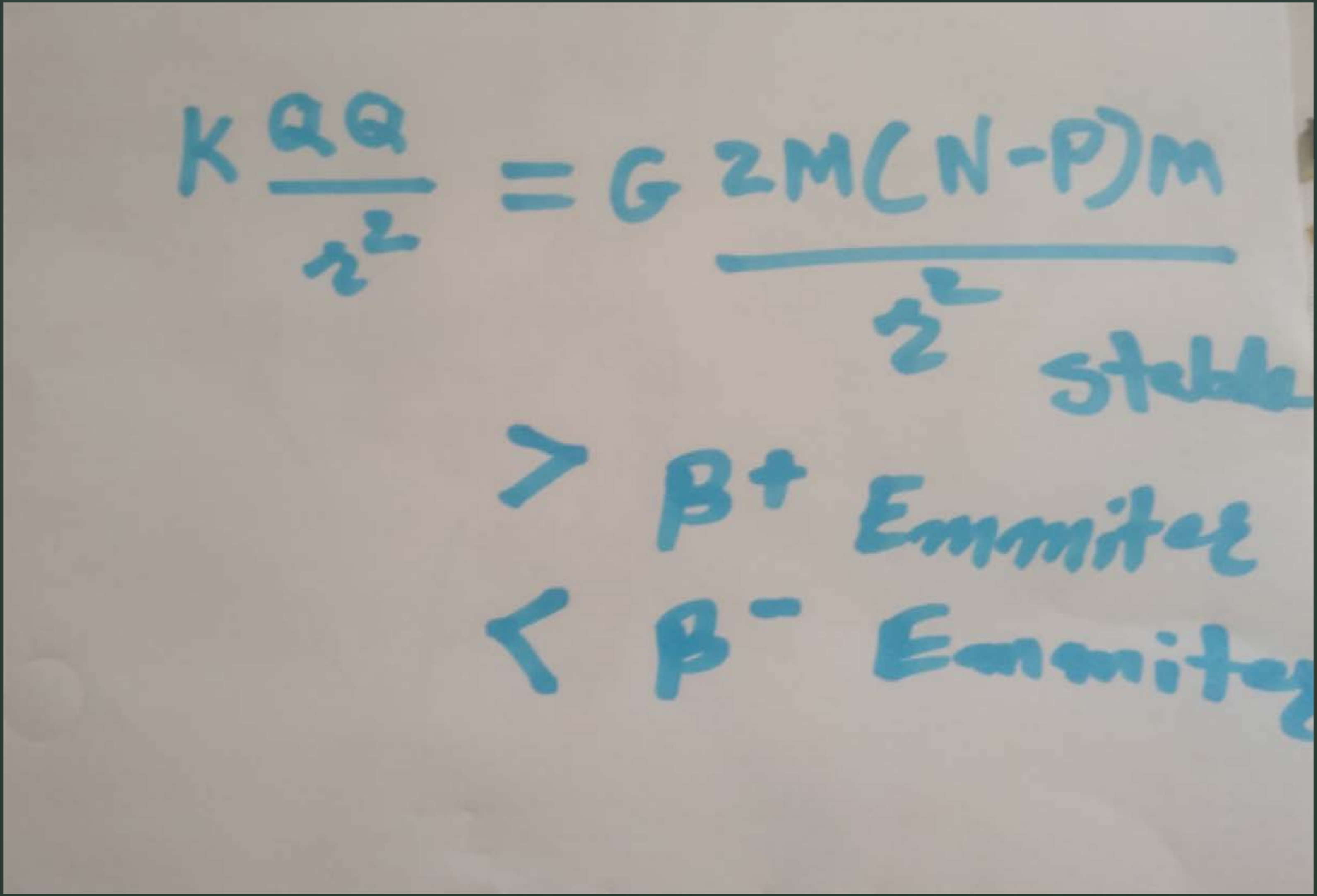


Orbital Energy Levels Au



	7s	2				
	6p	6				
	6s	2		6s	2	
	5d	10				
	5p	6				
	5s	2		5s	2	
	4f	5				
	4d	10				
	4p	6		4p	6	
	4s	2		4s	2	
	3d	10		3d	8	
	3p	6		3p	6	
	3s	2		3s	2	
	2p	6		2p	6	
	2s	2		2s	2	
	1s	2		1s	2	
				F	1	
	NP shell				39	
	79 NP pairs				Excess Neutron shell	
					39 (N-P)	

Initial condition

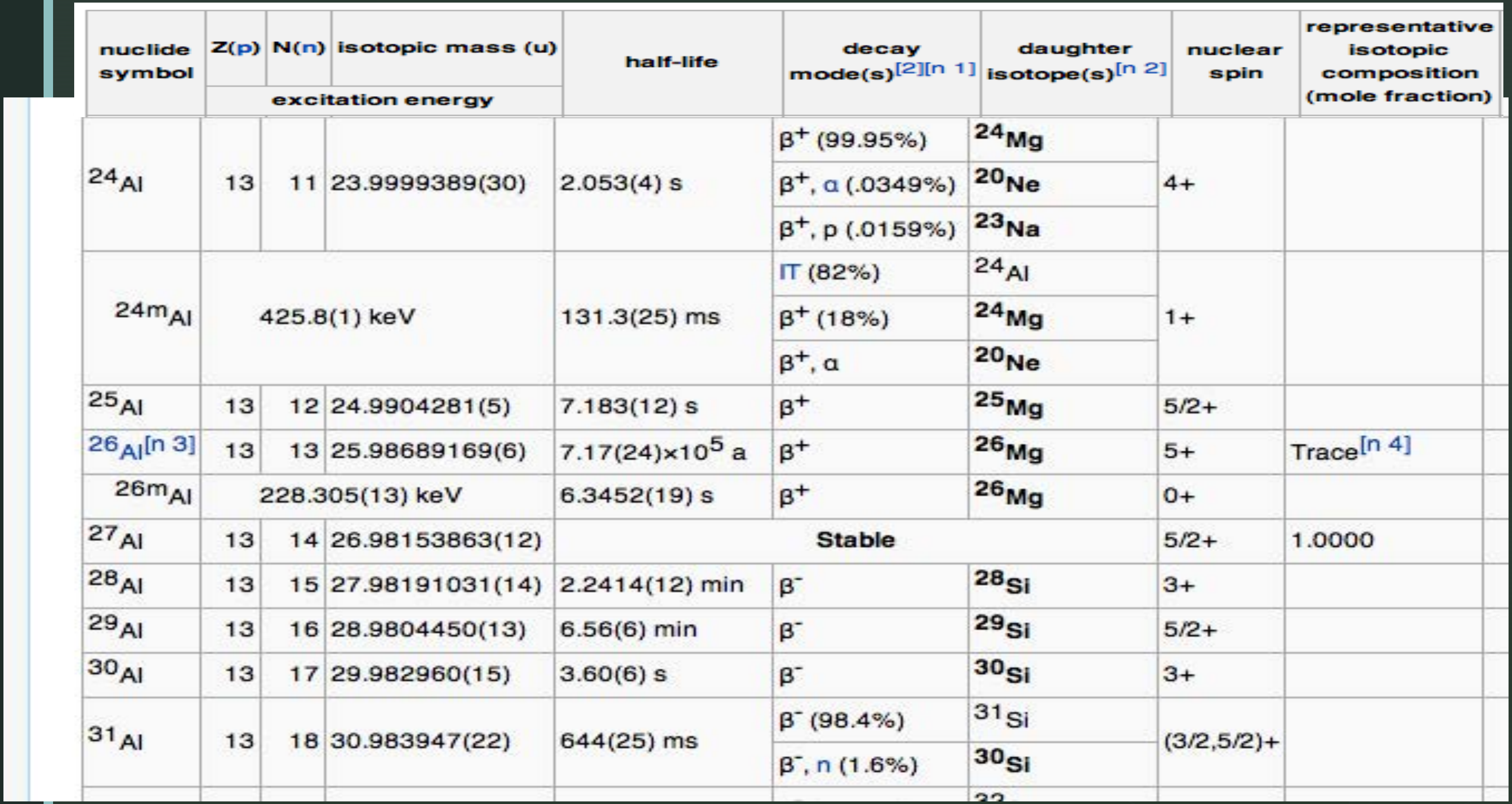


$$K\frac{QQ}{r^2} = G\frac{2M(N-P)m}{r^2}$$ stable

$>$ β^+ Emmiter

$<$ β^- Emmiter

Isotopes of odd z Element



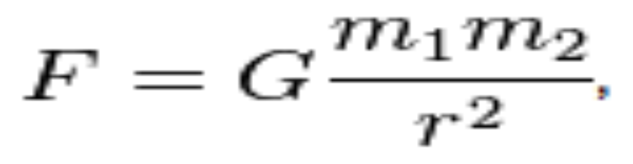
nuclide symbol	Z(p)	N(n)	isotopic mass (u)	half-life	decay mode(s)[2][n 1]	daughter isotope(s)[n 2]	nuclear spin	representative isotopic composition (mole fraction)
	excitation energy							
^{24}Al	13	11	23.9999389(30)	2.053(4) s	β^+ (99.95%)	^{24}Mg	4+	
					β^+, α (.0349%)	^{20}Ne		
					β^+, p (.0159%)	^{23}Na		
^{24m}Al	425.8(1) keV			131.3(25) ms	IT (82%)	^{24}Al	1+	
					β^+ (18%)	^{24}Mg		
					β^+, α	^{20}Ne		
^{25}Al	13	12	24.9904281(5)	7.183(12) s	β^+	^{25}Mg	5/2+	
^{26}Al[n 3]	13	13	25.98689169(6)	7.17(24)×10^5 a	β^+	^{26}Mg	5+	Trace[n 4]
^{26m}Al	228.305(13) keV			6.3452(19) s	β^+	^{26}Mg	0+	
^{27}Al	13	14	26.98153863(12)	Stable			5/2+	1.0000
^{28}Al	13	15	27.98191031(14)	2.2414(12) min	β^-	^{28}Si	3+	
^{29}Al	13	16	28.9804450(13)	6.56(6) min	β^-	^{29}Si	5/2+	
^{30}Al	13	17	29.982960(15)	3.60(6) s	β^-	^{30}Si	3+	
^{31}Al	13	18	30.983947(22)	644(25) ms	β^- (98.4%)	^{31}Si	(3/2,5/2)+	
					β^-, n (1.6%)	^{30}Si		

Isotopes of even Z Element

nuclide symbol	Z(p)	N(n)	isotopic mass (u)	half-life	decay mode(s)[2][n 1]	daughter isotope(s)[n 2]	nuclear spin	representative isotopic composition (mole fraction)	
	excitation energy								
^{111}Sn	50	61	110.907734(7)	35.3(6) min	β^+	^{111}In	7/2+		
^{111m}Sn	254.72(8) keV			12.5(10) μs			1/2+		
^{112}Sn	50	62	111.904818(5)	Observationally Stable[n 5]			0+	0.0097(1)	
^{113}Sn	50	63	112.905171(4)	115.09(3) d	β^+	^{113}In	1/2+		
^{113m}Sn	77.386(19) keV			21.4(4) min	IT (91.1%)	^{113}Sn	7/2+		
					β^+ (8.9%)	^{113}In			
^{114}Sn	50	64	113.902779(3)	Stable[n 6]			0+	0.0066(1)	
^{114m}Sn	3087.37(7) keV			733(14) ns			7-		
^{115}Sn	50	65	114.903342(3)	Stable[n 6]			1/2+	0.0034(1)	
^{115m1}Sn	612.81(4) keV			3.26(8) μs			7/2+		
^{115m2}Sn	713.64(12) keV			159(1) μs			11/2-		
^{116}Sn	50	66	115.901741(3)	Stable[n 6]			0+	0.1454(9)	
^{117}Sn	50	67	116.902952(3)	Stable[n 6]			1/2+	0.0768(7)	
^{117m1}Sn	314.58(4) keV			13.76(4) d	IT	^{117}Sn	11/2-		
^{117m2}Sn	2406.4(4) keV			1.75(7) μs			(19/2+)		
^{118}Sn	50	68	117.901603(3)	Stable[n 6]			0+	0.2422(9)	
^{119}Sn	50	69	118.903308(3)	Stable[n 6]			1/2+	0.0859(4)	
^{119m1}Sn	89.531(13) keV			293.1(7) d	IT	^{119}Sn	11/2-		
^{119m2}Sn	2127.0(10) keV			9.6(12) μs			(19/2+)		
^{120}Sn	50	70	119.9021947(27)	Stable[n 6]			0+	0.3258(9)	
^{120m1}Sn	2481.63(6) keV			11.8(5) μs			(7-)		
^{120m2}Sn	2902.22(22) keV			6.26(11) μs			(10+)#		
^{121}Sn[n 7]	50	71	120.9042355(27)	27.03(4) h	β^-	^{121}Sb	3/2+		

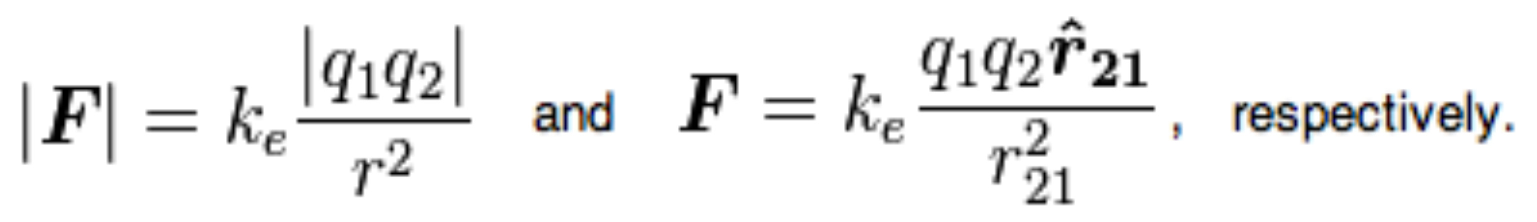
Mathematics of Force

- Strong Nuclear Forces , Nuclei should be unbreakable.. But it Breaks !!! Why?



$$F = G\frac{m_1 m_2}{r^2},$$

- Must Consider other influence as well



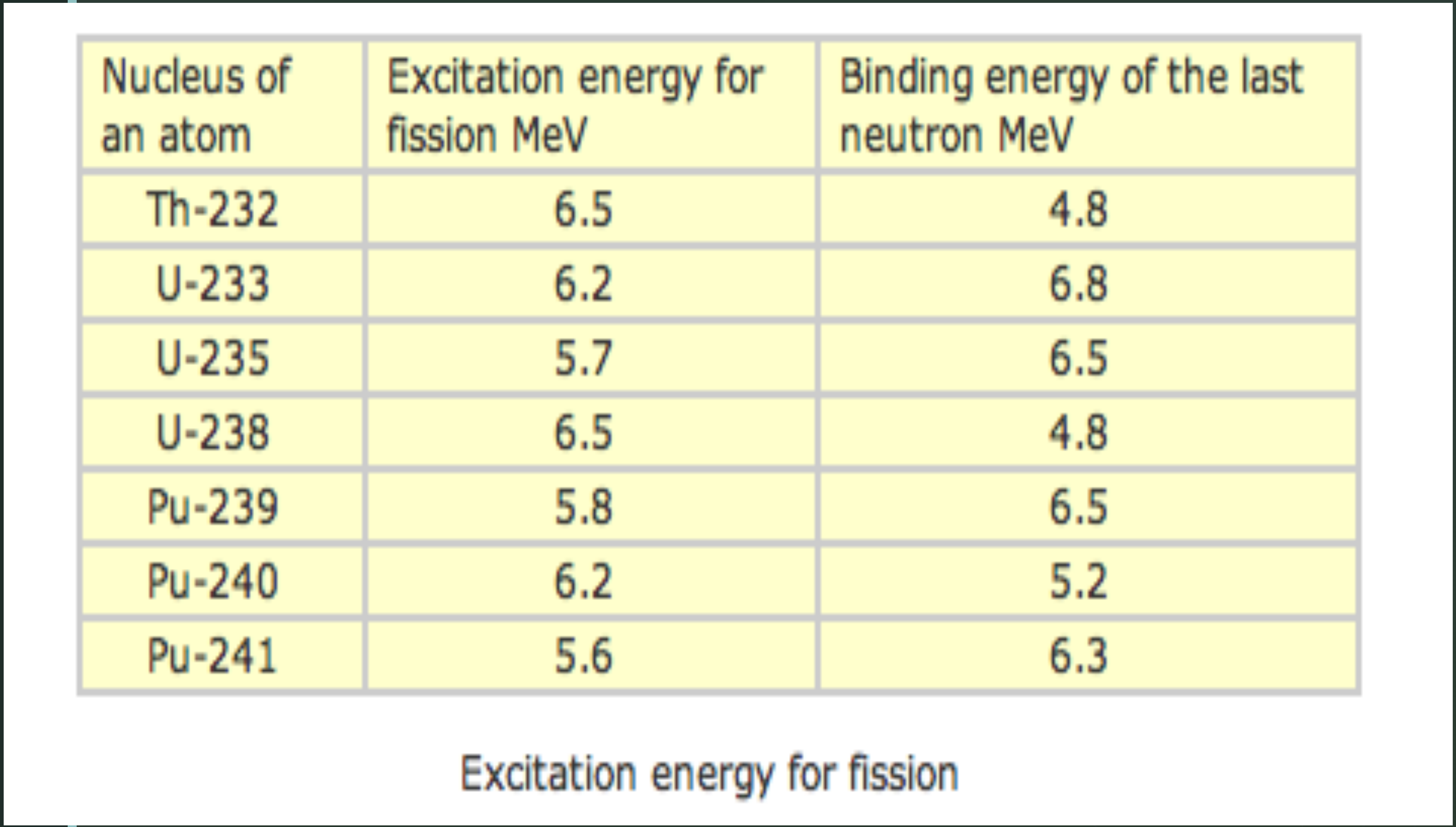
$$|\boldsymbol{F}| = k_e\frac{|q_1 q_2|}{r^2} \quad \text{and} \quad \boldsymbol{F} = k_e\frac{q_1 q_2 \hat{\mathbf{r}}_{\mathbf{21}}}{r_{21}^2}, \quad \text{respectively.}$$

Au197(n,γ)Au198 Reaction Mechanism

O. A. Wasson, R. E. Chrien, M. R. Bhat, M. A. Lone, and M. Beer Phys. Rev. **173**, 1170 – Published 20 September 1968

- The variation in intensity of 24 γ rays emitted in neutron capture near the 4.9-eV resonance in gold was measured as a function of neutron energy. Significant interference was observed in the partial capture cross sections, which was consistent with interference between local resonances provided that a bound level was postulated which contributes 3.5 b to the thermal-capture cross section. With this assumption, no direct reaction mechanism is required in the capture process. Capture γ-ray spectra were also observed in the various resonances for neutron energies <400 eV. Previously unreported γ rays were observed in thermal neutron capture, while additional new γ rays were observed in resonance capture. The choice of relative signs of the partial-width amplitudes of the 4.9- and 60-eV resonances required to fit the data is inconsistent with the usual assumption of normally distributed width amplitudes.

Fission Energies and Resonance



Nucleus of an atom	Excitation energy for fission MeV	Binding energy of the last neutron MeV
Th-232	6.5	4.8
U-233	6.2	6.8
U-235	5.7	6.5
U-238	6.5	4.8
Pu-239	5.8	6.5
Pu-240	6.2	5.2
Pu-241	5.6	6.3

Excitation energy for fission

Case of Bismuth Element Z=83

- 126 Bi   Half life **2.01(8)×10^{19} y formerly believed to be heaviest element stable isotope nuclide**
- **excess Neutrons 43 (126 – 83)**

Looks like For stability of nuclide P = 80 and N = 122 with Highest relative abundance among Hg stable nuclide and Thallium P = 81 and N = 124, 123 are stable. Even lead isotopes are not stable.

Excess Neutron shell Model some observations

- It shows that gravitational pull from innermost neutron shell gives the stability as well as upper limit to stable element (discuss)
- Alpha emission is the result of constant collision of neutron shell with NP shell
- Existence of Neutron shell thus postulated corelates to compressible spongy nature of neutron
- Excess Neutron shell resonances allows for cold neutron resonance capture

Fusion

- Must overcome coulomb forces and bring two nuclei close enough for strong forces to work
- Only Hydrogen isotope 2H and 3H fuses.
- To fuse 1H , neutron rich environment is needed

Diffused Hydrogen in Solid

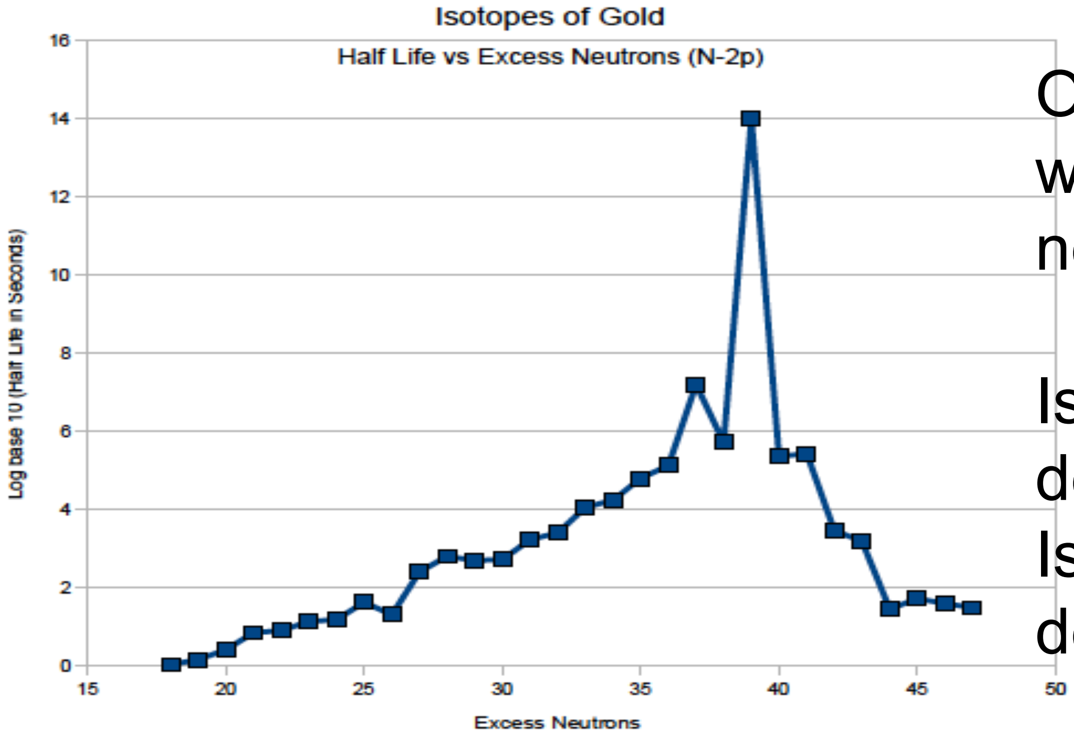
- It is a Free Proton since the electron will be lost in electron cloud

Emerging New Model of Nuclei
Bold Statements

- No neutrons.. No elements !!!!
- Are neutrons really neutral?
- How neutrons keep distinct identity inside nuclei?
- ? All elemets were created at the time of Big Bang” Example proof “black body spectrum of the Sun”

What Makes Nuclei unstable (Radio active)?

Radioactivity Revisited



Notes: Dips are associated with shell parity, please refer to the neutron shell tables provided in the full article. Down load it to view tables.

Only one stable isotope with 39 excess neutrons

Isotopes < 39 neutrons decay with Beta +
Isotopes > 39 neutrons decay with Beta -

Isotopes of Gold

Excess neutrons (N – Z) form own shell at the center..Excess Neutron Shell

- The first excess neutron stay at the center of Nuclei !!!? n = 0
- Protons Pair up with Neutrons and form outer shell
- Spin Balanced Shell gives stability to nuclei

Cold Neutron Resonance Capture Cross section

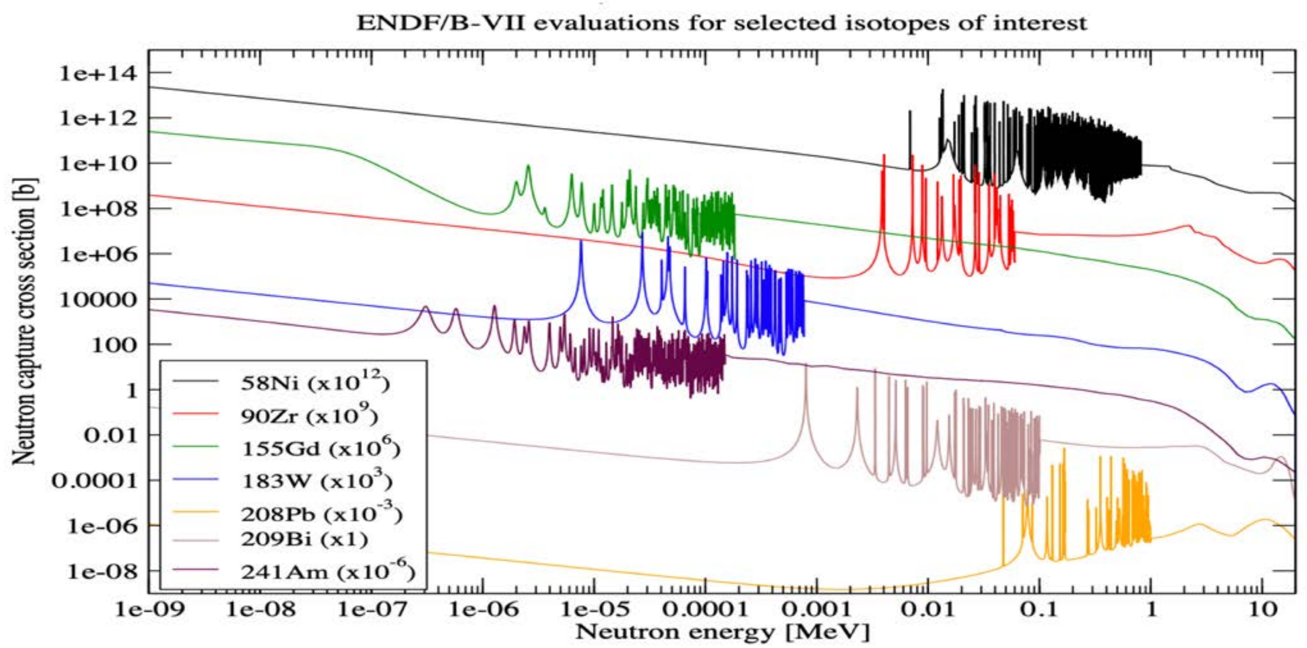
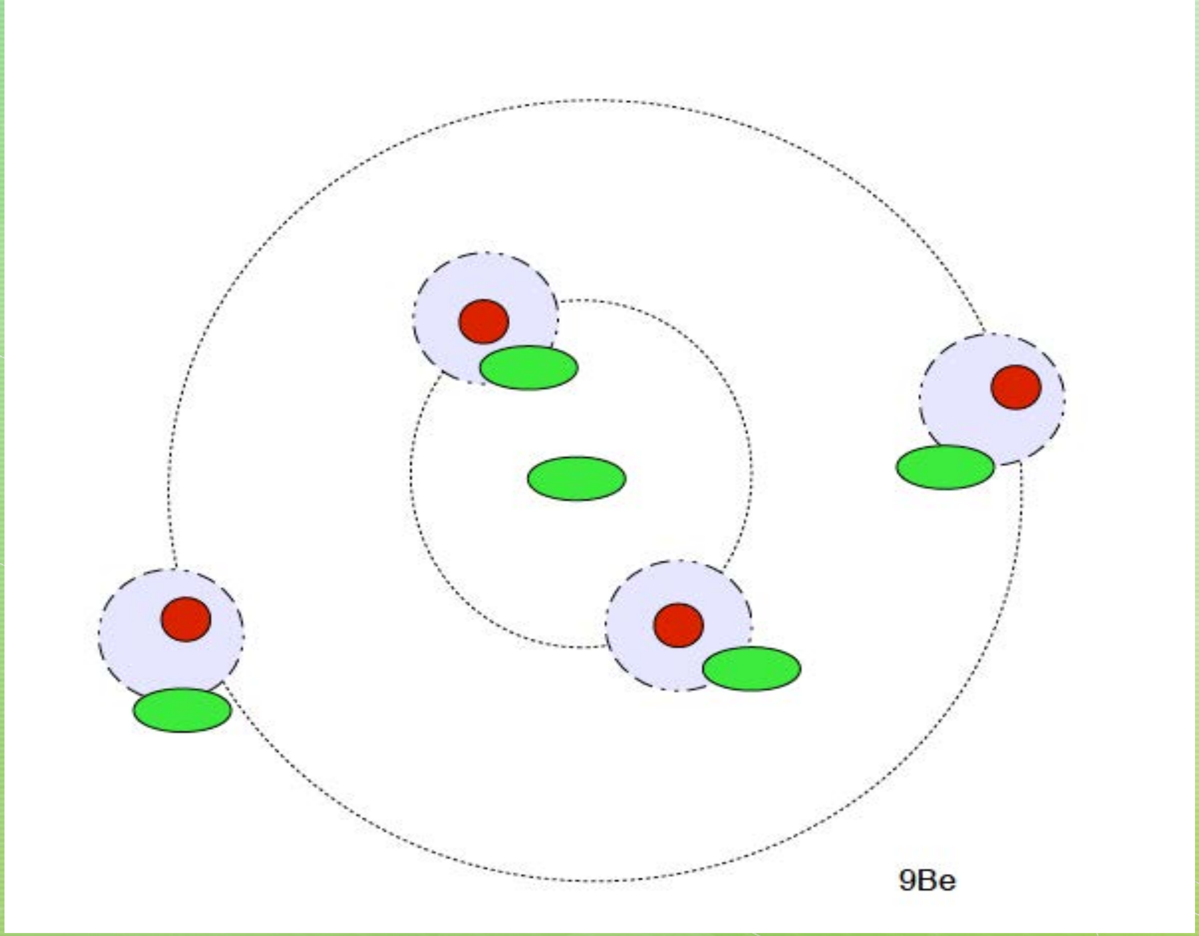


FIG. 1: Typical capture cross sections, for selected isotopes. Shown are evaluated cross sections for neutron energies from thermal to 20 MeV. The ENDF/B-VII evaluations, taken from the NNDC database, are calculations based on experimental data.

Applying Model to various stable and non stable Elements and their isotopes



RadioActivity & Half Life of elments

Neutrons in periodic Gravitational field may share neutrons temporary to increase stability.

Experiments at Cern has found that Neutron in elements found at several atom radius beyond the size of atom of the element.