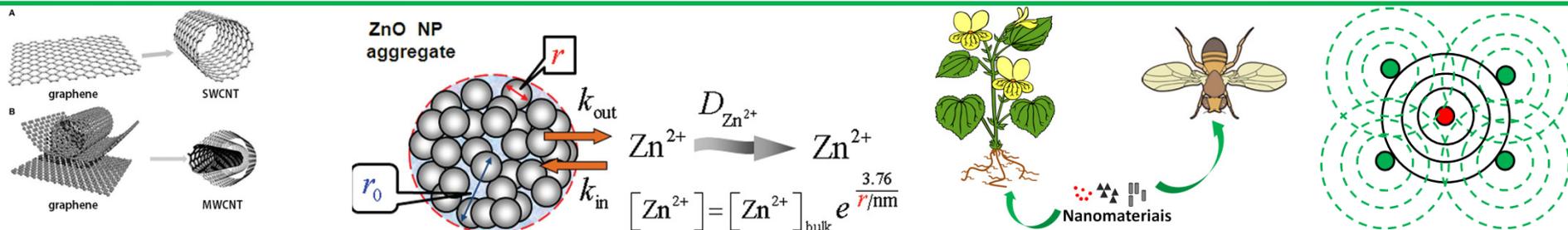


Centro de Energia Nuclear na Agricultura
Campus "Luiz de Queiroz"

USP

Estrutura Nuclear & Isótopos Estáveis e Radioativos

Prof. Dr. Hudson W.P. Carvalho
Group of Applied X-ray Spectroscopy
Laboratório de Instrumentação Nuclear





Estrutura Nuclear e Reações Nucleares

1.5 Isótopos Estáveis e Radioativos

☐ Partículas nucleares

- Prótons e nêutrons constituem o núcleo atômico

Os experimentos com materiais radioativos, mostram a existência de **partículas radioativas** e também revelaram a transmutação dos elementos

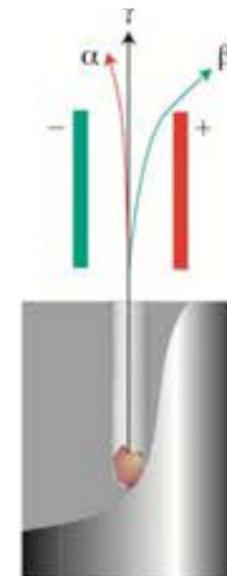


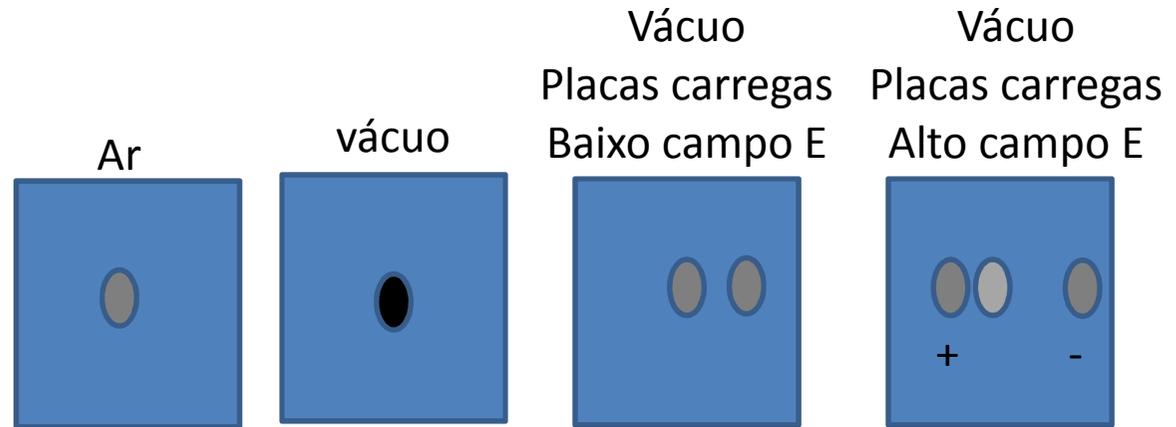
FIGURA 17.4 Efeitos de um campo elétrico sobre a radiação nuclear. A direção do desvio identifica os raios α como tendo carga positiva, os raios β como tendo carga negativa e os raios γ como não tendo carga.

1.5 Isótopos Estáveis e Radioativos

☐ Partículas radiotivas



FIGURA 17.4 Efeitos de um campo elétrico sobre a radiação nuclear. A direção do desvio identifica os raios α como tendo carga positiva, os raios β como tendo carga negativa e os raios γ como não tendo carga.



Partícula positiva- elevada massa- alfa- núcleo de ^4He
 Partícula negativa- baixa massa- beta - elétron
 Partícula neutra- gama – não tem massa- radiação eletromagnética de alta energia

Outras partículas que são produto do decaimento nuclear
 Os nuclídeos instáveis podem também emitir

Prótons

Nêutrons

Pósitron = a mesma do elétron, mas carga positiva

- A energia da radiação gama é medida em elétronvolt
- Para converter elétronvolt em comprimento de onda nós usamos a seguinte equação
- $E = hc/\lambda$
- E (eV), h = constant de Plank (eV s), velocidade da luz, λ (m)

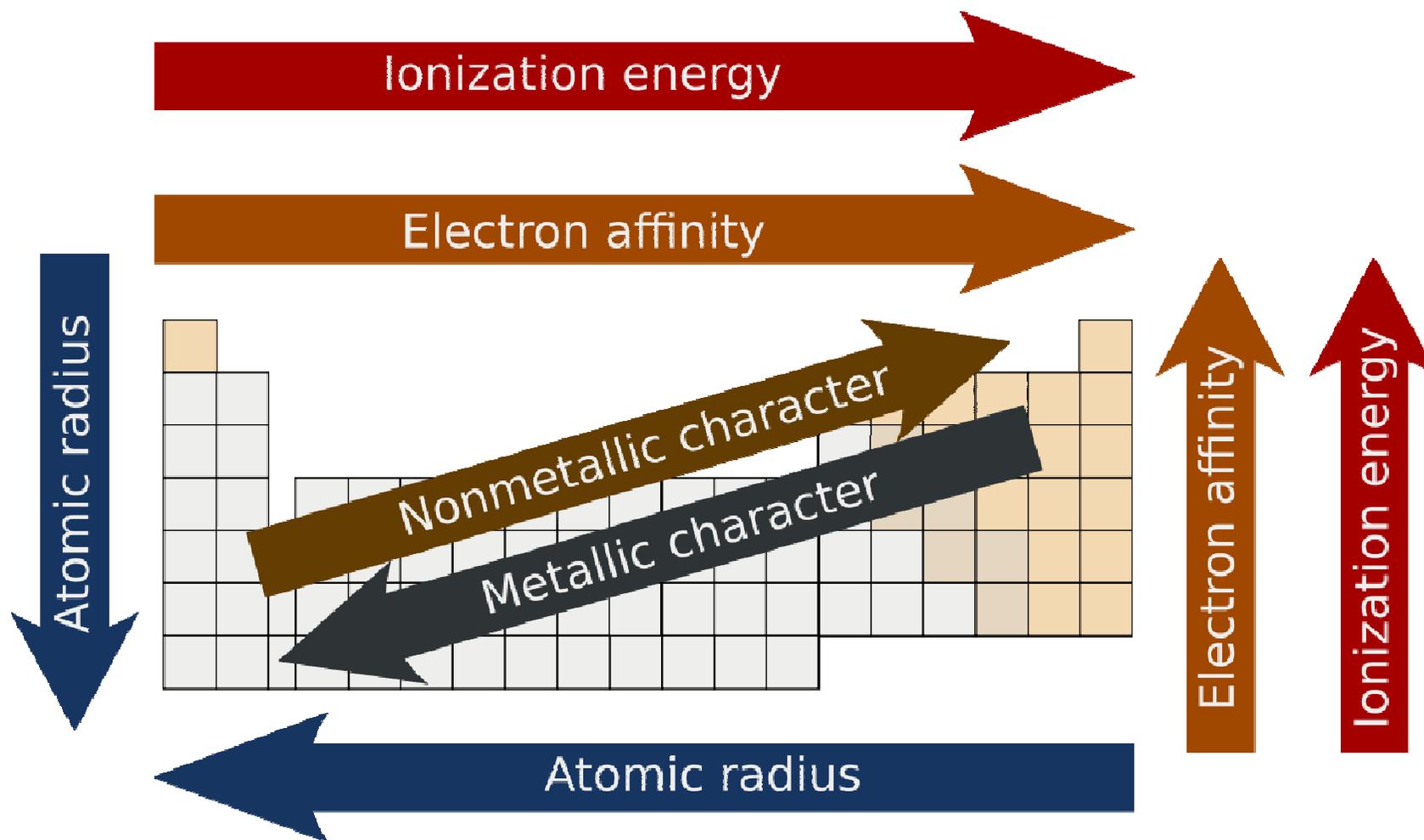
1.5 Isótopos Estáveis e Radioativos

- Existem núclídeos estáveis, ou seja, eles não se transformam em outros núclídeos.

- Existem núclídeos, instáveis, ou radioativos que vão, cedo ou tarde, em outro núclídeo.

A Tabela periódica

❑ Como os elementos estão organizados?



Massa atômica

❑ Como essa massa foi calculada?



Massa = 1

Carga = neutra

Partícula de Rutherford

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.008																	2 He Helium 4.002602
2	3 Li Lithium 6.94	4 Be Beryllium 9.0121831											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998403163	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.305											13 Al Aluminium 26.9815385	14 Si Silicon 28.085	15 P Phosphorus 30.973761998	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955908	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938044	26 Fe Iron 55.845	27 Co Cobalt 58.933194	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.921595	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90637	42 Mo Molybdenum 95.95	43 Tc Technetium 98	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Caesium 132.90545196	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.592	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
7	87 Fr Francium 223	88 Ra Radium 226	89-103	104 Rf Rutherfordium 261	105 Db Dubnium 268	106 Sg Seaborgium 269	107 Bh Bohrium 270	108 Hs Hassium 269	109 Mt Meitnerium 278	110 Ds Darmstadtium 281	111 Rg Roentgenium 281	112 Cn Copernicium 285	113 Uut Ununtrium 286	114 Fl Flerovium 289	115 Uup Ununpentium 289	116 Lv Livermorium 293	117 Uus Ununseptium 294	118 Uuo Ununoctium 294

Diagram illustrating the components of a hydrogen atom (H):

- Atomic Number:** 1
- Symbol:** H
- Atomic Mass:** 1.008
- Name:** Hydrogen

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

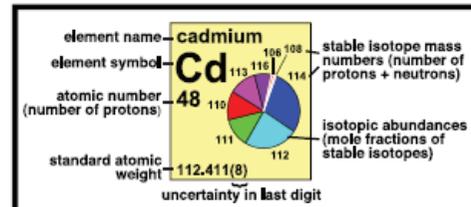
Tabela Periódica dos Isótopos

Element has two or more stable isotopes. Atomic weight and isotopic abundances of element vary in naturally occurring materials. The lower and upper bounds of atomic weight have been assessed by IUPAC and are presented as the standard atomic weight within square brackets, [].

Element has two or more stable isotopes and the standard atomic weight is not a constant of nature. The lower and upper bounds of the standard atomic weight have not been evaluated by IUPAC yet.

Element has one stable isotope and its standard atomic weight is a constant of nature.

Element has no stable isotopes. Thus, no standard atomic weight exists.



1 hydrogen H 1 [1,007 84; 1,008 11]	2 lithium Li 3 [6,938; 6,997]		beryllium Be 4 9,012 182(3)													18 helium He 2 4,002 602(2)	
sodium Na 11 22,989 769 28(2)	magnesium Mg 12 24,3050(6)	3 scandium Sc 21 44,955 912(6)	4 titanium Ti 22 47,867(1)	5 vanadium V 23 50,9415(1)	6 chromium Cr 24 51,9961(6)	7 manganese Mn 25 54,938 045(5)	8 iron Fe 26 55,845(5)	9 cobalt Co 27 58,933 195(5)	10 nickel Ni 28 58,6934(4)	11 copper Cu 29 63,546(3)	12 zinc Zn 30 65,38(2)	13 boron B 5 [10,806; 10,821]	14 carbon C 6 [12,0096; 12,0116]	15 nitrogen N 7 [14,006 43; 14,007 28]	16 oxygen O 8 [15,999 03; 15,999 77]	17 fluorine F 9 18,998 4032(5)	18 neon Ne 10 20,1797(5)
potassium K 19 39,0983(1)	calcium Ca 20 40,078(4)	yttrium Y 39 88,905 85(2)	zirconium Zr 40 91,224(2)	niobium Nb 41 92,906 38(2)	molybdenum Mo 42 95,96(2)	technetium Tc 43 []	ruthenium Ru 44 101,07(2)	rhodium Rh 45 102,905 50(2)	paladium Pd 46 106,42(1)	silver Ag 47 107,8682(2)	cadmium Cd 48 112,411(8)	aluminum (aluminium) Al 13 26,981 5386(8)	silicon Si 14 [28,084; 28,086]	phosphorus P 15 30,973 762(2)	sulfur S 16 [32,059; 32,076]	chlorine Cl 17 [35,446; 35,457]	argon Ar 18 39,948(1)
rubidium Rb 37 85,4678(3)	strontium Sr 38 87,62(1)	lanthanoids 57 - 71	hafnium Hf 72 178,49(2)	tantalum Ta 73 180,947 89(2)	tungsten W 74 183,84(1)	rhenium Re 75 186,207(1)	osmium Os 76 190,23(2)	iridium Ir 77 192,217(3)	platinum Pt 78 195,084(9)	gold Au 79 196,966 569(4)	mercury Hg 80 200,59(2)	indium In 49 114,818(3)	tin Sn 50 118,710(7)	antimony Sb 51 121,760(1)	tellurium Te 52 127,60(3)	iodine I 53 126,904 47(3)	xenon Xe 54 131,293(6)
caesium (cesium) Cs 55 132,905 4518(2)	barium Ba 56 137,327(7)	actinoids 89 - 103	rutherfordium Rf 104 []	dubnium Db 105 []	seaborgium Sg 106 []	bohrium Bh 107 []	hassium Hs 108 []	meitnerium Mt 109 []	darmstadtium Ds 110 []	roentgenium Rg 111 []	copernicium Cn 112 []	thallium Tl 81 [204,382; 204,385]	lead Pb 82 207,2(1)	bismuth Bi 83 208,980 40(1)	polonium Po 84 []	astatine At 85 []	radon Rn 86 []
francium Fr 87 []	radium Ra 88 []	actinoids 89 - 103	ununtrium Uut 113 []	ununquadium Uuq 114 []	ununpentium Uup 115 []	ununhexium Uuh 116 []	ununseptium Uus 117 []	ununoctium Uuo 118 []									

lanthanum La 57 138,905 47(7)	cerium Ce 58 140,12(1)	praseodymium Pr 59 140,907 65(2)	neodymium Nd 60 144,242(3)	promethium Pm 61 []	samarium Sm 62 150,36(2)	europium Eu 63 151,964(1)	gadolinium Gd 64 157,25(3)	terbium Tb 65 158,925 35(2)	dysprosium Dy 66 162,50(1)	holmium Ho 67 164,930 32(2)	erbium Er 68 167,259(3)	thulium Tm 69 168,934 21(2)	ytterbium Yb 70 173,054(5)	lutetium Lu 71 174,9668(1)
actinium Ac 89 []	thorium Th 90 232,038 06(2)	protactinium Pa 91 231,036 08(2)	uranium U 92 238,028 91(3)	neptunium Np 93 []	plutonium Pu 94 []	americium Am 95 []	curium Cm 96 []	berkelium Bk 97 []	californium Cf 98 []	einsteinium Es 99 []	fermium Fm 100 []	mendelevium Md 101 []	nobelium No 102 []	lawrencium Lr 103 []

O que as cores indicam?

- Element has two or more stable isotopes. Atomic weight and isotopic abundances of element vary in naturally occurring materials. The lower and upper bounds of atomic weight have been assessed by IUPAC and are presented as the standard atomic weight within square brackets, [].
- Element has two or more stable isotopes and the standard atomic weight is not a constant of nature. The lower and upper bounds of the standard atomic weight have not been evaluated by IUPAC yet.
- Element has one stable isotope and its standard atomic weight is a constant of nature.
- Element has no stable isotopes. Thus, no standard atomic weight exists.

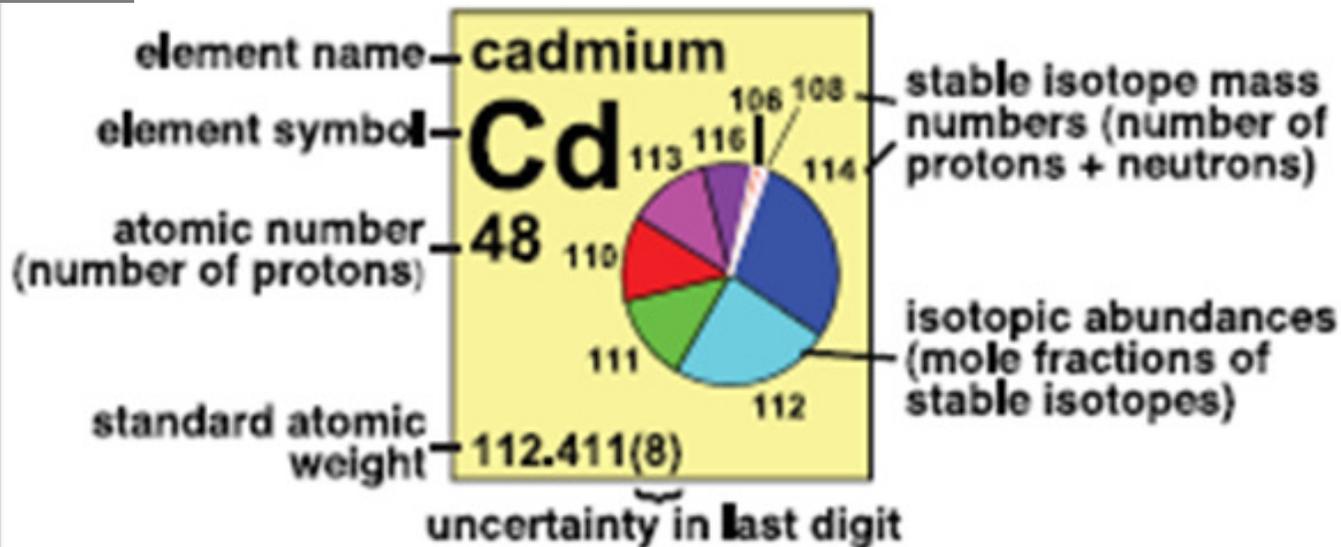
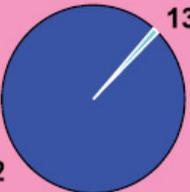
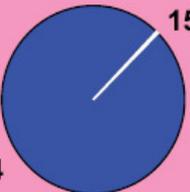
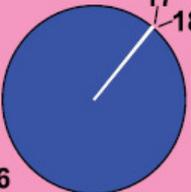
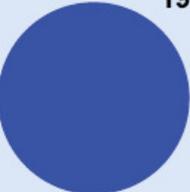
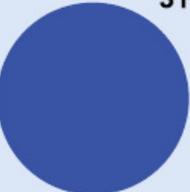
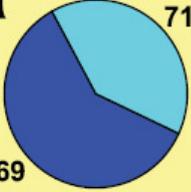
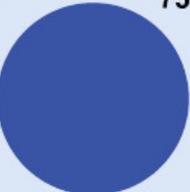
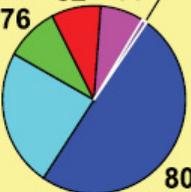
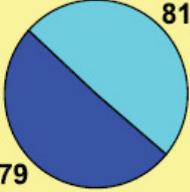


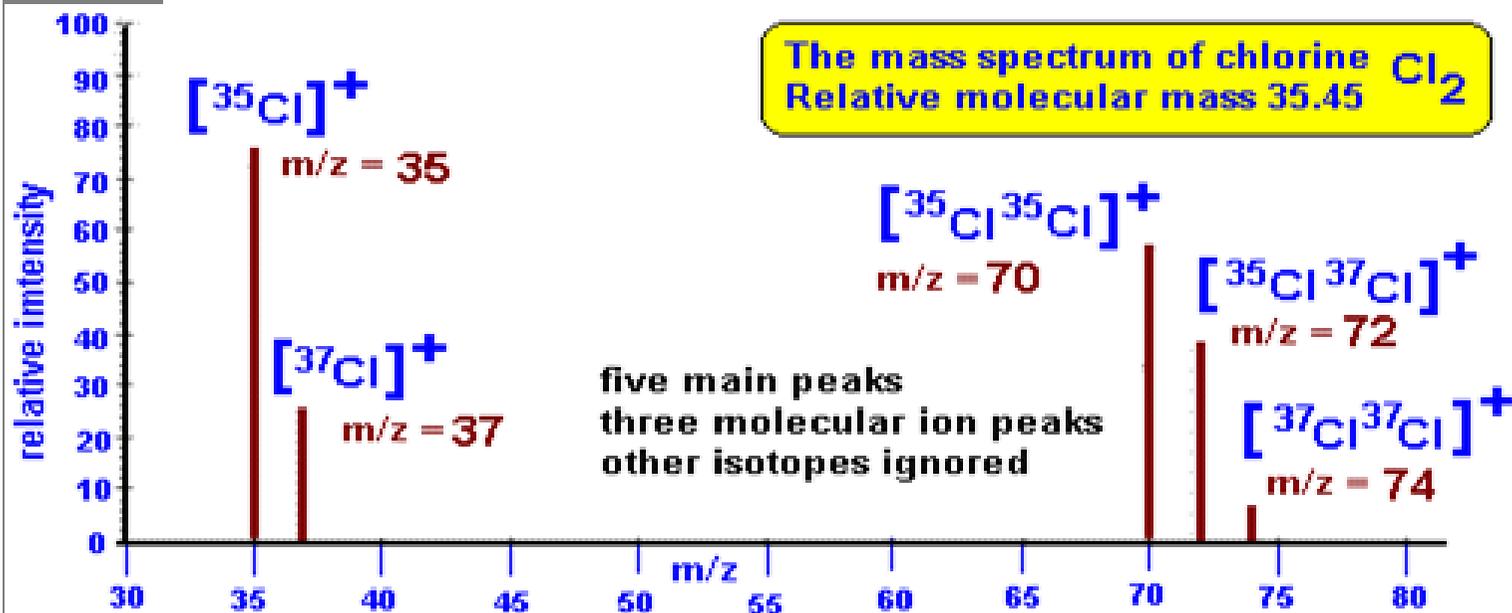


Tabela Periódica dos Isótopos

<p>boron B 5</p>  <p>[10.806; 10.821]</p>	<p>carbon C 6</p>  <p>[12.0096; 12.0116]</p>	<p>nitrogen N 7</p>  <p>[14.006 43; 14.007 28]</p>	<p>oxygen O 8</p>  <p>[15.999 03; 15.999 77]</p>	<p>fluorine F 9</p>  <p>18.998 4032(5)</p>
<p>aluminium (aluminum) Al 13</p>  <p>26.981 5386(8)</p>	<p>silicon Si 14</p>  <p>[28.084; 28.086]</p>	<p>phosphorus P 15</p>  <p>30.973 762(2)</p>	<p>sulfur S 16</p>  <p>[32.059; 32.076]</p>	<p>chlorine Cl 17</p>  <p>[35.446; 35.457]</p>
<p>gallium Ga 31</p>  <p>69.723(1)</p>	<p>germanium Ge 32</p>  <p>72.63(1)</p>	<p>arsenic As 33</p>  <p>74.921 60(2)</p>	<p>selenium Se 34</p>  <p>78.96(3)</p>	<p>bromine Br 35</p>  <p>79.904(1)</p>

Espectro de massas do cloro

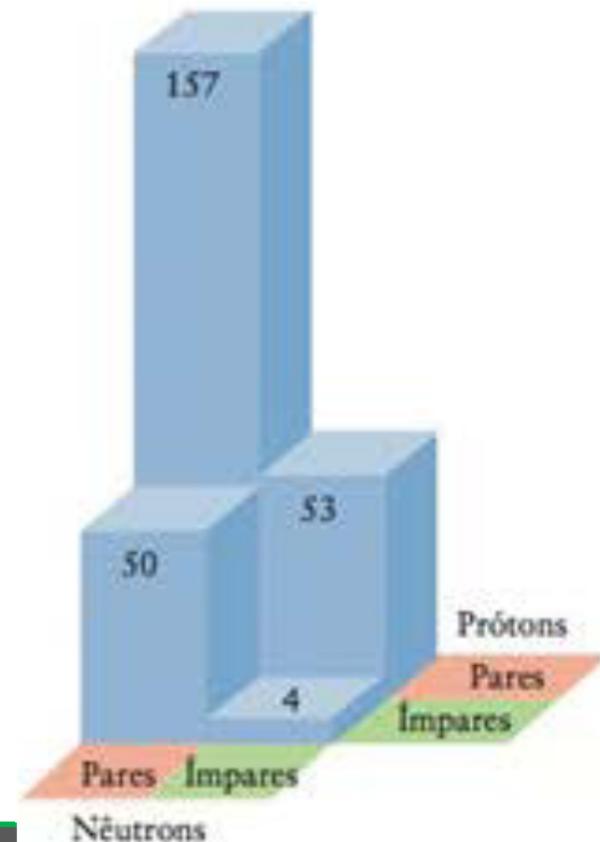
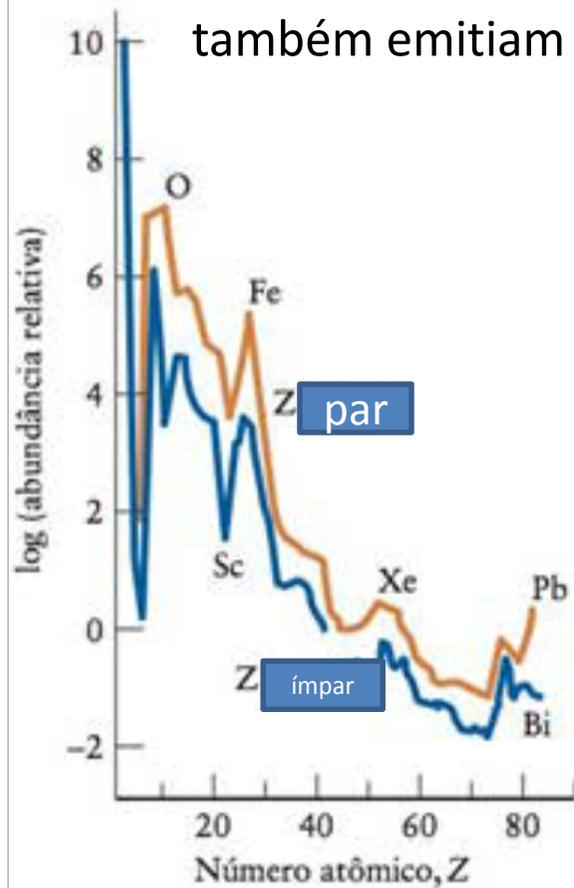
☐ Qual a massa encontrada na tabela periódica?



<https://chemdictionary.org/mass-spectrum-of-chlorine/>

1.6 Estabilidade Nuclear

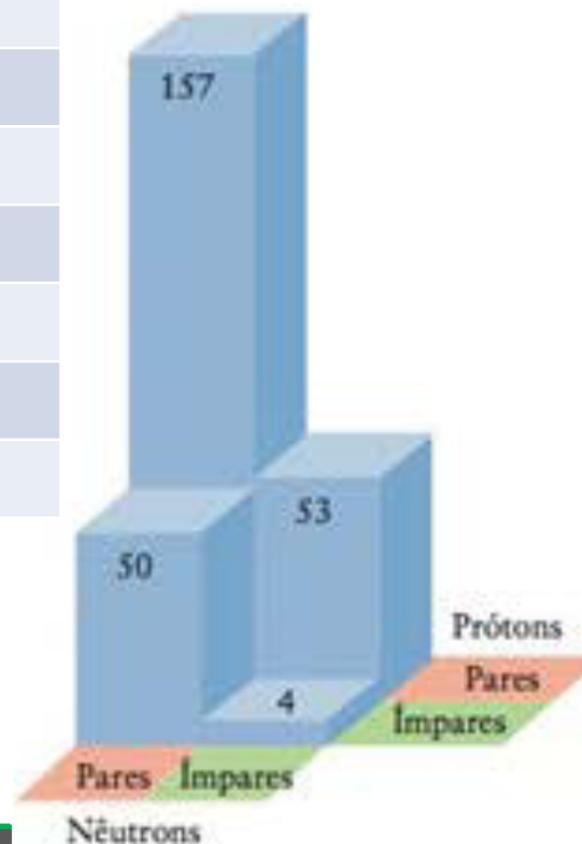
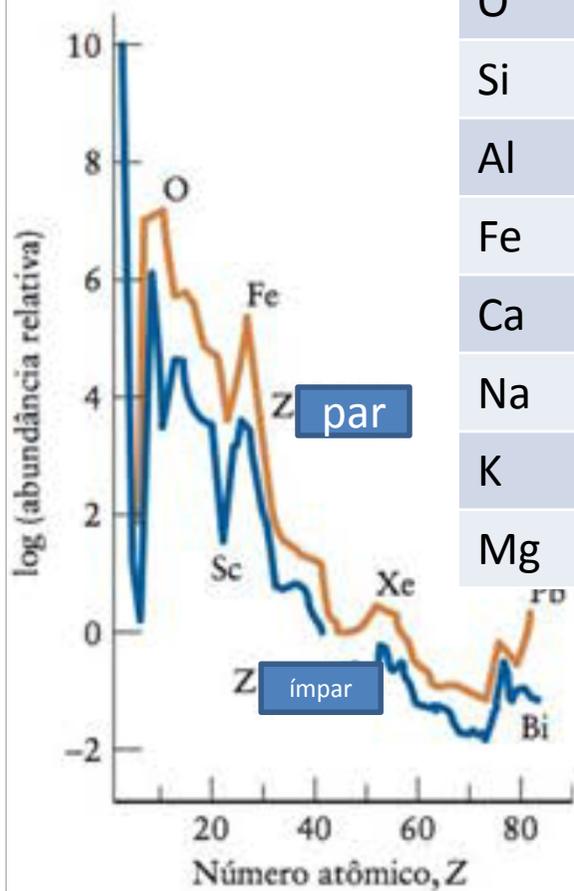
- ❑ As primeiras indicações da estabilidade vieram da radiação que os núclídeos emitiam
- ❑ Foi 1896 que H. Becquerel observou que minerais a base urânio escureciam chapas fotográficas que não haviam sido expostas à luz.
- ❑ P. e M. Curie mostraram que além do urânio, tório, rádio, e polônio também emitiam radiação.



1.6 Estabilidade Nuclear

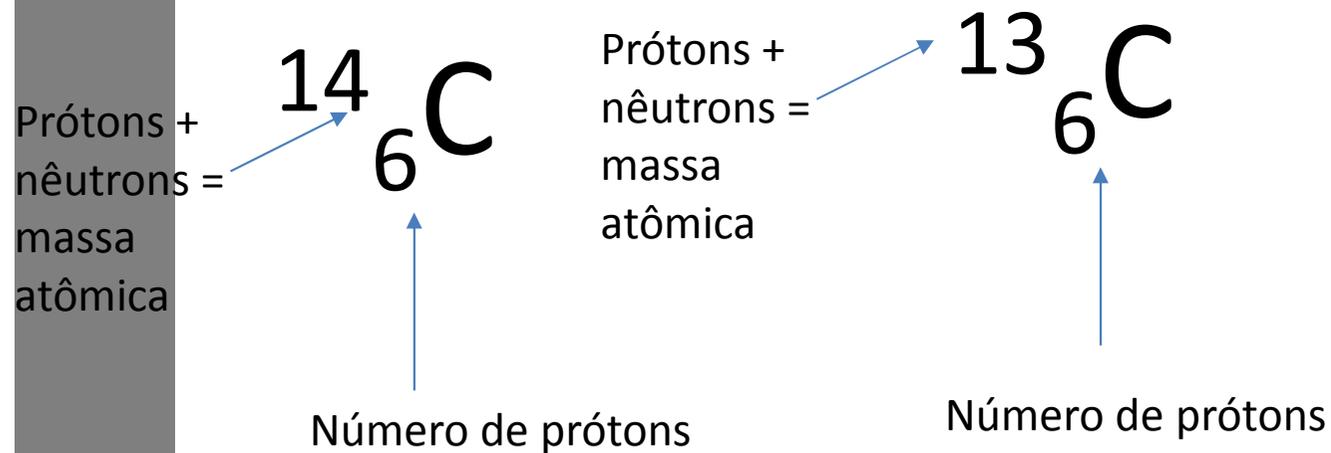
Elementos com número atômico par são abundantes do que elementos do que elementos com número ímpar.

Elemento	Z	Abundância relativa (%)
O	8	50
Si	14	26
Al	15	8
Fe	26	5
Ca	20	4
Na	11	3
K	19	2
Mg	12	2



1.6 Tipos de decaimento

☐ Nuclídeo é um núcleo com uma dada composição de prótons e nêutrons

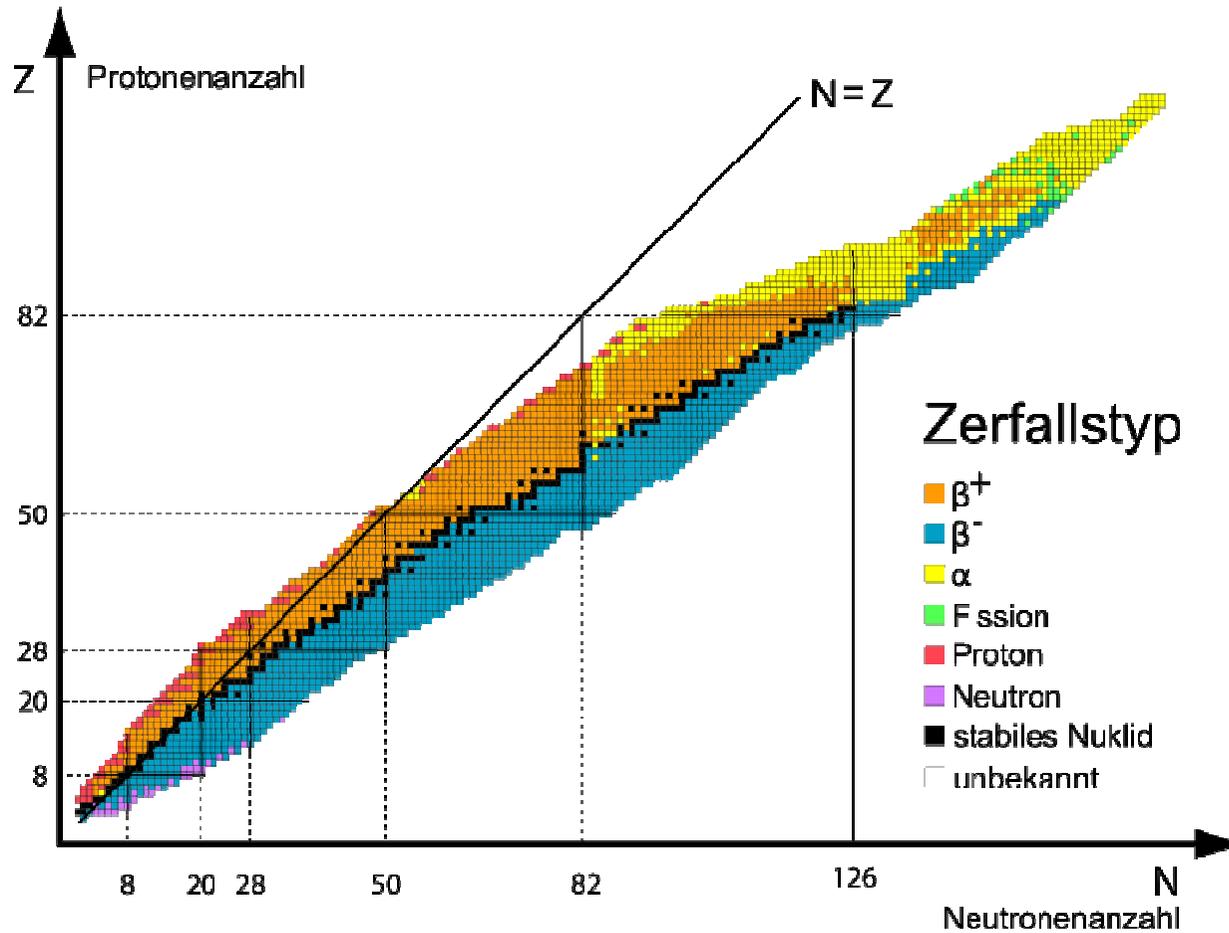


☐ Aqui vemos dois nuclídeos do mesmo elemento

1.6 Estabilidade Nuclear

☐ Vamos ver a carta de núcleos

<https://nds.iaea.org/relnsd/vcharthtml/VChartHTML.html>





1.6 Tipos de decaimento

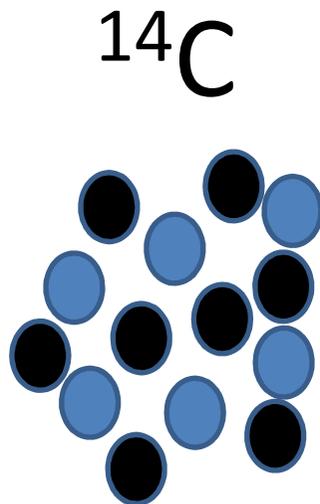
- Por que será que elementos com $Z > 82$ são radioativos?
- Elementos $>$ elevado parecem ser emissor alfa preferencial

1.8 Tipos de decaimento nuclear

□ Emissão beta



Um neutrôn se transforma em próton
E emite uma partícula beta

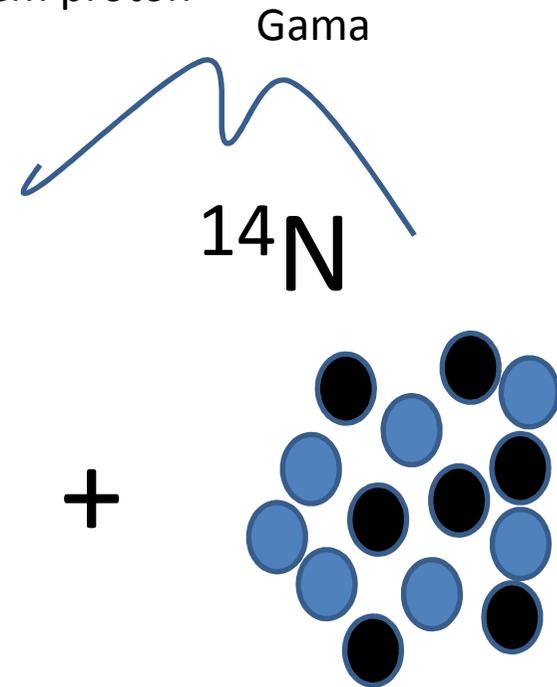


6 prótons
8 neutrôns



Elétron
(partícula beta)

+



7 prótons
7 neutrôns

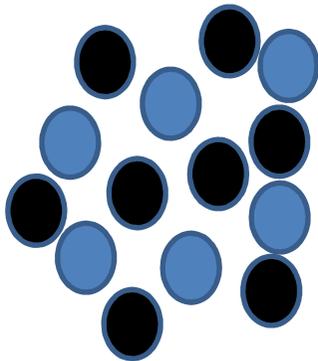
1.8 Tipos de decaimento nuclear

☐ Captura eletrônica

● prótons

● nêutrons

^{14}C



Elétron
(partícula beta)

+

