

# Atomes et molécules

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# Chapter 4 : Periodic classification of elements

1

H

Hydrogen

1.00794

79

Au

Gold

196.96657

15

P

Phosphorus

30.973762

78

Pt

Platinum

195.084

70

Yb

Ytterbium

173.04

83

Bi

Bismuth

208.9804

88

Ra

Radium

(226)

90

Th

Thorium

232.03806

105

Db

Dubnium

(262)

18

Ar

Argon

39.948

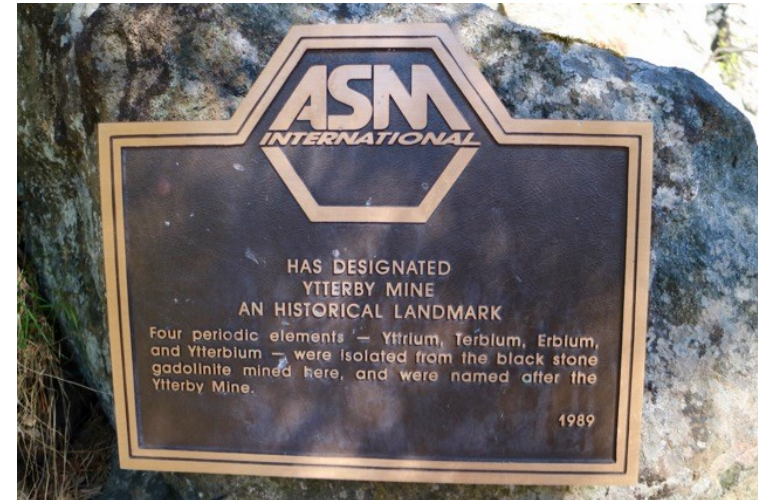
39

Y

Yttrium

88.90585

Google



*.. To all of the elements for a happy birthday to Dmitri Mendeleev, whose 1869 version of the periodic table helped us order and understand our world.*



## Introduction:

1 – Modern periodic classification – relation with electronic configuration

2 – Metals and nonmetals

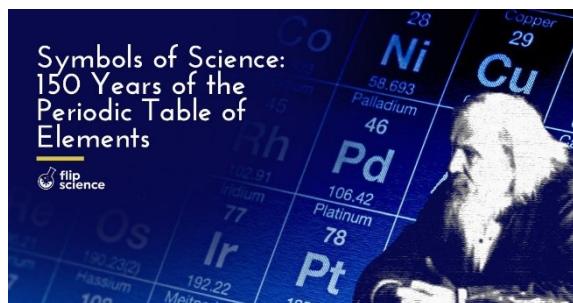
La liste de Lavoisier. 1787

PARTIE II, DES SUBSTANCES SIMPLES. 135

TABLEAU DES SUBSTANCES SIMPLES.

	NOMS NOUVEAUX.	NOMS ANCIENS CORRESPONDANTS.
Substances simples qui appartiennent aux trois règnes, et qu'on peut regarder comme les éléments des corps.	Lumière. ....	Lumière. Chaleur. Principe de la chaleur.
	Calorique. ....	Fluide igné. Feu. Matière du feu et de la chaleur.
	Oxygène. ....	Air déphlogistiqué. Air empiréal. Air vital. Base de l'air vital.
	Azote. ....	Gaz phlogistiqué. Mofette. Base de la mofette.
	Hydrogène. ....	Gaz inflammable. Base du gaz inflammable.
Substances simples, non métalliques, oxydables et acidifiables.	Soufre. ....	Soufre.
	Phosphore. ....	Phosphore.
	Carbone. ....	Charbon pur.
	Radical muriatique. ....	Inconnu.
	Radical fluorique. ....	Inconnu.
	Radical boracique. ....	Inconnu.
	Antimoine. ....	Antimoine.
	Argent. ....	Argent.
	Arsenic. ....	Arsenic.
	Bismuth. ....	Bismuth.
Substances simples, métalliques, oxydables et acidifiables.	Cobalt. ....	Cobalt.
	Cuivre. ....	Cuivre.
	Étain. ....	Étain.
	Fer. ....	Fer.
	Manganèse. ....	Manganèse.
	Mercure. ....	Mercure.
	Molybdène. ....	Molybdène.
	Nickel. ....	Nickel.
	Or. ....	Or.
	Platine. ....	Platine.
Substances simples, salifiables, terreuses.	Plomb. ....	Plomb.
	Tungstène. ....	Tungstène.
	Zinc. ....	Zinc.
	Chaux. ....	Terre calcaire, chaux.
	Magnésie. ....	Magnésie, base de sel d'Epsom.
	Baryte. ....	Barote, terre pesante.
	Alumine. ....	Argile, terre de l'alun, base de l'alun.
	Silice. ....	Terre siliceuse, terre vitrifiable.





## ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ, ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

H=1			Ti=50	Zr= 90	?=180.	
			V=51	Nb= 94	Ta=182.	
			Cr=52	Mo= 96	W=186.	
			Mn=55	Rh=104,4	Pt=197,1	
			Fe=56	Ru=104,4	Ir=198.	
			Ni=Co=59	Pd=106,6	Os=199.	
			Cu=63,4	Ag=108	Hg=200.	
		Be= 9,4	Mg=24	Zn=65,2	Cd=112	
		B=11	Al=27,3	?=68	Ur=116	Au=197?
		C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210?	
	O=16	S=32	Se=79,4	Te=128?		
	F=19	Cl=35,5	Br=80	I=127		
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204.	
		Ca=40	Sr=87,6	Ba=137	Pb=207.	
		?=45	Ce=92			
		?Er=56	La=94			
		?Yt=60	Di=95			
		?In=75,6	Th=118?			

Д. Менделѣевъ

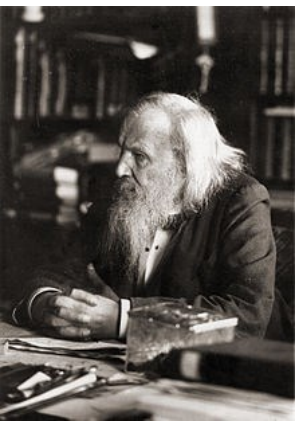
Mendeleev's 1869 periodic table: An experiment on a system of elements. Based on their atomic weights and chemical similarities.



# Introduction

Reihen	Gruppe I. — R <sup>0</sup>	Gruppe II. — R <sup>0</sup>	Gruppe III. — R <sup>0</sup> <sup>3</sup>	Gruppe IV. RH <sup>4</sup> R <sup>0</sup> <sup>4</sup>	Gruppe V. RH <sup>5</sup> R <sup>0</sup> <sup>5</sup>	Gruppe VI. RH <sup>6</sup> R <sup>0</sup> <sup>6</sup>	Gruppe VII. RH R <sup>0</sup> <sup>7</sup>	Gruppe VIII. — R <sup>0</sup> <sup>4</sup>
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Le tableau périodique de Mendeleïev (1869)





# Introduction

**XIX century:** by means of experimental observations, chemists have tried to find analogies and relations among the chemical species (about 60 had been discovered up to that moment) with the aim of classifying and grouping them in 'families', based on their chemical properties.

The first classification was proposed by **Mendeleev**. It was based on increasing atomic mass (the laws dictating the electronic distribution around the nucleus, i.e., the electronic structure of atoms, was yet unknown)

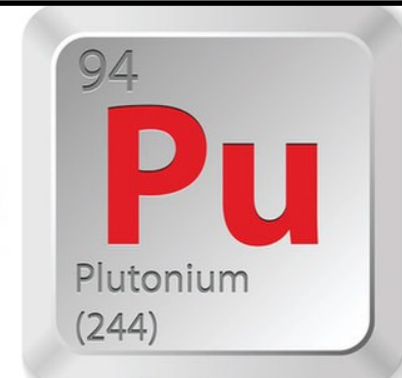
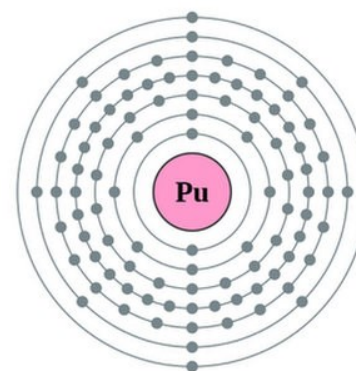
Nowadays the elements are arranged by increasing atomic number,  $Z$ .

A **chemical element** is a pure chemical substance consisting of one type of atom.

- 118 elements have been identified.
- 94 occur naturally on Earth.
- 24 are artificial.
- 80 of them are stable, while the others 38 are radioactive.

## Evolution de la découverte des éléments chimiques

Avant 1700	1700-1799	1800-1849	1850-1899
Antimoine	Azote	Aluminium	Actinium
Argent	Béryllium	Baryum	Argon
Arsenic	Bismuth	Bore	Cesium
Carbone	Chlore	Brome	Dysprosium
Cuivre	Chrome	Cadmium	Gadolinium
Etain	Cobalt	Calcium	Gallium
Fer	Fluor	Cérium	Germanium
Mercur	Hydrogène	Erbium	Hélium
Or	Manganèse	Iode	Holmium
Phosphore	Molybdène	Lanthane	Indium
Plomb	Nickel	Iridium	Krypton
Soufre	Oxygène	Lithium	Néodyme
	Platine	Magnésium	Néon
	Strontium	Niobium	Polonium
	Tellure	Osmium	Praséodyme
	Titane	Palladium	Radium
	Tungstène	Potassium	Rhodium
	Uranium	Rubidium	Ruthénium
	Yttrium	Sélénium	Samarium
	Zinc	Silicium	Scandium
	Zirconium	Sodium	Thallium
		Tantale	Thulium
		Thorium	Xénon
		Vanadium	Ytterbium
(12)	(21)	(24)	(24)





# 1 - Modern periodic classification – relation with electronic configuration

## Periodic table:

### Periodic Table of the Elements

atomic number

atomic weight

14

28.09

Si

Silicon

name

symbol:

black

solid

blue

liquid

red

gas

white

synthetically prepared

most stable isotope

alkali metals

alkaline earth metals

transitional metals

other metals

nonmetals

noble gases

1 1.01 <b>H</b> Hydrogen																	2 4.003 <b>He</b> Helium				
3 6.94 <b>Li</b> Lithium	4 9.01 <b>Be</b> Beryllium															5 10.81 <b>B</b> Boron	6 12.01 <b>C</b> Carbon	7 14.01 <b>N</b> Nitrogen	8 15.999 <b>O</b> Oxygen	9 18.998 <b>F</b> Fluorine	10 20.18 <b>Ne</b> Neon
11 22.99 <b>Na</b> Sodium	12 24.31 <b>Mg</b> Magnesium															13 26.98 <b>Al</b> Aluminum	14 28.09 <b>Si</b> Silicon	15 30.97 <b>P</b> Phosphorus	16 32.06 <b>S</b> Sulfur	17 35.45 <b>Cl</b> Chlorine	18 39.95 <b>Ar</b> Argon
19 39.10 <b>K</b> Potassium	20 40.08 <b>Ca</b> Calcium	21 44.96 <b>Sc</b> Scandium	22 47.90 <b>Ti</b> Titanium	23 50.94 <b>V</b> Vanadium	24 51.996 <b>Cr</b> Chromium	25 54.94 <b>Mn</b> Manganese	26 55.85 <b>Fe</b> Iron	27 58.93 <b>Co</b> Cobalt	28 58.70 <b>Ni</b> Nickel	29 63.55 <b>Cu</b> Copper	30 65.37 <b>Zn</b> Zinc	31 69.72 <b>Ga</b> Gallium	32 72.59 <b>Ge</b> Germanium	33 74.92 <b>As</b> Arsenic	34 78.96 <b>Se</b> Selenium	35 79.90 <b>Br</b> Bromine	36 83.80 <b>Kr</b> Krypton				
37 85.47 <b>Rb</b> Rubidium	38 87.62 <b>Sr</b> Strontium	39 88.91 <b>Y</b> Yttrium	40 91.22 <b>Zr</b> Zirconium	41 92.91 <b>Nb</b> Niobium	42 95.94 <b>Mo</b> Molybdenum	43 (98) <b>Tc</b> Technetium	44 101.07 <b>Ru</b> Ruthenium	45 102.91 <b>Rh</b> Rhodium	46 106.40 <b>Pd</b> Palladium	47 107.87 <b>Ag</b> Silver	48 112.41 <b>Cd</b> Cadmium	49 114.82 <b>In</b> Indium	50 118.69 <b>Sn</b> Tin	51 121.75 <b>Sb</b> Antimony	52 127.60 <b>Te</b> Tellurium	53 126.90 <b>I</b> Iodine	54 131.30 <b>Xe</b> Xenon				
55 132.91 <b>Cs</b> Cesium	56 137.33 <b>Ba</b> Barium	57 138.91 <b>La</b> Lanthanum	72 178.49 <b>Hf</b> Hafnium	73 180.95 <b>Ta</b> Tantalum	74 183.85 <b>W</b> Tungsten	75 186.21 <b>Re</b> Rhenium	76 190.20 <b>Os</b> Osmium	77 192.22 <b>Ir</b> Iridium	78 195.09 <b>Pt</b> Platinum	79 196.97 <b>Au</b> Gold	80 200.59 <b>Hg</b> Mercury	81 204.37 <b>Tl</b> Thallium	82 207.19 <b>Pb</b> Lead	83 208.98 <b>Bi</b> Bismuth	84 (209) <b>Po</b> Polonium	85 (210) <b>At</b> Astatine	86 (222) <b>Rn</b> Radon				
87 (223) <b>Fr</b> Francium	88 226.03 <b>Ra</b> Radium	89 227.03 <b>Ac</b> Actinium	104 (261) <b>Rf</b> Rutherfordium	105 (262) <b>Ha</b> Hahnium	106 (266) <b>Sg</b> Seaborgium	107 (262) <b>Bh</b> Bohrium	108 (265) <b>Hs</b> Hassium	109 (266) <b>Mt</b> Meitnerium	110 (271) <b></b>	111 (272) <b></b>	112 (277) <b></b>	(113)	114 (285) <b></b>	(115)	116 (289) <b></b>	(117)	118 (293) <b></b>				


58 140.12 <b>Ce</b> Cerium	59 140.91 <b>Pr</b> Praseodymium	60 144.24 <b>Nd</b> Neodymium	61 (145) <b>Pm</b> Promethium	62 150.40 <b>Sm</b> Samarium	63 151.96 <b>Eu</b> Europium	64 157.25 <b>Gd</b> Gadolinium	65 158.93 <b>Tb</b> Terbium	66 162.50 <b>Dy</b> Dysprosium	67 164.93 <b>Ho</b> Holmium	68 167.26 <b>Er</b> Erbium	69 168.93 <b>Tm</b> Thulium	70 173.04 <b>Yb</b> Ytterbium	71 174.97 <b>Lu</b> Lutetium
90 232.04 <b>Th</b> Thorium	91 231.04 <b>Pa</b> Protactinium	92 238.03 <b>U</b> Uranium	93 237.05 <b>Np</b> Neptunium	94 (244) <b>Pu</b> Plutonium	95 (243) <b>Am</b> Americium	96 (247) <b>Cm</b> Curium	97 (247) <b>Bk</b> Berkelium	98 (251) <b>Cf</b> Californium	99 (252) <b>Es</b> Einsteinium	100 (257) <b>Fm</b> Fermium	101 (260) <b>Md</b> Mendelevium	102 (259) <b>No</b> Nobelium	103 (262) <b>Lr</b> Lawrencium





# 1 - Modern periodic classification – relation with electronic configuration

## Periodic table: Version 2017

1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18			
													Pnictogens		Chalcogens		Halogènes																				
1 <b>H</b> Hydrogène 1,008		Atomique Sym Nom Masse		<b>C</b> Solide		<b>Métaux</b>										Métalloïdes		<b>Non-métaux</b>				273		2 <b>He</b> Hélium 4,0026													
3 <b>Li</b> Lithium 6,94		4 <b>Be</b> Béryllium 9,0122		<b>Hg</b> Liquide		<b>H</b> Gaz		<b>Rf</b> Inconnu		Métaux alcalins		Métaux alcalino-terreux		Lanthanides		Actinides		Métaux de transition		Post-transition metals		Non-métaux		Gaz rares		5 <b>B</b> Bore 10,81		6 <b>C</b> Carbone 12,011		7 <b>N</b> Azote 14,007		8 <b>O</b> Oxygène 15,999		9 <b>F</b> Fluor 18,998		10 <b>Ne</b> Néon 20,180	
11 <b>Na</b> Sodium 22,990		12 <b>Mg</b> Magnésium 24,305																								13 <b>Al</b> Aluminium 26,982		14 <b>Si</b> Silicium 28,085		15 <b>P</b> Phosphore 30,974		16 <b>S</b> Soufre 32,06		17 <b>Cl</b> Chlore 35,45		18 <b>Ar</b> Argon 39,948	
19 <b>K</b> Potassium 39,098		20 <b>Ca</b> Calcium 40,078		21 <b>Sc</b> Scandium 44,956		22 <b>Ti</b> Titane 47,867		23 <b>V</b> Vanadium 50,942		24 <b>Cr</b> Chrome 51,996		25 <b>Mn</b> Manganèse 54,938		26 <b>Fe</b> Fer 55,845		27 <b>Co</b> Cobalt 58,933		28 <b>Ni</b> Nickel 58,693		29 <b>Cu</b> Cuivre 63,546		30 <b>Zn</b> Zinc 65,38		31 <b>Ga</b> Gallium 69,723		32 <b>Ge</b> Germanium 72,630		33 <b>As</b> Arsenic 74,922		34 <b>Se</b> Sélénium 78,971		35 <b>Br</b> Brome 79,904		36 <b>Kr</b> Krypton 83,798			
37 <b>Rb</b> Rubidium 85,468		38 <b>Sr</b> Strontium 87,62		39 <b>Y</b> Yttrium 88,906		40 <b>Zr</b> Zirconium 91,224		41 <b>Nb</b> Niobium 92,906		42 <b>Mo</b> Molybdène 95,95		43 <b>Tc</b> Technétium (98)		44 <b>Ru</b> Ruthénium 101,07		45 <b>Rh</b> Rhodium 102,91		46 <b>Pd</b> Palladium 106,42		47 <b>Ag</b> Argent 107,87		48 <b>Cd</b> Cadmium 112,41		49 <b>In</b> Indium 114,82		50 <b>Sn</b> Étain 118,71		51 <b>Sb</b> Antimoine 121,76		52 <b>Te</b> Tellure 127,60		53 <b>I</b> Iode 126,90		54 <b>Xe</b> Xénon 131,29			
55 <b>Cs</b> Césium 132,91		56 <b>Ba</b> Baryum 137,33		57–71		72 <b>Hf</b> Hafnium 178,49		73 <b>Ta</b> Tantale 180,95		74 <b>W</b> Tungstène 183,84		75 <b>Re</b> Rhénium 186,21		76 <b>Os</b> Osmium 190,23		77 <b>Ir</b> Iridium 192,22		78 <b>Pt</b> Platine 195,08		79 <b>Au</b> Or 196,97		80 <b>Hg</b> Mercure 200,59		81 <b>Tl</b> Thallium 204,38		82 <b>Pb</b> Plomb 207,2		83 <b>Bi</b> Bismuth 208,98		84 <b>Po</b> Polonium (209)		85 <b>At</b> Astate (210)		86 <b>Rn</b> Radon (222)			
87 <b>Fr</b> Francium (223)		88 <b>Ra</b> Radium (226)		89–103		104 <b>Rf</b> Rutherfordium (267)		105 <b>Db</b> Dubnium (268)		106 <b>Sg</b> Seaborgium (269)		107 <b>Bh</b> Bohrium (270)		108 <b>Hs</b> Hassium (277)		109 <b>Mt</b> Meitnérium (278)		110 <b>Ds</b> Darmstadtium (281)		111 <b>Rg</b> Roentgenium (282)		112 <b>Cn</b> Copernicium (285)		113 <b>Nh</b> Nihonium (286)		114 <b>Fl</b> Flerovium (289)		115 <b>Mc</b> Moscovium (290)		116 <b>Lv</b> Livermorium (293)		117 <b>Ts</b> Tennesse (294)		118 <b>Og</b> Oganesson (294)			

Les masses atomiques entre parenthèses sont celles de l'isotope le plus stable ou le plus commun.

Tableau Périodique Copyright du design et interface © 1997 [Michael Dayah](#) Ptable.com Dernière mise à jour 16 juin 2017

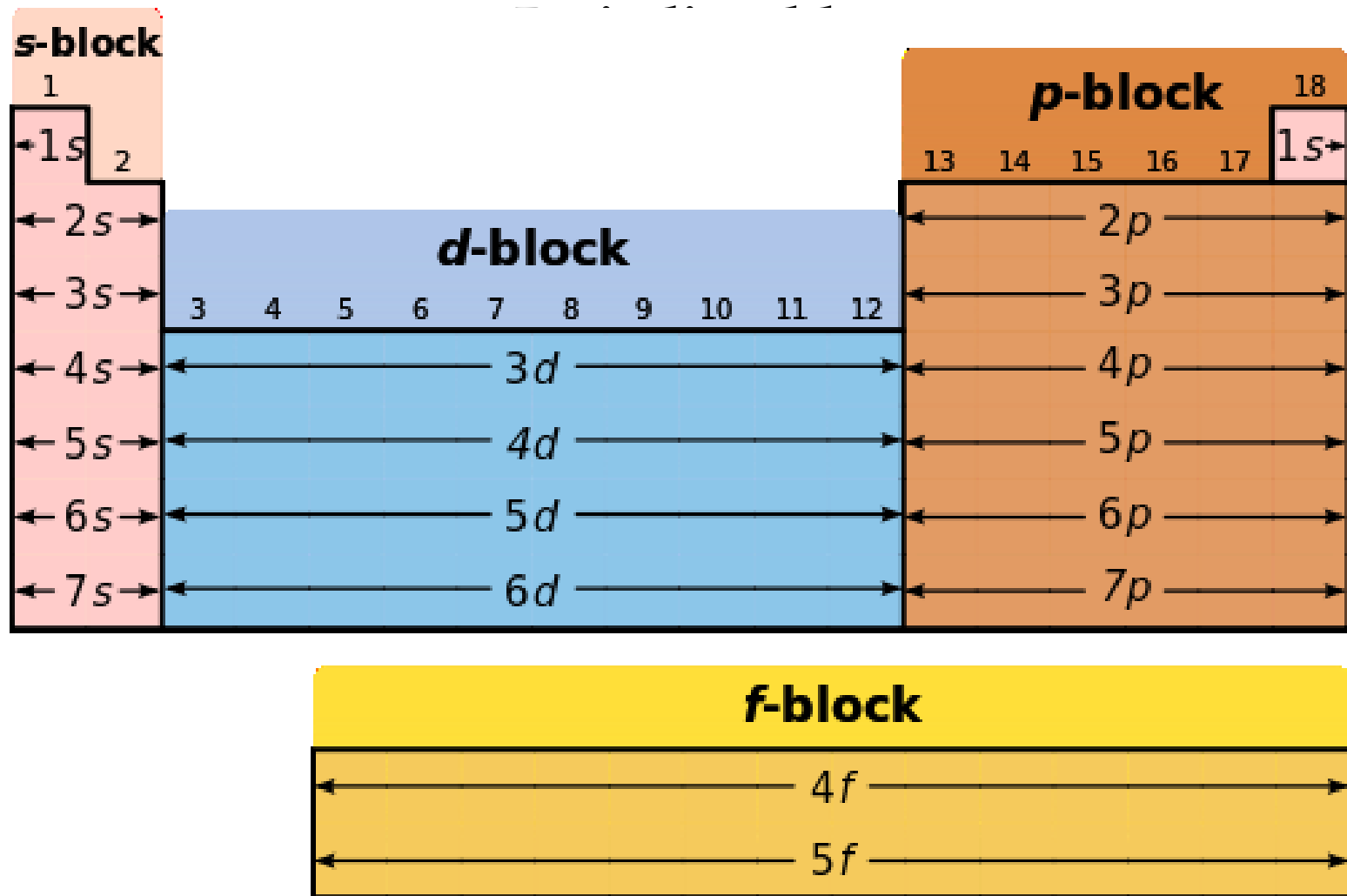
57 <b>La</b> Lanthane 138,91	58 <b>Ce</b> Cérium 140,12	59 <b>Pr</b> Praséodyme 140,91	60 <b>Nd</b> Néodyme 144,24	61 <b>Pm</b> Prométhium (145)	62 <b>Sm</b> Samarium 150,36	63 <b>Eu</b> Europium 151,96	64 <b>Gd</b> Gadolinium 157,25	65 <b>Tb</b> Terbium 158,93	66 <b>Dy</b> Dysprosium 162,50	67 <b>Ho</b> Holmium 164,93	68 <b>Er</b> Erbium 167,26	69 <b>Tm</b> Thulium 168,93	70 <b>Yb</b> Ytterbium 173,05	71 <b>Lu</b> Lutécium 174,97
89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232,04	91 <b>Pa</b> Protactinium 231,04	92 <b>U</b> Uranium 238,03	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Américium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkélium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendélévium (258)	102 <b>No</b> Nobélium (259)	103 <b>Lr</b> Lawrencium (266)







# 1 - Modern periodic classification – relation with electronic configuration



4 blocks of elements are determined according to the nature (s, p, d, f) of the layer being filled.



# 1 - Modern periodic classification – relation with electronic configuration

Periodic table organization

direct and  
systematic  
correspondence

Electronic levels  
filling order

Base rule: return to first column every time a new layer is started



Elements in the  
same **row**

→ **PERIOD** →

Are ordered from left to right according  
to increasing atomic number  $Z$

Have their peripheric electrons in the  
same layer

Elements in the  
same **column**

→ **FAMILY**  
**Or group** →

Have an identical electronic configuration  
in the external layer,  
Same number of valence electrons



# 1 - Modern periodic classification – relation with electronic configuration



Periodic

The **s block**:

Composed by elements with  
electronic structure of the form:  $ns^x$  is  
( $x = 1$  ou  $2$ )

$n s^1 = \text{Alcali}$ ;  $n s^2 = \text{Alcalins earths}$

										2	4.003	He	Helium
5	10.81	6	12.01	7	14.01	8	15.999	9	18.998	10	20.18	Ne	Neon
B	Boron	C	Carbon	N	Nitrogen	O	Oxygen	F	Fluorine				
13	26.98	14	28.09	15	30.97	16	32.06	17	35.45	18	39.95	Ar	Argon
Al	Aluminum	Si	Silicon	P	Phosphorus	S	Sulfur	Cl	Chlorine				
31	69.72	32	72.59	33	74.92	34	78.96	35	79.90	36	83.80	Kr	Krypton
Ga	Gallium	Ge	Germanium	As	Arsenic	Se	Selenium	Br	Bromine				
49	114.82	50	118.69	51	121.75	52	127.60	53	126.90	54	131.30	Xe	Xenon
In	Indium	Sn	Tin	Sb	Antimony	Te	Tellurium	I	Iodine				
81	204.37	82	207.19	83	208.98	84	(209)	85	(210)	86	(222)	Rn	Radon
Tl	Thallium	Pb	Lead	Bi	Bismuth	Po	Polonium	At	Astatine				
(113)		114	(285)	(115)		116	(289)	(117)		118	(293)		

1	1.01											10	20.18		
H	Hydrogen											Ne	Neon		
3	6.94	4	9.01									11	22.99	12	24.31
Li	Lithium	Be	Beryllium									Na	Sodium	Mg	Magnesium
19	39.10	20	40.08	21	44.96	22	47.90	23	50.94	24	51.996	25	54.94	26	55.85
K	Potassium	Ca	Calcium	Sc	Scandium	Ti	Titanium	V	Vanadium	Cr	Chromium	Mn	Manganese	Fe	Iron
37	85.47	38	87.62	39	88.91	40	91.22	41	92.91	42	95.94	43	(98)	44	101.07
Rb	Rubidium	Sr	Strontium	Y	Yttrium	Zr	Zirconium	Nb	Niobium	Mo	Molybdenum	Tc	Technetium	Ru	Ruthenium
55	132.91	56	137.33	57	138.91	72	178.49	73	180.95	74	183.85	75	186.21	76	190.20
Cs	Cesium	Ba	Barium	La	Lanthanum	Hf	Hafnium	Ta	Tantalum	W	Tungsten	Re	Rhenium	Os	Osmium
87	(223)	88	226.03	89	227.03	104	(261)	105	(262)	106	(266)	107	(262)	108	(265)
Fr	Francium	Ra	Radium	Ac	Actinium	Rf	Rutherfordium	Ha	Hahnium	Sg	Seaborgium	Bh	Bohrium	Hs	Hassium

58	140.12	59	140.91	60	144.24	61	(145)	62	150.40	63	151.96	64	157.25	65	158.93	66	162.50	67	164.93	68	167.26	69	168.93	70	173.04	71	174.97
Ce	Cerium	Pr	Praseodymium	Nd	Neodymium	Pm	Promethium	Sm	Samarium	Eu	Europium	Gd	Gadolinium	Tb	Terbium	Dy	Dysprosium	Ho	Holmium	Er	Erbium	Tm	Thulium	Yb	Ytterbium	Lu	Lutetium
90	232.04	91	231.04	92	238.03	93	237.05	94	(244)	95	(243)	96	(247)	97	(247)	98	(251)	99	(252)	100	(257)	101	(260)	102	(259)	103	(262)
Th	Thorium	Pa	Protactinium	U	Uranium	Np	Neptunium	Pu	Plutonium	Am	Americium	Cm	Curium	Bk	Berkelium	Cf	Californium	Es	Einsteinium	Fm	Fermium	Md	Mendelevium	No	Nobelium	Lr	Lawrencium



# 1 - Modern periodic classification – relation with electronic configuration

## Periodic

Composed by elements with electronic structure of the form:  $ns^2 np^x$  ( $x = 1$  to  $6$ )

$ns^2 np^6$  = rare gases

2p

3p

4p

5p

6p



The **p block**:  
Composed by elements with  
electronic structure of the form:  $ns^2$

$np^x$  ( $x = 1$  to  $6$ )

$ns^2 np^6$  = rare gases

2p

3p

4p

5p

6p

58 140.12 <b>Ce</b> Cerium	59 140.91 <b>Pr</b> Praseodymium	60 144.24 <b>Nd</b> Neodymium	61 (145) <b>Pm</b> Promethium	62 150.40 <b>Sm</b> Samarium	63 151.96 <b>Eu</b> Europium	64 157.25 <b>Gd</b> Gadolinium	65 158.93 <b>Tb</b> Terbium	66 162.50 <b>Dy</b> Dysprosium	67 164.93 <b>Ho</b> Holmium	68 167.26 <b>Er</b> Erbium	69 168.93 <b>Tm</b> Thulium	70 173.04 <b>Yb</b> Ytterbium	71 174.97 <b>Lu</b> Lutetium
90 232.04 <b>Th</b> Thorium	91 231.04 <b>Pa</b> Protactinium	92 238.03 <b>U</b> Uranium	93 237.05 <b>Np</b> Neptunium	94 (244) <b>Pu</b> Plutonium	95 (243) <b>Am</b> Americium	96 (247) <b>Cm</b> Curium	97 (247) <b>Bk</b> Berkelium	98 (251) <b>Cf</b> Californium	99 (252) <b>Es</b> Einsteinium	100 (257) <b>Fm</b> Fermium	101 (260) <b>Md</b> Mendelevium	102 (259) <b>No</b> Nobelium	103 (262) <b>Lr</b> Lawrencium



# 1 - Modern periodic classification – relation with electronic configuration

Periodic

The **d block**:

Composed by elements with electronic structure of the form:  **$ns^2 (n-1)d^x$**  ( $x = 1$  to  $10$ )

Appears from  $n=3$ :  $l = 0$  (s),

$l = 1$  (p),

$l = 2$  (d)  $\rightarrow m = -2, -1, 0, 1, 2$

**Transition elements**

form:  $ns(n-1)d^x$  ( $x = 1 \text{ to } 10$ )

Appears from  $n=3$ :  $l = 0$  (s),  
 $l = 1$  (p),  
 $l = 2$  (d)  $\rightarrow m = -2, -1, 0, 1, 2$

**Transition elements**

1 1.01 <b>H</b> Hydrogen																	2 4.003 <b>He</b> Helium														
3 6.94 <b>Li</b> Lithium	4 9.01 <b>Be</b> Beryllium																	98 20.18 <b>Ne</b> Neon													
11 22.99 <b>Na</b> Sodium	12 24.31 <b>Mg</b> Magnesium																	45 39.95 <b>Ar</b> Argon													
19 39.098 <b>K</b> Potassium	20 39.098 <b>Ca</b> Calcium	21 44.96 <b>Sc</b> Scandium	22 47.90 <b>Ti</b> Titanium	23 50.94 <b>V</b> Vanadium	24 51.996 <b>Cr</b> Chromium	25 54.94 <b>Mn</b> Manganese	26 55.85 <b>Fe</b> Iron	27 58.93 <b>Co</b> Cobalt	28 58.93 <b>Ni</b> Nickel	29 63.55 <b>Cu</b> Copper	30 65.37 <b>Zn</b> Zinc	31 69.72 <b>Ga</b> Gallium	32 72.59 <b>Ge</b> Germanium	33 74.92 <b>As</b> Arsenic	34 78.96 <b>Se</b> Selenium	35 79.90 <b>Br</b> Bromine	36 83.80 <b>Kr</b> Krypton														
37 85.468 <b>Rb</b> Rubidium	38 87.62 <b>Sr</b> Strontium	39 88.91 <b>Y</b> Yttrium	40 91.22 <b>Zr</b> Zirconium	41 92.91 <b>Nb</b> Niobium	42 95.94 <b>Mo</b> Molybdenum	43 (98) <b>Tc</b> Technetium	44 101.07 <b>Ru</b> Ruthenium	45 102.91 <b>Rh</b> Rhodium	46 106.40 <b>Pd</b> Palladium	47 107.87 <b>Ag</b> Silver	48 112.41 <b>Cd</b> Cadmium	49 114.82 <b>In</b> Indium	50 118.69 <b>Sn</b> Tin	51 121.75 <b>Sb</b> Antimony	52 127.60 <b>Te</b> Tellurium	53 126.90 <b>I</b> Iodine	54 131.30 <b>Xe</b> Xenon														
55 132.91 <b>Cs</b> Cesium	56 137.33 <b>Ba</b> Barium	57 138.91 <b>La</b> Lanthanum	58 140.91 <b>Ce</b> Cerium	59 140.91 <b>Pr</b> Praseodymium	60 140.91 <b>Nd</b> Neodymium	61 140.91 <b>Pm</b> Promethium	62 150.36 <b>Sm</b> Samarium	63 151.96 <b>Eu</b> Europium	64 157.25 <b>Gd</b> Gadolinium	65 158.93 <b>Tb</b> Terbium	66 162.50 <b>Dy</b> Dysprosium	67 164.93 <b>Ho</b> Holmium	68 167.26 <b>Er</b> Erbium	69 168.93 <b>Tm</b> Thulium	70 173.05 <b>Yb</b> Ytterbium	71 175.05 <b>Lu</b> Lutetium	72 175.05 <b>Hf</b> Hafnium	73 180.95 <b>Ta</b> Tantalum	74 183.85 <b>W</b> Tungsten	75 186.21 <b>Re</b> Rhenium	76 186.21 <b>Os</b> Osmium	77 192.22 <b>Ir</b> Iridium	78 195.09 <b>Pt</b> Platinum	79 196.97 <b>Au</b> Gold	80 200.59 <b>Hg</b> Mercury	81 204.37 <b>Tl</b> Thallium	82 207.19 <b>Pb</b> Lead	83 208.98 <b>Bi</b> Bismuth	84 (209) <b>Po</b> Polonium	85 (210) <b>At</b> Astatine	86 (222) <b>Rn</b> Radon
87 227.03 <b>Fr</b> Francium	88 227.03 <b>Ac</b> Actinium	89 227.03 <b>Th</b> Thorium	90 232.04 <b>Pa</b> Protactinium	91 231.04 <b>U</b> Uranium	92 238.03 <b>Np</b> Neptunium	93 237.05 <b>Pu</b> Plutonium	94 244.06 <b>Am</b> Americium	95 243.06 <b>Cm</b> Curium	96 247.07 <b>Bk</b> Berkelium	97 247.07 <b>Cf</b> Californium	98 251.08 <b>Es</b> Einsteinium	99 252.08 <b>Fm</b> Fermium	100 257.10 <b>Md</b> Mendelevium	101 258.10 <b>No</b> Nobelium	102 259.10 <b>Lr</b> Lawrencium	103 262.11 <b>Rf</b> Rutherfordium	104 261.10 <b>Db</b> Dubnium	105 262.11 <b>Sg</b> Seaborgium	106 266.12 <b>Bh</b> Bohrium	107 266.12 <b>Hs</b> Hassium	108 266.12 <b>Mt</b> Meitnerium	109 266.12 <b>Ds</b> Darmstadtium	110 (271) <b>Uu</b> Ununennium	111 (272) <b>Uub</b> Unbibium	112 (277) <b>Uut</b> Untrium	113 (285) <b>Uuh</b> Unhennium	114 (285) <b>Uuq</b> Unquadium	115 (285) <b>Uup</b> Unpentium	116 (289) <b>Uuq</b> Unsextium	117 (293) <b>Uus</b> Unseptium	118 (293) <b>Uuo</b> Unoctium

Sc  $z=21$

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^1$

Ti  $z=22$

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^2$

...



## The f block:

Composed by elements with electronic structure of the form:

Appears from  $n=4$ :

$$l = 0 \text{ (s)}$$

$$l = 1 \text{ (p)}$$

$$l = 2 \text{ (d)}$$

$$l = 3 \text{ (f)} \rightarrow m = -3, -2, -1, 0, 1, 2, 3$$

$ns^2 (n-2)f^x \quad (x = 1 \text{ to } 14)$

Composed by elements with electronic structure of the form:

$$1 = 0 \text{ (s)}$$
$$1 = 1 \text{ (p)}$$

1 = 2 (d)

$$l = 3 \text{ (f)} \rightarrow m = -3, -2, -1, 0, 1, 2, 3$$


4f

5f

58 140.12	59 140.91	60 144.24	61 144.91	62 150.40	63 151.96	64 157.25	65 158.93	66 162.50	67 162.50	68 167.26	69 168.93	70 173.04	71 174.97
<b>Ce</b>	<b>Pr</b>	<b>Nd</b>	<b>Pm</b>	<b>Sm</b>	<b>Eu</b>	<b>Gd</b>	<b>Tb</b>	<b>Dy</b>	<b>Ho</b>	<b>Er</b>	<b>Tm</b>	<b>Yb</b>	<b>Lu</b>
Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
90 232.04	91 231.04	92 238.03	93 237.05	94 (244)	95 (243)	96 (247)	97 (247)	98 (251)	99 (252)	100 (257)	101 (260)	102 (259)	103 (262)
<b>Th</b>	<b>Pa</b>	<b>U</b>	<b>Np</b>	<b>Pu</b>	<b>Am</b>	<b>Cm</b>	<b>Bk</b>	<b>Cf</b>	<b>Es</b>	<b>Fm</b>	<b>Md</b>	<b>No</b>	<b>Lr</b>
Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium

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Z = 58 (Ce : Cerium) to Z = 71 (Lu : Lutetium) : **lanthanides**  
 Z = 90 (Th : Thorium) to z=103 (Lawrencium) : **actinides**



# 1 - Modern periodic classification – relation with electronic configuration

Group → ↓ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

**Lanthanides**

57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------

**Actinides**

89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr
----------	----------	----------	---------	----------	----------	----------	----------	----------	----------	----------	-----------	-----------	-----------	-----------

4f

5f



# 1 - Modern periodic classification – relation with electronic configuration

## Lanthanum, $_{57}\text{La}$



### General properties

<b>Pronunciation</b>	<a href="#">/ˈlænθənəm/</a>
<b>Appearance</b>	silvery white
<b>Standard atomic weight (<math>A_r</math>)</b>	138.905 47(7) <sup>[1]</sup>

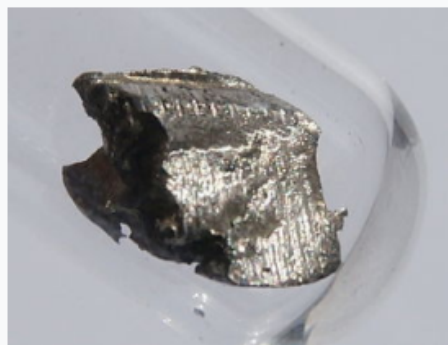
### Lanthanum in the periodic table

barium ← lanthanum → cerium

Y  
↑  
La  
↓  
Ac

<b>Atomic number (Z)</b>	57
<b>Group, period</b>	group 3, period 6
<b>Block</b>	d-block
<b>Element category</b>	<input type="checkbox"/> lanthanide, sometimes considered a transition metal
<b>Electron configuration</b>	$[\text{Xe}] 5d^1 6s^2$
<b>Electrons per shell</b>	2, 8, 18, 18, 9, 2

## Cerium, $_{58}\text{Ce}$



### General properties

<b>Pronunciation</b>	<a href="#">/ˈsɪəriəm/</a>
<b>Appearance</b>	silvery white
<b>Standard atomic weight (<math>A_r</math>)</b>	140.116(1) <sup>[1]</sup>

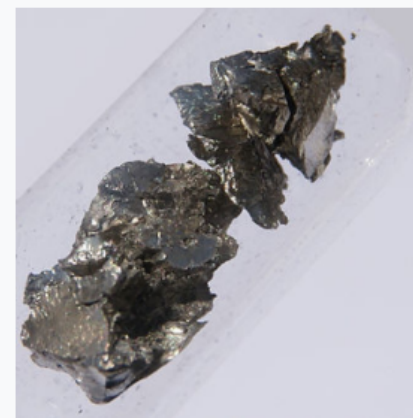
### Cerium in the periodic table

lanthanum ← cerium → praseodymium

—  
Ce  
↓  
Th

<b>Atomic number (Z)</b>	58
<b>Group, period</b>	group n/a, period 6
<b>Block</b>	f-block
<b>Element category</b>	<input type="checkbox"/> lanthanide
<b>Electron configuration</b>	$[\text{Xe}] 4f^1 5d^1 6s^2$ <sup>[2]</sup>
<b>Electrons per shell</b>	2, 8, 18, 19, 9, 2

## Praseodymium, $_{59}\text{Pr}$



### General properties

<b>Pronunciation</b>	<a href="#">/preɪːəˈdiːmiəm/<sup>[1]</sup></a> <i>pray-zee-ə-DIM-ee-əm</i>
<b>Appearance</b>	grayish white
<b>Standard atomic weight (<math>A_r</math>)</b>	140.907 66(2) <sup>[2]</sup>

### Praseodymium in the periodic table

cerium ← praseodymium → neodymium

—  
Pr  
↓  
Pa

<b>Atomic number (Z)</b>	59
<b>Group, period</b>	group n/a, period 6
<b>Block</b>	f-block
<b>Element category</b>	<input type="checkbox"/> lanthanide
<b>Electron configuration</b>	$[\text{Xe}] 4f^3 6s^2$
<b>Electrons per shell</b>	2, 8, 18, 21, 8, 2



**Why 15 lanthanide elements?**  
**Exception to the rule**  
**5d and 4f subshells are very close in energy**

<u>Chemical element</u>	<u>La</u>	<u>Ce</u>	<u>Pr</u>	<u>Nd</u>	<u>Pm</u>	<u>Sm</u>	<u>Eu</u>	<u>Gd</u>	<u>Tb</u>	<u>Dy</u>	<u>Ho</u>	<u>Er</u>	<u>Tm</u>	<u>Yb</u>	<u>Lu</u>
<u>Atomic number</u>	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
<u>Atomic electron configuration*</u>	5d <sup>1</sup>	4f <sup>1</sup> 5d <sup>1</sup>	4f <sup>3</sup>	4f <sup>4</sup>	4f <sup>5</sup>	4f <sup>6</sup>	4f <sup>7</sup>	4f <sup>7</sup> 5d <sup>1</sup>	4f <sup>9</sup>	4f <sup>10</sup>	4f <sup>11</sup>	4f <sup>12</sup>	4f <sup>13</sup>	4f <sup>14</sup>	4f <sup>14</sup> 5d <sup>1</sup>



## 2 - Metals and nonmetals

### Periodic Table of the Elements



atomic number

atomic weight

14

28.09

Si

Silicon

symbol:

black solid

blue liquid

red gas

white synthetically prepared

most stable isotope

name

alkali metals

alkaline earth metals

transitional metals

other metals

nonmetals

noble gases

1 1.01 <b>H</b> Hydrogen																	2 4.003 <b>He</b> Helium						
3 6.94 <b>Li</b> Lithium	4 9.01 <b>Be</b> Beryllium																	5 10.81 <b>B</b> Boron	6 12.01 <b>C</b> Carbon	7 14.01 <b>N</b> Nitrogen	8 15.999 <b>O</b> Oxygen	9 18.998 <b>F</b> Fluorine	10 20.18 <b>Ne</b> Neon
11 22.99 <b>Na</b> Sodium	12 24.31 <b>Mg</b> Magnesium																	13 26.98 <b>Al</b> Aluminum	14 28.09 <b>Si</b> Silicon	15 30.97 <b>P</b> Phosphorus	16 32.06 <b>S</b> Sulfur	17 35.45 <b>Cl</b> Chlorine	18 39.95 <b>Ar</b> Argon
19 39.10 <b>K</b> Potassium	20 40.08 <b>Ca</b> Calcium	21 44.96 <b>Sc</b> Scandium	22 47.90 <b>Ti</b> Titanium	23 50.94 <b>V</b> Vanadium	24 51.996 <b>Cr</b> Chromium	25 54.94 <b>Mn</b> Manganese	26 55.85 <b>Fe</b> Iron	27 58.93 <b>Co</b> Cobalt	28 58.70 <b>Ni</b> Nickel	29 63.55 <b>Cu</b> Copper	30 65.37 <b>Zn</b> Zinc	31 69.72 <b>Ga</b> Gallium	32 72.59 <b>Ge</b> Germanium	33 74.92 <b>As</b> Arsenic	34 78.96 <b>Se</b> Selenium	35 79.90 <b>Br</b> Bromine	36 83.80 <b>Kr</b> Krypton						
37 85.47 <b>Rb</b> Rubidium	38 87.62 <b>Sr</b> Strontium	39 88.91 <b>Y</b> Yttrium	40 91.22 <b>Zr</b> Zirconium	41 92.91 <b>Nb</b> Niobium	42 95.94 <b>Mo</b> Molybdenum	43 (98) <b>Tc</b> Technetium	44 101.07 <b>Ru</b> Ruthenium	45 102.91 <b>Rh</b> Rhodium	46 106.40 <b>Pd</b> Palladium	47 107.87 <b>Ag</b> Silver	48 112.41 <b>Cd</b> Cadmium	49 114.82 <b>In</b> Indium	50 118.69 <b>Sn</b> Tin	51 121.75 <b>Sb</b> Antimony	52 127.60 <b>Te</b> Tellurium	53 126.90 <b>I</b> Iodine	54 131.30 <b>Xe</b> Xenon						
55 132.91 <b>Cs</b> Cesium	56 137.33 <b>Ba</b> Barium	57 138.91 <b>La</b> Lanthanum	72 178.49 <b>Hf</b> Hafnium	73 180.95 <b>Ta</b> Tantalum	74 183.85 <b>W</b> Tungsten	75 186.21 <b>Re</b> Rhenium	76 190.20 <b>Os</b> Osmium	77 192.22 <b>Ir</b> Iridium	78 195.09 <b>Pt</b> Platinum	79 196.97 <b>Au</b> Gold	80 200.59 <b>Hg</b> Mercury	81 204.37 <b>Tl</b> Thallium	82 207.19 <b>Pb</b> Lead	83 208.98 <b>Bi</b> Bismuth	84 (209) <b>Po</b> Polonium	85 (210) <b>At</b> Astatine	86 (222) <b>Rn</b> Radon						
87 (223) <b>Fr</b> Francium	88 226.03 <b>Ra</b> Radium	89 227.03 <b>Ac</b> Actinium	104 (261) <b>Rf</b> Rutherfordium	105 (262) <b>Ha</b> Hahnium	106 (266) <b>Sg</b> Seaborgium	107 (262) <b>Bh</b> Bohrium	108 (265) <b>Hs</b> Hassium	109 (266) <b>Mt</b> Meitnerium	110 (271) <b></b>	111 (272) <b></b>	112 (277) <b></b>	(113) <b></b>	114 (285) <b></b>	(115) <b></b>	116 (289) <b></b>	(117) <b></b>	118 (293) <b></b>						

58 140.12 <b>Ce</b> Cerium	59 140.91 <b>Pr</b> Praseodymium	60 144.24 <b>Nd</b> Neodymium	61 (145) <b>Pm</b> Promethium	62 150.40 <b>Sm</b> Samarium	63 151.96 <b>Eu</b> Europium	64 157.25 <b>Gd</b> Gadolinium	65 158.93 <b>Tb</b> Terbium	66 162.50 <b>Dy</b> Dysprosium	67 164.93 <b>Ho</b> Holmium	68 167.26 <b>Er</b> Erbium	69 168.93 <b>Tm</b> Thulium	70 173.04 <b>Yb</b> Ytterbium	71 174.97 <b>Lu</b> Lutetium
90 232.04 <b>Th</b> Thorium	91 231.04 <b>Pa</b> Protactinium	92 238.03 <b>U</b> Uranium	93 237.05 <b>Np</b> Neptunium	94 (244) <b>Pu</b> Plutonium	95 (243) <b>Am</b> Americium	96 (247) <b>Cm</b> Curium	97 (247) <b>Bk</b> Berkelium	98 (251) <b>Cf</b> Californium	99 (252) <b>Es</b> Einsteinium	100 (257) <b>Fm</b> Fermium	101 (260) <b>Md</b> Mendelevium	102 (259) <b>No</b> Nobelium	103 (262) <b>Lr</b> Lawrencium

### Metals

- \_ They occupy the center and left wing (except for the H) of the periodic classification
- \_ They are in general solids (NCTP, except Hg)
- \_ Conductors
- \_ Cation donors







Is 'X' a metal or a nonmetal



**Sanderson's rule:**

An element is a METAL if the number of electrons ( $a$ ) in the highest layer is  $\leq$  to the period number ( $n$ )

### Examples

**Al**

$a = 3$  (3 e<sup>-</sup> in the layer  $n=3$ )

$n = 3$  (3<sup>rd</sup> period)

$a = n$

It is a metal!

**Si**

$a = 4$  (4 e<sup>-</sup> in the layer  $n=3$ )

$n = 3$  (3<sup>rd</sup> period)

$a > n$

It is a nonmetal!



# ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ● ALKALI METAL ● ALKALINE EARTH METAL ● TRANSITION METAL ● GROUP 13 ● GROUP 14 ● GROUP 15 ● GROUP 16 ● HALOGEN ● LANTHANIDE

## SCREEN



Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.



The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina ( $\text{Al}_2\text{O}_3$ ) and silica ( $\text{SiO}_2$ ). This glass also contains potassium ions, which help to strengthen it.



A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

## ELECTRONICS



Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.



Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.



Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.



Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

## BATTERY



The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

## CASING



Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

