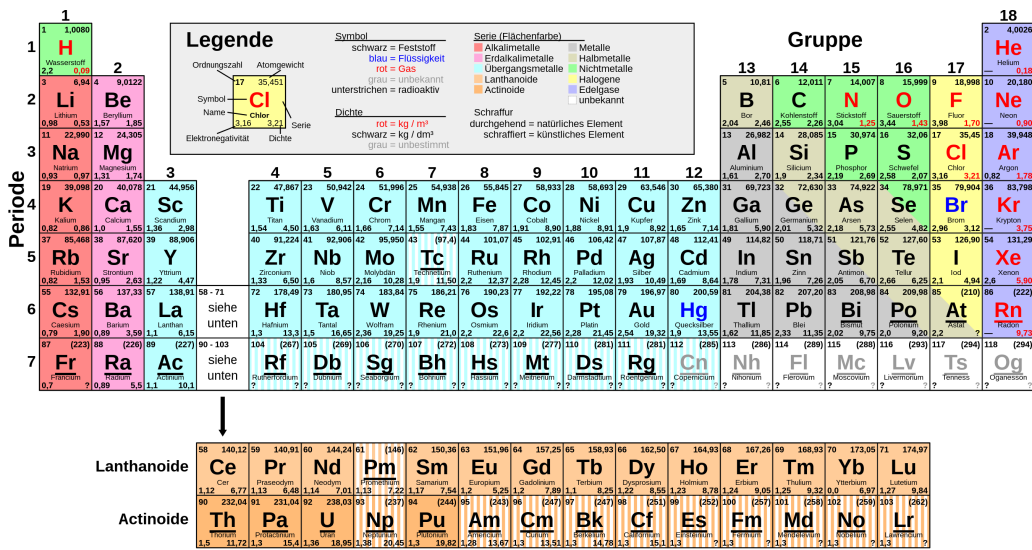


COURSE – MINT CHEMISTRY

TOPIC 2

Atoms, Atomic Structure, Periodic Table of the Elements

The Tool...



COMPOSITION OF MATTER

- An **atom** is the smallest particle that has the chemical properties of that element
- An **element** is a substance made up of one type of atom, all of which have the same chemical properties
- Currently 118 elements are known

Chemical elements are mostly non-atomic in nature (they form molecules from ONE type of atom)

Molecules are made up of more than one atom:

H₂, N₂, Cl₂, O₂, Fe, Au (Metals form crystals from one type of atom)

Molecules of Compounds

Molecules composed of more than one element (atoms of different elements)

H₂O, NH₃, HCl, Fe₂O₃ (Example of an iron ore as it occurs in nature)

More of that in unit 3!

ATOMS

Atomic theory from John Dalton 1805:

- 1) All matter is made up of **atoms**
- 2) All atoms of an element are the same
- 3) Atoms of different elements have different masses
- 4) A compound is a special combination of atoms from different elements
- 5) In a chemical reaction, atoms are neither created nor destroyed, only rearranged to form new substances



**John Dalton,
1776-1844**

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John Dalton,
1776-1844

HOW IS AN ATOM CONSTRUCTED? (Chat in groups)

Sketch an atomic structure on the concept board

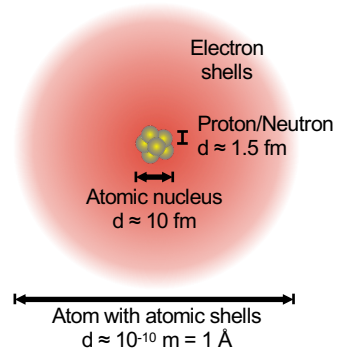


<https://app.conceptboard.com/board/qxdu-pyip-gpxe-2ouu-cb6x>

ATOMIC STRUCTURE

Meaning of the word atom:

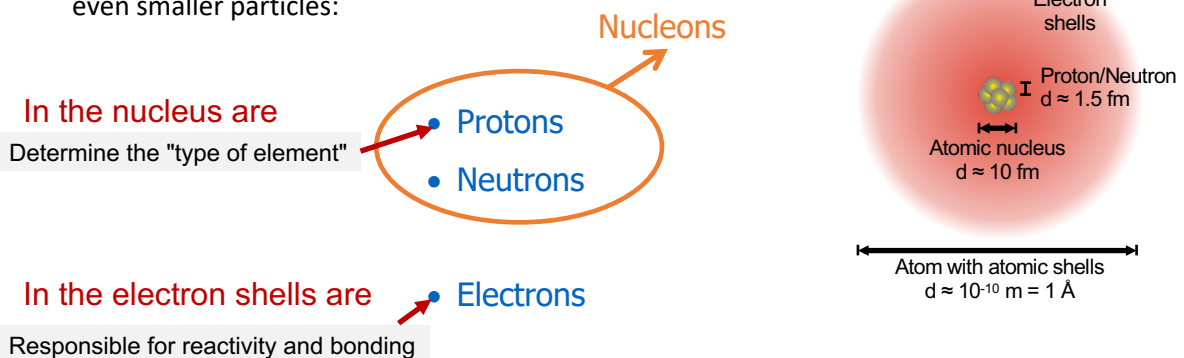
- „the indivisible“ ατομος/átomos
- not further divisible by chemical means



CAUTION:
Drawing is NOT to scale!!
Sizes range from fm (10^{-15} m) to nm (10^{-9} m)

ATOMIC STRUCTURE

⇒ However, atoms are made up of even smaller particles:



Atomic Structure

The **nucleus** (number of protons) determines:

- The **type of element**
- The **number of electrons**,
- The **electron probability density** (=orbitals)
- The **reactivity** (acceptance and donation of electrons)

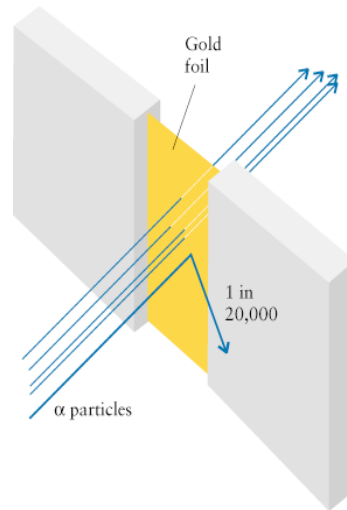
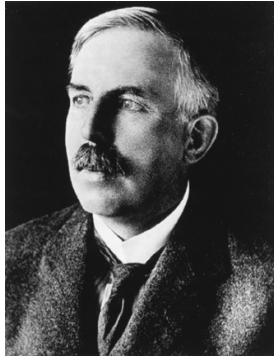
Atomic Structure

The **electronic structure** (electrons) of the atom determines:

- the **properties** of the elements (e.g.: Reactivity)
- the **reactions** that these atoms participate in
- the **form/type of molecules** that make up these elements

DISCOVERY OF THE NUCLEUS STRUCTURE

(Experiments by **Ernest Rutherford** with his students Hans Geiger and Ernest Marsden around 1910)



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PROTON/NEUTRON/ELECTRON PROPERTIES

	Mass		Charge ^b
	Mass [g]	Atomic mass ^a m_a [Da]	
Carrier of the negative charge Electron	$9.109535 \cdot 10^{-28}$	0.0005485803	-1
Proton	$1.672649 \cdot 10^{-24}$	1.007276	+1
Neutron	$1.674954 \cdot 10^{-24}$	1.008665	0

Carrier of the positive charge

^a Atomic mass unit $u = 1.6605 \cdot 10^{-27}$ kg

^b Charges in multiples of $e = 1.602 \cdot 10^{-19}$ C

Note:

Protons and neutrons are around ≈ 1840 times heavier than an electron!

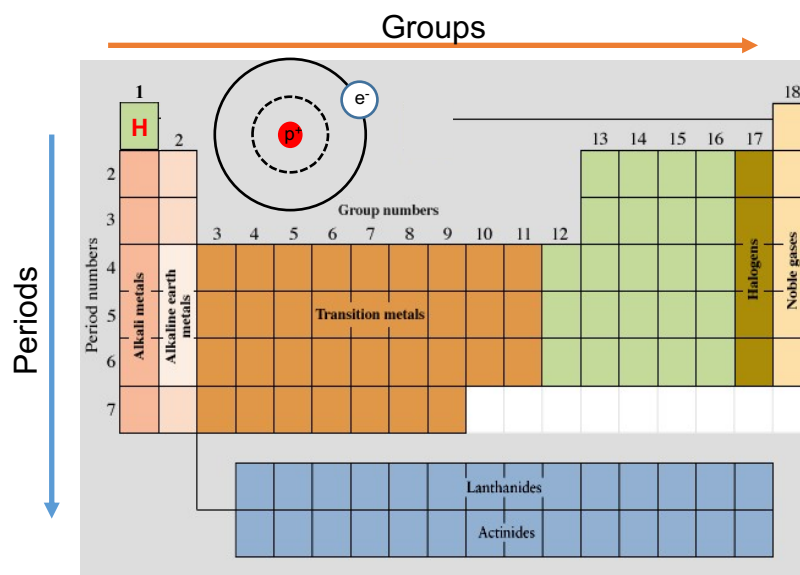
=> The mass of an atom is determined by the number of particles in its nucleus

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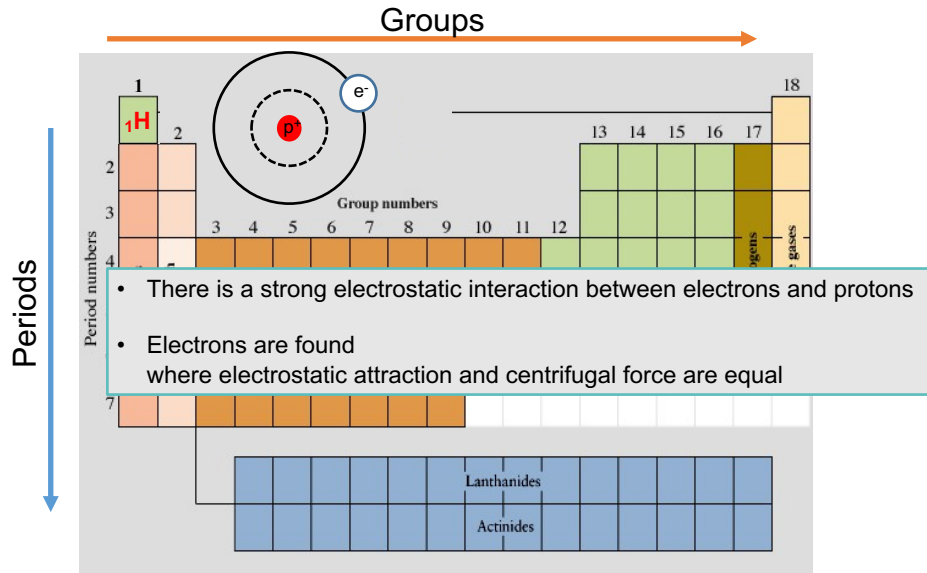
CLASSIFICATION OF THE CHEMICAL ELEMENTS

- The 'type' of the chemical element is determined by the number of protons.
- The elements are arranged in order of increasing number of protons
- This arrangement is shown in the periodic table of elements.
- A neutral atom (= atom without charge) has equally as many electrons as protons
- The mass of an atom results from the number of protons and neutrons in the nucleus

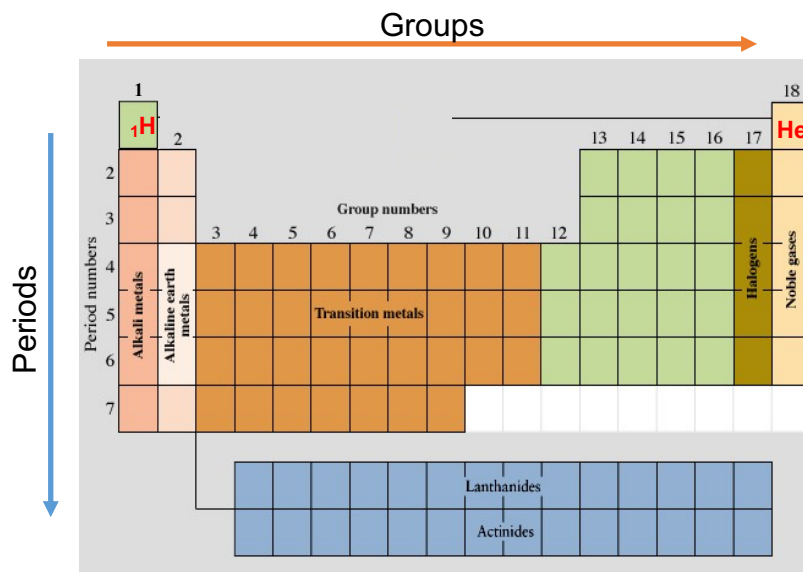
THE PERIODIC TABLE OF THE ELEMENTS



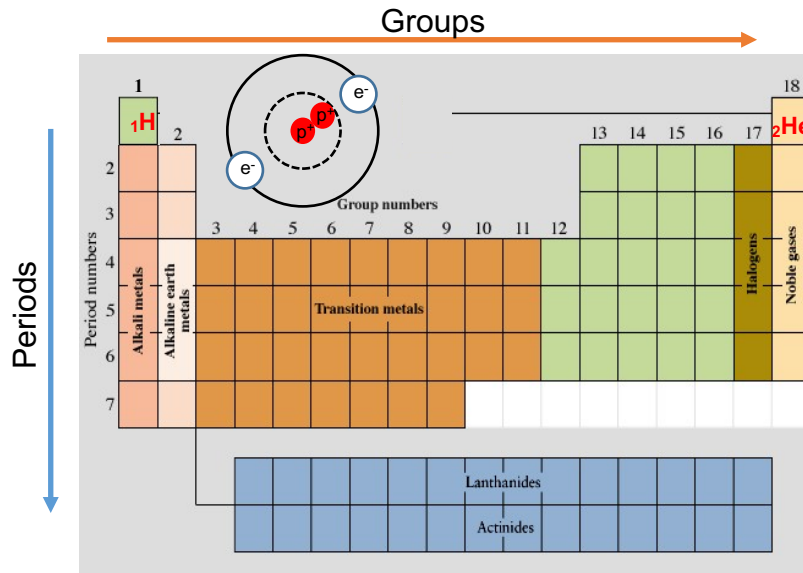
ARRANGEMENT OF THE ELEMENTS ACCORDING TO THE NUMBER OF PROTONS



ARRANGEMENT OF THE ELEMENTS ACCORDING TO THE NUMBER OF PROTONS

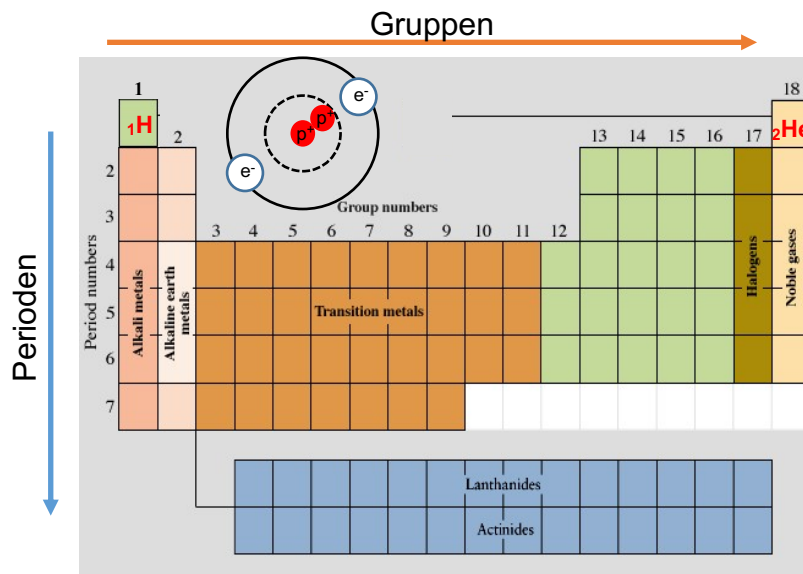


ARRANGEMENT OF THE ELEMENTS ACCORDING TO THE NUMBER OF PROTONS



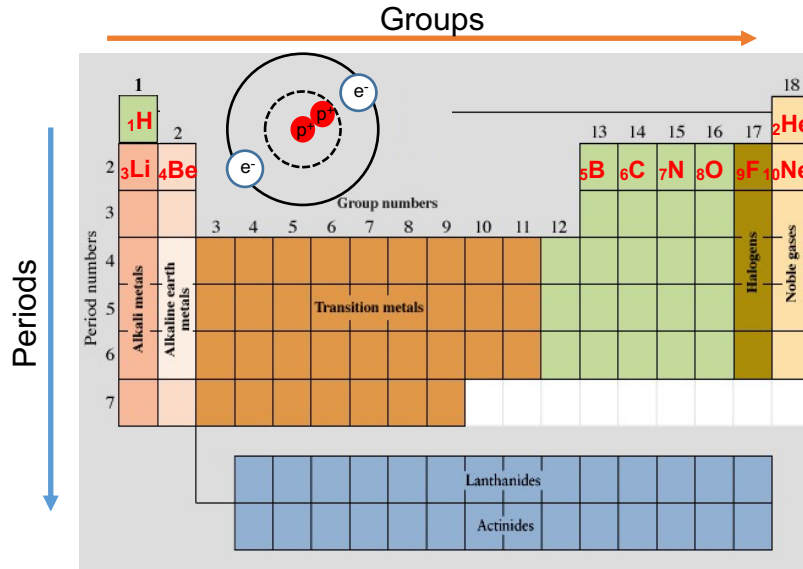
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ARRANGEMENT OF THE ELEMENTS ACCORDING TO THE NUMBER OF PROTONS



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ARRANGEMENT OF THE ELEMENTS ACCORDING TO THE NUMBER OF PROTONS



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Arrangement of the periodic table of elements according to the number of protons:

Atomic number = 1

H has 1 Proton.....

He has 2 Protons.....

		Gruppe																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																		
2	He																		
3	Li, Be																		
4	B, C, N, O, F, Ne																		
5	Al, Si, P, S, Cl, Ar																		
6	K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr																		
7	Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe																		
8	Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn																		
9	Fr, Ra, Ac, Rf, Db, Sg, Bh, Hs, Mt, Ds, Rg, Cn, Nh, Fl, Mc, Lv, Ts, Og																		
Lanthanoide		Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu																	
Actinoide		Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr																	

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- The mass of an atom results from the number of protons and neutrons in the nucleus

ATOMS AND IONS

- A neutral atom has equally as many electrons as protons:

How many electrons does the chlorine atom have (Cl)?

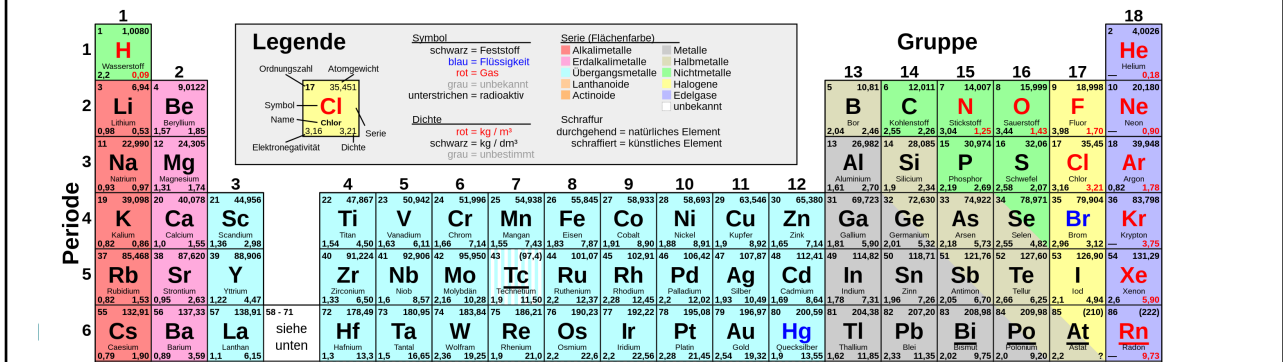
How many electrons does the sodium atom have (Na)?

ATOMS AND IONS

- A neutral atom has equally as many electrons as protons:

How many electrons does the chlorine atom have (Cl)? - 17

How many electrons does the sodium atom have (Na)? - 11



ATOMS AND IONS

- A neutral atom has equally as many electrons as protons:

How many electrons does the chlorine atom have (Cl)? - 17

How many electrons does the sodium atom have (Na)? – 11

What happens if I "take" an electron from an atom?

What happens if I "add" an electron to an atom?

ATOMS AND IONS

- A neutral atom has equally as many electrons as protons:

How many electrons does the chlorine atom have (Cl)? - 17

How many electrons does the sodium atom have (Na)? – 11

What happens if I "take" an electron from an atom?

It loses a negative charge, so becomes positive;

a positively charged ion is formed (Cation); $\text{Na} \rightleftharpoons \text{Na}^+ + \text{e}^-$

What happens if I "add" an electron to an atom?

It gains a negative charge, so becomes negative;

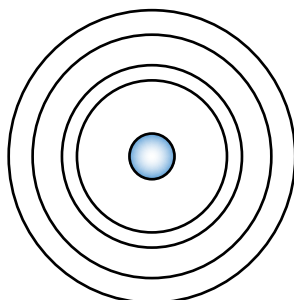
a negatively charged ion is formed (Anion); $\text{Cl} + \text{e}^- \rightleftharpoons \text{Cl}^-$

ATTENTION: the number of protons does NOT change - it remains the same chemical element

The Bohr Model of the Atom

first "mechanistic" atomic model by Niels Bohr

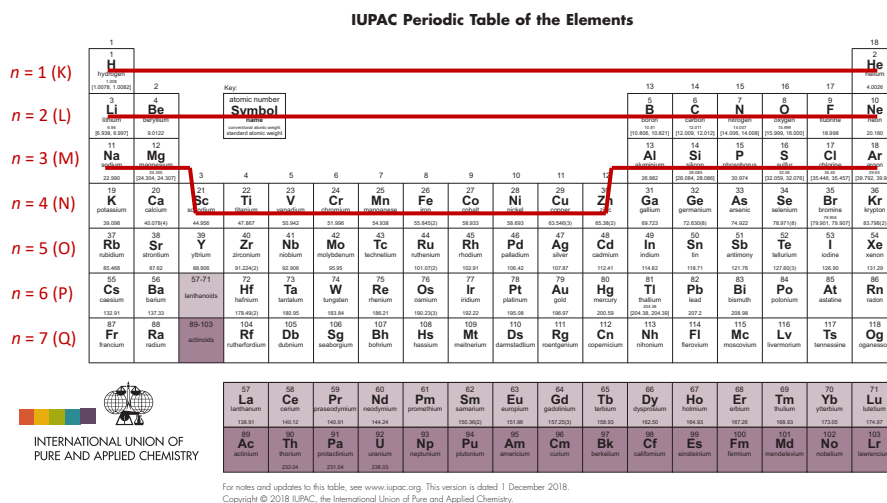
- The electrons are located in specific orbits around the nucleus
- Simplified, these are the "shells" denoted by K, L, M, N...
- The electrons in the outermost shell are the outer electrons or valence electrons



Niels Bohr
1885 - 1962

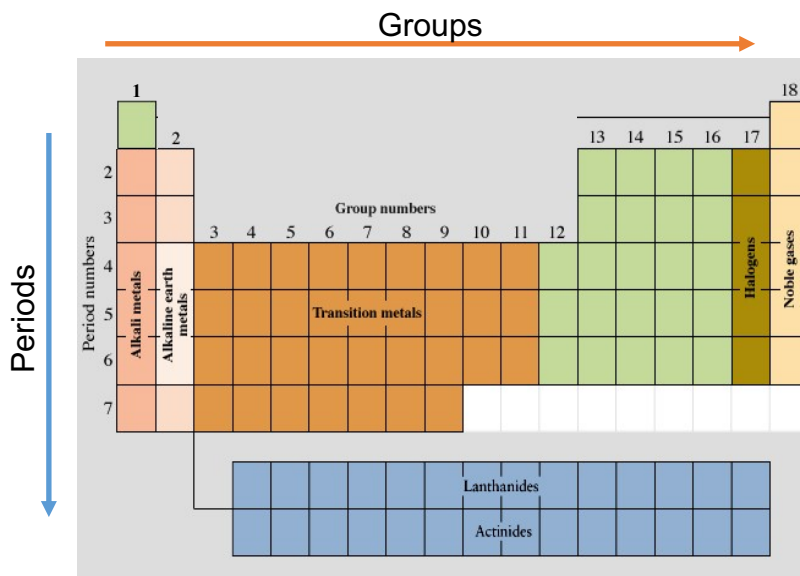


Principal Quantum Number and the Periodic Table of the Elements



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THE PERIODIC TABLE OF THE ELEMENTS



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STRUCTURE OF THE PERIODIC TABLE

Columns of the periodic table: **Groups**

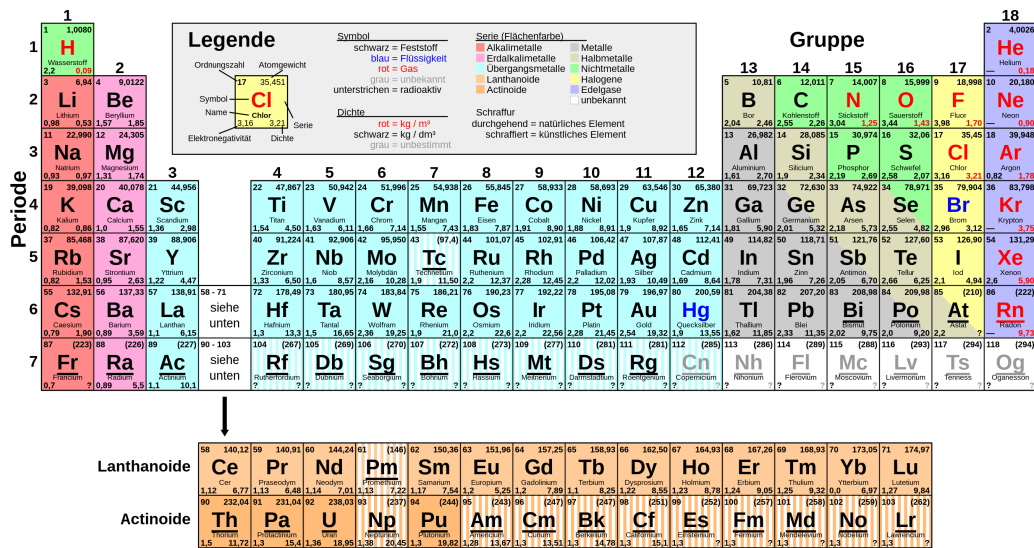
⇒ Elements in a group (homologs) have similar properties with **gradual increments**

Rows of the periodic table: **Periods**

⇒ Elements in a period show strongly **different properties** from left to right



THE IDEA OF THE GROUP PROPERTIES

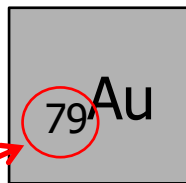


THE ATOMIC NUMBER

Atomic number (Z)

= Number of protons in the nucleus

(corresponds to the number of electrons in the electron shells of the neutral atom)

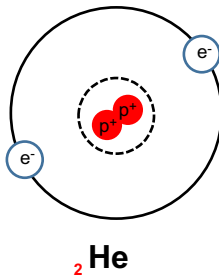


Atomic number – bottom left of the element symbol

NUCLEONS

Atomic number (Z)

= Number of protons in the nucleus



Why is an atomic nucleus stable?

- Positive particles repel each other
- However, the nuclear binding energy is greater than the repulsive forces between the protons

NUCLEONS

Atomic number (Z)

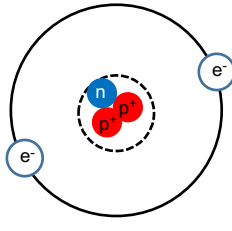
= Number of protons in the nucleus

Mass number (A)

= Sum of the protons and neutrons

$$A = Z + N$$

The nucleus makes up the mass of the atom!



${}^3_2\text{He}$ $Z = 2; N = 1; A = 3$

	Mass	
	Mass [g]	Atomic mass ^a m_a [Da]
Electron	$9.109535 \cdot 10^{-28}$	0.0005485803
Proton	$1.672649 \cdot 10^{-24}$	1.007276
Neutron	$1.674954 \cdot 10^{-24}$	1.008665

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NUCLEONS

Atomic number (Z)

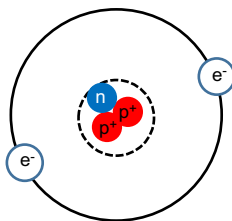
= Number of protons in the nucleus

Mass number (A)

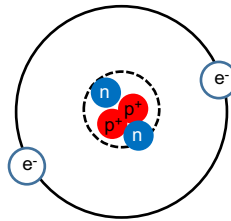
= Sum of the protons and neutrons

$$A = Z + N$$

The same type of atom (= **same number of protons**) can have a **different number of neutrons** = **different mass / different mass number**



${}^3_2\text{He}$ $N = 1$



${}^4_2\text{He}$ $N = 2; A = 4$

Both atoms are He – atoms, meaning the same element.

They only differ in mass:

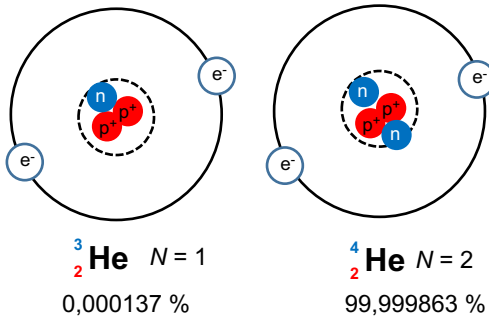
ISOTOPE

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NUCLEONS

Atomic number (Z)
= Number of protons in the nucleus

Mass number (A)
= Sum of the protons and neutrons
 $A = Z + N$



Both atoms are He – atoms, meaning the same element.

They only differ in mass:

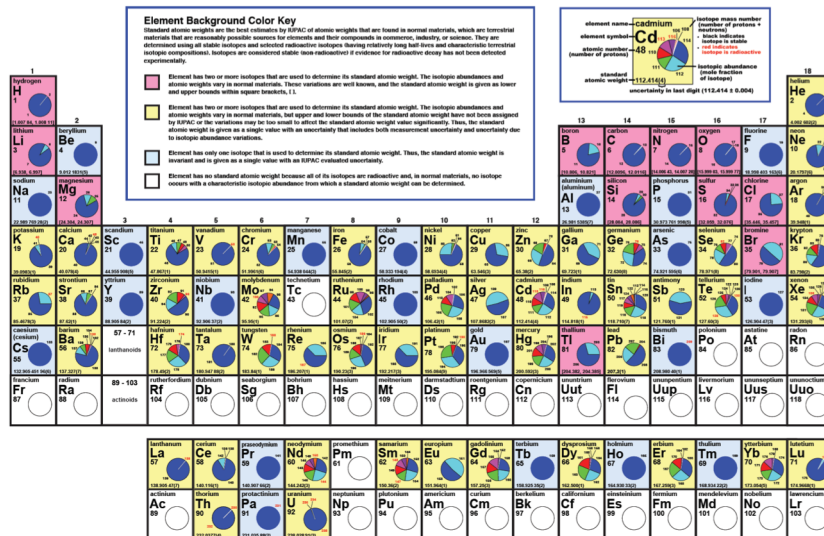
ISOTOPE

Natural isotopes do not occur in nature with the same abundance. The ratio of the abundances is called the **ISOTOPE RATIO**

${}^4\text{He}/{}^3\text{He} = 729926$

ISOTOPIC ABUNDANCES (ciaaw.org)

IUPAC Periodic Table of the Isotopes



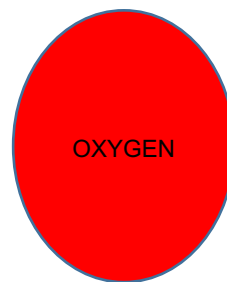
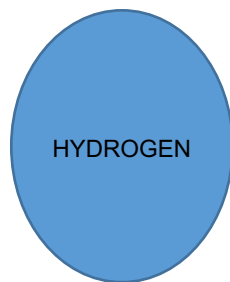
TO THE MASS OF ATOMS....

Since an atom is relatively small, it only has a veeeery small absolute mass (m_a):

An atom of the hydrogen isotope ^1H is $1.673532812 \times 10^{-27}$ kg

....AVOGADRO

$\rho = \text{const.}; T = \text{const.};$



$$V_1 = V_2$$

$$N_1 = N_2$$

$$m_1 \neq m_2 \quad m_2 = 16 \times m_1$$



Lorenzo
Romano
Amedeo Carlo
Avogadro,
Conte di
Quaregna e
Cerreto
1776 - 1856

TO THE MASS OF ATOMS....

Atomic masses were determined relative to hydrogen

(1858, Stanislao Cannizzaro)):

Hydrogen (H): has the relative atomic mass of 1

Oxygen (O): has the relative atomic mass of $16 \times 1 = 16$

etc....

TO THE MASS OF ATOMS....

(relative) Atomic masses (A_r) were determined **relative to hydrogen**

(1858, Stanislao Cannizzaro)):

Hydrogen (H): has the relative atomic mass of 1

Oxygen (O): has the relative atomic mass of $16 \times 1 = 16$

etc....

Later, (1865, Jean Servais Stas) A_r was determined **relative to oxygen**.

TO THE MASS OF ATOMS....

(relative) Atomic masses (A_r) were determined **relative to hydrogen** (1858, Stanislao Cannizzaro):

Hydrogen (H): has the relative atomic mass of 1

Oxygen (O): has the relative atomic mass of $16 \times 1 = 16$

etc....

Later (1865, Jean Servais Stas), A_r was determined **relative to oxygen**.

Since 1957 (Nier und Ölander), the carbon isotope ^{12}C was chosen as a reference point.

RELATIVE ATOMIC MASSES A_r (*atomic weight*)

Relative atomic mass A_r

The relative atomic mass A_r is the absolute atomic mass m_a of an atom relative to 1/12 of the atomic mass of the carbon-12 atom ($m_a(^{12}\text{C})$)

$$A_r = \frac{m_a}{m_a(^{12}\text{C}) \times \frac{1}{12}}$$

RELATIVE ATOMIC MASSES A_r (*atomic weight*)

absolute atomic mass m_a

The relative atomic mass A_r is the absolute atomic mass m_a of an atom relative to 1/12 of the atomic mass of the carbon-12 atom ($m_a(^{12}\text{C})$)

The unit of the relative atomic mass is
u (unified atomic mass) or the **Da (Dalton)**

1/12 of the relative atomic mass of ^{12}C is exactly 1 Dalton

1 Dalton therefore corresponds to $1.660539040 \times 10^{-27}$ kg

The absolute mass m_a of a ^{12}C -atom is therefore
 $12 \times 1.660539040 \times 10^{-27}$ kg = $1.99264685 \times 10^{-26}$ kg

ATOMIC MASSES

One atom of the hydrogen isotope ^1H is $1.673532812 \times 10^{-27}$ kg

One atom of the hydrogen isotope ^1H is 1.007825032 Da

Atomic masses of the isotopes are determined experimentally.
(Atomic Mass Evaluation, 2016 – IUPAP)

AVERAGE RELATIVE ATOMIC MASS (A_r) (standard atomic weight)

Determination of the **average relative atomic mass** of Cu:

Naturally occurring copper contains on average:

Copper-63 69.15 % ^{63}Cu $A_r = 62.929\,597$

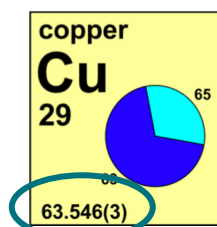
Copper-65 30.85 % ^{65}Cu $A_r = 64.927\,790$

$$A_r = 0.6915 \times 62.929597 + 0.3085 \times 64.927790 = 63.546$$

$$m_a = 63.546 \text{ Da}$$

AVERAGE RELATIVE ATOMIC MASS (Standard Atomic Weight)

The **mean relative atomic masses** with less significant numbers of digits are those that are given in the periodic table and are called "Abridged Standard Atomic Weights"



„Abridged Standard Atomic Weight“

NOTE: In the periodic table, the **simplified average relative atomic masses** are given, even if they exist in a larger interval in nature (see ciaaw.org)

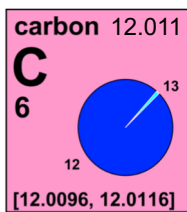
AVERAGE RELATIVE ATOMIC MASS

In nature, some elements have such a wide distribution of abundances that no single value can be given.

These elements have an interval in which the atomic weight value is found for a single sample.

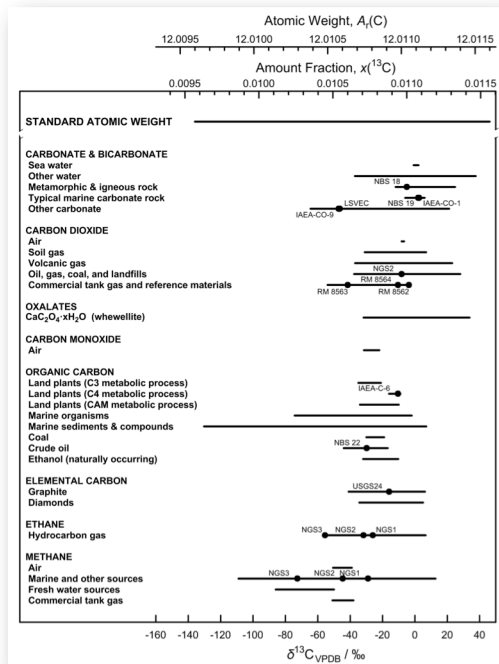
Example: Carbon

Atomic weight distribution of carbon on Earth (Source: ciaaw.org)



Simplified standard atomic weight

Interval



12.011 (Da)

Legende		Ordnungszahl		Symbol		Ordnungszahl		Serie	
Ordnungszahl		Symbol		Ordnungszahl		Serie		Serie	
Atomgewicht		Elektronen-konfiguration		Elektronen-güte		Elektronen-güte		Elektronen-güte	
1	H	1	H	1	H	1	H	1	H
2	He	2	He	2	He	2	He	2	He
3	Li	3	Li	3	Li	3	Li	3	Li
4	Be	4	Be	4	Be	4	Be	4	Be
5	B	5	B	5	B	5	B	5	B
6	C	6	C	6	C	6	C	6	C
7	N	7	N	7	N	7	N	7	N
8	O	8	O	8	O	8	O	8	O
9	F	9	F	9	F	9	F	9	F
10	Ne	10	Ne	10	Ne	10	Ne	10	Ne
11	Na	11	Na	11	Na	11	Na	11	Na
12	Mg	12	Mg	12	Mg	12	Mg	12	Mg
13	Al	13	Al	13	Al	13	Al	13	Al
14	Si	14	Si	14	Si	14	Si	14	Si
15	P	15	P	15	P	15	P	15	P
16	S	16	S	16	S	16	S	16	S
17	Cl	17	Cl	17	Cl	17	Cl	17	Cl
18	Ar	18	Ar	18	Ar	18	Ar	18	Ar
19	K	19	K	19	K	19	K	19	K
20	Ca	20	Ca	20	Ca	20	Ca	20	Ca
21	Sc	21	Sc	21	Sc	21	Sc	21	Sc
22	Ti	22	Ti	22	Ti	22	Ti	22	Ti
23	V	23	V	23	V	23	V	23	V
24	Cr	24	Cr	24	Cr	24	Cr	24	Cr
25	Mn	25	Mn	25	Mn	25	Mn	25	Mn
26	Fe	26	Fe	26	Fe	26	Fe	26	Fe
27	Co	27	Co	27	Co	27	Co	27	Co
28	Ni	28	Ni	28	Ni	28	Ni	28	Ni
29	Cu	29	Cu	29	Cu	29	Cu	29	Cu
30	Zn	30	Zn	30	Zn	30	Zn	30	Zn
31	Ga	31	Ga	31	Ga	31	Ga	31	Ga
32	Ge	32	Ge	32	Ge	32	Ge	32	Ge
33	As	33	As	33	As	33	As	33	As
34	Se	34	Se	34	Se	34	Se	34	Se
35	Br	35	Br	35	Br	35	Br	35	Br
36	Kr	36	Kr	36	Kr	36	Kr	36	Kr
37	Rb	37	Rb	37	Rb	37	Rb	37	Rb
38	Sr	38	Sr	38	Sr	38	Sr	38	Sr
39	Y	39	Y	39	Y	39	Y	39	Y
40	Zr	40	Zr	40	Zr	40	Zr	40	Zr
41	Nb	41	Nb	41	Nb	41	Nb	41	Nb
42	Mo	42	Mo	42	Mo	42	Mo	42	Mo
43	Tc	43	Tc	43	Tc	43	Tc	43	Tc
44	Ru	44	Ru	44	Ru	44	Ru	44	Ru
45	Rh	45	Rh	45	Rh	45	Rh	45	Rh
46	Pd	46	Pd	46	Pd	46	Pd	46	Pd
47	Ag	47	Ag	47	Ag	47	Ag	47	Ag
48	Cd	48	Cd	48	Cd	48	Cd	48	Cd
49	In	49	In	49	In	49	In	49	In
50	Sn	50	Sn	50	Sn	50	Sn	50	Sn
51	Sb	51	Sb	51	Sb	51	Sb	51	Sb
52	Te	52	Te	52	Te	52	Te	52	Te
53	I	53	I	53	I	53	I	53	I
54	Xe	54	Xe	54	Xe	54	Xe	54	Xe
55	Cs	55	Cs	55	Cs	55	Cs	55	Cs
56	Ba	56	Ba	56	Ba	56	Ba	56	Ba
57-71	Lanthanide	57-71	Lanthanide	57-71	Lanthanide	57-71	Lanthanide	57-71	Lanthanide
72	Hf	72	Hf	72	Hf	72	Hf	72	Hf
73	Ta	73	Ta	73	Ta	73	Ta	73	Ta
74	W	74	W	74	W	74	W	74	W
75	Re	75	Re	75	Re	75	Re	75	Re
76	Os	76	Os	76	Os	76	Os	76	Os
77	Ir	77	Ir	77	Ir	77	Ir	77	Ir
78	Pt	78	Pt	78	Pt	78	Pt	78	Pt
79	Au	79	Au	79	Au	79	Au	79	Au
80	Hg	80	Hg	80	Hg	80	Hg	80	Hg
81	Tl	81	Tl	81	Tl	81	Tl	81	Tl
82	Pb	82	Pb	82	Pb	82	Pb	82	Pb
83	Bi	83	Bi	83	Bi	83	Bi	83	Bi
84	Po	84	Po	84	Po	84	Po	84	Po
85	At	85	At	85	At	85	At	85	At
86	Rn	86	Rn	86	Rn	86	Rn	86	Rn
87	Fr	87	Fr	87	Fr	87	Fr	87	Fr
88	Ra	88	Ra	88	Ra	88	Ra	88	Ra
89-103	Actinide	89-103	Actinide	89-103	Actinide	89-103	Actinide	89-103	Actinide
104	Rf	104	Rf	104	Rf	104	Rf	104	Rf
105	Db	105	Db	105	Db	105	Db	105	Db
106	Sg	106	Sg	106	Sg	106	Sg	106	Sg
107	Bh	107	Bh	107	Bh	107	Bh	107	Bh
108	Hs	108	Hs	108	Hs	108	Hs	108	Hs
109	Mt	109	Mt	109	Mt	109	Mt	109	Mt
110	Ds	110	Ds	110	Ds	110	Ds	110	Ds
111	Rg	111	Rg	111	Rg	111	Rg	111	Rg
112	Cn	112	Cn	112	Cn	112	Cn	112	Cn
113	Nh	113	Nh	113	Nh	113	Nh	113	Nh
114	Fl	114	Fl	114	Fl	114	Fl	114	Fl
115	Mc	115	Mc	115	Mc	115	Mc	115	Mc
116	Lv	116	Lv	116	Lv	116	Lv	116	Lv
117	Ts	117	Ts	117	Ts	117	Ts	117	Ts
118	Og	118	Og	118	Og	118	Og	118	Og

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SI Units

The internationally valid SI system of units - SI, is an abbreviation for the French expression *Système international d'unités*.

It is the modern form of the metric system and the most widely used system of measurement in the world.

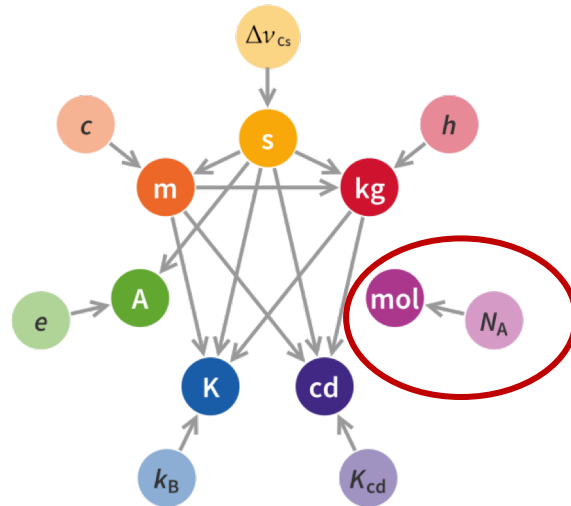


It consists of a total of

- a **coherent system of 7 basic units**,
- a set of **20 decimal prefixes** - prefixes representing multiples or fractions of the units (giving the non-coherent units (e.g. mg or km)) -
- and **22 SI units derived** from the basis set.

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Système international d'unités (see MINT Physics)



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Amount of substance
Quantity symbol: n
Dimension symbol: N
Unit: mol

mol

DEFINITION OF THE MOLE:

The mole, unit symbol mol, is the SI unit of amount of substance.

One mole contains exactly $6.022\,140\,76 \times 10^{23}$ individual particles.

This number corresponds to the fixed numerical value applicable to the Avogadro constant N_A , expressed in units of mol^{-1} , and is known as the Avogadro number.

The amount of substance, sign n , of a system is a measure of a number of specified constituents.

A single particle can be an atom, a molecule, an ion, an electron, another particle or a group of such particles with specified composition.

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THE MOLE ...

The number of particles corresponds to **6,022 140 76 x 10²³** particles.

The quantity is called the **Avogadro number** (N_A)

Thus the amount of substance of 1 mol has exactly $6.02214076 \times 10^{23}$ particles (=natural constant)

THE MOLE ...

The number of particles corresponds to **6,022 140 76 x 10²³** particles.

The quantity is called the **Avogadro number** (N_A)

Thus the amount of substance of 1 mol has exactly $6.02214076 \times 10^{23}$ particles (=natural constant)

(This is like 1 dozen = 12 particles)

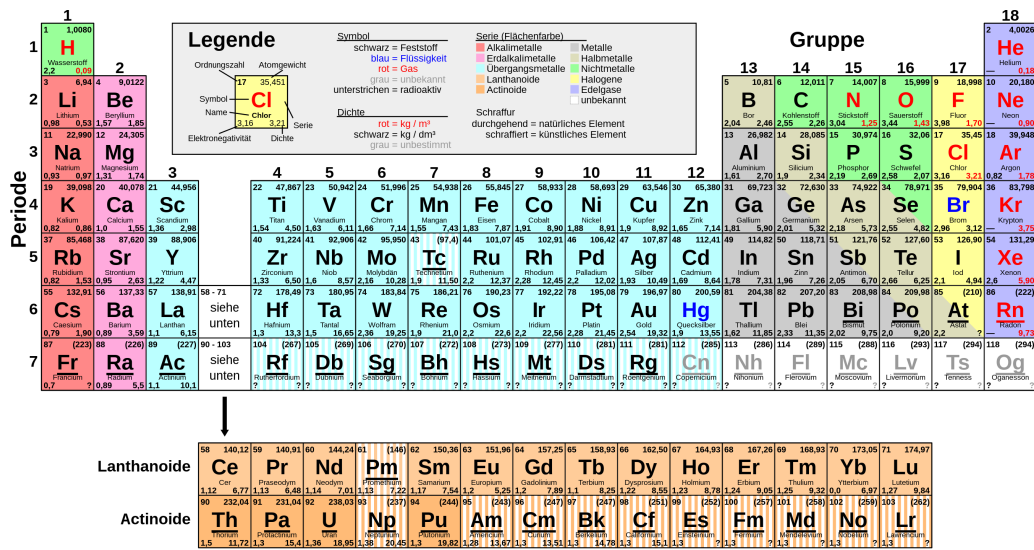


MOL und MOLAR MASSES (M)

The relative average atomic masses (A_r) in the periodic table correspond **in numerical value** (approximately) to the average **molar mass M in g/mol**



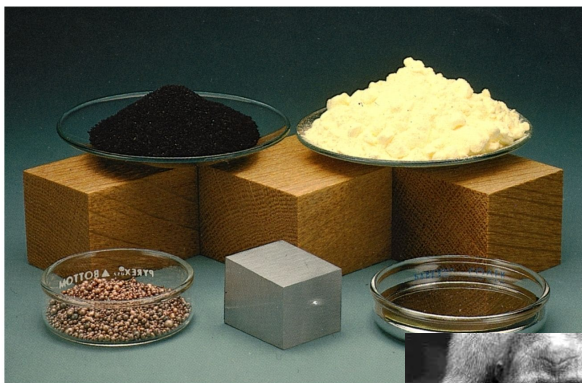
Molar Masses....



Each of these samples consists of 1 mole of the element

Clockwise from top right:

32.065 g	Sulphur
200.59 g	Mercury
207.2 g	Lead
63.546 g	Copper
12.011 g	Carbon



...how many atoms are there in each?
...and it's $6.02214076 \times 10^{23}$ atoms of that element each time



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EVALUATION OF ELEMENTS BASED ON POSITION ON THE PERIODICAL TABLE

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METALS

Legende

Ordnungszahl: Z Symbol: X Ordnungszahl: Z Serie: S

Name: X Atomgewicht: A_r Elektronenkonfiguration: $1s^2 2s^2 2p^6 3s^2 3p^4$ Elektronegativität: 1.9

schwarz = nicht radioaktiv gelb = radioaktiv rot = Gas blau = Flüssigkeit

Alkalimetalle Erdalkalimetalle Übergangsmetalle Lanthanoide Actinoide

Metalle Halbmetalle Nichtmetalle Halogenide Edelgase

durchgehend = natürliches Element schraffiert = künstliches Element

1	H																	18																																																																		
1	1																	2																																																																		
2	Li	4	Be											10	Ne																																																																					
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																				
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40																																																														
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120																		
7	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120																																																		

NONMETALS

Legende

Ordnungszahl: Z Symbol: X Ordnungszahl: Z Serie: S

Name: X Atomgewicht: A_r Elektronenkonfiguration: $1s^2 2s^2 2p^6 3s^2 3p^4$ Elektronegativität: 1.9

schwarz = nicht radioaktiv gelb = radioaktiv rot = Gas blau = Flüssigkeit

Alkalimetalle Erdalkalimetalle Übergangsmetalle Lanthanoide Actinoide

Metalle Halbmetalle Nichtmetalle Halogenide Edelgase

durchgehend = natürliches Element schraffiert = künstliches Element

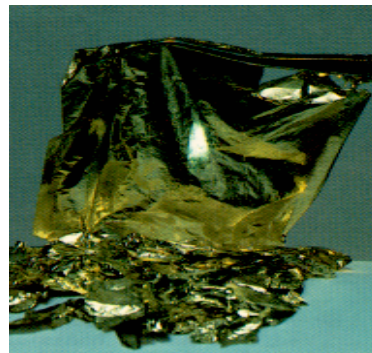
1	H																	18																																																																		
1	1																	2																																																																		
2	Li	4	Be											10	Ne																																																																					
3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																				
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40																																																														
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
6	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120																		
7	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120																																																		

SEMIMETALS

Legende	
Ordnungszahl	Symbol
Name	Ordnungszahl
Elektronen-konfiguration	Serie
Elektronen-gewicht	Elektronen-gewicht
Elektronen-gewicht	Elektronen-gewicht
1	2
3	4
5	6
7	8
9	10
11	12
13	14
15	16
17	18

Metals, Nonmetals, Semimetals

- A **metal** is a substance that conducts electricity, has a metallic sheen, and is ductile*.
- A **nonmetal** does not conduct electricity and is neither malleable nor ductile*.



Rolled out gold foil that lets light shine through

*malleable, plastic deformation

Characteristics of metals and non-metals

Metal

physical properties

good electrical conductor
deformable under pressure
malleable, ductile
shiny

typically:

solid
high melting point
good heat conductor

chemical properties

react with acids
form basic oxides
(that react with acids)
form cations

Nonmetal

bad electrical conductor
not deformable
not ductile
not shiny

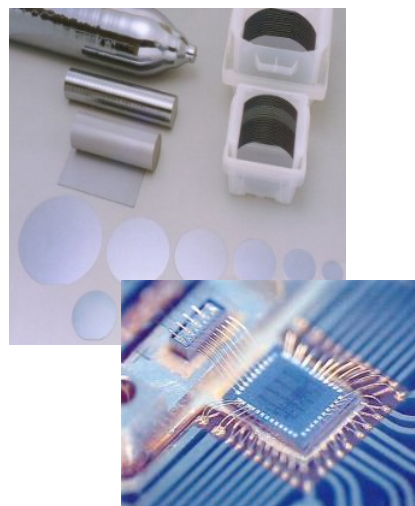
solid, liquid or gas
low melting point
bad heat conductor

do not react with acid
form acidic oxides
(that react with bases)
form anions

Metals, Nonmetals, Semimetals

Semimetals have

- the appearance and (certain) properties of metals, but
- chemically behave like nonmetals



SOLID – LIQUID - GAS

1																		18																
1 H Wasserstoff 1.00794 1																		2 He Helium 4.002602 2																
2 Li Lithium 6.941 3																		3 Be Beryllium 9.0122 4	4 B Bor 10.81 5	5 C Kohlenstoff 12.011 6	6 N Stickstoff 14.007 7	7 O Sauerstoff 15.999 8	8 F Fluor 18.998 9	9 Ne Neon 20.180 10										
3 Na Natrium 22.990 11																		12 Mg Magnesium 24.305 12	13 Al Aluminium 26.982 13	14 Si Silicium 28.086 14	15 P Phosphor 30.974 15	16 S Schwefel 32.065 16	17 Cl Chlor 35.453 17	18 Ar Argon 39.948 18										
4 K Kalium 39.098 19																		20 Ca Calcium 40.078 20	21 Sc Scandium 44.956 21	22 Ti Titan 47.887 22	23 V Vanadium 50.942 23	24 Cr Chrom 51.996 24	25 Mn Mangan 54.938 25	26 Fe Eisen 55.845 26	27 Co Cobalt 58.933 27	28 Ni Nickel 58.693 28	29 Cu Kupfer 63.546 29	30 Zn Zinn 65.38 30	31 Ga Gallium 69.723 31	32 Ge Germanium 72.64 32	33 As Arsen 74.922 33	34 Se Selen 78.96 34	35 Br Brom 79.904 35	36 Kr Krypton 83.798 36
5 Rb Rubidium 85.468 37																		38 Sr Strontium 87.62 38	39 Y Yttrium 88.906 39	40 Zr Zirkon 91.224 40	41 Nb Niobium 92.906 41	42 Mo Molybdän 95.94 42	43 Tc Technetium 98.906 43	44 Ru Ruthenium 101.07 44	45 Rh Rhodium 101.07 45	46 Pd Palladium 106.42 46	47 Ag Silber 107.87 47	48 Cd Cadmium 112.41 48	49 In Indium 114.82 49	50 Sn Zinn 118.71 50	51 Sb Antimon 121.76 51	52 Te Tellur 127.60 52	53 I Jod 126.905 53	54 Xe Xenon 131.29 54
6 Cs Cäsium 132.91 55																		56 Ba Barium 137.33 56	57-71 Lanthanoide siehe unten	72 Hf Hafnium 178.49 72	73 Ta Tantal 180.95 73	74 W Wolfram 183.84 74	75 Re Rhenium 186.21 75	76 Os Osmium 190.23 76	77 Ir Iridium 192.22 77	78 Pt Platin 195.08 78	79 Au Gold 196.97 79	80 Hg Quecksilber 200.59 80	81 Tl Thallium 204.38 81	82 Pb Blei 207.2 82	83 Bi Bismut 208.98 83	84 Po Polonium 209 84	85 At Astat 210 85	86 Rn Radon 222 86
7 Fr Francium 223 87																		88 Ra Radium 226 88	89-103 Actinoide siehe unten	104 Rf Rutherfordium (261) 104	105 Db Dubnium (262) 105	106 Sg Seaborgium (263) 106	107 Bh Bohrium (264) 107	108 Hs Hassium (265) 108	109 Mt Meitnerium (266) 109	110 Ds Darmstadtium (267) 110	111 Rg Roentgenium (268) 111	112 Cn Copernicium (269) 112	113 Nh Nihonium (270) 113	114 Fl Flerovium (271) 114	115 Mc Moscovium (272) 115	116 Lv Livermorium (273) 116	117 Ts Tenness (274) 117	118 Og Oganesson (276) 118
8 La Lanthan 138.91 57																		58 Ce Cer 140.12 58	59 Pr Praseodym 140.91 59	60 Nd Neodym 144.24 60	61 Pm Promethium 144.91 61	62 Sm Samarium 150.36 62	63 Eu Europium 151.96 63	64 Gd Gadolinium 157.25 64	65 Tb Terbium 158.93 65	66 Dy Dysprosium 162.50 66	67 Ho Holmium 164.93 67	68 Er Erbium 167.26 68	69 Tm Thulium 168.93 69	70 Yb Ytterbium 173.05 70	71 Lu Lutetium 174.97 71			
89 Ac Actinium 227 89																		90 Th Thorium 232.04 90	91 Pa Protactinium 231.04 91	92 U Uran 238.03 92	93 Np Neptunium 237.05 93	94 Pu Plutonium 244.08 94	95 Am Americium (243) 95	96 Cm Curium (247) 96	97 Bk Berkelium (247) 97	98 Cf Californium (251) 98	99 Es Einsteinium (252) 99	100 Fm Fermium (257) 100	101 Md Mendelevium (258) 101	102 No Nobelium (259) 102	103 Lr Lawrencium (260) 103			

IMPORTANT GROUPS

1																		18																
1 H Wasserstoff 1.00794 1																		2 He Helium 4.002602 2																
2 Li Lithium 6.941 3																		3 Be Beryllium 9.0122 4	4 B Bor 10.81 5	5 C Kohlenstoff 12.011 6	6 N Stickstoff 14.007 7	7 O Sauerstoff 15.999 8	8 F Fluor 18.998 9	9 Ne Neon 20.180 10										
3 Na Natrium 22.990 11																		12 Mg Magnesium 24.305 12	13 Al Aluminium 26.982 13	14 Si Silicium 28.086 14	15 P Phosphor 30.974 15	16 S Schwefel 32.065 16	17 Cl Chlor 35.453 17	18 Ar Argon 39.948 18										
4 K Kalium 39.098 19																		20 Ca Calcium 40.078 20	21 Sc Scandium 44.956 21	22 Ti Titan 47.887 22	23 V Vanadium 50.942 23	24 Cr Chrom 51.996 24	25 Mn Mangan 54.938 25	26 Fe Eisen 55.845 26	27 Co Cobalt 58.933 27	28 Ni Nickel 58.693 28	29 Cu Kupfer 63.546 29	30 Zn Zinn 65.38 30	31 Ga Gallium 69.723 31	32 Ge Germanium 72.64 32	33 As Arsen 74.922 33	34 Se Selen 78.96 34	35 Br Brom 79.904 35	36 Kr Krypton 83.798 36
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6 Cs Cäsium 132.91 55																		56 Ba Barium 137.33 56	57-71 Lanthanoide siehe unten	72 Hf Hafnium 178.49 72	73 Ta Tantal 180.95 73	74 W Wolfram 183.84 74	75 Re Rhenium 186.21 75	76 Os Osmium 190.23 76	77 Ir Iridium 192.22 77	78 Pt Platin 195.08 78	79 Au Gold 196.97 79	80 Hg Quecksilber 200.59 80	81 Tl Thallium 204.38 81	82 Pb Blei 207.2 82	83 Bi Bismut 208.98 83	84 Po Polonium 209 84	85 At Astat 210 85	86 Rn Radon 222 86
7 Fr Francium 223 87																		88 Ra Radium 226 88	89-103 Actinoide siehe unten	104 Rf Rutherfordium (261) 104	105 Db Dubnium (262) 105	106 Sg Seaborgium (263) 106	107 Bh Bohrium (264) 107	108 Hs Hassium (265) 108	109 Mt Meitnerium (266) 109	110 Ds Darmstadtium (267) 110	111 Rg Roentgenium (268) 111	112 Cn Copernicium (269) 112	113 Nh Nihonium (270) 113	114 Fl Flerovium (271) 114	115 Mc Moscovium (272) 115	116 Lv Livermorium (273) 116	117 Ts Tenness (274) 117	118 Og Oganesson (276) 118
8 La Lanthan 138.91 57																		58 Ce Cer 140.12 58	59 Pr Praseodym 140.91 59	60 Nd Neodym 144.24 60	61 Pm Promethium 144.91 61	62 Sm Samarium 150.36 62	63 Eu Europium 151.96 63	64 Gd Gadolinium 157.25 64	65 Tb Terbium 158.93 65	66 Dy Dysprosium 162.50 66	67 Ho Holmium 164.93 67	68 Er Erbium 167.26 68	69 Tm Thulium 168.93 69	70 Yb Ytterbium 173.05 70	71 Lu Lutetium 174.97 71			
89 Ac Actinium 227 89																		90 Th Thorium 232.04 90	91 Pa Protactinium 231.04 91	92 U Uran 238.03 92	93 Np Neptunium 237.05 93	94 Pu Plutonium 244.08 94	95 Am Americium (243) 95	96 Cm Curium (247) 96	97 Bk Berkelium (247) 97	98 Cf Californium (251) 98	99 Es Einsteinium (252) 99	100 Fm Fermium (257) 100	101 Md Mendelevium (258) 101	102 No Nobelium (259) 102	103 Lr Lawrencium (260) 103			

NOBLE GASES

1		2										3										4										5										6										7										8										9										10										11										12										13										14										15										16										17										18																																																																																																																																																																																																																																													
H		He		Li		Be		B		C		N		O		F		Ne		Na		Mg		Al		Si		P		S		Cl		Ar		K		Ca		Sc		Ti		V		Cr		Mn		Fe		Co		Ni		Cu		Zn		Ga		Ge		As		Se		Br		Kr		Rb		Sr		Y		Zr		Nb		Mo		Tc		Ru		Rh		Pd		Ag		Cd		In		Sn		Sb		Te		I		Xe		Ba		La		Ce		Pr		Nd		Pm		Sm		Eu		Gd		Tb		Dy		Ho		Er		Tm		Yb		Lu		Hf		Ta		W		Re		Os		Ir		Pt		Au		Hg		Tl		Pb		Bi		Po		At		Rn		Fr		Ra		Ac		Th		Pa		U		Np		Pu		Am		Cm		Bk		Cf		Es		Fm		Md		No		Lr		103		104		105		106		107		108		109		110		111		112		113		114		115		116		117		118		119		120		121		122		123		124		125		126		127		128		129		130		131		132		133		134		135		136		137		138		139		140		141		142		143		144		145		146		147		148		149		150		151		152		153		154		155		156		157		158		159		160		161		162		163		164		165		166		167		168		169		170		171		172		173		174		175		176		177		178		179		180		181		182		183		184		185		186		187		188		189		190		191		192		193		194		195		196		197		198		199		200	

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
Lanthanoide														
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
Actinoide														

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IMPORTANT GROUPS

1		2										3										4										5										6										7										8										9										10										11										12										13										14										15										16										17										18																																																																																																																																																																																																																																													
H		He		Li		Be		B		C		N		O		F		Ne		Na		Mg		Al		Si		P		S		Cl		Ar		K		Ca		Sc		Ti		V		Cr		Mn		Fe		Co		Ni		Cu		Zn		Ga		Ge		As		Se		Br		Kr		Rb		Sr		Y		Zr		Nb		Mo		Tc		Ru		Rh		Pd		Ag		Cd		In		Sn		Sb		Te		I		Xe		Ba		La		Ce		Pr		Nd		Pm		Sm		Eu		Gd		Tb		Dy		Ho		Er		Tm		Yb		Lu		Hf		Ta		W		Re		Os		Ir		Pt		Au		Hg		Tl		Pb		Bi		Po		At		Rn		Fr		Ra		Ac		Th		Pa		U		Np		Pu		Am		Cm		Bk		Cf		Es		Fm		Md		No		Lr		103		104		105		106		107		108		109		110		111		112		113		114		115		116		117		118		119		120		121		122		123		124		125		126		127		128		129		130		131		132		133		134		135		136		137		138		139		140		141		142		143		144		145		146		147		148		149		150		151		152		153		154		155		156		157		158		159		160		161		162		163		164		165		166		167		168		169		170		171		172		173		174		175		176		177		178		179		180		181		182		183		184		185		186		187		188		189		190		191		192		193		194		195		196		197		198		199		200	

Noble gases have 8 outer electrons (He has 2) and thus represent the most stable configuration

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