MODERN PERIODIC TABLE

A tabular arrangement of elements in rows and columns, highlighting the regular repetition of properties of the elements, is called a **periodic table.**

Development of the Periodic Table:

In 1869 the Russian chemist Dmitri Mendeleev (1834–1907) and the German chemist J. Lothar Meyer (1830–1895), working independently, made similar discoveries. They found that when they arranged the elements in order of atomic mass, they could place them in horizontal rows, one row under the other, so that the elements in each vertical column have similar properties.

Eventually, more accurate determinations of atomic masses revealed discrepancies in this ordering of the elements. When the elements in the periodic table are ordered by atomic number, such discrepancies vanish. In 1913, the British physicist Henry Moseley measured the wavelengths of certain X rays emitted by elements. His measurements showed that these wavelengths were related to the atomic numbers of the elements.

In modern version of the periodic table, each entry lists the atomic number, atomic symbol, and atomic mass of an element.

Modern Statement of the Law of Periodicity: ‘The modern periodic law states that the properties of the elements repeat after certain regular intervals when these elements are arranged in order of their increasing atomic numbers’.

The cause of periodicity in properties is the repetition of similar outer electronic configuration after certain regular intervals. Since the nucleus is situated at the center of an atom and is shielded by electrons in the outermost level, therefore, the atomic mass has little effect on the chemical properties of the elements. Electrons are exposed to the environment. Hence, they can interact with other atoms. As a result, the physical and chemical properties of the elements depend upon their atomic numbers rather than the atomic masses.

Main Features of Modern Periodic Table

Modern periodic table is based upon the electronic configuration of the elements. It consists of 18 vertical columns (Groups) and 7 horizontal rows (Periods).

Groups

Elements that have similar chemical properties are grouped in columns called groups. All the members of a Group have the same valence configuration but different principal quantum numbers. These groups are numbered from 1 to 18 in 1988 by IUPAC. The groups are also divided into two sub groups: A and B. These are numbered IA(1), IIA(2), IIIB(3), IVB(4), VB(5), VIB(6), VIIB(7), VIIIB(8,9,10), IB(11), IIB(12), IIIA(13), IVA(14), VA(15), VIA(16), VIIA(17) and VIIIA (0,18) groups.

Group 1 is called alkali metals. They are highly reactive and have a +1 charge. Group 2 is called alkaline earth metals. They have +2 charge. Transition metals are in the middle, they have groups from 3 to 12. The inner transition metals are at the bottom- as lanthanides and actinides. Group 17 is called halogens. They are also highly reactive and have a -1 charge. Group 18 or zero is called the Noble Gases/ Inert Gases.

Hydrogen occupies a unique position at the top of the periodic table. It does not fit naturally into any Group. It has a single positive charge, like the alkali metals, but at room temperature, it is a gas that doesn't act like a metal.

The elements in group VIIIB consist of three groups (8, 9 & 10) of elements at the middle of the periodic table. They contain triads, which are metals with very similar properties, usually found together.

Periods

The period number of an element signifies the highest unexcited energy level for an electron in that element. The period number equals the principal quantum number of the valence shell.

The first period consists of only two elements – Hydrogen and Helium. The 2nd and 3rd period consists of 8 elements each. On the other hand, the 4th and 5th consists of 18 elements each while the 6th and 7th period consists of 32 elements each. A separate panel at the bottom consists of 15 elements of the 6th period called the lanthanides and 15 elements of the 7th period called the actinides.

v·t·e **Groups in the periodic table** [hide]

IUPAC group	1	2	3[a]	[a]	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mendeleev (I–VIII)	I	II	III		IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	[b]
CAS (US, A-B-A)	IA	IIA	IIIB		IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
old IUPAC (Europe, A-B)	IA	IIA	IIIA		IVA	VA	VIA	VIIA	VIII			IB	IIB	IIIB	IVB	VB	VIB	VIIB	0
Trivial name	Alkali metals	Alkaline earth metals[r]										Coin-age metals	Vola-tile metals	Icosa-gens	Crys-tallo-gens	Pnicto-gens[r]	Chal-co-gens[r]	Halo-gens[r]	Noble gases[r]
Name by element[r]	Lith-ium group	Beryllium group	Scan-dium group		Titan-ium group	Vana-dium group	Chro-mium group	Manga-nese group	Iron group	Co-balt group	Nickel group	Copper group	Zinc group	Boron group	Car-bon group	Nitro-gen group	Oxy-gen group	Fluor-ine group	Helium *or* Neon group
Period 1	H[h]																		He
Period 2	Li	Be												B	C	N	O	F	Ne
Period 3	Na	Mg												Al	Si	P	S	Cl	Ar
Period 4	K	Ca	Sc		Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Period 5	Rb	Sr	Y		Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Period 6	Cs	Ba	La	Ce–Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Period 7	Fr	Ra	Ac	Th–Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

[a] Group 3 has scandium (Sc) and yttrium (Y). For the rest of the group, sources differ as either being (1) lutetium (Lu) and lawrencium (Lr), *or* (2) lanthanum (La) and actinium (Ac), *or* (3) the whole set of 15+15 lanthanides and actinides. IUPAC has initiated a project to standardize the definition as either (1) **Sc, Y, Lu and Lr**, or (2) **Sc, Y, La and Ac**.[20]

[b] Group 18, the noble gases, were not discovered at the time of Mendeleev's original table. Later (1902), Mendeleev accepted the evidence for their existence, and they could be placed in a new "group 0", consistently and without breaking the periodic table principle.

[r] Group name as recommended by IUPAC.

[h] Hydrogen (H), while placed in group 1, is not considered to be part of the alkali metals.

Elements 113, 115, 117 and 118, the most recent discoveries, were officially confirmed by the International Union of Pure and Applied Chemistry (IUPAC) in 2016. Their proposed names, nihonium (Nh), moscovium (Mc), tennessine (Ts) and oganesson (Og) respectively. Lanthanoids (La-Lu) and actinoids (Ac-Lr) are collective names also recommended by IUPAC.

CLASSIFICATION OF ELEMENTS

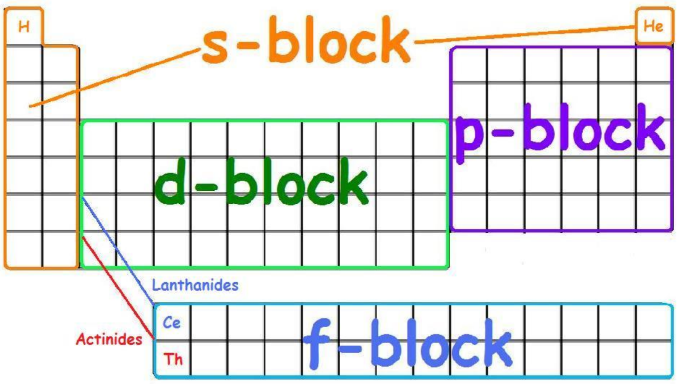
Classification of the elements into **BLOCKS**:

The **s-block elements** have valence configuration s^1 or s^2.

The **p-block elements** have valence configuration s^2p^1 to s^2p^6.

The **d-block elements** have valence configurations in which d-subshells are being filled.

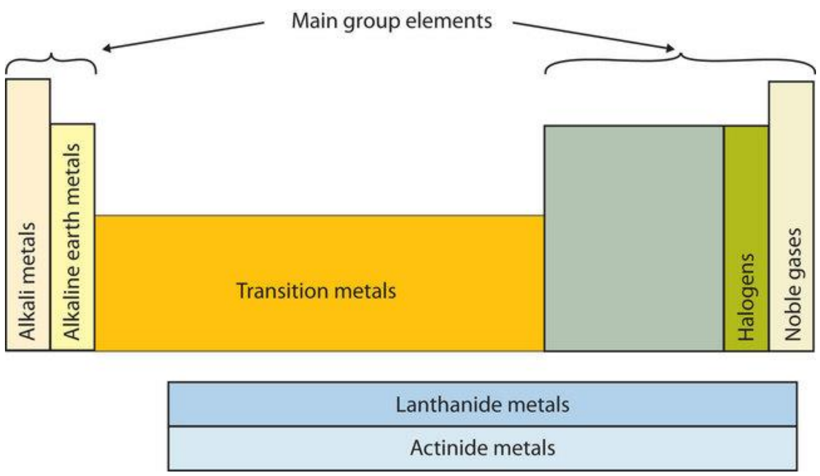
The **f-block elements** have valence configurations in which f-subshells are being filled.



Classification of elements depending on electronic configuration:

The physical and chemical properties of the elements are largely determined by their electronic structures:

1. The Inert Gases (elements of ‘0’ group)
2. The Representative Elements (‘s’ and ‘p’ block elements)
3. The Transition Elements (‘d’ block elements)
4. The Inner Transition Elements (‘f’ block elements)



Classification of elements into Metals, Nonmetals and Metalloids:

Metals

Most elements are metals. There are so many metals, they are divided into groups: *alkali metals*, *alkaline earth metals*, *transition metals and inner transition metals*. The inner transition metals can be divided into smaller groups, such as the *lanthanides* and *actinides*.

Properties of Metals: Metals share some common properties. They are lustrous (shiny), malleable (can be hammered into sheets) and ductile (can be drawn into wire) and are good conductors of heat and electricity. Except for mercury, the metallic elements are solids at room temperature (about 20^0C). These properties result from the ability to easily move the electrons in the outer shells of metal atoms.

Alkali Metals: The alkali metals are lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs) and francium (Fr). Hydrogen is unique in that it is generally placed in Group 1, but it is not a metal. The compounds of the alkali metals are common in nature and daily life. One example is table salt (sodium chloride); lithium compounds are used in greases, in batteries, and as drugs to treat patients who exhibit manic-depressive or bipolar behavior. Although lithium, rubidium, and cesium are relatively rare in nature, and francium is so unstable and highly radioactive that it exists in only trace amounts, sodium and potassium are the seventh and eighth most abundant elements in Earth's crust, respectively. These elements form ions with a +1 charge and have the largest atom sizes of elements in their periods. The alkali metals are highly reactive.

Alkaline Earth Metals: The alkaline earth metals are beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). Beryllium, strontium, and barium are rare, and radium is unstable and highly radioactive. In contrast, calcium and magnesium are the fifth and sixth most abundant elements on Earth, respectively; they are found in huge deposits of limestone and other minerals. They have ions with a +2 charge. Their atoms are smaller than those of the alkali metals.

Transition Metals: The transition elements are in Groups 3 to 12. Iron and gold are examples of transition metals. These elements are very hard, with high melting points and boiling points. The transition metals are good electrical conductors and are very malleable. They show positive oxidation states of +2 and +3 generally and contain two incomplete energy levels ('s' & 'd' orbitals). They are effective catalytic agents and generally form coloured and complex compounds.

The transition metals include most of the elements, so they can be categorized into smaller groups. The *lanthanides* and *actinides* are classes of transition elements. Another way to group transition metals is into **triads**, *which are metals with very similar properties, usually found together*.

Metal Triads: The iron triad consists of <u>iron, cobalt, and nickel</u>. Just under iron, cobalt, and nickel is the palladium triad of <u>ruthenium, rhodium, and palladium</u>, while under them is the platinum triad of <u>osmium, iridium, and platinum</u>.

Lanthanides and Actinides: When you look at the periodic table, you'll see there is a block of two rows of elements below the main body of the chart. The top row has atomic numbers following lanthanum. These elements are called the lanthanides (rare earths). *The lanthanides are silvery metals that tarnish easily. They are relatively soft metals, with high melting and boiling points. The lanthanides react to form many different compounds. These elements are used in lamps, magnets, lasers, and to improve the properties of other metals*.

The actinides are in the row below the lanthanides (trans-uranium). Their atomic numbers follow actinium. *All the actinides are radioactive, with positively charged ions. They are reactive metals that form compounds with most nonmetals. The actinides are used in medicines and nuclear devices*.

These elements have three incomplete outer levels (‘s’, ‘d’ & ‘f’ orbitals) and their properties are similar to as in the case of transition elements.

Nonmetals & Metalloids

A **nonmetal** is an element that does not exhibit the characteristics of a metal. Most of the nonmetals are gases (for example, chlorine and oxygen) or solids (for example, phosphorus and sulfur). The solid nonmetals are usually hard, lack metallic luster, brittle substances. Bromine is the only liquid nonmetal. The halogens and the noble gases are two groups of nonmetals.

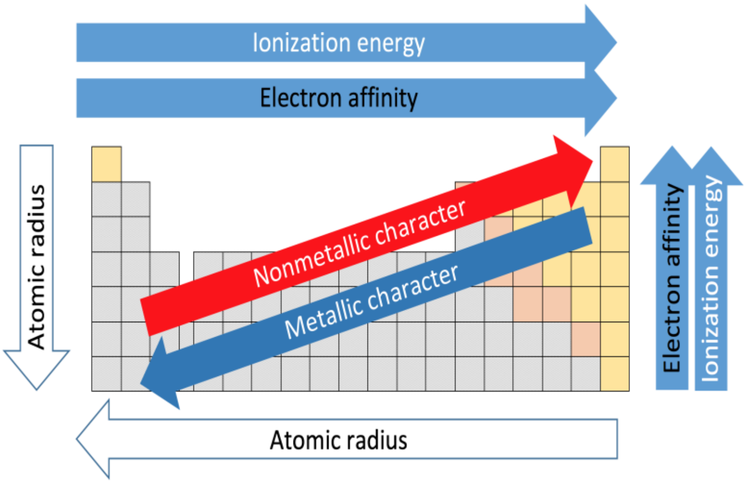
M**etalloids,** or **semimetals** (B, Si, Ge, As, Sb, Te, Bi, Po) are elements having both metallic and nonmetallic properties. These elements, such as silicon (Si) and germanium (Ge), are usually good semiconductors—elements that, when pure, are poor conductors of electricity at room temperature but become moderately good conductors at higher temperatures.

Halogens: Halogens are in Group 17 of the periodic table. The halogens are fluorine (F), chlorine (Cl), bromine (Br), iodine (I) and astatine (At). All the halogens react readily with metals to form compounds (salts), such as sodium chloride and calcium chloride (used in some areas as road salt). Compounds that contain the fluoride ion are added to toothpaste and the water supply to prevent dental cavities. Fluorine is also found in Teflon coatings on kitchen utensils. Although chlorofluorocarbon propellants and refrigerants are believed to lead to the depletion of Earth’s ozone layer and contain both fluorine and chlorine, the latter is responsible for the adverse effect on the ozone layer. Bromine and iodine are less abundant than chlorine, and astatine is so radioactive that it exists in only negligible amounts in nature. These elements are also found in bleaches and disinfectants. These nonmetals form ions with a -1 charge. The halogens are highly reactive.

Noble Gases: The noble gases are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Because the noble gases are composed of only single atoms, they are called monatomic. At room temperature and pressure, they are unreactive gases. Because of their lack of reactivity, for many years they were called inert gases or rare gases. However, the first chemical compounds containing the noble gases were prepared in 1962. Although the noble gases are relatively minor constituents of the atmosphere, natural gas contains substantial amounts of helium. Because of its low reactivity, argon is often used as an unreactive (inert) atmosphere for welding and in light bulbs. The red light emitted by neon in a gas discharge tube is used in neon lights. The noble gases are not reactive. Inactivity of the noble gases is due to- (a) complete pairing of all electrons present, (b) absence of any molecular orbital, (c) stable energy state, (d) very high ionization potential and (e) negligible electron affinities.

Periodic trends in modern periodic table

The periodic table helps predict some properties of the elements compared to each other. Atom size decreases as you move from left to right across the table and increases as you move down a column. Energy required to remove an electron from an atom increases as you move from left to right and decreases as you move down a column. The ability to form a chemical bond increases as you move from left to right and decreases as you move down a column. In general, electron affinity value decreases with the increasing atomic radius because the electrostatic force of attraction decreases between the electron being added and the atomic nucleus. This is due to an increase in the distance between them.



The **electronegativity** is a measure of the tendency of an atom to attract a bonding pair of electrons towards itself. The **electron affinity** of an atom or molecule is defined as the amount of energy released or spent when an electron is added to a neutral atom or molecule in the gaseous state to form a negative ion ($X + e^- \rightarrow X^-$). The **ionization energy** is the energy required to remove an electron from a gaseous atom or ion (X + energy $\rightarrow X^- + e^-$).

Usefulness & Limitations of the periodic table

Usefulness are- (1) Classification of the elements, (2) Prediction of undiscovered elements, (3) Correction of atomic weight, (4) Periodic table in industrial research etc.

Limitations are- (1) Position of hydrogen, (2) The position of Lanthanides and Actinides, (3) Properties which are not periodic functions, (4) Diagonal relationship etc.

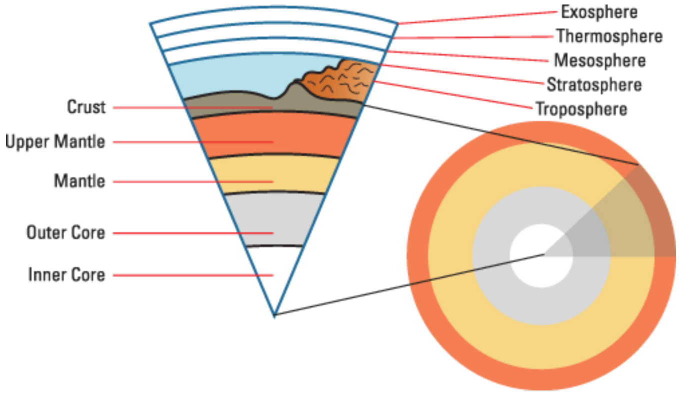
Naturally Occurring and Synthetic Elements

Of the 118 known elements, 94 are found in appreciable quantities in nature. Between hydrogen (H, 1) and uranium (U, 92), only technetium (Tc, 43) and promethium (Pm, 61) are prepared artificially. All trans-uranium elements, those following uranium in the periodic table are synthetic.

Elements are produced artificially in a variety of nuclear transmutation reactions by neutrons or charged particles, including heavy ions. The following are the quantities of trans-uranium elements that have been produced: plutonium (Pu, 94), in tons; neptunium (Np, 93), americium (Am, 95), and curium (Cm, 96), in kilograms; berkelium (Bk, 97), in 100 milligrams; californium (Cf, 98), in grams; and einsteinium (Es, 99), in milligrams. The remaining elements are produced in even smaller quantities.

Distribution of elements on Earth and in Living Systems

Earth's interior can be divided into- crust, mantle and core. Earth's crust extends from the surface to a depth of about 40 km. Scientists have been able only to study the crust.



Elements on Earth: Most elements are naturally occuring. Of the 94 elements that are found in nature, 12 make up 99.7% of Earth's crust by mass. They are (in decreasing order of natural abundance) oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca). magnesium (Mg), sodium (Na), potassium (K), titanium (Ti), hydrogen (H), phosphorus (P), and manganese (Mn). Core consisting mostly of iron at the centre of Earth. Surrounding the core is a layer called mantle, which consists of hot fluid containing iron, carbon, silicon, and sulfur.

Elements in Human Body: The essential trace elements in the human body which make up about 0.1 % of body mass are iron (Fe), copper (Cu), zinc (Zn), iodine (I), and cobalt (Co). These elements are necessary for biological functions such as growth, transport of oxygen for metabolism, and defense against disease. Too much or too little of these elements in our body over an extended period can lead to serious illness, retardation, or even death.

Natural Abundance of the Elements	
Element	**Percent by Mass** (g/100g of sample)
Oxygen	45.5
Silicon	27.2
Aluminum	8.3
Iron	6.2
Calcium	4.7
Magnesium	2.8
All others	5.3

Abundance of the Elements in the Human Body	
Element	**Percent by Mass** (g/100g of sample)
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	1.6
Phosphorus	1.2
All others	1.2

IUPAC Periodic Table of the Elements

Key: atomic number / **Symbol** / name / conventional atomic weight / standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.008 [1.0078, 1.0082]																	2 **He** helium 4.0026
3 **Li** lithium 6.94 [6.938, 6.997]	4 **Be** beryllium 9.0122											5 **B** boron 10.81 [10.806, 10.821]	6 **C** carbon 12.011 [12.009, 12.012]	7 **N** nitrogen 14.007 [14.006, 14.008]	8 **O** oxygen 15.999 [15.999, 16.000]	9 **F** fluorine 18.998	10 **Ne** neon 20.180
11 **Na** sodium 22.990	12 **Mg** magnesium 24.305 [24.304, 24.307]											13 **Al** aluminium 26.982	14 **Si** silicon 28.085 [28.084, 28.086]	15 **P** phosphorus 30.974	16 **S** sulfur 32.06 [32.059, 32.076]	17 **Cl** chlorine 35.45 [35.446, 35.457]	18 **Ar** argon 39.95 [39.792, 39.963]
19 **K** potassium 39.098	20 **Ca** calcium 40.078(4)	21 **Sc** scandium 44.956	22 **Ti** titanium 47.867	23 **V** vanadium 50.942	24 **Cr** chromium 51.996	25 **Mn** manganese 54.938	26 **Fe** iron 55.845(2)	27 **Co** cobalt 58.933	28 **Ni** nickel 58.693	29 **Cu** copper 63.546(3)	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.723	32 **Ge** germanium 72.630(8)	33 **As** arsenic 74.922	34 **Se** selenium 78.971(8)	35 **Br** bromine 79.904 [79.901, 79.907]	36 **Kr** krypton 83.798(2)
37 **Rb** rubidium 85.468	38 **Sr** strontium 87.62	39 **Y** yttrium 88.906	40 **Zr** zirconium 91.224(2)	41 **Nb** niobium 92.906	42 **Mo** molybdenum 95.95	43 **Tc** technetium	44 **Ru** ruthenium 101.07(2)	45 **Rh** rhodium 102.91	46 **Pd** palladium 106.42	47 **Ag** silver 107.87	48 **Cd** cadmium 112.41	49 **In** indium 114.82	50 **Sn** tin 118.71	51 **Sb** antimony 121.76	52 **Te** tellurium 127.60(3)	53 **I** iodine 126.90	54 **Xe** xenon 131.29
55 **Cs** caesium 132.91	56 **Ba** barium 137.33	57-71 lanthanoids	72 **Hf** hafnium 178.49(2)	73 **Ta** tantalum 180.95	74 **W** tungsten 183.84	75 **Re** rhenium 186.21	76 **Os** osmium 190.23(3)	77 **Ir** iridium 192.22	78 **Pt** platinum 195.08	79 **Au** gold 196.97	80 **Hg** mercury 200.59	81 **Tl** thallium 204.38 [204.38, 204.39]	82 **Pb** lead 207.2	83 **Bi** bismuth 208.98	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium	113 **Nh** nihonium	114 **Fl** flerovium	115 **Mc** moscovium	116 **Lv** livermorium	117 **Ts** tennessine	118 **Og** oganesson

57 **La** lanthanum 138.91	58 **Ce** cerium 140.12	59 **Pr** praseodymium 140.91	60 **Nd** neodymium 144.24	61 **Pm** promethium	62 **Sm** samarium 150.36(2)	63 **Eu** europium 151.96	64 **Gd** gadolinium 157.25(3)	65 **Tb** terbium 158.93	66 **Dy** dysprosium 162.50	67 **Ho** holmium 164.93	68 **Er** erbium 167.26	69 **Tm** thulium 168.93	70 **Yb** ytterbium 173.05	71 **Lu** lutetium 174.97
89 **Ac** actinium	90 **Th** thorium 232.04	91 **Pa** protactinium 231.04	92 **U** uranium 238.03	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

For notes and updates to this table, see www.iupac.org. This version is dated 1 December 2018.

United Nations Educational, Scientific and Cultural Organization

International Year of the Periodic Table of Chemical Elements