Language of Chemistry includes chemical **symbols** of elements, chemical **formulas**, & chemical **equations**

All known **elements** *(ca.100)* are arranged in **Periodic Table**.

Each element has its own **name & chemical symbol**:

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>Na</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Tin</td>
<td>Sn</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
</tr>
</tbody>
</table>

1\(^{st}\) character is CAPITAL

2\(^{nd}\) (if any) is low-key
**Co** is element cobalt, while **CO** is carbon monoxide, a compound.

Compounds are formed by combinations of elements, written as a chemical formula:

\[
\text{CO}_2 \quad \text{H}_2\text{O} \quad \text{CH}_4 \quad \text{BN}
\]

Combining into compounds, atoms change their properties:

Carbon **C** is a black stone, sulfur, **S** is a yellow powder, but carbon disulfide, **CS}_2\text{ is a toxic liquid.}
Rearrangement of atoms resulting in a new chemical compound is a **CHEMICAL REACTION:**

\[ \text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl} \]
Humphry Davy, by 1808, found that electrical current decomposes some substances to elements:

\[
\text{CuCl}_2^{(aq)} \rightarrow \text{Cu}^{(s)} + \text{Cl}_2^{(g)}
\]

Michael Faraday (1791-1867) introduced the concept of ions as electrically charged atoms that move to the battery poles, according to the Coulomb law:

Anions (\(-\)) travel to, & discharge at anode [+]

Cations (\(+\)) travel to, & discharge at cathode [-]
Thus:
Element Cl can exist either as
a **neutral atom** (in free chlorine, \( Cl_2 \)),
or as a **negative chloride ion**, \( Cl^- \).
i.e. although Cl atoms do not disappear in a chemical
transformation, they somehow change - in their charge.
Element Cu can exist as a **neutral atom**, or as a positive **copper ion**, \( Cu^{2+} \).
\[ \therefore \] atoms can either be neutral, or be electrically charged.
\[ \therefore \] atoms, though never destroyed in chemistry, must have some *inner structure*, with its subatomic particles.

**Jacob J. Berzelius** put forward
The ELECTRIC THEORY OF CHEMICAL BOND:
atoms are held together in compounds due to their opposite electrical charges:

\[
Na^+ \quad Cl^-
\]

Only **outer electrons** are involved in chemical rxns
ELEMENTS IN PERIODIC TABLE

Each element as posted in the Table, has:

- a **NAME**, potassium, hydrogen, ...
- a **SYMBOL**, K, Na, Cu, Cl, ...
- an **ATOMIC NUMBER** \( Z \) (integer only) &
- an **atomic mass** \( A \) (usually non-integer)

\[
\begin{array}{c|c}
\text{Name} & \text{Atomic Mass} \\
\hline
\text{Iron} & 55.847 \\
\hline
\text{Number} & 26 \\
\end{array}
\]
Atomic number $Z$ is the positive charge of the nucleus & the number of protons in it.

Atomic mass is the sum of masses of protons & neutrons.

Why is atomic mass non-integer? Because natural elements consist of a mix of isotopes: Atoms with the same atomic number, but different mass number.
Neon, Ne: \( Z=10 \) three isotopes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ne-20</td>
<td>90.51%</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Ne-21</td>
<td>0.21%</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Ne-22</td>
<td>9.22%</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

The average Atomic mass is 20.18

Copper, Cu: \( Z = 29 \) two isotopes

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu-63</td>
<td>69.17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu-65</td>
<td>30.83%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{At. mass} = 63 \times 0.6917 + 65 \times 0.3083 = 63.55 \text{ a.m.u.}
\]
To each isotope, besides a symbol, *two numbers* are associated:
atomic number \((Z)\) - position in the Table (element ID#)
mass number \((A)\)

\[
\begin{array}{c}
\text{Mass number} \\
59
\end{array}
\]

\[
\begin{array}{c}
\text{Symbol} \\
\text{Atomic number} \\
27
\end{array}
\]

means cobalt \((Z=27)\) atom with its mass number \(A=59\)
Although atoms are not destroyed, or disappear in chemical rxns, they have their inner structure: atom consist of 3 types of *subatomic particles*, with their known electrical charges & masses.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTON  $p^+$</td>
<td>1</td>
<td>$+1$</td>
</tr>
<tr>
<td>NEUTRON  $n$</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>ELECTRON  $e^-$</td>
<td>0</td>
<td>$-1$</td>
</tr>
</tbody>
</table>

Masses are in ATOMIC MASS UNITS (amu)

(1/2000)
- Protons & neutrons are heavy particles constituting atomic nucleus.
- The mass of atom is due to nucleus which is very small in size & positively charged.
- That charge is the atomic number.

**ATOMIC NUMBER Z** is the NUMBER of PROTONS in the NUCLEUS

**MASS NUMBER A** is the SUM of PROTONS & NEUTRONS, i.e. 

\[ A = Z + n \]
Electrons are almost weightless & spread around the nucleus. The **size** of atom is the size of its electron cloud.

- **Electron cloud:** No mass, negative charge
- **Outer (valence) electrons**
- **Inner shell (core) electrons**
- **Atomic nucleus:** protons & neutrons
  - Positive charge = number of protons,
  - mass = sum of protons & neutrons
Chemical properties (i.e. ability to undergo chemical rxns) depend on the **electron configuration** (primarily on the # of $e^-$), which itself is equal to the number of $p^+$ in a neutral atom (but not related to the number of neutrons)

:: atoms with the same number of $p^+$ (i.e. same $Z$, :: also the same number of $e^-$) but different number of $n$ are chemically indistinguishable, even though their masses differ.

| Atoms with the same $Z$ (number of protons or nuclear charge) but different number of neutrons (:: different masses) are **ISOTOPES** |
Neon, Ne: 3 isotopes:

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>A</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{20}\text{Ne}$</td>
<td>20</td>
<td>10</td>
<td>90.51%</td>
</tr>
<tr>
<td>$^{21}\text{Ne}$</td>
<td>21</td>
<td>10</td>
<td>0.21%</td>
</tr>
<tr>
<td>$^{22}\text{Ne}$</td>
<td>22</td>
<td>10</td>
<td>9.22%</td>
</tr>
</tbody>
</table>

The average atomic mass $A = 20.18$
Copper, Cu: 2 isotopes

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>A</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>63(^{63})Cu</td>
<td>69.17%</td>
<td>29</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65(^{65})Cu</td>
<td>30.83%</td>
<td>29</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ A = 63 \times 0.6917 + 65 \times 0.3083 = 63.55 \text{ amu} \]
Isotopes belong to the **same element**, have the **same symbol**, occupy the **same cell** in the Periodic Table, & have the same chemical properties.

“**ISOTOPE**” translates as “same place”, i.e. the same cell in Periodic Table.

Mass number of each isotope is an **integer** number (number of protons).

**Natural elements are mixtures of isotopes.**

Atomic masses *in the Table are not integer*: they are **average** out of all the natural isotopes of any particular element.
Dmitry Mendeleev, 1869 arranged all known (60 by his time) elements according to their increasing atomic masses & noticed some pattern: Properties of elements repeat each other with a period of 7 elements (8 after the discovery of noble gases, & 18 for heavier elements).

He organized the list of elements as a chart, so that elements with similar properties stand under each other in columns - groups. He successfully predicted several elements not yet known, & predicted, very precisely, their properties: they were later discovered in the nature, just where Mendeleev advised to look for them.
Horizontal rows are 7 **PERIODS**.

Vertical columns are 18 **GROUPS**.

Tall columns:

**8 MAIN GROUPS** (I\textsubscript{A} to VII\textsubscript{A}).

Their elements are **REPRESENTATIVE ELEMENTS**.

Short columns: **TRANSITION METALS**
(Numbered as 3 to 12 or IB to VIIIB)

Two cells contain LANTHANI DE \& ACTINI DE families (which are both INNER-SHELL TRANSITION METALS).
METALS vs. NONMETALS

Most of elements are **metals**: they **conduct electricity, heat**, are malleable, easily **release their electrons** producing **negative ions** while forming **compounds with non-metals**.

Example:

Metal Zn combines with non-metal sulfur S:

\[
\text{Zn} - 2e^- \rightarrow \text{Zn}^{2+}
\]

\[
\text{S} + 2e^- \rightarrow \text{S}^{2-}
\]

Almost all metals are solid (except mercury, Hg).
Nonmetals are in the upper right corner of the table. They exist as gases, liquids (as bromine, Br₂) or solids (carbon, iodine, phosphorus, sulfur, etc.) They do not conduct electricity.

They more likely accept electrons from metals, but also form compounds with other non-metals:

\[ S + 2e^- \rightarrow S^{2-} \]
\[ Zn -2e^- \rightarrow Zn^{2+} \]

Net reaction is: \( Zn + S \rightarrow ZnS \)

\[ S + O_2 \rightarrow SO_2 \]
Between metals & nonmetals are semimetals or \textit{metalloids}.

They are brittle solids & semiconductors (such as Si, Ge).

Diatomic gases:

- $\text{H}_2$, $\text{O}_2$, $\text{N}_2$, $\text{F}_2$, $\text{Cl}_2$
- & two other diatomics: $\text{Br}_2(l)$, $\text{I}_2(s)$.

Two liquid elements:

- $\text{Hg}$ & $\text{Br}_2$
In Periodic Table:

- Each **group** contains elements with similar properties.
- Within a group, metallic properties increase from top to bottom, while non-metallic properties decrease.
- Some groups have their special names:
  - 1st group (left column, IA), besides hydrogen, consists of **alkaline metals** - most active metals
  - In chemical rxns, they always lose 1 electron:
    \[ \text{Na} \rightarrow \text{Na}^+ + e^- \]
    neutral atom \hspace{0.5cm} positively charged ion (cation)
  - 2nd group (IIA) is **alkaline earth metals**
    always lose 2 electrons:
    \[ \text{Ca} \rightarrow \text{Ca}^+ + 2e^- \]
  - Groups 3 to 12 are all **transition metals**
  - 16th group (VIA) is **chalcogens**.
  - 17th group is **halogens (VIIA)** - most active non-metals
    readily accept electron:
    \[ \text{Cl} + e^- \rightarrow \text{Cl}^- \]
    neutral atom \hspace{0.5cm} negative ion (anion)
  - 18th group (right column, VIIIA) is **noble gases** – non-reactive elements.