PERIODIC TABLE, ATOMIC STRUCTURE & REACTIONS of ELEMENTS

Valence electrons: how many?
ATOM: nucleus \((p \& n)\) surrounded by electrons: core electrons & outermost, outer shell, or \textit{valence electrons}.

Valence electrons are most important for chemistry, since they are rearranged when atoms combine in compounds.

In a neutral atom, the total \# of \(e^-\) is equal to the \# of \(p^+\).
The number of \textit{valence} electrons is given by the Group \# in Periodic Table.
PERIODIC TABLE & ELECTRONIC STRUCTURE OF ATOMS

PERIOD: the total number of electron layers (SHELLS) around the nucleus (1 to 7), ∴ the outer (valence) shell number.

GROUP:
Main group: the number of outermost electrons
from 1 to 2 in the 1st Period,
from 1 to 8 in all other Periods,
Long Periods:
Transition metals: all have 2 or 3 outermost electrons, but in RAWS 4 & 5 their next-to-outermost shell contain up to 10e⁻,
i.e. the PERIOD has 18 elements.
RAWS 6 & 7 have 32 elements.

Maximum number of e⁻ on n\textsuperscript{th} shell: 2n\textsuperscript{2} \quad 2, 8, 18, 32
Examples:
Mg 3\textsuperscript{rd} Period, \(\therefore\) contains 3 shells. Valence \(e^-\) are on the 3\textsuperscript{rd} shell, Group II, \(\therefore\) there are 2 valence \(e^-\).
Electron configuration is:  \(\text{Mg}(+12)\ 2, 8, 2\)

\(\text{P}\) 3\textsuperscript{rd} Period, \(\therefore\) contains 3 shells. Valence \(e^-\) are on the 3\textsuperscript{rd} shell, Group V, \(\therefore\) there are 5 valence \(e^-\).
Electron configuration is:  \(\text{P}(+15)\ 2, 8, 5\)

\(\text{Sc}\) 4\textsuperscript{th} Period, \(\therefore\) contains 4 el. shells. Transition metal, \(\therefore\) there are 2 outermost \(e^-\) on the 4\textsuperscript{th} shell.
Electron configuration is:  \(\text{Sc}(+21)\ 2, 8, 9, 2\)
Mn  4\textsuperscript{th} Period, ∴ 4 el shells. Transition metal, ∴ 2 outermost electrons on the 4\textsuperscript{th} shell. Group 7, ∴ 5 extra $e^-$ to add to the pre-outermost octet, $8 + 5 = 13$, ∴

Bohr diagram: Mn\(_{(+25)}\) 2, 8, 13, 2

Zn  4\textsuperscript{th} Period, ∴ 4 el. shells. Transition metal, ∴ 2 outermost $e^-$ on the 4\textsuperscript{th} shell. Group 12, ∴ there are 10 extra electrons added to the octet at the pre-outermost shell.

Bohr diagram: Zn\(_{(+30)}\) 2, 8, 18, 2

I  5\textsuperscript{th} Period, ∴ contains 5 el. shells. Valence electrons are on the 5\textsuperscript{th} shell.

Group VII, ∴ there are 7 valence electrons.
Electron configuration is: I\(_{(+53)}\) 2, 8, 18, 18, 7
Consider *representative elements* only, i.e. 2 left & 6 right (main) groups

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**Periodic Table:**

**REPRESENTATIVE (main group) ELEMENTS**

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</tbody>
</table>

1st Period: 2 elements

1H, Z = 1, 1p⁺, 1e⁻ - one electron only, which is a *valence electron*  
H•

2He, Z = 2, 2p⁺, 2e⁻ - total, both at the same (1st) SHELL.

He: a noble gas, incapable to combine with anything,  
i.e. its e⁻ shell of 2 is stable, complete.
Within each period, elements on the extreme left are most active metals, i.e. they easily release their $e^-$ (they are electron donors) to non-metals, forming positive ions (cations):

$$Na \rightarrow Na^+ + e^-$$

$$S + 2e^- \rightarrow S^{2-}$$

Net rxn: $2Na + S \rightarrow Na_2S$

Elements on the extreme right (group VII) are most active nonmetals, i.e. they willingly accept $e^-$ from metals (they are electron acceptors) forming negative ions (anions):

$$Mg \rightarrow Mg^{2+} + 2e^-$$

$$Cl_2 + 2e^- \rightarrow 2Cl^-$$

Net rxn: $Mg + Cl_2 \rightarrow MgCl_2$

Compounds consisting of ions are IONIC COMPOUNDS, & the hemical bond due to attraction of ions is IONIC BOND
Important: the VIII group elements – noble gases – are completely nonreactive: they neither release, no accept e\textsuperscript{−}.
They all have \textbf{8} outer-shell e\textsuperscript{−}, & this is an especially \textbf{STABLE} configuration: \textit{ELECTRON OCTET}.

\textit{Essential question:}
How many e\textsuperscript{−} will a metal release & how many e\textsuperscript{−} will a non-metal accept?

That depends on the number of \textit{outer} electrons:

Left-hand elements contain few electrons (from 1 to 4), & release them until a cation is formed with its outer shell with \textit{ELECTRON OCTET}, same as in the \textit{preceding noble gas}:
All 3 cations: $\text{Na}^+$, $\text{Mg}^{2+}$, $\text{Al}^{3+}$ are *isoelectronic* to $\text{Ne}$

**OCTET RULE for metals:** metal atoms release as many electrons as necessary to form an electron configuration similar to their *preceding* noble gas.
Octet rule for nonmetals: elements on the extreme right are nonmetals, they have many outer electrons, & trend to accept more $e^-$ to form a stable octet of the next noble gas.

Group VII

- **Cl**: $+17 \bullet 2e^- 8e^- 7e^-$
  - $Cl + 1e^- \downarrow Cl^-$
  - $Cl^- +17 \bullet 2e^- 8e^-$

Group VI

- **S**: $+16 \bullet 2e^- 8e^- 6e^-$
  - $S + 2e^- \downarrow S^{2-}$
  - $S^{2-} +16 \bullet 2e^- 8e^-$

Group V

- **P**: $+15 \bullet 2e^- 8e^- 5e^-$
  - $P + 3e^- \downarrow P^{3-}$
  - $P^{3-} +15 \bullet 2e^- 8e^-$

All 3 anions: $Cl^-, S^{2-}, P^{3-}$ are isoelectronic to Ar
MOLECULAR COMPOUNDS & COVALENT BONDING

Metal + Nonmetal → Ionic Compound
Metal + Metal do not form definite compounds – they form alloys of variable composition (solid-phase homogeneous mixture).

Nonmetal + Nonmetal form MOLECULAR COMPOUNDS with a COVALENT BOND.

The driving force is still the trend to form a STABLE OCTET, but by SHARING ELECTRONS, rather then transferring $e^-$ from atom to another one.
1\textsuperscript{st} Period: 2 elements

\textsuperscript{1}H, Z = 1, 1p\(^+\), 1e\(^-\) - one electron only, which is a \textit{valence electron} \(\text{H}\).

\textsuperscript{2}He, Z = 2, 2p\(^+\), 2e\(^-\) - total, both at the same (1\textsuperscript{st}) SHELL. \(\text{He}\): a noble gas, incapable to combine with anything, i.e. its e\(^-\) shell of 2 is stable, complete.

H. atom needs one more e\(^-\) to complete its el. shell. That can be achieved by \textit{sharing} e\(^-\) with some other atom, e.g. another H.

\(\text{H.} + \cdot\text{H} \rightarrow \text{H : H} \) or \(\text{H – H} \) or \(\text{H}_2\)
In H\textsubscript{2} molecule, each H atom has 2 electrons, the molecular orbital thus formed due to overlap of two atomic orbitals is complete, similar to He atom.

*LEWIS DOT formulas* of elements: Symbol with dots denoting *VALENCE ELECTRONS* only.

H· He: Mg: ·B:
2\textsuperscript{nd} Period: 8 elements

- $^3\text{Li}$, $Z=3$, $3p^+$, $3e^-$
- $^4\text{Be}$, $Z=4$, $4p^+$, $4e^-$
- $^5\text{B}$, $Z=5$, $5p^+$, $5e^-$
- $^6\text{C}$, $Z=6$, $6p^+$, $6e^-$
- $^7\text{N}$, $Z=7$, $7p^+$, $7e^-$
- $^8\text{O}$, $Z=8$, $8p^+$, $8e^-$
- $^9\text{F}$, $Z=9$, $9p^+$, $9e^-$
- $^{10}\text{Ne}$, $Z=10$, $10p^+$, $10e^-$

All have 2 core electrons & 1 valence $e^-$

& 2 $e^-$

& 3 $e^-$

& 4 $e^-$

& 5 $e^-$

& 6 $e^-$

& 7 $e^-$

& 8 $e^-$

Lewis dot formula indicates the number of valence electrons
Noble gas  Neon, Ne has 8 valence $e^-$, a stable OCTET. No rxns are possible. Non-metals of the same period share electrons with other non-metals to complete such an octet:

\[ \cdot F\cdot + \cdot F\cdot \rightarrow \text{F:F} \quad \text{or} \quad |\text{F-F}| \]

\[ \cdot F\cdot + \cdot H \rightarrow H:\cdot F\cdot \quad \text{or} \quad H-F \]

\[ H\cdot + :\ddot{O}: + \cdot H \rightarrow H:\ddot{O}:H \quad \text{or} \quad H-O-H \]

needs 2 more $e^-$ to complete octet
Shared electron pair is a **COVALENT BOND**

One shared pair is **SINGLE BOND**.

More than one pair can be shared, giving **DOUBLE** or **TRIPLE** bonds.

\[ \text{:N: + :N: → :N≡N:} \]

One atom can form more than one covalent bond to complete the octet.

\[ \text{:Ö: + :C: + :Ö: → :Ö=C=Ö:} \]
3\textsuperscript{rd} Period

Starts with Na\textsuperscript{•} similar to Li\textsuperscript{•} above it.

This is the meaning of **PERIODICITY**, i.e. repetition of properties in PERIODS of 8 elements.

Then again, the outer shells of other elements of the 3\textsuperscript{rd} Period repeat those above them in each Group, i.e. they have the same Lewis formulas:
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<tr>
<th>I</th>
<th>II</th>
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<th>VI</th>
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**Representative Elements**
Since all the elements in a **GROUP** have the same number of valence electrons, they all behave alike when combine with other elements. Therefore, the formulas of their analogous compounds are similar:

Ionic Compounds (metal-nonmetal):

<table>
<thead>
<tr>
<th>I</th>
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<th>III</th>
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<tbody>
<tr>
<td>LiCl, Li₂O</td>
<td>BeF₂, BeO</td>
<td>BF₃, B₂O₃</td>
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<tr>
<td>NaCl, Na₂O</td>
<td>MgF₂, MgO</td>
<td>AlF₃, Al₂O₃</td>
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<td>KCl, K₂O</td>
<td>CaF₂, CaO</td>
<td>GaF₃, Ga₂O₃</td>
</tr>
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<td>CsCl, Cs₂O</td>
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<td>TlF₃, Tl₂O₃</td>
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Molecular Compounds (2 non-metals):

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<td>SbH₃</td>
<td>SnH₄</td>
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POLAR vs. NON-POLAR BONDS
When 2 atoms of the same element form a bond, electrons are shared equally:

\[
\begin{align*}
H-H & \quad F-F & \quad Cl-Cl & \quad N≡N \\
\end{align*}
\]
These bonds are nonpolar

When elements are different, electrons may be shared unequally – shifted towards one of them considered MORE ELECTRONEGATIVE

\[
\begin{align*}
\text{H : F :} & \quad \text{or} \quad H \quad \xrightarrow[]{} \quad F & \quad \text{or} \quad H - F
\end{align*}
\]
Those bonds are polar
Electronegativity: ability of element to attract electrons in a compound with another element

In Periodic Table, more electronegative elements stand to the TOP & RIGHT

Most electronegative is fluorine, F
### Periodic Table: Electronegativity

<table>
<thead>
<tr>
<th>Period</th>
<th>Group</th>
<th>Elements</th>
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<td>I</td>
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<td>H 2.1</td>
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<td>II</td>
<td></td>
<td>Li 0.98  Be 1.57</td>
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<tr>
<td>III</td>
<td></td>
<td>Na 0.93  Mg 1.31</td>
</tr>
<tr>
<td>IV</td>
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<td>K 0.82   Ca 1  Sc 1.36 Ti 1.54 V 1.63 Cr 1.66 Mn 1.55 Fe 1.83 Co 1.88 Ni 1.91 Cu 1.9  Zn 1.65 Ga 1.81 Ge 2.01 As 2.18 Se 2.55 Br 2.96 Kr 0</td>
</tr>
<tr>
<td>V</td>
<td></td>
<td>Rb 0.82  Sr 0.95 Y 1.22 Zr 1.33 Nb 1.6 Mo 2.16 Te 1.9 Ru 2.2 Rh 2.28 Pd 2.2 Ag 1.93 Cd 1.69 In 1.78 Sn 1.96 Sb 2.05 Te 2.1 I 2.66 Xe 2.6</td>
</tr>
<tr>
<td>VI</td>
<td></td>
<td>Cs 0.79  Ba 0.89 La 1.1 Hf 1.3 Ta 1.5 W 2.36 Re 1.9 Os 2.2 Ir 2.2 Pt 2.28 Au 2.54 Hg 2  Tl 2.04 Pb 2.33 Bi 2.02 Po 2  At 2.2 Rn 0</td>
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<tr>
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*Ce 1.12 Pr 1.13 Nd 1.14 Pm 1.13 Sm 1.17 Eu 1.2 Gd 1.2 Tb 1.1 Dy 1.22 Ho 1.23 Er 1.24 Tm 1.25 Yb 1.1 Lu 1.27

~Th 1.3 Pa 1.5 U 1.38 Np 1.28 Pu 1.3 Am 1.3 Cm 1.3 Bk 1.3 Cf 1.3 Es 1.3 Fm 1.3 Md 1.3 No 1.3 Lr