Topic 3: Periodicity

3.1 Periodic Table

Understanding (Learning Objectives):

- The periodic table is arranged into four blocks associated with the four sublevels— s, p, d, and f.
- The periodic table consists of groups (vertical columns) and periods (horizontal rows).
- The period number (*n*) is the outer energy level that is occupied by electrons.
- The number of the principal energy level and the number of the valence electrons in an atom can be deduced from its position on the periodic table.
- The periodic table shows the positions of metals, non-metals and metalloids.

1. Groups, Periods and s, p, d f Blocks

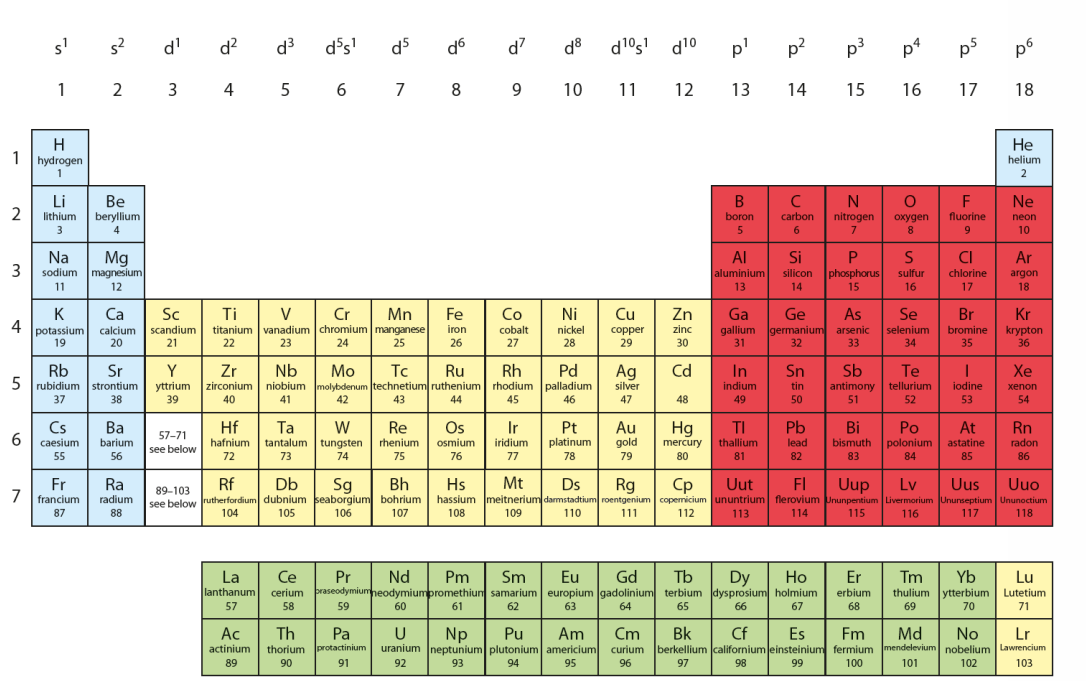
Group: Vertical Columns

Period: Horizontal Rows

由于 Periodic Table 是根据 Atomic Number（与电子数相同）排的，可以从 table 里面快速获取它的 spd arrangement.

[这里注意一下 Cr 和 Cu 所在的 group，这就是我们所说的 exception]

【参考如下，两边突出的分别是 s 和 p，中间凹进去的是 d block】



Number of Period → The outer energy level (n) occupied by electrons

e.g. K 位于 Period 4, 所以它要排到第四层 energy level, 也就是 $4s^1$

2. Positions of Metals, non-metals, metalloids……

Group 1: Alkali Metals （碱金属，你会在很多碱中看见，比如 KOH，NaOH）

Group 2: Alkali Earth Metals （碱土金属，在土里比较常见）

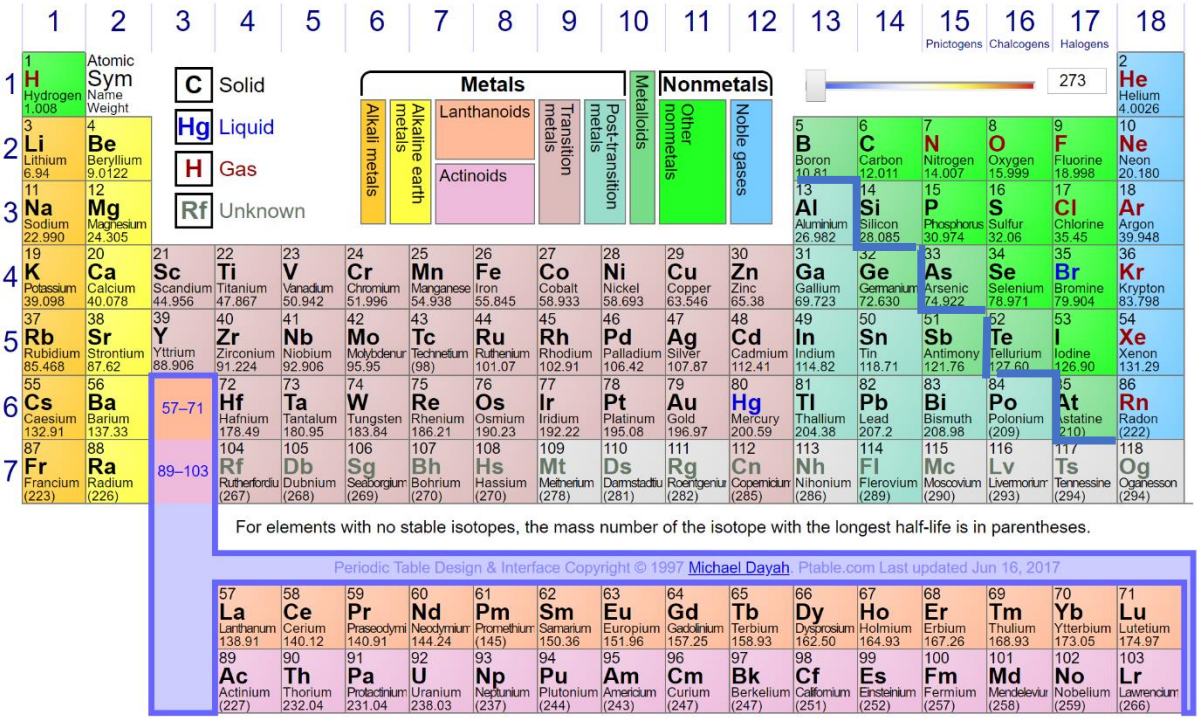
Group 3-12: Transition Metals （过渡金属，正好对应 d block）

Group 17: Halogens （卤素）

Group 18: Noble Gases （稀有气体）

下面两行（f block）的 first row：Lanthanoids（镧系）

Second row: Actinoids （锕系，带有放射性，所以 U 在那里）



如图，中间一条是 non-metal 和 metal 的分界线

Metalloids 位于这条线的左右（上下）两边，左边 2 个，右边→_→5 个

3.1 Practice Questions

2017 Nov. HL PP1 Q7

Which electron configuration is that of a transition metal atom in the ground state?

A. $[Ne]3s^23p^64s^1$

B. $[Ar]3d^9$

C. $1s^22s^22p^63s^23p^64s^23d^{10}4p^2$

D. $[Ar]4s^13d^5$

选 D，一是 transition metal belongs to d block,二是 energy level 中 4s 在 3d 之前。

3.2 Periodic Trends

Understanding (Learning Objectives):

• Vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity.

• Trends in metallic and non-metallic behavior are due to the trends above.

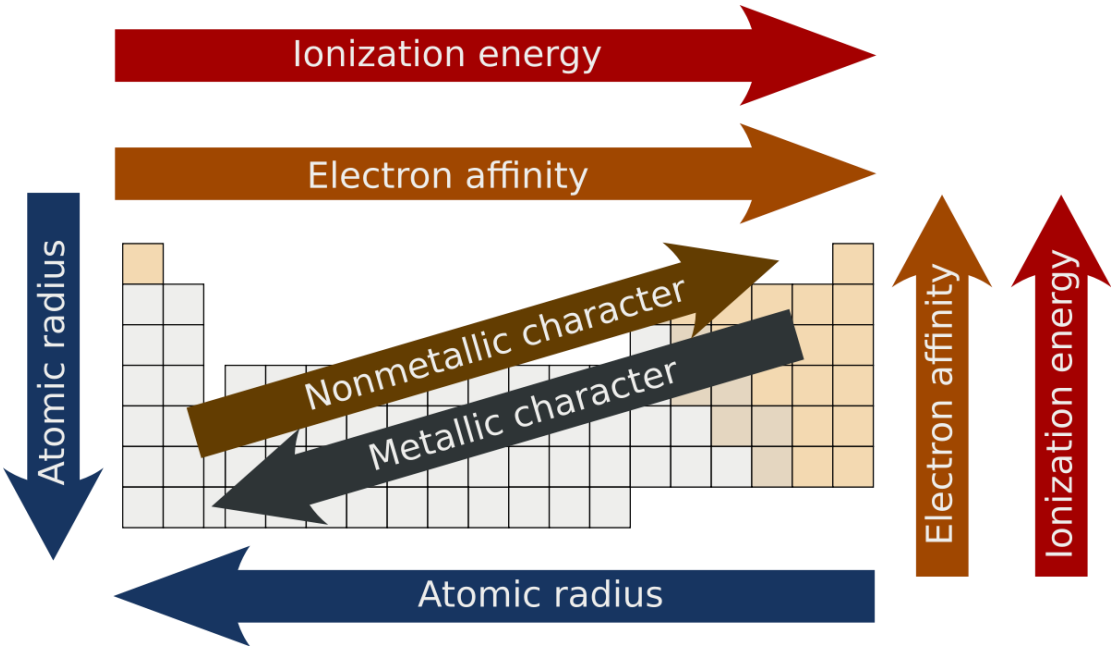
• Oxides change from basic through amphoteric to acidic across a period.

0. Definitions

First Ionization Energy: the energy required to remove one mole of electrons from the elements' gaseous state in their ground state.

First Electron Affinity: the energy change when one mole of electrons is added to one mole of gaseous atoms to form one mole gaseous ions.

1. Trends Overview



1.1 General Trends

The Biggest Atomic Radius at the bottom left corner

The largest electron affinity and ionization energy at the upright corner

(atomic radius 最大值出现在左下角，相反，electron affinity 和 ionization energy 最大值出现在右上角。)

1.2 Ionic Radius

+ ions < atom: loss of electrons

- ions > atom: gain electron → repulsion between the electrons

2. Explanation on General Periodic Trends

Across the Period

Atomic Radius （吸引力越大，距离越近）

1. Increasing nuclear charge
2. Electrons are added to same energy level

接下来就可以用 atomic radius 来解释了

(1^{st}) Electron Affinity and Ionization Energy

1. Decreased atomic radius (和 increased electrostatic attraction 一个道理)
2. Same energy level (和 shielding effects 一个道理)

Down the Group

Atomic Radius

1. Increased energy level
2. Increased shielding effects

Electron Affinity

1. Increased atomic radius
2. The electrostatic attraction is weaker

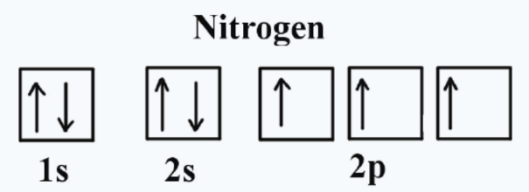
Ionization Energy

1. Increased energy level
2. Increased shielding effects

3. Exceptions and explanations

3.1 First Ionization Energy

3.1.0 Valence Shell Stability 理论



在最外层 s, p, d shell 当中：

最稳定的是 full shell, s^2, p^6, d^{10} 这种

其次稳定的是 half shell, 因为第二单元学的 Hund's Rule 告诉我们电子是先要 occupy 一个空 box 的。所以指的是 s^1,p^3, d^5 这种

3.1.1 Drops from Be to B and Mg to Al

Be 是 $2s^2$, 它已经是 full s shell 了，所以从它这里拿走 electron 相比 B 更不容易

同理 Mg 是 $3s^2$，相比 Al 来说需要更多的 energy

3.1.2 Drops from N to O and P to S

N 是 $2p^3$，P 是 $3p^3$，属于 half shell 的情况

官方表述：N has the electron configuration $2p^3$ which is more stable than O, so it requires more energy to remove one electron from its gaseous atom.

3.2 Electron Affinity

3.2.1 Gap for He, Ne and Ar （Group 18）

这是来源于 Group 17 和 Group 1 的巨大差值

Group 17 atoms have incomplete energy level (+7) to attract the electron most.

Group 1 atoms have +1 charge to attract the electron least.

3.2.2 Drop from Li to Be and Jump from N to O

这个对应着之前的 Hund's Rule，但在这里由于 Half Shell，electron 必须要被加进一个已经占了一个 shell 里，所以已有的 electron 会对新加进来的产生 repulsion。

官方表述：As the electron must be added to the occupied shell, the attraction between the nucleus and electrons will be less than expected as the repulsion between electrons.

3.2 Practice Questions

2015 May PP2 TZ1 Q6 b

b. Explain why the atomic radius of elements decreases across the period.

b. increasing nuclear charge/increasing number of protons / increased attraction of (valence) electrons to nucleus;

electrons added are in same (outer) energy level;

2010 May PP2 TZ2 Q5 b

b. (i) Define the term *first ionization energy* of an atom.

(ii) Explain the general increasing trend in the first ionization energies of the period 3 elements, Na to Ar.

(iii) Explain why sodium conducts electricity but phosphorus does not.

b. (i) energy/enthalpy change/required/needed to remove/knock out an electron (to form +1/uni-positive/M^{+1} ion);

in the gaseous state;

*Award **[1]** for* $M(g) \rightarrow M^{+}(g) + e^{-}$.

*Award **[2]** for* $M(g) \rightarrow M^{+}(g) + e^{-}$ *with reference to energy/enthalpy change.*

(ii) increasing number of protons/atomic number/Z/nuclear charge;

radius/size decreases / same shell/energy level / similar shielding/screening (from inner electrons);

No mark for shielding/screening or shielding/screening increases.

(iii) *Na:* delocalized electrons / mobile sea of electrons / sea of electrons free to move;

2009 May PP2 TZ1 Q5 b

b.i. Define the term *first ionization energy* and state what is meant by the term *periodicity*.

b.ii. State the electron arrangement of argon and explain why the noble gases, helium, neon and argon show the highest first ionization energies for their respective periods.

b.iii. A graph of atomic radius plotted against atomic number shows that the atomic radius decreases across a period. Explain why chlorine has a smaller atomic radius than sodium.

b.iv. Explain why a sulfide ion, S^{2-}, is larger than a chloride ion, Cl^{-}.

b.i. first ionization energy: $\mathrm{M(g) \rightarrow M^{+}(g) + e^{-}}$ / e / the (minimum) energy (in $\mathrm{kJ\,mol^{-1}}$) to remove one electron from a gaseous atom / the energy required to remove one mole of electrons from one mole of gaseous atoms;

periodicity: repeating pattern of (physical and chemical) properties;

b.ii 2.8.8/sp version;

Accept any two of the following:

the outer energy level/shell is full;

the increased charge on the nucleus;

great(est) attraction for electrons;

b.iii 17 p in Cl nucleus attract the outer level more than 11 p in Na nucleus / greater nuclear charge attracts outer level more;

Allow converse for Na.

Do not accept larger nucleus.

b.iv $\mathrm{S^{2-}}$ has one proton less/ smaller nuclear charge so outer level held less strongly / *OWTTE*;

2011 May PP2 Q5 a(ii)

a.ii. Explain why the first ionization energy of magnesium is higher than that of sodium.

a.ii. greater positive charge on nucleus / greater number of protons / greater core charge;

greater attraction by Mg nucleus for electrons (in the same shell) / smaller atomic radius;