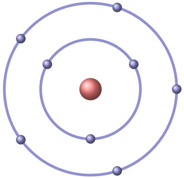
Atomic Structure and Properties

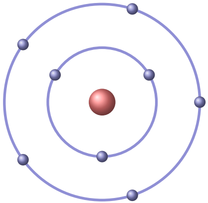
AP Chemistry ▪ Unit 1

AP Chemistry



What we will cover

1. Moles and molar mass
2. Mass spectra and isotopes
3. Formulas and mixtures
4. Electron configuration
5. Photoelectron spectroscopy
6. Periodic trends
7. Ionic compounds



1 Moles

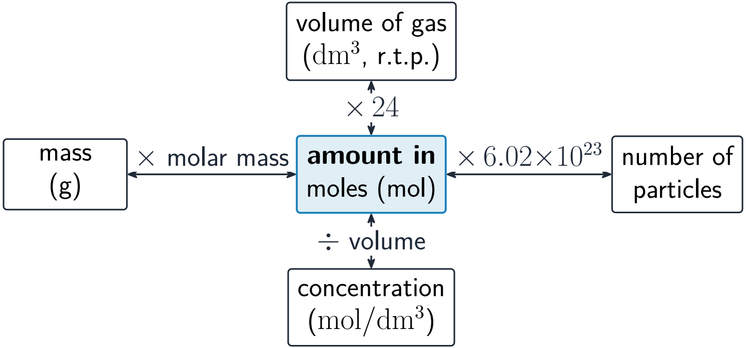
Moles and molar mass

The **mole** 摩尔 bridges grams (what we weigh) and particles (what a reaction sees):

mass m (g) $\xrightarrow{\div M}$ **moles** n (mol) $\xrightarrow{\times N_A}$ **particles** N

$N_A = 6.022 \times 10^{23}$; $n = \dfrac{m}{M}$. $36.0\,\mathrm{g}$ of water $= 2.0\,\mathrm{mol} = 1.2 \times 10^{24}$ molecules.

The mole is the hub



> The mole is the hub: convert between mass, particles, gas volume, and concentration

2 Mass spectra

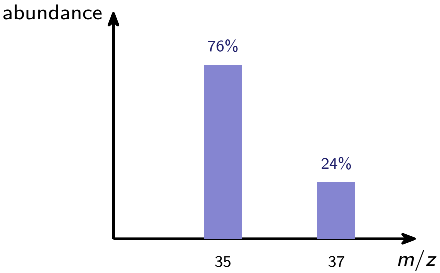
Mass spectra and isotopes

Isotopes 同位素 share protons but differ in neutrons – so in mass. A **mass spectrometer** 质谱仪 sorts them.

Average atomic mass

$$\overline{m} = \sum(\text{mass} \times \text{abundance})$$

Cl: $0.758(35) + 0.242(37) = 35.45$ – the taller bar pulls the average toward it.



3 Formulas & mixtures

Formulas and mixtures

Empirical formula recipe

percent $\rightarrow$ mass $\rightarrow$ mole $\rightarrow$ divide by small $\rightarrow$ multiply til whole

40%C, 6.7%H, 53.3%O $\Rightarrow$ $1{:}2{:}1$ $\Rightarrow$ **empirical formula** 实验式 CH_2O.

Molecular formula 分子式 $=$ a whole-number multiple of the empirical one.

A **mixture** 混合物 has variable composition; a **compound** 化合物 is fixed.

- **homogeneous** 均相混合物 – uniform (a solution)
- **heterogeneous** 非均相混合物 – visibly different parts

Molarity

$$c = \frac{n}{V} \quad \left(\frac{\text{mol}}{\text{L}}\right)$$

4 Electron configuration

Atomic structure and electron configuration

Electrons fill **subshells** 亚层 s, p, d, f (holding $2, 6, 10, 14$) by three rules:

- **Aufbau** 构造原理 – lowest energy first
- **Pauli** 泡利不相容原理 – 2 per orbital, opposite spin
- **Hund** 洪特规则 – spread out singly before pairing

Iron, $Z = 26$

$$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^6$$
$$= [\mathrm{Ar}]\,4s^2\,3d^6$$

The outer **valence electrons** 价电子 drive bonding – so a column shares chemistry.

5

PES

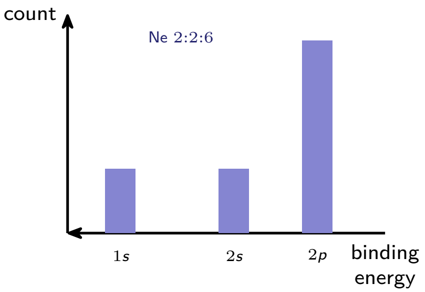
Photoelectron spectroscopy

PES 光电子能谱 measures how tightly each electron is held:

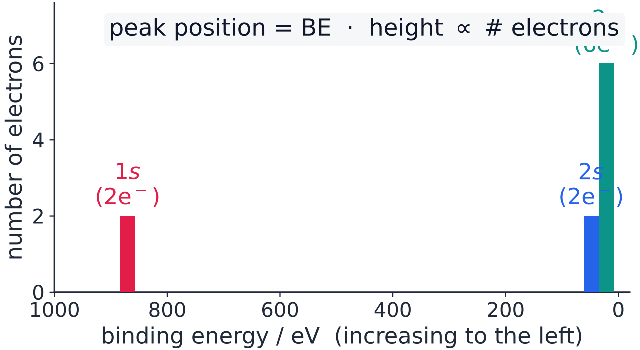
Binding energy

$$\text{BE} = \text{photon} - KE_{\text{electron}}$$

- each peak = one subshell (left = held tightest)
- peak height = number of electrons



The photoelectron spectrum of neon: one peak – one



The photoelectron spectrum of neon: one peak per subshell, height set by electron count

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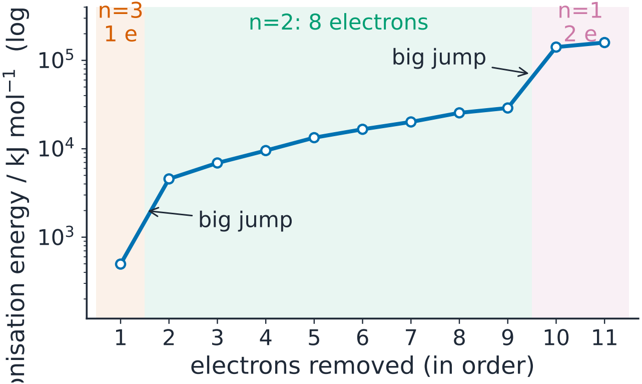
The photoelectron spectrum of neon: one peak – two



Successive ionisation energies reveal the shell structure through big jumps

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6 Periodic trends

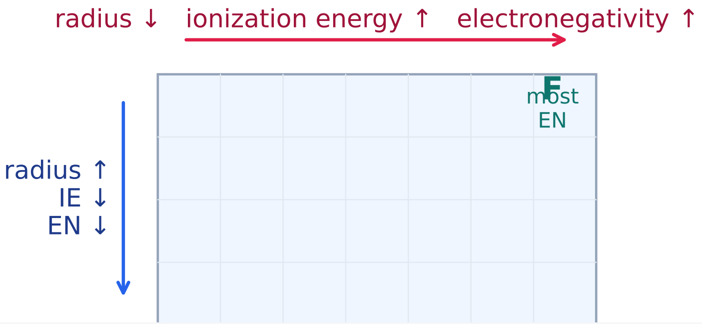
Periodic trends

Trends trace a tug-of-war: **effective nuclear charge** 有效核电荷 vs **shielding** 屏蔽.

- **atomic radius** 原子半径: down across, up a group
- **ionization energy** 电离能: up across, down a group
- **electronegativity** 电负性: up across (F is highest)

Flame colors reveal electron structure

Periodic trends: how radius



across a period: Z_{eff} rises (more protons, same shell) → smaller, harder to ionize

Periodic trends: how radius, ionization energy, and electronegativity change across and down

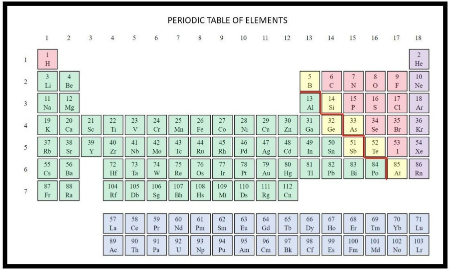
7 Ionic compounds

Valence electrons and ionic compounds

Main-group atoms chase a full **octet** 八隅规则:

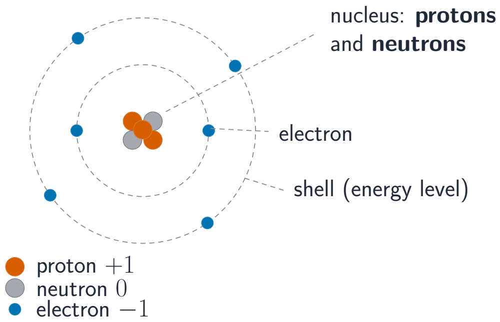
- **metals** 金属 lose electrons → cations
- **nonmetals** 非金属 gain them → anions

> An **ionic bond** 离子键 is the **Coulomb** 库仑定律 pull; higher charge + smaller ions ⇒ stronger **lattice energy** 晶格能 ($MgO \gg NaCl$).



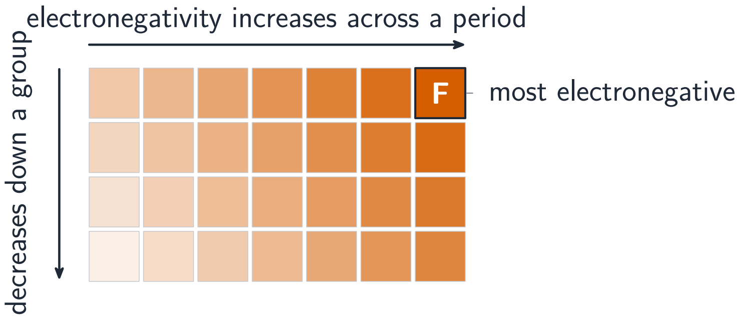
Trends follow the table's structure

Atomic Structure and Electron Configuration, continued



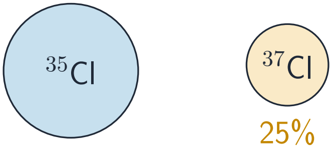
An atom: a tiny nucleus of protons and neutrons, with electrons in shells

Periodic Trends, continued



Electronegativity rises across a period and falls down a group

Mass Spectra of Elements



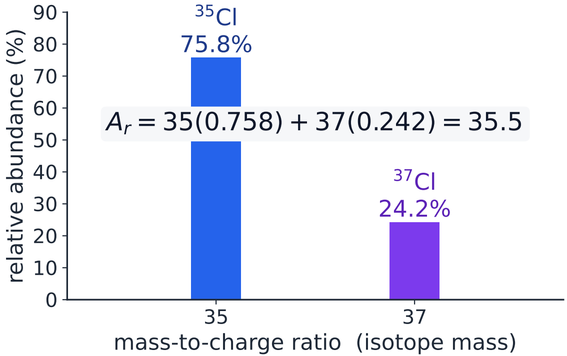
$A_r = 35.5$

closer to the common isotope

$$A_r = \frac{(35 \times 75) + (37 \times 25)}{100} = 35.5$$ - a **weighted average** by abundance

> Relative atomic mass is the abundance-weighted average of the isotopes

The mass spectrum of chlorine



The mass spectrum of chlorine: two isotopes with different abundances

Elemental Composition of Pure Substances

The **percent composition 百分组成** of a compound is each element's mass fraction.

> From it you find the **empirical formula 实验式** (simplest whole-number ratio of atoms) by converting each element's mass to moles and dividing by the smallest.

Finding the empirical formula

element	% by mass	$\div A_r \to$ moles	$\div$ smallest (3.33)	ratio
C	40.0	$40.0/12 = 3.33$	1.0	1
H	6.7	$6.7/1 = 6.7$	2.0	2
O	53.3	$53.3/16 = 3.33$	1.0	1

empirical formula CH_2O - if $M_r = 180$, it fits $180/30 = 6$ times: molecular formula $C_6H_{12}O_6$

Finding the empirical formula: mass to moles, divide by the smallest, read the ratio

Exam tips

- Use the mole as the hub: convert grams↔moles with $n = m/M$ and moles↔particles with Avogadro's number.
- Relative atomic mass is the **abundance-weighted average** of the isotopes – it lies closer to the more abundant one, not halfway.
- For an **empirical formula**, turn each element's mass into moles and divide by the smallest; scale up to whole numbers.
- Read **periodic trends** from nuclear charge and shielding: atomic radius decreases across a period, ionisation energy and electronegativity increase across (and up).
- Fill electron configurations in energy order; the outer **valence electrons** control the chemistry.

8 Recap

Unit 1 – key takeaways

1 Moles

$N_A = 6.022 \times 10^{23}$; $n = m/M$; $c = n/V$

2 Spectra

isotopes give a weighted-average mass; PES: peak = subshell

3 Configuration

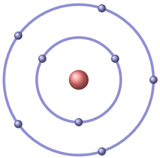
s, p, d, f by Aufbau/Pauli/Hund; valence drives chemistry

4 Trends

radius down across, IE/EN up; ionic bonds by Coulomb

Check yourself

1. How many moles are in $18\,\mathrm{g}$ of water ($M = 18$)?
2. In a PES spectrum, what does a peak's height tell you?
3. Across a period, does atomic radius rise or fall?
4. Na^{+} and O^{2-} – what is the formula of the compound?



Answers **1.** $1.0\,\mathrm{mol}$ **2.** the number of electrons in that subshell **3.** it falls **4.** Na_2O