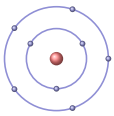
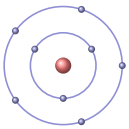
Atomic Structure and Properties

AP Chemistry ▪ Unit 1

AP Chemistry



What we will cover



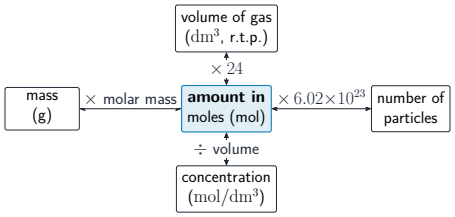
1 Moles

Moles and molar mass

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

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

The mole is the hub



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

2 Mass spectra

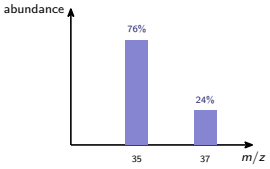
Mass spectra and isotopes

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

Average atomic mass

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

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 → mass → mole → divide by small → multiply til whole

40%C, 6.7%H, 53.3%O ⇒ 1:2:1 ⇒ **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, $Z = 26$

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

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

5 PES

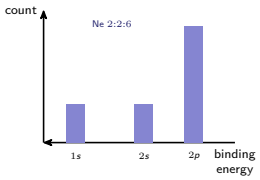
Photoelectron spectroscopy

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

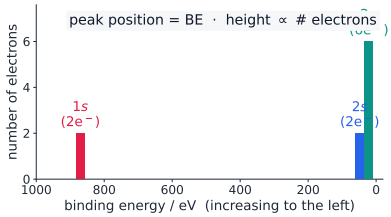
Binding energy

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

- 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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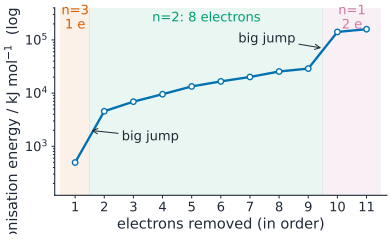
The photoelectron spectrum of neon: one peak – two



Successive ionisation energies reveal the shell structure through big jumps

Successive ionisation energies reveal the shell structure through big jumps

6 Periodic trends

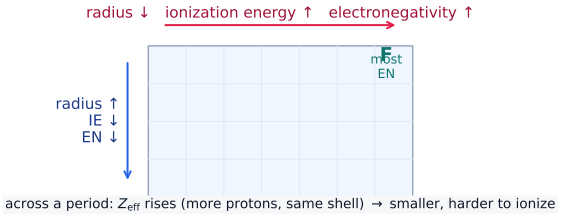
Periodic trends

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



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

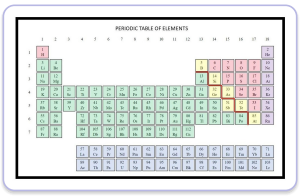
7 Ionic compounds

Valence electrons and ionic compounds

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

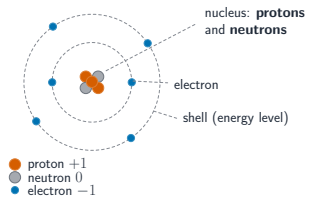
- **metals** 金属 lose electrons → cations
- **nonmetals** 非金属 gain them → anions

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



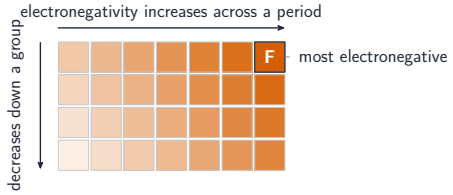
Trends follow the table's structure

Atomic Structure and Electron Configuration, continued



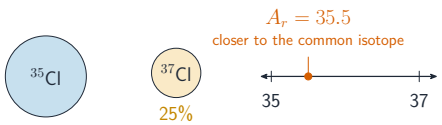
An atom: a tiny nucleus of protons and neutrons, with electrons in shells

Periodic Trends, continued



Electronegativity rises across a period and falls down a group

Mass Spectra of Elements

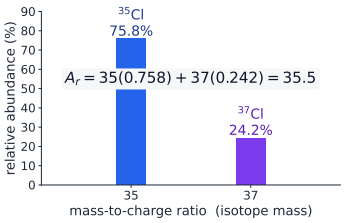


75%

$$A_r = \frac{(35 \times 75) + (37 \times 25)}{100} = 35.5$$ - 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 ÷ A_r → moles	÷ 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

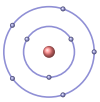
s, *p*, *d*, *f* by Aufbau/Pauli/Hund; valence drives chemistry

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