VC210 FALL2018 RECITATION CLASS

Quiz 1 Review

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Outline

1. Quantum Mechanics

2. Atoms

Quantum Mechanics

Investigating Atoms

$$
\begin{cases}
\text{J.J.Thomson} \rightarrow \text{“cathod rays”} \rightarrow \text{electrons} + e/m_e \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad \searrow \\
\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \text{"plum pudding" model} \\
\text{Robert Milliken} \rightarrow \text{oil-drop experiment} \rightarrow e + m_e \\
\text{Ernest Rutherford} \\
\qquad\qquad \searrow \\
\qquad\qquad \text{“}\alpha\text{ particles” experiment} \\
\qquad\qquad\qquad \downarrow \\
\qquad\qquad \text{nuclear model} \begin{cases} \text{nucleus} \begin{cases} \text{proton} \\ \text{neutron} \end{cases} \Rightarrow \text{mass} \\ \\ \text{electrons} \qquad\qquad\quad \Rightarrow \text{volume} \end{cases}
\end{cases}
$$

Quantum Mechanics

Spectrum

$$
\begin{cases}
\text{electromagnetic radiation:} \quad c = \lambda\nu \begin{cases} \text{infrared light: } \lambda > 700nm \\ \text{visible light: } 400nm < \lambda < 700nm \\ \text{ultraviolet light: } \lambda < 400nm \end{cases} \\
\text{atomic spectra} \begin{cases} \text{spectrum} \rightarrow \text{absorption spectrum} \\ \qquad\qquad \begin{cases} \text{white light} \rightarrow \text{continuous spectrum} \\ \text{emitted light} \rightarrow \text{discrete spectrum(spectral lines)} \end{cases} \\ \nu = R\left\{\dfrac{1}{n_1} - \dfrac{1}{n_2}\right\} \quad R = 3.29 \times 10^{15}\text{Hz} \begin{cases} \text{Balmer series: } n_1 = 2, n_2 \geq 2 \\ \text{Lyman series: } n_1 = 1, n_2 \geq 1 \end{cases} \\ \text{explanation: energy levels \& transition} \end{cases}
\end{cases}
$$

Quantum Mechanics

Quantum Theory

black body: absorb all incident electromagnetic radiation;

$\Downarrow$ idealized absorber & emitter

black-body radiation: T $\uparrow \rightarrow$ intensity of all wavelength $\uparrow$

$\Downarrow$ $\searrow$ peak moves toward shorter wavelength(higher frequency)

quanta(the smallest unit/packet of energy transfer): $E = h\nu \quad h = 6.626 \times 10^{-34}$ J·s

$\searrow$

photonics:

$$\begin{cases} E = h\nu \\ m = \dfrac{h\nu}{c^2} \\ p = mc = \dfrac{h\nu}{c} = \dfrac{h}{\lambda} \end{cases}$$

light intensity is determined by the number of photons in the unit volume i.e. "photon density".

$\nearrow$

photoelectric effect: $h\nu = \Phi + \frac{1}{2}mv^2 = h\nu_0 + \frac{1}{2}mv^2 \quad \nu_0 =$ "threshold frequency"

Quantum Mechanics

Wave-particle Duality of Matter

Wave-particle Duality : $p = \frac{h}{\lambda}$

physical particles

$$\begin{tikzcd}
\lambda \arrow[rr, leftrightarrow, "p = \frac{h}{\lambda}"] \arrow[d, leftrightarrow, "\lambda = \frac{u}{\nu}"'] & & p = mv \arrow[d, leftrightarrow, "E = \frac{p^2}{2m}"] \\
\nu \arrow[rr, leftrightarrow, "E = h\nu"'] & & E
\end{tikzcd}$$

photons

$$\begin{tikzcd}
\lambda \arrow[rr, leftrightarrow, "p = \frac{h}{\lambda}"] \arrow[d, leftrightarrow, "\lambda = \frac{c}{\nu}"'] & & p = mc \arrow[d, leftrightarrow, "E = pc"] \\
\nu \arrow[rr, leftrightarrow, "E = h\nu"'] & & E
\end{tikzcd}$$

Note

u is the speed of **particle wave**, neither the speed of particles(v) nor the speed of light(c).

$$E = h\nu = h\frac{u}{\lambda} = pu = mvu = \frac{1}{2}mv^2 \quad \Rightarrow \quad u = \frac{v}{2}$$

Quantum Mechanics

Uncertainty Principle

Heisenberg Uncertainty Principle

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

Usually:

$$\Delta p = m \Delta v$$

Quantum Mechanics

Wavefunctions and Energy level

Wavefunctions ψ

Eigenfunctions that solve Schrödinger equation.
ψ^2 is the **probability density**, which means $\int_{\mathbb{R}^3} \psi^2 d\tau = 1$.
Nodes: wherever ψ passes through 0.

Schrödinger equation

$H\psi = E\psi$ whose solution is the wavefunction and the energy of the system.

Particle in a box

$$E = \frac{n^2 h^2}{8mL^2}$$

Zero-point energy the lowest energy in a quantized system E(n=1). (Not 0!)

Atoms

Quantum Numbers

TABLE 1D.2 Quantum Numbers for Electrons in Atoms

Name	Symbol	Values	Specifies	Indicates
principal	n	$1, 2, \ldots$	shell	size
orbital angular momentum*	l	$0, 1, \ldots, n-1$	subshell: $l = 0, 1, 2, 3, 4, \ldots$ s, p, d, f, g, ...	shape
magnetic	m_l	$l, l-1, \ldots, -l$	orbitals of subshell	orientation
spin magnetic	m_s	$+\frac{1}{2}, -\frac{1}{2}$	spin state	spin direction

The number of orbitals in a shell with principle quantum number n is n^2.
The number of orbitals in a subshell with momentum quantum number l is $2l+1$.

Atoms

Energy Levels

Hydrogen Atom

$$E_n = -\frac{hR}{n^2} \quad \text{with} \quad R = \frac{m_e e^4}{8h^3\epsilon_0^2} = 3.29 \times 10^{15} Hz$$

One-electron atoms

$$E_n = -\frac{Z^2 hR}{n^2} \quad \text{Z is the atomic number}$$

Note

one-electron atoms same n $\Rightarrow$ same energy

many-electron atoms same l $\Rightarrow$ same energy

Atoms

Nodes

Nodes for particle in a box

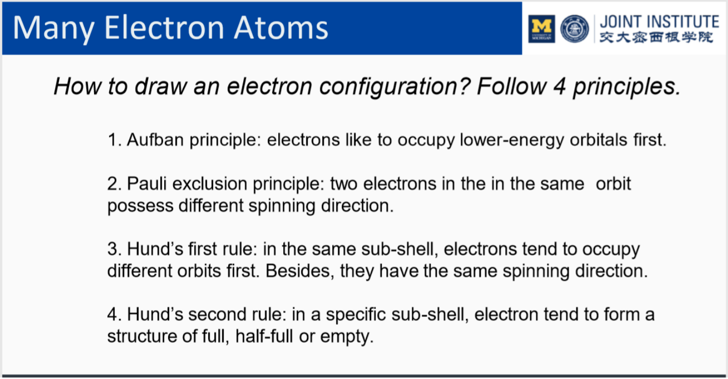
$$n - 1$$

Nodes for Atomic orbitals

- total nodes $\psi = 0$: n-1
- angular nodes(nodal plane) $Y = 0$: l
- radial nodes $R = 0$: n-l-1

Atoms

Many-electron atoms



Aufbau principle:

$$ns < \cdots < (n-3)g < (n-2)f < (n-1)d < np$$

Reference: Wang Yisen.VC210_2018FALL_Wang_Yisen_RC2.page 11.

Atoms
Periodicity

$$\begin{cases} \text{Structure of periodic table} \begin{cases} \text{blocks(s,p,d,ds,f)} \\ \text{periods(1-7)} \\ \text{groups(1-18)(maingroups \& subgroups)} \end{cases} \\ \text{Atomic radius : (generally)} \nearrow \text{decreasing} \\ \text{Ionic radius : (generally) cations/anions:} \nearrow \text{decreasing} \\ \text{Ionization Energy (always + absorbed)} \rightarrow \text{exception: Be \& N} \\ \text{Electron Affinity} \begin{cases} + \text{ released} \\ E_{ea}^{(2)} > 0 \\ E_{ea}^{(2)}(O) > E_{ea}^{(2)}(F) \end{cases} \\ \text{The inert-pair effect (post transition elements)} \\ \text{Diagonal Relationship (Li-Mg, Be-Al, B=Si)} \end{cases}$$

Thank you !