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CHAPTER 7 ATOMIC STRUCTURE

CATHODE RAYS ARE EMITTED FROM THE CATHODE.

REFER TO FIG 7.2 FOR THOMPSON'S EXPERIMENT DETERMINING THE MASS-TO-CHARGE RATIO OF THE ELECTRON

REFER TO FIG. 7.3 FOR MILLIKAN'S OIL DROP EXPERIMENT ESTABLISHING THE CHARGE OF THE ELECTRON

REFER TO FIGURE 7.5 FOR RUTHERFORD'S DISCOVERY OF THE NUCLEUS

ELECTRO MAGNETIC WAVES

REFER TO FIGURE 7.9 FOR A PICTURE OF EM WAVES

WAVE LENGTH - DISTANCE PEAK TO PEAK

FREQUENCY - NUMBER OF CYCLES/SEC = Hz (HERTZ)

SPEED OF LIGHT - 3.0×10^8 M/SEC IN A VACUUM

HIGH ENERGY = HIGH FREQUENCY = SHORT WAVE LENGTH

LOW ENERGY = LOW FREQUENCY = LONG WAVE LENGTH

LINE SPECTRA

ATOMS ABSORB AND EMIT ENERGY AT DISCRETE FREQUENCIES

MANY ELEMENTS WERE FIRST DISCOVERED THIS WAY

REFER TO FIGURE 7.11 AND THE BOX ON PG 272 FOR A DESCRIPTION OF THIS PHENOMENON

CALCULATE THE WAVE LENGTH OF A RADIO WAVE WITH A FREQUENCY OF 90.3 MEGA HERTZ (MH_2) (URI RADIO)

$\lambda \nu = c$ SOLVE FOR λ: $\lambda = \frac{c}{\nu}$

$$\lambda = \frac{3.00 \times 10^{8} \frac{m}{SEC}}{90.3 \times 10^{6} \frac{CYCLES}{SEC}} = 3.3\ M$$

PLANCK'S QUANTUM

IN 1900 MAX PLANCK PROPOSED THAT ENERGY IS QUANTIZED

$E = h\nu$ h = PLANCK'S CONSTANT

$h = 6.626 \times 10^{-34}\ J \cdot s$ THIS IS THE SMALLEST UNIT OF ENERGY

THE PHOTOELECTRIC EFFECT

EINSTEIN EXTENDS THIS QUANTIZATION TO LIGHT SOME METALS EJECT e^- WHEN STRUCK BY LIGHT OF HIGH ENOUGH ENERGY (PHOTONS WORK ALONE)

CALCULATE THE ENERGY OF A PHOTON WITH FREQUENCY OF 90.3 MH_2

$E = h\nu$

$E = 6.626 \times 10^{-34}\ J \cdot S \times 90.3 \times 10^{6}\ S^{-1}$

$E = 5.98 \times 10^{-26}\ J/PHOTON$

ONE MOL OF THESE PHOTONS HAS:

$6.02 \times 10^{23}\ PHTX \quad 5.98 \times 10^{-26}\ J = 3.6 \times 10^{-2}\ J/mol$

BOHR'S PLANETARY MODEL OF THE ATOM

HE SHOWED THAT e^- WERE RESTRICTED TO CERTAIN ENERGY LEVELS: "ORBITS"

THESE ENERGY LEVELS ARE DESCRIBED BY:

$$E_n = -R \times \frac{1}{n^2}$$

R IS THE RYDBERG CONSTANT = 2.18×10^{-18} J

n IS THE PRINCIPAL QUANTUM NUMBER

AN e^- IN THE 1st ORBIT HAS $n=1$. THIS IS THE "GROUND" STATE. IF THIS e^- IS "PROMOTED" IF $n > 1$ WE REFER TO THIS AS AN "EXCITED" STATE

$$\Delta E = E_{FINAL} - E_{INITAL}$$

ABSORPTION = $+\Delta E$

EMISSION = $-\Delta E$

FOR A TRANSITION BETWEEN ENERGY LEVELS:

CALCULATE THE ENERGY CHANGE WHEN AN e^- "FALLS" FROM $n=5$ TO $n=3$

$$\Delta E = -2.18 \times 10^{-18} J \times \left(\frac{1}{5^2} - \frac{1}{3^2}\right) = 2.18 \times 10^{-19} J = -1.55 \times 10^{-19} J$$

WHAT IS THE FREQUENCY OF THIS PHOTON?

$$E = h\nu \qquad \nu = \frac{E}{h}$$

$$\nu = \frac{1.55 \times 10^{-19} J}{6.62 \times 10^{-34} J \cdot s} = 2.34 \times 10^{14} Hz \ (\text{or } s^{-1})$$

PARTICLE/WAVE DUALITY

DE BROGLIE PROPOSED (AT AGE 21) THAT ANY PARTICLE HAS AN ASSOCIATED WAVELENGTH

$$\lambda = \frac{h}{mv}$$

WHAT IS THE WAVELENGTH OF AN e^- WITH A VELOCITY $v = 2 \times 10^6 \text{ m/s}$?

$$\lambda = \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{9.11 \times 10^{-28} \text{ g} \cdot 2 \times 10^6 \text{ m/s}}$$

INCORPORATING THE UNITS $1 \text{ J} = 1 \text{ kg} \frac{\text{m}^2}{\text{s}^2}$

$$\lambda = \frac{6.626 \times 10^{-34} \text{ kg} \cdot \text{m}^2 \cdot \frac{\text{s}}{\text{s}^2}}{9.11 \times 10^{-31} \text{ kg} \cdot 2 \times 10^6 \frac{\text{m}}{\text{s}}}$$

$$\lambda = 3.8 \times 10^{-10} \text{ m OR } 0.4 \text{ nm}$$

HEISENBERG'S UNCERTAINTY PRINCIPLE

WE CANNOT SIMULTANEOUSLY KNOW BOTH THE POSITION AND MOMENTUM OF TINY PARTICLES LIKE e^-

THE PRODUCT OF UNCERTAINTY IN POSITION Δx AND UNCERTAINTY IN MOMENTUM Δp MUST EXCEED A CERTAIN MINIMUM VALUE

$$\Delta x \cdot \Delta p \geq 5.3 \times 10^{-35} \text{ J} \cdot \text{s}$$

QUANTUM NUMBERS AND ATOMIC ORBITALS

THE WAVE FUNCTIONS FOR THE HYDROGEN ATOM CONTAIN PARAMETERS REQUIRING SPECIFIC INTEGER VALUES CALLED QUANTUM NUMBERS

ψ^2 = PROBABILITY OF FINDING AN e^- IN VARIOUS LOCATIONS IN AN ATOM

ψ^1, ψ^2 .... ETC THESE ARE WAVE FUNCTIONS

THEY DESCRIBE ORBITALS

EACH ORBITAL IS A DISTRIBUTION OF e^- IN SPACE, WITH CHARACTERISTIC ENERGY AND SHAPE

WE USE 3 QUANTUM NUMBERS TO DESCRIBE AN ORBITAL

n, ℓ, m_ℓ

- n: PRINCIPAL QUANTUM NUMBER
- ℓ: ANGULAR MOMENTUM QUANTUM NUMBER
- m_ℓ: MAGNETIC QUANTUM NUMBER

$n = 1, 2, 3 \ldots$ POSITIVE INTEGER INDICATES THE SIZE AND ENERGY OF AN ORBITAL
ALSO CALLED "SHELL"

$\ell = 0, 1, \ldots (n-1)$
INDICATES SHAPE OF ORBITAL "SUBSHELL"

ℓ =	0	1	2	3
	s	p	d	f

$m_\ell = 0, \pm 1, \pm 2 \ldots \pm \ell$ INDICATES ORIENTATION IN SPACE

EACH SHELL HAS (n) SUBSHELLS

n				
1	S			
2	S	P		
3	S	P	D	
4	S	P	D	F

EACH SUBSHELL IS DIVIDED INTO ORBITALS

S	HAS	1	ORBITAL
P	HAS	3	ORBITALS
D	HAS	5	ORBITALS
F	HAS	7	ORBITALS

ELECTRON PROBABILITIES

REFER TO FIGURE 7.23-5 FOR A VISUALIZATION OF ORBITALS AND THE PROBABILITY OF FINDING AN e^- ANYWHERE WITHIN AN ORBITAL

REFER TO FIG 7.26-7 FOR SHAPES OF P ORBITALS AND D ORBITALS

ELECTRON SPIN - A 4TH QUANTUM NUMBER

ELECTRONS HAVE A PROPERTY KNOWN AS SPIN

$m_s = \pm 1/2$ SPIN "UP" ↑ SPIN DOWN ↑

REFER TO FIGURE 7.28-8 FOR VISUALIZING SPIN AND THE FAMOUS STERN-GERLACH EXPERIMENT

CHAPTER 7

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