

LECTURE 9  
CHAPTERS 8.6

PHY 100: MATTER WAVES, ATOMS



MIDTERM 1: WEDNESDAY 17<sup>th</sup> HOYT 2 pm

- BRING A CALCULATOR
- I WILL PROVIDE A FORMULA SHEET
- MATERIAL COVERED:
  - LECTURES 1-7
  - RECITATIONS 1-3
  - PROBLEMS 1-4

NO PROBLEM SETS THIS WEEK.

RECITATIONS CONTINUE AS NORMAL

REVIEW SESSION TODAY B&L 208 7.15 pm

RECAP:

MAXWELL'S EQNS  
INTERFERENCE  
DIFFRACTION  
REFRACTION  
DISPERSION

LIGHT IS A WAVE!

BLACKBODY RADIATION  
(PLANCK)  
PHOTOELECTRIC EFFECT  
(EINSTEIN)

LIGHT IS A PARTICLE!

WAVE-PARTICLE DUALITY:



$$c = \lambda f \quad \text{WAVE}$$



$$E = hf \quad \text{PARTICLE}$$

PARTICLES, LIKE ELECTRONS, ARE PARTICLES AND WAVES

$$\lambda = \frac{h}{p} \text{ (DE BROGLIE)}$$

$$p = mv$$

$$h = 6.67 \times 10^{-34} \text{ Js}$$

h IS TINY!

p MUST BE VERY SMALL FOR  $\lambda$  TO BE LARGE

→ ONLY RELEVANT FOR SMALL PARTICLES AT LOW SPEED

WE SAW THAT FOR A BASEBALL  $\lambda = \frac{h}{p} \sim 10^{-34} \text{ m}$

FOR AN ELECTRON:  $m \sim 9 \times 10^{-31} \text{ kg}$   
MOVING SLOWLY  $\sim 1 \text{ eV} \rightarrow v = 596 \text{ m/s}$  }  $p = mv \sim 5 \times 10^{-28} \text{ kg m/s}$

$$\lambda = \frac{6.64 \times 10^{-34}}{5 \times 10^{-28}} = 1.3 \times 10^{-6} \text{ m} \text{ INFRARED.}$$

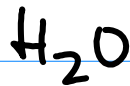
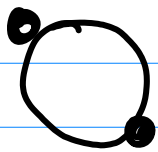
THE FACT PARTICLES BEHAVE LIKE WAVES WAS DEMONSTRATED WHEN A BEAM OF  $e^-$  SHOWED THE SAME INTERFERENCE PATTERN AS LIGHT IN SINGLE AND DOUBLE SLIT EXPS.

## ATOMS

DALTON (1808) : WHEN SUBSTANCES COMBINE TO FORM OTHER SUBSTANCES, THEY COMBINE IN SIMPLE RATIOS BY WEIGHT.

OXYGEN + HYDROGEN = WATER

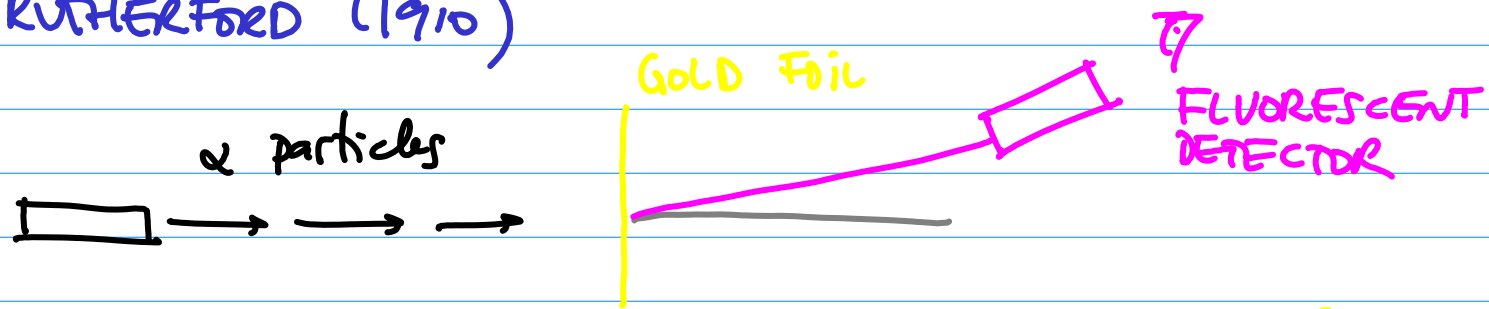
HYDROGEN : OXYGEN = 1 : 8      WEIGHT RATIO



WE KNOW THAT 1 ATOM OF O WEIGHS 16 TIMES MORE THAN 1 ATOM OF H.

"SUBSTANCES" ARE NOT INFINITELY DIVISIBLE.

# RUTHERFORD (1910)



ALL OF THE ATOM MATERIAL IS CONCENTRATED IN ITS CENTER  
= NUCLEUS

SIZE OF ATOM  $\sim 10^{-10}$  m

1 mile

SIZE OF NUCLEUS  $\sim 10^{-14}$  m

6 inches

# BOHR'S MODEL (1912)

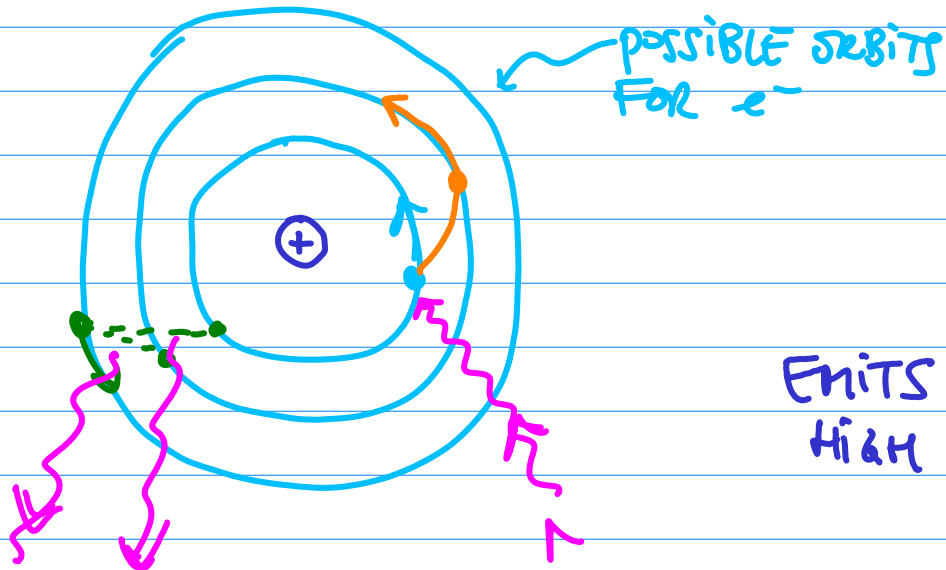
POSITIVE NUCLEUS

$e^-$  ORBIT NUCLEUS IN CIRCLES

NUCLEUS DOESN'T MOVE

$e^-$  ONLY OCCUPY CERTAIN DISCRETE ORBITS.

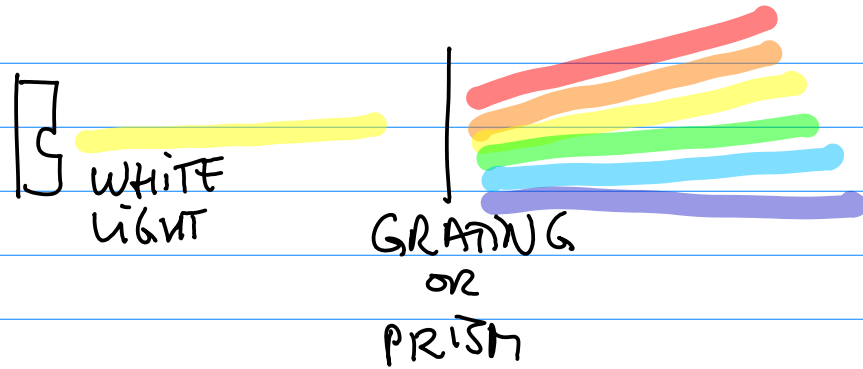
COULOMB FORCE HOLDS  $e^-$  IN ORBIT



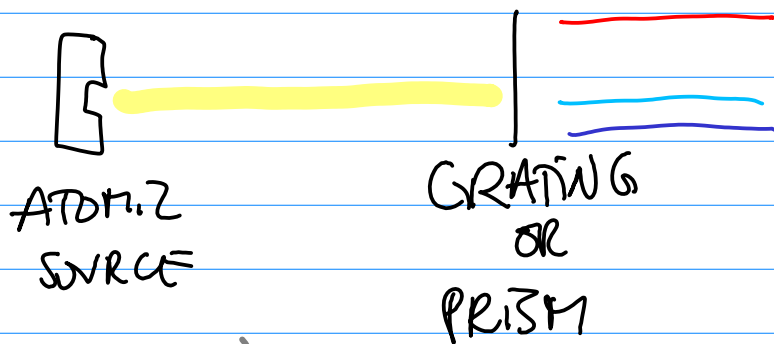
ABSORBS LIGHT:  $e^-$  JUMPS FROM LOW E ORBIT TO HIGHER ORBIT.

EMITS LIGHT:  $e^-$  TRANSITIONS FROM HIGH E TO LOW E ORBIT

# ATOMIC SPECTRA



CONTINUOUS RAINBOW

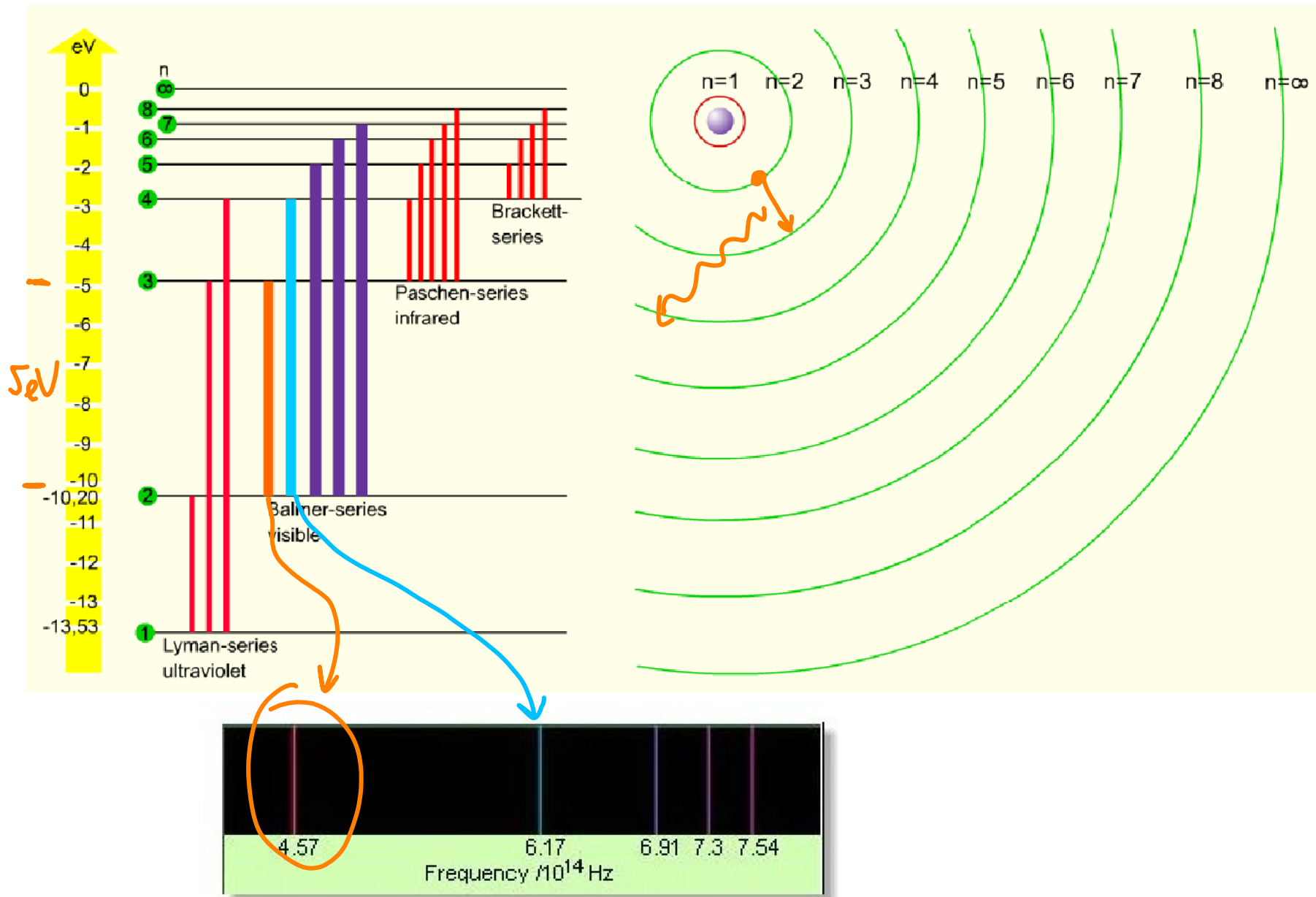


ONLY A FEW DISCRETE COLORS EMITTED

(NEON GAS)  
(FOR EXAMPLE)

COLORS  $\rightarrow$  FREQUENCIES  
( $E = hf$ )

# BALMER SPECTRUM OF HYDROGEN



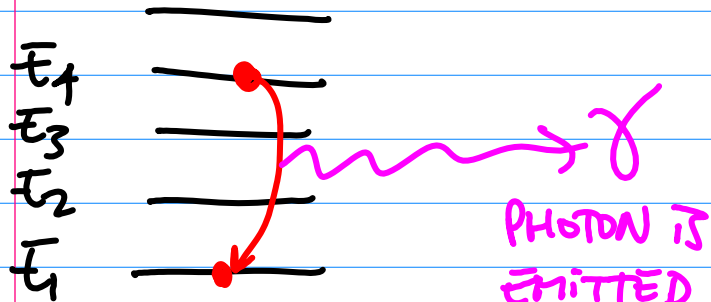
From <http://www.bigs.de/en/shop/anim/termsch01.swf>



BOHR MODEL DESCRIBED SPECTRA WELL

PHOTONS HAVE FIXED ENERGY WHEN EMITTED/ABSORBED  
BY  $e^-$

- E of  $e^-$  IN ORBITS IS DISCRETE



BOHR QUANTIZED ATOMIC ENERGY LEVELS.

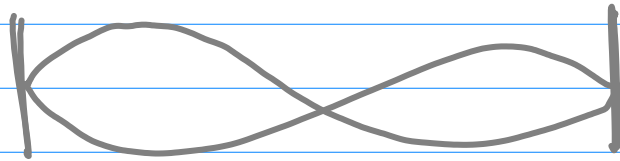
PHOTON IS EMITTED WITH SPECIFIC COLORS:  $f_{\gamma} = \frac{E_4 - E_1}{h}$

PROBLEMS. 1) FORCED THE ORBITS TO BE STABLE....  
NOT UNDERSTANDABLE IN CLASSICAL PHYSICS.

2) COULD NOT EXPLAIN LARGER ATOMS.

SOLUTION: DEVELOPMENT OF TRUE WAVE EQUATION FOR MATTER

DE BROGLIE MATTER-WAVE IDEA MOTIVATES BOHR'S STRANGE DISCRETE ORBITS



STANDING WAVE DEMO.  
INTERFERENCE BETWEEN WAVES  
TRAVELING  $\rightarrow$  AND  $\leftarrow$  CREATE  
RESONANCE  $\Rightarrow$  ONLY FOR FIXED  $\lambda$  OR  $f$ .

ONLY ORBITS WHERE  $\lambda$  OF  $e^-$  IS CORRECT LENGTH  
TO FORM A STANDING WAVE AROUND THE CIRCLE ARE  
STABLE

$\downarrow$   
LEADS TO DISCRETE ORBITS