

STRUCTURE OF MATTER

ATOMIC MODELS: FROM ANCIENT GREECE TO HIROSHIMA



ATOMISTIC MODEL: LEUCIPPUS AND DEMOCRITUS (400BC)

- **ATOM:** INDIVISIBLE AND IMMUTABLES ENTITIES
 - MATTER PROPERTIES ARE BASED ON GROUPING
 - DIFFERENT BY COLOR AND SIZE, NOT BY INNER QUALITIES
- “REFUTED” BY ARISTÓTELES (300AC):
 - POSTULATES ONLY 4 ELEMENT AS FUNDAMENTAL CONSITUTENTS OF ALL MATTER.
 - EARTH, WATER, AIR, FIRE
 - % OF EACH DEFINES PROPERTIES



Dark Ages:

- Emerald table/Philosopher's Stone
 - Attributed to Hermes Trimegistus (3rd century BC)
 - NO evidences until 1600AC (**FAKE**)
 - Arab predecesors (no evidences, but reffered):
 - *Kitab Sirr al-Khaliqa wa Sanat al-Tabia* (650AC)
 - *Kitab al-Asar* (800AC)
 - *Kitab Ustqus al-Uss al Thani* (S. XII)
 - *Secretum Secretorum* (1140AC)
 - Newton translates the Emerald Stone into Latin
 - Summarizes the Opus Magnum (Great Work)
 - Reading it was not enough
 - The reader must be prepared to undersand
 - Cryptic nature transform and enable the reader



- + m. Acidum minerale
- + Acidum Vitrioli
- + c. concentratum, d. dilutum
- + Acidum Nitri, a n. phlogificatum
- ∇ Aqua fortis
- + Acidum Salis a / dephlogificatum
- ∇ Aqua Regis
- + Acidum fluoris mineralis
- + Acidum Arsenici
- + v. Acidum Vegetabile
- + Acidum tartari
- + Acidum Sacchari
- Acetum
- + a. Acidum animale
- + Acidum urinae, phosphori
- + Acidum formicarum
- △ Acidum acreum, atmosphaericum
- ⊕ Sal alcalinus
- ⊕ p. Sal. alc. purus (Causticus)
- ⊕ v. Alkali fixum vegetabile.
- ⊕ m. Alkali fixum minerale
- ⊕ Alkali volatile
- ∇ Terra
- ∇ Lapis
- ∴ Arano



Alchemy (ProtoChemistry)

- Search for Quintaessentia (fifth element)
 - Capable of turns normal matter into Gold
 - Forever life
- Mystical and encoded/cryptic naming
- Leads to:
 - Isolation of lots of minerals and substances
 - Laboratory procedures
 - Distillation
 - Characterization of Acids/Alkalis

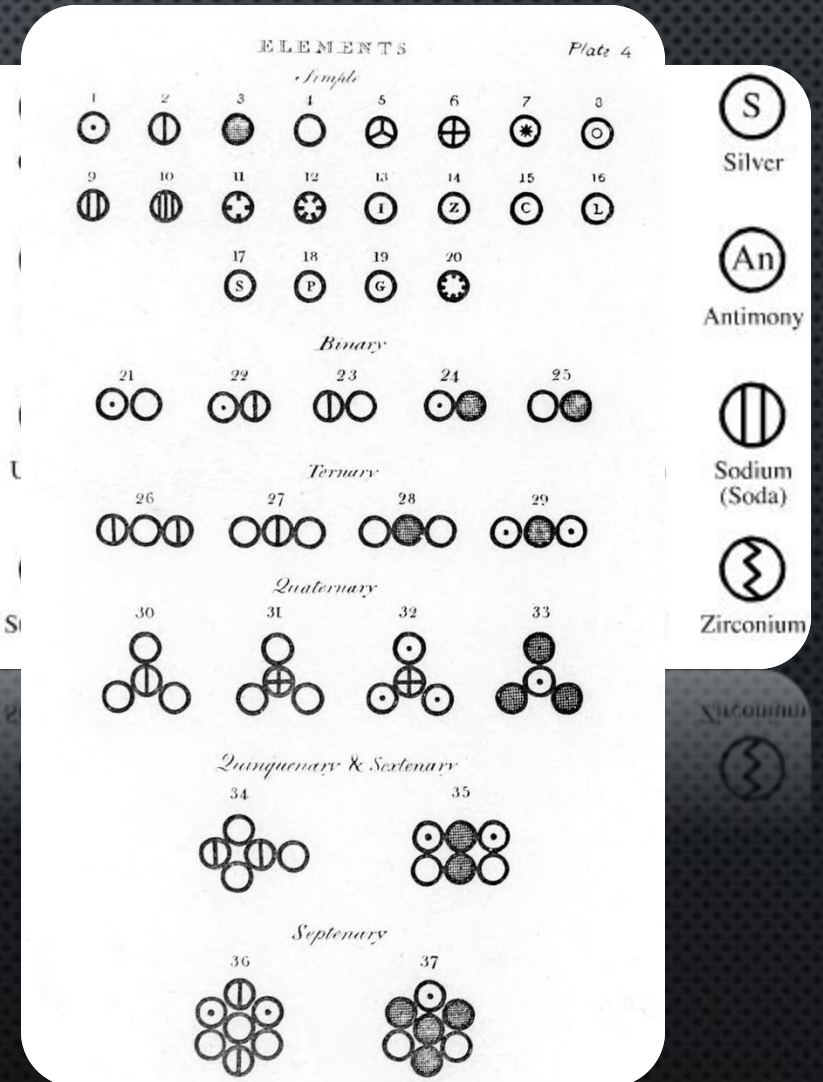
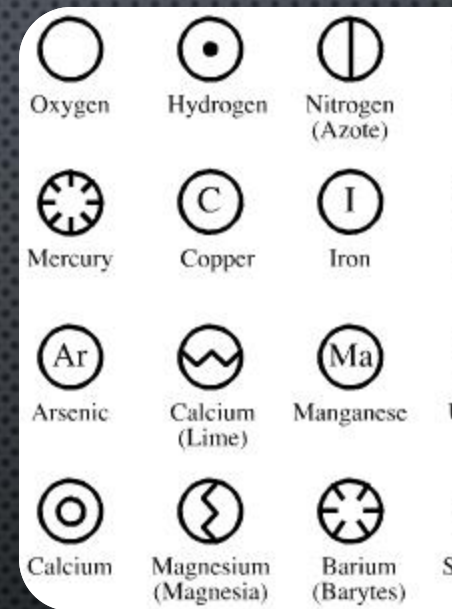
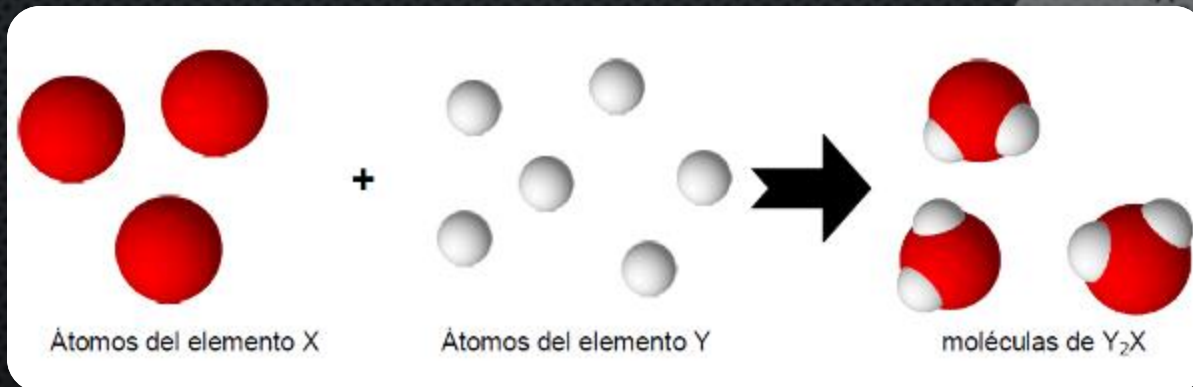


Croce Verde	☉ ☽ ☿	Reforta	☉ ☽ ☿
Crucibulum	☉ ☽ ☿	Sal. coarsus	☉ ☽ ☿
Cucurbitum	☉ ☽ ☿	Sal. Alkali	☉ ☽ ☿
Dies	☉ ☽ ☿	Sal. Ammoniac	☉ ☽ ☿
Digerere	☉ ☽ ☿	Sal. Gemma	☉ ☽ ☿
Disolvere	☉ ☽ ☿	Sal. potra	☉ ☽ ☿
Distillar	☉ ☽ ☿	Sapo	☉ ☽ ☿
Disturre	☉ ☽ ☿	Spiritus	☉ ☽ ☿
Equum	☉ ☽ ☿	Spiritus Vini	☉ ☽ ☿
	☉ ☽ ☿	Strat. p. strab.	☉ ☽ ☿
	☉ ☽ ☿	Solvere	☉ ☽ ☿
	☉ ☽ ☿	Sublimare	☉ ☽ ☿
	☉ ☽ ☿	Sulphur	☉ ☽ ☿
	☉ ☽ ☿	Sulphur viva	☉ ☽ ☿
	☉ ☽ ☿	Sulphur Philosophi	☉ ☽ ☿
	☉ ☽ ☿	Sulphurnigrum	☉ ☽ ☿
	☉ ☽ ☿	Tartar	☉ ☽ ☿
	☉ ☽ ☿	Calc. tartari	☉ ☽ ☿
	☉ ☽ ☿	Sal tartari	☉ ☽ ☿
	☉ ☽ ☿	Talcum	☉ ☽ ☿

DALTON (1803-1808): THE BEGINNING OF CHEMISTRY

(WITH LAVOISSIER'S PERMISSION)

- INDIVISIBLE
- ATOMS ARE ALREADY DISTINCT
 - NOTATION FOLLOWING ALCHEMY MANUSCRIPTS
 - MANUSCRYP TIC → MANUSCRIPT
 - MATTER BASED ON DIFFERENT ATOMS + ATOMS GROUPING
 - (AGAIN!: LEUCIPPUS+DEMOCRITUS WERE ALMOST RIGHT)
- DIFFERENTIATED BY CHEMICAL SPECIES
 - DIFFERENT ATOMS=DIFFERENT MASSES
 - DIFFERENT ATOMS=DIFFERENT PROPERTIES
- STOICHIOMETRIC ADJUSTEMENTS



DALTON: PROS. Y CONS. (BACK THEN)

PROS

- CAPABLE OF EXPLAINING MOST OF THE CHEMICAL REACTIONS

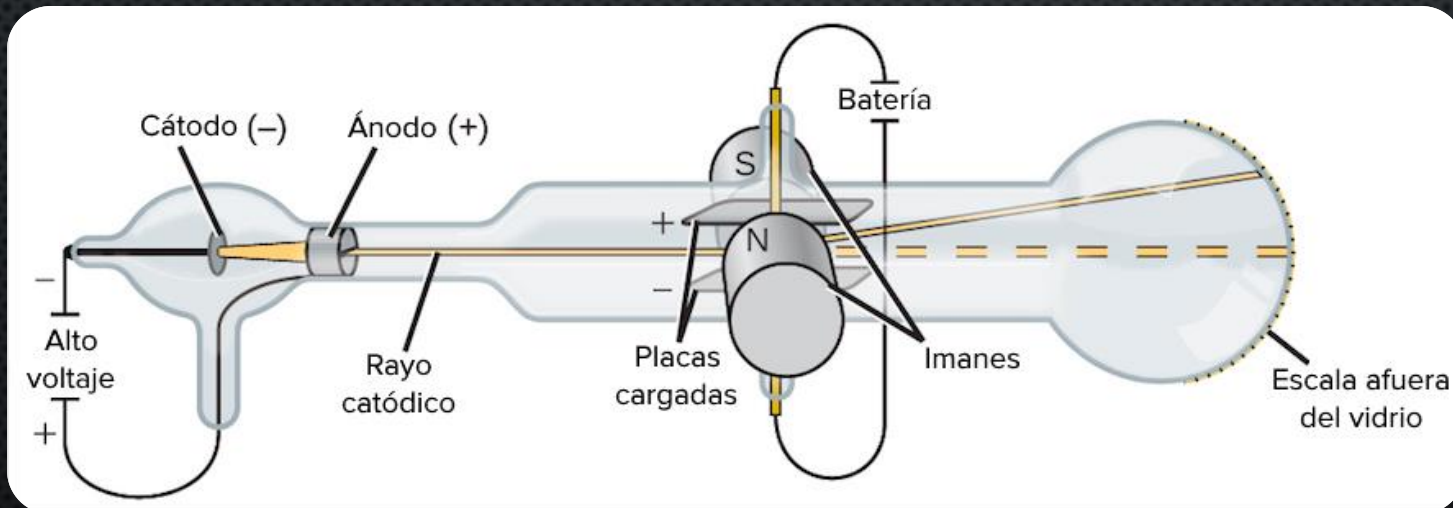
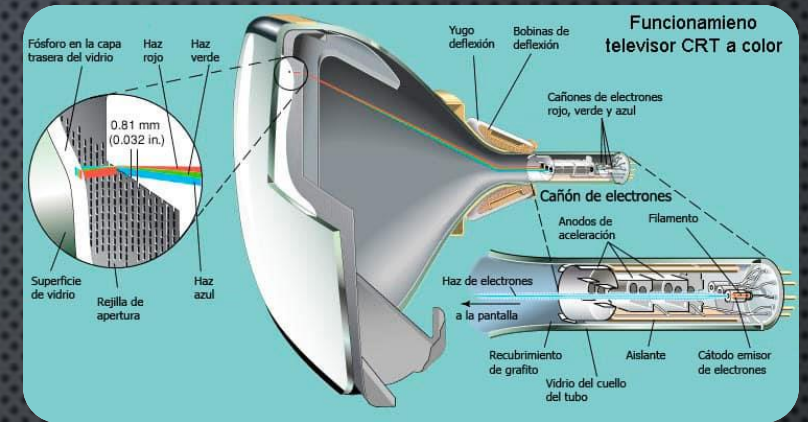
CONS

- ASSUME MONOATOMIC GASES
- “MOLECULAR” ISSUES
 - NOT SUITABLE FOR CORRECTLY ADDRESS MOLECULAR/COMPOUND MASSES (WITH/FROM SEVERAL ATOMS)
 - ~~ISOTOPES NOT SUPPORTED (NOR DISCOVERED YET)~~

JOSEPH THOMSON: RAISINS PUDDING (1904)

• THOMSON DISCOVERS THE ELECTRON

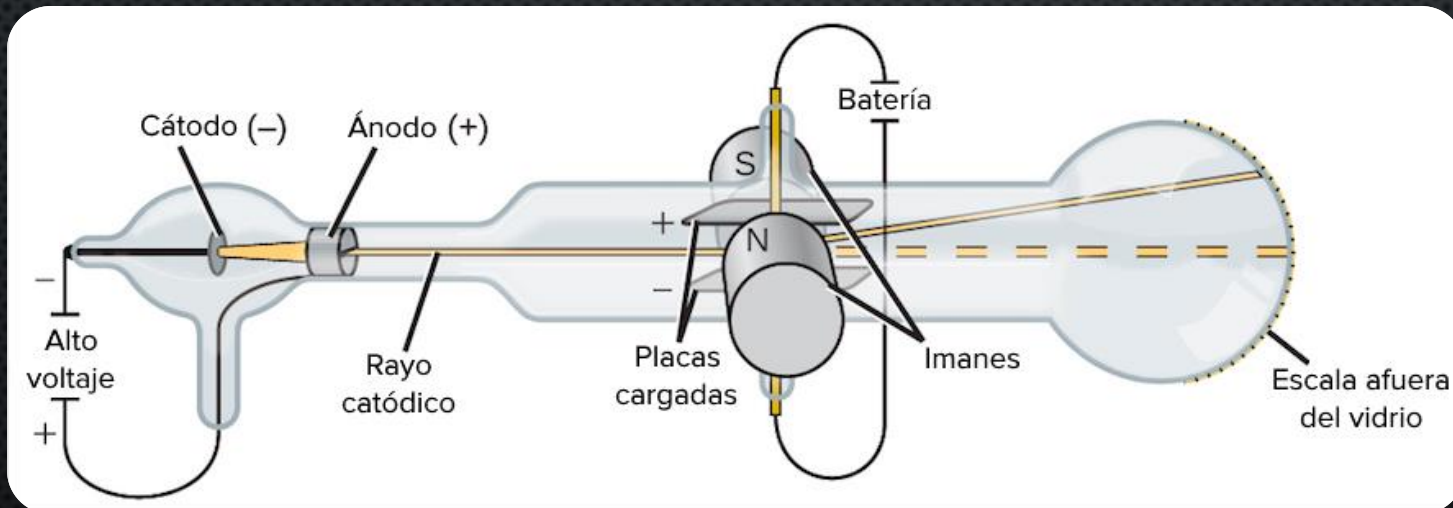
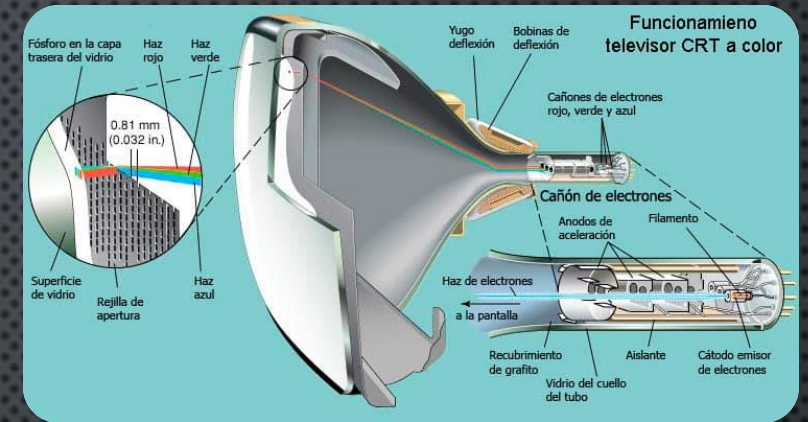
- ELECTRICITY: POSITIVE/NEGATIVE CHARGES EXISTANCES
- ATOMS ARE NOT INDIVISIBLE ANY MORE!!!: CONTAINS BOTH CHARGE TYPES
- CATHODIC RAY TUBE EXPERIMENT (CRT (A.K.A. FAT BOTTOMED) TV)
 - NEGATIVE CHARGES FLY IN A STRAIGHT LINE IN A VACUUM TUBE
 - ACCELERATED FROM (-) TO (+)
 - DEFLECTED ALSO BY MAGNETIC FIELDS



JOSEPH THOMSON: RAISINS PUDDING (1904)

- THOMSON DISCOVERS THE ELECTRON

- ELECTRICITY: POSITIVE/NEGATIVE CHARGES EXISTANCES
- ATOMS ARE NOT INDIVISIBLE ANY MORE!!!: CONTAINS BOTH CHARGE TYPES
- NO PROTONS NEITHER NEUTRONS (YET: NEUTRONS WILL BE **THEORETICALLY PREDICTED** BY CAVENDISH IN 1920)
- NEUTRAL ATOMS: ONLY SOLUTION: (+) CHARGES MAY COEXIST WITH (-) WITHIN THE ATOMS
 - RAISINS PUDDING MODEL



THOMSON: PROS Y CONS (BACK THEN AGAIN...)

PROS

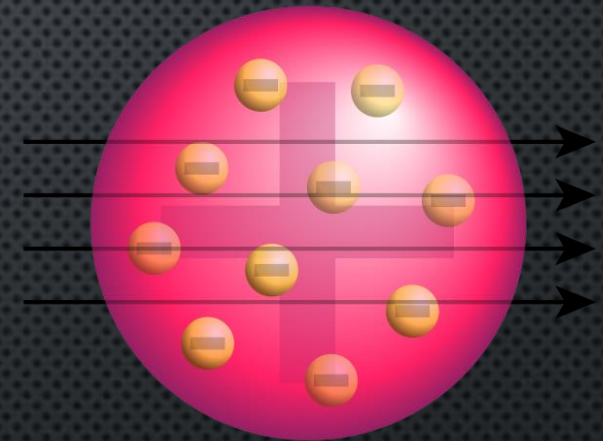
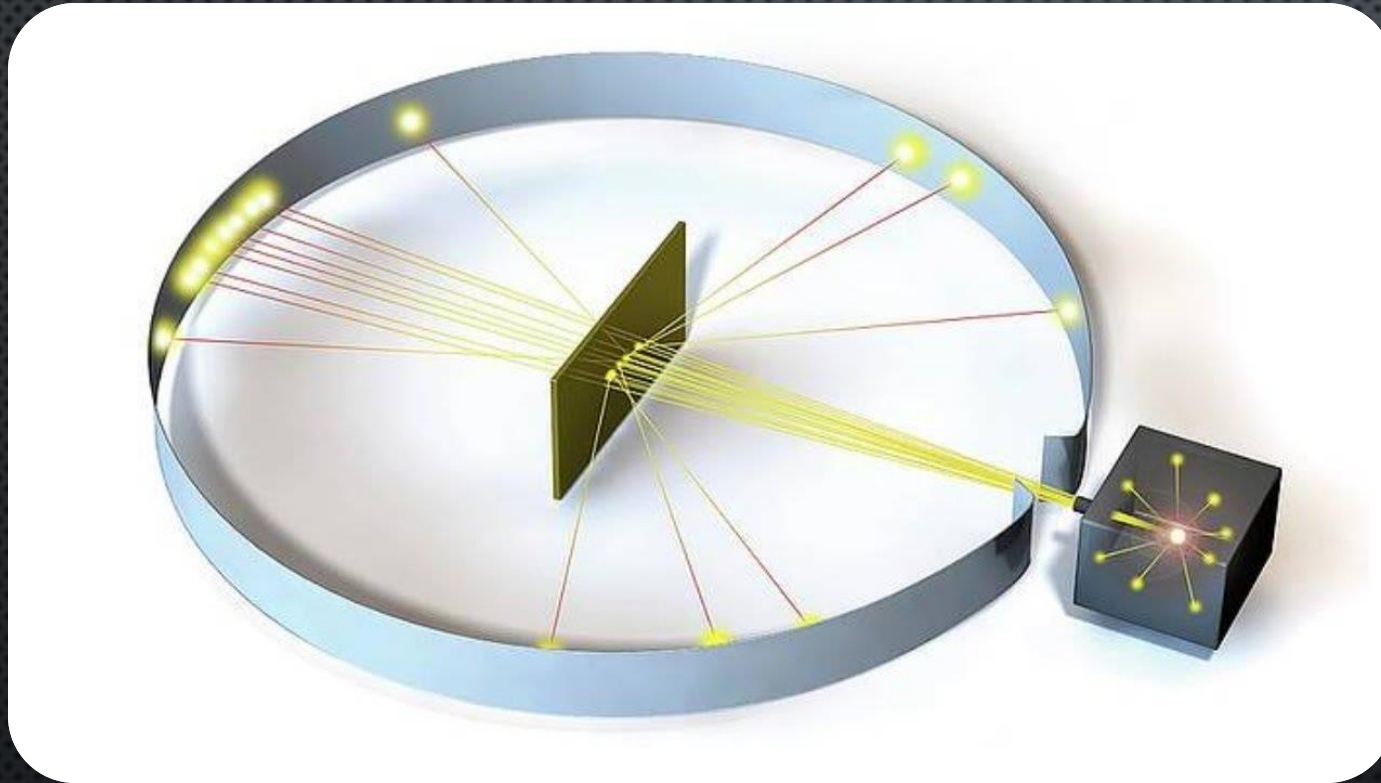
- CHEMISTRY WISE COMPATIBLE WITH DALTON'S MODEL.
- EXPLAINS THE CATHODIC RAY (ELECTRON BEAMS) APPEARANCE

CONS

- UNABLE TO EXPLAIN THE RUTHERFORD EXPERIMENT
- CAN NOT EXPLAIN PERIODICITY IN MENDELEEV'S PERIODIC TABLE

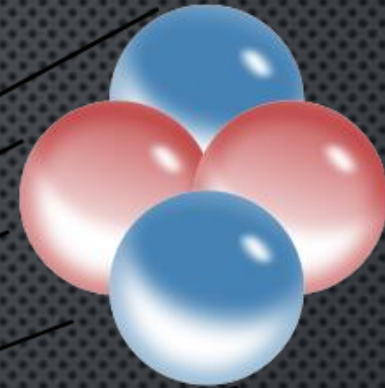
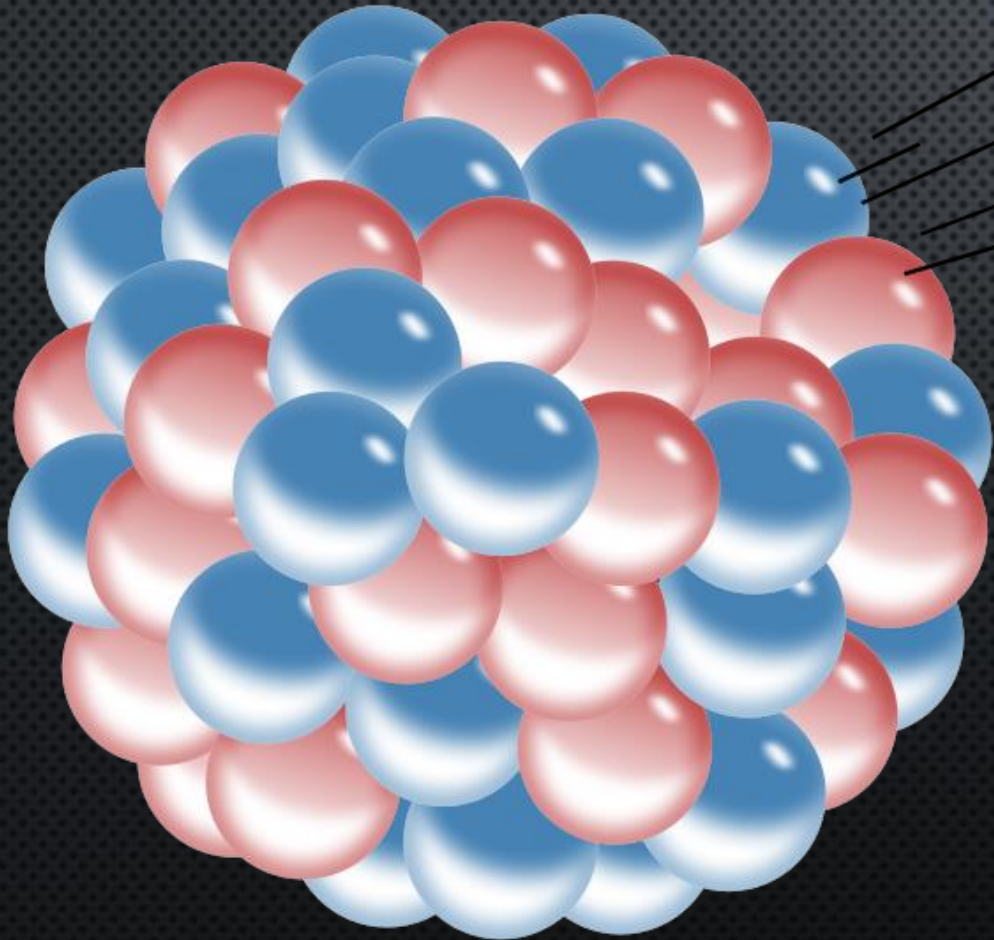
ATOMIC ORBITALS

RUTHERFORD'S MODEL (1911)



- RADIOACTIVE ALPHA PARTICLES SOURCE AGAINST GOLD FOIL
 - ANOMALOUS SCATTERING PATTERN: THOMSON MODEL PREDICTS NO SCATTERING (NEUTRAL ATOMS VS CHARGED PARTICLES)

ATOMIC ORBITALS RUTHERFORD'S MODEL (1911)

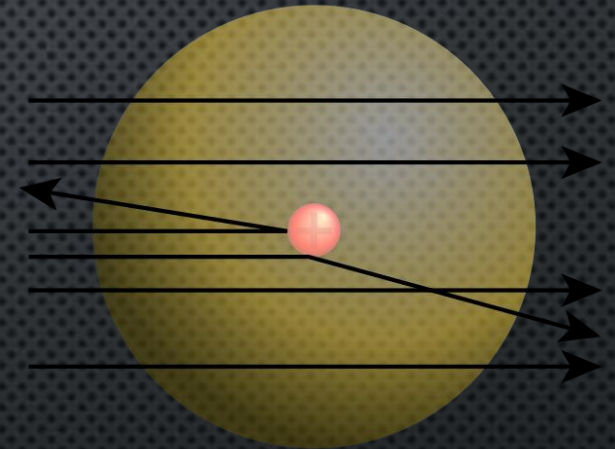
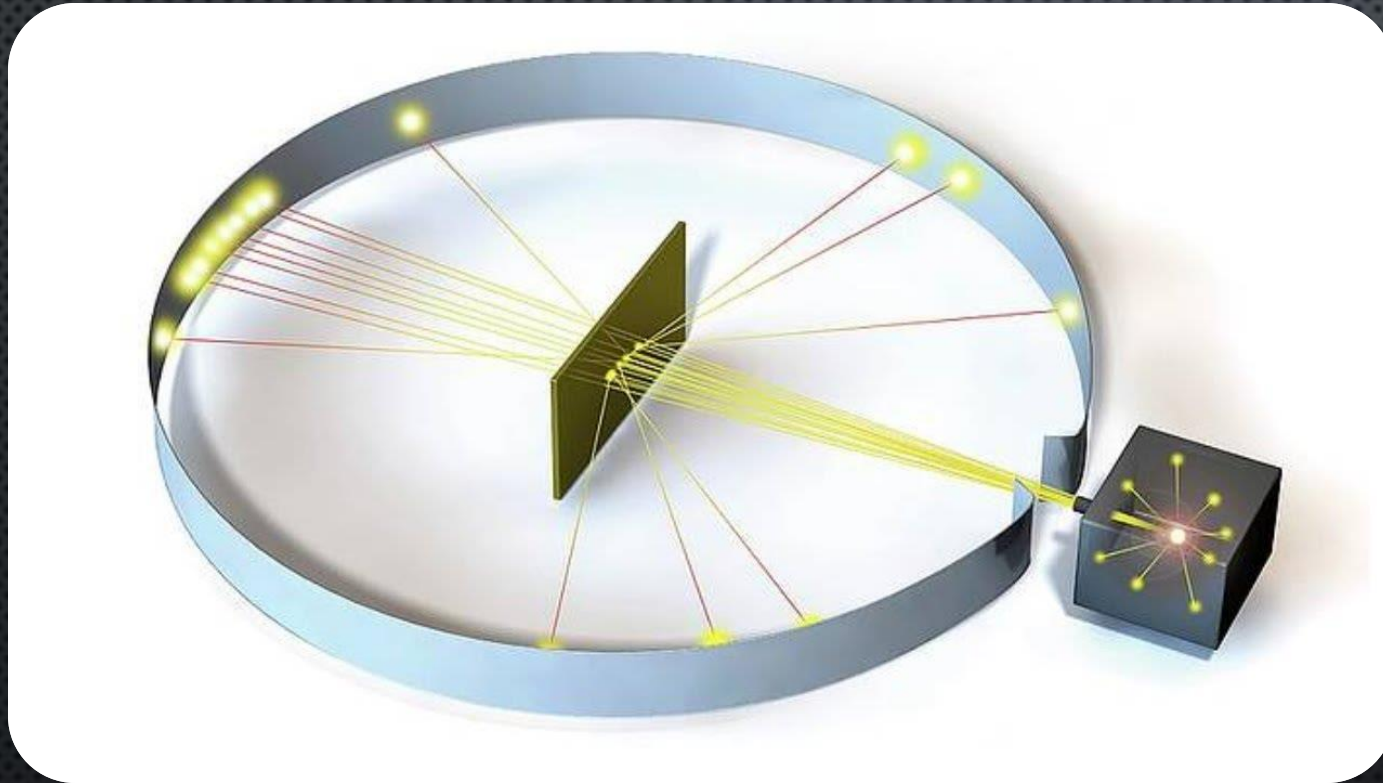


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- ALPHA PARTICLES:
 - FULLY IONIZED HE ATOMS: 2PROTONS+2NEUTRONS
 - TOTAL CHARGE: (+2) (2X ELECTRON CHARGE BUT OPPOSITE CHARGE SIGN)
 - TOTAL MASS: 4P (4X PROTON MASS)
 - COMES FROM RADIOACTIVE DECAY OF HEAVY NUCLEI

ATOMIC ORBITALS

RUTHERFORD'S MODEL (1911)



- DEFINES CORE + ORBITING ELECTRONS (ELLIPTIC TRAJECTORIES)
 - ALPHA PARTICLES ONLY INTERACTS (REPULSIVELY) WITH NUCLEI
- LOTS OF INNER FREE/VACUUM SPACE

RUTHERFORD: PROS AND CONS (BACK THEN AGAIN AND AGAIN...)

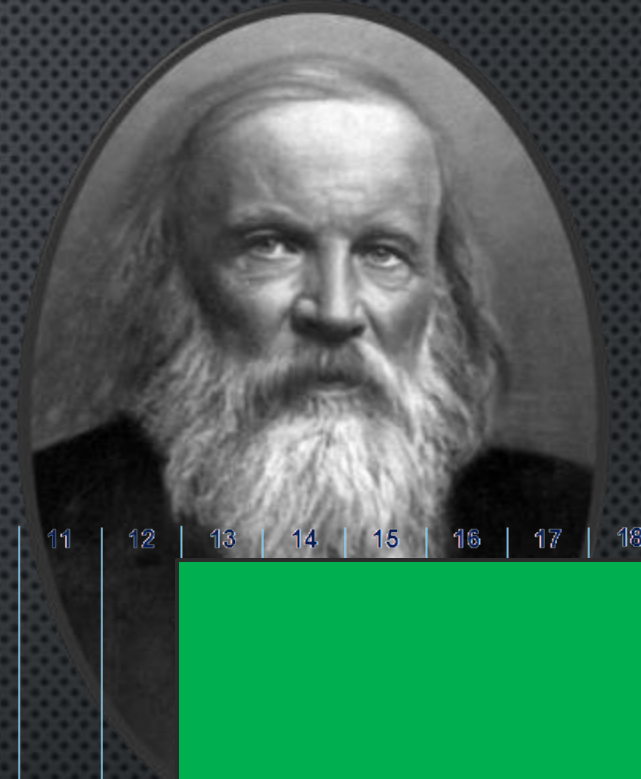
PROS

- CHEMISTRY WISE COMPATIBLE WITH DALTON'S AND THOMSON'S MODELS
- EXPLAINS ALPHA SCATTERING IN THE EXPERIMENT

CONS

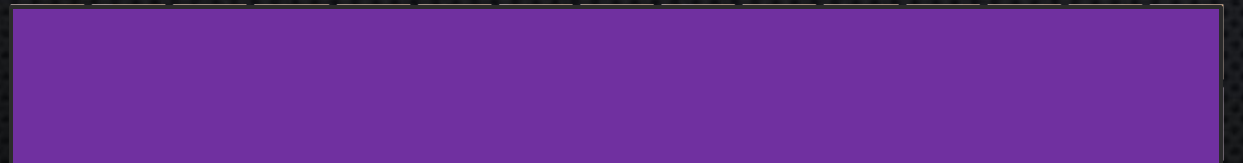
- (+) CHARGE CONCENTRATION IMPLIES NUCLEI UNSTABILITY (WEAK FORCE NEEDED)
- CLASSICAL ELECTRODYNAMICS
 - ORBITING ELECTRIC CHARGES (-) MAY LOSE ENERGY AND, THEREFORE, DECAY TOWARDS THE NUCLEUS.

“THAT OLD LITTLE TABLE”



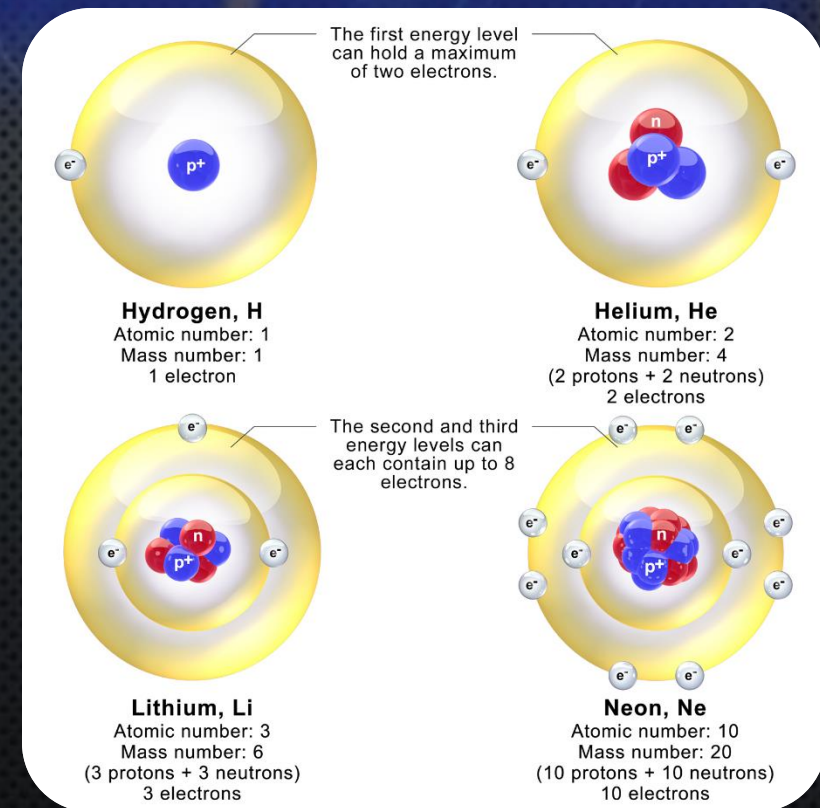
- STARTED AS A WAY TO SORT AND CLASSIFICATE THE ELEMENTS ACCORDING TO THEIR PROPERTIES
 - DEFINED “REGIONS”: s, p, d, f
- ELECTRONIC STRUCTURE
 - PROPERTIES
 - (SEE ALKALI METALS VIDEO IN MOODLE)
 - MOLECULES AND SOLIDS FORMATION EXPLAINED

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	s-block		d-block										p-block						
2																			
3																			
4																			
5			d-block										p-block						
6																			
7			d-block										p-block						
8																			



BOHR.'S MODEL (AND THE USUALLY FORGOTTEN SOMMERFELD)

- QUANTUM MECHANICS BASED
- POSTULATES:
 - ELECTRONS DRAW CIRCULAR ORBITS WITHOUT ENERGY LOSS
 - QUANTIZED ORBITS ACCORDING TO THEIR QUANTUM NUMBERS
 - PHOTONS: ENERGY EMISSION ASSOCIATED TO INTER-LEVEL GAP
 - SIMILARITIES WITH SEVERAL FLOOR BUILDINGS
 - $N = \text{\#}^{\text{TH}}$ FLOOR
 - MAX ALLOWABLE ELECTRONS PER LEVEL = NUMBER OF ROOMS
 - TOTAL ATOM ENERGY = RENTAL PRICE
- SOMMERFELD INTRODUCES ELLIPTICITY (RELATIVISTIC TERMS)

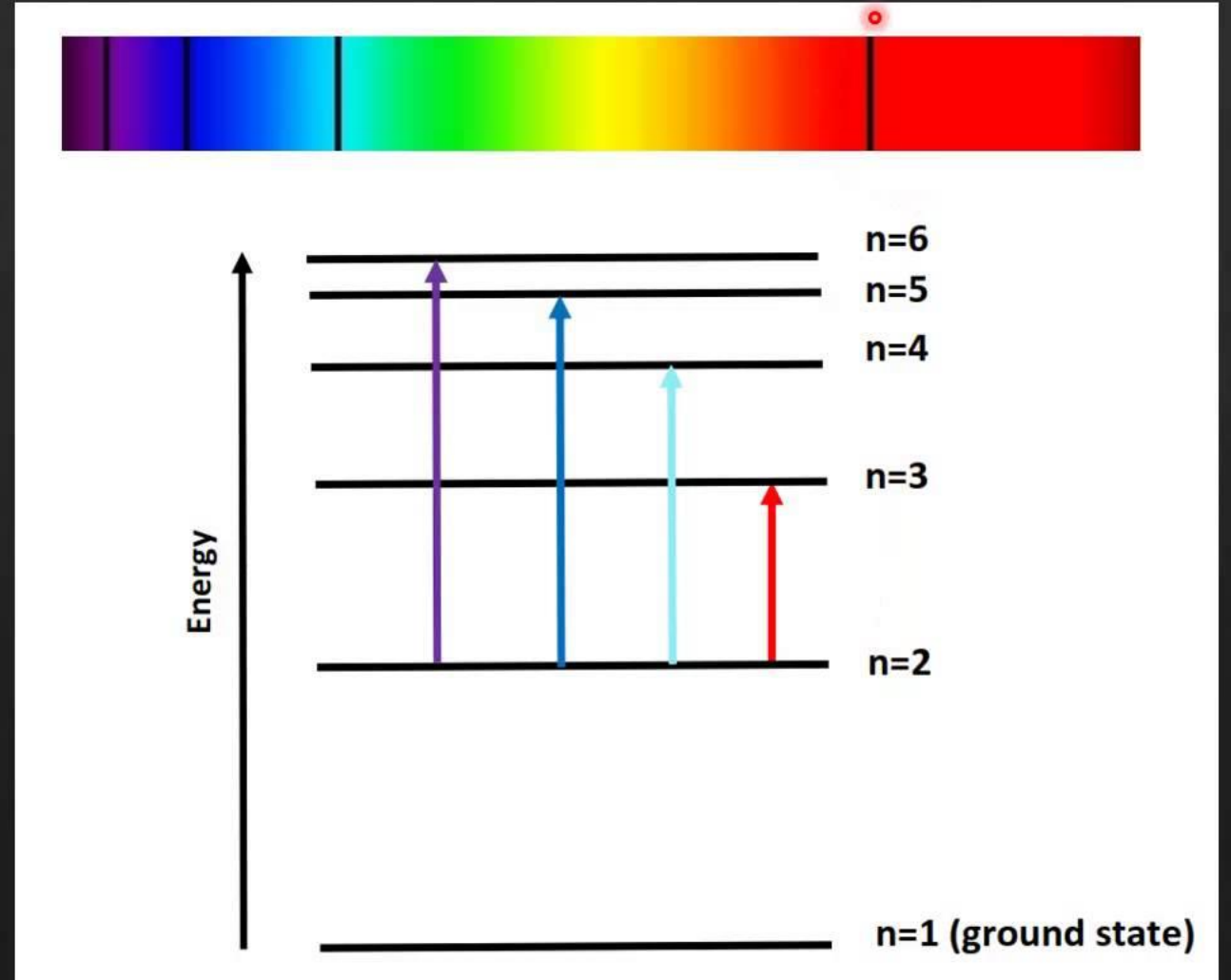
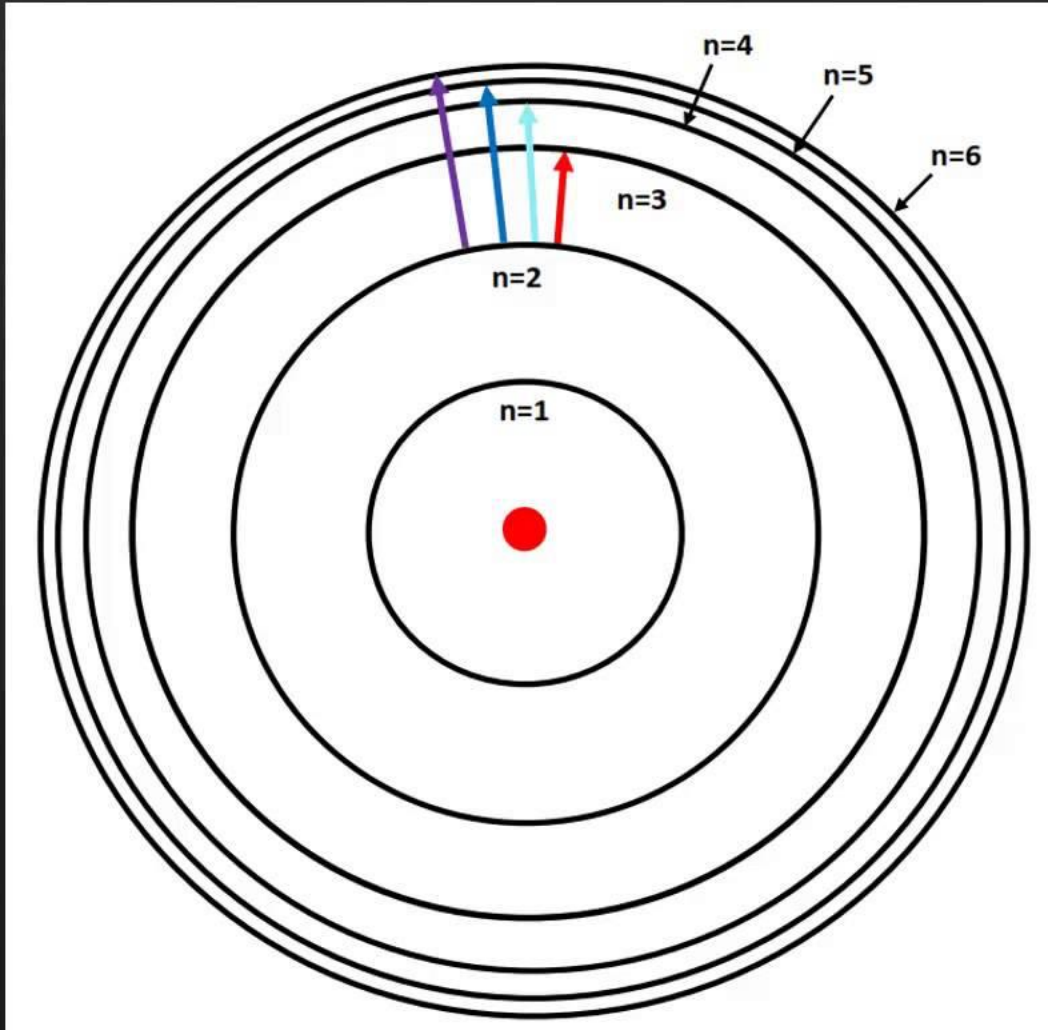




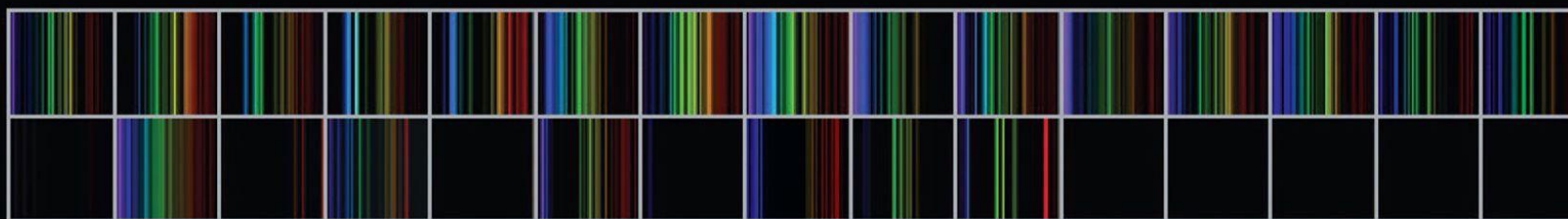
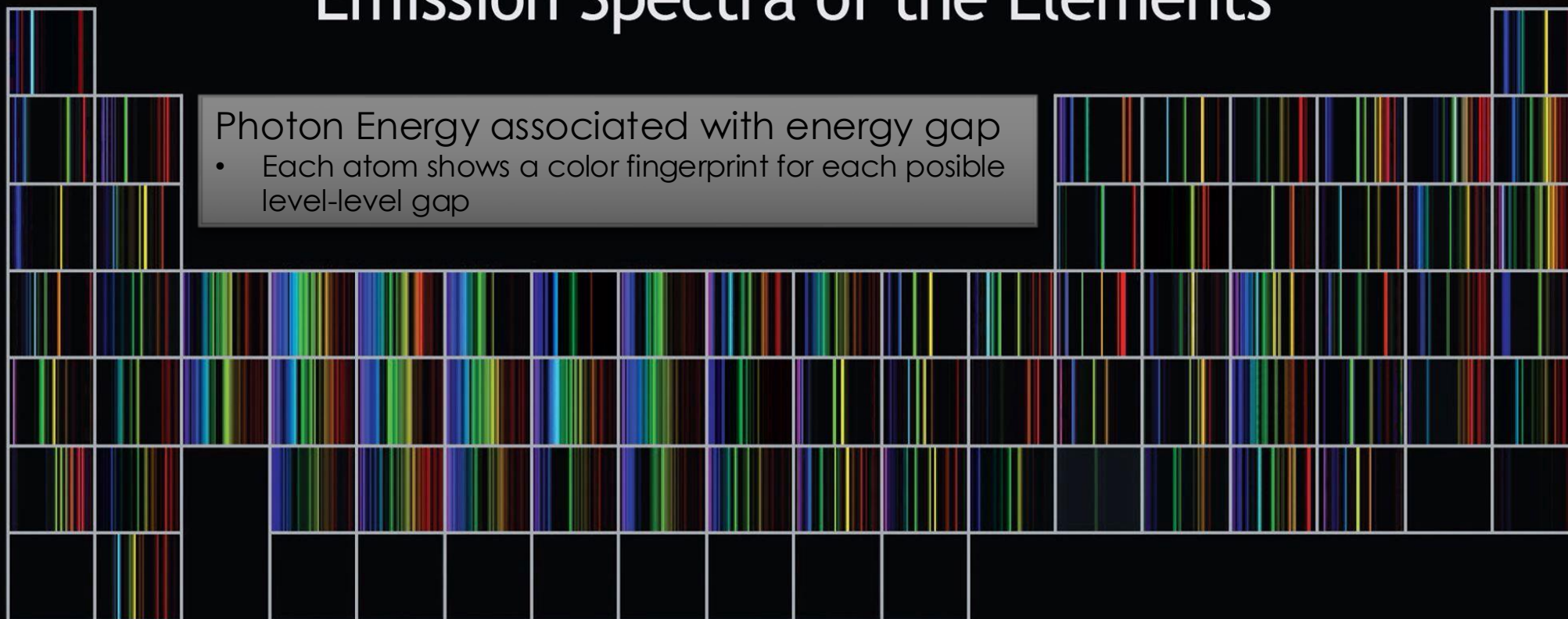
Photon Energy associated with energy gap

- Every transition associated with a color
- Excited atoms are now identifiable by their emitted color

Absorption spectrum



Emission Spectra of the Elements



BOHR-SOMMERFELD: PROS AND CONS (BACK THEN... WE ARE ALMOST THERE)

PROS

- COMPATIBLE WITH DALTON, THOMSON AND RUTHERFORD
- EXPLAINS MENDELEEV'S TABLE PERIODICITY
- SOLVES THE ELECTRONIC DECAY IN ATOMS BY INTRODUCING THE QUANTIZATION POSTULATES.

CONS

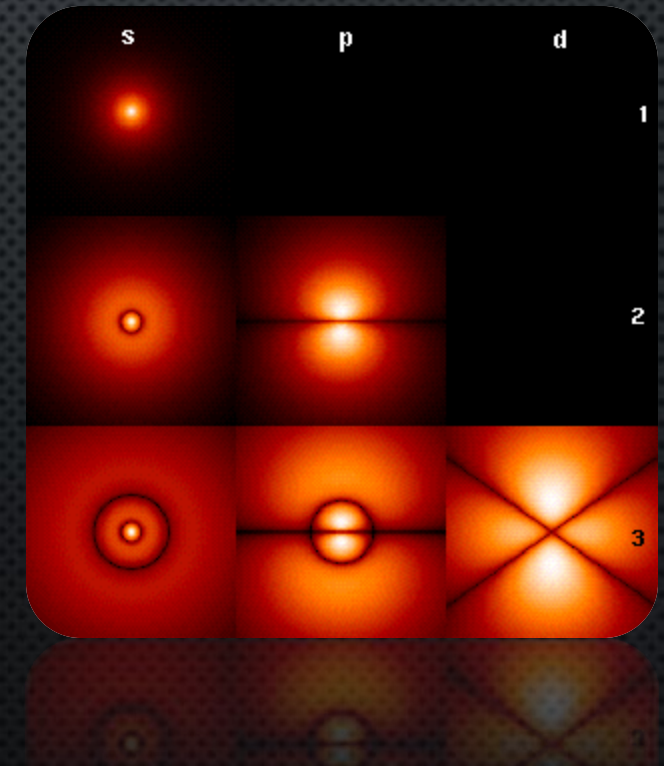
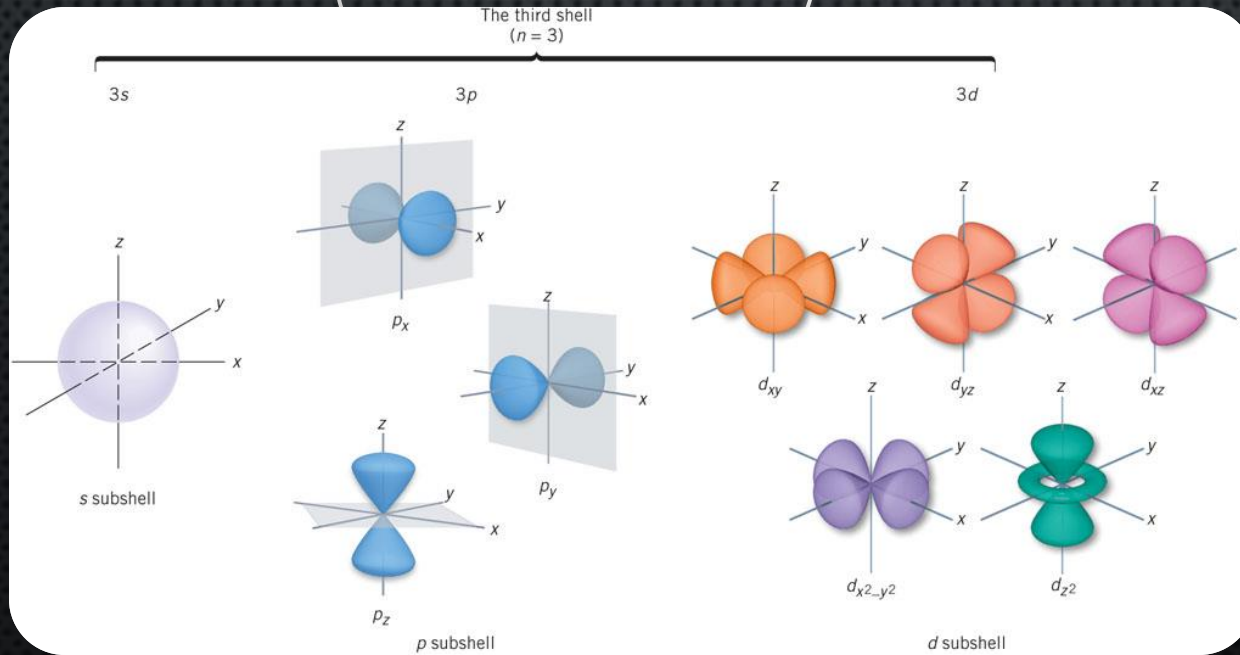
- NEW AND "EXCITING" QUANTUM MECHANICS

MAMA, I CAN'T FIND ANYTHING!!! SHRÖDINGER

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H} \Psi.$$

$$i\hbar \frac{\partial}{\partial t} \Psi(x, t) = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \Psi(x, t) + V(x, t) \Psi(x, t)$$

- NON-RELATIVISTIC QUANTUM MODEL NO
 - UNCERTAINTY PRINCIPLE (HEISENBERG)
- ELECTRONIC SHELLS (PROBABILITY REGIONS)



MAMÁ, I CAN'T FIND ANYTHING!!!

HEISENBERG

PROS

- PREDICTS SPECTRAL LINES
 - BOTH NEUTRAL AND IONIZED ATOMS
 - EVEN WITH EXTERNAL ELECTRICAL AND/OR MAGNETIC FIELD
- EXPLAINS CHEMICAL BOND AND MOLECULAR STABILITY

CONS

- LACK OF RELATIVISTIC CONTRIBUTIONS:
 - DIRAC
- DOES NOT TAKE INTO ACCOUNT THE SPIN:
 - SHRÖDINGER+PAULI
- UNABLE TO EXPLAINS THE NUCLEI STABILITY
 - INTERACCIÓN FUERTE
- DOES NOT EXPLAINS ELECTRONIC DECAY
 - ELECTRODINÁMICA CUÁNTICA

MODERN PHYSICS

(101 COURSE)

WAVE-PARTICLE DUALITY

LOUIS DEBROGLIE
(1929)

$$E = h\nu$$



UNCERTAINTY PRINCIPLE

WERNER HEISENBERG
(1933)

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \cdot \Delta \tau \geq \frac{\hbar}{2}$$



ERWIN SCHRÖDINGER
(1934)

- $F=MA$ "WAVY VERSION"
- WAVEFUNCTION COLLAPSE
 - THE "CAT"

RELATIVIDAD

EINSTEIN (UNCLE ALBERT)
(1921)



- NO, IT IS **NOT** $E=MC^2$
- NO, HE WAS NOT AWARDED WITH NOBEL PRICE FOR IT

QUADVECTOR S-T (XYZT)

SPECIAL

- HIGH SPEED ALTERS (S-T)
- CASTOR+POLLUX PARADOX
- GENERAL
 - GRAVITY ITSELF ALTERS (S-T) ALSO
 - INTERSTELLAR

AND EVEN FURTHER MORE...

- PARTICLES:
 - FERMIONS: ELECTRONS, QUARKS
 - LEPTONS (LIGHT PARTICLES) (1 FERMIÓN): ELECTRON, MUON, TAU LEPTON
 - MESONS (MÉDIUM WEIGHTED PARTICLES) (QUARK+ANTIQUARK)
 - BARIONS (HEAVY PARTICLES) (3 QUARKS):
 - PROTONS
 - NEUTRONS
 - ALL THE REST OF THEM (UNSTABLES)
 - BOSONS
- STRINGS
- BRANAS
 - P-BRANAS, D-BRANAS, ...