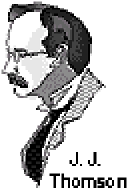


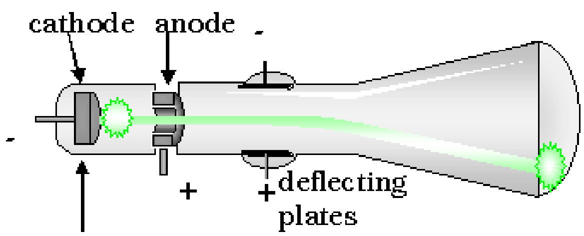
- J. J. Thomson's cathode ray experiment
  - "cathode rays" pass from negative electrode towards positive electrode in an evacuated tube
  - hypothesis: cathode rays are streams of electrons
  - calculated mass to charge ratio for electrons by observing bending of cathode rays in electric and magnetic fields
  - proposed the plum pudding model of the atom

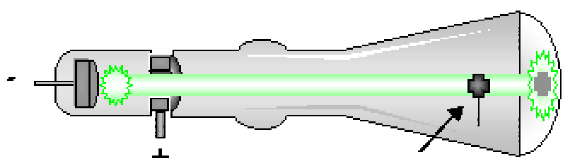
Table: Hypothetical properties of the electron. How J. J. Thomson used properties of cathode rays to hypothesize properties of the electron.

observations	hypothesis
ray properties are independent of the cathode material	... cathode ray stuff is a component of all materials
cathode rays bend near magnets	... magnets bend the paths of moving charged particles; maybe cathode rays are streams of moving charged particles
rays bend towards a positively charged plate. rays impart a negative charge to objects they strike.	... cathode rays are streams of negative charges
Cathode rays don't bend around small obstacles, cast sharp shadows, can turn paddlewheels placed in their path, and travel in straight lines	... cathode rays behave like streams of particles

Probing Atomic Structure:

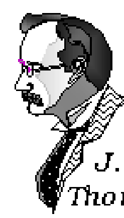
Cathode Rays

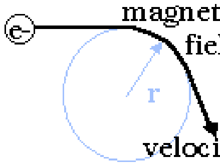




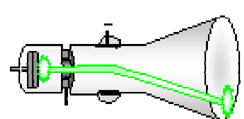
Discovery of the Electron

- measurement of mass-to-charge ratio (m/e) for electrons

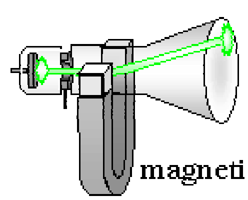




force on electron $= mv^2/r$

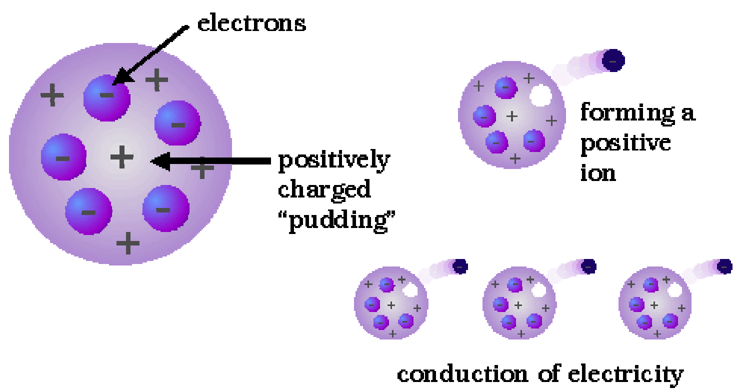


force on electron $= Ee$

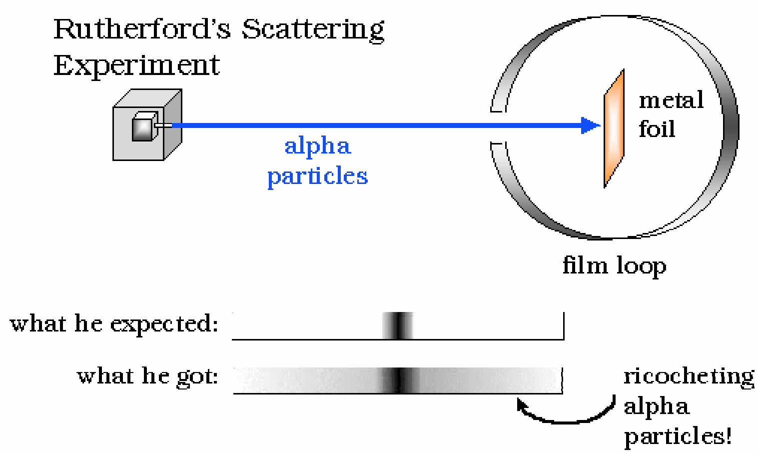


force on electron $= Hev$

Thomson's Plum Pudding Atom



Discovery of the Nucleus



Discovery of the Nucleus

- Radioactivity
  - heavy elements are radioactive
  - electric field resolves radiation into 3 components: alpha, beta, and gamma

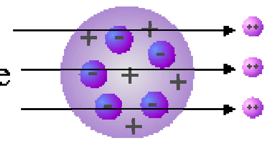
    Table: hypothetical description of alpha particles based on properties of alpha radiation

observation	hypothesis
alpha rays don't diffract	... alpha radiation is a stream of particles
alpha rays deflect towards a negatively charged plate and away from a positively charged plate	... alpha particles have a positive charge
alpha rays are deflected only slightly by an electric field; a cathode ray passing through the same field is deflected strongly	... alpha particles either have much lower charge or much greater mass than electrons

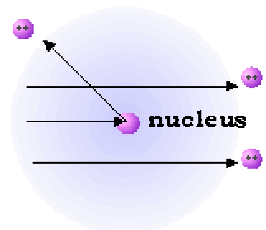
- scattering experiment
  - hypothesis: If the plum pudding model of the atom is correct, atoms have no concentration of mass or charge (atoms are 'soft' targets)
  - experiment to test hypothesis:
    - fire massive alpha particles at the atoms in thin metal foil
    - alpha particles should pass like bullets straight through soft plum pudding atoms
  - observation: a few alpha particles ricocheted!
  - new hypotheses:
    - all of the positive charge and nearly all of the mass of the atom is concentrated in a tiny, incredibly dense 'nucleus', about 10^{-14} m in diameter
    - electrons roam empty space about 10^{-10} m across, around the nucleus

The Nuclear Atom

- **Thomson's Atom**
  - diffuse mass and charge



- **Rutherford's Atom**
  - concentrated mass and positive charge at the nucleus
  - electrons roam empty space around the nucleus



- Composition of the Nucleus
  - nuclei are composed of "nucleons": protons and neutrons
  - atomic mass units
    - 1 amu (aka 1 dalton) = exactly 1/12 the mass of a carbon-12 nucleus
    - 1 dalton = 1.67×10^{-24} g

Table: Subatomic particles important in chemistry.

particle	symbol	charge	mass, kg	mass, daltons
electron	e-	-1	9.10953×10^{-31}	0.000548
proton	p+	+1	1.67265×10^{-27}	1.007276
neutron	n	0	1.67495×10^{-27}	1.008665

Structure of the Nucleus

- nuclei are composed of "nucleons": protons and neutrons

	Symbol	Charge	Mass, kg	Mass, amu
electron	e^-	-1	9.10953×10^{-31}	0.000548
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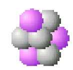
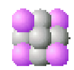
hydrogen nucleus

helium nucleus



lithium nucleus



beryllium nucleus

Isotopes

- isotopes: same Z, different M

$^{1}_{1}\mathrm{H}$ $^{2}_{1}\mathrm{H}$ $^{3}_{1}\mathrm{H}$ $^{12}_{6}\mathrm{C}$ $^{13}_{6}\mathrm{C}$ $^{14}_{6}\mathrm{C}$ $^{235}_{92}\mathrm{U}$ $^{238}_{92}\mathrm{U}$

- isotopic abundance: $\dfrac{\text{\# atoms of isotope present}}{\text{\# atoms of element present}}$

isotope	natural abundance	mass (amu)
carbon-12	98.89 %	12.000000
carbon-13	1.11 %	13.003354

average mass: 12.01_{11} amu