Physics 114 - January 24, 2006

Organizational CRUD:

e-mail list

Workshop section signup

Project Poster Session date

- Friday Afternoon Apr. 7
- Sat. " Apr. 8
- Sunday " Apr 23
- Friday " Apr. 28
- ~~SAT.~~ Sun. " Apr. 30

Will be in touch abt Visual interactives

LAST TIME:

Class organization

10 Commandments Not the version in Exodus 20:2-17

Started thinking about forces

$$\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$$ gravitation

What is a force?

might view as $\rightarrow$ $$\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}$$

$\Delta x \Delta p \gtrsim \hbar$

$\Delta E \Delta t \gtrsim \hbar$

modern view of essence of a force is tied up w/ quantum mechanics and the Uncertainty Principle

$\Rightarrow$ Quantum Field Theory

electromagnetism

Strong Nuclear force

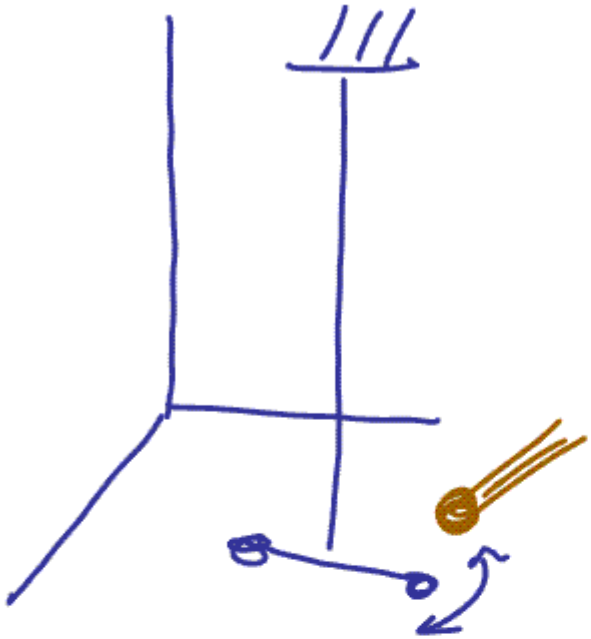
Weak Nuclear force

Gravity

All that we know about can be explained in terms of 4 fundamental forces

$$\vec{F} = k \frac{q_1 q_2}{r^2} \hat{r}$$

Describes force of Electro-magnetism



Torsion Balance

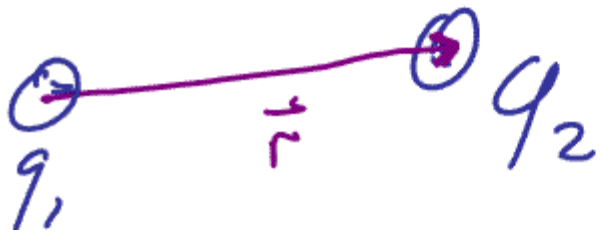
Charles Coulomb

1785

$$\vec{F} = k \frac{q_1 q_2}{r^2} \hat{r}$$

Coulomb's Law

Important



Mks units

F in Newtons

r in meters

q in Coulombs $\equiv C$

$k \equiv$ Constant

$8.99 \times 10^9 \ \frac{N m^2}{C^2}$

$k \equiv \frac{1}{4\pi\epsilon_0}$

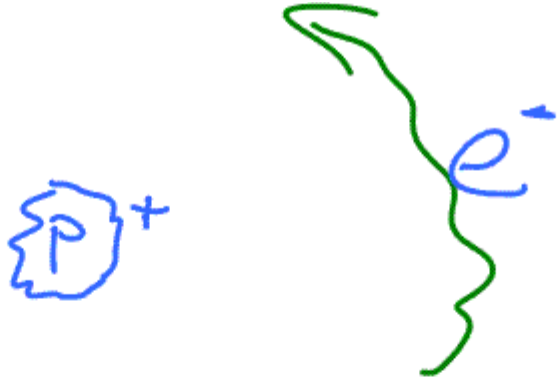
$\epsilon_0 = 8.85 \times 10^{-12} \ \frac{C^2}{N m^2}$

ϵ_0

Permittivity of free space

k and ϵ_0 set the scale for the strength of the Electromagnetic force.

H atom



$Q_{proton} = 1.6 \times 10^{-19}\ C$ $\quad$ $Q_{e^-} = -1.6 \times 10^{-19}\ C$

$= +1\,|e|$ $\quad$ $= -1\,|e|$

Charge is quantized

Electrostatics

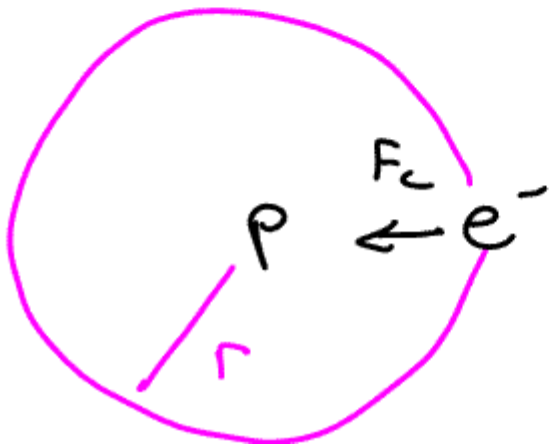
$$|\vec{F}_{em}| = k\frac{q_1 q_2}{r^2} = \frac{8.99 \times 10^9 \frac{N m^2}{C^2} (1.6 \times 10^{-19} C)^2}{(5.29 \times 10^{-11} m)^2}$$

$$F_{em} = 8.2 \times 10^{-8}\ N$$

$$F_{grav} = \frac{G M_p M_e}{r^2} \sim 3.6 \times 10^{-47}\ N$$

$$\frac{F_{em}}{F_{grav}} = 2.3 \times 10^{39}$$!!!

Em force is Much stronger than force of gravitation



Assume e^- Moves in a circle about proton

What is the speed of electron moving about the proton in the H atom?

e^- moves in a circle

SO ⇒

$$F_{em} = \frac{m_e v_e^2}{r}$$

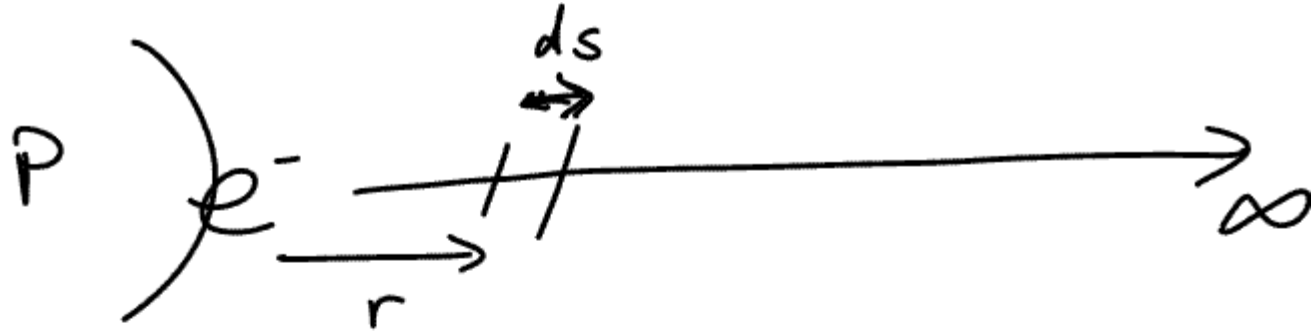
$$v_e = 2.2 \times 10^6 \text{ m/s} \sim 1\% \text{ speed of light}$$

Which is 3×10^8 m/s

How much Energy does it take to ionize the H atom?

perhaps the most important # in chemistry

Sets the energy scale for chemical reactions.



Energy to remove electron ~ Work $= \int \vec{F} \cdot d\vec{s}$

$$dW = \vec{F} \cdot d\vec{s} = F\,ds \qquad ds \sim dr$$

$$\int dW = \int F\,ds = \int_{r_0}^{\infty} F\,dr$$

$$W = \int_{r^0}^{\infty} \frac{k\,e^2}{r^2}\,dr$$

$$W = ke^2 \int_{r_0}^{\infty} \frac{1}{r^2} dr = ke^2 \left[\frac{-1}{r}\right]_{r_0}^{\infty}$$

$$= ke^2 \left[\frac{-1}{\infty} + \frac{1}{r_0}\right]$$

$\infty \to 0$

$$W = 4.3 \times 10^{-18} \text{ Joules}$$

eV ≡ electron-Volt
unit of energy

$$4.3 \times 10^{-18} J \times \frac{6.2 \times 10^{18} eV}{J} = 26.9 eV$$

e^- already Moving

$$KE \text{ of } e^- \sim \frac{1}{2} m v^2 = \frac{1}{2} \left(9.11 \times 10^{-31} kg\right) \left(2.2 \times 10^6 \frac{m}{s}\right)^2$$

KE $\sim$ 13.6eV

Work I do to remove e^- =

Total Energy to remove e^- − KE e^- already has

= 26.9 eV − 13.6 eV = 13.3 eV

With nothing more than Coulomb's Law we have calculated the (very important) ionization energy of hydrogen !!

Ain't that AMazin?