Which of the following principles of classical physics is violated in the Bohr model?

(A) Opposite charges attract with a force inversely proportional to the square of the distance between them.

(B) The force on an object is equal to its mass times its acceleration.

(C) Accelerating charges radiate energy.

(D) Particles always have a well-defined position and momentum.

(E) All of the above.

Bohr hydrogen atom

In the Bohr hydrogen model the radii of the stationary orbitals are given by:

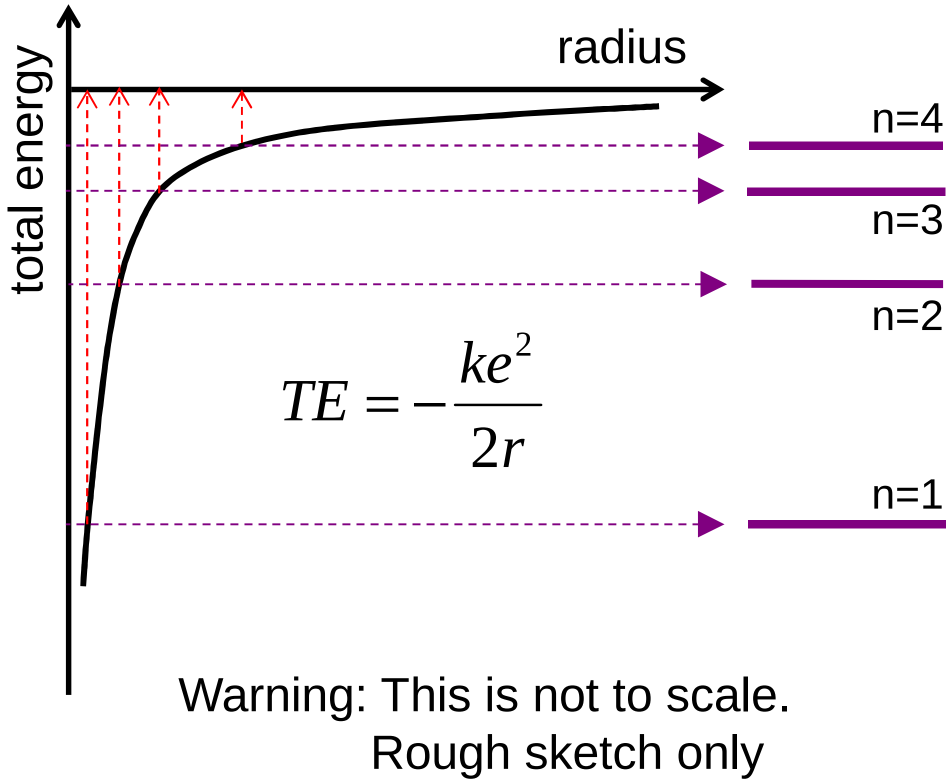
$$r_n = a_B n^2 \quad \text{with} \quad a_B = \frac{\hbar^2}{kme^2}$$

$$\text{and} \quad n = 1, 2, 3, 4, ...$$

The difference between r_{n+1} and r_n …

(A) increases (B) remains the same

(C) decreases … when *n* increases.


total energy
radius
n=4
n=3
n=2
n=1
$TE = -\frac{ke^2}{2r}$
Warning: This is not to scale.
Rough sketch only

Bohr model can …

Explains quantitatively Balmer formula and predicts empirical constant from fundamental constants:

$$1/\lambda_{12} = R(1/n_2^2 - 1/n_1^2)$$

$$\Rightarrow E_{photon} = E_1(1/n_2^2 - 1/n_1^2)$$

$$R = 1/(91.2\text{nm}) = mk^2e^4/4\pi c\hbar^3$$

Explains variations in R for different single electron atoms(ions)

Predicts approximate size of hydrogen atom

Explains (sort of) why atoms emit discrete spectral lines and why electron doesn’t spiral into nucleus

Bohr model cannot …

- Explain WHY angular momentum is quantized?
- Explain WHY electrons do not radiate when they are in stationary orbitals?
- Explain how electron knows which level it jumps to? (i.e. how to predict intensities of spectral lines)
- Be generalized to more complex (multi-electron) atoms
- Explain shapes of molecular orbits and how bonds work
- Explain more complex features of spectral lines (doublet spectral lines)

Bohr model is …
… a kind of weird mix of classical physics and
Arbitrary (quantum) rules

Why is angular momentum quantized yet Newton's laws still work?

Why don't electrons radiate when they are in stationary orbitals yet Coulomb's law still works?

No way to know *a priori* which rules to keep and which to throw out…

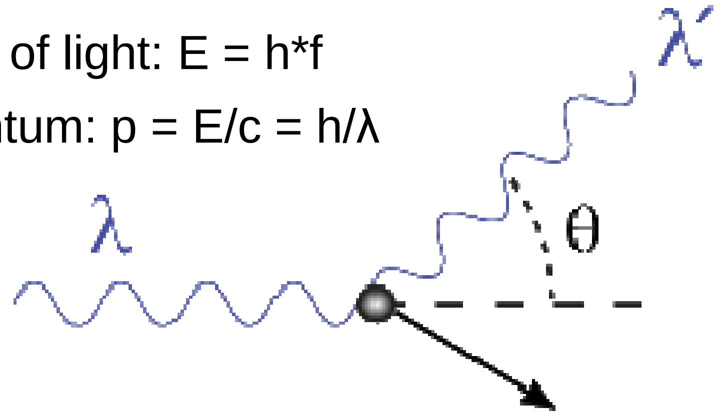
BUT IT WORKS (for certain things)!

Compton effect (1923)

Compton irradiated atoms with X-ray light (energy: ~ 17 keV). What happens?

Energy of light: E = h*f

Momentum: p = E/c = h/λ



Looks like the scattering of particles

Compton found that the momentum of light is given by $p = h/\lambda$. Which of the following relations is also true for the light momentum?

(A) $p = \frac{hf}{c}$ (B) $p = \hbar k$

(C) Both are correct

(D) None of these are correct

de Broglie (1923): Wave-particle duality

All material particles also display a dual wave-particle behavior with

$$\lambda = \frac{h}{p} \quad \text{and} \quad k = \frac{p}{\hbar}$$

where λ is the (de Broglie) wavelength and k is the (de Broglie) wavenumber of the material particle.

Consider the following particles:

• electron A with kinetic energy of 1 eV

• electron B with kinetic energy of 1 keV

• proton C with kinetic energy of 1 eV

Order the (de Broglie) wavelengths of these particles?

$$\lambda = \frac{h}{p} \quad \text{and} \quad k = \frac{p}{\hbar}$$

(A)A = C > B (B) A > B = C

(C) A > B > C (D) A = B = C

(E) Some other order