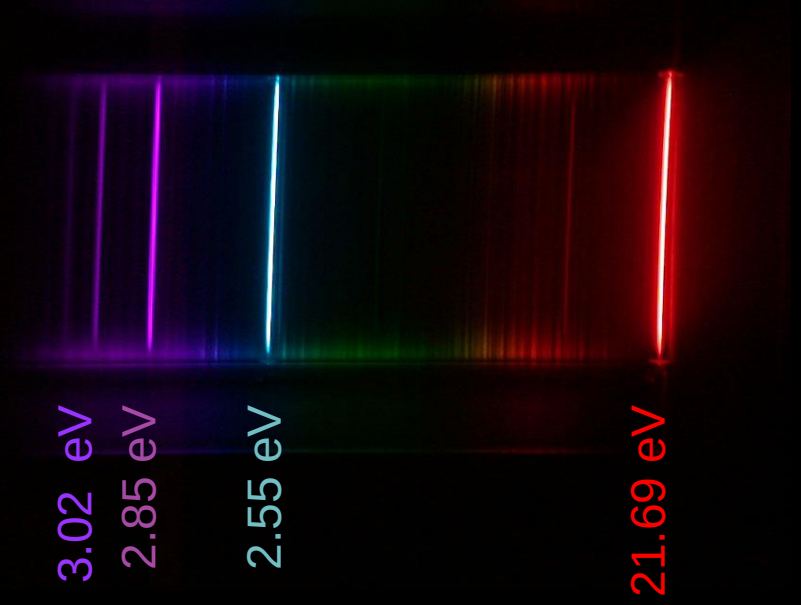
Wed. Lab Fri.	8.1-.3, (.8,.9) Photons & Quantization Quiz 7 L7 Microscopic Energy Transfer 8.4-.7 More Energy Quantization	RE 8.a RE 8.b
Mon. Tues. Wed. Lab Fri.	9.1-.2, (.8) Momentum and Energy in Multi-particle Systems 9.3 Rotational Energy Quiz 8 Review Exam 2 (Ch 5-8) Exam 2 (Ch 5-8)	RE 9.a HW8: Ch 8 Pr's 21, 23, 27(a-c) RE 9.b Practice Exam 2 (bring to class)

Shedding light on atomic energy levels
(segment of Hydrogen spectrum)



Where we've been:

Energy on the macroscopic scale

$$\Delta K_{paper} + \Delta U_{p\&E}$$

$$\Delta\left(\tfrac{1}{2} m_p v_p^2\right) + \Delta\left(mgh\right)$$

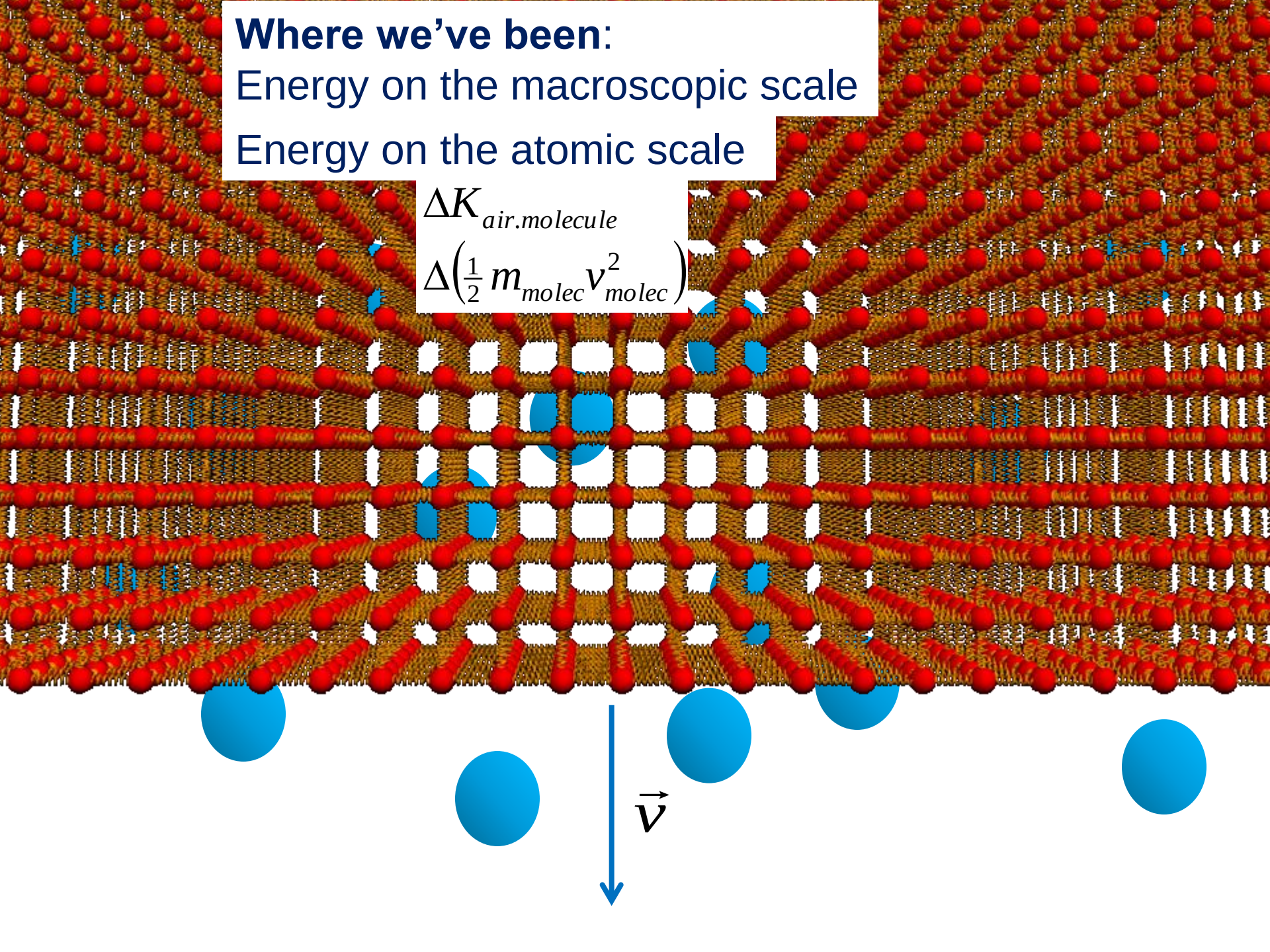
Where we've been:

Energy on the macroscopic scale

Energy on the atomic scale

$$\Delta K_{air.molecule}$$

$$\Delta\left(\tfrac{1}{2} m_{molec} v_{molec}^2\right)$$



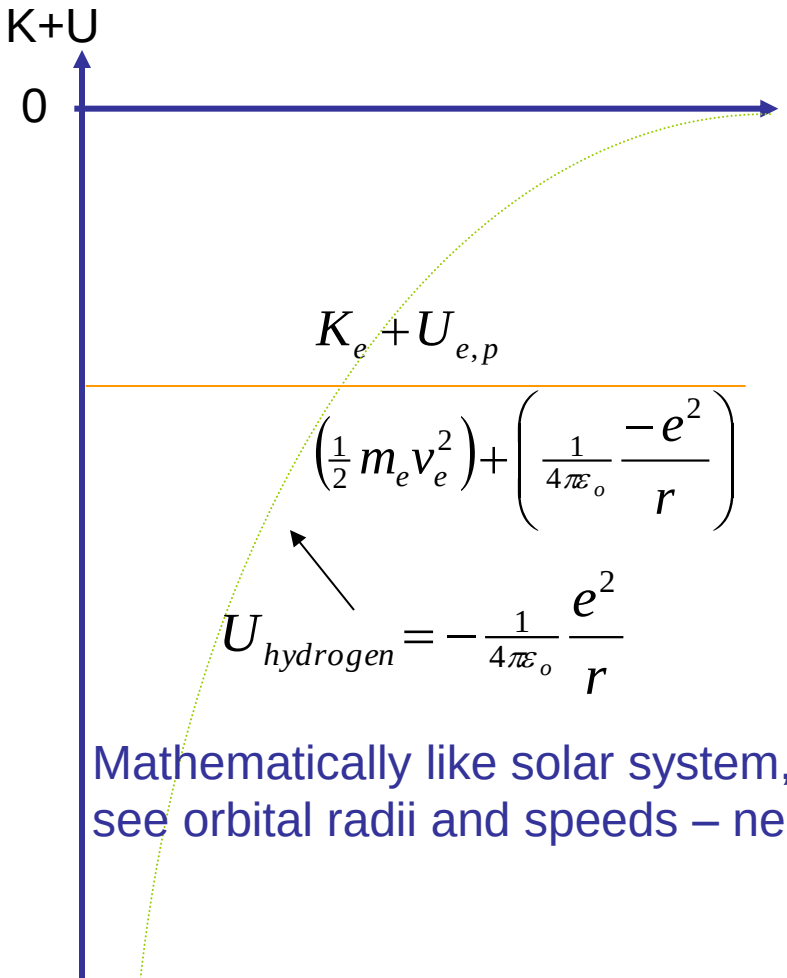
Where we've been:

Energy on the macroscopic scale

Energy on the atomic scale

Where we're going:

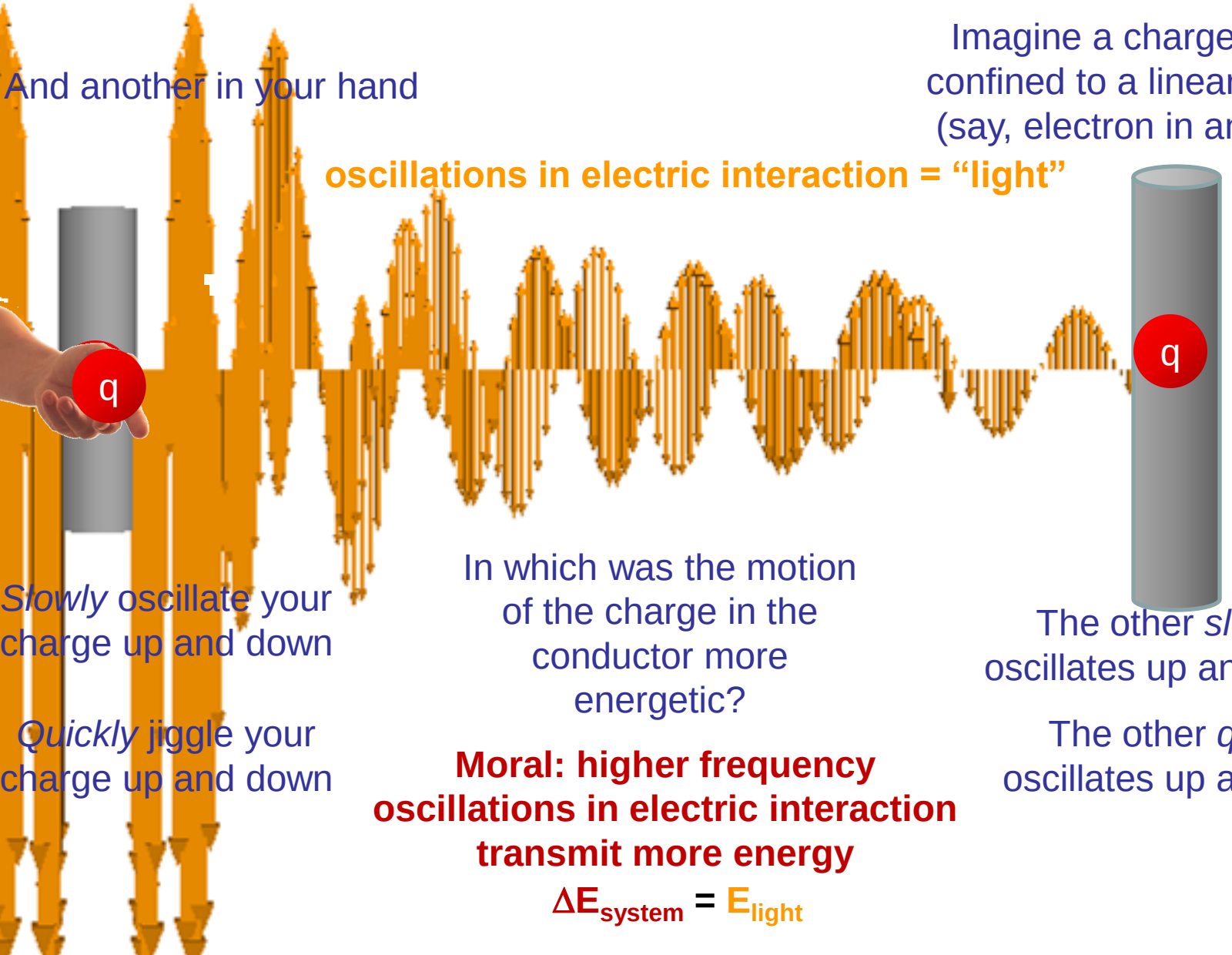
Energy on the electronic scale



$$E_H \approx m_e c^2 + m_p c^2 + \left(K_e + U_{e,p}\right)$$

Mathematically like solar system, but much too small and delicate to directly see orbital radii and speeds – need another way to deduce

Spectroscopy
Light and energy



And another in your hand

Imagine a charged particle confined to a linear conductor (say, electron in an antenna)

oscillations in electric interaction = "light"

Slowly oscillate your charge up and down

Quickly jiggle your charge up and down

In which was the motion of the charge in the conductor more energetic?

The other *slowly* oscillates up and down

The other *quickly* oscillates up and down

Moral: higher frequency oscillations in electric interaction transmit more energy

$\Delta E_{system} = E_{light}$

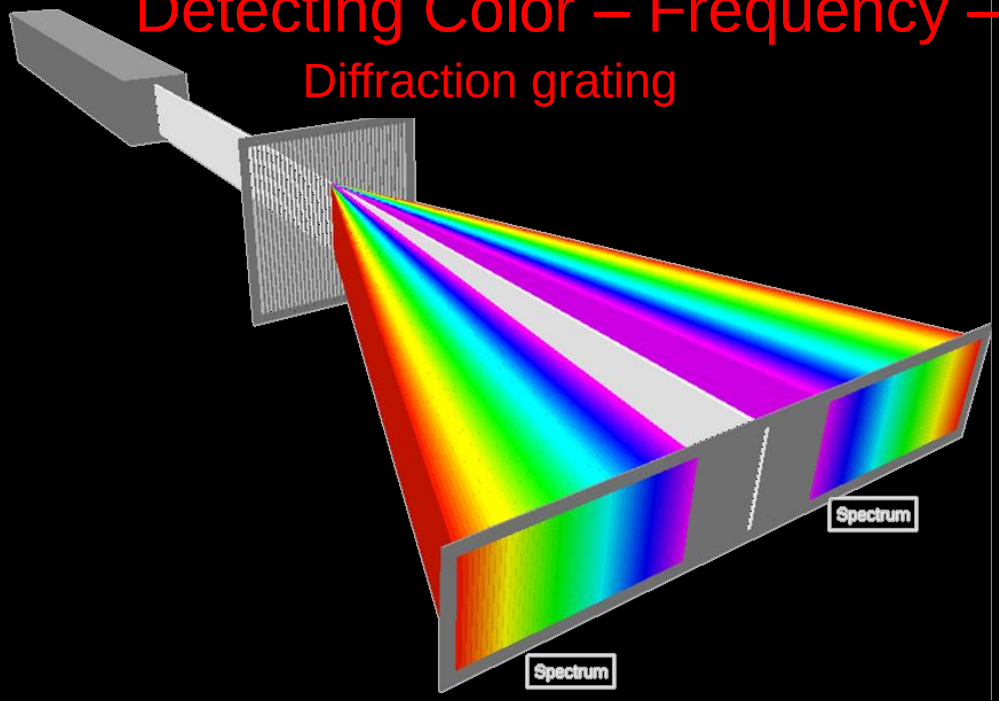
23_antena.py

White light source

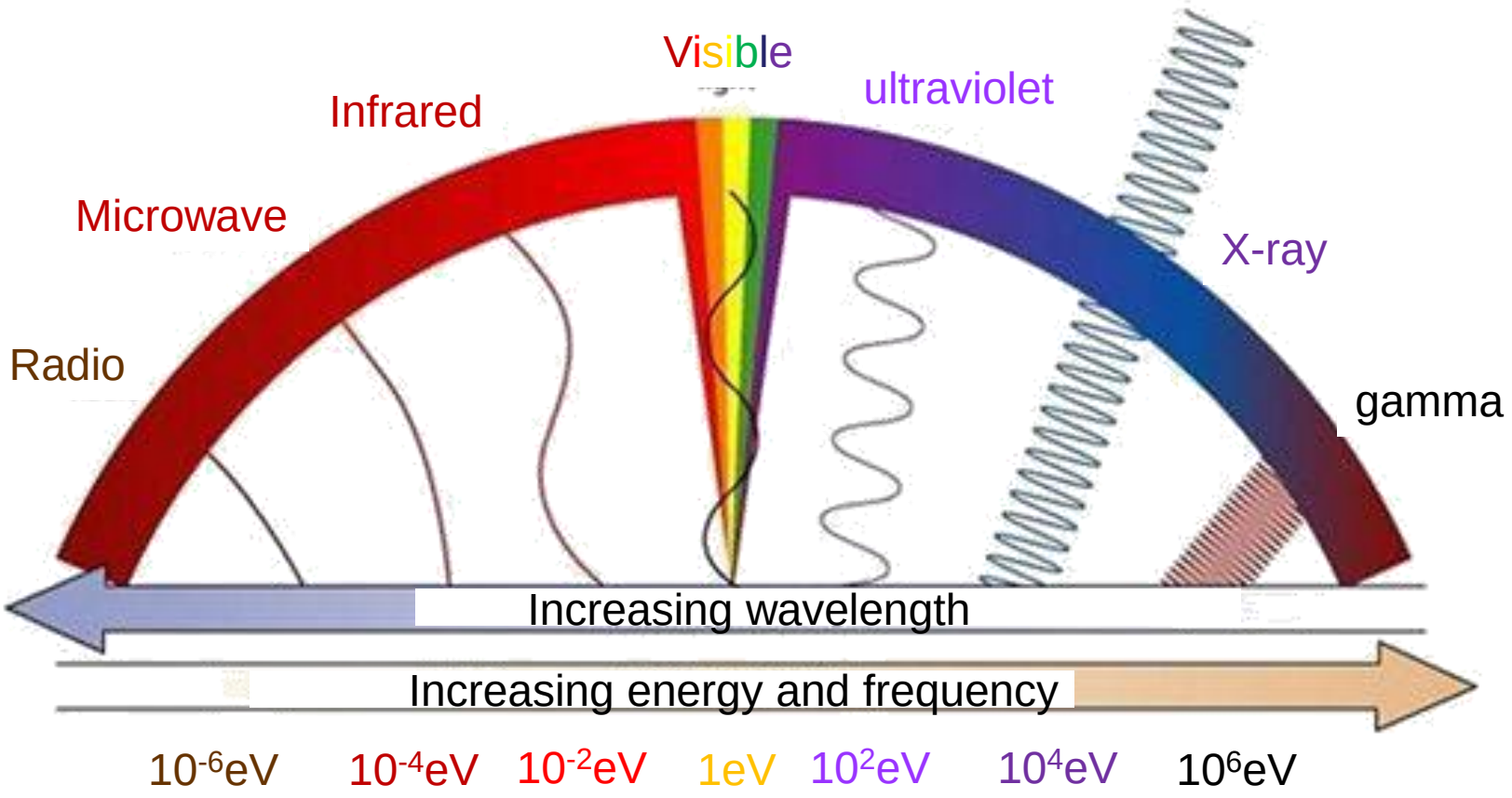
Spectrometer:

Detecting Color – Frequency – Energy

Diffraction grating



Spectrometer:
Detecting Color – Frequency – Energy

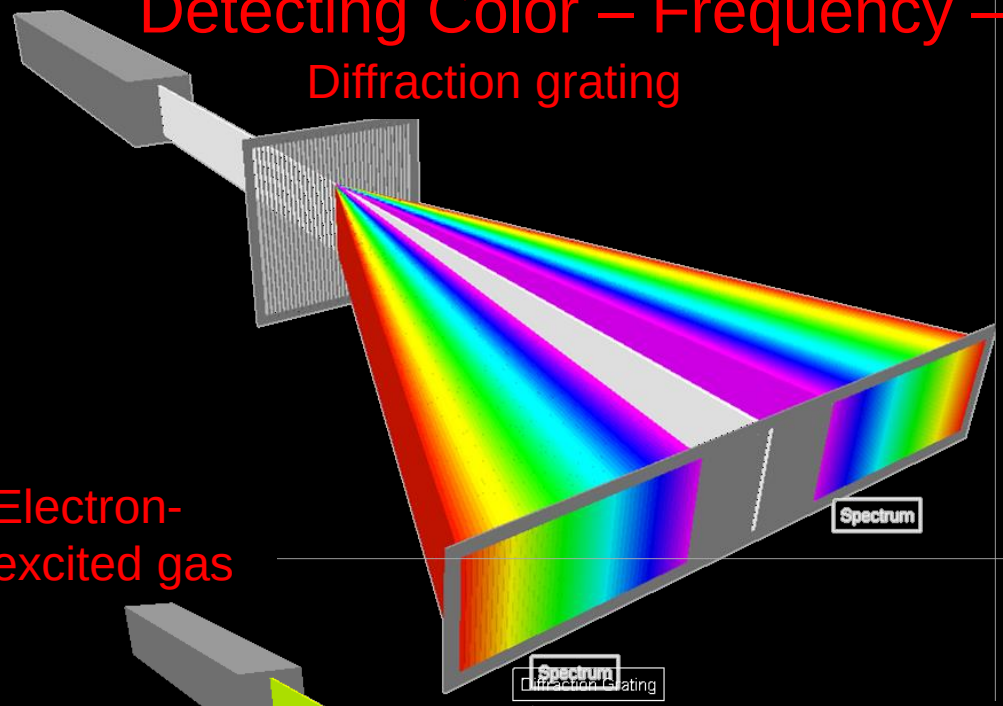


White light source

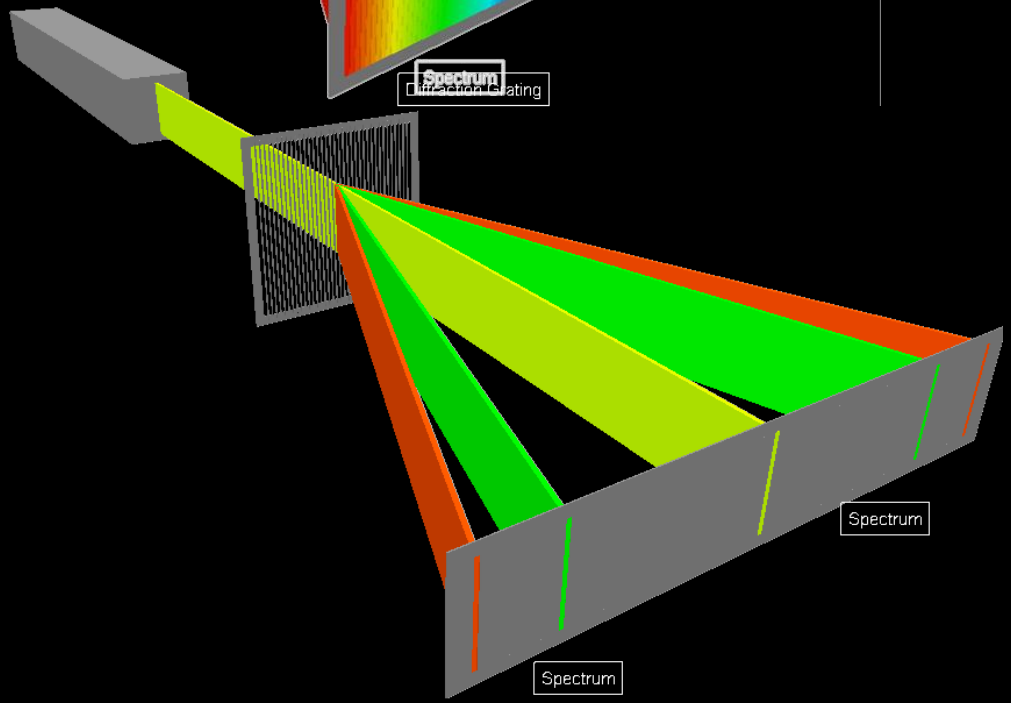
Spectrometer:

Detecting Color – Frequency – Energy

Diffraction grating



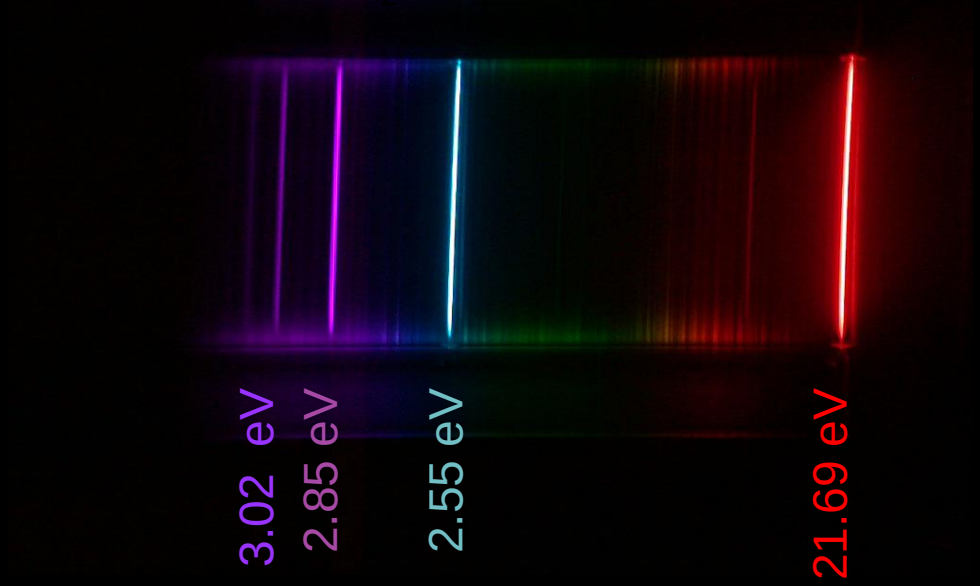
Electron-excited gas



Spectrometer:
Detecting Color – Frequency – Energy
Hydrogen

$$E_{light.\,from.H} = 13.6eV\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Where $n_2 > n_1$, integers



Only specific E_{light} , so…

Only specific ΔE_H , so…

Only specific E_H

$$E_{H,n} \approx m_e c^2 + m_p c^2 + \left(K_e + U_{e,p}\right) = m_e c^2 + m_p c^2 + \left(\frac{-13.6eV}{n^2}\right)$$

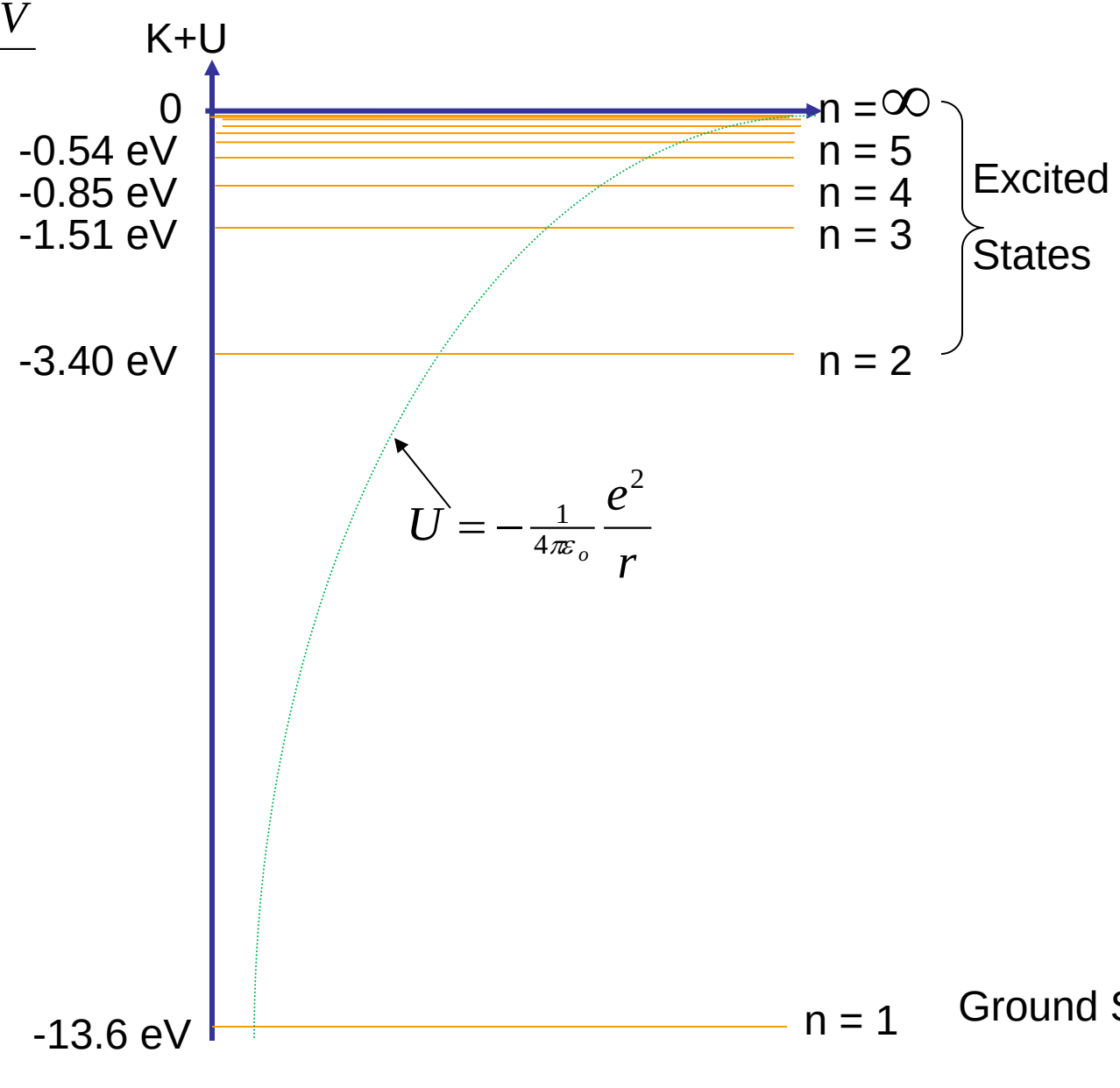
$$E_{H,n} \approx m_e c^2 + m_p c^2 + \left(K_e + U_{e,p}\right) = m_e c^2 + m_p c^2 + \left(\frac{-13.6eV}{n^2}\right)$$

Q8.2.a: What is (K+U) of the sixth electronic energy level (n=6) of a hydrogen atom?

1) – 13.6 eV
2) – 2.27 eV
3) + 2.27 eV
4) – 0.38 eV
5) + 0.38 eV

Hydrogen Energy Levels

$$(K+U)_n = -\frac{13.6eV}{n^2}$$



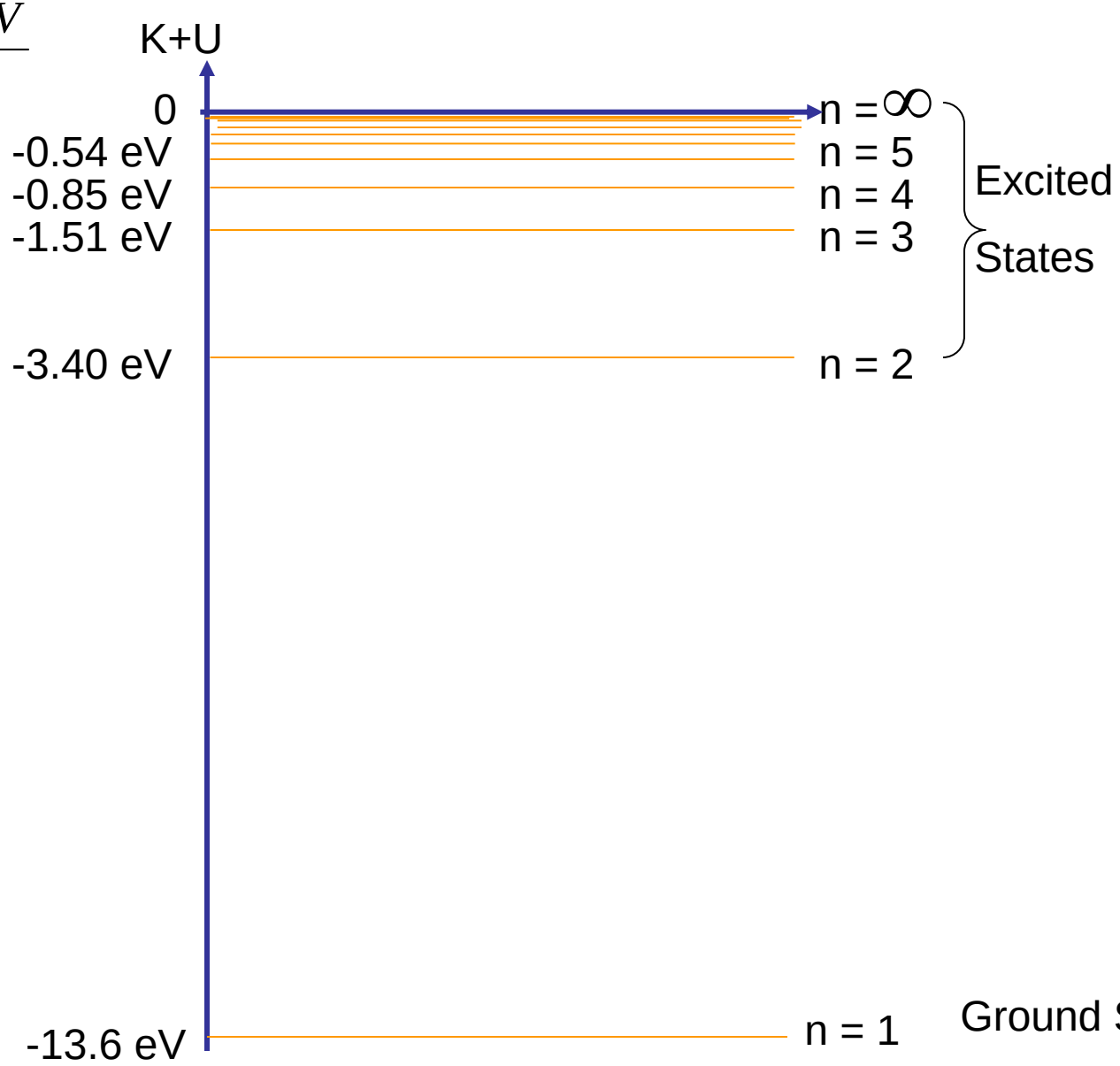
etc.

$$(K+U)_2 = -\frac{13.6eV}{2^2}$$

$$(K+U)_1 = -\frac{13.6eV}{1^2}$$

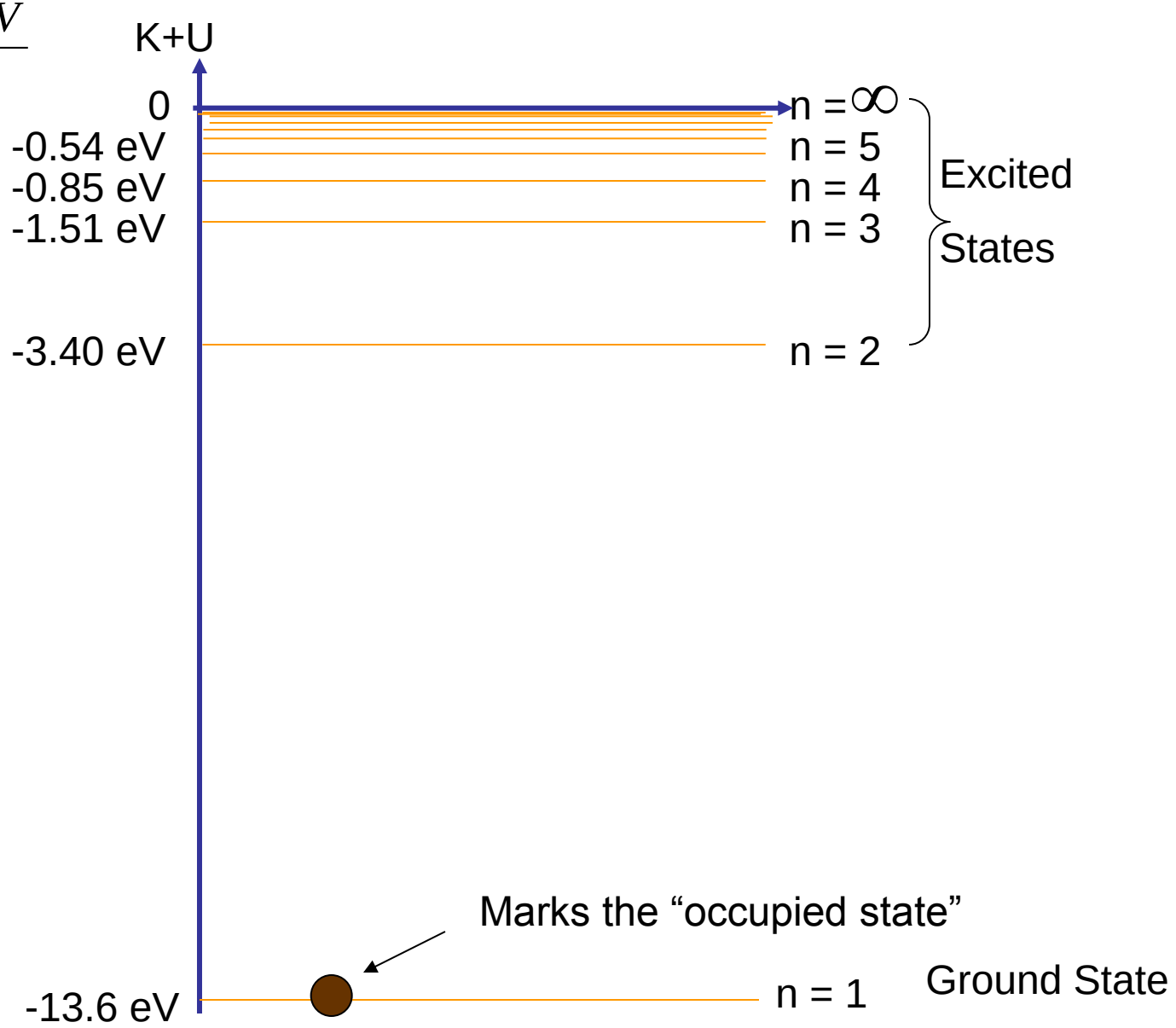
Hydrogen Energy Levels: Excitation

$$(K+U)_n = -\frac{13.6eV}{n^2}$$



Hydrogen Excitation: 1st in ground state

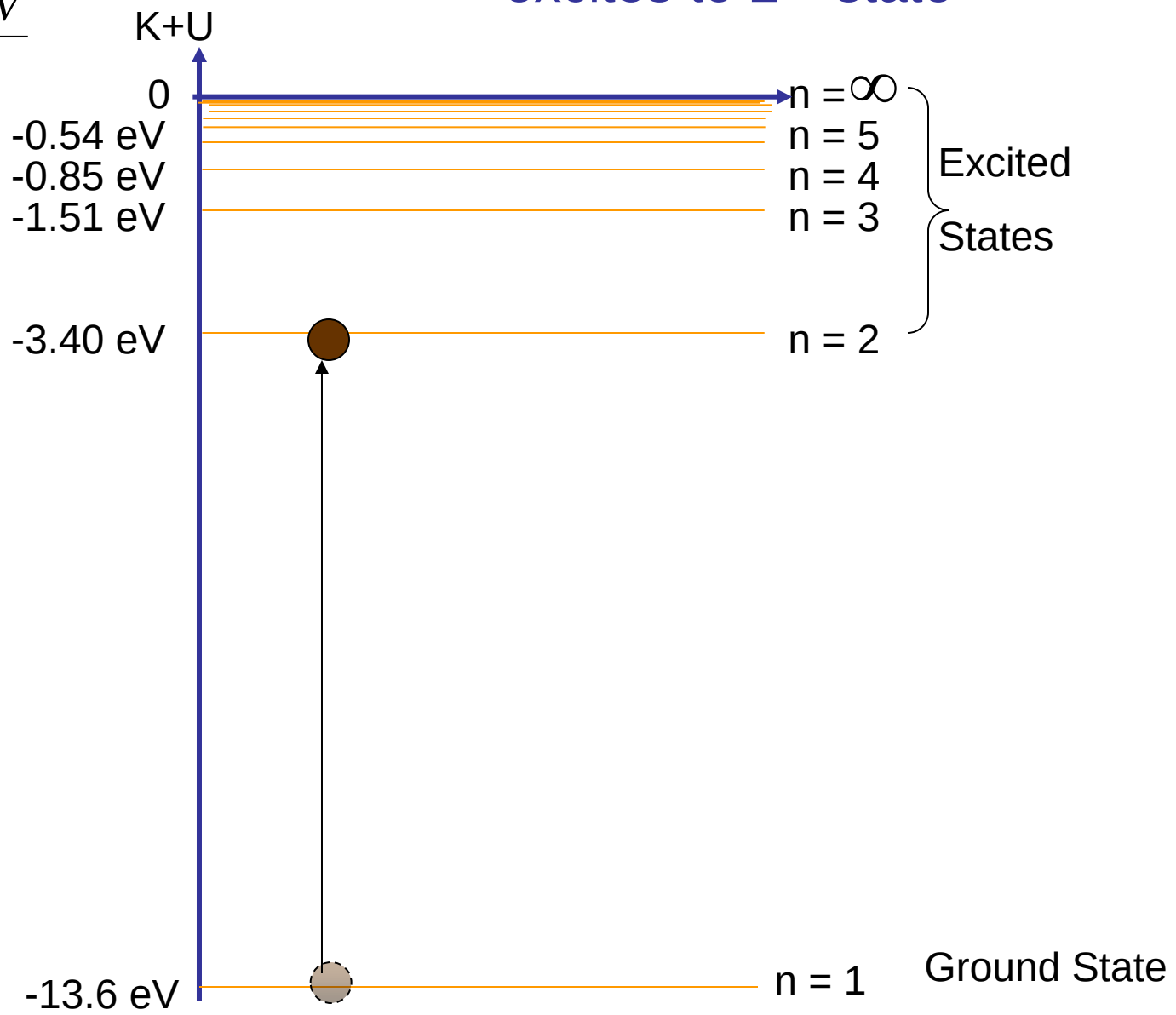
$$(K+U)_n = -\frac{13.6eV}{n^2}$$



Hydrogen Excitation: 2nd Adsorbs energy from Collision

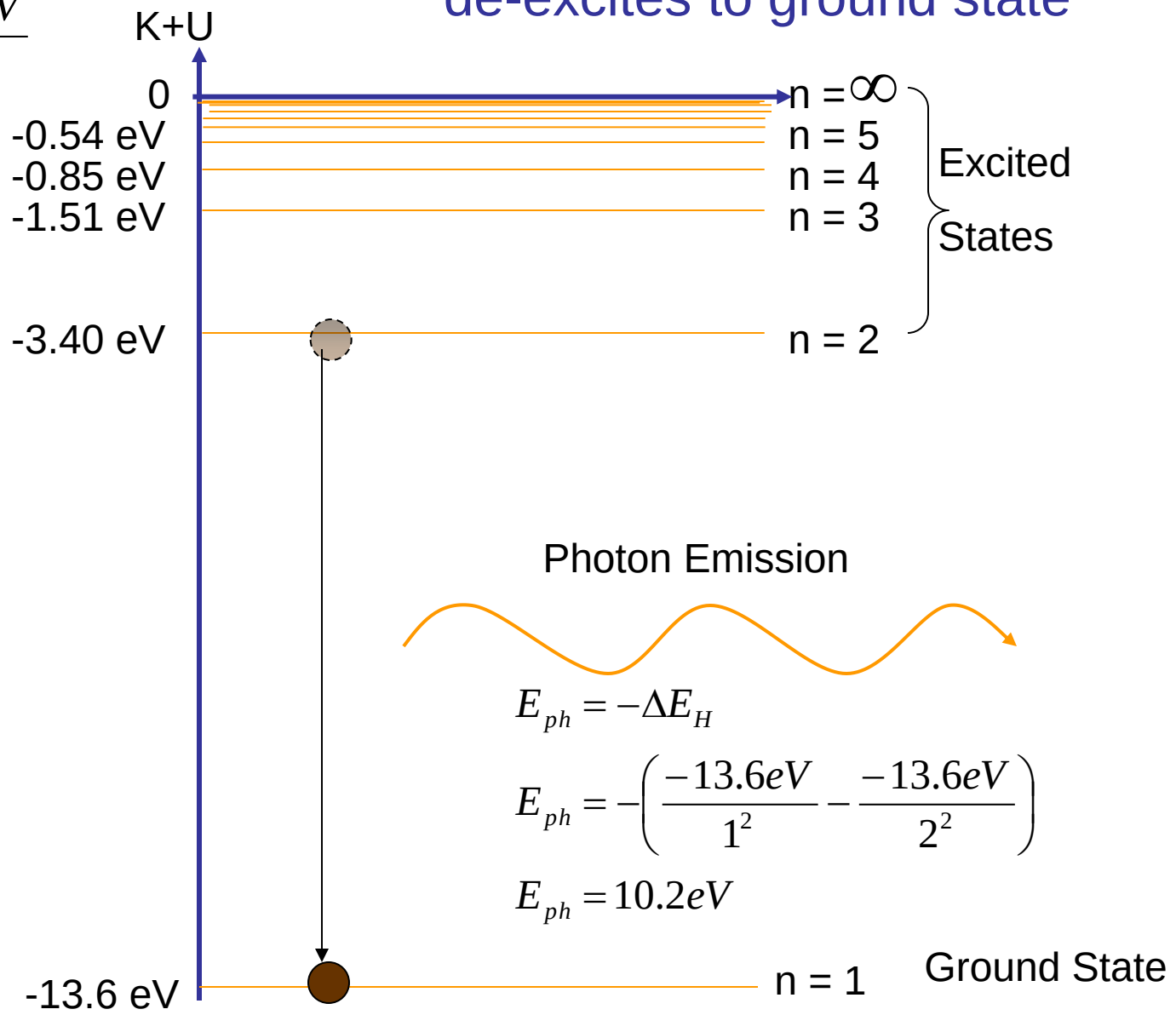
excites to 2nd state

$$(K+U)_n = -\frac{13.6eV}{n^2}$$



Hydrogen Excitation: 3rd Looses Energy by photon emission, de-excites to ground state

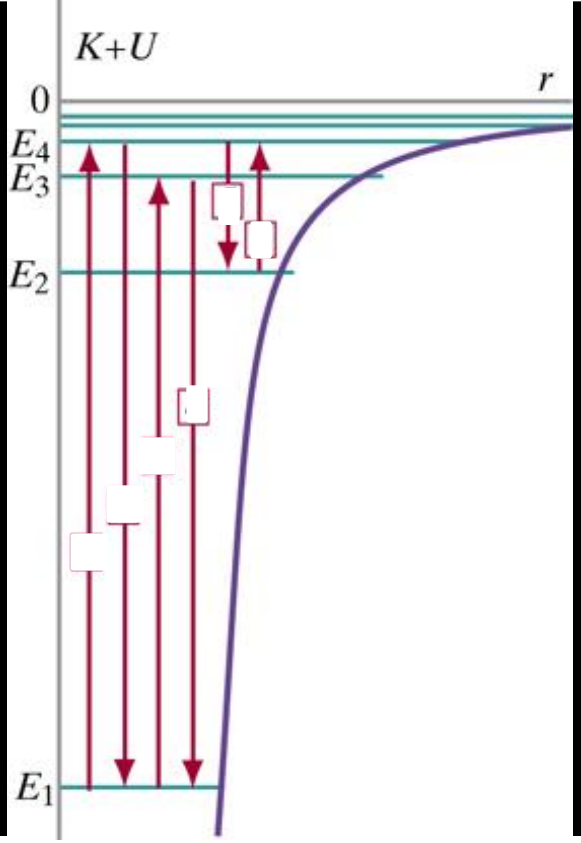
$$(K+U)_n = -\frac{13.6eV}{n^2}$$



$$E_{ph} = -\Delta E_H$$

$$E_{ph} = -\left(\frac{-13.6eV}{1^2} - \frac{-13.6eV}{2^2}\right)$$

$$E_{ph} = 10.2eV$$



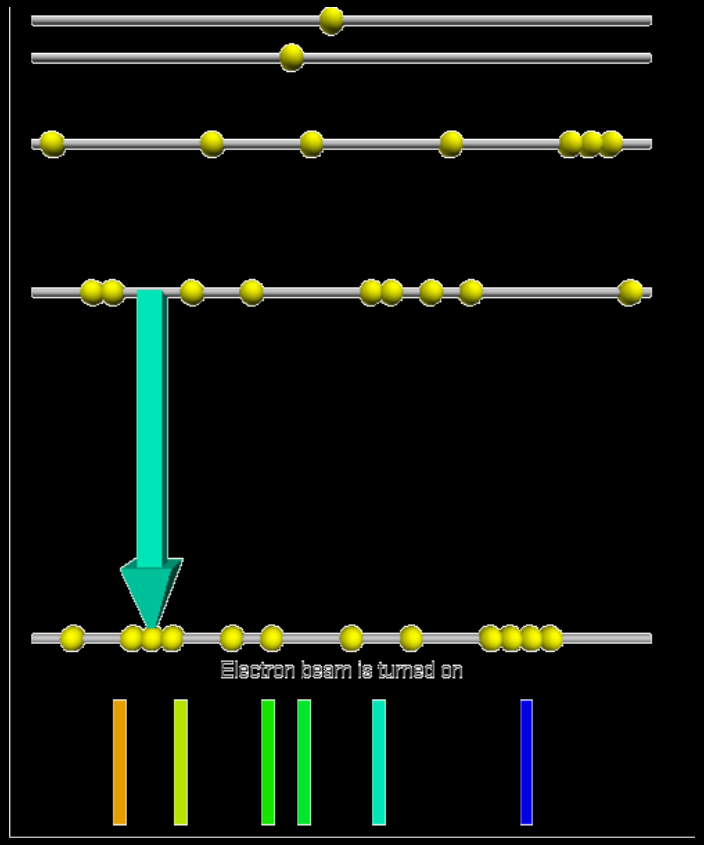
Q.8.2.c

A hydrogen atom is initially in the excited state (N = 4). It emits a photon and ends up in the state (N = 2).

What is the energy of the emitted photon?

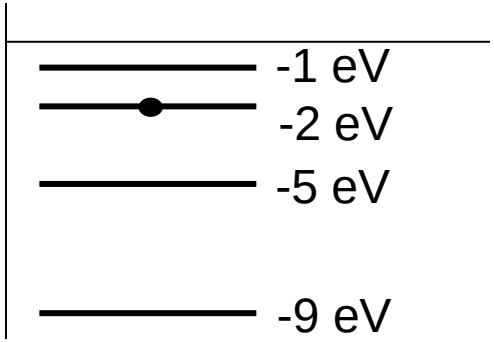
1) E4 – E2
2) E2 – E4
3) E4
4) E2
5) |E4|
6) |E2|

Example Atoms in Gas-Discharge Tube



06_Adsorb_emit.py.

Emission Example Here are the quantized energy levels (K+U) for some atomic or molecular object. If the object is excited to the third level (marked by a dot), what are the possible energies of photons that may be emitted?



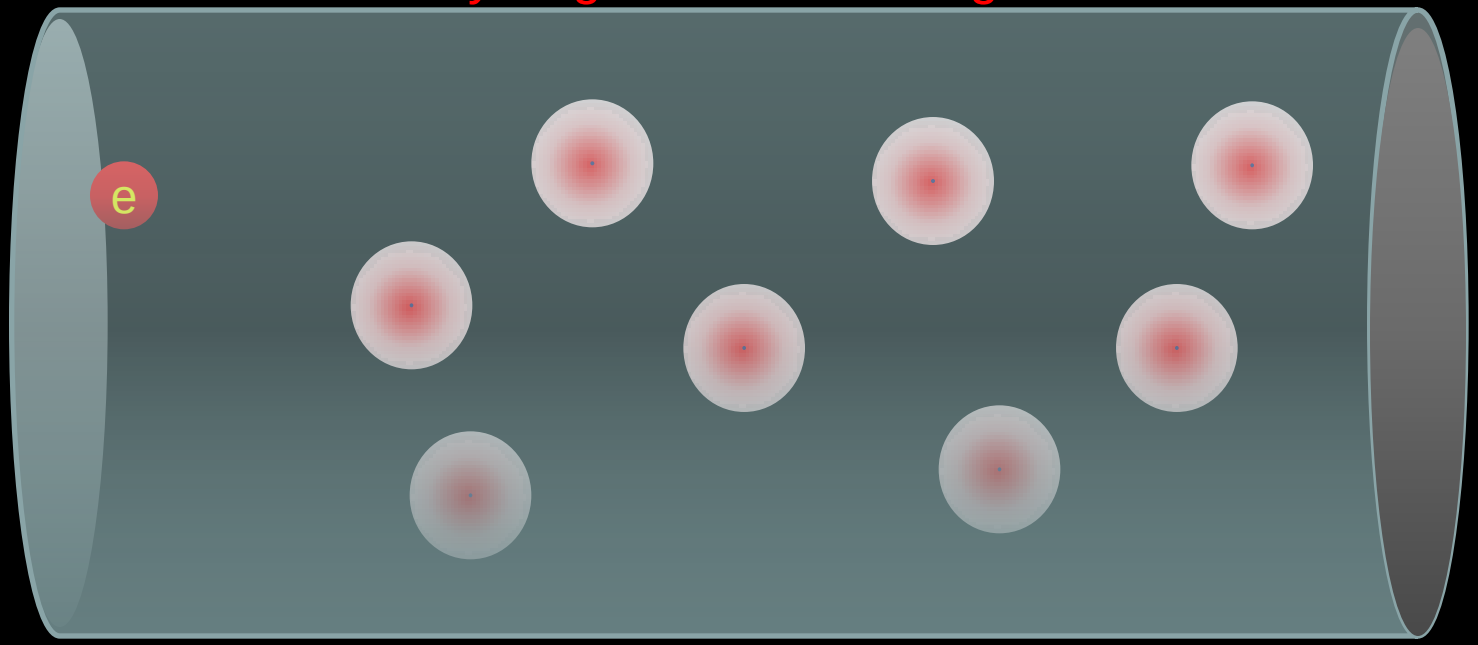
Say we have a very hot gas of such atoms, so the electron can get knocked into any of the levels. How many distinct energies can emitted photons have? (note: you'll want to actually determine each value to check for duplicates).

a) 2
b) 3
c) 4
d) 5
e) 6
f) 7
g) 8

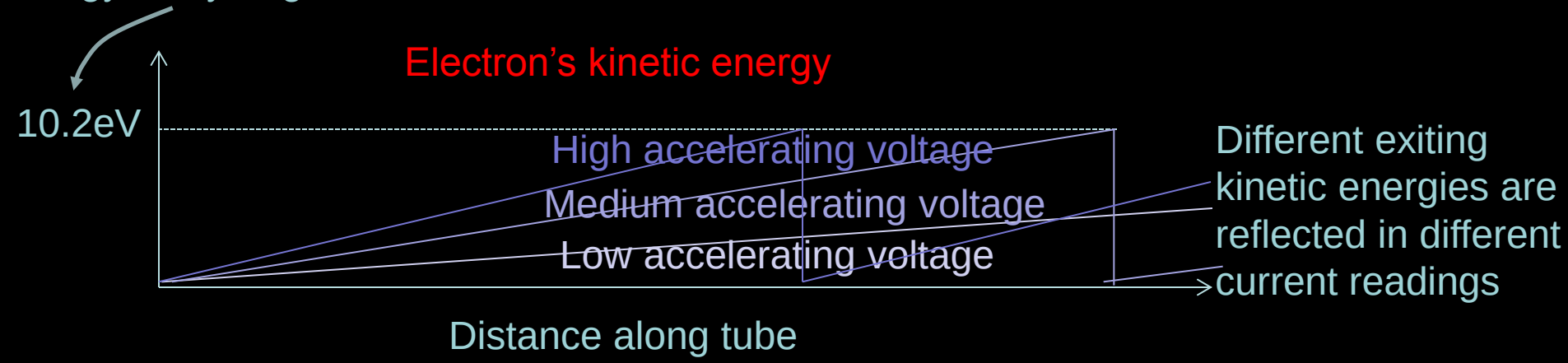
Frank-Hertz Experiment

Monitoring electron beam's *loss* of energy to the atoms

Hydrogen Gas Discharge Tube

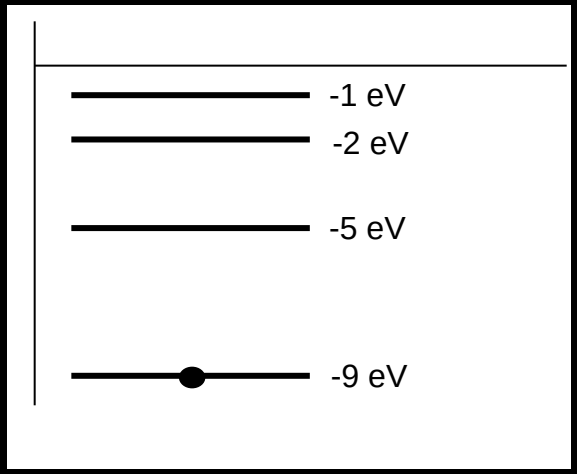


Energy of Hydrogen's n=1 to 2 transition

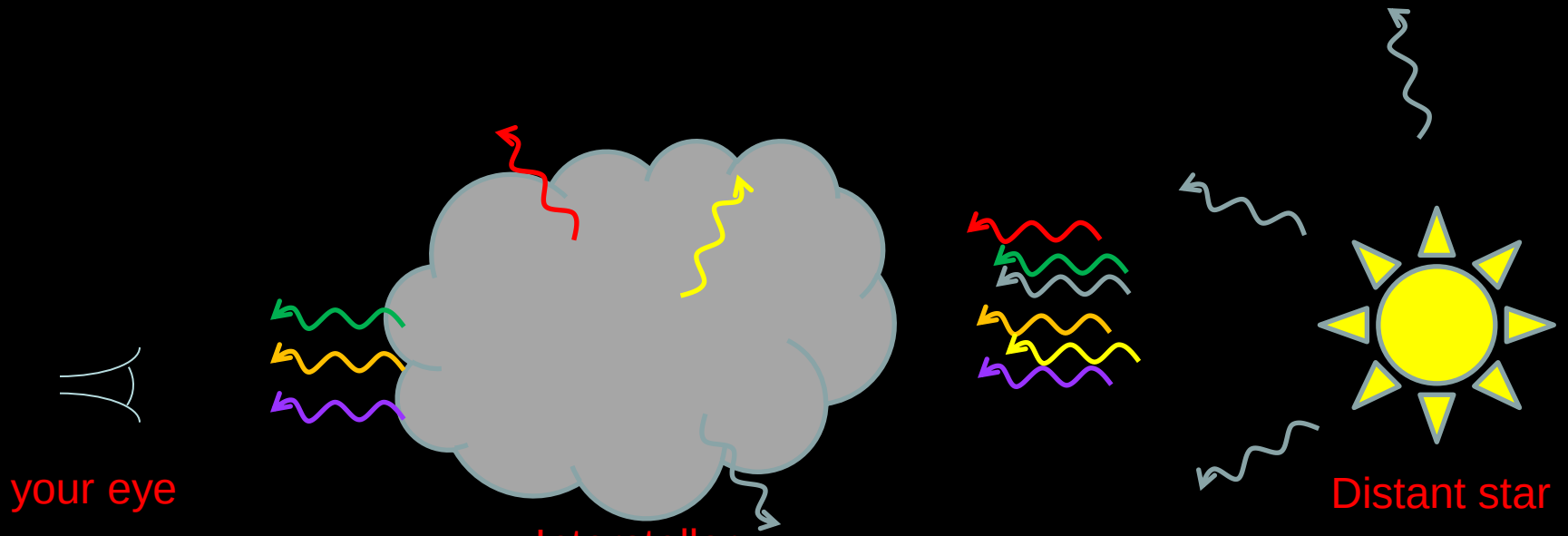


Here are the quantized energy levels (K+U) for an atomic or molecular object, and the object is in the "ground state" (marked by a dot). An electron with kinetic energy 6 eV is fired at the object and excites the object to the –5 eV energy state. What is the remaining kinetic energy of this electron?

a) 9 eV
b) 6 eV
c) 4 eV
d) 3 eV
e) 2 eV



Absorption Spectrum

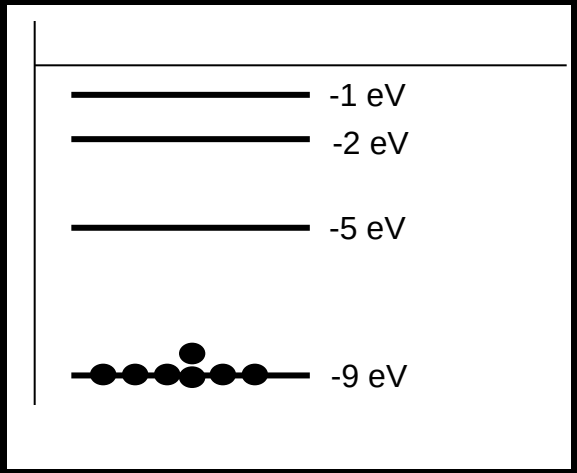


Colors / energies of light from the star that interact with cloud's atoms scatter; it's depleted from the star light you see.

06_spectrum.py.

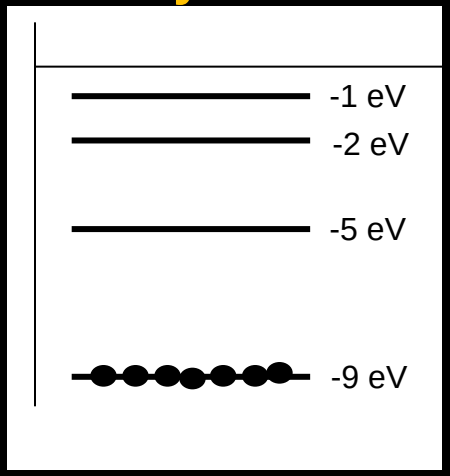
A collection of some atoms objects is kept **very cold**, so that all the objects are in the ground state. Light consisting of photons with a range of energies from 1 to 7.5 eV passes through this collection of objects. What photon energies will be depleted from the light beam (“dark lines”)?

a) 2 eV, 5 eV, 9 eV
b) 3 eV, 4 eV
c) 0.5 eV, 3 eV, 4 eV
d) 4 eV, 7 eV
e) 3 eV, 4 eV, 7 eV



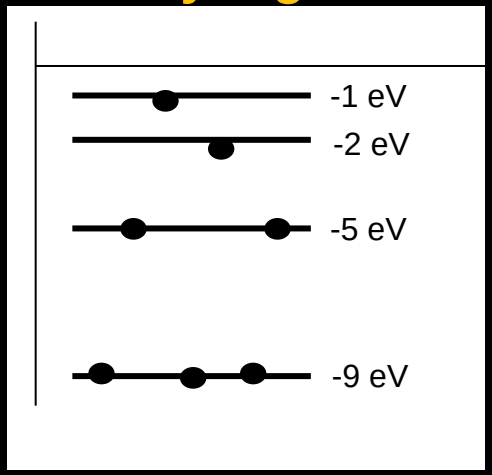
Temperature Effects on Absorption Spectrum

T very low



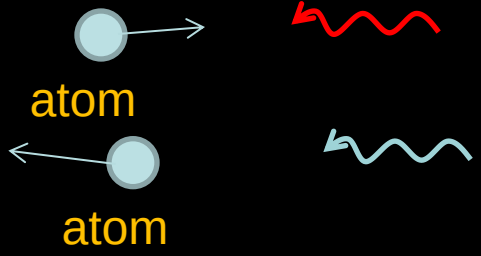
All atoms initially in ground state; only absorption lines for transitions from it

T very high



Many states have some atoms; you see absorption lines between many states

T medium



More energetic collision; lower-energy (redder) light excites transition

Less energetic collision; higher (bluer) light excites transition

Thermally broadened Spectral lines

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Shedding light on atomic energy levels
(segment of Hydrogen spectrum)