November 3

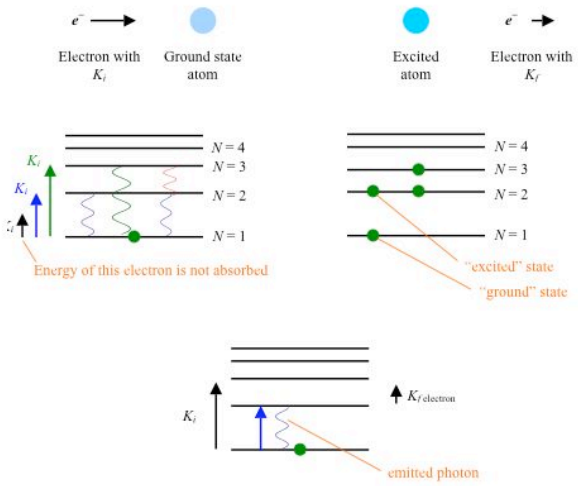
Get Clickers and whiteboards

TA Evaluation: Please evaluate Damon Hansen using the sheets provided.

The answer to the question 1-15 should be answered on bubble sheet.

Additional comments can be written on green sheet in space at bottom and continued on the back.

THIS IS NOT AN EVALUATION OF ME!
THAT WILL BE LATER…



$$\Delta E = E_f - E_i = W_{fQ} = 0$$

$$\left(m_e c^2 + K_{f,\text{electron}} + E_{f,\text{atom}}\right)$$

$$- \left(m_e c^2 + K_{i,\text{electron}} + E_{i,\text{atom}}\right) = 0$$

$$E_{f,\text{atom}} - E_{i,\text{atom}} = K_{i,\text{elec}} - K_{f,\text{elec}}$$

$$\Rightarrow \Delta E_{\text{atom}} = -\Delta K_{\text{electron}}$$

Ponderable: CSI identification of elements

Find energy levels of atomic hydrogen that is visible

$E_N = -\frac{13.6\,eV}{N^2}$

$1.8\,eV - 3.1\,eV$

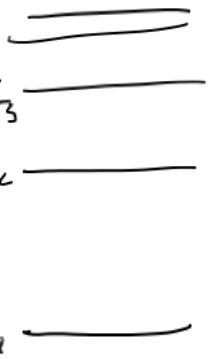
$E_1 = -13.6\,eV$

$E_2 = -3.40\,eV$

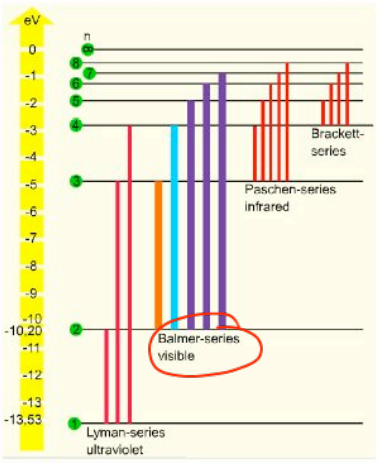
$E_3 = -1.51\,eV$

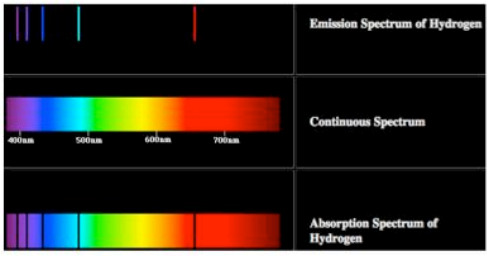
$E_4 = -0.85\,eV$

$\vdots$



N	Energy	to 1	to 2	to 3	to 4
1	-13.60				
2	-3.40	10.20			
3	-1.51	12.09	**1.89**		
4	-0.85	12.75	**2.55**	0.66	
5	-0.54	13.06	**2.86**	0.97	0.31
6	-0.38	13.22	**3.02**	1.13	0.47
7	-0.28	13.32	3.12	1.23	0.57
8	-0.21	13.39	3.19	1.30	0.64
9	-0.17	13.43	3.23	1.34	0.68
10	-0.14	13.46	3.26	1.38	0.71
11	-0.11	13.49	3.29	1.40	0.74


eV
n
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-10.20
-11
-12
-13
-13.53
Brackett-series
Paschen-series infrared
Balmer-series visible
Lyman-series ultraviolet

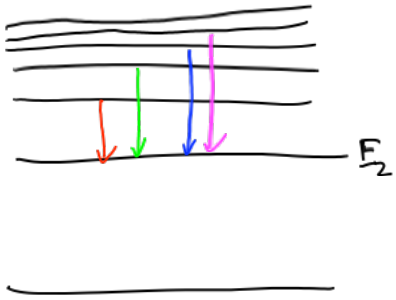

Emission Spectrum of Hydrogen
Continuous Spectrum
400nm
500nm
600nm
700nm
Absorption Spectrum of Hydrogen

Gratings, tubes, and filament

Orion

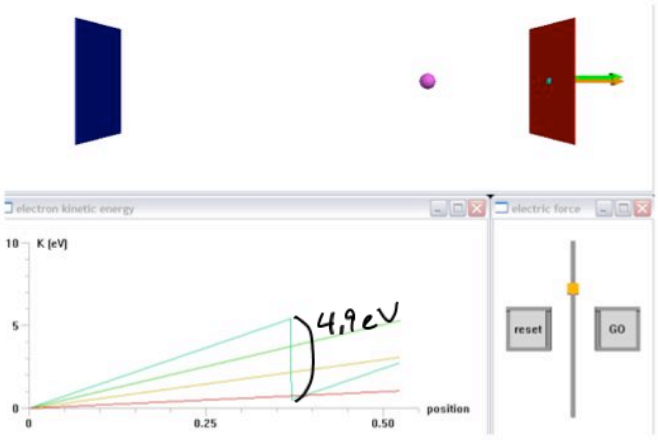
www.bigs.de/en/shop/anim/termsch01.swf

Balmer series for atomic hydrogen



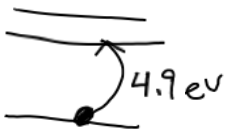
Ponderable: Let's be Franck(-Hertz)

frankhertz.py



E discrete

E = K + U

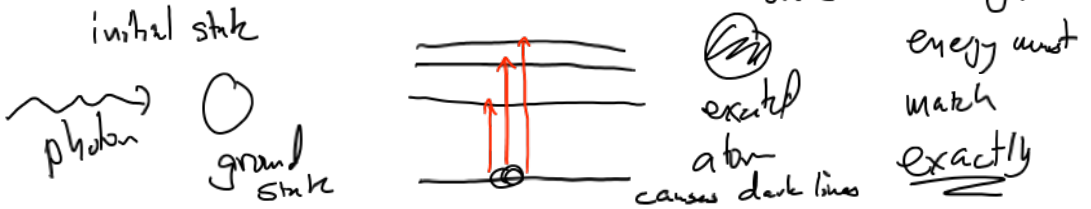


Three key processes:

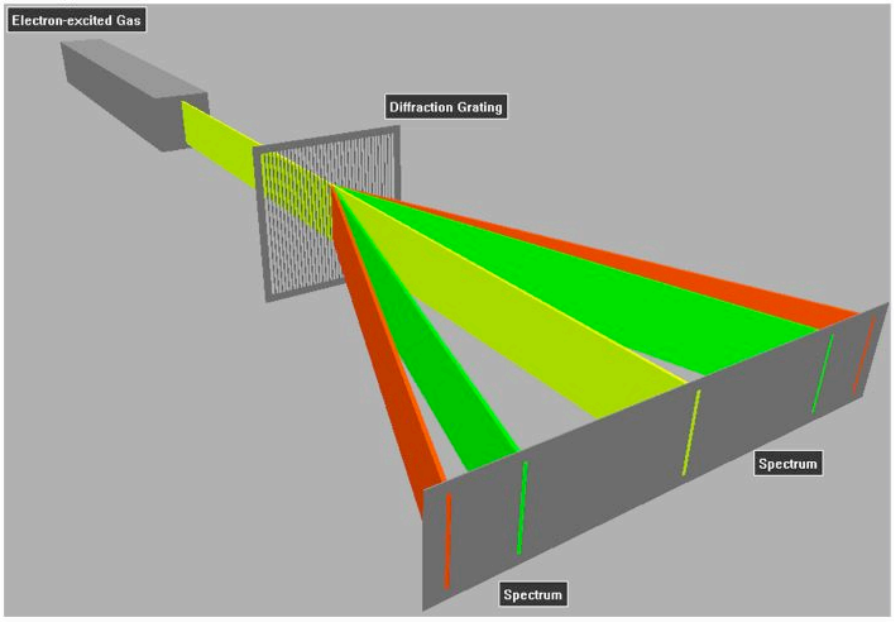
Electron excitation

Photon emission

Photon absorbtion

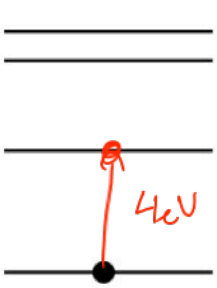


spectrum.py


Electron-excited Gas
Diffraction Grating
Spectrum
Spectrum

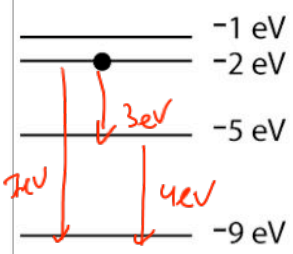
Clicker questions

Q1 Electron excitation of a gas

	Suppose that these are the quantized energy levels (K+U) for an atom. Initially the atom is in its ground state (symbolized by a dot). An electron with kinetic energy 6 eV collides with the atom and excites it. What is the remaining kinetic energy of the electron?	A) 9 eV B) 6 eV C) 5 eV D) 3 eV E) 2 eV

6 − 4 = 2 eV

Q2 Photon emission



Suppose that these are the quantized energy levels (K+U) for an atom. If the atom is excited to the second excited state (marked by a dot), what are the possible energies of photons it might emit?

A) 2, 5, and 9 eV
B) 3, 4, and 7 eV
C) 3 or 7 eV
D) 5 or 9 eV
E) 2 eV

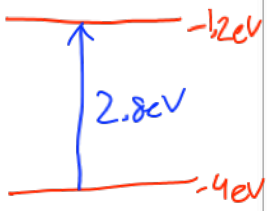
Q3 Photon absorption

Imagine an atom which only has two electronic energy levels. The ground state energy is -4.0 eV and the excited state has an energy of -1.2eV.

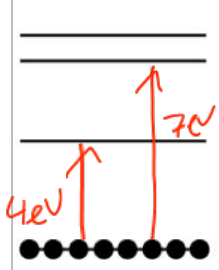
I irradiate a sample containing many atoms with visible light which contains photons of all energies from 1.8 eV up to 3.1 eV.

What will be the energy of the missing photons?

A) no photons will be missing
B) 1.2 eV
C) 4.0 eV and 1.2 eV
D) 4.0 eV
E) 2.8 eV



Q4 Photon absorption, cold sample



A collection of these atoms is kept very cold, so that all 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 absorbed 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

? very very very unlikely

Q5. What is the energy of the sixth electronic energy level (N=6) of a hydrogen atom?

A) – 13.6 eV
B) – 2.27 eV
C) + 2.27 eV
D) – 0.38 eV
E) + 0.38 eV

$K+U<0$

$-\frac{13.6}{6^2}$

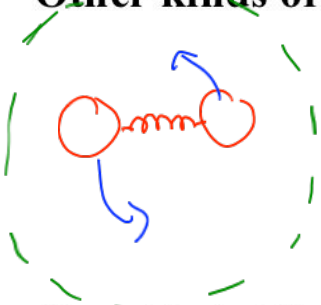
oscillator.py

harmonic oscillator

← equal spacing = $\hbar\omega = \hbar\sqrt{\frac{k_s}{m}}$

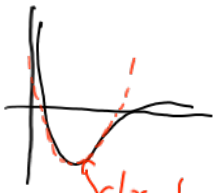
$\hbar = \frac{h}{2\pi} = 1.05 \times 10^{-34}\ J \cdot s$

Other kinds of quantized energy



Vibrational levels ~10^{-2} eV

↑ evenly spaced



close to harmonic oscillator $U \approx \frac{1}{2} k_s s^2$

NOT TO SCALE

Electronic levels ~1eV

Rotational levels ~10^{-4} eV

Nuclear energy $\approx 10^6$ eV

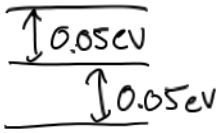
Hadronic energy $\approx 10^8$ eV

More Clicker questions

Q6

Two atoms joined by a chemical bond can be modeled as two masses connected by a spring. In one such molecule, it takes 0.05 eV to raise the molecule from its vibrational ground state to the first excited vibrational energy state.	How much energy is required to raise the molecule from its first excited state to the second excited vibrational state? A) 0.0125 eV B) 0.025 eV C) 0.05 eV D) 0.10 eV E) 0.20 eV

equally spaced



Q7: Spacing of vibrational energy levels

Molecule A: 2 atoms of mass M_A Molecule B: 2 atoms of mass $4*M_A$ Stiffness of interatomic bond is approximately the same for both.	Which molecule has vibrational energy levels spaced closer together? A) A B) B C) the spacing is the same

$$\omega = \sqrt{\frac{k_s}{m}}$$

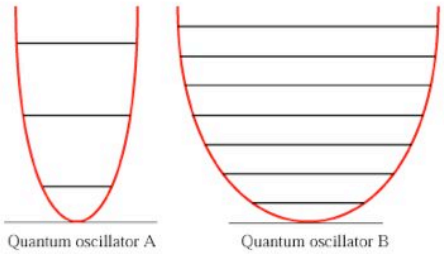
Q8: Spacing of vibrational energy levels

Suppose the atoms in diatomic molecules C and D had approximately the same masses, but Stiffness of bond in C is 3 times as large as stiffness of bond in D.	Which molecule has vibrational energy levels spaced closer together? A) C B) D C) the spacing is the same

$\hbar\sqrt{\frac{3k_s}{m}}$ vs $\hbar\sqrt{\frac{k_s}{m}}$

C

Q9: Spacing of vibrational energy levels



Pb: $k_s \sim 5$ N/m Al: $k_s \sim 16$ N/m
Which vibrational energy level diagram represents Pb, and which is Al?

A) *A* is Pb and *B* is Al
B) *A* is Al and *B* is Pb
C) *A* is both Pb and Al
D) *B* is both Pb and Al

Pb 207 g/mole $k_s = 5$ N/m

Al 27 g/mole $k_s = 16$ N/m