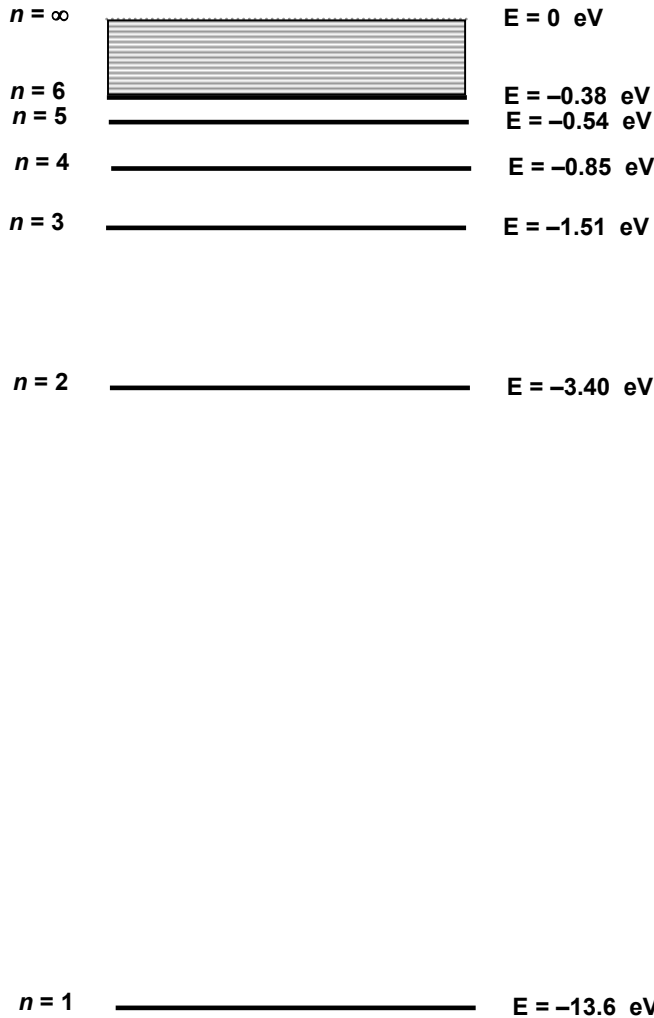# Atomic Physics Worksheet

1. Which of the gas samples shows an emission line with a wavelength

    between 4000 and 5000 Angstroms (400-500 nanometers): _____

    between 6500 and 7500 Angstroms (650-750 nanometers): _____

    (There may be more than one.)

$n = \infty$		E = 0 eV
$n = 6$		E = –0.38 eV
$n = 5$		E = –0.54 eV
$n = 4$		E = –0.85 eV
$n = 3$		E = –1.51 eV
$n = 2$		E = –3.40 eV
$n = 1$		E = –13.6 eV

   In the diagram above we have represented some allowed energy levels of the electron in a hydrogen atom. Ordinarily, the electron is in the "ground state" ($n = 1$) and has energy of –13.6 eV. (1 eV = 1.6×10^{-19} J.) This means that you would have to **add** 13.6 eV of energy to the electron in order to break it away from the hydrogen atom. (If the electron just barely escaped from the atom – and had no energy left over to go anywhere – we would say that it has "zero" total energy, or E = 0 eV.) If an electron in the ground state ($n = 1$) **gains** energy its energy level would rise, for instance to $n = 2$, $n = 3$, or some higher value of n. The **larger** the value of n, the **greater** is the energy of the electron. The **maximum** possible energy for an electron in the hydrogen atom (E ≈ 0 eV) would correspond to $n = \infty$.

When fast-moving electrons are sent flowing through a tube of hydrogen gas, some of them collide with the hydrogen atoms and increase the energy of the electrons in the atoms. In this way, the hydrogen electrons may briefly acquire some of the higher energy levels shown in this diagram. Usually, after a brief moment, these electrons will abruptly lose at least some of their extra energy. When they do this, we say they "drop" in energy level. In this process, they can emit *one single* electromagnetic photon – sort of a "particle" composed of e-m waves. *The energy of the emitted photon must exactly equal the amount of energy that is <u>lost</u> by the electron as it changes its energy level.*

When observing hydrogen gas in an electrical discharge tube (in which high-energy electrons are passed through the gas), the hydrogen glows with a colorful light. When the light is examined through a specially designed filter (a spectroscopic "grating"), it is possible to identify the wavelengths of the individual electromagnetic waves that make up that glowing light. These include the following wavelengths: 656.3 nm; 486.1 nm; 434.1 nm; 410.2 nm. (1 nm = 1×10^{-9} m). Let's try to identify which electronic transitions in the hydrogen atom correspond to these different e-m photons. *(Here we'll need to recall that the energy of a photon of frequency f is given by* $E = hf$; *Planck's constant h has the value* $h = 6.63 \times 10^{-34}$ J-s $= 4.14 \times 10^{-15}$ eV-s.)

2. In the following table, enter for each of these four different wavelengths of light the corresponding frequency of the e-m wave, as well as the color of light of that wavelength. Also find the minimum "energy package size" for that e-m wave. That would be the *lowest energy* with which that e-m wavelength could possibly be observed, and it corresponds to the energy of a "photon" of that wavelength.

symbol	wavelength (nm)	frequency (Hz)	color	photon energy (eV)
H_α	656.3			
H_β	486.1			
H_γ	434.1			
H_δ	410.2			

3. Suppose an electron drops from the n = 2 energy level down to the n = 1 level; in this process it would have to emit an e-m photon.
      a) Could that photon correspond to one of the four shown here? If so, which one is it?

      b) If not, state whether or not the e-m wave corresponding to that photon should be visible. Explain your reasoning. If yes, what color would it be?

4. Photons produced by electrons dropping directly into the n = 1 level are said to be part of the "Lyman" series.

      a) How many different photons in the Lyman series could be emitted as a result of electronic transitions *among the six levels represented on this diagram?* (There exist many others besides these.

b) Of the transitions corresponding to your answer to (a), which transition produces:

      i)   the highest frequency photon? What is the energy of that photon (in eV)?

      ii)   the longest wavelength photon? What is the energy of that photon (in eV?)

5. Identify the electronic transition (initial energy level → final energy level) corresponding to each of the four listed photons:

     a) H_α

     b) H_β

     c) H_γ

     d) H_δ

   (These four are said to be part of the "Balmer" series.)

6. Is it possible for an electron in a hydrogen atom to emit a gamma ray by falling to a lower energy level? Explain.

*If e-m waves strike an atom, some of the photons may be **absorbed**. In that process, one of the electrons in the atom will absorb the e-m wave and experience an **increase** in its energy as a result. This can only happen if the **change** in the energy of the electron exactly matches the energy of the incoming photon.*

7. Suppose it is found that when a white light is passed through a tube of hydrogen gas, some of the **red** light is absorbed. Which electronic transition would have to occur for this to be observed?

8. What frequency of light could be absorbed if an electron is raised from the $n = 1$ energy level to the $n = 6$ energy level? Could this wavelength of e-m wave be observed as visible light?

9. If a gamma ray photon struck the hydrogen atom and was absorbed in the process, what do you think would happen to the electron in the hydrogen atom? Would it still be bound to the nucleus of the atom? Explain. *(Hint: Refer to the discussion at the bottom of page 1.)*

Questions #10-15 refer to this energy level diagram of some unknown atom. The <u>distances</u> between the horizontal lines are proportional to the <u>energy</u> differences between the levels.
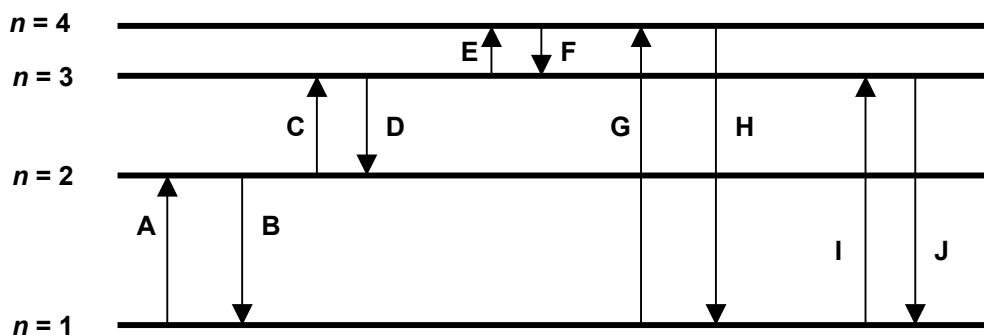
10. Suppose that transition B corresponds to the energy of a photon of blue light.

Then could transition D represent:

A) emission of infrared light

B) emission of ultraviolet light

C) absorption of infrared light

D) absorption of ultraviolet light

Explain your answer:

11. Which transition corresponds to the longest wavelength absorption?

12. Which transition corresponds to the highest frequency emission?

13. We'll use the notation ΔE_{12} to represent the *absolute value* of $(E_{n = 2} - E_{n = 1})$; this is the energy *change* of an electron that makes a transition between level 1 and level 2. Suppose we are given that $\Delta E_{23} \div h =$ [frequency of yellow light]. Which transition could represent the emission of infrared waves?

14. Rank all transitions in order of *increasing frequency of <u>emitted</u> photon (but only include transitions corresponding to emission):*

lowest frequency _____highest frequency

15. Rank all transitions in order of *increasing wavelength of <u>absorbed</u> photon (but only include transitions corresponding to absorption):*

smallest wavelength _____longest wavelength

Explain how you found the answer to this question.