

HYDROGEN EMISSION SPECTRUM

ENTER YOUR ANSWERS AND INFORMATION IN THE LIGHT BLUE FIELDS

Purpose

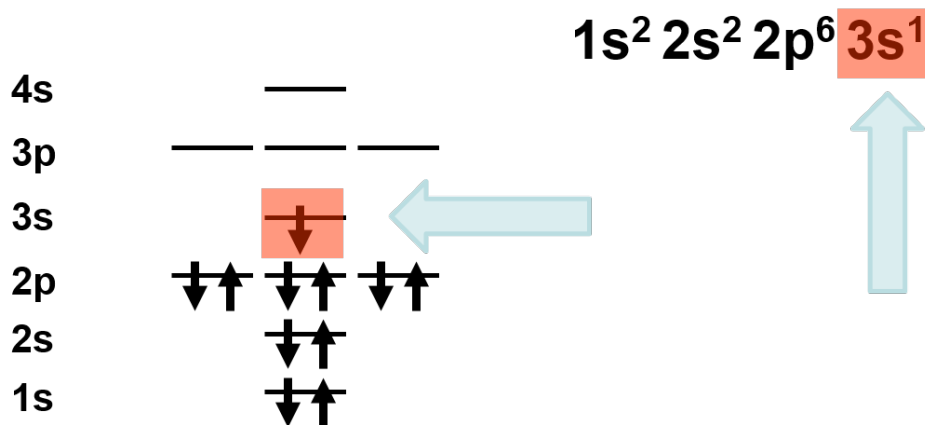
The purpose of this laboratory exercise is to learn about electron transitions and emission spectra.

Theory

Electron Configurations, Energy Level Diagrams and Electron Transitions

Electrons in an atom are arranged in shells and subshells around the nucleus. The electrons in different shells and subshells have different amounts of energy. Electrons that are furthest from the nucleus have the largest amount of energy of the electrons in that atom.

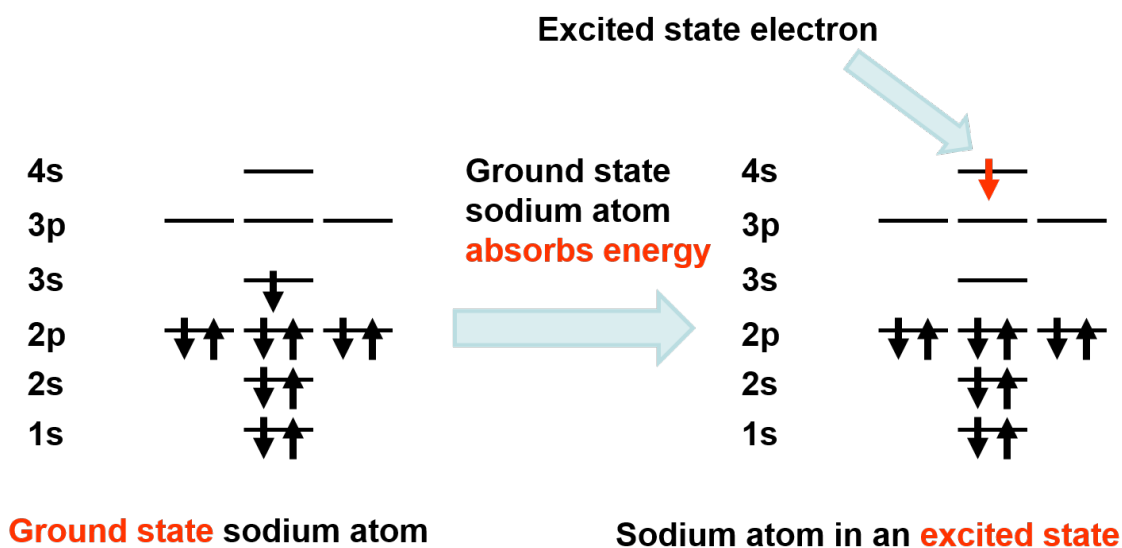
Consider a sodium atom as an example. The electron configuration and the energy level diagram for a sodium atom are shown below. The electron in the 3s orbital is the electron in this atom that is furthest from the nucleus. This is the highest energy electron in a sodium atom.



Electrons always occupy the lowest energy shells, subshells and orbitals possible. Electrons in their lowest energy locations are called **ground state electrons**. An atom that has all its electrons in the lowest energy possible is a **ground state atom**. Ground state electrons are as close to the nucleus as possible. Atoms are most stable when they are in their ground state.

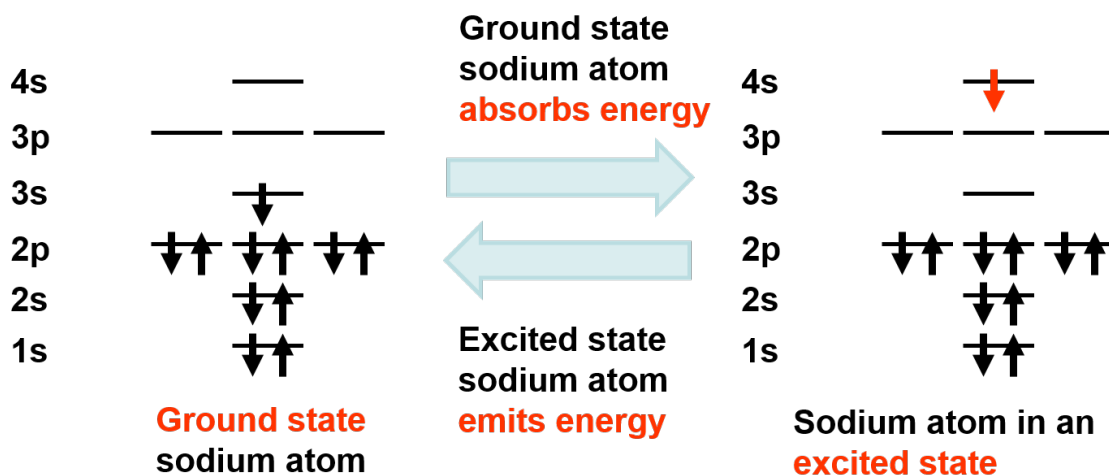
Ground state electrons can absorb energy and move to higher energy shells. Electrons that do this are **excited state electrons**. An atom that has excited state electrons is an atom in an excited state. Excited state electrons are higher in energy than ground state electrons. Excited state electrons are further from the nucleus than ground state electrons.

Using a sodium atom as an example, the electron in the 3s subshell can absorb energy and move to the 4s subshell. The electron in the 4s subshell is an excited state electron. The sodium atom with the excited state electron is in an excited state.



Electrons in an excited state will not stay in an excited state for long. These electrons will return to their ground state. Energy is emitted or released when the electron returns to the ground state. Using a sodium atom as an example, the amount of energy that is required to move the electron in the 3s subshell to the 4s subshell is the **same amount of energy** that is released or emitted when the electron in the 4s subshell returns to the 3s subshell.

The energy that is released is in the form of **light**, or more accurately, **electromagnetic radiation**. Electromagnetic radiation is a form of energy.



Electromagnetic Spectrum

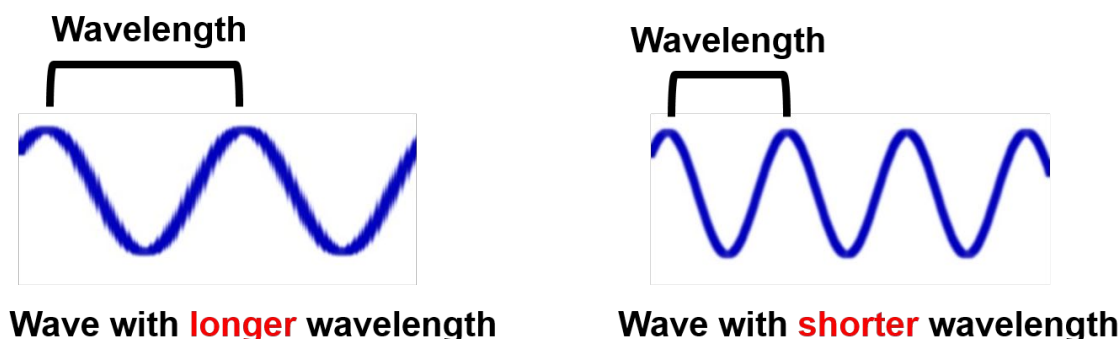
Electromagnetic radiation energy is transmitted in the form of waves. All waves of electromagnetic radiation travel at a speed of approximately **3.0×10^8 meters per second** or **6.7×10^8 miles per hour**. This is typically referred to as the **speed of light**.

As a point of reference:

- The distance from the earth to the moon is about two hundred and thirty eight thousand, nine hundred miles. It takes about 1.3 seconds for light reflected off the surface of the moon to reach the earth.
- The distance from the earth to the sun is approximately ninety—two million, nine hundred sixty thousand miles. It takes about 8.3 minutes or 500 seconds for light emitted from the sun to reach the earth.

Electromagnetic waves can be described with a **wavelength**. The wavelength of a wave is the distance between two identical points on a wave.

The wavelength for two waves are shown below. You can see that the wavelengths for the two waves are different.



A wavelength is a length or distance. Typical units used for wavelength are the meter and the **nanometer (nm)**. A nanometer is a very small length. There are 1×10^9 nanometers in one meter.

$$1 \times 10^9 \text{ nm} = 1 \text{ m}$$

The Greek letter lambda (λ) is typically used to represent the wavelength of a wave.

Electromagnetic radiation can also be described with a **frequency**. Remember that all electromagnetic radiation travels at the same speed, which is about 3.0×10^8 meters per second. **The frequency of a wave is the number of times an identical point on a wave passes a particular point in one second.**

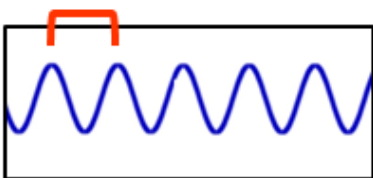
The unit for frequency is the number one in the numerator and the second unit in the denominator. Another name for this unit is Hertz. The symbol or abbreviation for Hertz is uppercase "H" and lowercase "z". The frequency of a wave is typically designated with the Greek letter nu (ν).

$$\frac{1}{s} = \text{Hz} = \nu$$

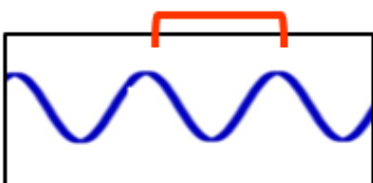
As I mentioned all electromagnetic waves travel at the same speed. However different electromagnetic waves have different wavelengths and different frequencies.. The two electromagnetic waves below move at the same speed but they have different wavelengths.

Remember that the frequency of a wave is the number of times an identical point in a wave passes a particular point in one second. More peaks pass a particular point per second for the wave with the shorter wavelength than for the wave with the longer wavelength.

Shorter wavelength



- **More** peaks pass a particular point in one second in this wave. Peaks are **closer** together. **Higher** frequency.



Longer wavelength

- **Fewer** peaks or crests pass a particular point in one second in this wave. Peaks are **further** apart. **Lower** frequency.

The relationship between the speed of light, designated with the lowercase "c", wavelength, designated with the Greek letter lambda, and frequency, designated with the Greek letter nu, is shown below. Remember that the speed of all electromagnetic waves, designated with the lowercase "c", is a constant value. This value never changes. So if the wavelength of a wave increases the frequency of the wave must decrease, and if the wavelength of a wave decreases the frequency of the wave must increase.

wavelength (λ)

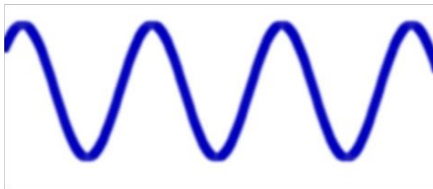
↓

speed
 $3.0 \times 10^8 \text{ m/s}$ → $c = (\lambda) \times (\nu)$

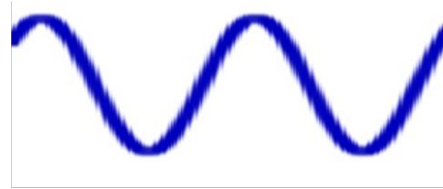
↑
 frequency (ν)

There is also a relationship between wavelength, frequency and energy.
 Electromagnetic waves travel at the same speed, but they have different wavelengths, different frequencies, and different energies.

- Waves with shorter wavelengths have higher frequencies and higher energies.
- Waves with longer wavelengths have lower frequencies and lower energies.



- Short wavelength
- High frequency
- High energy

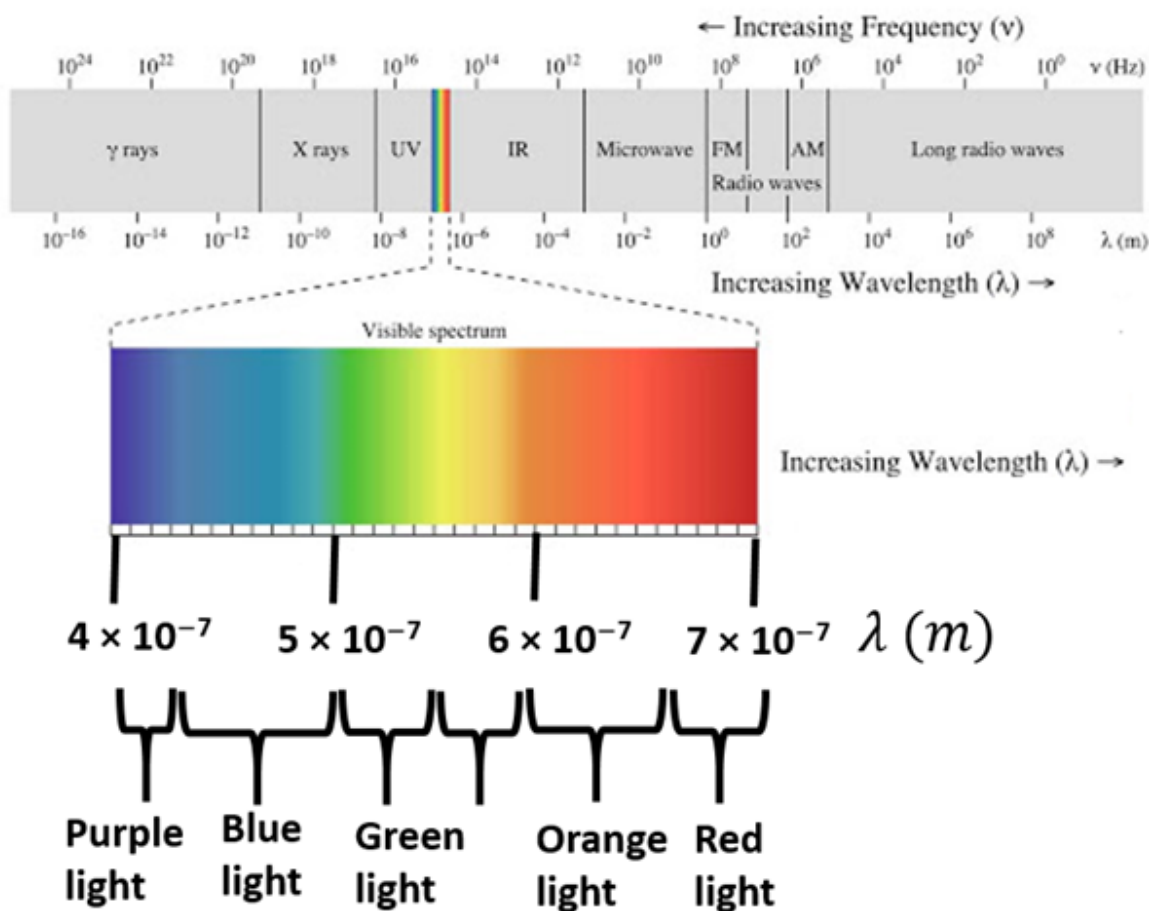


- Long wavelength
- Low frequency
- Low energy

The picture below shows the electromagnetic spectrum. This picture shows different types of electromagnetic radiation.

- **Short wavelength**
- **High frequency**
- **High energy**

- **Long wavelength**
- **Low frequency**
- **Low energy**



- Notice that the frequency, designated with the Greek letter nu (ν) in Hertz, increases going from the right side of the spectrum to the left.
- The wavelength, designated with the Greek letter lambda (λ), in meters, increases going from the left side of the spectrum to the right.

Also notice that:

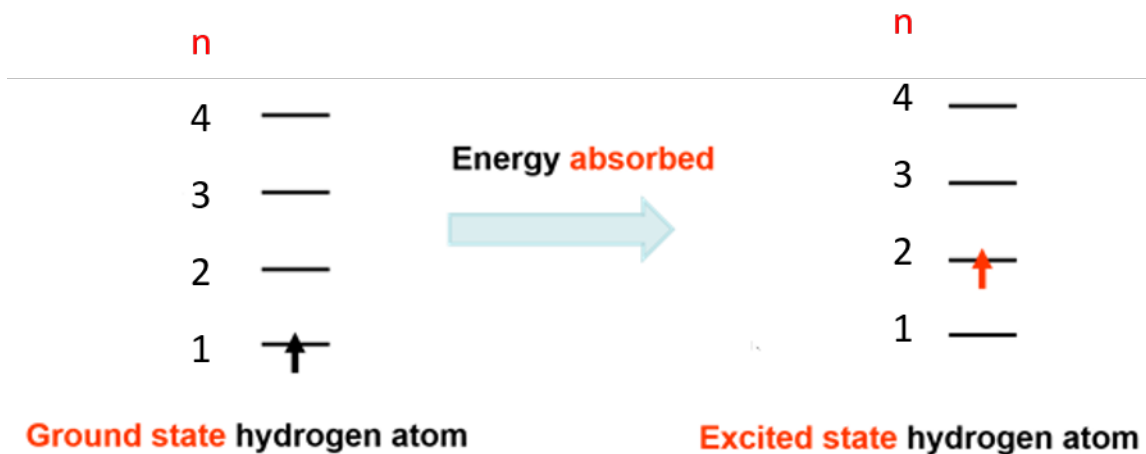
- Radio waves have long wavelengths, low frequency and low energy.
- Gamma rays and X-rays have short wavelengths, high frequency and high energy.
- Visible light is also electromagnetic radiation. Different colors of visible light don't have the same wavelength, frequency or energy.

Electron Transitions and the Electromagnetic Spectrum

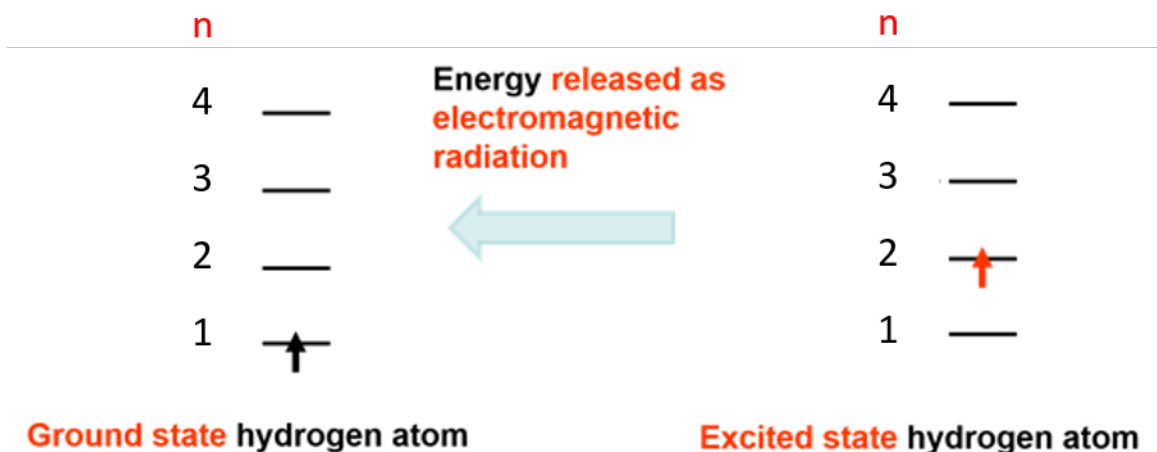
Now let's think about the transitions between ground state and excited state in atoms. Let's consider a hydrogen atom as a simple example.

- **Here we will look at transitions between principle energy levels (shells) designated with the letter "n" instead of transitions between specific sublevels (s, p, d and f).**

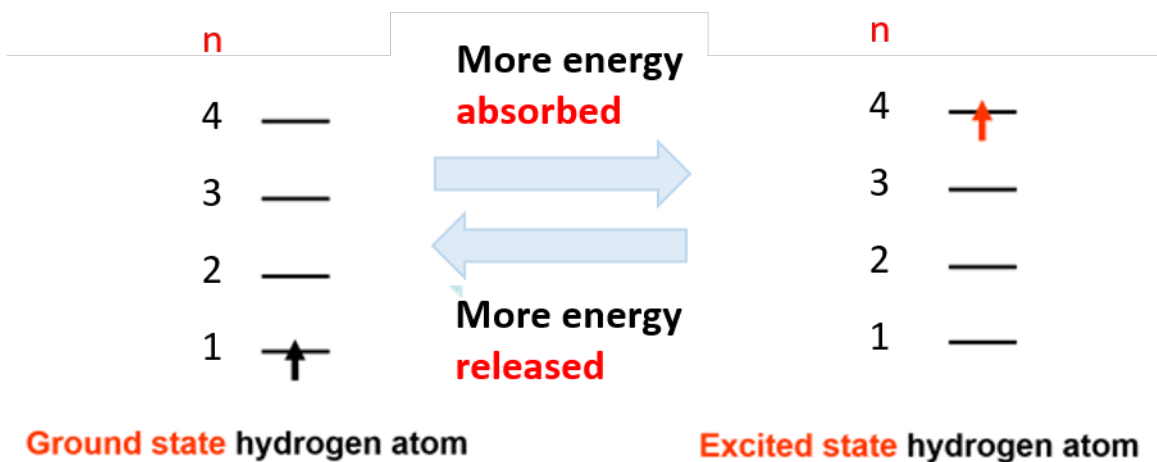
Remember that a hydrogen atom only has one electron, and the ground state electron in a hydrogen atom is in the first principle energy level ($n = 1$). The absorption of energy can result in the electron moving to the second principle energy level ($n = 2$).



Also remember that the excited state electron in the second principle energy level will return to the ground state, to the first principle energy level. Energy will be released in when the electron returns to the ground state. The energy that is released will be in the form of electromagnetic radiation.



Now assume that the hydrogen atom absorbs more energy and the electron moves from the first principle energy level ($n = 1$) to the fourth principle energy level ($n = 4$). More energy will be released when the electron returns to the ground state because more energy was absorbed to create this excited state.

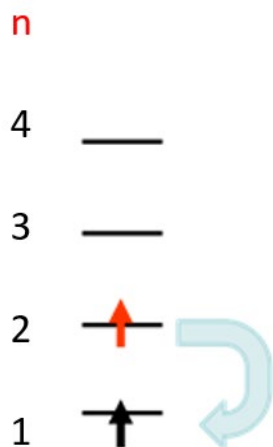


So the electromagnetic radiation emitted or released during the $n = 2$ to $n = 1$ transition has a lower energy than the electromagnetic radiation emitted or released during the $n = 4$ to $n = 1$ transition.

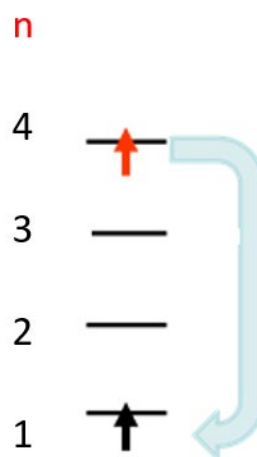
We know the relationship between wavelength, frequency and energy. So the electromagnetic radiation emitted during the $n = 2$ to $n = 1$ transition will have lower

energy, lower frequency and longer wavelength. The electromagnetic radiation emitted during the $n = 4$ to $n = 1$ transition will have higher energy, higher frequency and shorter wavelength.

Lower energy released
Lower frequency
Longer wavelength



Higher energy released
Higher frequency
Shorter wavelength



In this lab report you will analyze the different electron transitions that can occur in a hydrogen atom and complete the wavelength, frequency and energy of the electromagnetic radiation emitted during the transitions.

Name _____

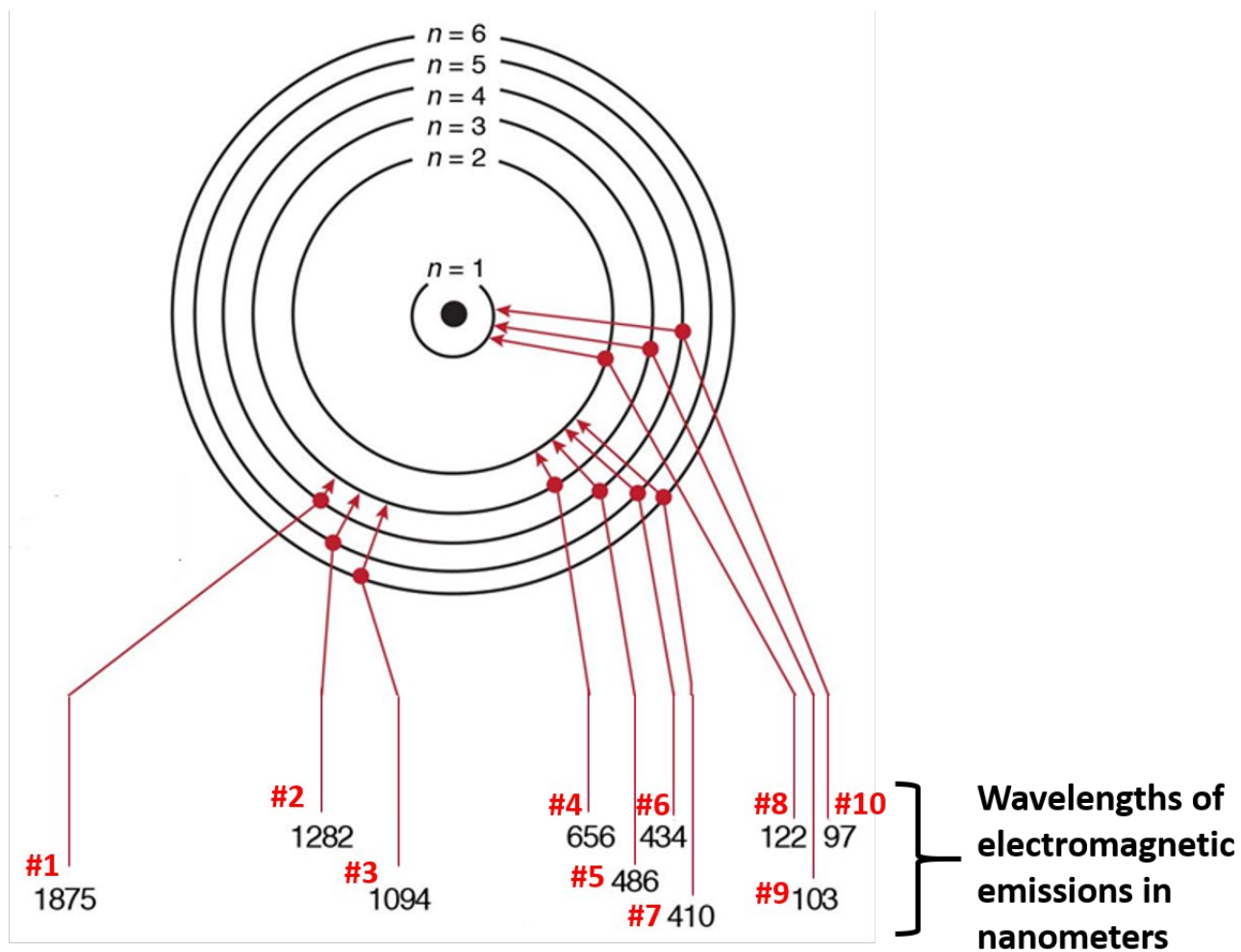
Date _____

HYDROGEN EMISSION SPECTRUM

Procedure, Data Sheet and Questions

A. Analysis of Emission Spectrum of a Hydrogen atom

1. The picture below shows ten possible electron transitions from higher principle energy levels to lower levels, and the wavelengths of the electromagnetic radiation emitted during these transitions in nanometers. Notice that these transitions are numbered **#1** through **#10**.



2. Complete the table below using the information given in the picture on the previous page. Refer to the **Theory** section to see how to perform the calculations.

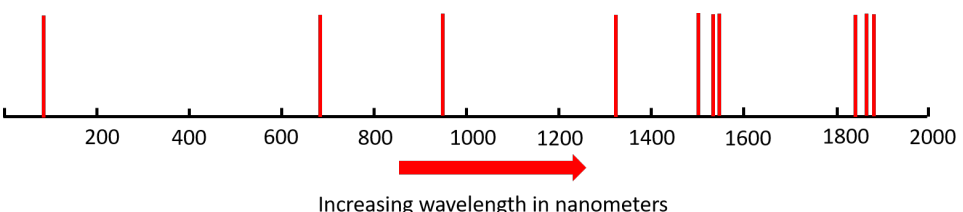
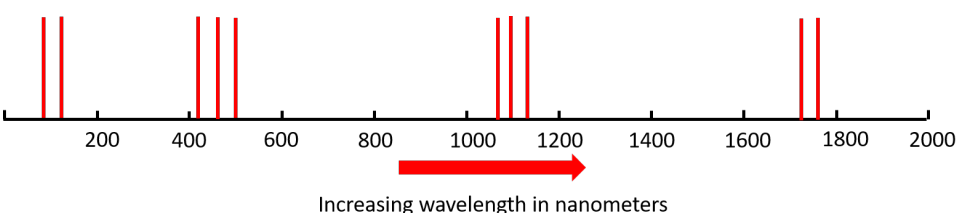
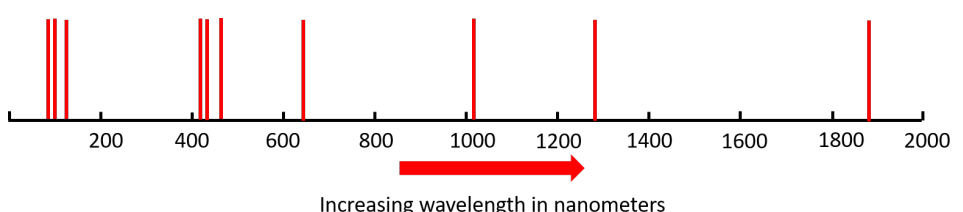
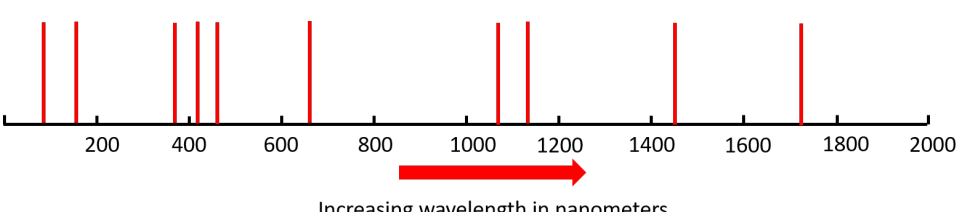
Transition	Wavelength in nanometers	Wavelength in meters	Frequency in Hertz
#1			
#2			
#3			
#4			
#5			
#6			
#7			
#8			
#9			
#10			

3. Classify each hydrogen atom transition in the table below as gamma rays (γ), X rays, ultraviolet (UV), visible, infrared (IR), microwave, radio waves, or long radio waves.

Transition	Classification
#1	
#2	
#3	
#4	
#5	
#6	
#7	
#8	
#9	
#10	

4. An emission spectrum shows the emissions from an atom, where each emission is represented by one vertical line. The lines are typically listed low wavelength to high wavelength in the spectrum. Emission spectra of atoms are unique. In other words the emission spectra of different atoms look different.

Four emission spectra are shown below. Notice that the wavelengths are listed in nanometers. Indicate “**Correct**” for the emission spectrum that corresponds to a hydrogen atom based on the information given in this report.

Emission Spectrum	Indicate “Correct” for the Hydrogen Atom Spectrum
	
	
	
	

5. List the ten electron transitions in a hydrogen atom in order from low energy to high energy below.

**Low energy
transition**



**High energy
transition**