Unit 1, Tutorial 10: Waves, the Electromagnetic Spectrum and Atomic Spectra

Directions: Use the word bank to answer the following questions. **Each word may be used only once.**

Crest	Frequency	Mechanical	Infrared
Trough	Transverse	Radio	Gamma
Wavelength	Longitudinal	Ultraviolet	X-Rays
Visible Light	Amplitude	Electromagnetic	

1. ____________________ waves are used to penetrate solids and are used in doctor's offices and as airports.

2. ____________________ is the distance between one point of a wave to the same point in the next wave.

3. ____________________ is the number of waves per unit of time.

4. ____________________ waves have a color spectrum known as ROYGBIV.

5. ____________________ is the maximum distance that matter is displaced from the resting position.

6. ___________________ waves are produced by radioactive sustenance such as Polonium.

7. ___________________ waves are important in photosynthesis.

8. ___________________ waves are often used in heat lamps.

9. ___________________ waves are utilized by insects to locate nectar.

10. ___________________ waves are used to identify the vibrations of bonds in molecules.

11. ___________________ waves have an electrical and a magnetic component.

12. In each of the following pairs, circle the form of radiation with the LONGER WAVELENGTH:

    a. red light **or** blue light
    b. microwaves **or** radiowaves
    c. infrared radiation **or** red light
    d. gamma rays **or** UV radiation

13. In each of the following pairs, circle the form of radiation with the GREATER FREQUENCY:

    a. yellow light **or** green light
    b. x-rays **or** gamma rays
    c. UV radiation **or** violet light
    d. gamma waves **or** FM radio waves

14. In each of the following pairs, circle the form of radiation with the lower energy:

    a. red light **or** blue light
    b. microwaves **or** radiowaves
    c. infrared radiation **or** red light
    d. gamma rays **or** UV radiation
    e. yellow light **or** green light

15. Sri Lanka's "E-Fm" radio station broadcasts at a frequency of 88.3 MHz. What is the length of the radio wave **in meters**?

    (3.397 m)

16. A beam of light has a wavelength of 506 nanometers. What is the frequency of the light?

    (5.92×10^{14} Hz)

17. Blue light has a frequency of 6.98×10^{14} Hz. Calculate the wavelength of blue light **in nanometers.**

    (429.98 nm)

Use the table below to answer the questions which follow.

Frequency, s^{-1} or (1/s)	7.1×10^{14}	6.4×10^{14}	5.7×10^{14}	5.2×10^{14}	4.8×10^{14}	4.3×10^{14}
Colour	violet	blue	green	yellow	orange	red

18. A photon of light with an energy of 2.2×10^{-19} Joules is emitted. What is the **frequency** of this photon? What **colour** is it?

    (3.32×10^{14} Hz, infrared)

19. What is the **wavelength, in nanometers,** of light with a frequency of 7.1×10^{14} Hz?

    (420 nm, violet)

20. A photon of light has a wavelength of 698 nm. How much **energy** does it have in Joules? What colour is it?

    (2.85×10^{-19} J, infrared)

21. How much **energy** does a photon of light carry if it has a wavelength of 526 nanometres? What **colour** is that photon? (3.78×10^{-19} J, green)

22. What is the **wavelength, in nanometers,** of a photon of light if it has an energy of 4.01×10^{-19} Joules? What colour is it?

496 nm blue/green

23. A photon has a frequency (ν) of 2.68×10^{6} Hz. Calculate its energy.

$E = 1.78 \times 10^{-27}$ J

24. Calculate the energy (E) and wavelength (λ) of a photon of light with a frequency (ν) of 6.165×10^{14} Hz. $E = 4.1 \times 10^{-19}$ J $\lambda = 4.87 \times 10^{-7}$ m

25. Calculate the frequency and the energy of blue light that has a wavelength of 400 nm ($h = 6.62 \times 10^{-34}$ J-s). $\nu = 7.5 \times 10^{14}$ Hz $E = 4.97 \times 10^{-19}$ J

26. Calculate the wavelength and energy of light that has a frequency of 1.5×10^{15} Hz.

Ans: $\lambda = 2.0 \times 10^{-7}$ m $E = 9.95 \times 10^{-19}$ J

27. A photon of light has a wavelength of 0.050 cm. Calculate its energy.

$E = 3.98 \times 10^{-22}$ J

28. Calculate the number of photons having a wavelength of 10.0 μm required to produce 1.0 kJ of energy. 5.0×10^{22} photons

29. Calculate the total energy in 1.5×10^{13} photons of gamma radiation having $\lambda = 3.0 \times 10^{-12}$ m.

1.0 J

30. Calculate the energy and frequency of red light having a wavelength of 6.80×10^{-5} cm.

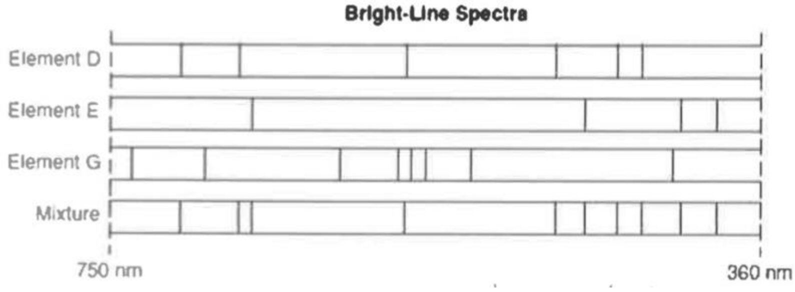
$E = 2.92 \times 10^{-19}$ J $\nu = 4.4 \times 10^{14}$ Hz

31. Calculate the frequency of light that has a wavelength of 4.25×10^{-9}m. Identify the type of electromagnetic radiation. $\nu = 7.1 \times 10^{16}$ Hz. UV radiation

32.

1. Compare the energy of an electron in the ground state and electron in the excited state.
2. When an electron absorbs energy and moves up from the ground state to a higher energy level, what do we observe? Will there be any light emission?
3. When an electron falls from a higher energy level to a lower energy level, how is the energy released?

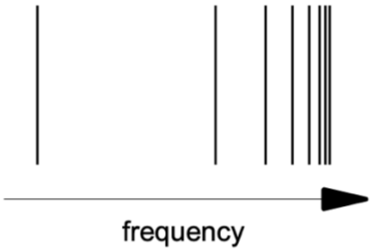
4. Use the diagram below to answer the next question



What elements are present in the mixture.

33. Explain how is an atomic hydrogen spectrum obtained experimentally?

34. This diagram shows the pattern of lines in the Lyman series of the atomic hydrogen spectrum.

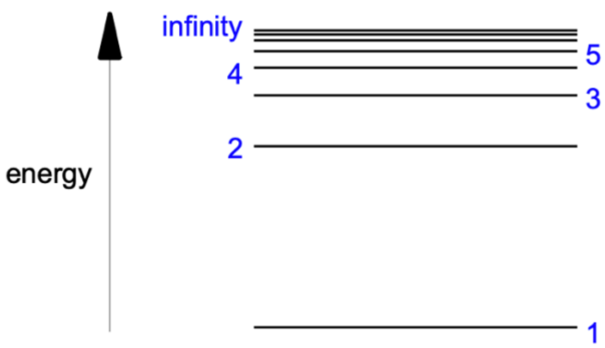


a) Which part of the electromagnetic spectrum (UV, visible or IR) is the Lyman series found in?

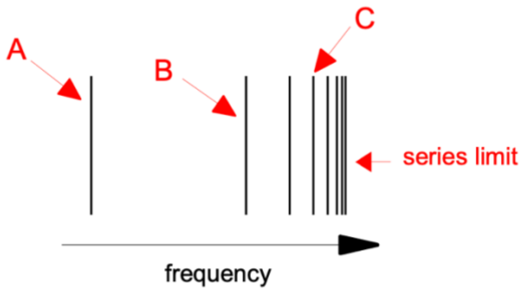
b) Why does the series consist of a number of individual lines rather than a continuous spectrum?

c) Which of the lines in the Lyman series has the lowest energy of light? Explain your answer.

d) The diagram shows the arrangement of the various electron energy level hydrogen atom (not to scale)



Lines in an emission spectrum are produced when an electron falls from a higher level to a lower one. Which transitions are responsible for the lines A, B and C in this diagram of the Lyman series?



a) Which fall corresponds to the series limit of the Lyman series?
b) Which transition would correspond to the series limit of the Balmer series?
c) What fall would produce the lowest frequency line in the Balmer series?

35. The Rydberg equation enables you to calculate the frequency of a line in the hydrogen spectrum. The version of the Rydberg equation in terms of frequency is

$$\nu = cR_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$c = 3 \times 10^8$ m s^{-1}; $R_H = 1.1 \times 10^7$ m^{-1}

a) Calculate the frequency of the line produced when an electron falls back from the infinity level to the 1st-level.

b) Write the equation which relates the energy gap between two levels and the frequency of light emitted.

c) Ionisation of a hydrogen atom happens when an electron is promoted from the ground state (the 1st -level) to the infinity level. Use the equation you have written in (b) to calculate the energy needed to move an electron from the 1st-level to the infinity level. State clearly any assumptions you are making. h (Planck's constant) = 6.626×10^{-34} J s

d) Calculate the ionisation energy of hydrogen in kJ mol^{-1}. The Avogadro constant (L) = 6.022×10^{23} mol^{-1}

36. Distinguish between an atomic emission spectrum and an atomic absorption spectrum. (b) Distinguish between a continuous spectrum and a line spectrum.

37. Prepare a sketch that shows a ground energy state and three excited energy states Using vertical arrows, indicate the transitions that would correspond to the absorption spectrum for H-atom.

38. Hydrogen atoms absorb energy so that the electrons are excited to the energy level $n = 7$. Electrons then undergo these transitions: (1) n=7 →n=1; (2) n=7→n=2; (3) n= 2 → n =1. Which of these transitions will produce the photon with (a) the smallest energy; (b) the highest frequency; (c) the shortest wavelength? (d) What is the frequency of a photon resulting from the transition n= 6 → n = 1? *Use the data given earlier for calculations.*

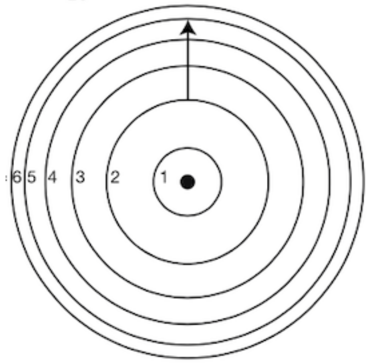
39. Five energy levels of the He atom are given in joules per atom above an *arbitrary* reference energy: (1) 6.000×10^{-19}; (2) 8.812×10^{-19}; (3) 9.381×10^{-19}; (4) 10.443×10^{-19}; (5) 10.934×10^{-19}. Construct an energy level diagram for He and find the energy of the photon (a) absorbed for the electron transition from level 1 to level 5 and (b) emitted for the electron transition from level 4 to level 1.

40. The following are prominent lines in the visible region of the emission spectra of the elements listed. The lines can be used to identify the elements. What color is the light responsible for each line? (a) lithium, 4603 Å; (b) neon, 540.0 nm; (c) calcium, 6573 Å; (d) potassium, $\nu = 3.90 \times 10^{14}$ Hz.

41. Hydrogen atoms have an absorption line at 1026 Å. What is the frequency of the photons absorbed, and what is the energy difference, in joules, between the ground state and this excited state of the atom?

42. An argon laser emits blue light with a wavelength of 488.0 nm. How many photons are emitted by this laser in 2.00 seconds, operating at a power of 515 milliwatts? One watt (a unit of power) is equal to 1 joule/second.

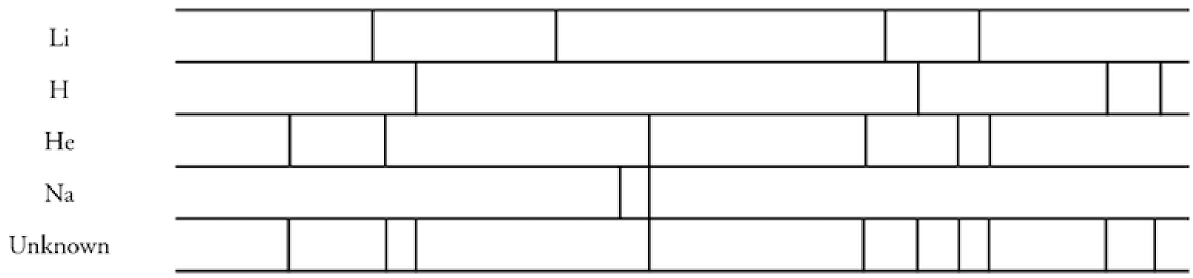
43. A hydrogen atom falls to its ground state emitting light with a wavelength of 1.03×10^{-7} m. What is the final energy level of the electron?
    a. Is energy absorbed or released in the diagram given below? Explain.



44. Why does hydrogen only emit four wavelengths of light in the visible spectrum instead of every possible color of visible light?

45. Why can't a single hydrogen atom emit all four colors simultaneously?

46. Below are diagrams for the line spectra of four elements and a mixture of gases.



a. Which elements are not present in the mixture? Explain.

b. Which elements are present in the mixture? Explain?

47. Calculate the absorbed energy for the n=4 to n=2 transition in the hydrogen atom. What is the frequency of light emitted for this energy change?

48. What wavelength is predicted by the Rydberg equation for each of these electron transitions in the hydrogen atom?

a. n = 6 to n = 2

b. n =4 to n =1

49. The power output of a laser is measured by its wattage, that is, the number of joules of energy it radiates per second (J s^{-1}). A 10W laser produces a beam of green light with a wavelength of 520 nm.

(a) Calculate the energy carried by each photon.

(b) Calculate the number of photons emitted by the laser per second.

50.

According to the Bohr Theory, which of the following transitions in the hydrogen atom will give rise to the least energetic photon?

1. n = 5 to n = 3
2. n = 6 to n = 1
3. n = 5 to n = 4
4. n = 6 to n = 5

51.

Emission transitions in the Paschen series end at orbit n = 3 and start from orbit n and can be represented as v = 3.29 × 10^{15} (Hz $\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$. The value of n if the transition is observed at 1285 nm is

1. 6 2. 5 3. 8 4. 9 5. 12

52.

The wavelength of light emitted when the electron in a H atom undergoes the transition from an energy level with n = 4 to an energy level with n = 2, is

1. 586 nm 2. 486 nm 3. 523 nm 4. 416 pm 5. 375 nm

53.

The maximum number of emission lines obtained when the excited electron of the H atom jumps from n = 6 to the ground state is -

1. 30 2. 21 3.15 4.28 5. 25

54.

Which of the following series of transitions in the spectrum of hydrogen atom falls in visible region?

1. Brackett series
2. Lyman series
3. Balmer series
4. Paschen series

55.

When an electron jumps from n=5 to n=1 in a hydrogen atom, the number of spectral lines obtained is

1. 3 2. 4 3. 6 4. 10 5.15

56.

The spectrum of He-atom may be considered similar to the spectrum of -

1. H 2. Li^+ 3. Na 4. He^+ 5. Be^+

57.

The electronic transition in the hydrogen atom that emits maximum energy is:

1. 2 $\rightarrow$ 1
2. 1 $\rightarrow$ 4
3. 4 $\rightarrow$ 3
4. 3 $\rightarrow$ 2

58.

The brackett series of spectral lines arise when an electron in an excited hydrogen atom jumps from an energy level

1. n=5 to n=1
2. n=5 to n=3
3. n=5 to n=4
4. n=5 to n=2

59.

With a certain exciting radiation of a particular frequency, to which hydrogen atoms are exposed, the maximum number of spectral lines obtainable in the emission is 15. The uppermost energy level to which the electron is excited is

1. 4 2. 5 3. 6 4. 7 5. 8