Worksheet: The Bohr model and Spectra

1. The Bohr Theory of the atom states that electrons can only exist in specific energy levels. If an atom absorbs energy, its electrons are temporarily at a higher energy level and the atom is said to be in an excited state.

   (a) Describe three ways by which an atom can be caused to be in an excited state.

   (b) By what process can an atom lose its excited state? To what state does it go to?

2. Bohr predicted the energy levels of a hydrogen atom by using the relationship:

$$E_n = \frac{-13.6\ \text{eV}}{n^2} \qquad \text{where } n = 1, 2, 3, ...$$

   (a) Use this relationship to find the energies of the fifth and sixth energy level of the hydrogen atom (E_5, E_6).

   (b) Determine the wavelength of a photon that would be emitted by an electron transition from E_6 to E_5.

   (c) In which part of the electromagnetic spectrum does this photon belong?

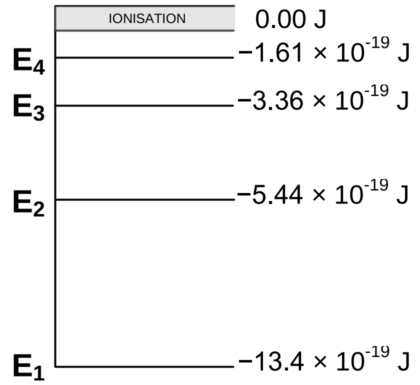
3. The first four energy levels of an atom are shown at right.

   (a) Why are the energies indicated as negatives?

   (b) What minimum energy would be required to:

      (i) cause this atom to attain an excited state,
      (ii) cause this atom to become ionised?

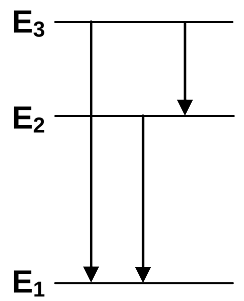
   (c) If the atom is excited to the E_3 level, what are the possible photon energies emitted thereafter? Determine the maximum frequency of these photons



4. The first three energy levels of a sodium atom are shown. The electron transition between E_2 and E_1 result in visible light ($\lambda = 5.89 \times 10^{-7}$m) while the transition between E_3 and E_1 result in ultraviolet light ($\lambda = 3.88 \times 10^{-7}$m).

   (a) Determine the wavelength of the photon which would be released by an electron transition between E_3 and E_2.

   (b) To which region of the e/m spectrum does this photon belong?

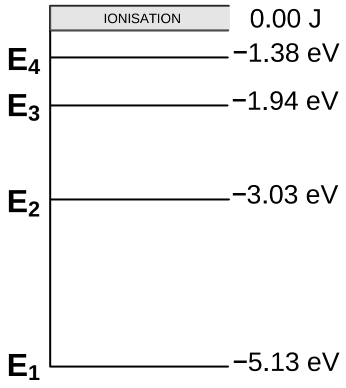


5. A few of the energy levels of an atom are shown at right.

   (a) If this atom is in the ground state what minimum frequency photon will cause it to be ionised?

   (b) How many different frequency photons are possible when ionised atoms of this element return to the ground state? Show each possible transition that results in the emission of a photon on the diagram.

   (c) Determine the longest wavelength in the emission spectrum of this atom.



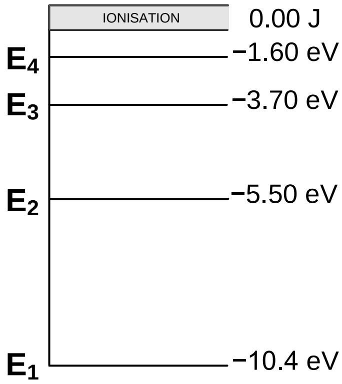
6. The first four energy levels of a hydrogen atom are −13.6 eV, −3.4 eV, −1.5 eV and −0.85 eV.

   (a) If this atom is bombarded by photons with energies up to 12.0 eV, which photon energies would be absorbed?

   (b) If this atom was instead bombarded by electrons with energies up to 12.0 eV how would the interaction between the atom and the electrons be different to that with the photons?

   (c) If this atom was in an excited state with its electron at the E_3 level, what would be the highest frequency photon it could emit as it returned to the ground state?

7. Atoms of mercury are to be bombarded with photons. Use the energy levels shown to answer the following:



   (a) What would occur if a stream of photons of 7.5 eV were used to bombard mercury atoms?

   (b) If all photon energies up to 10.0 eV were used, which photons would be absorbed?

   (c) In this latter case which photon energies would be emitted?

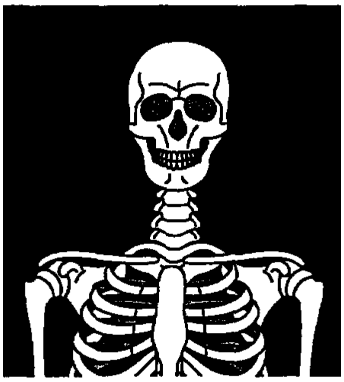
8. Minerals such as calcite and fluorite can often be fluorescent due to the presence of rare earth elements which can absorb short wavelength light and then re-emit it at longer wavelengths. In one such occurrence photons of 1.15×10^{15} Hz are absorbed and then the energy is released in two separate photons. If one of the photons emitted has an energy of 2.07 eV determine:

   (a) The energy of the other photon emitted,

   (b) The wavelengths of the two photons emitted,

   (c) The part of the e/m spectrum or colour that these photons belong to.

9. When taking chest X-rays the voltage required can be as high as 120 kV. The current drawn is 100 mA while the duration of the X-ray is 0.040 s. Determine:



   (a) The kinetic energy of the electrons accelerated towards the target anode.

   (b) The maximum possible frequency of the X-rays produced.

   (c) Assuming that the average photon energy is half of the maximum energy, calculate the number of photons you are exposed to during a typical chest X-ray.

Answers:

1. a) Atoms can be excited:
   - i) thermally
   - ii) by bombarding electrons
   - iii) by absorbing photons

2. a) E_5 = 0.544 eV E_6 = 0.378 eV
   b) 7.48 μm
   c) IR

3. b) i) 7.96 x 10^{-19} J
   ii) 1.34 x 10^{-18} J
   c) $E_3 \rightarrow E_1$ = 1.0 x 10^{-18} J
   $E_3 \rightarrow E_2$ = 2.08 x 10^{-19} J
   $E_2 \rightarrow E_1$ = 7.96 x 10^{-19} J
   Max frequency = 1.51 x 10^{15} Hz

4. a) λ = 1140 nm
   b) IR

5. a) 1.24 x 10^{15} Hz
   b) 10
   c) 2.23 μm

6 a) 10.2 eV
   b) All energies between 10.2 eV and 12.0 eV
   c) 2.92 x 10^{15} Hz

7. a) no interaction
   b) 4.90 eV, 6.70 eV, 8.80 eV
   c) 8.80 eV, 6.70 eV, 4.90 eV, 3.90 eV, 2.10 eV, 1.80 eV

8. a) 2.70 eV
   b) 601 nm (red/orange) , 460 nm (blue)

9. a) 1.92 x 10^{-14} J
   b) 2.90 x 10^{19} Hz
   c) 5 x 10^{16} photons