

Atomic Physics

Problem C**INTERPRETING ENERGY-LEVEL DIAGRAMS****PROBLEM**

A part of the overall energy diagram for calcium is shown below.

$$E_3 \text{ ————— } E = -1.54 \text{ eV}$$

$$E_2 \text{ ————— } E = -3.17 \text{ eV}$$

$$E_1 \text{ ————— } E = -6.11 \text{ eV}$$

SOLUTION**1. DEFINE**

Given: $E_{\text{initial}} = E_3 = -1.54 \text{ eV}$

$$E_{\text{final}} = E_1 = -6.11 \text{ eV}$$

Unknown: $\lambda = ?$

2. PLAN

Choose the equation(s) or situation: Calculate the energy of the emitted photon, then use Planck's equation and the relation between frequency, wavelength, and the speed of light to determine the wavelength of the emitted photon.

$$E = E_{\text{initial}} - E_{\text{final}}$$

$$E = hf$$

$$c = f\lambda$$

$$\lambda = \frac{hc}{E} = \frac{hc}{E_{\text{initial}} - E_{\text{final}}} = \frac{hc}{E_3 - E_1}$$

3. CALCULATE

Substitute the values into the equation(s) and solve:

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{-5.4 \text{ eV} - (-6.11 \text{ eV})} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8 \text{ m/s})}{4.57 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{2.72 \times 10^{-7} \text{ m} = 272 \text{ nm}}$$

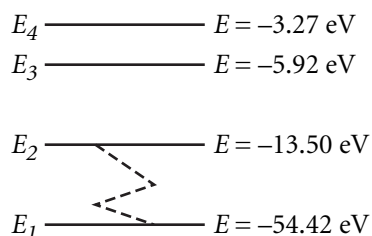
4. EVALUATE

The electron drops 4.57 eV, causing the emission of a photon with a wavelength of 272 nm.

ADDITIONAL PRACTICE

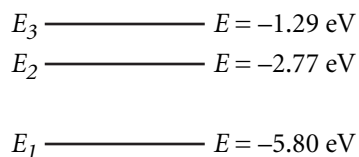
- Using the energy diagram for calcium shown in the Sample problem, calculate the wavelength of a photon that is emitted when an electron drops from the E_2 energy level to the E_1 energy level.

2. Ionized helium has only one electron, making it similar to a hydrogen atom, except that its nucleus has a positive charge of +2. A basic diagram of ionized helium energy levels is shown below. (Because the ground state for ionized helium is much lower than the excited states, the diagram is not to scale.)



If an electron drops from the E_4 energy level to E_1 , what is the energy of the emitted photon?

3. The ground state for ionized helium has a much lower energy than its excited states, so the photons emitted by ionized helium are in the ultra-violet portion of the spectrum. Calculate the wavelength of a photon emitted when an electron drops between the E_4 and E_1 energy levels of an ionized helium atom.
4. Calculate the energy of a photon emitted when an electron drops from the E_2 energy level to the E_1 energy level of an ionized helium atom.
5. Calculate the energy of a photon emitted when an electron drops between the E_2 and E_1 energy levels of an ionized helium atom.
6. Calculate the energy of a photon emitted when an electron drops from the E_3 energy level to the E_1 energy level of an ionized helium atom.
7. Calculate the wavelength of a photon emitted when an electron drops between the E_3 and E_1 energy levels of an ionized helium atom.
8. Indium was named for the bright indigo line in its emission spectrum. This line is produced when an electron drops from the E_2 energy level to the E_1 energy level (depicted in the diagram below).



Use the diagram to calculate the energy of this emitted photon, then calculate the photon's wavelength.

9. Calculate the energy of a photon emitted when an electron drops from the E_3 energy level to the E_1 energy level of an indium atom.
10. Calculate the wavelength of the photon emitted when an electron drops from the E_3 energy level and the E_1 energy level of an indium atom.

Additional Practice C

Givens

1. $E_{\text{initial}} = E_2 = -3.17 \text{ eV}$

$$E_{\text{final}} = E_1 = -6.11 \text{ eV}$$

Solutions

$$E = E_{\text{initial}} - E_{\text{final}} = E_2 - E_1$$

$$E = hf$$

$$c = f\lambda$$

$$\lambda = \frac{hc}{E} = \frac{hc}{E_{\text{initial}} - E_{\text{final}}} = \frac{hc}{E_2 - E_1}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{-3.17 \text{ eV} - (-6.11 \text{ eV})} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{2.94 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{4.23 \times 10^{-7} \text{ m} = 423 \text{ nm}}$$

2. $E_{\text{initial}} = E_4 = -3.27 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_4 - E_1$$

$$E = -3.27 \text{ eV} - (-54.42 \text{ eV}) = \boxed{51.15 \text{ eV}}$$

3. $E_{\text{initial}} = E_4 = -3.27 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_4 - E_1 = 51.15 \text{ eV}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{51.15 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{2.43 \times 10^{-8} \text{ m} = 24.3 \text{ nm}}$$

4. $E_{\text{initial}} = E_2 = -13.50 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_2 - E_1$$

$$E = -13.50 \text{ eV} - (-54.42 \text{ eV}) = \boxed{40.92 \text{ eV}}$$

5. $E_{\text{initial}} = E_2 = -13.50 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_2 - E_1 = 40.92 \text{ eV}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{40.92 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{3.04 \times 10^{-8} \text{ m} = 30.4 \text{ nm}}$$

6. $E_{\text{initial}} = E_3 = -5.92 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_3 - E_1$$

$$E = -5.92 \text{ eV} - (-54.42 \text{ eV}) = \boxed{48.50 \text{ eV}}$$

7. $E_{\text{initial}} = E_3 = -5.92 \text{ eV}$

$$E_{\text{final}} = E_1 = -54.42 \text{ eV}$$

$$E = E_{\text{initial}} - E_{\text{final}} = E_3 - E_1 = 48.50 \text{ eV}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{48.50 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{2.56 \times 10^{-8} \text{ m} = 25.6 \text{ nm}}$$

Givens

8. $E_{\text{initial}} = E_2 = -2.77 \text{ eV}$
 $E_{\text{final}} = E_1 = -5.80 \text{ eV}$

Solutions

$$E = E_{\text{initial}} - E_{\text{final}} = E_2 - E_1$$

$$E = -2.77 \text{ eV} - (-5.80 \text{ eV}) = \boxed{3.03 \text{ eV}}$$

$$E = hf$$

$$c = f\lambda$$

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{3.03 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{4.10 \times 10^{-7} \text{ m} = 4.10 \times 10^2 \text{ nm}}$$

9. $E_{\text{initial}} = E_3 = -1.29 \text{ eV}$
 $E_{\text{final}} = E_1 = -5.80 \text{ eV}$

$$E = E_{\text{initial}} - E_{\text{final}} = E_3 - E_1$$

$$E = -1.29 \text{ eV} - (-5.80 \text{ eV}) = \boxed{4.51 \text{ eV}}$$

10. $E_{\text{initial}} = E_3 = -1.29 \text{ eV}$
 $E_{\text{final}} = E_1 = -5.80 \text{ eV}$

$$E = E_{\text{initial}} - E_{\text{final}} = E_3 - E_1 = 4.51 \text{ eV}$$

$$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\cdot\text{s})(3.00 \times 10^8 \text{ m/s})}{4.51 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$$

$$\lambda = \boxed{2.76 \times 10^{-7} \text{ m} = 276 \text{ nm}}$$

Additional Practice D

1. $v = 28 \text{ m/s}$
 $\lambda = 8.97 \times 10^{-37} \text{ m}$

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(8.97 \times 10^{-37} \text{ m})(28 \text{ m/s})} = \boxed{26 \text{ kg}}$$

2. $v = 7.1 \times 10^2 \text{ m/s}$
 $\lambda = 5.8 \times 10^{-42} \text{ m}$

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(5.8 \times 10^{-42} \text{ m})(7.1 \times 10^2 \text{ m/s})} = \boxed{1.6 \times 10^5 \text{ kg}}$$

3. $v = 5.6 \times 10^{-6} \text{ m/s}$
 $\lambda = 2.96 \times 10^{-8} \text{ m}$

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(2.96 \times 10^{-8} \text{ m})(5.6 \times 10^{-6} \text{ m/s})} = \boxed{4.0 \times 10^{-21} \text{ kg}}$$

4. $v = 12 \text{ m/s}$
 $\lambda = 2.6 \times 10^{-29} \text{ m}$

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(2.6 \times 10^{-29} \text{ m})(12 \text{ m/s})} = \boxed{2.1 \times 10^{-6} \text{ kg}}$$

5. $m_e = 9.109 \times 10^{-31} \text{ kg}$
 $v = 2.19 \times 10^6 \text{ m/s}$

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.109 \times 10^{-31} \text{ kg})(2.19 \times 10^6 \text{ m/s})} = \boxed{3.3 \times 10^{-10} \text{ m}}$$

6. $m = 7.6 \times 10^7 \text{ kg}$
 $v = 35 \text{ m/s}$

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(7.6 \times 10^7 \text{ kg})(35 \text{ m/s})} = \boxed{2.5 \times 10^{-43} \text{ m}}$$

7. $m = 5.94 \times 10^{24} \text{ kg}$
 $v = 3.0 \times 10^4 \text{ m/s}$

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(5.94 \times 10^{24} \text{ kg})(3.0 \times 10^4 \text{ m/s})} = \boxed{3.7 \times 10^{-63} \text{ m}}$$