NAME ______________________ DATE ______________ CLASS ______________

Atomic Physics

# Problem C

## INTERPRETING ENERGY-LEVEL DIAGRAMS

**PROBLEM**

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

$E_3$ ———— $E = -1.54$ eV

$E_2$ ———— $E = -3.17$ eV

$E_1$ ———— $E = -6.11$ eV

**SOLUTION**

**1.** DEFINE

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

$E_{final} = E_1 = -6.11$ 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.

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

$$E = hf$$

$$c = f\lambda$$

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

**3.** CALCULATE

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

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

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

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

**4.** EVALUATE

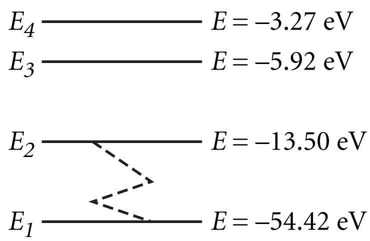
The electron drops 4.57 eV, causing the emission of a photon with a wavelength of 272 nm.

## ADDITIONAL PRACTICE

**1.** 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.

NAME ______________________ DATE ____________ CLASS ______________

**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 ultraviolet 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.

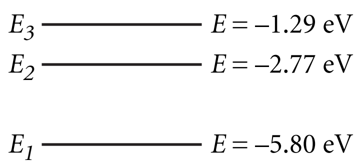
**4.** Calculate the energy of a photon emitted when an electron drops from the $E_2$ energy level to the $E_1$ energy level of an ionized helium atom.

**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* | *Solutions* |
|---|---|
| **1.** $E_{initial} = E_2 = -3.17$ eV<br>$E_{final} = E_1 = -6.11$ eV | $E = E_{initial} - E_{final} = E_2 - E_1$<br>$E = hf$<br>$c = f\lambda$<br>$\lambda = \frac{hc}{E} = \frac{hc}{E_{initial} - E_{final}} = \frac{hc}{E_2 - E_1}$<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{-3.17 \text{ eV} - (-6.11 \text{ eV})} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{2.94 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{4.23 \times 10^{-7} \text{ m} = 423 \text{ nm}}$ |
| **2.** $E_{initial} = E_4 = -3.27$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_4 - E_1$<br>$E = -3.27 \text{ eV} - (-54.42 \text{ eV}) = \boxed{51.15 \text{ eV}}$ |
| **3.** $E_{initial} = E_4 = -3.27$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_4 - E_1 = 51.15$ eV<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{51.15 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{2.43 \times 10^{-8} \text{ m} = 24.3 \text{ nm}}$ |
| **4.** $E_{initial} = E_2 = -13.50$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_2 - E_1$<br>$E = -13.50 \text{ eV} - (-54.42 \text{ eV}) = \boxed{40.92 \text{ eV}}$ |
| **5.** $E_{initial} = E_2 = -13.50$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_2 - E_1 = 40.92$ eV<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{40.92 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{3.04 \times 10^{-8} \text{ m} = 30.4 \text{ nm}}$ |
| **6.** $E_{initial} = E_3 = -5.92$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_3 - E_1$<br>$E = -5.92 \text{ eV} - (-54.42 \text{ eV}) = \boxed{48.50 \text{ eV}}$ |
| **7.** $E_{initial} = E_3 = -5.92$ eV<br>$E_{final} = E_1 = -54.42$ eV | $E = E_{initial} - E_{final} = E_3 - E_1 = 48.50$ eV<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{48.50 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{2.56 \times 10^{-8} \text{ m} = 25.6 \text{ nm}}$ |

| *Givens* | *Solutions* |
|---|---|
| **8.** $E_{initial} = E_2 = -2.77$ eV<br>$E_{final} = E_1 = -5.80$ eV | $E = E_{initial} - E_{final} = E_2 - E_1$<br>$E = -2.77 \text{ eV} - (-5.80 \text{ eV}) = \boxed{3.03 \text{ eV}}$<br>$E = hf$<br>$c = f\lambda$<br>$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34} \text{ J}\bullet\text{s})(3.00 \times 10^8 \text{ m/s})}{3.03 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{4.10 \times 10^{-7} \text{ m} = 4.10 \times 10^2 \text{ nm}}$ |
| **9.** $E_{initial} = E_3 = -1.29$ eV<br>$E_{final} = E_1 = -5.80$ eV | $E = E_{initial} - E_{final} = E_3 - E_1$<br>$E = -1.29 \text{ eV} - (-5.80 \text{ eV}) = \boxed{4.51 \text{ eV}}$ |
| **10.** $E_{initial} = E_3 = -1.29$ eV<br>$E_{final} = E_1 = -5.80$ eV | $E = E_{initial} - E_{final} = E_3 - E_1 = 4.51$ eV<br>$\lambda = \frac{(6.63 \times 10^{-34} \text{ J}\bullet\text{s})(3.00 \times 10^8 \text{ m/s})}{4.51 \text{ eV}} \times \frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}$<br>$\lambda = \boxed{2.76 \times 10^{-7} \text{ m} = 276 \text{ nm}}$ |

## Additional Practice D

| | |
|---|---|
| **1.** $v = 28$ m/s<br>$\lambda = 8.97 \times 10^{-37}$ m | $m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(8.97 \times 10^{-37} \text{ m})(28 \text{ m/s})} = \boxed{26 \text{ kg}}$ |
| **2.** $v = 7.1 \times 10^2$ m/s<br>$\lambda = 5.8 \times 10^{-42}$ m | $m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(5.8 \times 10^{-42} \text{ m})(7.1 \times 10^2 \text{ m/s})} = \boxed{1.6 \times 10^5 \text{ kg}}$ |
| **3.** $v = 5.6 \times 10^{-6}$ m/s<br>$\lambda = 2.96 \times 10^{-8}$ m | $m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(2.96 \times 10^{-8} \text{ m})(5.6 \times 10^{-6} \text{ m/s})} = \boxed{4.0 \times 10^{-21} \text{ kg}}$ |
| **4.** $v = 12$ m/s<br>$\lambda = 2.6 \times 10^{-29}$ m | $m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(2.6 \times 10^{-29} \text{ m})(12 \text{ m/s})} = \boxed{2.1 \times 10^{-6} \text{ kg}}$ |
| **5.** $m_e = 9.109 \times 10^{-31}$ kg<br>$v = 2.19 \times 10^6$ m/s | $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(9.109 \times 10^{-31} \text{ kg})(2.19 \times 10^6 \text{ m/s})} = \boxed{3.3 \times 10^{-10} \text{ m}}$ |
| **6.** $m = 7.6 \times 10^7$ kg<br>$v = 35$ m/s | $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(7.6 \times 10^7 \text{ kg})(35 \text{ m/s})} = \boxed{2.5 \times 10^{-43} \text{ m}}$ |
| **7.** $m = 5.94 \times 10^{24}$ kg<br>$v = 3.0 \times 10^4$ m/s | $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J}\bullet\text{s}}{(5.94 \times 10^{24} \text{ kg})(3.0 \times 10^4 \text{ m/s})} = \boxed{3.7 \times 10^{-63} \text{ m}}$ |