NAME ______________________ DATE ____________ CLASS ______________

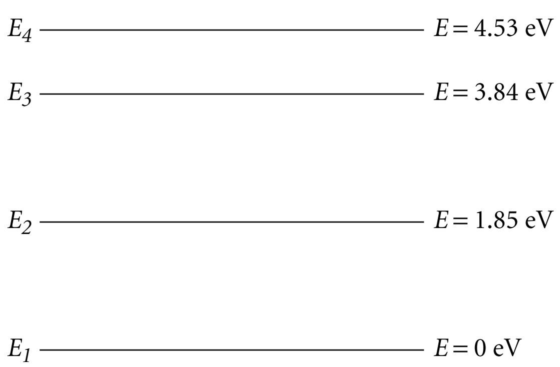
Atomic Physics

Problem C

INTERPRETING ENERGY-LEVEL DIAGRAMS

PROBLEM

Although neutral lithium has three electrons, two of the electrons are in the $n = 1$ energy level, which is filled. The third electron is in the $n = 2$ energy level, and behaves like the single electron in a hydrogen atom, except that the nucleus has a +3 charge and the two inner electrons partially shield the stronger attraction of the nucleus. Of the various possible energy levels that can be occupied by one or more of lithium's electrons, the simplest one for the single outer electron is shown below.



An electron in a lithium atom drops from an energy level to E_1. If the photon emitted has a wavelength of 323.7 nm, which energy level did the electron initially occupy, and what is its value (in eV) relative to E_1? Assume that the ground state E_1 has an energy of 0 eV.

SOLUTION

1. DEFINE **Given:** $\lambda = 323.7$ nm

$E_{final} = E_1 = 0$ eV

Unknown: $E_{initial} = ?$

2. PLAN **Choose the equation(s) or situation:** Calculate the energy of the emitted photon, and equate this to the difference between the energy levels.

$$E = hf$$

$$c = f\lambda$$

$$E = \frac{hc}{\lambda}$$

$$E = E_{initial} - E_{final} = E_{initial} - E_1$$

$$E_{initial} = E + E_1 = \frac{hc}{\lambda} + E_1$$

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

$$E_{initial} = \frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{323.7\ \text{nm}} \times \frac{10^{9}\ \text{nm}}{1\ \text{m}} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} + 0\ \text{eV}$$

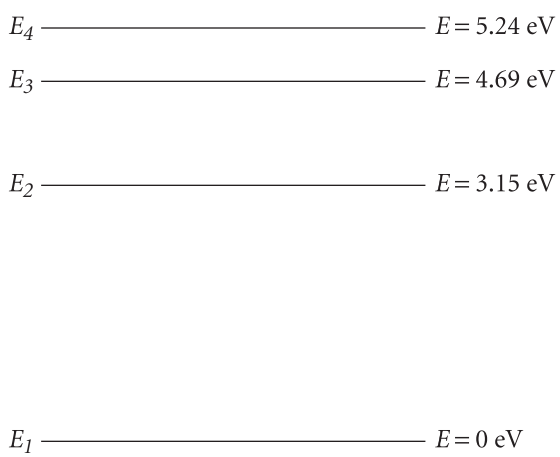
$$E_{initial} = 3.84\ \text{eV} + 0\ \text{eV} = \boxed{3.84\ \text{eV}}$$

4. EVALUATE The photon drops from the energy level that is 3.84 eV higher than the ground state E_1, which according to the energy diagram is the level with energy E_3. It is this transition in the lithium atom that causes the emission of the photon with wavelength 323.7 nm.

ADDITIONAL PRACTICE

1. Using the energy diagram for lithium shown in the Sample problem, determine which energy level provides the initial state for an electron that, in dropping to energy E_1, produces photon with the wavelength 671.9 nm.

2. Aluminum has electrons that fill the orbitals of the two lowest energy states, and another pair of electrons that fill the 3*s* level. This leaves one unpaired electron in the 3*p* that can behave in certain transitions like the single electron of the hydrogen atom. A diagram of some of these transitions is shown below.



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

3. Calculate the wavelength of a photon emitted between the E_3 and E_1 energy levels of an aluminum atom.

4. Calculate the wavelength of a photon emitted between the E_2 and E_1 energy levels of an aluminum atom.

Givens | *Solutions*

8. $hf_t = 2.3$ eV

$\lambda = 410 \text{ nm} = 4.1 \times 10^{-7}$ m

$h = 4.14 \times 10^{-15}$ eV•s

$c = 3.00 \times 10^8$ m/s

$$KE_{max} = \frac{hc}{\lambda} - hf_t$$

$$KE = \frac{(4.14 \times 10^{-15} \text{ eV•s})(3.00 \times 10^8 \text{ m/s})}{4.1 \times 10^{-7} \text{ m}} - 2.3 \text{ eV}$$

$$KE = 3.03 \text{ eV} - 2.3 \text{ eV} = \boxed{0.7 \text{ eV}}$$

9. $hf_{t,Zn} = 4.3$ eV

$hf_{t,Pb} = 4.1$ eV

$KE_{max,Zn} = 0.0$ eV

$m_e = 9.109 \times 10^{-31}$ kg

$$KE_{max} = hf - hf_t$$

$$KE_{max,Pb} = hf - hf_{t,Pb} = (KE_{max,Zn} + hf_{t,Zn}) - hf_{t,Pb}$$

$$KE_{max,Pb} = \tfrac{1}{2}m_e v^2$$

$$\tfrac{1}{2}m_e v^2 = (KE_{max,Zn} + hf_{t,Zn}) - hf_{t,Pb}$$

$$v = \sqrt{\frac{2(KE_{max,Zn} + hf_{t,Zn} - hf_{t,Pb})}{m_e}}$$

$$v = \sqrt{\left(\frac{(2)(0.0 \text{ eV} + 4.3 \text{ eV} - 4.1 \text{ eV})}{9.109 \times 10^{-31} \text{ kg}}\right)\left(\frac{1.60 \times 10^{-19} \text{ J}}{1 \text{ eV}}\right)}$$

$$v = \sqrt{\left(\frac{(2)(0.2 \text{ eV})}{9.109 \times 10^{-31} \text{ kg}}\right)\left(\frac{1.60 \times 10^{-19} \text{ J}}{1 \text{ eV}}\right)} = \boxed{3 \times 10^5 \text{ m/s}}$$

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Additional Practice C

1. $\lambda = 671.9$ nm

$E_{final} = E_1 = 0$ eV

$$E = E_{initial} - E_{final} = E_{initial} - E_1$$

$$E = \frac{hc}{\lambda}$$

$$E_{initial} = \left(\frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{671.9 \text{ nm}}\right)\left(\frac{10^9 \text{ nm}}{1 \text{ m}}\right)\left(\frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}\right) + 0 \text{ eV}$$

$$E_{initial} = 1.85 \text{ eV} + 0 \text{ eV} = \boxed{1.85 \text{ eV}}$$

The photon is produced by the transition of the electron from the E_2 energy level to E_1.

2. $E_{initial} = E_4 = 5.24$ eV

$E_{final} = E_1 = 0$ eV

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

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{hc}{E_4 - E_1}$$

$$\lambda = \left(\frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}{5.24 \text{ eV} - 0 \text{ eV}}\right)\left(\frac{1 \text{ eV}}{1.60 \times 10^{-19} \text{ J}}\right)$$

$$\lambda = \boxed{2.37 \times 10^{-7} \text{ m} = 237 \text{ nm}}$$

Givens	*Solutions*
3. $E_{initial} = E_3 = 4.69$ eV $E_{final} = E_1 = 0$ eV	$E = E_{initial} - E_{final} = E_3 - E_1$ $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{hc}{E_3 - E_1}$ $\lambda = \left(\frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{4.69\ \text{eV} - 0\ \text{eV}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right)$ $\lambda = \boxed{2.65 \times 10^{-7}\ \text{m} = 265\ \text{nm}}$
4. $E_{initial} = E_2 = 3.15$ eV $E_{final} = E_1 = 0$ eV	$E = E_{initial} - E_{final} = E_2 - E_1$ $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{hc}{E_2 - E_1}$ $\lambda = \left(\frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{3.15\ \text{eV} - 0\ \text{eV}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right)$ $\lambda = \boxed{3.95 \times 10^{-7}\ \text{m} = 395\ \text{nm}}$

II