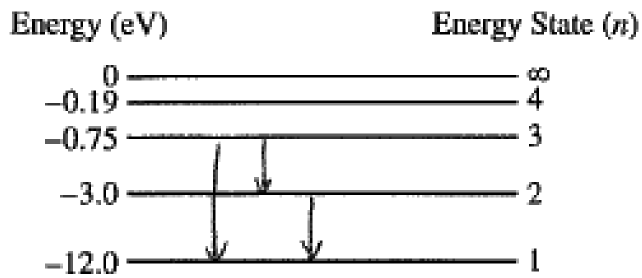
Question 7

10 points total **Distribution of points**

(a) 3 points



For an arrow from the $n = 3$ to the $n = 2$ energy state — 1 point
For an arrow from the $n = 3$ to the $n = 1$ energy state — 1 point
For an arrow from the $n = 2$ to the $n = 1$ energy state — 1 point
One earned point was deducted if there were any incorrect or extra lines on the diagram.

(b) 2 points

Use an expression relating energy to wavelength
$E = hf = hc/\lambda$
For substitution using the correct 3 to 2 transition energy — 1 point
$\lambda = hc/E = (1240\ \text{eV}\bullet\text{nm})/((3.0 - 0.75)\ \text{eV})$
For an answer consistent with whichever transition was chosen — 1 point
$\lambda = 551\ \text{nm}$ or $5.51 \times 10^{-7}\ \text{m}$
(138 nm for the 2 to 1 transition, and 110 nm for the 3 to 1 transition)

(c) 1 point

For the correct, positive value for the ionization energy — 1 point
$E = 12\ \text{eV}$ or $1.9 \times 10^{-18}\ \text{J}$

(d) 2 points

For correctly stating that an 11.0 eV photon has no effect — 1 point
For a correct explanation — 1 point

Example
Since there is no energy level at −1.0 eV, an 11.0 eV photon will have no effect on electrons in the −12.0 eV (n = 1) energy state.

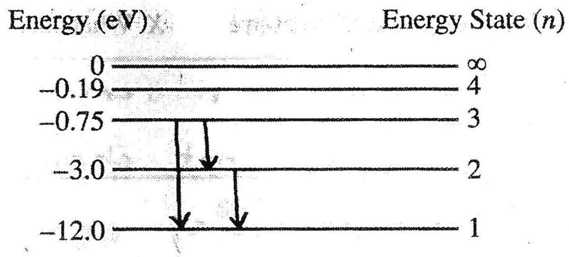
Question 7 (continued)

	Distribution of points
(e) 2 points	
For correctly stating that a 14.0 eV photon will remove the electron from (or ionize) the atom	1 point
For a correct explanation	1 point

Example

A 14.0 eV photon has sufficient energy to ionize the atom, since only 12.0 eV is required for ionization.

B7 A1



Note: Figure not drawn to scale.

7. (10 points)

The energy-level diagram for an isolated hypothetical atom is shown above.

(a) A collection of such atoms with electrons in the $n = 3$ state undergo transitions in which the atoms only emit photons, and the electrons eventually end in the $n = 1$ state. On the diagram above, draw arrows to indicate all possible transitions, given the starting and ending states for the electrons.

(b) Calculate the longest wavelength of photons that the atom can emit during the transitions identified in part (a).

$E = \frac{h}{\lambda} c$

$2.25(1.6\times10^{-19}) = \frac{6.63\times10^{-34}}{\lambda}(3\times10^{8})$

$\lambda = 5.525\times10^{-7}$ m

(c) What is the ionization energy of an atom in the ground state?

$E = (12 \text{ eV})(1.6\times10^{-19})$

$E = 1.92\times10^{-18}$ J

(d) Photons of energy 11.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

There will be no effect, as the electron in the ground state can neither emit nor absorb a photon of 11eV.

(e) Photons of energy 14.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

The photons will be absorbed by the electron, and the electron will be released from the isolated atom, as 14 eV exceeds the energy levels given

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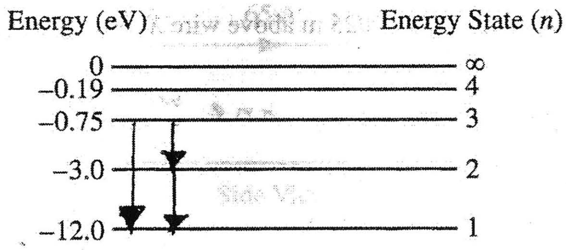

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(b) Calculate the longest wavelength of photons that the atom can emit during the transitions identified in part (a).

$\lambda = \frac{h}{p}$ $E = pc$ $2.25\,eV (= 3.6\times10^{-19}\,J$

$\lambda = \frac{6.63\times10^{-34}\,Js}{1.2\times10^{-27}\,Ns}$ $3.6\times10^{-19}\,J = p(3\times10^{8}\,m/s)$

$p = 1.2\times10^{-27}\,Ns$

$\lambda = 5.525\times10^{-7}\,m$

(c) What is the ionization energy of an atom in the ground state?

12eV

(d) Photons of energy 11.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

This can excite the electron to the n=2 state, it would require 11.25eV to get it to the n=3 state

(e) Photons of energy 14.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

This would cause the atom to ionize, the electron would have enough energy to escape the pull of the atom.

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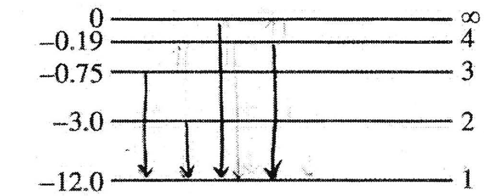

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(b) Calculate the longest wavelength of photons that the atom can emit during the transitions identified in part (a).

$\lambda = \frac{h}{p}$ $E = pc$ $p = \frac{E}{c}$

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

$\lambda = \frac{4.14\times10^{-15} \cdot 3\times10^{8}}{12 - 3} = 1.38 \times 10^{-7}$ m

(c) What is the ionization energy of an atom in the ground state?

$-12\ eV \cdot \frac{1.6\times10^{-19} J}{1\ eV} = 1.92 \times 10^{-18}$ J

$1\ eV = 1.6\times10^{-19}$ J

(d) Photons of energy 11.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

It has no effect because there is no energy level where the energy drop equals 11 eV.

(e) Photons of energy 14.0 eV are incident on the atom. What effect can this have on an electron in the $n = 1$ state? Justify your answer.

It has no effect because there is no energy level where the energy drop equals 14 eV.

GO ON TO THE NEXT PAGE.

Question 7

Overview

This question assessed students' understanding of the interaction between photons and electrons and the energy levels of an atom. It also assessed students' understanding of the ground state and the energy required to change the energy of the atom or to remove an electron from the atom.

Sample: B7-A
Score: 9

This response represents an excellent display of work and almost earned full credit. Part (a) has the correct three arrows drawn with no extraneous arrows. Part (b) correctly relates wavelength to energy. Part (c) determines the correct ionization energy. Part (d) correctly stated that the photon will have no effect but did not explain why. One point was lost for not explaining that there is no energy level of −1.0 eV for an electron to move to from the ground state. Part (e) correctly states and explains why the photon will remove the electron from the atom.

Sample: B7-B
Score: 8

This response earns full credit for parts (a), (b), (c), and (e). Part (b) uses the de Broglie wavelength and energy-momentum relationship for a photon to calculate the wavelength. No credit was earned in part (d) because it incorrectly states that the electron could be excited to the $n = 2$ state. Because this is incorrect, the justification is not scored.

Sample: B7-C
Score: 4

In part (a) two of the three correct transitions are drawn, earning two points. However, there are extraneous arrows resulting in a 1 point deduction. Part (a) earned a total of 1 point. In part (b), 1 point was earned for a wavelength value for a transition from level 2 to level 1. Full credit was earned for a transition from level 3 to level 2. In part (c), the answer was boxed (in joules), which negated the negative sign out in front of the 12 eV, and earned full credit. Only 1 point was earned in part (d) because a valid justification is missing. No credit was earned in part (e).