2019

AP® CollegeBoard

AP® Chemistry

Sample Student Responses and Scoring Commentary

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Free Response Question 5

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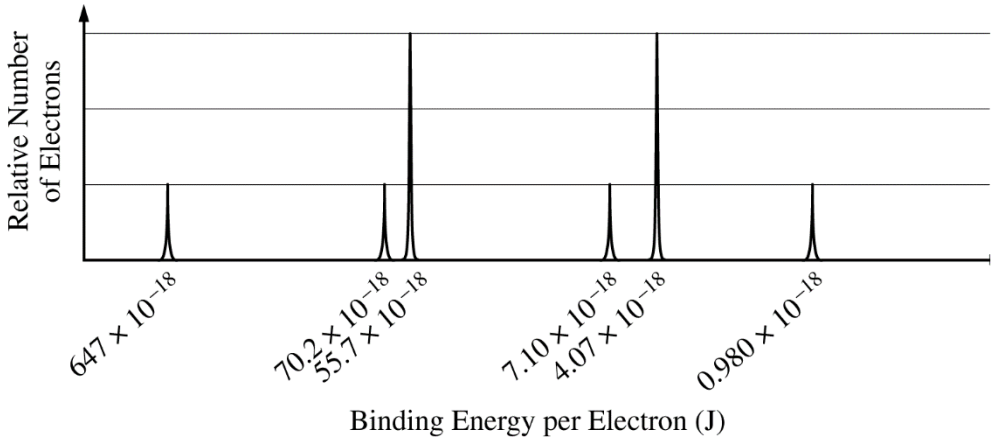
AP® CHEMISTRY
2019 SCORING GUIDELINES

Question 5

The complete photoelectron spectrum of an element in its ground state is represented below.



(a) Based on the spectrum,

(i) write the ground-state electron configuration of the element, and

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ or [Ar] $4s^2$	1 point is earned for the correct answer.

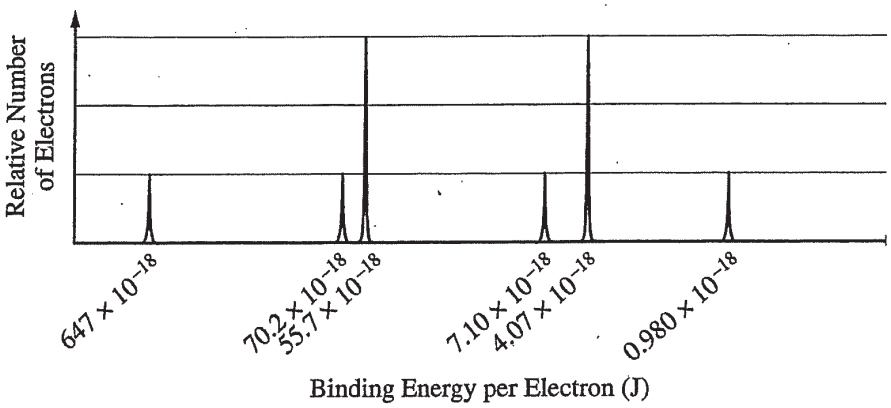
(ii) identify the element.

Ca	1 point is earned for the correct answer.

(b) Calculate the wavelength, in meters, of electromagnetic radiation needed to remove an electron from the valence shell of an atom of the element.

Energy (E) required = 0.980×10^{-18} J $E = h\nu = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$ $\lambda = \frac{(6.626 \times 10^{-34}\ \text{Js})(2.998 \times 10^{8}\ \text{m s}^{-1})}{0.980 \times 10^{-18}\ \text{J}}$ $\lambda = 2.03 \times 10^{-7}$ m	1 point is earned for the correct identification of the energy required to remove an electron from the valence shell (may be implicit). 1 point is earned for calculating the correct wavelength.

5. The complete photoelectron spectrum of an element in its ground state is represented below.



(a) Based on the spectrum,

(i) write the ground-state electron configuration of the element, and

(ii) identify the element.

(b) Calculate the wavelength, in meters, of electromagnetic radiation needed to remove an electron from the valence shell of an atom of the element.

a. i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

ii) Ca (Calcium)

b. $E = h\nu$

$.980 \times 10^{-18}\ J = (6.626 \times 10^{-34}\ J \cdot s)(\nu)$

$\nu = 1.479 \times 10^{15}\ s^{-1}$

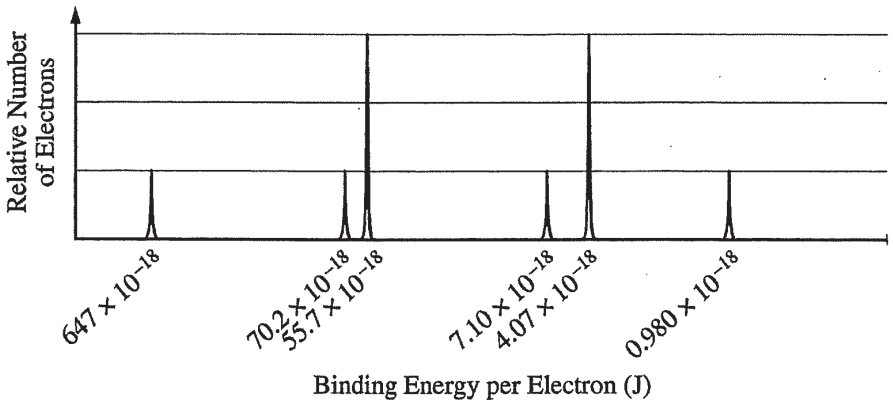
$c = \lambda\nu$

$2.998 \times 10^{8}\ m\ s^{-1} = \lambda(1.479 \times 10^{15}\ s^{-1})$

$\boxed{\lambda = 2.03 \times 10^{-7}\ m}$

GO ON TO THE NEXT PAGE.

5. The complete photoelectron spectrum of an element in its ground state is represented below.



(a) Based on the spectrum,

(i) write the ground-state electron configuration of the element, and

(ii) identify the element.

(b) Calculate the wavelength, in meters, of electromagnetic radiation needed to remove an electron from the valence shell of an atom of the element.

a. (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(ii) Calcium

b. $E = h\nu$

$.980 \times 10^{-18}\ J = (6.626 \times 10^{-34}\ J\,s)\,\nu$

$\nu = 1.48 \times 10^{15}\ s$

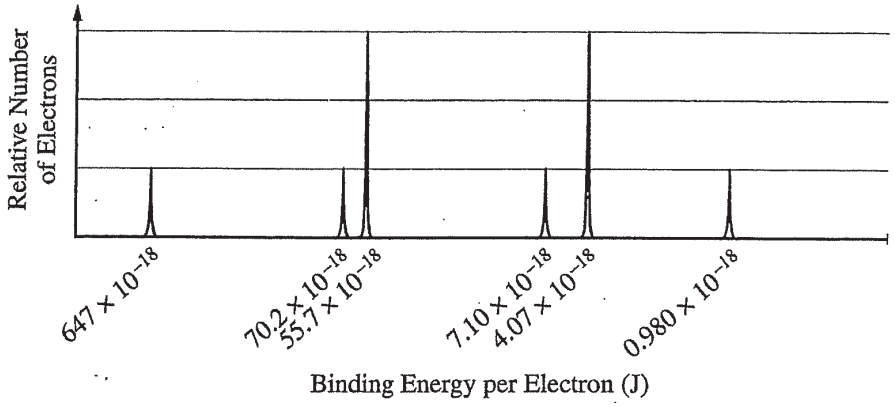
$c = \lambda\nu$

$2.998 \times 10^{8}\ m/s = (1.48 \times 10^{15}\ s)\,\lambda$

$\lambda = \boxed{2.03 \times 10^{-9}\ m}$

GO ON TO THE NEXT PAGE.

5. The complete photoelectron spectrum of an element in its ground state is represented below.



(a) Based on the spectrum,

(i) write the ground-state electron configuration of the element, and

(ii) identify the element.

(b) Calculate the wavelength, in meters, of electromagnetic radiation needed to remove an electron from the valence shell of an atom of the element.

a. (I) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

(II) calcium

b. $E = h\nu$

$647 \times 10^{-18} = (6.626 \times 10^{-34})\nu$

$\nu = 4.29 \times 10^{-49}$ V

$c = \lambda\nu$

$2.998 \times 10^{8} = (\lambda)(4.29 \times 10^{-49})$

$\lambda = 6.99 \times 10^{56}$ m

AP® CHEMISTRY
2019 SCORING COMMENTARY

Question 5

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

This question uses a photoelectron spectrum as the focal point of questions about electron configuration, chemical identity, and energy-wavelength conversions within the context of atomic structure. All parts of this question address LO 1.7; SP 5.1 and 6.2.

Part (a)(i) asks students to interpret the spectrum to determine the ground-state electron configuration of the element. They must realize that the position and height of each signal in the spectrum corresponds to the energy and relative number of electrons in an orbital shell, respectively. In part (a)(ii) students use the spectrum and/or their electron configuration to identify the unknown element.

Part (b) assesses students' ability to recognize that the PES peak with the lowest energy (on the right of the spectrum) corresponds to removing an electron from the valence shell. The question further assesses students' ability to calculate the wavelength of light associated with this energy. Students need to combine two mathematical relationships ($E=h\nu$ and $c=\lambda\nu$) and use several constants from the exam booklet.

Sample: 5A
Score: 4

This response earned 4 out of 4 possible points. In part (a)(i) the student earned 1 point for writing the correct ground-state electron configuration. In part (a)(ii) the student earned 1 point for correctly identifying calcium. In part (b) the student earned 2 points for using the appropriate energy to calculate the correct wavelength.

Sample: 5B
Score: 3

This response earned 3 out of 4 possible points. In part (a)(i) the student earned 1 point for writing the correct ground-state electron configuration. In part (a)(ii) the student earned 1 point for correctly identifying calcium. In part (b) the student earned 1 point for implicitly recognizing that 0.980×10^{-18} J of energy is required to remove an electron from the valence shell of calcium. This is demonstrated by writing $E = h\nu$ and then substituting 0.980×10^{-18} J for E. The response correctly calculates the associated frequency but does not successfully convert this to a wavelength. Therefore, the student did not earn the second point in part (b).

Sample: 5C
Score: 2

This response earned 2 out of 4 possible points. In part (a)(i) the student earned 1 point for writing the correct ground-state electron configuration. In part (a)(ii) the student earned 1 point for correctly identifying calcium. In part (b) no points were earned. An incorrect energy (the energy required to remove an electron from the 1*s* orbital instead of the valence shell) is chosen from the photoelectron spectrum, so the first point was not earned. The response is unsuccessful in converting this energy to a frequency, so the calculated wavelength is incorrect for the chosen energy, and no point was earned.