2018

AP CollegeBoard

AP Chemistry

Sample Student Responses and Scoring Commentary

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Free Response Question 7

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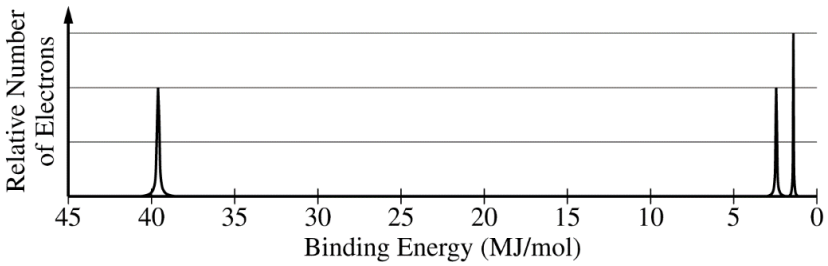
AP® CHEMISTRY
2018 SCORING GUIDELINES

Question 7



The complete photoelectron spectrum of an element is represented above.

(a) Identify the element.

The element is nitrogen, N.	1 point is earned for correctly identifying the element.

A radioactive isotope of the element decays with a half-life of 10. minutes.

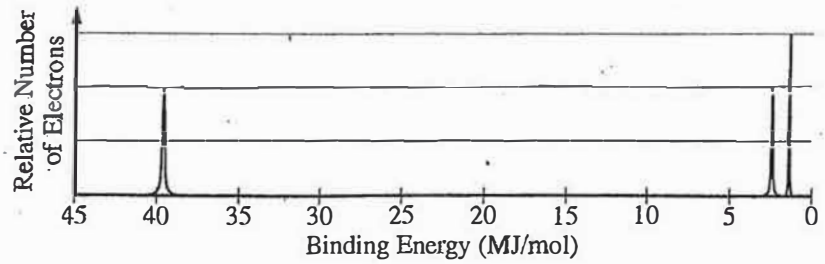
(b) Calculate the value of the rate constant, k, for the radioactive decay. Include units with your answer.

$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{10.\ \text{min}} = 0.069\ \text{min}^{-1}$	1 point is earned for the correct numerical answer. 1 point is earned for the correct unit.

(c) If 64 atoms of the radioactive isotope are originally present in a sample, what is the expected amount of time that will pass until only one atom of the isotope remains? Show how you arrived at your answer.

$64 \rightarrow 32 \rightarrow 16 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1$ 6 half-lives are required. $6 \times 10.\ \text{min} = 60.\ \text{min}$ **OR** $\ln[\text{A}]_t - \ln[\text{A}]_0 = -kt$ $t = \frac{\ln(1) - \ln(64)}{-0.069\ \text{min}^{-1}} = 60.\ \text{min}$	1 point is earned for the correct answer and a valid method.

7A 1 of 1



7. The complete photoelectron spectrum of an element is represented above.

(a) Identify the element.

A radioactive isotope of the element decays with a half-life of 10. minutes.

(b) Calculate the value of the rate constant, k, for the radioactive decay. Include units with your answer.

(c) If 64 atoms of the radioactive isotope are originally present in a sample, what is the expected amount of time that will pass until only one atom of the isotope remains? Show how you arrived at your answer.

(a) Nitrogen ; N

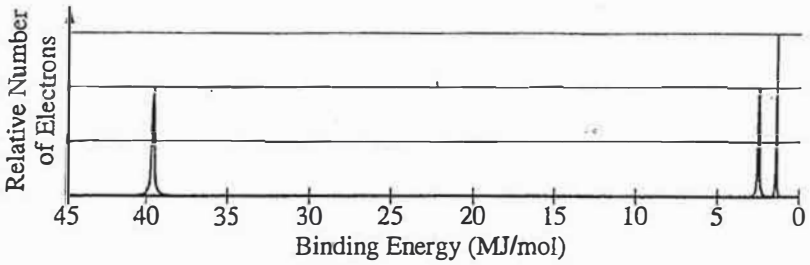
(b) $t_{\frac{1}{2}} = \frac{0.693}{k}$ $k = \frac{0.693}{10.\,min} = 0.0693\ min^{-1} = 0.069\ min^{-1}$

(c) $\log_2 64 = \frac{\log 64}{\log 2} = 6$ $6 \times 10.\ min = 60.\ min.$

Since $64 \times \frac{1}{2^6} = 1$

After 60. minutes, there will only be one atom of the isotope remains.

7B 1 of 1



7. The complete photoelectron spectrum of an element is represented above.

(a) Identify the element.

A radioactive isotope of the element decays with a half-life of 10. minutes.

(b) Calculate the value of the rate constant, k, for the radioactive decay. Include units with your answer.

(c) If 64 atoms of the radioactive isotope are originally present in a sample, what is the expected amount of time that will pass until only one atom of the isotope remains? Show how you arrived at your answer.

a) The element is Nitrogen

b) $t_{1/2} = \frac{0.693}{K}$

$K = \frac{0.693}{600.\,s}$

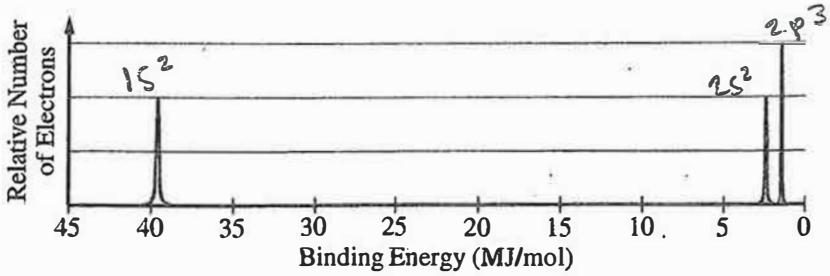
$K = .0012\ s^{-1}$

c) 64 atoms $\xrightarrow{10\,min}$ 32 atoms $\xrightarrow{10}$ 16 atoms $\xrightarrow{10}$ 8 atoms $\xrightarrow{10}$ 4 atoms $\xrightarrow{10}$ 2 atoms $\xrightarrow{10}$ 1 atom

5(10) = 50. min

Approximately 50. minutes will pass until only one atom remains.

7C 1 of 1



7. The complete photoelectron spectrum of an element is represented above.

   (a) Identify the element.

   A radioactive isotope of the element decays with a half-life of 10. minutes.

   (b) Calculate the value of the rate constant, k, for the radioactive decay. Include units with your answer.

   (c) If 64 atoms of the radioactive isotope are originally present in a sample, what is the expected amount of time that will pass until only one atom of the isotope remains? Show how you arrived at your answer.

a) boron

b) $600s = \frac{0.693}{k}$

$k = 0.0012\ m/s$

c) $\ln[1] - \ln[64] = -.0012t$

$= 3465$ seconds

$= \boxed{58.\ \text{minutes}}$

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AP® CHEMISTRY
2018 SCORING COMMENTARY

Question 7

Overview

The intent of this question was for students to describe various attributes of nitrogen, from its photoelectron spectrum to the first-order decay of one of its radioisotopes.

Part (a) presents students with the photoelectron spectrum of an unknown element and asks for the identity of the element (LO 1.5; SP 1.5, 6.2). Students had to realize that the peaks represented different energy sublevels, that electrons in the lowest-energy sublevel had the greatest binding energy, and that the height of the peaks correlated with the number of electrons.

Part (b) of the question assessed students' ability to calculate the rate constant when given the half-life of a radioactive isotope (LO 4.3; SP 2.1, 2.2). Students needed to recognize nuclear decay as a first-order process and then use an appropriate mathematical routine to calculate the value of k (with appropriate units).

Part (c) assessed students' ability to determine the expected amount of time for the radioactive decay, given initial and final numbers of atoms (LO 4.2; SP 5.1, 6.4). Students were required to show some work explaining how they arrived at their answer. Several mathematical approaches were possible with the two most common methods included in the rubric.

Sample: 7A
Score: 4

The response earned 4 out of 4 possible points. In part (a) the student correctly identifies the element as nitrogen and earned 1 point. In part (b) the response earned 2 points because the student substitutes 10. min into the half-life formula, calculates the correct value, and includes correct units. In part (c) the student uses a valid alternative method to correctly calculate time and earned 1 point.

Sample: 7B
Score: 3

The response earned 3 out of 4 possible points. In part (a) the student correctly identifies the element as nitrogen and earned 1 point. In part (b) the student substitutes an equivalent time of 600 s into the half-life formula, calculates a correct rate constant of 0.0012 s^{-1}, and includes a unit consistent with the value. The response earned 2 points. The conversion of minutes to seconds is unnecessary but yields a correct rate constant. In part (c) the student uses a valid method to determine time but then calculates an incorrect time, so no point was earned.

Sample: 7C
Score: 2

The response earned 2 out of 4 possible points. In part (a) the student incorrectly identifies the element as boron and did not earn the point. In part (b) the student substitutes an equivalent time of 600 s into the half-life formula, calculates a correct value of 0.0012, and earned 1 point. The conversion of minutes to seconds is unnecessary but yields a correct value and earned the value point. The student includes an incorrect unit and did not earn the unit point. The response earned 1 point in part (c). The student uses the integrated rate law, substitutes the calculated value for k, and correctly calculates the time that is consistent with the answer for part (b).