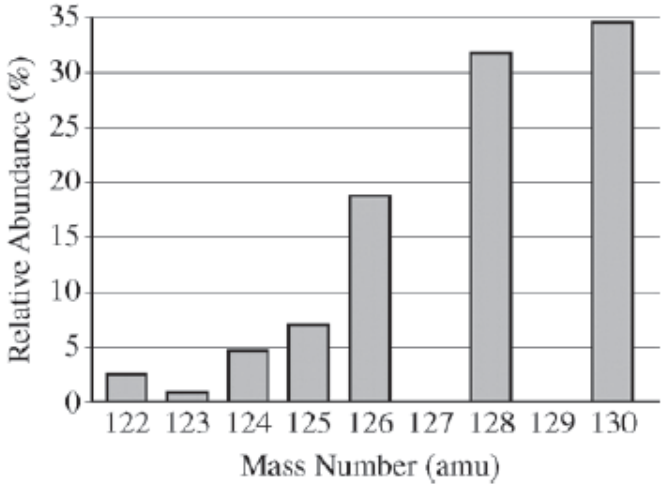
PES & Atomic Sample AP Problems: Key

2014 Released & Mock AP Exam

3. Which of the following correctly identifies which has the higher first-ionization energy, Cl or Ar, and supplies the best justification?

(A) Cl, because of its higher electronegativity
(B) Cl, because of its higher electron affinity
(C) Ar, because of its completely filled valence shell
(D) Ar, because of its higher effective nuclear charge



10. The elements I and Te have similar average atomic masses. A sample that was believed to be a mixture of I and Te was run through a mass spectrometer, resulting in the data above. All of the following statements are true. Which one would be the best basis for concluding that the sample was pure Te?

(A) Te forms ions with a –2 charge, whereas I forms ions with a –1 charge.
(B) Te is more abundant than I in the universe.
(C) I consists of only one naturally occurring isotope with 74 neutrons, whereas Te has more than one isotope.
(D) I has a higher first ionization energy than Te does.

Element	Atomic Radius	First Ionization Energy
Calcium	194 pm	590 kJ/mol
Potassium	—	—

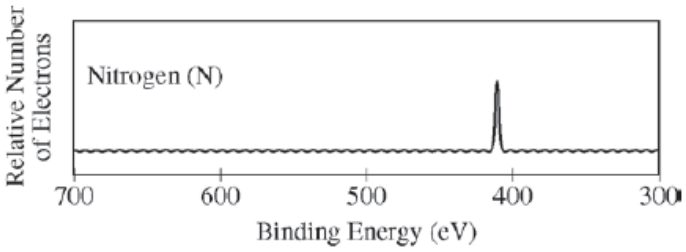
58. Based on periodic trends and the data in the table above, which of the following are the most probable values of the atomic radius and the first ionization energy for potassium, respectively?

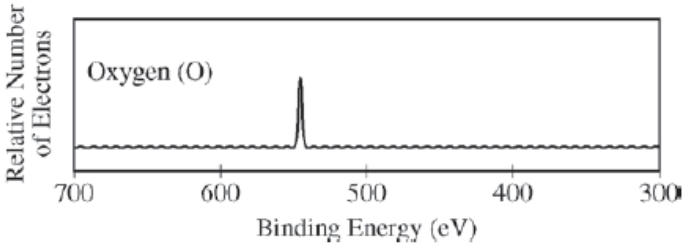
(A) 242 pm, 633 kJ/mol
(B) 242 pm, 419 kJ/mol
(C) 120 pm, 633 kJ/mol
(D) 120 pm, 419 kJ/mol

Element	First Ionization Energy (kJ/mol)	Atomic Radius (pm)
B	801	85
C	1086	77
N	1400	75
O	1314	73
F	1680	72
Ne	2080	70

12. The table above shows the first ionization energy and atomic radius of several elements. Which of the following best helps to explain the deviation of the first ionization energy of oxygen from the overall trend?

(A) The atomic radius of oxygen is greater than the atomic radius of fluorine.
(B) The atomic radius of oxygen is less than the atomic radius of nitrogen.
(C) There is repulsion between paired electrons in oxygen's 2*p* orbitals.
(D) There is attraction between paired electrons in oxygen's 2*p* orbitals.





43. The photoelectron spectra above show the energy required to remove a 1*s* electron from a nitrogen atom and from an oxygen atom. Which of the following statements best accounts for the peak in the upper spectrum being to the right of the peak in the lower spectrum?

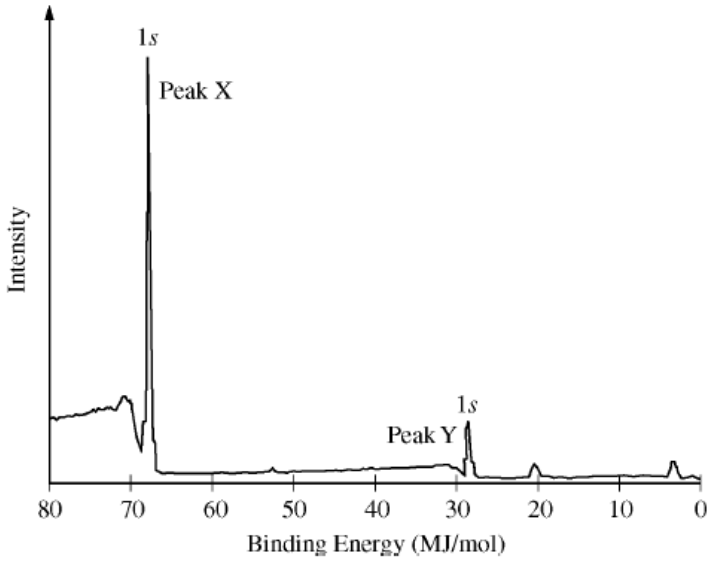
(A) Nitrogen atoms have a half-filled *p* subshell.
(B) There are more electron-electron repulsions in oxygen atoms than in nitrogen atoms.
(C) Electrons in the *p* subshell of oxygen atoms provide more shielding than electrons in the *p* subshell of nitrogen atoms.
(D) Nitrogen atoms have a smaller nuclear charge than oxygen atoms.

	NaF	MgO
Boiling Point (°C)	1695	3600

	Na^+	Mg^{2+}	F^-	Cl^-	O^{2-}
Ionic Radius (pm)	76	72	133	181	140

54. Based on the data in the tables above, which of the following statements provides the best prediction for the boiling point of NaCl ?

(A) NaCl will have a lower boiling point than NaF because the coulombic attractions are weaker in NaCl than in NaF .
(B) NaCl will have a boiling point between that of NaF and MgO because the covalent character of the bonds in NaCl is intermediate between that of MgO and NaF.
(C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.
(D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO .



31. A sample containing atoms of C and F was analyzed using x-ray photoelectron spectroscopy. The portion of the spectrum showing the 1*s* peaks for atoms of the two elements is shown above. Which of the following correctly identifies the 1*s* peak for the F atoms and provides an appropriate explanation?

(A) Peak X, because F has a smaller first ionization energy than C has.
(B) Peak X, because F has a greater nuclear charge than C has.
(C) Peak Y, because F is more electronegative than C is.
(D) Peak Y, because F has a smaller atomic radius than C has.

2008 Released Exam

Atom	First Ionization Energy ($kJ\ mol^{-1}$)
F	1,681.0
O	1,313.9
Xe	?

(a) Write the equation for the ionization of atomic fluorine that requires 1,681.0 $kJ\ mol^{-1}$.

$F(g) \rightarrow F^+(g) + e^-$	One point is earned for the correct equation. (Phase designations are not required.)

(b) Account for the fact that the first ionization energy of atomic fluorine is greater than that of atomic oxygen. (You must discuss both atoms in your response.)

In both cases the electron removed is from the same energy level ($2p$), but fluorine has a greater effective nuclear charge due to one more proton in its nucleus (the electrons are held more tightly and thus take more energy to remove).	One point is earned for recognizing that the effective nuclear charge of F is greater than that of O.

(c) Predict whether the first ionization energy of atomic xenon is greater than, less than, or equal to the first ionization energy of atomic fluorine. Justify your prediction.

The first ionization energy of Xe should be less than the first ionization energy of F. To ionize the F atom, an electron is removed from a $2p$ orbital. To ionize the Xe atom, an electron must be removed from a $5p$ orbital. The $5p$ is a higher energy level and is farther from the nucleus than $2p$, hence it takes less energy to remove an electron from Xe.	One point is earned for a prediction based on size and/or energy level.

2007 B Released Exam

(a) Which element is most metallic in character? Explain your reasoning.

Element 2. It has the lowest first-ionization energy. Metallic elements lose electron(s) when they become ions, and element 2 requires the least amount of energy to remove an electron.	One point is earned for the identification. One point is earned for the justification.

(b) Identify element 3. Explain your reasoning.

Magnesium. Element 3 has low first and second ionization energies relative to the third ionization energy, indicating that the element has two valence electrons, which is true for magnesium. (The third ionization of element 3 is dramatically higher, indicating the removal of an electron from a noble gas core.)	One point is earned for the identification. One point is earned for the justification.

(c) Write the complete electron configuration for an atom of element 3.

$1s^2\ 2s^2\ 2p^6\ 3s^2$	One point is earned for the correct electron configuration.

(d) What is the expected oxidation state for the most common ion of element 2?

1+	One point is earned for the correct oxidation state.

(e) What is the chemical symbol for element 2?

Na	One point is earned for the correct symbol.

(f) A neutral atom of which of the four elements has the smallest radius?

Element 1	One point is earned for the correct identification of the element.

Additional AP Chemistry Practice Exam (Flinn)

1. The following are experimentally-determined values, in kJ/mol, of successive ionization energies for a third period element: $IE_1 = 578$, $IE_2 = 1820$, $IE_3 = 2750$, IE_4 11600. That is, 578 kJ of energy are required to remove the outermost electron from 1 mole of atoms of the element, 1820 kJ of energy are required to remove the next (of the remaining electrons) valence electron, and so on.

   a) To which element do these successive ionization energies correspond? Justify your answer.
   Aluminum. There is a large jump from IE_3 to IE_4. A large jump corresponds to transitions between energy levels. IE_4 corresponds to an electron from energy level 2. IE_3 is the last of the valence electrons from energy level 3.

   b) Explain why IE_2 is larger than IE_1.
   Successive ionization energies ALWAYS increase. After losing an electron, there are fewer electrons being pulled inward by the nucleus. This makes it more difficult to remove an electron because each feels a larger inward pull from the protons. There is also less electron-electron repulsion, which also makes removing an electron more difficult because there isn't as much "pushing" them away.

   c) Estimate a value for IE_5. Justify your answer.
   IE_5 should be 15,000-20,000 kJ. It must be larger than IE_4 because successive IE always increases (see part b). There shouldn't be another huge jump until electrons are removed from level 1, so it is only slightly larger than IE_4.

Other Sample Problems

1. Based upon the ionization energy data presented below, element *Z* is most likely to be

Ionization Energies for Element *Z* (kJ mol^{-1})				
First	Second	Third	Fourth	Fifth
580	1,815	2,740	11,600	14,800

(A) Na
(B) Mg
(C) Al
(D) Si

2. The effective nuclear charge experienced by the outermost electron of Na is different than the effective nuclear charge experienced by the outermost electron of Ne. This difference best accounts for which of the following?

(A) Na has a greater density at standard conditions than Ne.
(B) Na has a lower first ionization energy than Ne.
(C) Na has a higher neutron-to-proton ratio than Ne.
(D) Na has fewer naturally occurring isotopes than Ne.

3. Based upon the ionization energy data presented below, what is the most likely formula for the product of the combustion of *W* in excess oxygen?

Ionization Energies for Element *W* (kJ mol^{-1})		
First	Second	Third
520	7,298	11,815

(A) WO
(B) W_2O
(C) W_2O_3
(D) WO_2