Photoelectron Spectroscopy

Key to how it works:

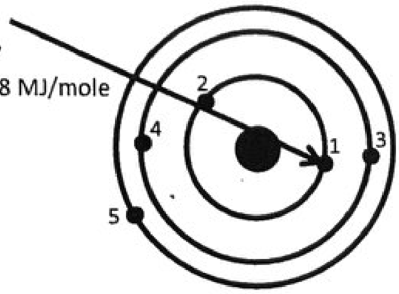
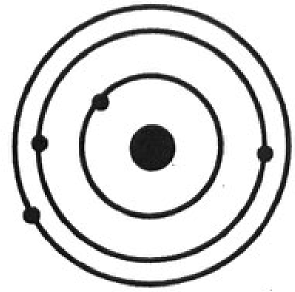
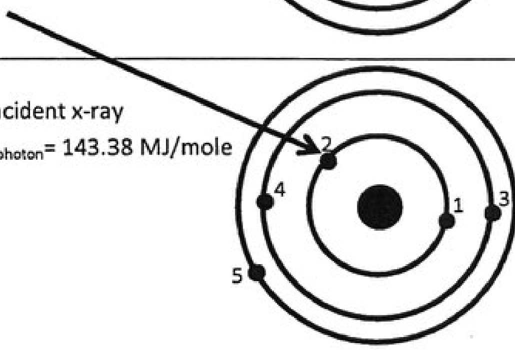
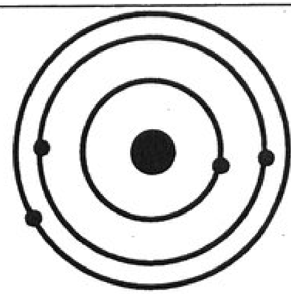
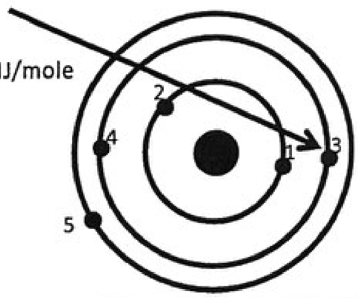
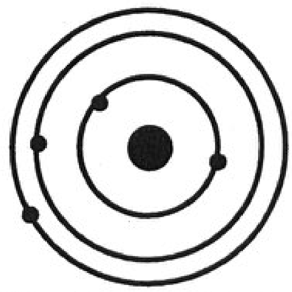
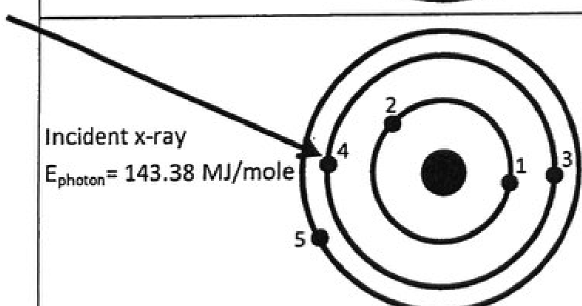
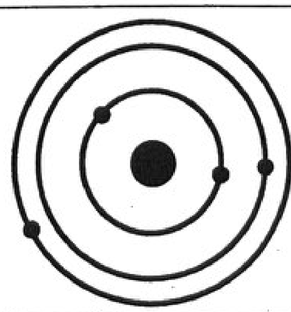
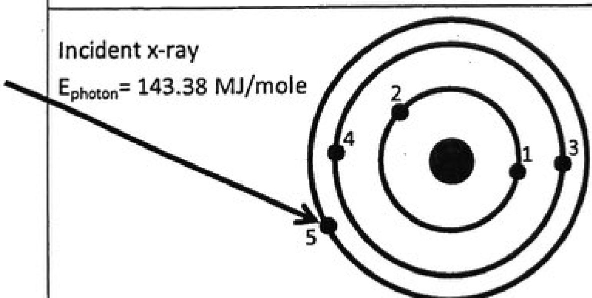
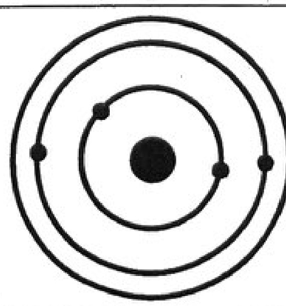
Photoelectron spectroscopy is a technique that is used to gather information about the electrons in an atom. An atom is bombarded with photons. Some of the photons are absorbed and electrons are emitted. The electrons are collected and their energy is analyzed. Since we can know the energy of the photons, and we know that energy is conserved, we know that the difference in energy between the photons sent into the atom and the electrons emitted will be the potential energy of the electrons when they are attached to the atom (binding energy).

Remember that the potential energy of the electron in the atom is the work needed to remove the electron from the atom (also called the binding energy).

Energy of emitted electron = Energy of the photon − Work needed to remove the electron from atom

Model 1: X-rays interacting with atoms of boron

Imagine a sample of neutral boron atoms being struck with x-rays. There are five possible outcomes, depicted on the chart on the next page. The boron atoms are depicted using the shell model (also called Bohr model diagrams).

Before	After
Incident x-ray E_{photon}= 143.38 MJ/mole 	 Ejected electron KE = 124.08 MJ/mole
Incident x-ray E_{photon}= 143.38 MJ/mole 	 Ejected electron KE = 124.08 MJ/mole
Incident x-ray E_{photon}= 143.38 MJ/mole 	 Ejected electron KE = 142.02 MJ/mole
Incident x-ray E_{photon}= 143.38 MJ/mole	 Ejected electron KE = 142.02 MJ/mole
Incident x-ray E_{photon}= 143.38 MJ/mole 	 Ejected electron KE = 142.55 MJ/mole

Questions

1. For the first electron shell representation above, what is the difference between the before and after states?

2. For all five situations, circle the electron that has been ejected from the atom.

3. What is causing the electrons to be ejected from their atoms?

4. Fill in the following table. For now leave the column labeled "binding energy" blank.

Electron number	Kinetic energy of ejected electron (MJ/mole)	Binding energy (MJ/mole)
1		
2		
3		
4		
5		

5. (a) Do all of the ejected electrons have the same kinetic energy after they have been separated from the atom?

   (b) On the table above, note which electrons have the same kinetic energy after being separated from the atom.

   (c) What do the electrons with the same kinetic energy after ejection have in common with each other in the shell models?

Information

Each electron in an atom is attracted to the nucleus. The energy necessary to separate an electron from an atom is called the electron's **binding energy.**

In photoelectron spectroscopy a beam of x-rays is directed at a sample of atoms. The x-rays have much more energy than is necessary to knock these electrons out of the atom, producing a stream of electrons called "photoelectrons". Because the x-rays have more energy than the binding energy, the photoelectrons exit the atom with a (relatively) large amount of kinetic energy.

The binding energy is the difference between the incoming photon's energy and the kinetic energy of the photoelectron.

$$E_{binding} = E_{photon} - E_{kinetic}$$

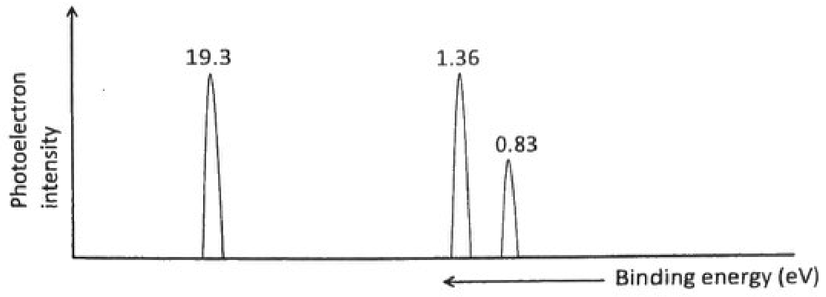
Questions

6. Explain what is the binding energy of an electron is.

7. What general law of science makes the equation above true?

8. Use the equation given above to calculate the binding energy of each of the 5 electrons in model 1 and fill these values in on the table in question 4.

9. Often the data from photoelectron spectroscopy is displayed as a graph of the binding energies as shown below.



(a) The values of the binding energy are placed above each peak. What is unusual about the order of the peaks on the graph?

(b) Why are there three peaks and not five peaks on this graph?

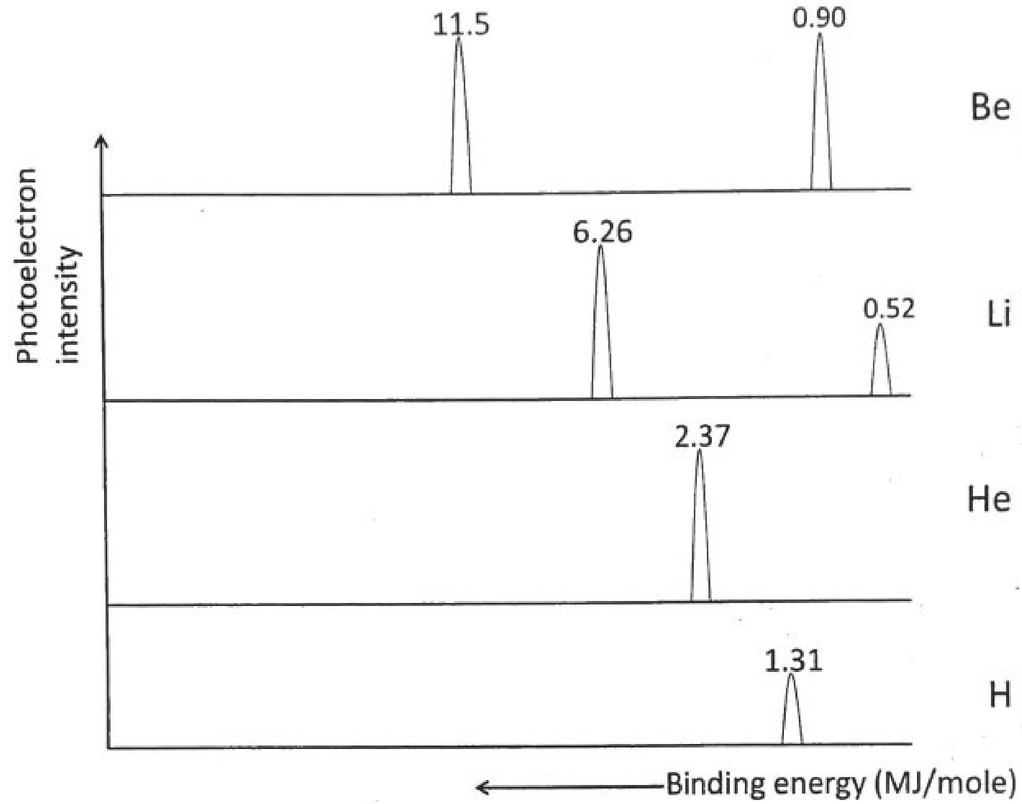
(c) Based on the number of electrons in each shell, why is the peak farthest to the right half the height of the other two?

10. Given the shell model for Li and Be below,

(a) How many photoelectron peaks would be observed for each?

(b) Draw a photoelectron spectrum for each. You needn't label the values, just draw the graph in a qualitative manner.

Model II: Comparisons of photoelectric spectra of different atoms



Questions

11. (a) Put a star above the peak for each atom with the highest energy value.
    (b) Does the energy of this highest energy peak increase or decrease as the atomic number (number of protons) increases?

12. Use Coulomb's law to explain the observation made in the previous answer.

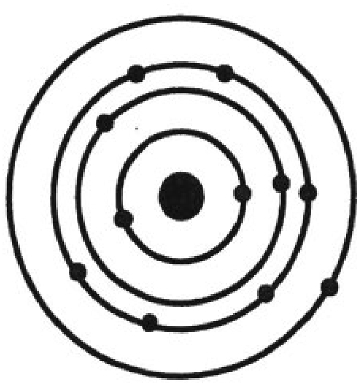
13. Without looking back at Model I, would you expect the highest energy photoelectron for Boron to be higher or lower in energy than the highest energy

electron for beryllium? Justify your answer not in terms of a trend but in terms of Coulomb's law and the number of electrons in the nucleus of B and Be.

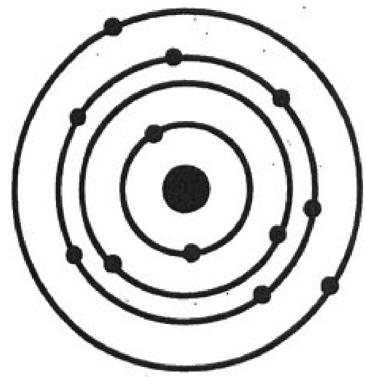
14. Carbon has 3 photoelectron peaks. Draw a qualitative photoelectron spectrum for carbon on the photoelectron spectrum for B given in Question 9.

15. Sodium and magnesium have the shell structures drawn below. Qualitatively sketch photoelectron spectra for each atom, one above the other.

Na



Mg

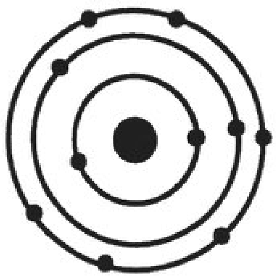


Exercises

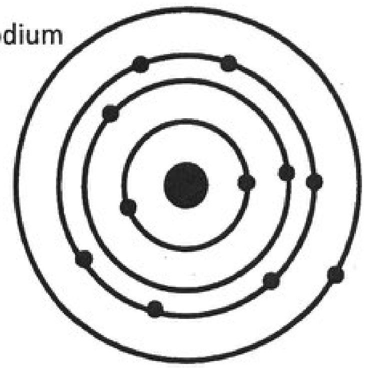
1. Looking at the data in Model 2, why is the He peak twice as high as the H peak for the n=1 electrons?

2. Draw photoelectric spectra for each of the following atoms. Draw each spectra on top of the other and make sure that the relative energies of each shell are correct.

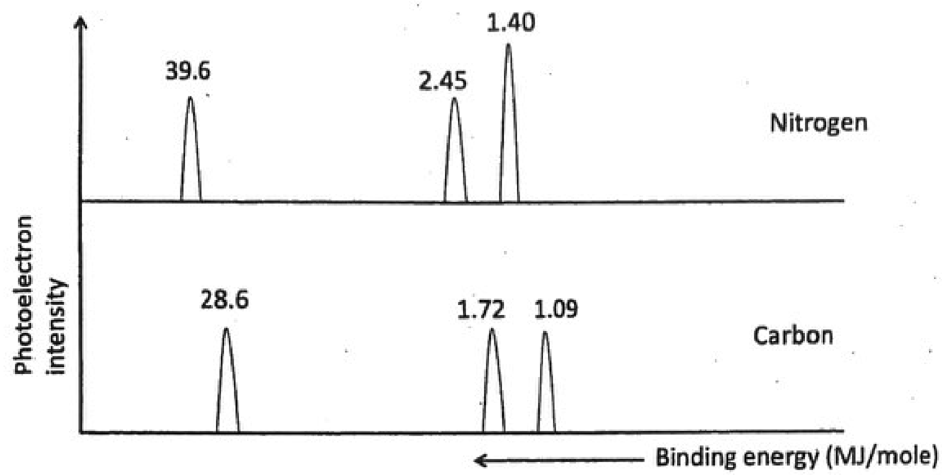
Neon



Sodium



3. Sketch shell models for each of the following PE spectra.



4. (a) In the photoelectron spectra in the previous question, put a star above the lowest energy peak of each atom.

In terms of Coulomb's law and the number of protons in the nucleus, and the number of electrons in each shell, explain why:

(b) The lowest energy peak of carbon is lower in energy than the lowest energy peak of nitrogen.

(c) The lowest energy peak of nitrogen is 50% higher in intensity than the lowest energy peak of carbon.

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http://www.sciencegeek.net/APchemistry/Quizzes/PES/

and take the quiz! SCORE ? /12