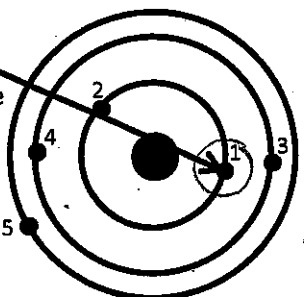
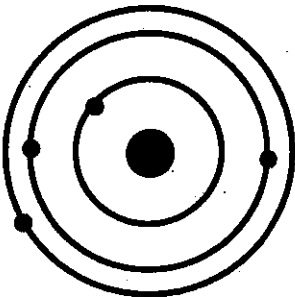
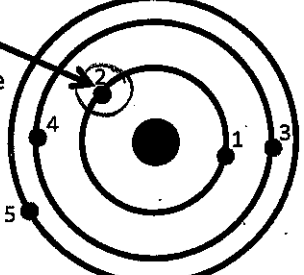
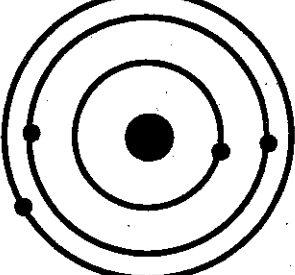
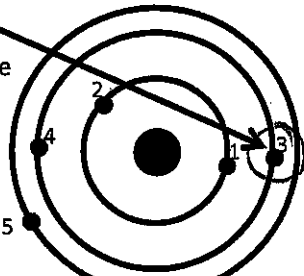
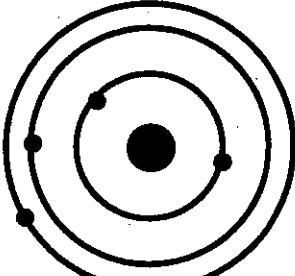
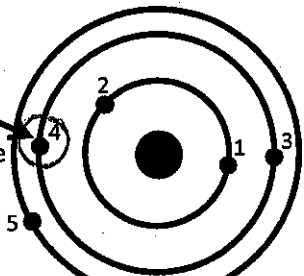
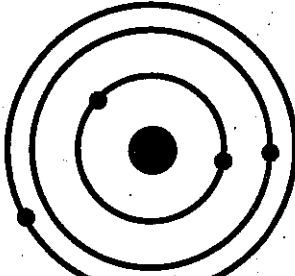
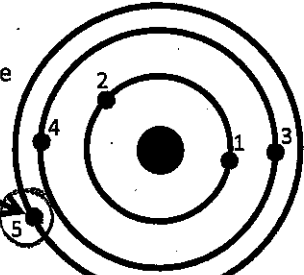
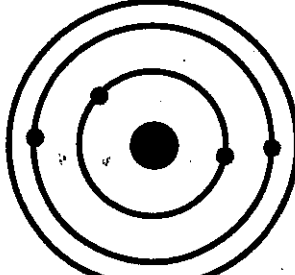


Before	After
<p>Incident x-ray  <math>E_{\text{photon}} = 143.38 \text{ MJ/mole}</math></p> 	 <p>Ejected electron  <math>KE = 124.08 \text{ MJ/mole}</math></p>
<p>Incident x-ray  <math>E_{\text{photon}} = 143.38 \text{ MJ/mole}</math></p> 	 <p>Ejected electron  <math>KE = 124.08 \text{ MJ/mole}</math></p>
<p>Incident x-ray  <math>E_{\text{photon}} = 143.38 \text{ MJ/mole}</math></p> 	 <p>Ejected electron  <math>KE = 142.02 \text{ MJ/mole}</math></p>
<p>Incident x-ray  <math>E_{\text{photon}} = 143.38 \text{ MJ/mole}</math></p> 	 <p>Ejected electron  <math>KE = 142.02 \text{ MJ/mole}</math></p>
<p>Incident x-ray  <math>E_{\text{photon}} = 143.38 \text{ MJ/mole}</math></p> 	 <p>Ejected electron  <math>KE = 142.55 \text{ MJ/mole}</math></p>

## Questions

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

The 1s electron has been ejected.

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

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

A photon with energy = to or > than the binding energy

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	124.08	19.30
2	124.08	19.30
3	142.02	1.36
4	142.02	1.36
5	142.55	.83

} 1s electrons

} 2s

2p

5. (a) Do all of the ejected electrons have the same kinetic energy after they have been separated from the atom? No

(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?

They are in same shell.

### 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.

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

### Questions

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

B.E. is the energy needed to separate an electron from an atom.

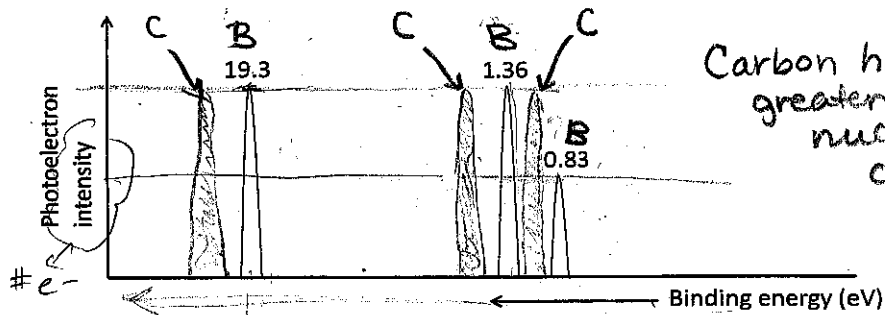
7. What general law of science makes the equation above true?

Law of Conservation of Energy (First Law of Thermodynamics)

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.

OK

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?

*the electron closest to nucleus is 1s<sup>+</sup> on graph, has highest*

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

*Electrons 1 & 2 have same binding E. As do electrons 3 & 4 energy.*

(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?

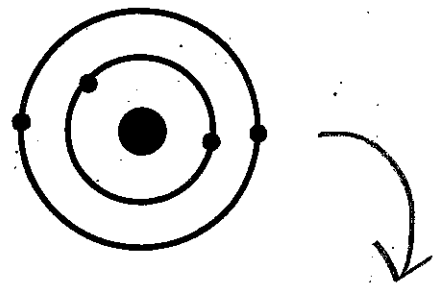
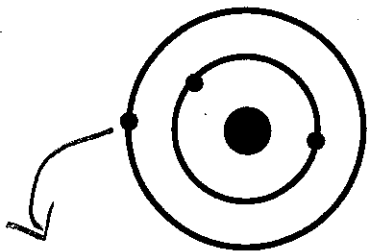
- shorter peak represents one e<sup>-</sup> with that amount of energy
- taller peaks represent two e<sup>-</sup> with that amount of energy

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

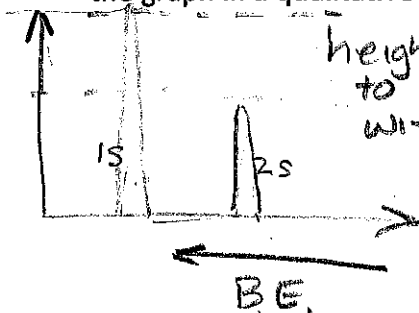
(a) How many photoelectron peaks would be observed for each?

Li → 2 peaks

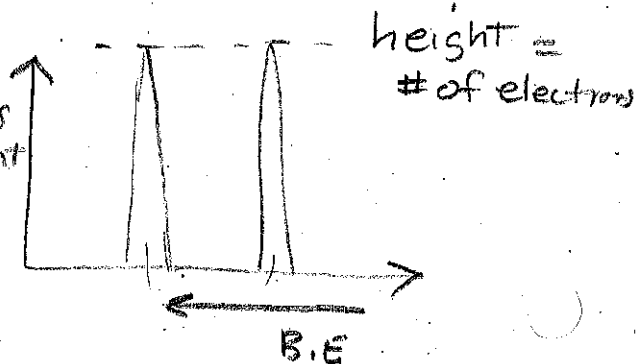
Be → 2 peaks



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

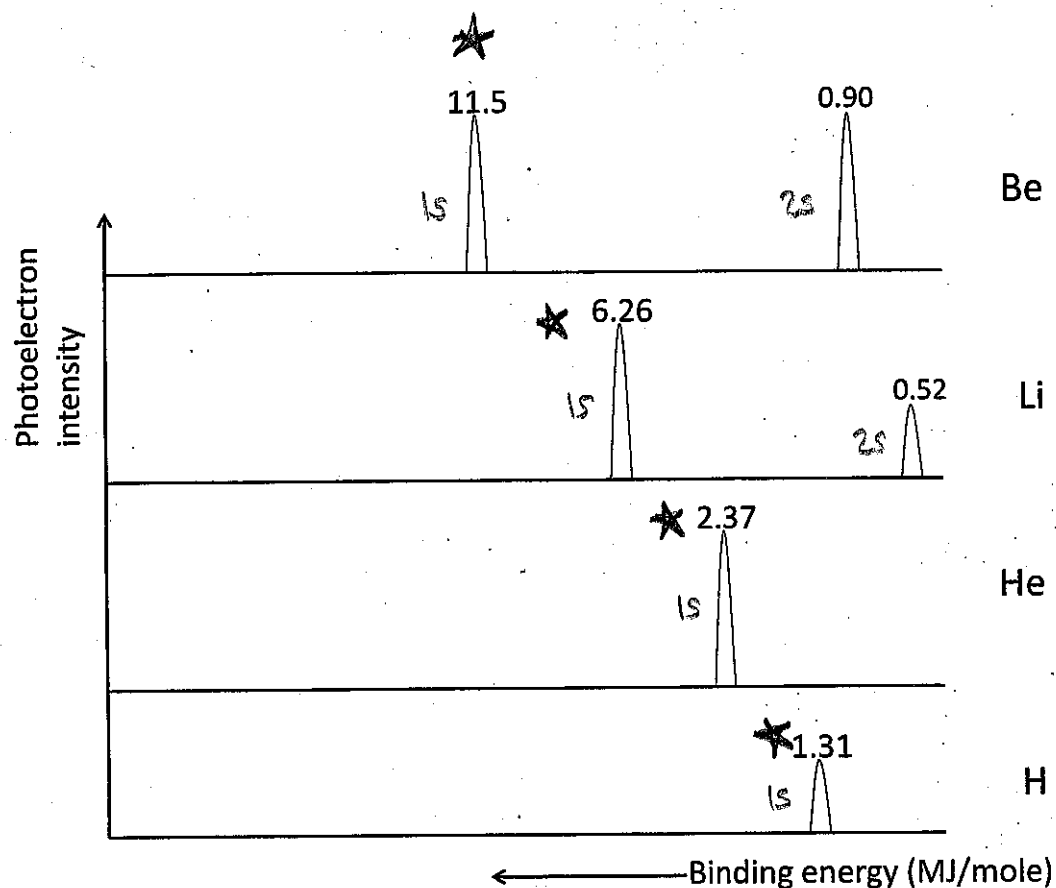


*height corresponds to # of electrons with that amount of energy.*



*height = # of electrons*

## 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?

*AS atomic number increases, Binding energy increases.*

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

$$E = k \frac{(q_1)(q_2)}{r^2}$$

$$E = \frac{(Q_1)(Q_2)}{r}$$

*# of protons*

*More E to remove Be's 1s electrons due to more protons in nucleus*

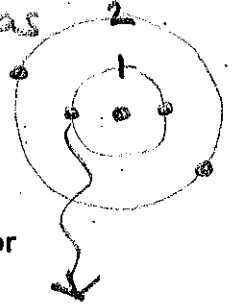
13. Without looking back at Model I, would you expect the highest energy photoelectron for Boron to be higher or lower in energy than the highest energy

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.

B's 1s electron would be higher in Energy than the 1s electron of Be because B has a greater nuclear charge.

$$\text{Be } E = \frac{(+4)(-1)}{r}$$

$$\text{B } E = \frac{(+5)(-1)}{r}$$



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

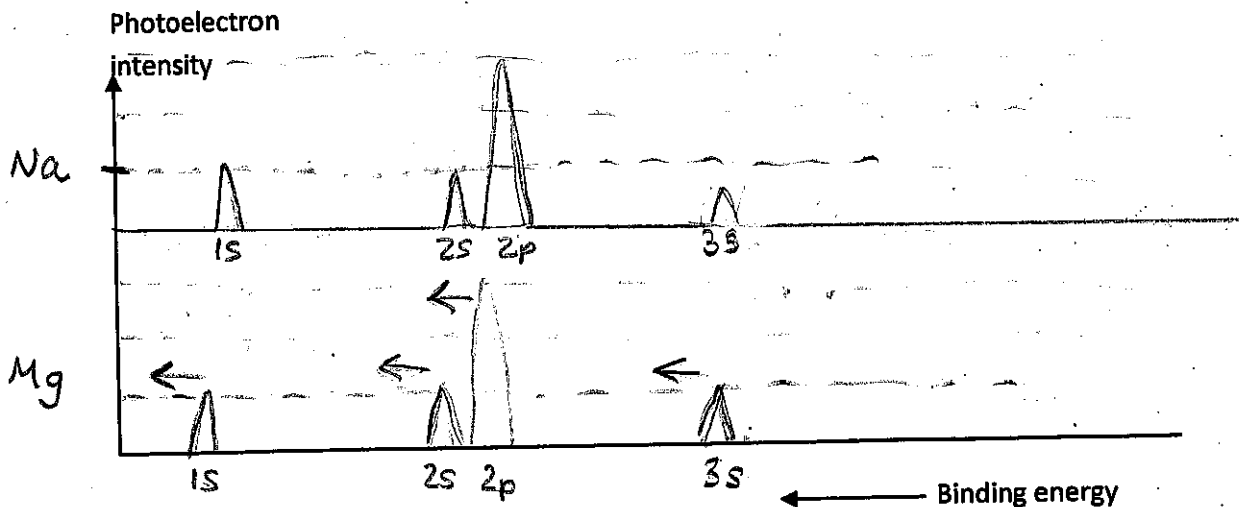
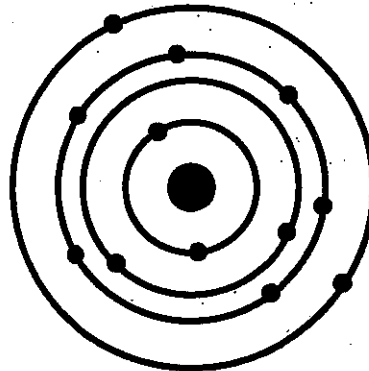
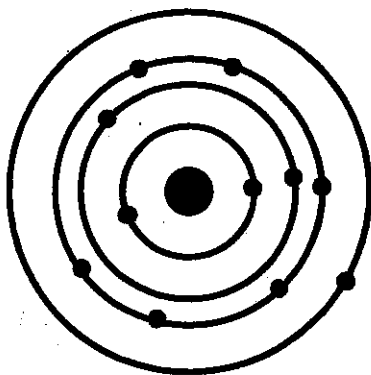
See # 9



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

Na

Mg

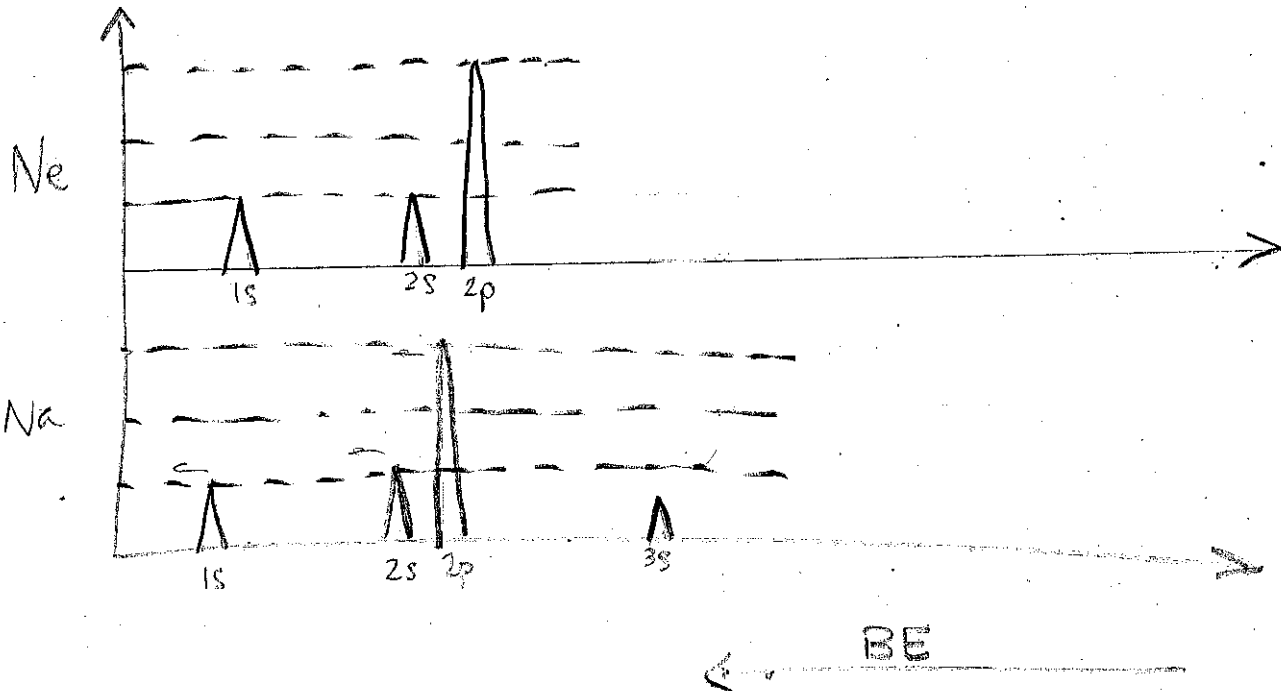
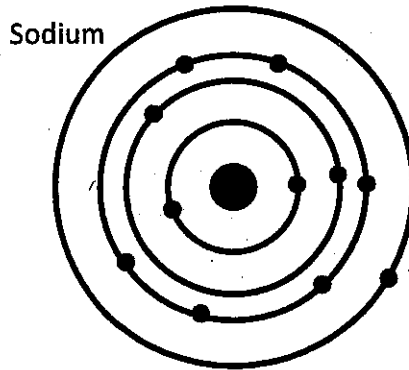
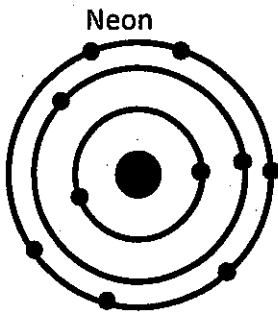


**Exercises**

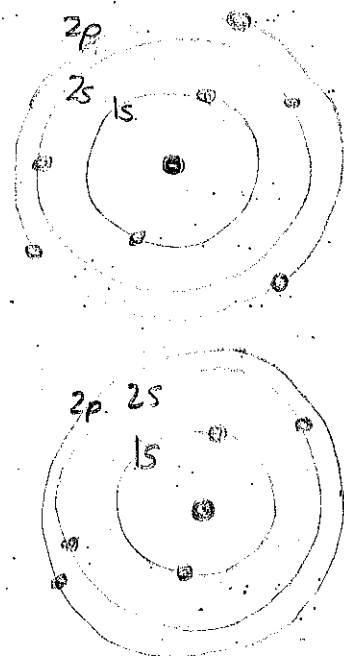
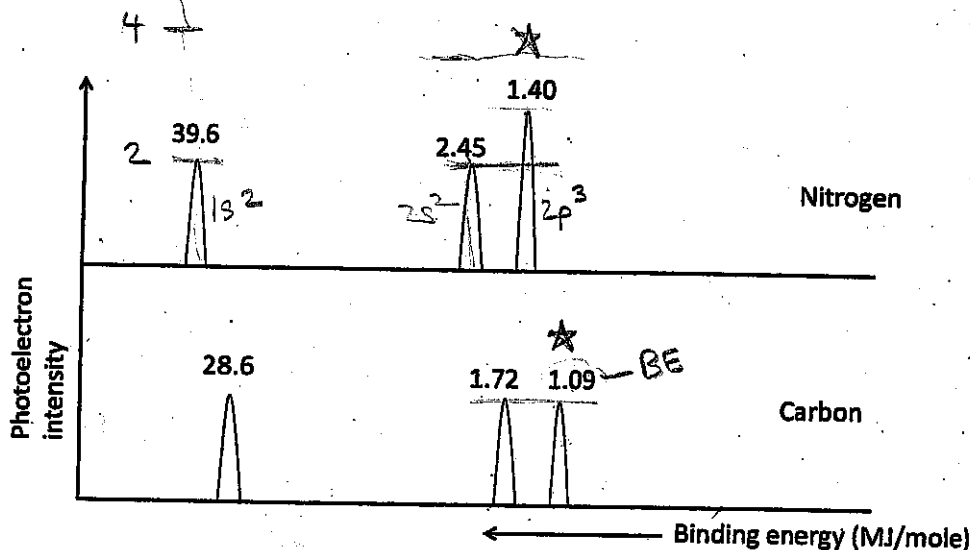
- Looking at the data in Model 2, why is the He peak twice as high as the H peak for the  $n=1$  electrons?

He has 2 electrons in  $n=1$  while H has only one electron.

- 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.



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.

$$C \quad E = \frac{(+6)(-1)}{r} = \frac{-6}{r}$$

$$N \quad E = \frac{(+7)(-1)}{r} = \frac{-7}{r}$$

Nitrogen has greater nuclear charge than carbon and therefore more energy is required to remove an electron from nitrogen.

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

N has 3 electrons in the lowest E shell while Carbon has 2 electrons in the lowest E shell.

Now go to

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

and take the quiz!