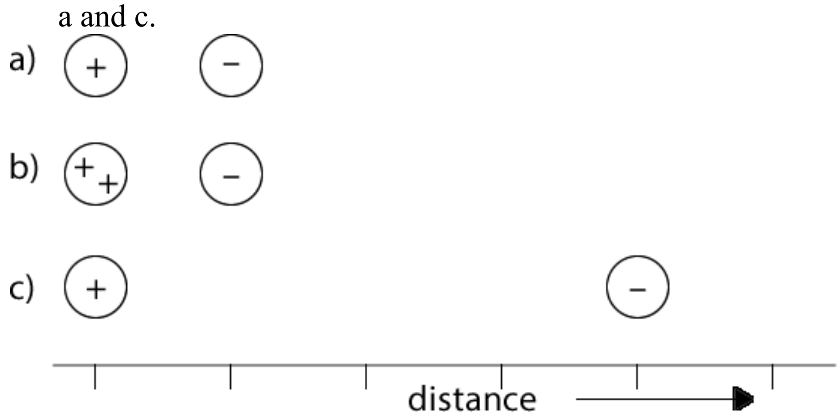
During Class Invention

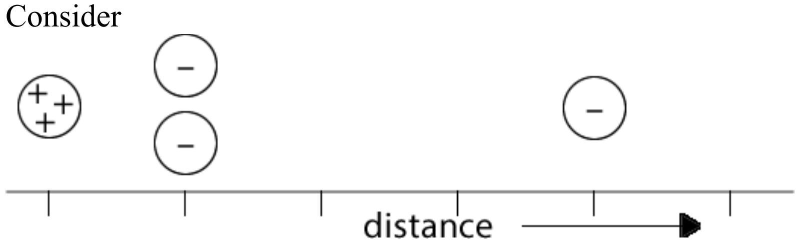
Question: Can we use our simple shell model of the atom to make some predictions?

1. Describe the nature of the interaction between protons and electrons in an atom? Consider using some or all of the following terms in your description: attraction, repulsion, neutral, positive, negative, charge, distance, nucleus, force, energy, Coulomb's Law.

2. Compare the relative energy necessary to separate positive and negative electrical charges in the following situations? Compare a and b, then compare a and c.



3. Consider



a) how many electrons do you see in the picture? How many protons?

b) which of these electrons is the easiest (requires the least amount of energy) to remove (ionize)?

c) Explain your response in b.

d) compare the energy from 3b with the energy in 2a and then in 2c.

The first ionization energy is defined as the minimum energy that must be added to a neutral atom, in the gas phase, to remove an electron from an atom. This definition can be represented in the following chemical equation;

$$\text{energy} + A(g) \rightarrow A^{+}(g) + 1e^{-}$$

4. In the ionization equation above, which is at lower energy? A(g) or $A^{+}(g)$ and $1e^{-}$? Which is at higher energy? A(g) or $A^{+}(g)$ and $1e^{-}$? Explain.

5. Explain why energy is required (an endothermic process) to remove the electron in a neutral atom.

6. The value of the first ionization energy for hydrogen is 1312 kJ mol^{-1}. In the graph below use a short horizontal line to indicate the energy of H(g) (reactant) and a short horizontal line to indicate the energy of $H^{+}(g) + 1e^{-}$ (product). (NOTE: Be sure to consider your responses to Q4 and Q5 above.)

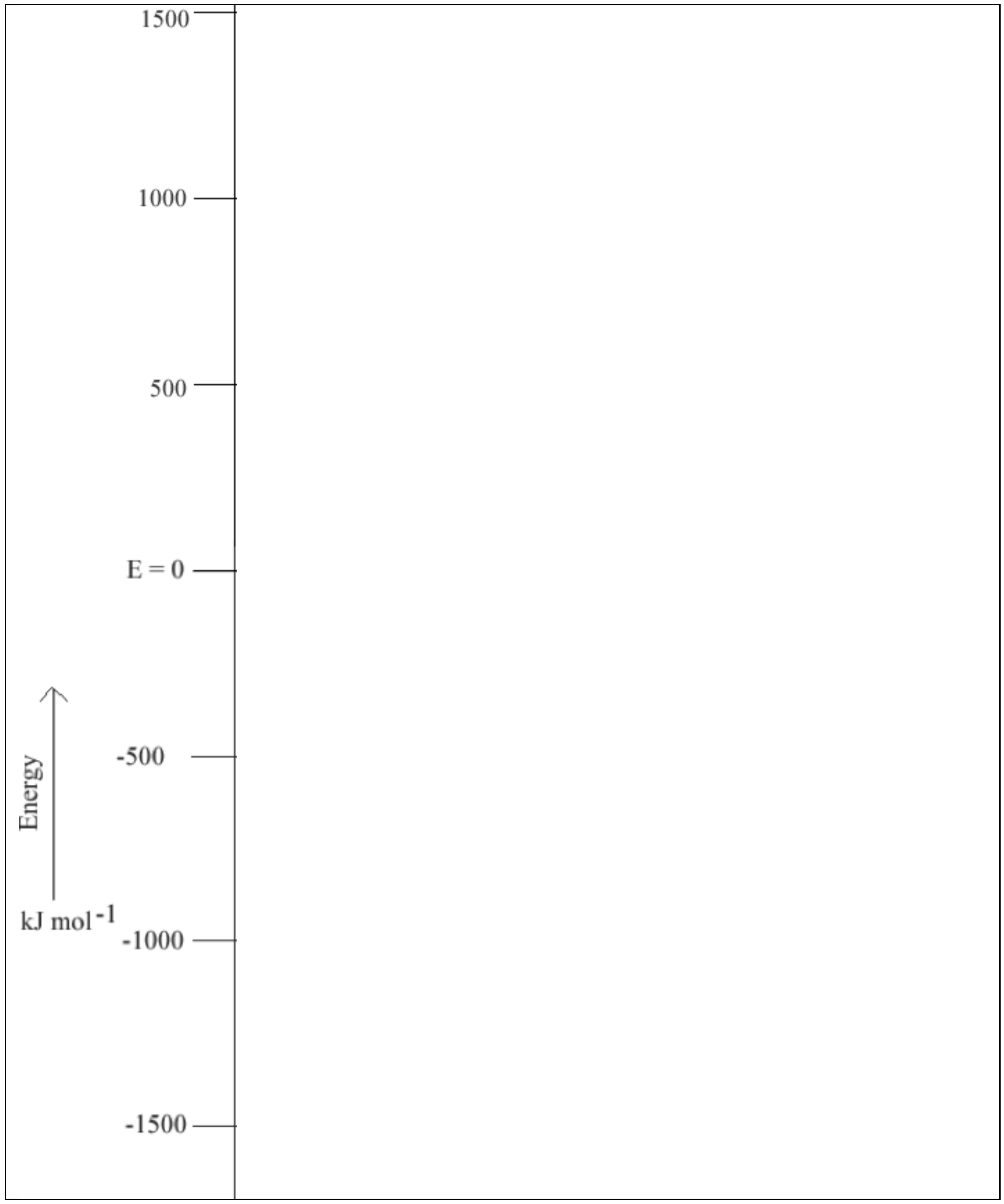


Figure I.

7. What does the difference in energy in the lines in your diagram above represent?

8. The units of energy in Figure I are kJ mol^{-1}. Convert the energy the electron has in a hydrogen atom to J $atom^{-1}$. In Figure II draw the two horizontal lines for the energy of the electron in a single hydrogen atom (H(g)) and the energy of the hydrogen ion and one electron (H^+(g) + $1e^-$).

In the energy diagram below draw two horizontal lines that can be used to represent the first ionization energy (J atom^{-1}) for hydrogen.

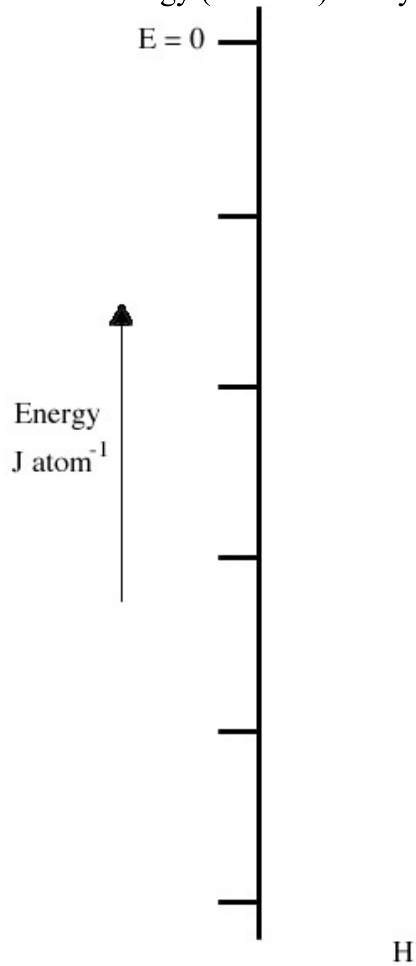
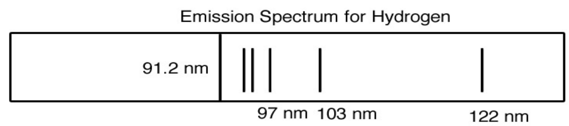


Figure II.

9. How much energy (J atom^{-1}) is require to remove the electron from a hydrogen atom (H(g))?

10. Calculate the wavelength in nanometers of a photon of light capable of ionizing a electron from a hydrogen atom (H(g)).

11. Figure III shows an emission spectrum produced by hydrogen atoms in the gas phase.



12. What region of the electromagnetic spectrum are photons of light with the wavelengths shown in Figure III?

13. What is the significance of the line at 91.2 nm?

14. The two lines between the line at 91.2 nm and 97 nm have wavelengths of 93.8 nm and 95 nm. Compared to the line at 91.2 nm, the energy of the photons emitted by the hydrogen atom, as depicted in Figure III, are greater than, less than or equal to the energy of the photon at 91.2 nm?

15. In a previous activity we used the first ionization energy data as evidence to support a shell model for atoms. In the space below draw an energy level diagram that depicts the energy levels for the first five shells.

16. We have indicated that at E = 0 in the energy level diagram the shell value (n) is infinity. We also know that energy required to remove the electron from a hydrogen atom has a value of 2.18×10^{-18} J. What if a smaller amount of energy is absorbed by a hydrogen atom?

17. What might the electron do if the energy absorbed by the atom is smaller than the amount of energy required to remove the electron?

18. How much energy does a photon of light that has a wavelength of 122 nm have? 103 nm? 97 nm? 95 nm? 94 nm?

19. Can you match up the energy of each of these photons with possible transitions between different shells? Use the energy level diagram below to label these transitions.

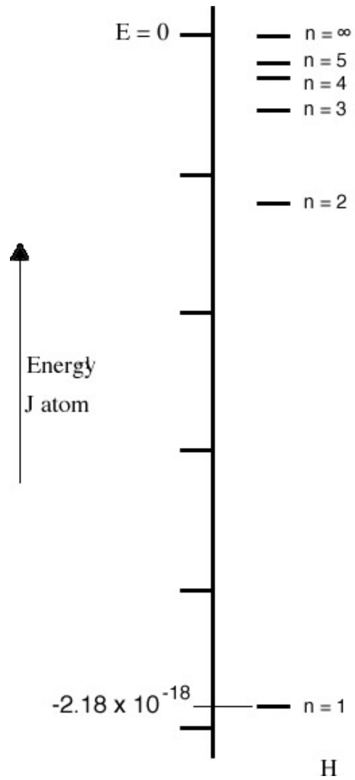


Figure IV

20. What was the assigned energy of the photon you believe is required to excite the electron from n = 1 level to the n = 2 level?

21. Knowing the energy of the electron in the n = 1 shell and the energy of the photon required to excite the electron from the n = 1 shell to the n = 2 shell, what is the energy of the n = 2 shell?

22. What is the energy of the n = 3 shell? The n = 4 shell? The n = 5 shell?

23. Determine the energy of the n = 2 through n = 5 levels in terms of value of the n = 1 level and n. Try different combinations of -2.18×10^{-18} J and n to obtain the energy of the other levels. What is the relationship that you come up with?

24. In the space below draw an energy level diagram that depicts the energy levels for the first five shells and include the energy for each of these levels.

25. The energy level diagram drawn above represents, for the hydrogen atom, the energy for the first five shells. These energies were determine based on experimental evidence from emission spectra in the ultraviolet region of the electromagnetic spectrum. The lines in the emission spectrum can be understood as being produced when an excited electron in a higher energy level drops to the $n = 1$ level, and at the same time releasing a photon with an energy that is the difference between the two levels.

Predict some additional lines that could be produced as a result of an excited electron undergoing different electronic transitions. Determine the region of the electromagnetic spectrum the lines would appear. Explore the internet to determine if your predicted emission lines have actually been experimentally verified and when they were verified and by whom.