

Graphing and Analyzing Ionization Energy Data

Background

Ionization energy, in kJ mol^{-1} , provides information about the structure of atoms. When successive electrons are removed from atoms, **the outermost electrons are removed first before the inner core electrons are removed**. When an electron is eventually removed from a different energy level, a large increase in the ionization energy is observed. When the first ionization energy, IE_1 , of the elements are graphed, discontinuities appear when electrons are removed from different sublevels or orbitals.

Pre-Lab

Deduce the full and condensed electron configurations for calcium, Ca.

Deduce the orbital diagram for Ca.

Procedure

Part A: Successive Ionization Energies

Table 1. Successive ionization energies (kJ mol^{-1}) for calcium

Ionization Number	Enthalpy / kJ mol^{-1}	Ionization Number	Enthalpy / kJ mol^{-1}	Ionization Number	Enthalpy / kJ mol^{-1}
1	590	8	14210	15	86260
2	1145	9	18190	16	93950
3	4912	10	20380	17	105000
4	6491	11	57080	18	111704
5	8140	12	63510	19	494859
6	10500	13	70300	20	527761
7	12270	14	78850		

Values obtained from webelements.com

1. Go to graphicalanalysis.app. Select *Manual Entry*.
2. Enter the values found in Table 1 into the table to generate a scatter plot of the data.
3. Click on the three dots next to Y and select *Add Calculated Column*. Select *Insert Expression* and select *A Log(X)*. Click *Apply*.
 - a. Plotting the log of successive ionization energies allows for a better visualization of any trends that may exist in the data.
4. On the bottom-left corner of the screen, select *Graph Options*. Select *Edit Graph Options*. Under *Appearance*, select *Lines*.
5. **Sketch** the appearance of the graph.
6. On the graph, add annotations to identify key aspects of the graph. The following annotations to be added include:

2 e- in $n = 4$

8 e- in $n = 3$

8 e- in $n = 2$

2 e- in $n = 1$

e- removed from new energy level (three times)

Graph 1. Successive ionization energies (kJ mol^{-1}) for calcium ($z=20$), logarithmic scale

Why are there large increases in the graph? Use the electron configuration of calcium in your explanations.

Explain why a logarithmic scale on the y-axis is useful in this case.

Part B. First Ionization Energies for Period 3 Elements

1. In the upper-left corner of the graph, select *Untitled* and *New Experiment*. Do not save the file. Select *Manual Entry*.
2. Using Sections 7 and 9 of the data booklet, plot the IE_1 for elements 11-19. Place Atomic Number (z) in the X column and IE_1 (kJ mol^{-1}) in the Y column.
3. Add the connecting lines to the graph. Refer to Step 4 of *Part A*.
4. **Sketch** the appearance of the graph below.
5. Add the following annotations to the graph:

3s full

1st e- in 3p

e- begin to pair in 3p

3p full

1st e- in 4s

Graph 2. IE_1 (kJ mol^{-1}) for $z=11$ through $z=19$



Deduce the orbital diagrams for $z=12$ and $z=13$. Explain why there is a change in IE_1 between $z=12$ and $z=13$ by referring to the orbital diagrams.

Deduce the orbital diagrams for $z=15$ and $z=16$. Explain why there is a change in IE_1 between $z=15$ and $z=16$ by referring to the orbital diagrams.

Deduce the orbital diagrams for $z=18$ and $z=19$. Explain why there is a change in IE_1 between $z=18$ and $z=19$ by referring to the orbital diagrams.