The Variation of Atomic Properties

PURPOSE: To search for any periodic variations (repeating patterns) in the atomic radius and first ionization energy of elements in the periodic table.

Part A: Atomic Radius

Plot atomic radius versus atomic number for the first 38 elements. (This means that atomic radius is plotted on the vertical axis and atomic number is plotted on the horizontal axis.)
The data are given in the attached table.
The following directions are for graphs plotted by hand. If you have the appropriate software you are encouraged to plot the graphs by computer. You may not be able to follow all the directions below using the computer, but come as close as you can. You may wish to add some finishing touches by hand.

Directions for plotting graphs:
When choosing appropriate scales, keep two things in mind:

- The scales should be easy to read (One division equals 0.1, 1, 2, 5, 10) Do not use a scale that ends up having one division equal to 0.25 or 0.33. These scales are difficult to read. When putting numbers on the scales, only number every 4^{th} or 5^{th} line. Otherwise the scale gets too crowded and clarity is lost.

- The graph should cover most of the page. Often you have to sacrifice using the entire page to get a scale that is easy to read.

Be sure to label each axis and include units if there are any. After you have plotted the data for each element with a pencil, join consecutive points with solid straight lines. When information for an element is missing, use dotted straight lines to join the adjacent points and estimate where the point should be. Give your graph an appropriate title. Label each point corresponding to an alkali metal or a noble gas with the symbol for the element.

QUESTIONS:

Have both the graphs you plotted and a periodic table in front of you as you answer the following questions. Use complete sentences, which are understandable without looking at the questions.

1. From your graph, describe what happens to the size of the atoms for the elements of the 2^{nd} period, going from lithium to neon. Is this what you would expect, base only on the number of protons, neutrons and electrons per atom? Why or why not?

2. Is the trend in the size of atoms noticed for the 2^{nd} period repeated for the 3^{rd} period of elements, going from sodium to argon?

3. What happens consistently to the size of the atoms, going from a noble gas of one period to an alkali metal of the next larger period?

4. Looking just at one group, the alkali metals (Li, Na, K and Rb), what happens to the size of the atoms going from lithium to rubidium?

5. Is the trend just described fro the alkali metal group repeated for the size of atoms going down the noble gas group?

6. The pattern on the graph for the 4th period, from potassium to krypton, does not look like the pattern for the 2nd and 3rd periods. What elements have been introduced into the 4th period that was not present in the 3rd period?

7. Draw an approximate shape of the periodic table and use two arrows to summarize the general trends in size of atoms that you have discovered while doing this exercise.

8. One of the uses of trends in the periodic table is predicting properties of elements. What are your estimated values for the atomic radii of carbon and manganese? Use figure 5.10 on page 151 of your text book to list the accepted values of these two radii. (The atomic radii for carbon and manganese are 77 pm and 139 pm respectively.) Calculate the percentage error for each estimate using the formula:

$$\%error = \frac{accepted\ value - estimated\ value}{accepted\ value}(100\%)$$

Part B: First Ionization Energy

<u>PROCEDURE</u>:
Repeat the procedure of part A, but this time plotting first ionization energy versus atomic number. These data are given in the attached table.

QUESTIONS:
Again, refer to both the graph you plotted and the periodic table as you answer the following questions.

1. From your graph, describe what happens to the 1st ionization energy for the elements of the 2nd period, going from lithium to neon.

2. Is the trend in the 1st ionization energy noticed for the 2nd period repeated for the 3rd period of elements, going from sodium to argon?

3. What happens consistently to the 1st ionization energy, going from a noble gas of one period to an alkali metal of the next larger period?

4. Looking just at one group, the noble gases (He, Ne, Ar, Kr), what happens to the 1st ionization energy going from He to Kr?

5. Is the pattern noticed for the noble gas group repeated for the alkali metal group, from lithium to rubidium?

6. Draw an approximate shape of the periodic table and use two arrows to summarize the trends in 1st ionization energy that you have discovered while doing this exercise. Ignore the exceptions, and just give the general trends.

7. What is your estimated value for the 1st ionization energies of carbon? The accepted value is 1.09 MJ /mol. Calculate the percentage error for your estimated value.

8. Examine both graphs for the first twenty elements. What is the general relationship between the atomic radius and the first ionization energy?

9. State the electron configuration of Al, B and Mg. Explain how the first ionization energy of aluminium compares with the first ionization energies of boron and magnesium.

THE PERIODIC TABLE: ATOMIC SIZE AND FIRST IONIZATION ENERGIES

ELEMENT	ATOMIC NUMBER	ATOMIC RADIUS (pm)	1^{ST} IONIZATION ENERGY (MJ/mol)
ALUMINUM	13	130	0.58
ARGON	18	97	1.52
ARSENIC	33	122	0.94
BERYLLIUM	4	125	0.90
BORON	5	90	0.80
BROMINE	35	114	1.14
CALCIUM	20	170	0.59
CARBON	6		
CHLORINE	17	99	1.25
CHROMIUM	24	118	0.65
COBALT	27	126	0.76
COPPER	29	117	0.74
FLUORINE	9	71	1.68
GALLIUM	31	120	0.58
GERMANIUM	32	122	0.76
HELIUM	2	32	2.37
HYDROGEN	1	37	1.31
IRON	26	125	0.76
KRYPTON	36	110	1.35
LITHIUM	3	134	0.52
MAGNESIUM	12	145	0.74
MANGANESE	25		
NEON	10	69	2.08
NICKEL	28	121	0.74
NITROGEN	7	75	1.40
OXYGEN	8	73	1.31
PHOSPHORUS	15	110	1.01
POTASSIUM	19	196	0.42
RUBIDIUM	34	216	0.42
SCANDIUM	21	144	0.63
SELENIUM	34	117	0.94
SILICON	14	118	0.79
SODIUM	11	154	0.50
STRONTIUM	38	191	0.55
SULPHUR	16	102	1.00
TITANIUM	22	132	0.66
VANADIUM	23	122	0.65
ZINC	30	120	0.91