9A The Periodic Table

In 1869, a Russian chemist named Dmitri Mendeleev realized that in order to advance knowledge of chemistry the elements needed to be organized in such a way as to show relationships between them. Accordingly, he placed elements with similar chemical properties in vertical columns or groups, arranged in order of increasing atomic mass. There were a number of gaps in his table, but he predicted there were elements yet to be discovered that would fit in those positions. Subsequent research soon led to these discoveries, therefore validating his classification. In 1871 he published a table showing 59 elements, which you will study in this activity.

The modern periodic table accommodates over 50 more elements (up to 116), with more being actively sought. Note that the form of the periodic table allows it to accommodate an unlimited number of extra elements. The table is arranged in order of increasing atomic number, which is a concept that had not been discovered at the time of Mendeleev. However, the arrangement of elements within the chart is similar in organization to the table he published in 1871. Trends in the chemical and physical properties of elements are now seen as a periodic function of electron configuration, which is determined by the atomic number.

In the three parts of this experiment, you will first determine the electronic configurations for a number of elements. Then, you will relate these configurations to observed trends in the properties of atomic radii and first ionization energies for these elements. Lastly, you will construct Mendeleev's periodic table from a list of clues, using the modern periodic table and other reference sources.

OBJECTIVES

1. to show the relationship between electron configuration and the location of an element within the periodic table
2. to examine and graph periodic trends in atomic radii and the first ionization energies for the first twenty elements in the periodic table
3. to construct the periodic table published by Mendeleev in 1871 by identifying the elements from a list of clues

SUPPLIES

Equipment
pencil
ruler
textbook and other reference materials
graph paper

PROCEDURE

Part I: Electron Configuration and the Periodic Table

1. Make a copy in your notebook of the section of the periodic table illustrated in Figure 9A-1. For each element shown, write its electron configuration within the appropriate box. As a check, remember that the sum of all the electrons (which are represented as superscripts after the shell and subshell designations) must equal the atomic number of the element.

Part II: Atomic Number, Atomic Radius, Ionization Energy, and the Periodic Table

1. Using the data listed in Table 1, plot a graph of the atomic radius of each element against increasing atomic number. The atomic radii shown here are given in nanometres. (1 nm = 1×10^{-9}m)
2. Using the data listed in Table 1, plot a graph of the first ionization energy of each element against increasing atomic number.

Table 1 Atomic Number, Atomic Radius, and Ionization Energies for Selected Elements

Element	Atomic Number	Atomic Radius (nm)	First Ionization Energy (kJ/mol)
Hydrogen	1	0.078	1312
Helium	2	0.128	2372
Lithium	3	0.152	513
Beryllium	4	0.113	899
Boron	5	0.083	801
Carbon	6	0.077	1086
Nitrogen	7	0.071	1402
Oxygen	8	0.066	1314
Fluorine	9	0.071	1681
Neon	10	0.070	2081
Sodium	11	0.186	496
Magnesium	12	0.160	738
Aluminum	13	0.143	577
Silicon	14	0.117	787
Phosphorus	15	0.093	1012
Sulfur	16	0.104	1000
Chlorine	17	0.099	1251
Argon	18	0.174	1520
Potassium	19	0.227	418
Calcium	20	0.197	590

Part III: Other Characteristics of Elements and the Periodic Table

1. The positions of the 59 elements found on Mendeleev's 1871 version of the periodic table are coded below for Figure 9A-2, first with a number representing the column number, followed by a letter indicating the position within that column. Use a text or other reference sources to find the name of the element corresponding to the clue given. Write the name in the correct position in your copy of Figure 9A-2 in your notebook.

1A has a nucleus containing just one proton.
1B is an alkali metal with two electrons in its +1 ion
1C is a highly reactive metal formed in the electrolysis of table salt.
1D has a first ionization energy of 418 kJ/mol.
1E has a major use as a conducting metal in electrical wiring.
1F is the first alkali metal with a completed 3d subshell.
1G has a symbol that was derived from its Latin name argentum.
1H is an alkali metal with atomic number 55.
1I has a Latin name aurum, derived from the Latin word for dawn, aurora.
2A is the first element in the alkaline earth group of elements.
2B burns with a bright white light and is used in flares and fireworks.
2C is the metallic component of the mineral marble.
2D is a metal used to galvanize iron to protect it from rusting.
2E has 36 electrons in its 2+ ion.
2F is used along with nickel in one type of rechargeable battery.
2G is a metal with an outermost electron configuration of $6s^2$.
2H is a liquid metal, which once went by the name of quicksilver.
3A is the first member of group 13 (IIIA) of the modern periodic table.
3B is a lightweight metal obtained from bauxite and used for making beverage cans.
3C is a transition metal with 39 protons in the nucleus.
3D has only 1 electron in the 5p subshell.
3E gives its name to the series of metals starting here that also go by the name rare earth metals.
3F has only 1 electron in its 6p subshell.
4A is the element whose compounds comprise the branch of chemistry called organic chemistry.
4B is the second most abundant element in the earth's crust.
4C has 2 electrons in the 3d subshell.
4D has a nuclear charge of 40+.
4E derives its symbol from the Latin word stannum.
4F is the stable metal that is the end product of the radioactive decay of uranium.
4G is the element formed when uranium gives off an alpha particle.
5A is the most abundant element in the atmosphere.
5B is a non-metallic element that ignites spontaneously when exposed to air.
5C has 23 protons in its nucleus.
5D is a very poisonous non-metal belonging to period 4 and group 15 (VA) in the modern periodic table.
5E is found between zirconium and molybdenum in the modern periodic table.

5F has a symbol derived from its Latin name stibium.
5G has an atomic number of 73.
5H is the heaviest member of group 15 (VA) in the modern periodic table.
6A is the most abundant element in earth's crust.
6B is a yellow non-metal, made as a byproduct in purification of natural gas.
6C is an ingredient along with iron and nickel in stainless steel.
6D has 4 electrons in its 4p subshell.
6E has a nuclear charge of 42+.
6F is a group 16 (VIA) element whose atomic mass is larger than the element after it in the periodic table.
6G has a major use as a filament in incandescent light bulbs because of its high melting point.
6H is the most abundant naturally occurring radioactive element, used in many nuclear reactors.
7A is a greenish-yellow diatomic gas, produced by electrolysis of common salt.
7B has a nuclear charge of 25+.
7C is the only non-metallic element that is a liquid at room temperature.
7D is a halogen whose crystals sublime, giving a violet vapor.
8A is the major metal used in construction.
8B is often used to make coins, and one coin is commonly called by this name.
8C has 7 electrons in its 3d subshell.
8D is located directly above osmium in the modern periodic table.
8E has a nuclear charge of 45+.
8F has 8 electrons in its 4d subshell.
8G has the greatest density of any known element at 22.57 g/cm^3.
8H has 77 protons in its nucleus.
8I is an inert metal often used in electrodes and jewelry, and is more valuable than gold.

EXPERIMENTAL RESULTS

Part I: Electron Configuration and the Periodic Table

Group 1	Group 2		Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1 H								2 He
3 Li	4 Be		5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg		13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	TRANSITION ELEMENTS	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr

Figure 9A-1 *Representative elements of periods 1-4*

Part II: Atomic Number, Atomic Radius, Ionization Energy, and the Periodic Table

On your own graph paper, choose the correct axes and appropriate scales for plots of atomic radii and first ionization energy versus atomic number.

Part III: Other Characteristics of Elements and the Periodic Table

Figure 9A-2

Mendeleev's Periodic Table of Elements (1871)
Columns (or groups)

Rows (or periods)	I	II	III	IV	V	VI	VII	VIII
1	1A ____							
2	1B ____	2A ____	3A ____	4A ____	5A ____	6A ____		
3	1C ____	2B ____	3B ____	4B ____	5B ____	6B ____	7A ____	
4	1D ____	2C ____		4C ____	5C ____	6C ____	7B ____	8A ____ 8B ____
	1E ____	2D ____			5D ____	6D ____	7C ____	8C ____
5	1F ____	2E ____	3C ____	4D ____	5E ____	6E ____		8D ____ 8E ____
	1G ____	2F ____	3D ____	4E ____	5F ____	6F ____	7D ____	8F ____
6	1H ____	2G ____	3E ____		5G ____	6G ____		8G ____ 8H ____
	1I ____	2H ____	3F ____	4F ____	5H ____			8I ____
7				4G ____		6H ____		

COMPLETE IN YOUR NOTEBOOK

Rows (or periods)

ANALYSIS OF RESULTS

1. Examine the placement of electron configurations in Figure 9A-1. What relationship exists between an element's placement within a group and its electron configuration?
2. Examine your graph of atomic radius plotted against increasing atomic number. Can a periodic tendency be observed (a) across each period and (b) down each group? If so, describe the indicated trends.
3. Which group has members of the largest atomic radii for a given period? Which group has the smallest?
4. Examine your graph of first ionization energy plotted against increasing atomic number. Can a periodic tendency be observed (a) across each period and (b) down each group? If so, describe the indicated trends.

FOLLOW-UP QUESTIONS

1. No members of group 18 (VIIIA) of the modern periodic table can be found on Mendeleev's version of the periodic table. Suggest a reason for their absence.
2. What factor may account for the observed trend in atomic radii as the atomic number increases across a period?
3. The observed general trend in ionization energies shows two slight discontinuities in each period. Examine the electron configuration at these points and explain why such a discontinuity may occur.

CONCLUSION

State the relationship between electron configuration and location of an element in the periodic table. Also, state the general trend in atomic radii and first ionization energy as the atomic number increases across a given period and down a given group of the table.