EXPERIMENT 4 – The Periodic Table - Atoms and Elements

INTRODUCTION

Primary substances, called **elements**, build all the materials around you. There are more than 109 different elements known today. The elements are composed of **atoms**, the smallest units that are characteristic of a particular element. Some elements occur in different forms, such as graphite and diamond for the element carbon. But whatever the form of the element, it is composed of its characteristic atoms.

In this experiment, you will be looking at some elements in the laboratory display. Some look different from each other, while others look similar. Elements can be categorized in several ways. In this experiment, you are going to group elements by similarities in their physical properties. Elements that appear shiny or lustrous are called **metals**. Metals are usually good conductors of heat and electricity, somewhat soft and ductile, and can be molded into a shape. Some of the metals you will see such as sodium or calcium may have an outer coating of a white oxide formed due to combination with oxygen in the air. If cut, you would see the fresh shiny metal underneath. Other elements called **nonmetals** are not good conductors of heat and electricity, are brittle, and appear dull (not shiny).

Atoms are made of tiny particles of matter called **subatomic particles**. Of these particles, we are interested in **protons (p)**, **neutrons (n)**, and **electrons (e)**. Protons are positively charged particles (+1), electrons are negatively charged particles (–1), and neutrons are neutral (charge = 0). The charge is often included with the symbol: $\mathbf{p^+}$, $\mathbf{e^-}$, and $\mathbf{n^0}$.

Within the atom, the protons and neutrons are tightly packed together in the **nucleus** and are collectively called "nucleons." Moving electrons outside of the nucleus occupy the rest of the atom, which is mostly empty space. Electrons are so small that their mass is almost negligible compared to the mass of the protons and neutrons in the nucleus.

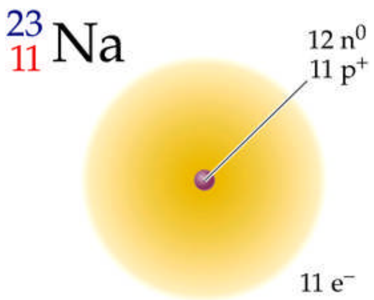
Atoms of a particular element have one feature in common: the number of protons in the nucleus. The number of protons, called the **atomic number** (Z) is unique for each element. Atoms of the element hydrogen always have one proton in their nuclei, while atoms of the next element, helium, always have two protons in their nuclei. Atoms of the element carbon similarly contain six protons, and atoms of iron have 26 protons.

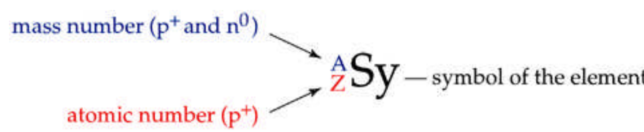
The sum of the number of protons and neutrons in the nucleus of an atom is called the **mass number (A)** of the atom (remember A for "all"):

Mass Number = Number of Protons + Number of Neutrons

Protons attract the electrons because they have opposite charges. *In a neutral atom, the number of protons is equal to the number of electrons*. This is the normal situation in atoms. However, through chemical reactions, an imbalance in the number of protons and electrons can result. For example, when the element sodium ($11p^+$, $11e^-$) reacts with the element chlorine ($17p^+$, $17e^-$) the compound sodium chloride, NaCl, is formed. Sodium chloride is an *ionic* compound composed of sodium *ions*, Na^+, with +1 charges, and an equal number of chloride ions, Cl^-, with –1 charges. In the reaction, each sodium atom *loses* one electron and each chlorine atom *gains* one electron, so the number of protons and electrons are now $11p^+$, $10e^-$ in the Na^+ ion and $17p^+$, $18e^-$ in the Cl^- ion.

All neutral atoms of the same element have the same number of protons and electrons, but interestingly, they often differ in the number of neutrons. This means that atoms of the same element while having the same atomic number can have different mass numbers. The atoms of an element that have different numbers of neutrons are called **isotopes** of that element. In the **complete chemical symbol** or **atomic notation** of an element, the mass number and atomic number are indicated next to the symbol. For example, the isotope of the element sodium that has 12 neutrons has the following symbol:

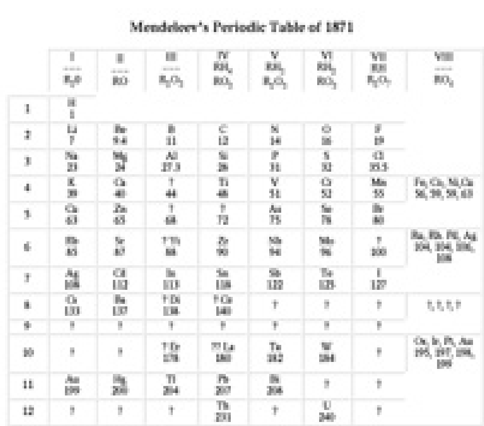


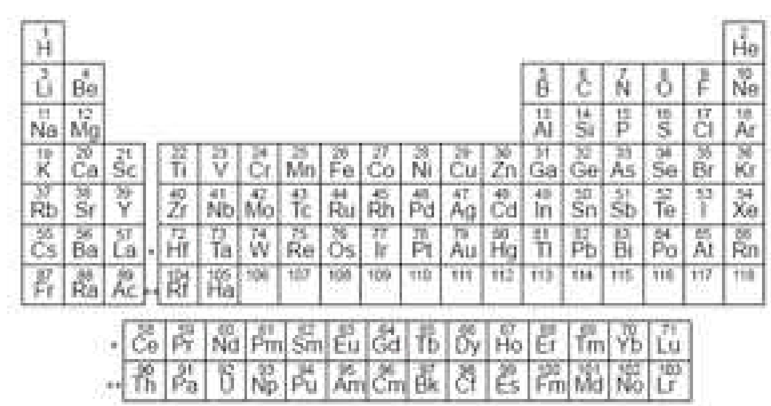


The number of protons in an atom (and the number of electrons if the atom is neutral) is given by the atomic number. To determine the number of *neutrons*, the *mass number* of the atom is needed. The number of neutrons is determined by subtracting the atomic number from the mass number, A – Z.

The Periodic Table

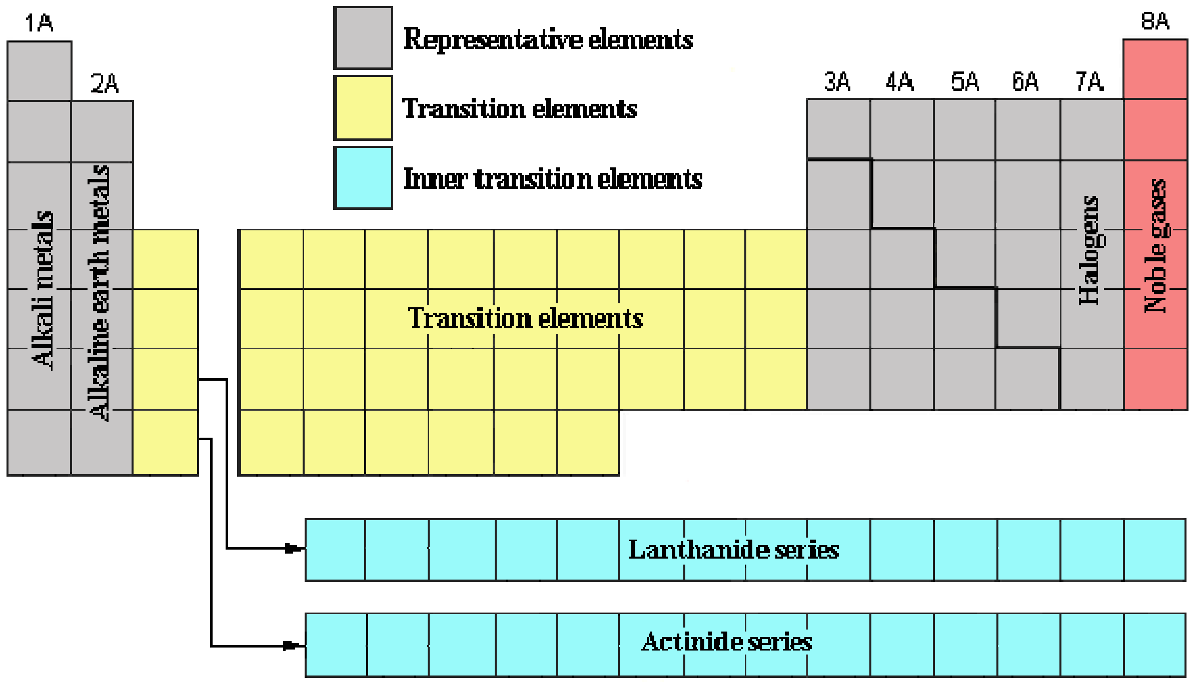
The periodic table is a listing, in chart form, of the known elements. It has gone through many revisions and sometimes appears in alternate forms, but with the discovery of atomic numbers in the early 20th century, this has been the basis for the order of the elements in the table. But even before this time, it was long recognized that certain elements shared similar properties, and when the property, such as density, was plotted against atomic mass, a repeating, or "periodic" pattern was observed. Beginning with Dmitri Mendeleev in 1869, chemists began organizing the elements in rows and columns in an attempt to explain the periodic nature of various physical and chemical properties of the elements. Below are shown an early table of Mendeleev's and a modern periodic table:





The modern periodic table is arranged in horizontal **rows** (also called **periods**) and vertical columns called **groups** or **families**. The rows are numbered from 1 to 7. The groups have not always been numbered consistently, but are usually numbered 1A, 2A, 3A, etc., from left to right, excluding the groups of the *transition* elements in the middle, which have a different numbering. Because of this confusion, most modern tables have the groups numbered 1 through 18, excluding the lower, separate rows of elements (the *lanthanides* and *actinides*) below the main table.

Below is a table with the common names of different sections and columns given:



The **alkali metals**, found in Group 1 (or 1A) of the periodic table are very reactive metals and as such do not occur freely in nature. They are the elements Li, Na, K, Rb, Cs, and Fr.

The **alkaline earth** elements are metallic elements found in the second group of the periodic table. They are not as reactive as the alkali metals, but are so reactive that they are likewise never found free in nature. These are the elements Be, Mg, Ca, Sr, Ba, and Ra.

The elements of Group 17 (7A) are called the **halogens**, which mean "salt formers." These are the elements F, Cl, Br, I, and At.

The **noble gases** are found in group 18 of the periodic table. These elements were considered to be chemically inert until the 1960's when their first compounds were characterized.

The **representative elements** occur in Groups 1-2 and 13-18 and exclude the transition metals and inner transition metals.

The term "**transition elements**" most commonly refers to the "d-block" elements in which the d electronic sublevel is being filled with electrons.

The "**inner transition elements**" are the "f-block" elements in which the f-sublevel is being filled with electrons. The inner transition metals are further divided into the **lanthanide** series and the **actinide** series. They are normally separated from the rest of the elements in the periodic table in order to save space.

Experimental Procedure

For this experiment a laboratory display of the elements and a wall periodic table is required.

Part I. Comparison of Physical Properties of Elements

Complete the table in the report form by writing the name and atomic number for each element. Observe the elements in the laboratory display. Describe their properties (color and luster). From your observations, describe each type of element as a metal or a non-metal

Part II. Predicting Properties Based on Location in the Periodic Table

Use the location of the given elements in the periodic table to predict whether the elements listed would be a metal or non-metal and shiny or dull.

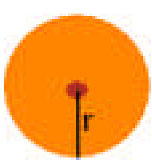
After you have completed your predictions, observe those same elements in the posted periodic table to determine if you predicted their properties correctly.

Part III. Subatomic Particles and Chemical Symbols

(a) Complete the table given in the report form with the correct atomic numbers, mass numbers, and number of protons, electrons, and neutrons for the neutral atom of each element.

(b) Complete the table with the number of protons, electrons, neutrons, and complete chemical symbol (showing the mass number and atomic number) for each neutral atom.

Part IV. Graphing a Periodic Property



For this part of the experiment you will make a graph of a periodic property vs. atomic number. The property chosen is **atomic radius**, given in pm (1 pm = 10^{-12} m). The atomic radius, r, is related to the **volume** of the atom by the formula of a sphere, $V = 4/3\ \pi\ r^3$.

In Table 1 below, the atomic radii of the first 54 elements are given. Plot the points on the accompanying graph paper. Label selected "tick mark" values on each axis to make each scale clear. For the atomic radius scale (the Y-axis), 10 pm per mark will work well.

Connect the points and note where the high and low parts of your pattern occur in the periodic table. Does your graph indicate a reason for beginning and ending each row of the periodic table at certain elements? Why are the rows of the periodic table called "periods"?

Table 1. Atomic Radii of the First 54 Elements

From http://www.periodictable.com/Properties/A/AtomicRadius.an.html

Atomic Number	Element	Atomic Radius, pm
1	H	53
2	He	31
3	Li	167
4	Be	112
5	B	87
6	C	67
7	N	56
8	O	48
9	F	42
10	Ne	38
11	Na	190
12	Mg	145
13	Al	118
14	Si	111
15	P	98
16	S	88
17	Cl	79
18	Ar	71
19	K	243
20	Ca	194
21	Sc	184
22	Ti	176
23	V	171
24	Cr	166
25	Mn	161
26	Fe	156
27	Co	152

Atomic Number	Element	Atomic Radius, pm
28	Ni	149
29	Cu	145
30	Zn	142
31	Ga	136
32	Ge	125
33	As	114
34	Se	103
35	Br	94
36	Kr	88
37	Rb	265
38	Sr	219
39	Y	212
40	Zr	206
41	Nb	198
42	Mo	190
43	Tc	183
44	Ru	178
45	Rh	173
46	Pd	169
47	Ag	165
48	Cd	161
49	In	156
50	Sn	145
51	Sb	133
52	Te	123
53	I	115
54	Xe	108

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REPORT FORM

Name ________________________________

Instructor ____________________________

Date _________________________________

Part I

Symbol	Element	Atomic Number	Color	Shiny/Dull	Metal/Nonmetal
Zn	…………..	……..	……..	……..	……….
Al	…………..	……..	……..	……..	……….
Mg	…………..	……..	……..	……..	……….
Pb	…………..	……..	……..	……..	……….
O	…………..	……..	……..	……..	……….
C	…………..	……..	……..	……..	……….
Sn	…………..	……..	……..	……..	……….
I	…………..	……..	……..	……..	……….
Fe	…………..	……..	……..	……..	……….
S	……………	……..	……..	……..	……….
Hg	…………..	……..	……..	……..	……….
Ca	…………..	……..	……..	……..	……….
Cu	…………..	……..	……..	……..	……….

Part II

Element	Metal/Nonmetal	Shiny/Dull
Osmium (Os)	……….	……….
Cadmium (Cd)	……….	……….
Phosphorus (P)	……….	……….
Radium (Ra)	……….	……….
Seaborgium (Sg)	……….	……….

Part III (a)

Element Symbol	Atomic Number	Mass Number	Protons	Electrons	Neutrons
F	……..	19	……..	……..	……..
……..	……..	……..	……..	19	20
Br	……..	80	……..	……..	……..
……..	79	197	……..	……..	……..
……..	……..	127	……..	53	……..

Part III (b)

Chemical Symbol	Protons	Electrons	Neutrons
${}^{39}_{19}K$	……..	……..	……..
${}^{32}_{16}S$	……..	……..	……..
……..	20	……..	20
……..	……..	19	22
……..	17	……..	20

Part IV

Atomic Number

Atomic Radius, pm

EXPERIMENT 4 **Name:**

Pre-Laboratory Questions and Exercises

Due before lab begins. Answer in the space provided.

1. Define the following terms:

a) Isotopes

b) Subatomic particle

2. Compare the physical properties of metals and nonmetals (at least four properties).

3. Use the periodic table to categorize the following elements as metals (M) or nonmetals (NM).

S …….. P …….. Cr …….. Ni …….. Sr …….. I ……..

4. A neutral atom has a mass number of 58 and contains 30 neutrons. Write its complete chemical symbol (showing the mass number and atomic number).

5. Determine the number of protons, electrons, and neutrons in the following atoms:

Aluminum-27 Bromine-80 Uranium-238

EXPERIMENT 4 **Name:**

Post- laboratory Questions and Exercises
Answer in the space provided.

1. Define the following terms:

a) Nucleon

b) Transition Element

2. Compare mass, charge, and location of the subatomic particles in the atom.

Particle	Mass	Charge	Location
Proton	____________	______	_____________________
Neutron	____________	______	_____________________
Electron	____________	______	_____________________

3. Describe the location (group and period) of the following metals and nonmetals on the periodic table.

Element	Group	Period
I	_____	_____
Fr	_____	_____
Kr	_____	_____

4. Write the complete chemical symbol (including the <u>mass number</u>, <u>atomic number</u>, and <u>charge</u> if any) of the element that corresponds to the following subatomic particles:

a) p =1, e = 1, and n = 0

b) p = 36, e = 36, and n = 48

c) p = 26, e = *<u>23</u>*, and n = 30

d) p = 35 , e = *<u>36</u>*, and n = 44