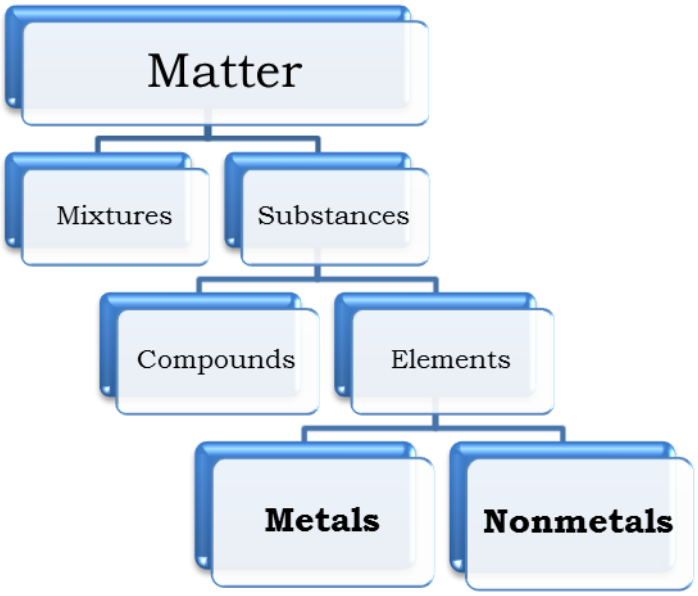
Suggested time allotment: 5 to 6 hours

MODULE 5 METALS AND NONMETALS

Elements are the simplest form of substances. This means that whatever you do with an element, it remains to be the same element. Its physical state may change but the identity of the element will not. It may form compounds with other elements but the element will never form anything simpler than it already is.

There are already more than a hundred elements and are organized in a Periodic Table. Some of them are naturally occurring and some were produced in a laboratory.

In this module, you will find out more about the elements. You will see that majority of them are **metals**, while some are **nonmetals**. In addition to these are the **metalloids**, so called because they exhibit properties of both metals and nonmetals.



How are metals different from nonmetals?
How are they similar?

Properties of Metals

In the earlier grades, you segregated objects according to the material they are made of. You did this when you were starting the habit of 5Rs — recycle, reuse, recover, repair or reduce. Look around you. Which objects are made of metals? What made you say that they are metals?

Perhaps, you have been identifying a metal based on its appearance. Most of the time, metals are shiny. They exhibit a **luster** which is the reason that they are used as decorations.

Many metals are **ductile**. This means that metals can be drawn into wires. An example is copper. The ductility of copper makes it very useful as electrical wires. Gold is also a metal that is ductile; however, it is rarely used as an electrical wire. What could be the reason for this?

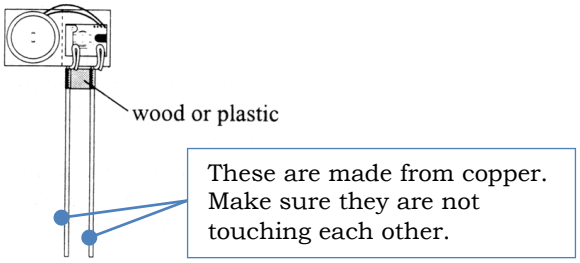
Some metals are **malleable**. This means that they can be hammered or rolled into thin sheets without breaking. An example is aluminum. It is passed into mills and rolled thinly to produce the aluminum foil used to wrap food. Most soda cans are made of aluminum, too.

Some metals are **magnetic**. This means that they are attracted by a magnet. The common ones are iron, nickel and cobalt. Get a magnet. Try them in different metals in your home or school. Were they all attracted to the magnet? What metals are these?

The general properties of metals are luster, ductility, malleability and magnetic properties. Metals exhibit these properties in varying degrees.

Other properties exhibited by metals

In the next activity, you will investigate the **electrical conductivity** of different materials. This property allows electricity to pass through a material. You will find out whether this property is exhibited by metals or nonmetals. You will use an improvised conductivity tester as the one shown on the right.



Activity 1
Which can Conduct Electricity, Metals or Nonmetals?

Objective

In this activity, you should be able to distinguish between metals and nonmetals based on its electrical conductivity.

Materials Needed

- samples of copper, aluminum, sulfur, iron and iodine
- white paper
- improvised conductivity apparatus

Procedure

1. Place a sample in a sheet of white paper. This will help you observe the samples better. In Table 1, note down the appearance of each of them.

Table 1. Electrical conductivity of different materials

Sample	Appearance	Electrical Conductivity
aluminum		
copper		
iodine		
iron		
sulfur		

Q1. Which of the samples look like metals? How about nonmetals?

2. Place the end tip of the improvised conductivity apparatus in contact with each sample. If the tester gives off a sound, the sample is said to be electrically conductive. Otherwise, it is electrically nonconductive.

Note: Do not let the end tips of the conductivity tester touch each other.

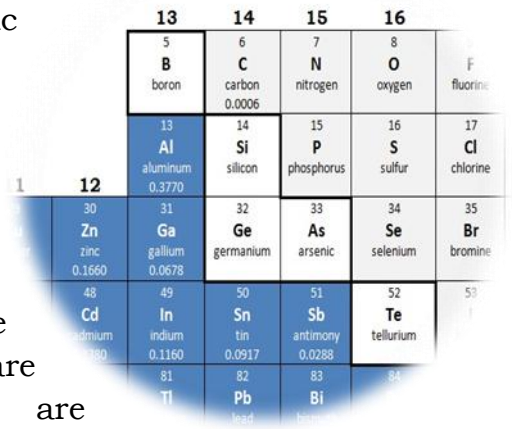
Q2. Which of the samples are electrical conductors? Which are not? Note them down in Table 1.

In the activity above, you determined qualitatively the electrical conductivity of each sample. However, if you wish to know the electrical conductivity values, a more sophisticated tester may be used such as the one in the figure below.

The metallic probe in the figure on the left is the one that comes in contact with the sample. It will measure then display the electrical conductivity value in the liquid crystal display (LCD) screen. Refer to the periodic table found at the back page of this module.

The electrical conductivity values are written at the bottom line of each box. It is expressed in $x10^6$ $Ohm^{-1}cm^{-1}$. What do you notice about the elements with electrical conductivity values?

Where are they located in the periodic table?



One amazing feature of the periodic table is that all the metals are placed in one side. Those that are on the other side (grayish shade) are the nonmetals.

Notice that there is a stair step line formed by some elements which somewhat divides the metals and nonmetals. These elements are the **metalloids**. They are elements exhibiting properties that are intermediate to metals and nonmetals. Name the metalloids. Name some metals. Name some nonmetals.

Which are electrically conductive, metals or nonmetals? Which element has the highest electrical conductivity value? What could be the reason for using copper as an electrical wire more than this element?

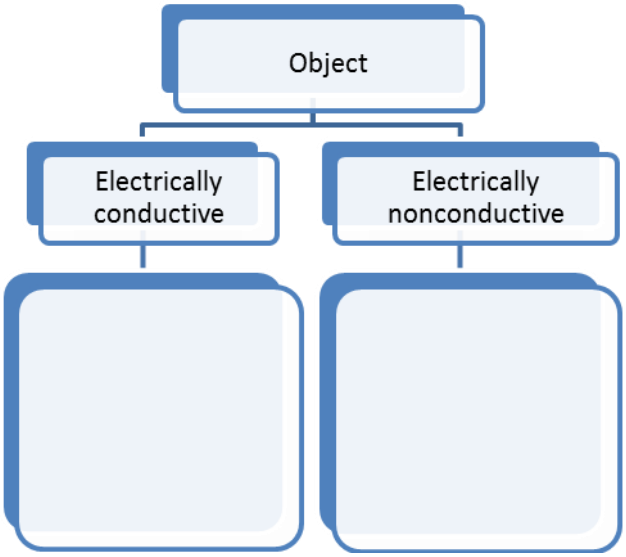
You might wonder why some metals do not have electrical conductivity values when supposedly all of them possess such property. Notice that these metals are the ones mostly found at the last rows of the periodic table. Elements in those rows are mostly radioactive. This means that the element is very unstable and exists in a very short period of time. In effect, it would be difficult to test for their properties. In the higher grade levels, you will learn that there are ways to infer the electrical conductivities of these elements.

Electrical conductivity clearly distinguishes metals from nonmetals but there is one exception. Refer to the periodic table. Which element is electrically conductive even if it is a nonmetal?

One form of carbon is graphite. It is commonly available as the black rod in your pencils. Get your sharpened pencil. Place the black rod in between the end tips of your improvised conductivity tester. Make sure that the black rod is in contact with the tips of the tester. What happened?

In the higher grade levels, you will learn why carbon (graphite) though a nonmetal is electrically conductive.

Look for other objects and test if they are made up of metal or nonmetal. Write down these objects in the appropriate box of the diagram below.



Were you able to find a cooking pot as one of your test objects? What element is it mainly made of?

Refer to Table 2. This table shows the thermal conductivity values of some elements expressed in Watt/centimeter-Kelvin (W/cmK). **Thermal conductivity** is the ability of an element to allow heat to pass through it. The higher the value, the better **heat conductor** an element is. Find the elements that are mainly used for the cooking pots. What can you say about the thermal conductivity of this element compared with the other elements? Is this element, a metal or nonmetal? In general, which are better heat conductors, metals or nonmetals? Based on Table 2, what other elements can be used as cooking pots? Note as well that the malleability of a metal is a consideration in using it as a material for cooking pot.

Table 2. Thermal conductivities of some elements

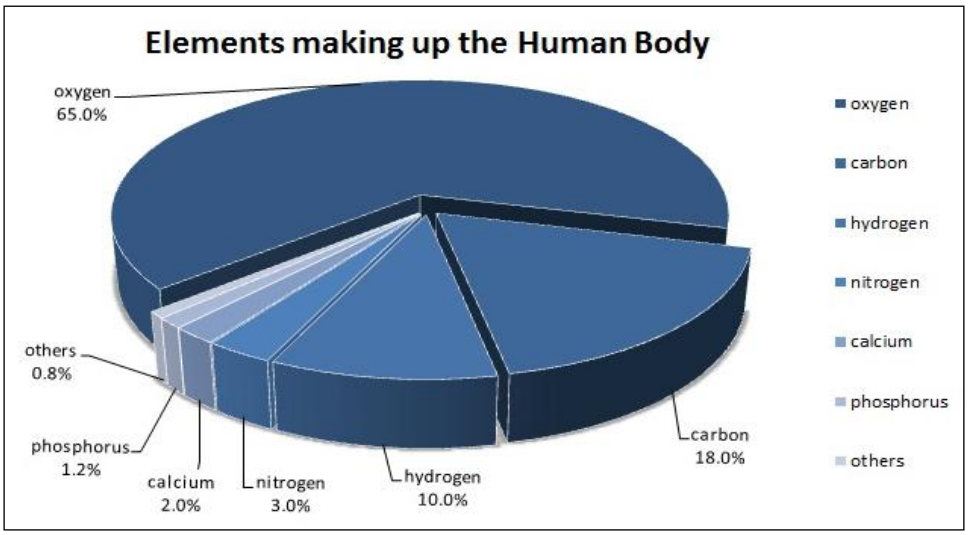
Element	**Symbol**	**Thermal Conductivity* (W/cmK)**
Copper	Cu	4.01
Aluminum	Al	2.37
Iron	Fe	0.802
Selenium	Se	0.0204
Sulfur	S	0.00269
Phosphorus	P	0.00235

*Kenneth Barbalace. Periodic Table of Elements - Sorted by Thermal Conductivity. EnvironmentalChemistry.com. 1995 - 2012. Accessed on-line: 3/14/2012 http://EnvironmentalChemistry.com/yogi/periodic/thermal.html

Metals and Nonmetals In and Around You

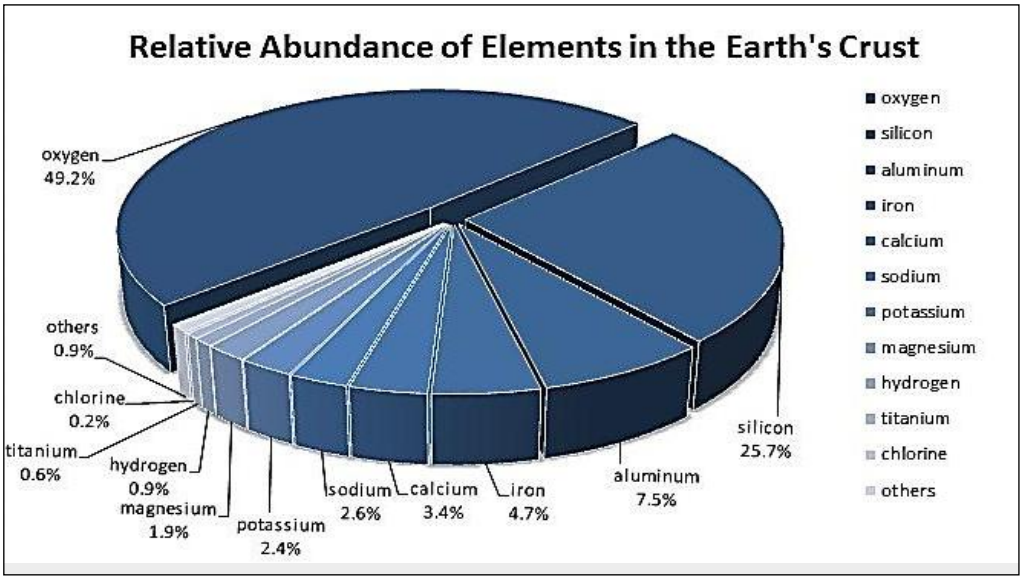
In the figure below, you will find the elements that your body is made up of. What element are you made up of the most? Is it a metal or a

nonmetal? Of all the elements reported in the graph, how many are metals? How about nonmetals?



Data taken from Burns, 1999

Refer to the figure below. The figure shows how much of one element is present in the Earth's crust relative to the other elements. What element is the most abundant in the Earth's crust? What comes second? Are these metals or nonmetals?



Data taken from Burns, 1999

Refer to the periodic table. What constitutes majority of the elements, metals or nonmetals?

Interestingly, even with the fewer number of nonmetals, their abundance is higher than metals. As you have seen above from the two

graphs, both living and nonliving systems are mainly composed of nonmetals.

As you learned in Module 3, elements form compounds. The percentage abundance of the elements reported in the graphs above accounts some elements that are present in compounds, much like the food ingredients you encountered in Module 3. For instance, sodium is present in sodium chloride. The 18.0% carbon that makes up the human body is mostly compounds of carbon such as the DNA that carries your genetic code.

Oxides of Metals and Nonmetals

Similarly, oxygen accounted in the graphs may also be in compounds. Some of these compounds are called **oxides**. These oxides may be formed when an element is burned. These oxides exhibit different acidities. In Module 4, you learned that there are indicators that you can use to determine such. One of these acid indicators is the litmus paper. What color does the litmus paper show when the sample is acidic? How about when the sample is basic?

In the next activity, you will separately burn a sample of a metal and a nonmetal. You will test the acidity of the oxide of a metal and that of the oxide of a nonmetal.

Activity 2
Acidity of the Oxides of Metals and Nonmetals

Objective

In this activity, you should be able to distinguish between metals and nonmetals based on the acidity of their oxides.

Materials Needed

- magnesium (Mg) ribbon
- sulfur (S)
- iron wire (holder)
- alcohol lamp
- test tube
- beaker
- litmus paper (red and blue)
- water
- cork
- watch glass
- dropper/stirring rod

Procedure

1. Get a piece of iron wire. Make a small loop at one end. Insert the other end into a cork to serve as a handle.

2. Get a piece of magnesium ribbon. Describe its appearance. Note this in Table 3.

Q1. Is magnesium a metal or a nonmetal?

3. Coil a small piece of Mg ribbon (about 2 cm) and place on top of the loop. Place the looped end of the wire into the flame of an alcohol lamp. Note what happens. Record your observations in Table 3.

TAKE CARE! Do not inhale the fumes/vapor.

4. Place 2 mL of water in a small test tube. Add the ash produced when you burned the Mg ribbon. Shake the test tube gently.

5. Get a watch glass and place a piece each of red and blue litmus papers.

6. Wet one end of a stirring rod with the solution and place a drop of this solution on a piece of blue litmus paper. Repeat the test on red litmus paper.

Q2. Which litmus paper changed in color? Describe the change. Note this in Table 3.

Q3. Is the oxide of magnesium acidic or basic?

Table 3. Data for Activity 2

	Observations			**Reaction of its oxide with litmus paper**
	Before heating	**During heating**	**After heating**	
Magnesium (Mg)				
Sulfur (S)				

7. Place 2 mL of water in another test tube. Clean the wire loop and dip in powdered sulfur (S).

Q4. Is sulfur a metal or nonmetal?

8. Place the looped end of the wire containing the sample over the flame. As soon as the sulfur starts to burn, put the loop into the test tube without touching the water. Remove the loop into the test tube once the sulfur is completely burned. Cover the test tube immediately and shake well.

9. Get a watch glass and place a piece each of red and blue litmus papers.

10. Wet one end of a stirring rod with the solution and place a drop of this solution on a piece of blue litmus paper. Repeat the test on red litmus paper.

Q5. Which litmus paper changed in color? Describe the change. Note this in Table 3.

Q6. Is the oxide of sulfur acidic or basic?

In this module, you learned about the properties of metals and nonmetals. These properties are the ones that determine their uses like aluminum's malleability to become soda cans, and copper's ductility to become electrical wires.

Most of the elements are metals. They are shiny, malleable and ductile but just in varying degrees — like electrical and thermal conductivity. Nonmetals are electrically nonconductive except for some forms of carbon.

It is important to note though that most objects are made not of a single material, rather of a combination of materials so they become fitter for a purpose. This is where your knowledge on the properties of materials comes in. Which materials do you combine to make it fit for a purpose? As you can see from the image in this module cover, the electrical wire made of copper was covered with rubber. Rubber is mainly made of compounds of nonmetals such as carbon, hydrogen and chlorine. As you have learned, nonmetals are nonconductors of electricity. Using a nonmetal to cover a metal makes it safer to use as an electrical wire.

As you advance to another grade level, there are more properties of matter that you will encounter. It is hoped that you will be able to maximize the properties of different materials to create new beneficial products or find other uses for them.

PERIODIC TABLE

Key

atomic number
Symbol
name
electrical conductivity**

1	2	3	4	5	6	7	8	9
1 **H** hydrogen								
3 **Li** lithium 0.1080	4 **Be** beryllium 0.3130							
11 **Na** sodium 0.2100	12 **Mg** magnesium 0.2260							
19 **K** potassium 0.1390	20 **Ca** calcium 0.2980	21 **Sc** scandium 0.0177	22 **Ti** titanium 0.0234	23 **V** vanadium 0.0489	24 **Cr** chromium 0.0774	25 **Mn** manganese 0.0069	26 **Fe** iron 0.0993	27 **Co** cobalt 0.1720
37 **Rb** rubidium 0.0779	38 **Sr** strontium 0.0762	39 **Y** yttrium 0.0166	40 **Zr** zirconium 0.0236	41 **Nb** niobium 0.0693	42 **Mo** molybdenum 0.1870	43 **Tc** technetium 0.0670	44 **Ru** ruthenium 0.1370	45 **Rh** rhodium 0.2110
55 **Cs** cesium 0.0489	56 **Ba** barium 0.0300		72 **Hf** hafnium 0.0312	73 **Ta** tantalum 0.0761	74 **W** tungsten 0.1890	75 **Re** rhenium 0.0542	76 **Os** osmium 0.1090	77 **Ir** iridium 0.1970
87 **Fr** francium 0.0300	88 **Ra** radium		104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium
			57 **La** lanthanum 0.0126	58 **Ce** cerium 0.0115	59 **Pr** praseodymium 0.0148	60 **Nd** neodymium 0.0157	61 **Pm** promethium	62 **Sm** samarium 0.096
			89 **Ac** actinium	90 **Th** thorium 0.0653	91 **Pa** protactinium 0.0529	92 **U** uranium 0.0380	93 **Np** neptunium 0.0082	94 **Pu** plutonium 0.0067

*newly named elements, as of June 2011. For more information, please access http://iupac.org/publications/pac/83/7/1485/
**electrical conductivity values ($x10^6$/Ohm-cm)

OF ELEMENTS

								18
								2 **He** helium
			13	**14**	**15**	**16**	**17**	
			5 **B** boron	6 **C** carbon 0.0006	7 **N** nitrogen	8 **O** oxygen	9 **F** fluorine	10 **Ne** neon
			13 **Al** aluminum 0.3770	14 **Si** silicon	15 **P** phosphorus	16 **S** sulfur	17 **Cl** chlorine	18 **Ar** argon
10	**11**	**12**						
28 **Ni** nickel 0.1430	29 **Cu** copper 0.5960	30 **Zn** zinc 0.1660	31 **Ga** gallium 0.0678	32 **Ge** germanium	33 **As** arsenic	34 **Se** selenium	35 **Br** bromine	36 **Kr** krypton
46 **Pd** palladium 0.0950	47 **Ag** silver 0.6300	48 **Cd** cadmium 0.1380	49 **In** indium 0.1160	50 **Sn** tin 0.0917	51 **Sb** antimony 0.0288	52 **Te** tellurium	53 **I** iodine	54 **Xe** xenon
78 **Pt** platinum 0.0966	79 **Au** gold 0.4520	80 **Hg** mercury 0.0104	81 **Tl** thallium 0.0617	82 **Pb** lead 0.0481	83 **Bi** bismuth 0.0087	84 **Po** polonium 0.0219	85 **At** astatine	86 **Rn** radon
110 **Ds** darmstatdtium	111 **Rg** roentgenium	112 **Cn** copernicium	113 **(Uub)**	114 **Fl** flerovium*	115 **(Uuq)**	116 **Lv** livermorium*	117 **(Uuh)**	118 **(Uuo)**

63 **Eu** europium 0.0112	64 **Gd** gadolinium 0.0074	65 **Tb** terbium 0.0089	66 **Dy** dysprosium 0.0108	67 **Ho** holmium 0.0124	68 **Er** erbium 0.0117	69 **Tm** thulium 0.0150	70 **Yb** ytterbium 0.0351	71 **Lu** lutetium 0.0185
95 **Am** americium 0.0220	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium