Answer Key: Observing Properties of Those Marvelous Metals

**Background**
An *element* is a substance made up of only one kind of atom. Elements are generally classified as either *metals* or *nonmetals*. The majority of elements listed in the periodic table are classified as metals and exhibit *physical properties* of luster, malleability, and conductivity. *Chemical properties* of most metals include the ability to oxidize or corrode when the metals are exposed to oxygen, water, or acid. Some metals like gold or platinum are inert, meaning they are resistant to oxidation or corrosion.

Metals may be combined with other metals or nonmetals to produce a homogeneous mixture called an *alloy*. There are generally two main methods for forming an alloy. *Substitutional alloys* are made by replacing some of the atoms of the pure element with another element. Brass is an example of this type of alloy. *Interstitial alloys* are made by filling the space between the atoms of the pure metal are with another smaller element. Steel is made in this manner.

The physical and chemical properties of the resulting alloy are often superior to the metal from which the alloy was formed. Alloys such as steel (iron and carbon) and brass (copper and zinc) are useful building materials in the construction and manufacturing industries. They are also used in the making of musical instruments, sporting equipment, and jewelry.

Heating and cooling can alter the properties of the metals and alloys to provide an even wider range of uses particularly in the steel industry. These processes have been around for centuries as the ancients used the heating and cooling of metals to produce better weapons and tools that increased their chance of survival. Today the different forms of metals allow us to build stronger buildings and lighter-weight vehicles.

**Prelab Questions**
1. What is the difference between an element and an alloy?
   *An element is a pure substance composed of a single kind of atom. An alloy is a mixture of a metal and another element either a metal or a nonmetal.*

2. What is the difference between a physical and chemical property?
   *Physical properties describe matter without changing its chemical composition. Chemical properties may only be observed by changing the chemical composition of the matter.*

3. How do metals differ in their physical and chemical properties?
   *Metals typically are shiny, malleable, ductile, good conductors of heat and electricity. Metals will oxidize and corrode when exposed to oxygen, water, or acids.*
4. How do the properties of metals affect their use in manufacturing and construction? 

*Pure metals such as copper are selected for wiring and plumbing because it is a good conductor of electricity and heat. Alloys such as steel are used in building bridges and automobiles because of its strength and malleability.*

**Objective**

In today’s lab, you will observe the properties of metals and alloys. You will also change the properties of metals through physical and chemical manipulation in order to see how industries select certain metals and alloys to build our world.

**Materials**

- **Station 1:**
  - 4 Bobby pins (high carbon steel)
  - 4 Paperclips (low carbon steel)
  - Tongs or forceps
  - Bunsen burner
  - Striker
  - Beaker of ice water

- **Station 2:**
  - Thermal conductivity apparatus
  - Sheet of aluminum foil
  - 6 pieces of wax

- **Station 3:**
  - Ball and ring apparatus
  - Bimetal strip apparatus
  - Bunsen burner
  - Striker

- **Station 4:**
  - 1M hydrochloric acid
  - Well plate
  - Iron nail
  - Steel nail
  - Sand paper

**Safety**

- Goggles and lab aprons (PPE) must be worn during the entire lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- 1M hydrochloric acid is very corrosive. If contact occurs with skin, alert teacher and skin immediately rinse the area with water.
- Always use caution around open flames. Keep flames away from flammable substances.
- Always be aware of an open flame. Do not reach over it, tie back hair, and secure loose clothing.
- Open flames can cause burns. Liquid wax is hot and can burn the skin.
- Be aware of space and proximity to burners and chemicals and take precaution when moving from one station to another.
**Procedure**

**Station 1: Observing Steel**

An *alloy* is a *homogeneous mixture* of metals or a mixture of a metal and a nonmetal. Steel is an alloy made of iron and carbon. The bobby pin is made of high carbon steel. The paperclip is made of low carbon steel. Draw a model of iron as element and high/low carbon steel as an alloy.

![Diagram of Iron, High Carbon Steel, and Low Carbon Steel]

1. Set aside one bobby pin and one paperclip for comparison. (Control)
2. Using tongs or forceps, heat the loop of one bobby pin and a loop of one paperclip red hot and slowly lift out of flame. Place them on the table to slowly cool. This process is called annealing (Anneal).
3. Using tongs heat two of each to red hot and quench by dropping them in the beaker of ice water. This will quickly cool the metals (Quench).
4. Take one of each from step 3 and heat again in the top of the flame for a few seconds and then quench. Do NOT let it get red hot. (Temper)
5. Test the bobby pins one at a time by slowly pulling the ends apart using your fingers. Record observations.
6. Test the paperclips one at a time by pulling the heat-treated loop open using your fingers. Record observations.
7. Place your used metal in the waste container.

**Data: Station 1**

<table>
<thead>
<tr>
<th>Metal Sample</th>
<th>Control</th>
<th>Anneal</th>
<th>Quench</th>
<th>Temper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobby Pin</td>
<td><em>Springy, snaps back</em></td>
<td><em>Loss of springiness; easy to bend</em></td>
<td><em>Brittle; pin breaks in half</em></td>
<td><em>Feels like the control, springy</em></td>
</tr>
<tr>
<td>Paperclip</td>
<td><em>Flexible; bends with pressure</em></td>
<td><em>Easier to bend</em></td>
<td><em>Easy to bend; doesn’t break</em></td>
<td><em>Doesn’t change much from others</em></td>
</tr>
</tbody>
</table>

**Station 2: Comparing Metals Thermal Conductivity**
1. Observe the conductivity tester. Note that each spoke is made from a different metal or an alloy. Now look at the thermal conductivity value for each metal or alloy found in the data table below. Make a prediction as to which metal will conduct heat the fastest. Record your predictions in the data table. Ranking (1-6 or 1-5 depending on the number of spokes) with “1” being the fastest sample to melt/conduct heat to “6” being the slowest.

2. Place a small piece of wax from the birthday candle on the end of each spoke.

3. Situate the aluminum foil under your burner. Light the burner and be sure the burner is sitting on the aluminum foil to catch the wax as it drips.

4. Heat the center circle over the open flame of a burner. CAUTION! Do not heat the wax directly. The metal will get very hot. Hold the instrument by the handle.

5. Record the order as the wax falls from each spoke.

6. Place your used candle wax in the waste container.

### Data: Station 2

<table>
<thead>
<tr>
<th>Metal</th>
<th>Thermal Conductivity (Watts/m K)</th>
<th>Predictions</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (Al)</td>
<td>240</td>
<td>Predictions will vary</td>
<td>2</td>
</tr>
<tr>
<td>Brass (BS)</td>
<td>110</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>400</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>80</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>90</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Steel (SS)</td>
<td>50</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

### Station 3: Thermal Expansion of Metals

1. Test the ball and ring apparatus to see if the ball will fit through the ring. Record your observation in the data table.


3. Try to fit the ball through the ring. Record your observations in the data table.

4. Allow it to cool and try again to see if the ball fits in the ring.

5. What is causing this to happen?

6. Draw a model of the particles in the ball before heating and after:
7. Obtain the bi-metal strip. Observe it in order to see that the sides are different. One side is made of copper; the other side is made of steel. Record your observations in the data table.
8. Heat the bi-metal strip for a few seconds in the flame. Record your observations in the data table.
9. Allow it to cool and observe what happens. Record your observations in the data table.

**Data: Station 3**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball and Ring before heating</td>
<td>Ball fits through the ring.</td>
</tr>
<tr>
<td>Ball and Ring after heating</td>
<td>Ball expands and no longer fits through the ring.</td>
</tr>
<tr>
<td>Bimetal Strip after heating</td>
<td>Metal strip bends as metals are heated.</td>
</tr>
<tr>
<td>Bimetal Strip after cooling</td>
<td>Metal strip straightens as it cools.</td>
</tr>
</tbody>
</table>

**Station 4: Reactivity of Iron and Steel with Acid**
1. There will be a piece of iron metal and steel alloy at your station. With a piece of sand paper, sand the metal samples to remove any oxidation.
2. Observe and record the appearance of the metals in data table 4 below.
3. Place the iron in one of the spots on the well plate. Place the steel in a separate well.
4. Add 20 drops of 1M hydrochloric acid solution to each metal.
5. Allow the samples to sit for five minutes. Record your observations in data table 4.
6. Place your metals in the waste container and pour the acid solution in the waste container.

**Data: Station 4**

<table>
<thead>
<tr>
<th>Type of Metal</th>
<th>Appearance</th>
<th>Observations with Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Silver, shiny</td>
<td>Some corrosion</td>
</tr>
<tr>
<td>Steel</td>
<td>Silver, shiny</td>
<td>More corrosion</td>
</tr>
</tbody>
</table>
**Analysis**

1. What is the difference between a pure metal and an alloy? Give examples from today’s experiment.
   
   A pure metal is made of a single kind of an atom such as iron, nickel, or copper. An alloy is a mixture of a metal with another element such as steel or brass.

2. In station 1, compare the strength and flexibility of the different high carbon steel (bobby pin) to the low carbon steel (paperclip) as you heated and cooled the metal alloys to produce different forms of steel (annealed, quenched, and tempered).
   
   Low carbon steel had less changes in its strength and flexibility than high carbon steel. Paper clips are low carbon steel – approximately 0.2%. Therefore tempering doesn’t alter the properties, and there isn’t enough carbon to cause brittleness during quenching. Bobby pin is high carbon steel – approximately 0.7%. Therefore, the carbon has a large effect on the properties and greater differences are observed in the various heat treatments.

3. In station 2, which metal conducted heat the best? Did that surprise you? Why are metals such good conductors of heat?
   
   Copper is the best conductor of heat. Metals have free moving electrons which allow them to transfer heat very quickly.

4. In station 3, explain why the ball would not fit through the ring once it is heated.
   
   Metals expand upon heating.

5. In station 4, which is more resistant to corrosion, iron or steel?
   
   Pure iron actually corrodes at a slower rate than the alloy steel.

6. What is the difference between physical and chemical properties? Give examples of both.
   
   Physical properties such as color, conductivity, expansion can be observed without changing the matter’s chemical composition. However, chemical properties such as corrosion or oxidation can only be observed by changing the matter chemically.

**Conclusion**

Select an alloy used in industry or construction. Discuss the properties of that alloy and explain how those properties benefit that particular application.

Students answers will vary but should include a real world application such as the manufacturing of a product such musical instruments, sporting equipment, or cars.