Chemistry and Art: Metals Lab #1
Metals and Alloys
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Write a purpose for each part of this lab.
Include procedures only for changes to the instructions provided below.

Part I. Properties of Metals and Nonmetals

A. Classifying Three Unknowns as Metals or Nonmetals

What are the characteristic properties of metals and nonmetals? List them.

Use the characteristic properties of metals and nonmetals to help you classify three unknown element samples. These samples are in vials numbered 1, 2 and 3 at your workspace.

- Record your observations in a small table.
- Use the piezo conductivity device to measure relative electrical conductivity.
- Use the mortar and pestle to observe malleability.
- Do not destroy the samples, because they must be used again.
- Classify each of the three samples as metal or nonmetal.
- Discuss your conclusions at the end of your observations.

B. Classifying Known Samples

Now that you are aware of the distinguishing characteristics of metals and nonmetals and realize that there is a third category, metalloid, you will proceed to characterize and classify known samples.

You will examine the following samples (there may be slight variations on this list):

- Strips of Cu, Sn, Zn, and Ag (also to be used in Part V, Activity Sries)
- In the plastic tray at your workspce, left to right: Zn tablet, Mg tablet, S, Fe strip, SiC (Silicon Carbide), P (Red Phosphorus), C (graphite)
- At the front of the lab, Se, I, and O

Prepare a large data table in your notebook, possibly across two facing pages. You will need enough columns so that there is one for each sample, plus one extra for labels. Here is a start:

	Cu	Sn	Zn	…
Metal/Nonmetal…				
Appearance				
Conductivity				
…				

- The first column should be used for labels for each row.
- In the top row, one entry per column, list the various substances that you will test.
- In the second row, give your assumptions as to whether each item is a metal, nonmetal or metalloid.
- In the third row, write your observations about the appearance of each item.
- In row four, give the results of testing each item with the piezo conductivity device.
- In row five, give the results of using pestle and mortar (do not destroy samples—you may chip off small chunks)
- In row six, state, from observations, whether each item is a metal, nonmetal, or metalloid.
- In row seven explain any discrepancies between row two and row six.

Part II. Alloys

A. Properties of Alloys and Their Components

Metals are defined as pure substances that are shiny, malleable, and conductors of heat and electricity. Metals comprise the largest class of elements in the Periodic Table. When metals are melted and mixed with each other and then allowed to harden, the resulting mixture is called an alloy (solid solution). The alloying process has been widely used since ancient times to modify the properties of metals. For instance, when tin is alloyed with copper, bronze is formed. The bronze alloy is harder and stronger and also has a lower melting point than either of its components. Hence, bronze is useful for casting metal sculptures. Brass is an alloy containing 33 % copper and 67 % zinc. Plumber's solder is an alloy containing 67 % lead and 33 % tin. Stained glass artists use a variety of solders made of lead and tin whose melting points depend upon the proportions of lead to tin. In this investigation, you will observe the relative melting points of some alloys and the metals that they are made from.

Materials:

Bunsen burner	Iron ring and ring stand
Metal can lid	Matches
Tooth picks	Vials of Bi, Pb, Sn, Woods Metal, And 50:50 Solder, 60:40 Solder

B. Woods Alloy (50:Bi, 25:Pb, 12.5:Sn, 12.5:Cd)

On the metal can lid, place a sample each of Bi, Pb, Sn and Woods Metal (Cd is not available). Space them equal distance apart, leaving room for other samples in the second part of the investigation. Give them room to melt, without melting into each other. Support the lid with samples on the iron ring attached to the ring stand.

Light your Bunsen burner and adjust the flame to a low, clear blue flame. Place the lit burner flame under the middle of the metal can lid. The flame must not touch the under side of the lid, in fact it should be about five inches beneath the lid.

Observe how the samples behave as they are heated. Record your observations. Compare the relative melting points of the samples. Which melts first, second, third and fourth? Do all of the samples melt? How does the alloying of the metals affect the melting point?

You may use the Handbook of Chemistry & Physics to find the melting points of Bi, Pb and Sn. Does the Handbook data support your observations? Did the alloy melt before its components melted? Draw a conclusion from your experimental results.

C. Solders of Pb and Sn

In this activity, compare two Solders (Alloys) containing the same metals in different proportions. Place samples of Stained Glass I (40:Sn, 60:Pb) and Stained Glass II (50:Sn, 50:Pb) on the lid and heat gently as before. Which composition has the higher melting point? Record your observations.

When Sn and Pb are mixed in different proportions, one set of these proportions will result in an alloy with the lowest melting point. This is called the Eutectic Point. For Sn and Pb this composition is 63:Sn, 37: Pb. This Eutectic Solder has a melting point of 183 ˚C. A mixture of 70:Sn and 30:Pb melts at 192 ˚ C. The packages for the Stained Glass Solders list the following melting points: Stained Glass I (245 ˚C) and Stained Glass II (215 ˚C). Draw a conclusion.

Part III. Heat Treatment of Steel

In this activity you will perform some basic heating and cooling operations on a common alloy, steel. Steel is an alloy of Iron and Carbon. Your purpose is to determine the effect of these operations on the physical properties of the steel. Ordinary "bobby pins" will serve as steel samples. These are normally coated with plastic to keep them from rusting and to soften their edges, and this coating will burn off with much smoke and smell when the pins are first heated. This minor nuisance has nothing to do with the experiment, and you can ignore it when recording your observations.

Materials Needed:

Bunsen Burner	Bobby pins	Matches
Tongs	Beaker of tap water	

Procedure: (Make a big table for these tests and observations)

1. Manipulate a "bobby pin" for a few minutes to discover the properties of the steel. Is it springy or brittle? Can you straighten it out easily? Can you now re-bend it into its original shape, or bend it into the shape of a hook, such as is used to hang a Christmas tree ornament? Does repeated bending crack it? Try these manipulations and any others you can think of and write down your observations. Are the properties of the steel well suited to the function of a "bobby pin"?
2. Annealing. Heat the folded end of a new "bobby pin" while keeping the tips cool enough to hold, and try now to open it straight. If it won't open easily, heat the folded end a little more, and repeat this operation until the folded end has been heated red-hot if necessary. Let the straightened pin cool, and then deform it gently and slightly (keep it basically straight) and note any differences in properties along its length. Record your observations.
3. Annealing the entire pin. Heat the entire length of the "bobby pin". First the plastic coat will burn off. Heat to glowing red-hot after the plastic coat is gone. Then, let it cool slowly to room temperature. Remove it gradually out of and away from the flame to keep the cooling process as slow as possible. When cool, observe and record the properties of the wire. Try to bend it into a hook. Put some weight on the hook by pressing with you finger.
4. Hardening. Heat the entire hook to red-hot, then quench it by plunging it quickly into a beaker of cold water. Observe the properties of the metal now.
5. Anneal another hook (step 3) and harden it (step 4). Handle this one carefully so it does not break.
6. Tempering. Hold the hook from step 5 near, but not in the Bunsen burner flame and keep it below red-hot while a blue oxide coating forms over its entire surface. Observe and record its properties.
7. Compare the original properties of the "bobby pin" to the annealed "bobby pin" and the hardened "bobby pin" and the tempered "bobby pin". Offer an explanation for the differences in properties of the different forms of the "bobby pin".

Part IV. The Golden Penny (The Alchemist's Dream Come True!)

Materials Needed:

Zinc, granular (tip of spatula)
Copper penny dated 1982 or earlier
3M Sodium hydroxide solution (NaOH)
Sodium chloride (salt)/ Vinegar solution
Wash bottle of R.O. Water
Beaker, 100 ml

Ring stand and ring
Bunsen burner
Tongs
Wire gauze
Matches
Graduated cylinder

Procedure: (***Wear Goggles at All Times***)

1. Pour 15 ml of salt/vinegar solution in a 100 ml beaker and place several copper pennies in the solution to be cleaned. Keep the pennies in the cleaning solution until they are shiny.
2. Remove the pennies and rinse them with water and pat them dry with paper toweling. Keep your fingers off of the pennies so they do not get oil smudges on them from your fingers!
3. Pour your salt/vinegar solution down the drain. Rinse the beaker and wipe it dry.
4. To your clean 100 ml beaker add 25 ml of 3M sodium hydroxide solution and the tip of a spatula amount of granular zinc.
5. Place a wire gauze on an iron ring attached to a ring stand. Place your 100 ml beaker of NaOH and zinc on the wire gauze.
6. Light your Bunsen burner and heat the NaOH and zinc mixture gently to steaming. Do not bring the solution to a boil.
7. Using tongs, immerse a penny into the mixture until it is completely coated with a "silver" coating.
8. Using tongs, remove the "silver" penny and rinse it with R.O. water. Wipe dry with a paper towel. Can you shine it?
9. Using tongs, heat the penny gently by moving it in and out of a low, blue burner flame until the penny turns gold. Immediately rinse the "golden" penny with R.O. water. Handle with tongs until it cools.

Did you really make silver and gold pennies? What are the 1982 and earlier pennies made of? Why not use newer pennies in this experiment? What caused the gold sheen to form on the surface of the penny? Is there an alloy of copper and zinc?

V. Activity Series

In each case you combine two, half-reactions to make a 'whole' reaction
In each case, one half-reaction will go as written (undergo reduction) and one will be reversed (go in the opposite way as written) (undergo oxidation)
These are the half-reactions you will examine (all written as reductions, as per the convention):

$Ag^{+} + e^{-} \rightarrow Ag\ (s)$
$Cu^{+2} + 2\ e^{-} \rightarrow Cu\ (s)$
$Sn^{+2} + 2\ e^{-} \rightarrow Sn\ (s)$
$Zn^{+2} + 2\ e^{-} \rightarrow Zn\ (s)$
$2\ H_3O^{+} + 2\ e^{-} \rightarrow 2\ H_2O + H_2\ (g)$ (for HCl)
$2\ H_3O^{+} + NO_3^{-}\ \ e^{-} \rightarrow 3\ H_2O + NO_2\ (g)$ (for HNO_3)

Put this table into your lab notebook and fill it in with brief observations.

In each case, add a drop or two of the species in the first column to the species you are checking in one of the other columns.

Reduced forms-> Oxidized forms	**Ag** (Silver)	**Cu** (Copper)	**Sn** (Tin)	**Zn** (Zinc)
Ag^{+}	**X**			
Cu^{2+} (Cupric)		**X**		
Sn^{2+} (Stannous)			**X**	
Zn^{2+}				**X**
HCl (Hydrochloric acid)				
HNO_3 (Nitric acid)				

1. What does it mean if a spot appears on a metal strip after a drop of one of the liquids is added?

2. What does it mean if no spot appears?

3. If metal ion A^+ reacts with metal B, what is happening? What is reduced to what? What is oxidized to what?

Using your experimental results from above, arrange the half reactions in order from most likely to undergo reduction (least likely for the reverse reaction to take place, i.e., least likely for the oxidation to take place) to least likely to undergo reduction (most likely for the reverse reaction to take place, i.e., most likely for the oxidation to take place). Include the acid half reactions.

	Half Reaction
Most easily reduced/least easily oxidized	
Least easily reduced/Most easily oxidized	

How closely does your ordering compare to the ‘standard values’ (given here with their ‘standard’ reduction potentials:

A large positive value of E means that the reaction tends to go ‘as written’
A not-so-large positive value means the reaction is less likely to go ‘as written’
A negative value means the reaction is likely to go in the opposite direction as written
But really what is meant is that when you combine two half reactions, the one with the more positive value will go as written and the other one will go in the opposite direction as written.

Half-reaction	ε°
$Au^{3+} + 3\,e^- \rightarrow Au\,(s)$	+1.50
$2\,H_3O^+ + NO_3^-\ \ e^- \rightarrow 3\,H_2O + NO_2\,(g)$	+0.89
$Ag^+ + e^- \rightarrow Ag\,(s)$	+0.80
$Fe^{+3} + e^- \rightarrow Fe^{+2}$	+0.77
$Cu^{+2} + 2\,e^- \rightarrow Cu\,(s)$	+0.34
$2\,H_3O^+ + 2\,e^- \rightarrow 2\,H_2O + H_2\,(g)$	0.00
$Sn^{+2} + 2\,e^- \rightarrow Sn\,(s)$	–0.16
$Zn^{+2} + 2\,e^- \rightarrow Zn\,(s)$	–0.76
$2\,H_2O + 2\,e^- \rightarrow 2\,OH^- + H_2\,(g)$	–0.83
$Na^+ + e^- \rightarrow Na$	–2.71

Some practice (using the table of standard values and your observations):

1. What do you predict should happen if sodium metal is placed in water? (we did this demonstration in class!)
2. What should happen when zinc metal is placed in water?
3. How can we etch a piece of zinc metal? (what does it mean to etch a piece of zinc?)
4. How can we etch a piece of copper metal?
   Give two possibilities
5. Will gold dissolve in nitric acid?
6. Explain why gold dissolves in aqua regia, a mixture of nitric and hydrochloric acids.