EXPERIMENT 1

What Difference Does an Electron Make?

This experiment is assigned on page 5 of the textbook.

FOR THE INSTRUCTOR

This laboratory experiment differs from all the others; parts of it must be done in hoods. It is *not* a prerequisite to any of the remaining experiments. The experiment can be done by individual students or small groups of students.

The most difficult and riskiest parts of the experiment, Parts ID and IIG, have been or soon will be placed online as videos at uscibooks.aip.org/videos/. If the instructor wishes to perform Part ID herself, she should arrange to have warm French fries or cottage fries available (these may need to be slightly moistened). She should try this ahead of time to determine how much Na metal should be used and how much I_2 should be used (only a spatula-tipful). If the instructor likes great excitement and wants to try the demonstration of Part II himself, careful attention to the following instructions are required: It is important to have the hood thor-oughly clear of paper, since paper will be ignited by the flames. The front shield of the hood should be as closed as possible to keep burning sulfur fumes inside and to keep sparks from igniting the clothing of bystanders! The instructor should wear heavy rubber gloves to avoid the risk of second-degree burns.

ADDITIONAL INSTRUCTIONS. Only bottled solid samples of elements and salts are required; only one solution is needed.

Zn, powdered	Zn, granular	Al, granular
$Al_2(SO_4)_3$, hydrate	Sn, granular or lump	$SnCl_2$, hydrate
Mg, granular	$MgSO_4$, hydrated	Na metal, small cubes
NaI	I_2, freshly ground	ZnS
S_8	ZnI_2	"N_2" (air in bottle)

"Mg_3N_2" (any white powder)	Graphite, labelled "Frost"**
NaCl, labelled "Horn"**	Nickel chunks, labelled "Green"**
(French fries, warm and moist)	Sn strips as electrodes
Starch peanuts (in water)	(Mixed Zn powder (6g) with S_8 (1 g))

Items in parentheses are not needed if videos used.

**Or name these elements after students in your class.

\FOR THE STUDENTS

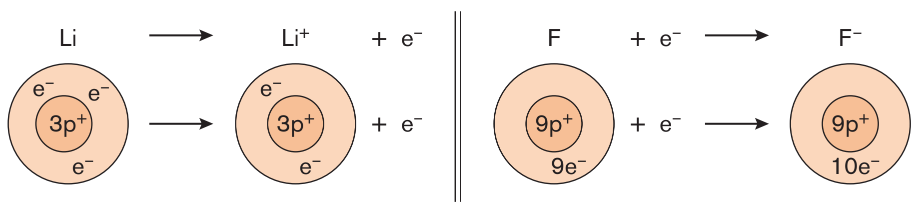
Purpose. When a metallic element and a nonmetallic element react with each other, the characteristic product is an **ionic salt** which contains two kinds of ions: positively-charged **metal ions** formed by the loss of one or more electrons from the metal atoms originally found in the metallic element; and negatively-charged **nonmetal ions** formed by the addition of one or more electrons to the nonmetal atoms originally found in the nonmetallic element. Using lithium and fluorine as a typical metal and nonmetal, respectively, we can show these changes symbolically by writing the following two half-reactions:

$Li \rightarrow Li^+ + e^-$

$F \text{ (from } F_2) + e^- \rightarrow F^-$

The whole reaction is the sum of these two half-reactions; the electrons provided by metal atoms are used by the nonmetal atoms.

We can also show this at the atomic scale:



A major purpose of this lab is to connect these symbolic and submicroscopic ideas with concrete observations of the actual consequences in the macroscopic visible world: What difference does an electron make?

PART I. What Are the Differences Between Atoms (in Elements) and Ions (in Salts)?

A. Bench 1 has sample of some metallic elements and some corresponding salts containing ions of those elements:

Zn and $(Zn^{2+})(SO_4^{2-})$

Al and $(A1^{3+})_2(SO_4^{2-})_3$

Sn and $(Sn^{2+})(Cl^-)_2$

Mg and $(Mg^{2+})(SO_4^{2-})$

On a report sheet, compare and contrast the following physical properties of the element and of the corresponding salt that contains the ion of the same element:

a. Physical appearance
b. Solubility in water (stir a spatula-tipful of the sample in the small beaker of water labeled for that sample)

B. Bench 2 has samples of some metallic elements, some nonmetallic elements, and the corresponding salts that contain the positive ion derived from the metallic element, and the negative ion derived from the nonmetallic element. **These are to be observed only,**

not put in water or otherwise reacted. It is OK to open the lids of the brown bottles to observe their contents. Compare and contrast the appearances of the metallic element, the nonmetallic element, and of the salt that contains ions of both of them:

Na, I_2, and $(Na^+)(I^-)$
Zn, S_8, and $(Zn^{2+})(S^{2-})$
Mg, N_2, and $(Mg^{2+})_3(N^{3-})_2$

QUESTIONS TO ANSWER ABOUT A AND B

a. Draw *atomic-scale* pictures to represent the difference between the sodium atom and the sodium ion. In these pictures neutrons can be omitted, but show the numbers of protons (eleven protons can be represented as $11p^+$) and electrons (20 electrons can be represented as $20e^-$) in each. Write the atomic *symbol* we use to indicate the sodium atom. Write the symbol we use for the sodium ion, and describe how it is different. Finally, write a balanced *chemical half-reaction* using these symbols that shows what happens when a sodium atom is converted to a sodium ion.
b. Also draw submicroscopic pictures to represent the difference between an I atom (half an I_2 molecule) and the iodide ion. Likewise write the symbols for the iodine atom and the iodide ion. Finally, write a balanced *chemical half-reaction* using these symbols that shows what happens when an iodine atom is converted to an iodide ion.
c. As a group, which has the most diverse types of physical appearance: metallic elements, nonmetallic elements, or ionic salts?

C. Bench 3 has three substances, which are provisionally identified as Frost, Horn, and Green. The group should decide whether Frost is a metal, nonmetal, or salt, and likewise for Horn and Green. (Or your instructor may have named these elements after members of your class.) Use a spatula-tipful of the nonmetal to see whether it is soluble in tap water (a beaker is provided). Which substance, if ingested, would most likely pass- from the digestive tract into the bloodstream?

D. How do you like to season your french fries? (A video of step D is being filmed.) French fries are notoriously high in "sodium"; does this mean that the cook adds Na or Na^+ to the French fries? To prevent goiter, iodine in some form should be added; should the cook add I_2 or I^-? Place your order at the first hood. Your instructor, being a lousy cook, will misunderstand your order and will prepare your fries for you the wrong way! The video shows another lousy cook. Describe the results of the wrong choices.

E. In preparation for part II of this experiment, think about mixing a metallic element (Zn) with a nonmetallic element (I_2).

1. If this were to produce a physical mixture, describe what it would probably look like.
2. If this were to result in a chemical reaction, predict what the product might be, what it would look like, and whether it might be soluble in water.

PART II. What Happens When a Mixture of Two Types of Atoms (Two Elements) Reacts Chemically to Give a Salt Containing Ions, Not Atoms?

F. Lab experiment: Zinc and iodine.

1. Each member of the class should weigh about 0.3 g (not more) of powdered zinc on a watch glass. In a small beaker each student should weigh about 0.3 g of iodine crystals (wear gloves). Then mix the two carefully on the watch glass using a glass rod. Does this now look like a physical mixture of Zn and I_2, or does it look like what you predicted in part **E** for the product of the chemical reaction between Zn and I_2?
2. Proceed to the first hood, and place your watch glass in the back of the hood. Get an eyedropper full of water, and carefully add a drop or a few drops of water to the zinc/iodine. What happens? Compare the results with your predictions in part E, taking into account what you predicted about the solubility of the ionic salt. Has a chemical reaction now occurred?
3. Add the rest of the water, then stir. Take the watch glass to the filter which has been set up by the instructor, and filter the solution. Note what seems to be caught by the filter paper. But we principally want the *filtrate:* the solution that comes through the filter paper into the beaker. We will collect all of the filtrates from the whole class in the same beaker, so that there is enough material for the later steps.

QUESTIONS TO ANSWER

a. Draw an atomic-scale picture (as in the questions about sections A and B) to show how the zinc atoms have changed during this reaction. (Zinc forms a +2 ion). Write a balanced equation using the symbols for Zn and its ion; this is the *balanced half-reaction.*

b. Draw an atomic-scale picture to show how the *iodine molecules* (I_2) have changed during this reaction. Write a balanced equation using the symbols for the iodine molecule and the iodine ion; this is the *balanced half-reaction.*

4. When all solutions have been filtered, the instructor will take the solution to the second hood, and add half of the filtered solution to the beaker that is sitting on the hot plate. Recall your prediction in Part I, section **E** what the product of a chemical reaction between zinc and iodine would look like. After the water has evaporated, describe the material that is left in the beaker. Was your prediction confirmed or refuted?
5. The instructor will pour the other half of the zinc-plus-iodine solution into the other common beaker, into which the instructor has placed two electrodes that are connected to an electrical source. The electrodes are connected in a way that will *force* the subatomic particles that moved between atoms to go back where they came from. Predict what will eventually appear on (or near) the two electrodes. The When the reaction has run sufficiently, the instructor will help you to check to see what is on the electrodes. The instructor may use a solution of starch to detect the iodine if it does not come out of the aqueous solution.) Record your descriptions of the products appearing near the two electrodes.

G. An additional mixture/reaction of elements is demonstrated on a video found at uscibooks.aip.org/videos/, which demonstrates the reaction of zinc+ sulfur.

QUESTIONS TO ANSWER

a. Describe the appearance of the reaction mixture before it is ignited, and the appearance of the product of the chemical reaction (after it has cooled down).

b. On the atomic-scale level, describe (in terms of subatomic particles) what happened during this chemical reaction.

c. On the symbolic level, name the product, and write the two half-reactions involved in this chemical reaction.