

Chemistry 1215 Experiment #10

The Reaction of Zinc and Iodine: The Combination of Two Elements

Objective

The objective of this experiment is to perform a combination reaction by reacting elemental zinc with elemental iodine. By carefully measuring the masses of the reactants and products you will explore the concepts of limiting reagents, theoretical yields and percent yields.

Introduction

The reaction of zinc and iodine is an example of a combination reaction where two reactants combine to form a single product, zinc iodide (See Equation 1).



Elemental zinc, which has a melting point of 420°C, is a typical metal. A piece of zinc is silvery gray in color, insoluble in water, and is ductile, malleable, and conducts electricity. Zinc metal consists of monatomic zinc atoms.

Iodine on the other hand is a typical nonmetal. It exists as diatomic I₂ meaning that two iodine atoms are joined to each other by a single covalent bond. In the elemental form iodine is a purple solid with a melting point of 113.5 °C. It is brittle, sublimates relatively easily to form a purple gas, and is quite reactive. It is slightly soluble in water yielding a brown colored solution.

Under the appropriate conditions, zinc and iodine will react to form a white crystalline ionic compound, ZnI₂. Zinc iodide consists of zinc (II), or Zn⁺² cations and iodide, I⁻ anions. During the reaction two electrons are transferred from each zinc atom to two separate iodine atoms as shown in Equations 2 and 3. The sum of equations 2 and 3 gives Equation 1.



The reaction is done in water to increase the physical contact of zinc with iodine. The result of this two electron transfer is the formation of a Zn⁺² ion and two I⁻ ions. When water is removed these two ions combine to form ZnI₂ which is an ionic solid that is very soluble in water and has a melting point of 446°C. The properties of ZnI₂ are markedly different than those of zinc or iodine in their elemental forms. It is important to note, however, that the product contains only two elements, zinc and iodine. Under the right set of conditions ZnI₂ can be decomposed by reversing the electron transfer and the starting materials, elemental zinc and iodine, will be obtained again.

A chemical species that gives up electrons in a chemical reaction is said to have been oxidized. In the reaction described in Equation 1, the zinc atoms are oxidized to zinc ions, Zn⁺². A chemical species that gains electrons is said to have been reduced. In this case iodine, I₂, is reduced. Each of the two iodine atoms in I₂ gains one electron to form two iodide ions, I⁻. The combination reaction in Equation 1 is an example of an

oxidation-reduction reaction. Oxidation and reduction always occur together, i.e., for a chemical species to be oxidized it must pass electrons to another chemical species which is itself reduced by accepting the electrons. The zinc atoms cannot be oxidized without the presence of another chemical species, in this case iodine, which can be reduced. Thus iodine acts as an agent to carry out the oxidation of zinc and is therefore referred to as an oxidizing agent. At the same time, zinc is acting as an agent to carry out the reduction of iodine and is referred to as the reducing agent. To summarize, an oxidizing agent is the chemical species that is reduced and the reducing agent is the chemical species that is reduced.

In this experiment zinc and iodine will be mixed in a test tube. The reaction is very slow if both reactants are in the solid phase so water is added to dissolve the iodine and speed up the reaction rate. Water acts as a solvent and increases the contact between the iodine and the surface of the zinc, thus increasing the reaction rate. It is not possible to visually observe the production of the zinc iodide because it dissolves in the aqueous solution as fast as it is formed. The water must be removed by evaporation in the final step to leave behind the desired zinc iodide. A small amount of acetic acid is added to the solution to aid in the dissolution of the iodine and to prevent formation of zinc hydroxide, an insoluble side product that will form if the solution is even slightly basic.

The law of conservation of mass states that mass is neither lost nor gained in a chemical reaction. That is, the mass of the products must be the same as that of the reactants. This law will be verified for this particular reaction by carefully measuring the mass of the reactants before the reaction and comparing their mass with those of the product obtained at the end of the reaction. In order to ensure that the reaction goes to completion, one of the reactants needs to be present in a molar excess over the other reactant. The reactant present in lesser quantity is called the limiting reactant because it limits the amount of product that can be formed. Once the limiting reactant has been consumed the reaction stops and no more products can be formed.

Based on the amount (in either moles or grams) of limiting reagent added to a reaction one can calculate the theoretical yield of the product. Using the ratios of the coefficients of the limiting reagent and the desired product from the balanced chemical equation, you can convert moles of limiting reagent to moles of product and then to grams of product. This is the theoretical yield or the maximum amount of product that can be made from the reagents added. The percent yield is then calculated by dividing the experimental yield (also called the actual yield) by the theoretical yield and multiplying by 100%.

Example calculation

Suppose that 5.00 g of calcium was reacted with an excess of oxygen according to Equation 4. If 6.39 grams of CaO was obtained, calculate the theoretical and percent yields of CaO.



Solution

Convert 5.00 g of Ca to moles, then use stoichiometry to convert to moles then grams of CaO as shown in Equation 5.

$$(5.00 \text{ g Ca})(1 \text{ mole Ca}/40.1 \text{ g Ca})(2 \text{ moles CaO}/2 \text{ moles Ca})(56.1 \text{ g CaO}/1 \text{ mole}) = 7.00 \text{ g CaO} \quad \text{Equation 5}$$

The theoretical yield of CaO is 7.00 g. The experimental yield was 6.39 g, so the percent yield is

$$(6.39 \text{ g}/7.00 \text{ g})(100\%) = 91.3\% \quad \text{Equation 6}$$

Procedure

1. Determine the mass of a clean and dry test tube to at least four decimal places. Label it tube #1. Make sure that the tube touches only the metal pan of the balance and not the outside casing. Alternatively you can stand the tube in a small tared beaker to get its mass.
2. Place approximately 0.5 grams of zinc metal (20 mesh) in the tube and record the mass as accurately as possible.
3. Place approximately 0.5 grams of I₂ in the tube making sure that all of the I₂ reaches the bottom of the tube and does not stick to the walls. Weigh the iodine on a piece of paper and use a paper chute for the transfer of the I₂ to the test tube. Record the mass of the tube and its contents.
4. Measure 1.3 mL of water and place it in the tube. Add 3 drops of acetic acid to the tube and mix it well. The acid is to prevent formation of insoluble zinc hydroxide. At this point the solution should be brown.
5. Shake the contents of the tube until the solution becomes clear and colorless. This will take several minutes. Record your observations on the data sheet.
6. Measure and record the mass of **another** clean, dry test tube. Label it tube #2.
7. When the reaction in tube #1 is finished (becomes colorless), transfer the solution into tube #2 using a pipet. Be careful not to transfer any of the unreacted zinc powder. Wash the contents of tube #1 three separate times with three 1.0 mL portions of water and add the washings to the solution in tube #2.
8. Dry the unreacted zinc by heating tube #1 and its washed contents in a cool flame of a Bunsen burner. Make sure all the water drops in the tube are evaporated. Weigh the tube and determine the mass of the remaining zinc.
9. Carefully evaporate the water from the solution in tube #2 using a cool flame of a Bunsen burner. Continue heating until all the water is evaporated and only the dry zinc iodide remains. Don't heat too strongly or the solution will "bump" out of the tube.
10. When the second tube and its contents are dry, stopper the tube and allow it to cool to room temperature. ZnI₂ is hygroscopic, meaning that it will absorb water from the air if not covered tightly.
11. When the tube is cool, remove the stopper and quickly weigh the tube and contents. Determine the mass of zinc iodide. This is the actual or experimental yield.
12. Based on the weight of iodine used and Equation 1, calculate the theoretical yield of zinc iodide.
13. Calculate the percent yield for your reaction.

Chemistry 1215 Experiment 10 Data Sheet

Data

1. Mass of test tube #1 _____
2. Mass of test tube #1 plus Zinc _____
3. Mass of Zinc _____
4. Mass of test tube #1 plus zinc plus iodine _____
5. Mass of iodine _____
6. Mass of test tube #1 plus unreacted zinc _____
7. Mass of unreacted zinc _____
8. Mass of test tube #2 _____
9. Mass of test tube #2 plus dried zinc iodide _____
10. Mass of dried zinc iodide (Experimental Yield) _____

Observations and calculations.

1. Describe the reaction between zinc and iodine. Record your observations.

2. Is the reaction between Zn and I₂ endothermic or exothermic?

3. Calculate the theoretical yield of ZnI₂ based on Equation 1 and the mass of the limiting reagent.

4. Calculate the percent yield of ZnI₂ for your reaction.

Discussion

Write a brief discussion of your results in which you briefly describe the reaction, state your experimental results including the actual, theoretical, and percent yields, and discuss any difficulties encountered and suggest ways you could improve your experimental technique.

Chemistry 1215, Experiment #10; The reaction of zinc and iodine, **Post-lab**

Name _____

1. Consider the following observations: an unknown quantity of zinc was mixed with an unknown quantity of iodine in a test tube. Water and acetic acid were added and the contents of the tube were shaken for 20 minutes. After this time the solution in the tube was brown. Agitating the tube for an additional 10 minutes produces no lightening of the color of the solution. What is the limiting reactant in the reaction? What reagent is present in excess? Explain.

2. Is it possible to determine the yield in the above experiment? Why or why not?

3. A student produced ZnI_2 then allowed the product to cool to room temperature without covering the vessel. How will the percent yield be affected? Will it be higher or lower than the true value? Why?

4. If 2.00 g of zinc are combined with 5.00 g of iodine and reacted according to the instructions in this lab, which reactant will be left over? How much (in grams) of the excess reagent will remain?