USING CONDUCTIVITY TO FIND EQUIVALENCE POINT

Westminster College

From *Vernier Chemistry with Labquest*
LAB 26

In this experiment, you will monitor conductivity during the reaction between sulfuric acid, H_2SO_4 and barium hydroxide, $Ba(OH)_2$, in order to determine the equivalence point. From this information, you can find the concentration of the $Ba(OH)_2$ solution. You will also see the effect of ions, precipitates, and water on conductivity. The equation for the reaction in this experiment is:

$$Ba^{2+}(aq) + 2\ OH^{-}(aq) + 2\ H^{+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s) + H_2O(l)$$

Before reacting, $Ba(OH)_2$ and H_2SO_4 are almost completely dissociated into their respective ions. Neither of the reaction products, however, is significantly dissociated. Barium sulfate is a precipitate and water is predominantly molecular.

As 0.0200 M H_2SO_4 is slowly added to $Ba(OH)_2$ of unknown concentration, changes in the conductivity of the solution will be monitored using a Conductivity Probe. When the probe is placed in a solution that contains ions, and thus has the ability to conduct electricity, an electrical circuit is completed across the electrodes that are located on either side of the hole near the bottom of the probe body (see Figure 1). This results in a conductivity value that can be read by the interface. The unit of conductivity used in this experiment is the microsiemens, or µS/cm.

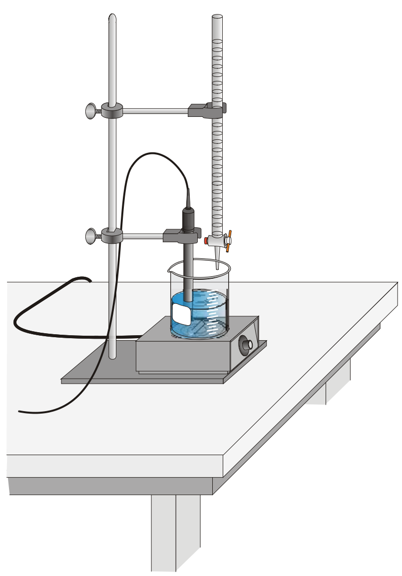


Figure 1

Prior to doing the experiment, it is very important for you to hypothesize about the conductivity of the solution at various stages during the reaction. Would you expect the conductivity reading to be high or low, and increasing or decreasing, in each of these situations?

- When the Conductivity Probe is placed in $Ba(OH)_2$, prior to the addition of H_2SO_4.
- As H_2SO_4 is slowly added, producing $BaSO_4$ and H_2O.
- When the moles of H_2SO_4 added equal the moles of $BaSO_4$ originally present.
- As excess H_2SO_4 is added beyond the equivalence point.

OBJECTIVES

In this experiment, you will

- Hypothesize about the conductivity of a solution of sulfuric acid and barium hydroxide at various stages during the reaction.
- Use a Conductivity Probe to monitor conductivity during the reaction.
- See the effect of ions, precipitates, and water on conductivity.

CHOOSING A METHOD

Method 1 has the student deliver volumes of H_2SO_4 titrant from a buret. After titrant is added, and conductivity values have stabilized, the student is prompted to enter the buret reading manually and a conductivity-volume data pair is stored.

Method 2 uses a Vernier Drop Counter to take volume readings. H_2SO_4 titrant is delivered drop by drop from the reagent reservoir through the Drop Counter slot. After the drop reacts with the reagent in the beaker, the volume of the drop is calculated, and a conductivity-volume data pair is stored.

MATERIALS

Materials for *both* Method 1 (buret) *and* Method 2 (Drop Counter)

LabQuest	magnetic stirrer (if available)
LabQuest App	stirring bar or Vernier Microstirrer
Vernier Conductivity Probe	100 mL graduated cylinder
60 mL of ~0.02 M H_2SO_4	Phenolphthalein (optional)
50 mL of $Ba(OH)_2$, unknown concentration	ring stand
250 beaker	1 utility clamp

Materials required *only* for Method 1 (buret)

50 mL buret	2nd utility clamp
2nd 250 mL beaker	

Materials required *only* for Method 2 (Drop Counter)

Vernier Drop Counter	100 mL beaker
60 mL reagent reservoir	10 mL graduated cylinder

METHOD 1: Measuring Volume Using a Buret

1. Obtain and wear goggles.

2. Measure out approximately 60 mL of 0.020 M H_2SO_4 into a 250 mL beaker. Record the precise H_2SO_4 concentration in your data table. **CAUTION:** *H_2SO_4 is a strong acid, and should be handled with care.* Obtain a 50 mL buret and rinse the buret with a few mL of the H_2SO_4 solution. Use a utility clamp to attach the buret to the ring stand as shown in Figure 1. Fill the buret a little above the 0.00 mL level of the buret. Drain a small amount of H_2SO_4 solution so it fills the buret tip *and* leaves the H_2SO_4 at the 0.00 mL level of the buret. Dispose of the waste solution in this step as directed by your teacher.

3. Measure out 50.0 mL of $Ba(OH)_2$ of unknown concentration using a 100 mL graduated cylinder. Transfer the solution to a clean, dry 250 mL beaker. Then add 120 mL of distilled water to the beaker. **CAUTION:** *$Ba(OH)_2$ is toxic. Handle it with care.*

4. Set the selector switch on the side of the Conductivity Probe to the 0–2000 µS/cm range. Connect the Conductivity Probe to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.

5. Set up the data-collection mode.
   a. On the Meter screen, tap Mode. Change the data-collection mode to Events with Entry.
   b. Enter the Name (Volume) and Units (mL). Select OK.

6. Arrange the buret, Conductivity Probe, beaker containing $Ba(OH)_2$, and stirring bar as shown in Figure 1. The Conductivity Probe should extend down into the $Ba(OH)_2$ solution to just above the stirring bar, so the hole in the probe end is completely submerged.

7. You are now ready to perform the titration. This process goes faster if one person manipulates and reads the buret while another person enters volumes.
   a. Start data collection.
   b. Before adding H_2SO_4 titrant, tap Keep. Enter **0**, the volume (in drops). Select OK to save this data pair.

c. Add 1.0 mL of 0.0200 M H_2SO_4 to the beaker. When the conductivity readings stabilize, tap Keep. Enter **1** as the volume in drops and then select OK. The conductivity and volume values have now been saved for the second trial.

d. Continue adding 1.0 mL increments of H_2SO_4 solution, each time entering the buret reading, until the conductivity has dropped *below 100 µS/cm*.

e. After the conductivity has dropped below 100 µS/cm, add one 0.5 mL increment and enter the buret reading.

f. After this, use 2-drop increments (~0.1 mL) until the minimum conductivity has been reached at the equivalence point. Enter the volume after each 2-drop addition. When you have passed the equivalence point, continue using 2-drop increments until the conductivity is greater than 50 µS/cm again.

g. Now use 1.0 mL increments until the conductivity reaches about 1000 µS/cm, or 25 mL of H_2SO_4 solution has been added, whichever comes first.

8. Stop data collection.

9. To examine the data pairs on the displayed graph of conductivity *vs.* volume, tap any data point. As you tap each data point (or use the ► or ◄ keys on LabQuest), the conductivity and volume values are displayed. Find the *equivalence point*—that is, the volume when the conductivity value reaches a minimum. Record the H_2SO_4 volume of the point with the minimum conductivity value in the data table.

10. Dispose of all solutions as directed by your instructor. Rinse off and dry the Conductivity Probe.

11. (optional) Print a copy of the graph of conductivity *vs.* volume.

METHOD 2: Measuring Volume with a Drop Counter

1. Obtain and wear goggles.

2. Measure out 25.0 mL of $Ba(OH)_2$ solution of unknown concentration using a 100 mL graduated cylinder. Transfer the solution to a clean, dry 100 mL beaker. Then add 60 mL of distilled water to the beaker. **CAUTION:** *$Ba(OH)_2$ is toxic. Handle it with care.*

3. Measure out approximately 40 mL of ~0.02 M H_2SO_4 solution into a 250 mL beaker. Record the precise H_2SO_4 concentration in your data table. **CAUTION:** *H_2SO_4 is a strong acid, and should be handled with care.*

4. Obtain the plastic 60 mL reagent reservoir. **Note:** The bottom valve will be used to open or close the reservoir, while the top valve will be used to finely adjust the flow rate. For now, close both valves by turning the handles to a horizontal position.

Rinse it with a few mL of the 0.02 M H_2SO_4 solution. Use a utility clamp to attach the reagent reservoir to the ring stand. Add 30 mL of 0.02 M H_2SO_4 solution to the reagent reservoir.

Drain a small amount of H_2SO_4 solution into the beaker so it fills the reservoir's tip. To do this, turn both valve handles to the vertical position for a moment, then turn them both back to horizontal.

5. Set up LabQuest.

   a. Set the selection switch on the Conductivity Probe to the 0–2000 μS/cm range. Connect the Conductivity Probe to CH 1 of LabQuest.
   b. Lower the Drop Counter onto a ring stand and connect it to DIG 1.
   c. Choose New from the File menu. If both sensors are identified, proceed to Step 6.

   If you have older sensors that do not auto-ID, manually set them up:

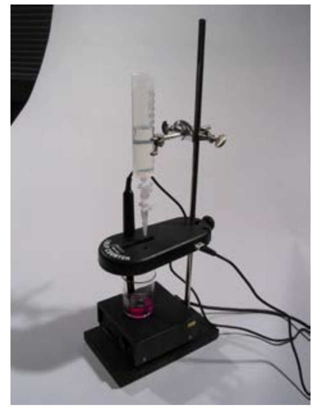
   d. Choose Sensor Setup from the Sensors menu.
   e. Select Drop Counter from the DIG 1 sensor list, or pH Sensor from the CH 1 sensor list.
   f. Select OK.

6. Calibrate the Drop Counter so that a precise volume of titrant is recorded in units of milliliters.

   a. Choose Calibrate ► Drop Counter from the Sensors menu.
      - If you have previously calibrated the drop size of your reagent reservoir and want to continue with the same drop size, tap Equation. Enter the values for Drops/mL. Select Apply to make the changes take effect. Select OK. Proceed to Step 7.
      - If you want to perform a new calibration, select Calibrate Now, and continue with this step.
   b. Place a 10 mL graduated cylinder directly below the slot on the Drop Counter, lining it up with the tip of the reagent reservoir.
   c. Open the bottom valve on the reagent reservoir (vertical). Keep the top valve closed (horizontal).
   d. Slowly open the top valve of the reagent reservoir so that drops are released at a slow rate (~1 drop every two seconds). You should see the drops being counted on the screen.
   e. When the volume of H_2SO_4 solution in the graduated cylinder is between 9 and 10 mL, close the bottom valve of the reagent reservoir.
   f. Enter the precise Volume of H_2SO_4 to the nearest 0.1 mL. Select Stop. Record the number of drops/mL displayed on the screen for possible future use. Select OK.
   g. Discard the H_2SO_4 solution in the graduated cylinder as indicated by your instructor and set the graduated cylinder aside.

7. Assemble the apparatus.

   a. Place the magnetic stirrer on the base of the ring stand.
   b. Insert the Conductivity Probe through the large hole in the Drop Counter.
   c. Attach the Microstirrer to the bottom of the Conductivity Probe, as shown in the small picture. Rotate the paddle wheel of the Microstirrer and make sure that it does not touch the bottom of the Conductivity Probe.



   d. Adjust the positions of the Drop Counter and reagent reservoir so they are both lined up with the center of the magnetic stirrer.
   e. Lift up the Conductivity Probe, and slide the beaker containing the $Ba(OH)_2$ solution onto the magnetic stirrer. Lower the Conductivity Probe into the beaker.
   f. Adjust the position of the Drop Counter so that the Microstirrer on the Conductivity Probe is just touching the bottom of the beaker.
   g. Adjust the reagent reservoir so its tip is just above the Drop Counter slot.

8. Turn on the magnetic stirrer so that the Microstirrer is stirring at a fast rate.

9. Start data collection. No data will be collected until the first drop goes through the Drop Counter slot. Fully open the bottom valve—the top valve should still be adjusted so drops are released at a rate of about 1 drop every 2 seconds. When the first drop passes through the Drop Counter slot, check the data table to see that the first data pair was recorded.

10. Continue watching your graph to see when the conductivity has reached a minimum value—this will be the equivalence point of the reaction. After this minimum conductivity occurs, let the titration proceed until the conductivity reading is about the same as the initial conductivity value, then stop data collection to view a graph of conductivity *vs.* volume. Turn the bottom valve of the reagent reservoir to a closed (horizontal) position.

11. To examine the data pairs on the displayed graph of conductivity *vs.* volume, tap any data point. As you tap each data point (or use the ► or ◄ keys on LabQuest), the conductivity and volume values are displayed. Find the *equivalence point*—that is, the volume when the conductivity value reaches a minimum. Record the H_2SO_4 volume of the point with the minimum conductivity value in the data table.

12. Dispose of the beaker contents as directed by your teacher.

13. (optional) Print copies of the table and the graph.

PROCESSING THE DATA

1. From the data table and graph, determine the volume of H_2SO_4 added at the equivalence point. The graph should give you the *approximate* volume at this point. The *precise* volume of H_2SO_4 added can be determined by further examination of the data table for the minimum conductivity. Record the volume of H_2SO_4.

2. Calculate moles of H_2SO_4 added at the equivalence point. Use the molarity, M, of the H_2SO_4 and its volume, in L.

3. Calculate the moles of $Ba(OH)_2$ at the equivalence point. Use your answer in the previous step and the ratio of moles of $Ba(OH)_2$ and H_2SO_4 in the balanced equation (or use the 1:1 ratio of moles of H^+ to moles of OH^- from the equation).

4. From the moles and volume of $Ba(OH)_2$, calculate the concentration of $Ba(OH)_2$, in mol/L.

DATA TABLE

Molarity of H_2SO_4	M
Volume of H_2SO_4	mL = L
Volume of $Ba(OH)_2$	mL = L

Moles of H_2SO_4	mol
Moles of $Ba(OH)_2$	mol
Molarity of $Ba(OH)_2$	M