Midn

Determining the Stoichiometry for the Reaction of Hydrogen Peroxide and Potassium Permanganate

Problem: Using the analytical technique of titration and the concept of solution stoichiometry, determine which of these two possible reactions occurs

$$3\ H_2O_2\ (aq) + 2\ KMnO_4\ (aq) + 3\ H_2SO_4\ (aq) \rightarrow 4\ O_2\ (g) + 2\ MnSO_4\ (aq) + K_2SO_4\ (aq) + 6\ H_2O\ (\ell)$$

$$5\ H_2O_2\ (aq) + 2\ KMnO_4\ (aq) + 3\ H_2SO_4\ (aq) \rightarrow 5\ O_2\ (g) + 2\ MnSO_4\ (aq) + K_2SO_4\ (aq) + 8\ H_2O\ (\ell)$$

Pre-Laboratory Assignment

1. a. Assign oxidation numbers to each element in this unbalanced equation. (remember peroxide is an exception)

$$H_2O_2\ (aq) + KMnO_4\ (aq) + H_2SO_4\ (aq) \rightarrow O_2\ (g) + MnSO_4\ (aq) + K_2SO_4\ (aq) + H_2O\ (\ell)$$

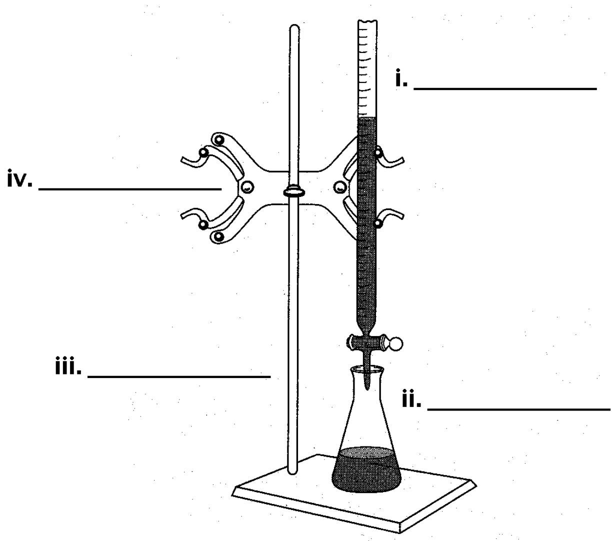
2. Hydrogen peroxide solutions are not stable; they decompose quickly. Because of this you must prepare it fresh for your experiment. You will do so by reacting sodium perborate tetrahydrate, $NaBO_3{\cdot}4H_2O$, with water

$$BO_3^-\ (s)\ +\ 2\ H_2O\ (\ell)\ \rightarrow\ H_2O_2\ (aq)\ +\ H_2BO_3^-\ (aq)$$

(The Na^+ ion and 4 H_2O molecules are spectators and therefore omitted from the equation.)

Calculate the mass of $NaBO_3{\cdot}4H_2O$ needed to make 250.0 mL of a 0.0300 M H_2O_2 solution.

3. The apparatus for your titration is shown in the illustration.



a. Identify each piece of equipment.

b. Based on the information in the Experiment Procedures, which solution(s) will you put in the glassware labeled **i**?

c. Based on the information in the Experiment Procedures, which solution(s) will you put in the glassware labeled **ii**?

4. What safety precaution should you follow when handling the H_2O_2 solution in the laboratory? (Hint: this is more important if you are wearing service dress blues or working blues than whiteworks.)

Experiment Procedures

1. Prepare 250.0 mL of a H_2O_2 solution.
   a. In a clean, dry weighing dish measure the mass of $NaBO_3 \cdot 4H_2O$ you calculated in Pre-Laboratory Assignment 2. Use an analytical balance. The mass may be ±0.02 g of the calculated mass. Record the actual mass you weighed.
   b. Transfer the $NaBO_3 \cdot 4H_2O$ to a 250.0-mL volumetric flask. Add about 100 mL of distilled water and 50 mL of 1.0 M H_2SO_4. Swirl until the $NaBO_3 \cdot 4H_2O$ is completely dissolved.
   c. Add distilled water to the mark. Insert a stopper and mix well by inverting the flask several times.

2. Obtain 50 mL of $KMnO_4$ in a clean, dry beaker. Rinse the buret with 3–5 mL of $KMnO_4$. Fill the buret with $KMnO_4$ (don't forget the tip). Record the initial volume of $KMnO_4$ and its concentration.

3. Titrate the H_2O_2 solution.
   a. Rinse a 25.00-mL pipet with 3–5 mL of the H_2O_2 solution. Pipet 25.00 mL of H_2O_2 solution into a 250-mL Erlenmeyer flask. Any liquid remaining in the tip at this time should be left in the tip, because the pipet is calibrated to deliver the specified volume with liquid remaining in the tip.
   b. Add about 20 mL of 1.0 M H_2SO_4. Swirl to mix well.
   c. Titrate the H_2O_2 with $KMnO_4$ until a purple color appears and remains for at least 20 seconds. (Note: the solution in the Erlenmeyer flask will change from colorless to brown to purple. The brown color signals the equivalence point is near, but it is not the equivalence point.) Place a white tissue under the flask to observe the color change more easily.
   d. Record the final volume of $KMnO_4$.
   e. Dispose of the reaction mixture by pouring in the drain.

4. Titrate 2–4 more H_2O_2 samples. The volume of $KMnO_4$ used in at least 3 of the titrations should agree within 0.5 mL.

Experiment Data and Observations

Post-Laboratory Questions

1. Using the actual mass of $NaBO_3 \cdot 4H_2O$ you weighed out, calculate the concentration of the H_2O_2 solution you prepared.

2. a. Calculate the moles of H_2O_2 titrated in each of your determinations.

   b. Calculate the moles of $KMnO_4$ needed to reach the equivalence point for each of your titrations.

   c. Which of the two possible H_2O_2 and $KMnO_4$ reactions occurred (see problem statement p 1)? Briefly explain your choice.

3. Would these experimental errors cause the calculated moles of $KMnO_4$ to be higher, lower, or the same as the actual moles of $KMnO_4$? Briefly explain.

   a. The titration was stopped when the reaction mixture was brown.

   b. The tip of the buret was not filled with $KMnO_4$ at the start of the titration, but was filled at the end of the titration.

4. Would these experimental errors cause the calculated moles of H_2O_2 titrated to be higher, lower, or the same as the actual moles of H_2O_2 titrated? Briefly explain.

   a. The pipet used to measure the H_2O_2 had water droplets in it that were not rinsed out first.

   b. When transferring the H_2O_2 to the Erlenmeyer flask, the last bit of H_2O_2 in the pipet was forced into the flask as well.

5. The net ionic oxidation-reduction reaction

$$5\ H_2O_2\ (aq)\ +\ 2\ MnO_4^-\ (aq)\ +\ 6\ H^+\ (aq)\ \rightarrow\ 5\ O_2\ (g)\ +\ 2\ Mn^{2+}\ (aq)\ +\ 8\ H_2O\ (\ell)$$

can be written as two net ionic half-reactions

$$MnO_4^-\ (aq)\ +\ 8\ H^+\ (aq)\ \rightarrow\ Mn^{2+}\ (aq)\ +\ 4\ H_2O\ (\ell)$$

$$H_2O_2\ (aq)\ \rightarrow O_2\ (g)\ +\ 2\ H^+\ (aq)$$

   a. Which is the oxidation half-reaction?

   b. Which is the reduction half-reaction?

   c. How many electrons are lost in the oxidation reaction?

   d. How many electrons are gained in the reduction reaction?