Percentage Yield

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

UNIT 2 PERFORMANCE TASK: PRODUCTION CONTROL TECHNICIAN

Question

Do reactions using reagent-grade chemicals produce a higher percentage yield than reactions using store-bought (household quality) reagents?

Prediction

Reactions carried out with reagent-grade chemicals will produce a higher percentage yield than reactions carried out using store-bought reagents.

Experimental Design

A preliminary percentage yield test (Trial 1) was performed according to the procedure outlined in the student text. In this test, store-bought baking soda and store-bought vinegar were used as the sources of sodium hydrogen carbonate and acetic acid, respectively. A second experiment (Trial 2) was conducted in an effort to increase the percentage yield of sodium acetate. In Trial 2, a 5% V/V solution of aqueous (reagent-grade) acetic acid, and an aqueous solution of (reagent-grade) sodium hydrogen acetate (prepared according to the student text procedure) were used as the reagents. In both cases (Trial 1 and Trial 2), the reagents were mixed in a clean, dry 500-mL beaker (according to the instructions in the student text procedure), and allowed to react until all bubbling stopped.

Materials

balance
scoopulas
stirring rods
hot plate
100-mL graduated cylinder
500-mL beaker
watch glass large enough to fit over the mouth of a 500-mL beaker
store-bought baking soda
reagent-grade sodium hydrogen carbonate, $NaHCO_{3(s)}$
store-bought vinegar
5% V/V solution of reagent-grade acetic acid, $HC_2H_3O_{2(aq)}$
distilled water

Procedure

The procedures employed in Trial 1 and Trial 2 were the same as the procedures outlined in the student text, except that in Trial 1, store-bought vinegar and store-bought baking soda were used as the reagents, and in Trial 2, reagent-grade acetic acid, reagent-grade sodium hydrogen acetate, and distilled water (as a solvent) were used as reagents. All reactions were carried out at ambient room temperature (22°C). See the student text procedure for details.

Observations

Trial 1

Mass of baking soda used	4.23 g
Mass of empty beaker	193.03 g
Mass of empty beaker + $NaC_2H_3O_{2(s)}$	196.07 g
Mass of $NaC_2H_3O_{2(s)}$ collected	3.04 g

Trial 2

Mass of $NaHCO_3$ used	4.23 g
Mass of empty beaker	193.03 g
Mass of beaker + $NaC_2H_3O_{2(s)}$	196.90 g
Mass of $NaC_2H_3O_{2(s)}$ collected	3.87 g

Analysis

Since vinegar (Trial 1) and acetic acid (Trial 2) were continuously added to the reaction mixtures until all bubbling stopped, sodium hydrogen carbonate is the limiting reagent in both trials.

The balanced equation for the reaction in Trial 1 and Trial 2 is:

$$NaHCO_{3(aq)} + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Trial 1

$$\text{theoretical yield}_{NaC_2H_3O_2} = 4.23\ \cancel{\text{g NaHCO}_3} \times \frac{1\ \cancel{\text{mol NaHCO}_3}}{84.01\ \cancel{\text{g NaHCO}_3}} \times \frac{1\ \cancel{\text{mol NaC}_2\text{H}_3\text{O}_2}}{1\ \cancel{\text{mol NaHCO}_3}} \times \frac{82.04\ \text{g NaC}_2\text{H}_3\text{O}_2}{1\ \cancel{\text{mol NaC}_2\text{H}_3\text{O}_2}}$$

$$\text{theoretical yield}_{NaC_2H_3O_2} = 4.13\ \text{g}$$

$$\text{actual yield}_{NaC_2H_3O_2} = 3.04\ \text{g}$$

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{3.04\ \cancel{\text{g}}}{4.13\ \cancel{\text{g}}} \times 100\%$$

$$\text{percentage yield} = 73.6\%$$

Trial 2

$$\text{theoretical yield}_{NaC_2H_3O_2} = 4.23\ \cancel{\text{g NaHCO}_3} \times \frac{1\ \cancel{\text{mol NaHCO}_3}}{84.01\ \cancel{\text{g NaHCO}_3}} \times \frac{1\ \cancel{\text{mol NaC}_2\text{H}_3\text{O}_2}}{1\ \cancel{\text{mol NaHCO}_3}} \times \frac{82.04\ \text{g NaC}_2\text{H}_3\text{O}_2}{1\ \cancel{\text{mol NaC}_2\text{H}_3\text{O}_2}}$$

$$\text{theoretical yield}_{NaC_2H_3O_2} = 4.13\ \text{g}$$

$$\text{actual yield}_{NaC_2H_3O_2} = 3.87\ \text{g}$$

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{3.87\ \cancel{\text{g}}}{4.13\ \cancel{\text{g}}} \times 100\%$$

$$\text{percentage yield} = 93.7\%$$

Evaluation

Answer to Question

The evidence obtained in this experiment (Trials 1 and 2) indicates that reactions carried out with reagent-grade chemicals produce a higher percentage yield than reactions carried out using store-bought (household quality) chemicals.

Sources of Error

In addition to measurement and calculation error, a major source of error in these experiments is the purity of the reagents used. Higher-grade reagents such as "reagent grade" chemicals probably contain a higher proportion of the compounds ($HC_2H_3O_2$ and $NaHCO_3$) that participate in the chemical reaction on which the theoretical yield calculation is based.

Conclusions and Recommendations

In the reaction between sodium hydrogen carbonate and acetic acid, the use of reagent-grade reactants gives a significantly higher percentage yield of sodium acetate than the use of store-bought baking soda and vinegar. It is recommended that reagent-grade compounds be used as reagents in the commercial production of sodium acetate if it can be shown that that the increased costs of the reagent-grade compounds does not exceed the proportional increase in percentage yield.