The synthesis of 2-butanone, a ketone, from 2-butanol, an alcohol, is shown as an example of a common type of organic synthesis. Three basic steps are developed: synthesis, purification, and identification. In the synthesis, 2-butanol is oxidized by sodium dichromate and sulfuric acid to yield 2-butanone. Purification is accomplished by solvent extraction with ether followed by distillation of the 2-butanone. The identity of the product is established by infrared absorption spectroscopy, and then more clearly by nuclear magnetic resonance spectroscopy.

**Purpose:**

To give students an opportunity to observe an outstanding organic chemist perform the synthesis of a simple compound and to indicate the general steps which are important in any synthesis.

**Outline:**

1. Oxidation of 2-butanol to 2-butanone using acidified sodium dichromate.
   - The balanced equation is obtained by writing the half-reaction for the oxidation of 2-butanol:
     \[
     \text{CH}_3\text{CHOHCH}_2\text{CH}_3 + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{CH}_3\text{COCH}_2\text{CH}_3 + 7\text{H}_2\text{O}.
     \]
   - Inspection of these half-reactions shows that multiplying the butanol half-reaction by 3 and adding the half-reactions gives the overall equation:
     \[
     3\text{CH}_3\text{CHOHCH}_2\text{CH}_3 + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightarrow 3\text{CH}_3\text{COCH}_2\text{CH}_3 + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}.
     \]
   - Calculating from the equation, the proper amounts of the reagents are weighed out. With ½ mole or 37 grams of 2-butanol as the starting material, ½ as many moles of chromate are needed.
   
   \[
   \begin{align*}
   1 \text{ mole butanol} & \times 1 \text{ mole Na}_2\text{Cr}_2\text{O}_7 \times \frac{298 \text{ g}}{2} \times \frac{1}{3} \text{ mole butanol} \\
   & = 50 \text{ g}.
   \end{align*}
   \]
   - For every 3 moles of 2-butanol, 8 H\(^+\) ions must be supplied from the H\(_2\)SO\(_4\). Remember that each H\(_2\)SO\(_4\) supplies 2 H\(^+\) ions.
   
   \[
   \begin{align*}
   1 \text{ mole butanol} & \times 3 \text{ mole H}^+ \times \frac{98 \text{ g}}{2} \times \frac{1}{3} \text{ mole butanol} \\
   & = 65 \text{ g}.
   \end{align*}
   \]

2. Purification of the 2-butanone product.
   - The ether layer, containing the product, is separated from the aqueous layer in a separatory funnel. The ether is washed with water to remove traces of ketone. The ether wash is added to the original ether layer. This removal of ketone dissolved in the aqueous layer is necessary to ensure a good yield. Butanone-2 is appreciably soluble in water (37g/100g H\(_2\)O).

3. Identification of the product.
   - The infrared spectrum is used for identification by taking the spectrum of the product and comparing it to the spectrum of a known sample of 2-butanone.

   A. Nuclear magnetic resonance spectroscopy, NMR, is also used to characterize the compound. This technique involves the absorption of radio waves by a sample placed in a strong magnetic field. The energies that the protons in the sample absorb are characteristic of their chemical environment—this is, the proximity in the molecule of other specific atoms or groups of atoms. Comparison of this NMR spectrum with spectra of protons in known environments in various molecules can clearly identify the product.

4. Supplementary material:

2-butanone is also known as methyl ethyl ketone, or MEK, a common industrial solvent.

The weighing technique (to 0.1 gram) is typical of that for organic reactions. Often a large excess of one reagent (usually the least expensive) is added to cause additional formation of product as predicted by Le Chatelier's Principle.

The experiment actually requires 3-4 hours, and is typical of experiments done in a beginning course in organic chemistry. Students must be cautioned not to try this type of experiment until they have a full understanding of and availability to safety procedures.