Limiting Reactant for Camphor Production:

\[
\frac{18 \text{ mL NaOCl}}{1 \text{ mL}} \times \frac{0.06 \text{ mL}}{1 \text{ mL NaOCl}} \times \frac{1.1 \text{ g NaOCl}}{74.44 \text{ g NaOCl}} \times \frac{1 \text{ mol NaOCl}}{1 \text{ mol NaOCl}} = 0.01596 \text{ mol Camphor}
\]

\[
\frac{1 \text{ g Borneol}}{154.25 \text{ g Borneol}} \times \frac{1 \text{ mol Camphor}}{1 \text{ mol Borneol}} = 0.00648 \text{ mol Camphor}
\]

18 mL of NaOCl produces 15.96 mmol of Camphor product, whereas 1 g of Borneol produces 6.48 mmol of Camphor, making Borneol the limiting reactant and NaOCl the reactant in excess.

Theoretical Yield of Camphor: 0.993 g Camphor

\[
\frac{1 \text{ g Borneol}}{154.25 \text{ g Borneol}} \times \frac{1 \text{ mol Camphor}}{1 \text{ mol Borneol}} \times \frac{153.23 \text{ g Camphor}}{1 \text{ mol Camphor}} = 0.993 \text{ g Camphor}
\]

Limiting reactant determination for Isoborneol:

\[
\frac{0.25 \text{ g NaBH}_4}{37.83 \text{ g NaBH}_4} \times \frac{1 \text{ mol NaBH}_4}{1 \text{ mol NaBH}_4} \times \frac{4 \text{ mol Isoborneol}}{1 \text{ mol NaBH}_4} = 0.0264 \text{ mol Isoborneol}
\]

\[
\frac{0.25 \text{ g Camphor}}{153.23 \text{ g Camphor}} \times \frac{1 \text{ mol Camphor}}{1 \text{ mol Camphor}} \times \frac{1 \text{ mol Isoborneol}}{1 \text{ mol Isoborneol}} = 0.00163 \text{ mol Isoborneol}
\]

0.25 g NaBH₄ produces 26.4 mmol of Isoborneol product, whereas 0.25 g Camphor produces 1.63 mmol of Isoborneol, making camphor the limiting reactant and NaBH₄ the reactant in excess.

Theoretical yield of Isoborneol: 0.252 g Isoborneol

\[
\frac{0.25 \text{ g Camphor}}{153.23 \text{ g Camphor}} \times \frac{1 \text{ mol Camphor}}{1 \text{ mol Camphor}} \times \frac{1 \text{ mol Isoborneol}}{1 \text{ mol Isoborneol}} \times \frac{154.25 \text{ g Isoborneol}}{1 \text{ mol Isoborneol}} = 0.252 \text{ g Isoborneol}
\]

Limiting Reactant Reagents used:

Borneol: 1.001 g
Camphor: 0.255 g

Experimental Yield of Products:

Camphor Product: 0.457 g
Isoborneol product: 0.227 g

Percent Yield for Camphor: 45.96%
Example of Calculations

\[
1.001 \frac{\text{g Borneol}}{154.25 \text{g Borneol}} \times 1 \frac{\text{mol Camphor}}{1 \text{mol Borneol}} \times 153.23 \frac{\text{g Camphor}}{1 \text{mol Camphor}} = 0.994 \text{ g Camphor}
\]

\[
\frac{0.457 \text{ g Camphor}}{0.994 \text{ g Camphor}} \times 100 = 46.0\%
\]

**Percent Yield for Isoborneol: 88.3%**

\[
0.255 \frac{\text{g Camphor}}{153.23 \text{ g Camphor}} \times 1 \frac{\text{mol Isoborneol}}{1 \text{mol Camphor}} \times 154.25 \frac{\text{g Isoborneol}}{1 \text{mol Isoborneol}} = 0.257 \text{ g Isoborneol}
\]

\[
\frac{0.227 \text{ g Camphor}}{0.257 \text{ g Camphor}} \times 100 = 88.3\%
\]

**Melting Point Analysis:**

Camphor Literature melting point: 174°C

The camphor synthesized was found to have a melting point of 142-148°C. Because the melting point is very far from the literature melting point, this indicates a very impure product. The melting range is so much lower because Camphor’s melting point is drastically shifted when impurities are present.

Isoborneol Literature melting point: 212°C

The isoborneol synthesized was found to have a melting point range of 206.5-211°C. This is very close to the literature value for the melting point, indicating a pure product.

**TLC monitoring:**

After the oxidation steps of borneol to camphor were performed, TLC was done to determine the progress of the reaction. Stock borneol and camphor were run with the reaction product to compare Rf values and see how the reaction progressed. Unfortunately, there were spots at the same travelling distance as both borneol and camphor. This indicates that not all of the original borneol was converted into camphor. Because the spots were about equal, it can be said that about 50% of borneol was converted to camphor.

The evidence of an impure product from the melting point determination of the camphor product is confirmed by the evidence of both the product and the reactant by the TLC.

**IR Analysis of stock Camphor:**

The IR scan of Camphor done in class looks to be a very pure sample of Camphor. When comparing the peaks of the experimental IR to the ones in the laboratory manual, identification of camphor can be verified. There are distinct, strong sp³ C-H stretch peaks in the 2800-3000 cm⁻¹ range. In addition, there is a distinct, strong peak at 1730 cm⁻¹ from a C=O carbonyl stretch from the present ketone in camphor.
Notably, there is no evidence of an alcohol (3300 cm$^{-1}$) present from borneol, indicating a fully oxidized camphor product.