

# Coffee monopoly takes a hit: an experiment to extract caffeine out of tea leaves

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## Experimental Procedure

Four tea bags were emptied into a 400mL beaker of known mass and the tealeaves were weighed. Approximately 4.8g of calcium carbonate and 125mL of deionized water (dH<sub>2</sub>O) were added to the beaker. The solution was boiled on a hot plate for 15min, and was stirred every 1-2min. After boiling, the solution was cooled to 55°C. The cool mixture was filtered using a vacuum filtration apparatus: a conical funnel was placed in a 250mL filter flask, a cotton ball was placed in the funnel, the flask was connected to the vacuum by a rubber hose, the vacuum was turned on, and the entire solution was poured into the funnel. The filtrate collected was then cooled to 15-20°C using an ice water bath.

After the liquid cooled, approximately 100mL of the solution was poured into a 125mL separatory funnel, followed by 15mL of dichloromethane (DCM). The funnel was then inverted and the stopcock was immediately opened to release vapors. The funnel was rotated for 2-3min and the stopcock was opened frequently to vent the solution. After the mixture has separated, the DCM layer was drained into a 50mL Erlenmeyer flask. An additional 15mL was added to the separatory funnel, and the separation was repeated; the DCM layer was drained into the same flask as the layer from the initial separation. The tealeaves mixture was poured out of the separatory funnel into a beaker and the funnel was rinsed clean. Then the DCM filtrate collected in the 50mL flask is poured into the funnel, followed by 20mL dH<sub>2</sub>O. The separatory funnel was inverted, immediately vented, and rocked for approximately 2-3min with frequent venting. The bottom layer in the

separatory flask was drained into a clean 50mL Erlenmeyer flask, which was then corked.

Two micro-spatula scoops of anhydrous magnesium sulfate drying agent was added to last the filtrate collected, the flask was corked, and the solution was allowed to sit for 10min with occasional swirling. After drying was complete, the solution was poured through fluted filter paper in a conical funnel into a 50mL round-bottom flask of known mass, and the flask was corked. The DCM in the round-bottom flask was evaporated using rotary evaporation system. After evaporation was complete, the round-bottom flask is weighed to obtain the mass of the remaining dried crude caffeine sample. The round-bottom flask was corked and the crude extract was saved.

## Results and Calculations

Empty 400mL Beaker = 142. 112g

400mL Beaker + Tealeaves = 151. 088g

Tealeaves Used = 8. 976g

ASSUMING: > 300mg of caffeine in 10g of tealeaves

THEN: 300mg Caffeine/10g Tealeaves = X/8. 976g Tealeaves

X = 269. 28mg Caffeine in Total Tealeaves Sample

\*100mL filtrate (out of 125mL total) used for extraction

269. 28mg Caffeine/125mL dH2O = Y/100mL dH2O

Y = 215.424mg Caffeine in Filtrate Used

ASSUMING: Theoretical Yield Range, Percent = 10-30%

THEN: Low Theoretical Yield = (215.424mg Caffeine)\*0.1 = 21.5424mg  
Caffeine

High Theoretical Yield = (215.424mg Caffeine)\*0.3 = 64.6272mg Caffeine

Theoretical Yield Range, Mass = 21.5-64.6mg

Vacuum Filtration: Tealeaves = 8.976g

Calcium Carbonate = 4.801g

dH<sub>2</sub>O = 125mL

Extraction: Filtrate Solution Used = 100mL

Separation1, DCM = 15mL

Separation2, DCM = 15mL

Washing, dH<sub>2</sub>O = 20mL

Solvent Removal: Empty Round-Bottom Flask = 37.989g

Round Bottom Flask + Dried Crude = 38.02g

Crude Caffeine Recovered = 31mg

Experimental Crude Yield = (31mg/215.424mg)\*100 = 14.39%

## Discussion and Conclusion

Crude caffeine was successfully extracted from tealeaves and the resulting yield fell within the predicted theoretical yield range for this extraction. The maximum theoretical yield of caffeine expected was 30% (minimum= 10%) and the experimental yield obtained was approximately 14%. Several assumptions were made when determining the theoretical caffeine concentration of the tealeaves sample: caffeine is present in concentrations of 30mg Caffeine/g Tealeaves, the total caffeine content is evenly dispersed through the solution volume after boiling (269. 28mg Caffeine/125mL Solution), the caffeine content in the filtrate used for extraction is proportional to the caffeine content present in the total solution used (215. 424mg Caffeine/100mL Solution), these specific experimental procedures yield 10-30% of caffeine. Each assumption represents a possible source of error because the actual outcome of each part of the experiment did not exactly represent the assumed/expected conditions, and the precise values of caffeine concentrations in the samples are unknown. It is possible that the caffeine content of the solution was not uniform throughout its entire volume, so the experimental crude yield recovered may have been increased if the entire filtrate solution collected was used for extraction instead of only a portion. The entire filtrate solution was not used because extraction was to be carried out in a 125mL separatory funnel, which could not contain the entire 125mL filtrate with the 15mL of DCM also required for the process.

## Post Lab Questions

### **Why is the tea boiled with water in this experiment?**

In this experiment, the tea is boiled with water because the target compound, caffeine, is highly soluble in water at 100°C.

### **Why is the aqueous tea solution cooled to 15-20°C before the dichloromethane is added?**

Before the dichloromethane is added, the aqueous tea solution must be cooled to 15-20°C to avoid overheating the dichloromethane, which has a boiling point of approximately 40°C. If dichloromethane is boiled or otherwise decomposed into vapor, the fumes emitted will be highly toxic.

### **Why does the addition of salt (NaCl) to the aqueous layer sometimes help to break up an emulsion that forms in an extraction?**

Adding a salt to the aqueous layer will help break up emulsions for two reasons: the salt will dissolve and make the aqueous layer highly ionic, which weakens the strength of the emulsion layer bonds; the density of the aqueous layer will also increase, facilitating its separation from the less dense solvent.