CHEM 333L
Organic Chemistry Laboratory
Revision 1.3

Isolation of Caffeine from Tea

In this laboratory exercise we will isolate Caffeine from Tea and then derivatize it to form Caffeine Salicylate. The purpose of this last step is to generate a compound whose melting point is fixed and easily measured; Caffeine itself sublimes, making it difficult to characterize. Tea is an excellent source for Caffeine as the Caffeine can be steeped from the Tea Leaves with very few other interfering compounds. The Caffeine so isolated can then be extracted into an organic solvent and away from the Tannins that also steep from the Leaves. Once the organic solvent is stripped away, impure Caffeine remains. It can then be purified using sublimation.

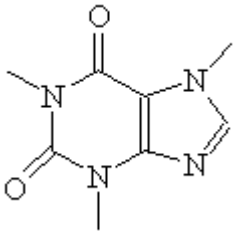
Some experts assert that the medical use of tea was reported as early as 2737 BC in the pharmacopeia of Shen Nung, an emperor of China. However, the first indisputable reference is from the Chinese dictionary of Kuo P'o, which appeared in 350 AD. The nonmedical use of tea appears to have spread slowly. Not until about 700 AD was tea widely cultivated in China. Since tea is native to upper Indochina and upper India, it must have been cultivated in these places before its introduction to China. It wasn't until 1660 that Tea became available in coffee houses in London.

Camellia sinensis **(http://en.wikipedia.org/wiki/File:Csinensis.jpg)**

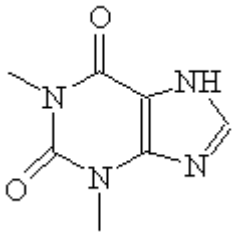
Cultivation of Tea involves harvesting the leaves at various stages in their development followed by oxidation, heating and blending of the leaves. Differences in processing produce a variety of types of Tea.

Type	Processing
White	Unwilted & Unoxidized
Yellow	As for White Tea but allowed to Yellow
Green	Wilted & Unoxidized
Oolong	Wilted, Bruised & Partially Oxidized
Black	Wilted, Crushed & Oxidized
Post-Fermented	Green Tea that Ferments or Composts

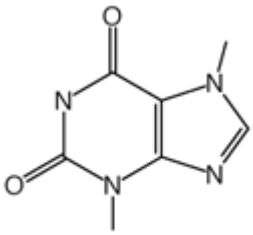
The active ingredients in tea are a group of structurally similar alkaloids, withCcaffeine being dominant amongst them. These methylxanthines (Caffeine, Theophylline, Theobromine) are found in varying amounts in tea, coffee, cola nuts, cacao beans, mate and other plants.



(caffeine)

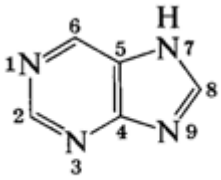


(Theophylline)



(Theobromine)

These alkaloids are based on the amine Purine:



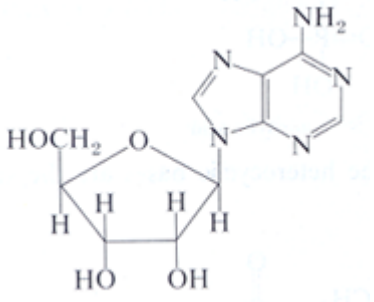
purine

Amounts of Caffeine in Various Products

	Serving	milligrams
Coffee	8 oz	80 - 185
Tea	8 oz	30 - 70
Coca-Cola	12 oz	45
Chocolate	6 oz	30 - 50
Vivarin	1 tablet	200

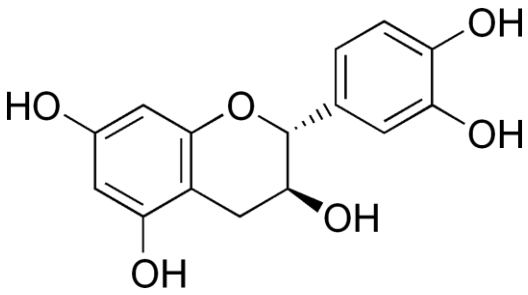
Caffeine was first isolated in 1821 by the French chemist Pierre Jean Robiquet, from coffee. In its pure state it is an intensely bitter white powder. Caffeine acts as a stimulant of the central nervous system, cardiac muscle and respiratory system as well as a diuretic. As such, it is found to delay fatigue.

Caffeine is thought to act on the brain by blocking adenosine receptors. Adenosine, when bound to receptors of nerve cells, slows down nerve cell activity; this happens, among other times, during sleep. The Caffeine molecule, being similar to Adenosine, binds to the same receptors but doesn't cause the cells to slow down; instead, the Caffeine blocks the receptors and thereby Adenosine action. The resulting increased nerve activity causes the release of the hormone Epinephrine, which in turn leads to several effects such as higher heart rate, increased blood pressure, increased blood flow to muscles, decreased blood flow to the skin and inner organs, and release of glucose by the liver.

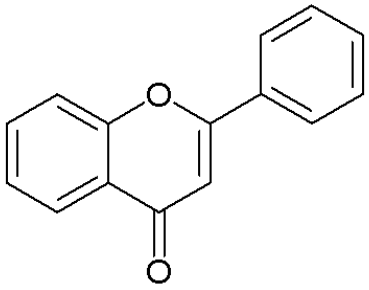


adenosine

In this experiment, Caffeine will be isolated directly from tea leaves. The chief problem with the isolation is that Caffeine does not exist alone in tea leaves, but is accompanied by other natural substances from which it must be separated. Caffeine constitutes as much as 5% by weight of the leaf material in tea plants and is water soluble. Unfortunately, Tannins in the tea leaf are also water soluble. The Tannins which steep from Tea leaves are in the form of Catechin and Flavonoid derivatives.



(Catechin)

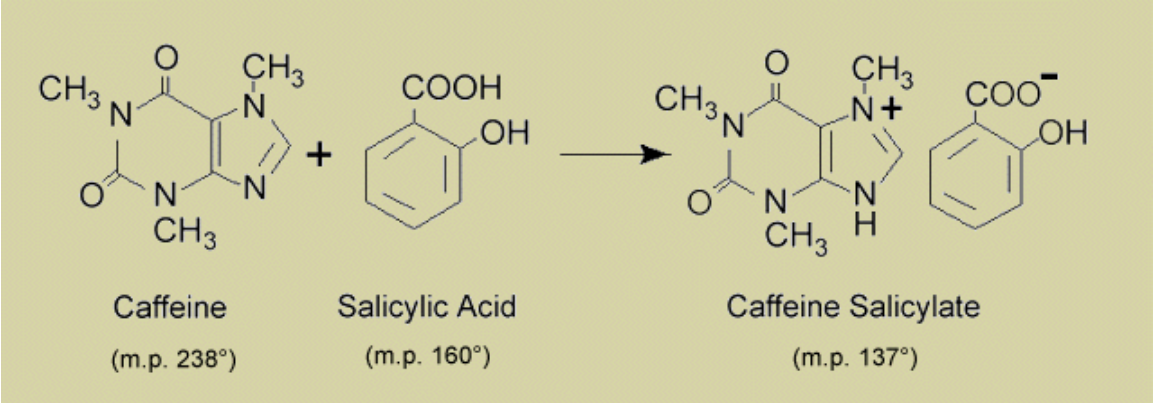


(Flavone)

Fortunately, Caffeine is soluble in polar aprotic solvents whereas the Tannins are soluble in protic solvents due to hydrogen bonding. Thus, we can carry-out the isolation of caffeine from tea leaves in the following steps:

1. Extract the Caffeine and Tannins into hot Water.
2. Extract the Caffeine into a non-polar organic solvent; Methylene Chloride.
3. Dry the Methylene Chloride of any remaining Water.
4. Evaporate the Methylene Chloride, leaving impure Caffeine.
5. Purify the Caffeine by sublimation.

Then, we will use the isolated Caffeine to prepare Caffeine Salicylate:



This is a rather straight-forward reaction between an Acid and a Base to form a Salt.

The product obtained is considered a Caffeine "derivative"; meaning it has a well defined melting point. This is important because the melting point of Caffeine is difficult to obtain; Caffeine sublimes as it melts. Hence, a better way of characterizing Caffeine is to prepare the Salicylate derivative and determine the melting point of this compound instead. Having a solid derivative which melts at the correct temperature strongly implies the starting compound was indeed correct.

Pre-Lab Questions

1. What is the pK_a of Phenol?

2. What is the pK_a of Purine?

3. What is the approximate concentration of a solution prepared by adding 1g Sodium Carbonate to 100 mL of Water. What is the pH of this solution? ($K_{b1} = 2.13 \times 10^{-4}$ for Sodium Carbonate)

4. What is the Theoretical Yield of Caffeine Salicylate if we start with 50 mg of Caffeine and an excess of Salicylic Acid.

Procedure

Week 1

1. Weigh the tea bag or tea leaves.

2. Heat 100 mL of water in a 250 mL beaker to 85^{o}C - 90^{o}C on a hot plate. When heated, suspend a tea bag by the string into the water for approximately 20 minutes. During this period, gently press the tea bag several times with the flat side of a spatula.

3. After 20 minutes, remove the tea bag, place it in a 50 mL beaker and squeeze it with the bent flat end of the spatula and add the drippings to the rest of the extract.

4. Remove the beaker from the hot plate and allow it to cool. Add 1 gram of Sodium Carbonate monohydrate to it. This is to convert Tannins to Phenoxides, which will remain in the aqueous phase during extraction of the caffeine.

   Phenolic Tannins + Sodium Carbonate $\longrightarrow$ Sodium Phenoxides

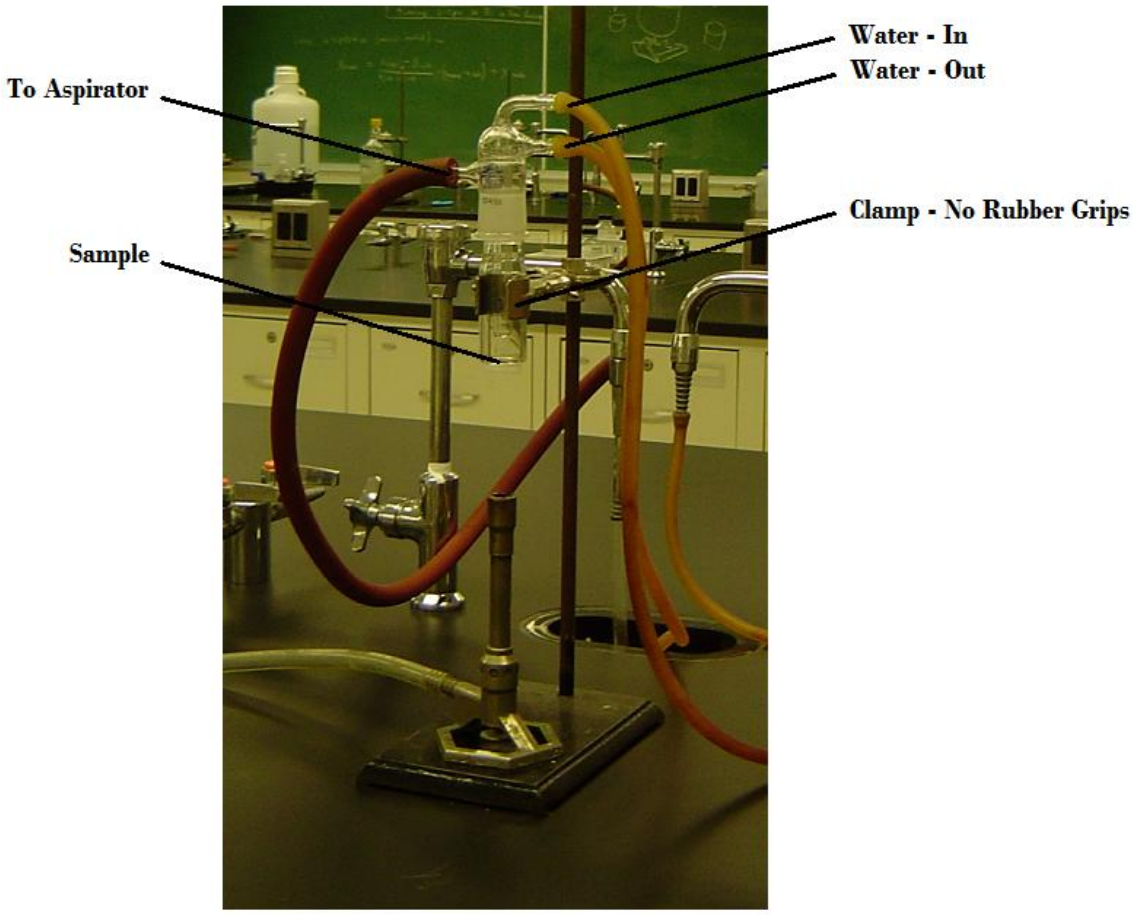
5. Set-up a ring stand and separatory funnel. Place 10 mL of Methylene Chloride in the funnel. Add the tea extract to the funnel, when the extract is cooled. Gently swirl the funnel for 5 minutes. Collect the Methylene Chloride layer; as this now contains the Caffeine. Repeat with an additional 10 mL portion of Methylene Chloride.

6. Transfer the extract into a micro distillation apparatus. Add a few boiling chips to the distillate. Remove the Methylene Chloride by distillation. Stop heating when a white precipitate first appears in the distilling flask.

   As an alternative, use the Rotovap to drive off most of the Methylene Chloride. Again stop when a white precipitate begins to form.

   Dispose of the Methylene Chloride in the appropriately labeled waste container.

7. Use a pipet to transfer the solution to the base of a sublimation apparatus.



8. Now evaporate the remaining Methylene Chloride using a warm heating mantle filled with a little Sand. Near the end of the evaporation allow the Methylene Chloride to boil so that vapor condensing on the wall of the tube washes all the deposited solid to the bottom of the tube.

9. When all the of the Methylene Chloride has been removed, the sublimation tube can be removed from the hood and the sublimation can be carried out using the aspirator vacuum and trap bottle system and water cooled cold finger. Heat cautiously with a small flame on a microburner.

10. Allow the Caffeine to dry until the next lab period.

Week 2

11. Measure the mass of the recovered caffeine.

12. Weigh out ~50mg of Caffeine. (If you do not have enough material from last week's isolation, you may supplement it with some from the chemical stores.) Place this in a small 25mL Erlenmeyer Flask.

13. Determine how much Salicylic Acid is required to react with this much caffeine and weight this out. Add it to the Caffeine.

14. Add ~0.5mL Dichloromethane (CH_2Cl_2) for every 10mg Caffeine to the Erlenmeyer Flask.

15. Heat the mixture to boiling and gently boil for ~5 minutes.

16. Crystallize the product using a "mixed solvent" crystallization. The ionic solid dissolves nicely in Dichloromethane, but not in Petroleum Ether. So, add Petroleum Ether until the solution is cloudy. Insulate the flask and allow the mixture to cool slowly to Room Temperature. Then chill it on Ice.

17. Collect the crystals using Vacuum Filtration.

18. Air dry the crystals.

19. Weigh the crystals and obtain a Melting Point.

20. Determine the Theoretical Yield and Percentage Yield of your product.

21. Compare the actual melting point to the literature value.

Post Lab Questions

1. What is a natural source of Salicylic Acid?

2. Salicylic Acid is classified as an Analgesic that is a precursor to Aspirin. Why is Salicylic Acid not used in place of Aspirin?

3. What is involved in the practice of "Freebasing" illicit Alkaloid drugs, such as Cocaine or Heroin? How is this practice related to our laboratory procedure?

4. Red Wine also has high levels of Tannins. What does this impart to the Wine?

5. The crude Caffeine we isolated had a green tinge to it. Why is this?