# INTRODUCTION

The following experiment deals with the isolation process of an essential oil from seeds by means of hydro-distillation technique. Hydro-distillation is a method of distillation employing boiling water to extract essential oils from certain raw materials. Hydro-distillation is so far becoming the cheapest and most general distillation method employed in the isolation of essential oils from plant materials.

In practice, the raw material is soaked in water, then the mixture is heated to boiling and the distillates are collected after being cooled in the condenser. Due to polarity difference between isolated essential oils and water, the essential oils normally do not mix with water and accordingly separate from the water layer. Separation of the oils by means of an external separating funnel would result in the production of crude essential oils. Further purification technique is often required to obtain pure components present in the isolated essential oils.

The plant material used in this experiment is the fruit and the seed of *Myristica fragrans* Houtt, an evergreen tree, native of the East Moluccas, Indonesia. The seed of plant is known as 'nutmeg' and attached with arillus (specialized covering of a seed that partly or completely covered the seed), and is used for flavoring food and medicinal purposes. In this experiment, the participants will perform the following experiments related to "nutmeg and hydro-distillation".

In this competition, you will perform the experimental procedure that will be used to answer all the questions in Physics, Biology and Chemistry. Read each step of the procedure thoroughly and carefully.

**The hydro-distillation apparatus consists of:**

1. Electric stove
2. Three-necks cylindrical boiling flask
3. Glass Allihn Condenser, Ball Shape Column
4. Modified Dean-Stark apparatus connected to Condensor equipped with water inlet and outlet
5. Rubber tubing (not shown)
6. Stand
7. Clamp holder
8. Clamp universal
9. Water bucket (not shown)
10. Aquarium pump (not shown)
11. Thermometers
12. 600 mL glass beaker (not shown)

**The supporting equipment consists of:**

a. 10 mL volumetric (graduated) cylinder
b. Plastic funnel
c. Sample tube
d. Cutting board
e. Gloves
f. Magnifying glass
g. Goggles
h. Rubber Stopper

**Materials:**

a. Nutmeg fruit
b. Nutmeg seed powder
c. Water
d. Boiling stone

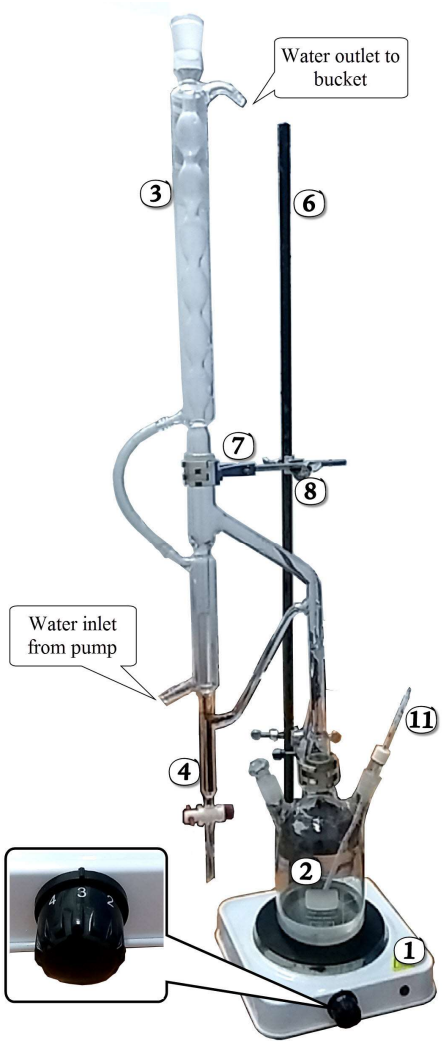


Figure 1. Hydrodistillation Apparatus, will be used to isolate nutmeg oil from nutmeg seeds

## Experimental Procedure

1. Make sure that the experimental equipment has been installed properly.
2. Fill the flask with 400 mL of water. Put the thermometer into the flask. Ensure that the tip of thermometer does not touch the bottom of the flask.
3. Turn on the electric stove (adjust the power of the electric stove to setting number 3) and at the same time push the stopwatch START button. ***BE CAREFUL. DO NOT TOUCH THE ELECTRIC STOVE PLATE.*** **The stove is equipped with automatic ON-OFF to maintain the temperature and to prevent overheating.**
4. Record the temperature of the water every 0.5 minute up to 12 minutes. Write the data on the answer sheet. After an interval of 12 minutes turn off the stove, and turn off the stopwatch.
5. Take the thermometer out and replace with cap provided.
6. With the water still in the flask, add more water up to 500 mL. Pour nutmeg powder that has been provided (120 grams) to the flask by using a funnel that has been provided. Add 3-5 pieces of boiling stone provided to the flask as well.
7. Turn on the electric stove, adjust the power to maximum setting (setting number 5). Continue heating until 90 minutes. Use stopwatch provided.
8. While waiting the 90 minutes, answer the **PART ONE: Physics, The effectiveness of energy absorption by water** questions on the answer sheet.
9. After you finish working on the problems of PART ONE, continue to work on **Biology experiments** as follows.
10. On the table you have been provided with a nutmeg fruit (including seed), the longitudinal and cross sections of nutmeg fruits and seeds.
11. Examine the nutmeg fruit and its parts carefully.
12. Examine the longitudinal and cross sections of fruit and seed and their parts.
13. Answer **PART TWO**: **Biology, Characteristics of Nutmeg** questions on the answer sheets provided.
14. After 90 minutes heating of the flask, turn off the electric stove. Measure the volume of nutmeg oil that has been produced in the Dean-stark. You may have to wait a while until the nutmeg oil is separated from water.

15. Transfer the entire collected nutmeg oil in the sample tube provided, close it, label it and leave it together with your answer sheets. Write your team code on the label provided and stick it to the sample tube.
16. Answer **PART THREE: Chemistry, Nutmeg Oil Distillation** questions on the answer sheets provided.

# QUESTIONS

## PART ONE: Physics, The effectiveness of energy absorption by water [13 point]

Transitions between solid, liquid, and gaseous phases typically involve large amounts of heat absorbed. If heat were added at a constant rate to a mass of ice to take it through its phase changes to liquid water and then to steam, the energies required to accomplish the phase changes (called the latent heat of fusion and latent heat of vaporization) would lead to plateaus in the temperature vs time graph. The graph below (Figure 1) presumes that the pressure is one standard atmosphere.

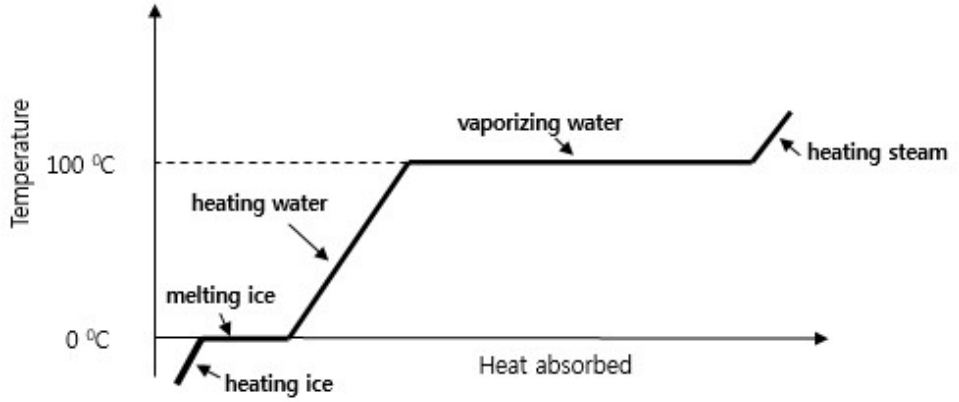


Figure 1. Graph of temperature versus heat absorbed

**Ph-1 [3.0 points]** Make a graph of the temperature (°C) of water as a function of time (in minute).

**Ph-2 [1.5 points]** Determine the linear range of water temperature change ($\Delta T$) and time change ($\Delta t$).

**Ph-3 [2.0 points]** Calculate the rate of change of temperature of water (in °C/s) with respect to time by using the linear part of the graph (which means linear process in water).

**Ph-4 [2.0 points]** Calculate how much electrical energy (in Joule) is used within the linear part of the graph (electric power used by the stove is 600W).

**Ph-5 [1.5 points]** Calculate how much heat (in Joules) is used to increase the temperature of the water in the linear part of the graph. (Note that $c_{water}$ = 4180 J/kg.°C and ρ = 1000 kg/m$^3$).

**Ph-6 [1.5 points]** Calculate how much heat (in Joule) is released into the environment within the linear part of the graph.

**Ph-7 [1.5 points]** Calculate the percentage of energy used to raise the temperature of water with respect to the total energy of the stove within the linear part of the graph.

## PART TWO: Biology, Characteristics of Nutmeg [13 points]

### A. Nutmeg Fruit

**Bi-1 [2.0 points]** Draw the longitudinal section of the fruit with the seed intact.

**Bi-2 [3.0 points]** Label parts of the fruit with reference provided on the answers box.

Show the fruit parts by arrows. Choose the corresponding parts from the answers box and write down the answer by writing the letter only (for example A, B, C etc.).

### B. Nutmeg Seed

**Bi-3 [3.0 points]** Draw the cross section of the seed.

**Bi-4 [2.0 points]** Label parts of the seed with reference provided on the answers box.

Show the seed parts by arrows. Choose the corresponding parts from the answers box and write down the answer by writing the letter only (for example A, B, C etc).

**Answers Box**

| | | | |
|---|---|---|---|
| A. Receptacle | E. Locule | I. Seed | M. Embryo |
| B. Mesocarp | F. Nucellus | J.Testa/Seed Coat | N. Exocarp |
| C. Peduncle | G. Endosperm | K. Arillus | O. Placenta |
| D. Perisperm | H. Endocarp | L. Funiculus | P. Hypanthium |

### C. Nutmeg Fruit and Seed Characteristics

**Fruit and Seed Classification:**

| | | |
|---|---|---|
| Simple fruit | : | A fruit that develops from a single pistil |
| Compound fruit | : | A fruit in which one flower contains several separate ovaries which merge during development (aggregate) or a fruit in which several flowers, each with an ovary, develop into small fruits that are clustered or fused together into a larger fruit (multiple) |
| True fruit | | A fruit in which all tissues are derived from a ripened ovary and its contents |
| Accessory fruit | : | A fruit that develops from a ripened ovary or |

| | | |
|---|---|---|
| | | ovaries but includes a significant portion derived from non-ovarian tissue |
| Fleshy fruit | : | A fruit that has a soft and pulpy wall at maturity |
| Dry fruit | : | A fruit that has a dry wall at maturity |
| Pome | : | A fruit that derived from several carpels, receptacle and outer portion |
| Drupe | : | A fruit that derived from a single carpel and containing (usually) one seed |
| Monocotyledon | : | Having a single cotyledon in the seed |
| Dicotyledon | : | Having two cotyledons in the seed |
| Round | : | Having the shape of a sphere or ball |
| Ovoid | : | Egg-shaped with the broader end at the base |

**Bi-5 [3.0 points]** Examine the fruit and the seed carefully. Tick (√) one correct answer on each classification categories (A-F) in the box provided below.

| **Question:** | **Answer:** | |
|---|---|---|
| A. Fruit origin: | ☐ Simple fruit | ☐ Compound fruit |
| B. Fruit composition: | ☐ True fruit | ☐ Accessory fruit |
| C. Fruit description: | ☐ Fleshy fruit | ☐ Dry fruit |
| D. Fruit type: | ☐ Pome | ☐ Drupe |
| E. Seed cotyledon: | ☐ Monocotyledon | ☐ Dicotyledon |
| F. Seed shape: | ☐ Round | ☐ Ovoid |

**PART THREE: Chemistry, Nutmeg Oil Distillation [14.0 points]**

After conducting experiment by using 120 g of ground nutmeg seed, you have obtained certain amount of nutmeg oil.

**Ch-1 [4.50 points]** How much is the volume of nutmeg oil you have obtained?

**Ch-2 [1.50 point]** It is known that the mass of exactly 1.00 mL of nutmeg oil is 0.862 g at 25 $^{o}$C. What is the percentage by mass of nutmeg oil in nutmeg seed according to your experiment if it is measured at 25 $^{o}$C?

**Ch-3 [3.00 point]** It is known that the main component of nutmeg oil is myristicin. Assume that your sample of nutmeg oil contains 65% of myristicin ($C_{11}H_{12}O_3$) by mass.

**(a) [1.5 point]** Calculate the number of myristicin molecules in your sample.

**(b) [1.5 point]** Calculate the mass of the carbon in grams in the myristicin in your sample. (atomic mass of C = 12, H = 1, and O = 16)

**Ch-4 [1.00 point]** Based on the result of your experiment, calculate how many kilograms of nutmeg seed powder are required to produce 100 grams of nutmeg oil?

**Ch-5 [0.50 point]** What is the function of boiling stones added in your experiment?
(a) to accelerate the heating of water
(b) to speed up the separation of nutmeg oil from water
(c) to assist the distribution of heat inside the cylindrical flask content.

**Ch-6 [0.50 point]** What is the main aim of using nutmeg seed powder rather than nutmeg seed granules in your experiment?
(a) to increase the solubility of nutmeg seed in water
(b) to increase the contact surface of nutmeg seed and water
(c) to speed up the evaporation of water in the flask.

**Ch-7 [0.75 point]** The separation of water and nutmeg oil in the Dean-Stark apparatus reflects the principle of .....
(a) like dissolves like
(b) vapor pressure difference
(c) chemical equilibrium.

**Ch-8 [0.75 point]** If the flow of cooling water in your experiment is changed from upper to lower part of the condensor, the condensation of the steam and nutmeg oil will be .....
(a) more effective
(b) less effective
(c) no effect.

**Ch-9 [0.75 point]** Which of these following alternative separation techniques can be used to obtain nutmeg oil from the seed of nutmeg
(a) Centrifugation
(b) Solvent extraction
(c) Paper chromatography

**Ch-10 [0.75 point]** What kind of changes in the experimental design would not reduce the yield of nutmeg oil
(a) Heating too rapidly
(b) Using more boiling stones
(c) Using too short water condensor

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