



Dr. Bbosa Science

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Immiscible liquids

These are liquids that do not form a uniform solution but separate into two layers when mixed.

For these liquids, the total vapor pressure (P_t) is the sum of the vapor pressure of individual components at that temperature.

$$\text{i.e. } P_t = P_A^0 + P_B^0 \text{ where } P_A^0 \text{ is the vapor pressure of component A}$$

It implies that the vapor pressure of the mixture is usually higher than that of either components and thus the boiling point of the mixture is lower than that of either component.

NB: a liquid boils when its vapor pressure equals that of the atmospheric pressure.

Steam distillation

It is a technique of separating a volatile liquid/substance that is immiscible with water from nonvolatile component at temperature below its boiling point by bubbling steam through the mixture

Principles of separation of mixtures by steam distillation

The substance to be separated by steam distillation should

- be volatile to separate as vapor from nonvolatile substance,
- has relatively high molecular mass to give reasonable amount in distillate
- immiscible with water to be separate from the distillate using a separating funnel and
- mixed with other nonvolatile components.

Since the components and water are immiscible, at any given temperature, each contributes its own vapor to the total vapor pressure of the mixture.

So the total vapor pressure of the component and water will be higher than that of either component and thus boils at a lower temperature than that of either water or the component.

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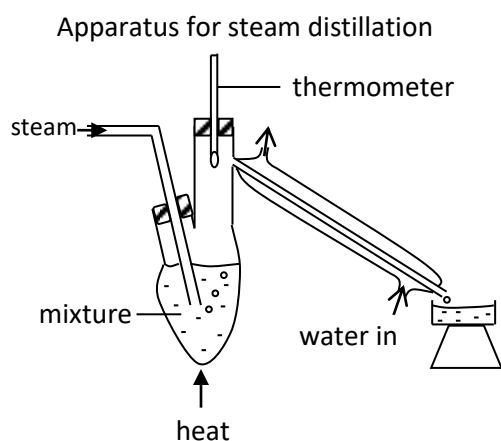
Components that can be separated by steam distillation include: amino benzene, nitrobenzene, chlorobenzene, bromobebzene, e.t.c.

Advantages of steam distillation

- Distillation occurs at a temperature below the boiling point of either that of the component or that of water. This is useful if the organic compound is liable to decompose at temperature near its normal boiling point.
- used to determine the relative molecular mass of substance

Disadvantages of steam distillation

- The distillate will be a mixture of water and the organic liquid, thus another method of separation is required such as a separating funnel. i.e., it is not a complete separation method.



Composition of steam distillate

The ratio of the amount of the substance to that of water in the distillate is equal to the ratio of their vapors. If P_A^0 , P_w^0 are vapor pressure of A and water and n_A , n_w are the moles of A and water in volume V of the distillate, then

$$P_A V = n_A RT$$

$$P_w V = n_w RT$$

$$\text{and } \frac{n_A}{n_w} = \frac{P_A}{P_w}$$

If m_A and m_w are the masses and M_A and M_w are the molar masses of A and water respectively, then

$$\frac{m_A/M_A}{m_w/M_w} = \frac{P_A}{P_w}$$

Taking 100g of the distillate

$$\frac{\%A}{\%water} = \frac{P_A^0 \times M_A}{P_w^0 \times M_{Aw}}$$

But %water 100 - %A

Example 1

- (a) Aniline (nitrobenzene) is prepared in laboratory by the reduction of nitrobenzene using tin and hydrochloric acid. the mixture is then treated with sodium hydroxide and aniline isolated by steam distillation.
- What is meant by term steam distillation?
 - Describe briefly how you would perform steam distillation in the laboratory and draw a labeled diagram of the apparatus required (5marks)
 - What is the advantage of using steam distillation to isolate aniline? (2marks)
- (b) At 760mmHg the steam distillation of a certain liquid of molecular mass 45 takes place at 96°C. If the vapor pressure of water at the same temperature is 658mmHg; calculate the composition of the distillate as a percentage by mass.

Solution

$$P_{liquid}^0 = 760 - 658\text{mmHg} = 102$$

Let x be the percentage by mass of the liquid in the distillate, then the percentage of water = 100-x

$$\text{since, } \frac{\%liquid}{\%water} = \frac{P_{liquid}^0 \times M_{liquid}}{P_w^0 \times M_{Aw}}$$

$$\text{then, } \frac{x}{100-x} = \frac{102 \times 45}{658 \times 18}$$
$$x = 27.93\%$$

Therefore, percentage of a liquid in distillate =27.93

Trial 1

X was steam distilled at 70°C and 760mmHg. The distillate was found to contain 87.5% by mass X. (The vapor pressure of water at 70°C is 234mmHg). Calculate the formula mass of X

Trial 2

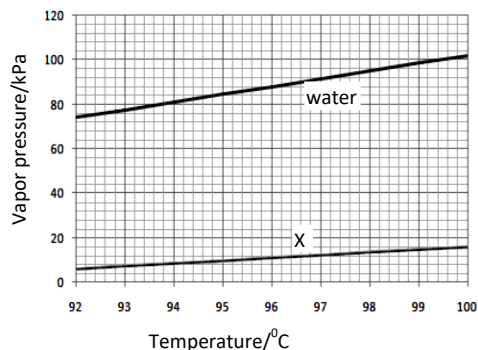
When substance Y was steam distilled at 93°C and 750mmHg, the distillate contained 55% of Y by mass. Calculate the relative molecular mass of Y. (the partial vapor pressure of water at 93°C is 694mmHg)

Trial 3

- (i) Explain the process of steam distillation (diagram no required) (5marks)
 - (ii) Name one compound that can be isolated by steam distillation (1mark)
- (c) When a compound Y was steam distilled at standard pressure, the distillation temperature was 86°C. The vapor pressure of water is 740mmHg. The distillate contained 85% by mass of water. Calculate the relative molecular mass of Y (4marks)

Trial 4

The vapor pressures of water and of an immiscible liquid X at different temperatures are given below



- (a)(i) Construct on the figure above the vapor pressure curve for a mixture of water and X (1mark)
(ii) At what temperature will the mixture boil at the following pressures (1mark)
- (b) After distilling at 101kPa pressure for some time the distillate was found to consist of 1.00g of water and 0.480g of X. By using the graph in the figure or otherwise calculate the relative molecular mass of X (3marks)
- (c) How will the composition of the distillate change if any during distillation (1mark)

Trial 5

The vapor pressures (V.P) of water and of an immiscible liquid A at different temperatures are given in the table below:

Temp/°C	92	94	96	98	100
V.P of X/kPa	6	8	12	15	17
V.P. of H ₂ O/kPa	74	80	88	94	101

- (a) On the same axes, plot graphs of vapor pressure against temperature (4marks)
- (b) (i) Determine the vapor pressures of the mixture of X and water at the same temperature given in the table. (02marks)
(ii) On the same axes of the graph in (a), plot a graph of the vapor pressure of the mixture versus the temperature (2marks)
- (c) The distillate obtained from the mixture at 101kPa contained 1.6g of water and 1.1g of X. Calculate the relative molecular mass of X using the information from the graph (5marks)
- (d) (i) Explain the principles in the separation of mixture by steam distillation (5marks)
(i) State any two advantages of steam distillation (2marks)

Trial 5

- (a) (i) What is meant by steam distillation?
(ii) Draw a diagram of a setup of the apparatus that can be used to purify steam distillation (03marks)
- (b) (i) state three properties of a substance that enable it to be purified by steam distillation (03marks)
(ii) Explain how the properties you have stated in (b)(i) enable the substance to be purified by steam distillation (04marks)

(iii) State the advantages of isolating substances by steam distillation. (02marks)

(c) The vapour pressure of water (VP_{H_2O}) and that of substance A (VP_A) at different temperatures are given in the table below

Temperature / $^{\circ}C$	20	40	60	80	100
VP_{H_2O} (atm)	0.22	0.26	0.30	0.35	0.39
VP_A (atm)	0.35	0.42	0.49	0.56	0.63

- (i) On the same axes, plot graphs of vapour pressure against temperature for water and substance A.
(ii) When substance A was distilled in steam at 1 atm. pressure, the temperature of distillation was $97^{\circ}C$, and the distillate obtained contained 4.29g of substance A and 1.1g of water. Using your graph in c(i), calculate the relative molecular mass of substance A. (04marks)

Trial 6

When an amine, Z was steam distilled at $98.6^{\circ}C$ and 760 mmHg pressure, the distillate contained 25g of water and 7.4g of Z. calculate the relative formula mass of Z.(the vapor pressure of water at $98.6^{\circ}C$ is 720mmHg).

Trial 7

- (a) When 4.90g of an organic compound X containing carbon and hydrogen only was burnt in oxygen 15.78g of carbon dioxide and 5.38g of water were formed. Calculate the empirical formula of X. (2 ½ mark)
(b) X was steam distilled at $80^{\circ}C$ and 760mmHg and the distillate was found to contain 90.8% by mass X. (The vapour pressure at $80^{\circ}C$ is 240mmHg)
(i) calculate the formula mass of X (2 ½ marks)
(ii) Deduce the molecular mass of X.

Trial 8

- (i) Explain what is meant by the term steam distillation (3marks)
(ii) When a compound Y, was steam distilled at standard temperature, the temperature of distillation was $96^{\circ}C$. The vapour pressure of water at this temperature was 730mmHg and the distillate contained 74% of water.
Calculate the relative molecular mass of Y (04marks)

Suggested answers

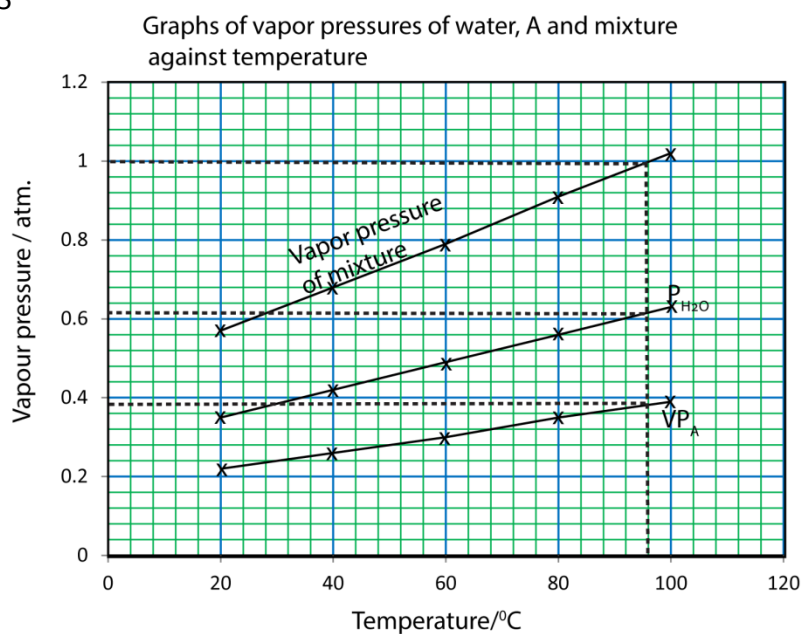
Trial 1: 56

Trial 2: 273

Trial 3: 118

Trial 4: 70.7

Trial 5



(ii) 130

Trial 6: 192

Trial 7: 82

Trial 8: 154