THE DEPENDENCE OF VAPOUR PRESSURE ON TEMPERATURE - DISTILLATION

INTRODUCTION

Per the phase rule, the number of degrees of freedom increases with an increase in the number of components in the system. A system composed of a mixture of two liquids and vapour remaining in equilibrium with the mixture has two degrees of freedom. This equilibrium may be presented graphically in a system of two coordinates if the other parameters remain constant.
The dependence found between the parameters: temperature (*T*), pressure (*p*), the mole fraction of the liquid (*x*), and the mole fraction of the components in the gaseous phase (*y*) may be investigated in the following coordinates:

$p(x)_T$	-	The dependence of pressure of the saturated vapour on the composition of the liquid under isothermal conditions
$T(x)_p$	-	The dependence of boiling point of the solution on its composition under isobaric conditions
$y(x)_T$	-	The dependence of the vapour composition on the composition of the liquid at constant temperature
$y(x)_p$	-	The dependence of the vapour composition on the composition of the liquid at constant pressure

According to ***Dalton's law,*** total vapour pressure *p* in the headspace of the solution of liquids A and B comprises partial pressures of vapour components p_A and p_B.

$$p = p_A + p_B \tag{1}$$

Considering respective mole fractions y_A and y_B of components A and B in the vapour, we may state:

$$p_A = py_A \quad \text{and} \quad p_B = py_B \tag{2}$$

In the case when liquids A and B produce an ideal solution the quantitative dependence of pressure of saturated vapour of a substance on its concentration in a liquid under isothermal conditions $p(x)_T$ is defined by ***Raoult's law***. For two-component solutions we obtain the following relationships:

$$p_A = p_A^0 \cdot x_A \quad \text{and} \quad p_B = p_B^0 \cdot x_B \tag{3}$$

where p_A^0, p_B^0 denote pressures of vapours of substances A and B in the pure state.

In view of the equation

$$x_A + x_B = 1 \tag{4}$$

These equations lead to the following linear dependence:

$$p = p_B^0 + x_A(p_A^0 - p_B^0) \tag{5}$$

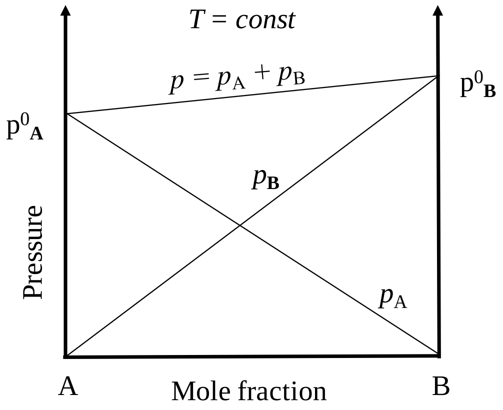


Fig. 1 Total and partial pressures of vapours in the headspace of ideal solutions.
The coordinate system $p(x)_T$

As mentioned above, the composition of vapour, usually, differs from the composition of a liquid, which may be presented in a *phase equilibrium diagram* (Fig. 2)

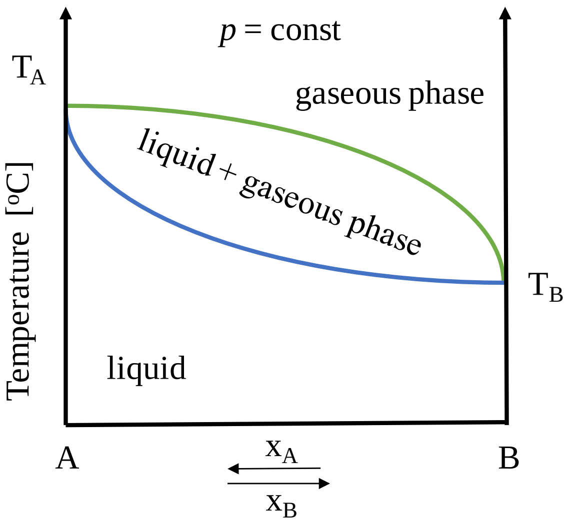


Fig. 2 The phase equilibrium diagram for ideal solutions.

The boiling point of a solution depends on its composition and changes along the curves referred to as the *boiling curve*. The line defining the composition of a vapour in the headspace of a respective liquid in an equilibrium of both phases is called the *dew point curve.*
Based on such diagrams we may predict the composition of a liquid and vapour at specific temperature and pressure conditions, which is relevant for the distillation technology applied to purify and separate mixtures.

OBJECTIVE OF THE TASK

The objective of this task is to determine distillation curves for a two-component system - the composition of the solution and the composition of vapours in the headspace as a function of boiling point.

APPARATUS, GLASSWARE

1. an Abbe refractometer
2. glassware for boiling point measurements:
    - a distillation flask,
    - a distillation column - a condenser with a thermometer port,
    - a thermometer.
3. a stand with a clamp and a connector
4. an electric heating mantle
5. a syringe to collect samples of condensate
6. a 2 cm^3 pipette
7. a 50 cm^3 graduated beaker
8. boiling chips
9. a porcelain cuvette
10. a fixing clip
11. a Petri dish
12. protective gloves

REAGENTS

1. Samples (7) composed of mixtures of chlorobenzene and acetone at varying proportions.

EXPERIMENT PROCEDURES

1. *Measurement of refraction index.*

Measure refraction indexes for seven samples (samples 1 and 7 are pure substances: chlorobenzene and acetone). Repeat each measurement of the refraction index 3 times and use the mean in calculations (**reading accuracy to 3 decimal places**).

2. *Measurement of boiling point*

- pour approx. 20 cm^3 of a respective mixture to a flask,
- fix the flask to the distillation column and secure it with a clip,
- turn on the faucet with feed water to a condenser,
- turn on the heating mantle,
- read each boiling after the reading on the thermometer stabilises,
- take successive measurements of boiling points.

The range of boiling points of 56°C - 132°C.

3. *Measurements of refraction indexes of condensates.*

During each distillation process wait until the boiling point stabilises, then collect a sample of the condensate through a condenser using a syringe in order to measure the refraction index and thus determine the composition of the condensate at a given boiling point.

4. *After each distillation:*

Set the heating to zero, lift the glassware up the stand, wait until boiling stops completely, and pour the warm solution back into the bottle, from which the sample was collected.
The next sample needs to be poured into a dry flask - remember to provide new boiling chips!!!

CAUTION!!!

Handle the provided samples with care (highly flammable mixtures)!

PREPARATION OF RESULTS

1. Using the standard curve (attached at the end of the instruction) determine the composition of original samples and condensate samples.

2. Based on the obtained results (which need to be presented in a table) draw distillation curves in the coordinate systems of temperature-mole fractions of used components.

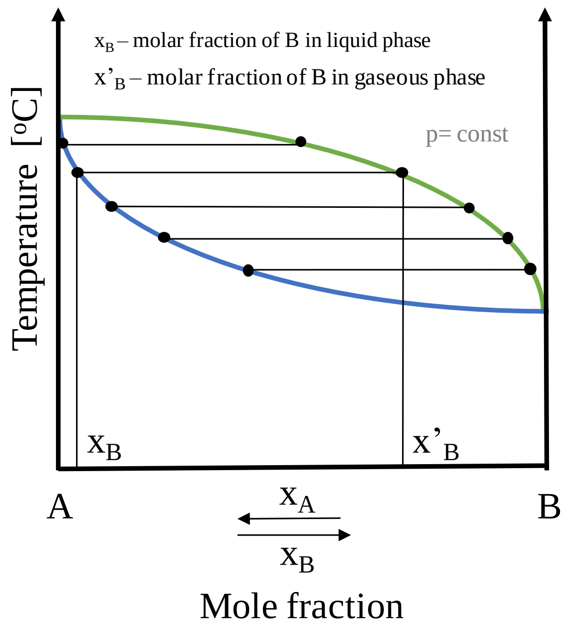
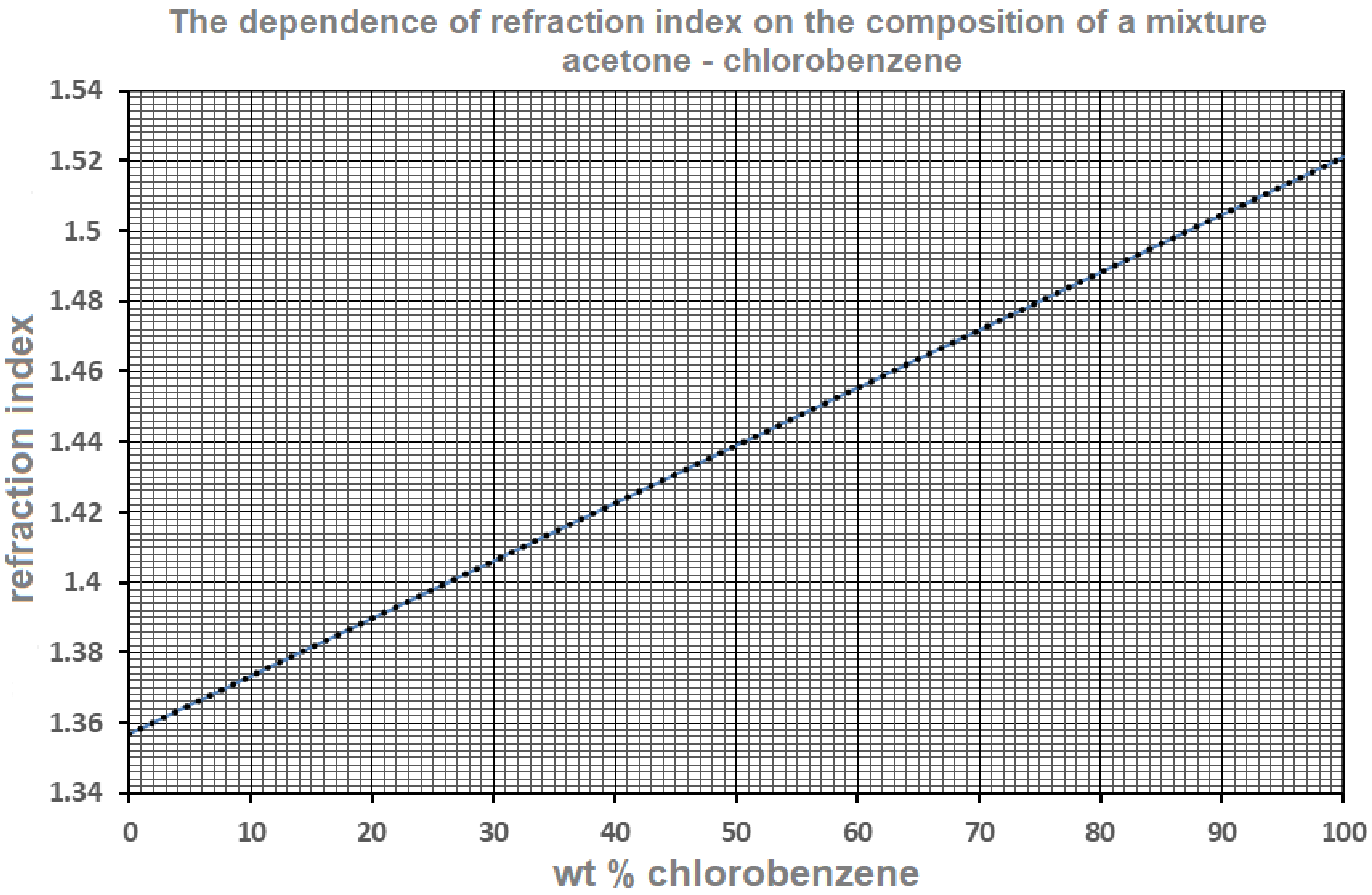


Fig. 3. An example phase equilibrium diagram based on recorded measurements


The dependence of refraction index on the composition of a mixture
acetone - chlorobenzene
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
refraction index
0
10
20
30
40
50
60
70
80
90
100
wt % chlorobenzene

Template of the table and draft of the study

……………………………... *Faculty* ………………………………. *Field of study* *Full-time/ part-time studies*	……………………………………………… *Name and surname*	…………………………………... *Date:*
Group no.: ………………… *Team no.:* …………………	………..…………… *Exercise no.:*	……………………………………. *Instructor:*

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Nr grupy: …………………... *Nr zespołu:* ………………….	………..…………… *Nr ćwiczenia:*	……………………………………. *Nazwisko Prowadzącego:*

1. Temat ćwiczenia
2. Cel ćwiczenia:
3. Wstęp teoretyczny:
4. Pomiary:
5. Obliczenia:
6. Wykresy:
7. Wnioski

1. Exercise title:
2. The aim of the exercise:
3. Theoretical introduction:
4. Results:
5. Calculations:
6. Graphs:
7. Conclusions: