DDR Vapour Pressure and Evaporation Cooling of Pure Organic Liquids

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Introduction:	17 May 2021, 13:00 Uhr, HCI J 296	*matthias.buetikofer@phys.chem.ethz.ch*

Aims

Measurement of index of refraction n_D and density ρ of two pure organic solvents. Comparison with literature data to verify the identity of the substances.
Measurement of the boiling temperature of solvents at different pressures. Vapour pressure diagram with model functions. Determination of the enthalpy and entropy of vaporization and of the normal boiling temperature. Comparison with literature data.
Measurement of the evaporation cooling with small drops of liquids. Determination of the enthalpy of vaporization from the transient cooling curves.

How to prepare to the introduction

Read the chapter *Dampfdruck* in the praktikum book and the handout *VerdunstungskÃ¼hlung* and mark questions that you would like to discuss with the assistant. Get the relevant physico-chemical and risk information about the substances to be used.

Experiments

Lab journal: You maintain a perfect lab journal (bounded journal, no loose pages). A copy of this lab journal is part of the report and will be marked.

Substances:

You will investigate the following pure solvents:

(a) **ethanole** und (b) **n-hexane**

Please keep the solvent containers closed as to avoid high and irritating concentrations of organic solvents in the ambient air!

Measurements:

Verification: Of both pure solvents measure the refractive index n_D (using the Atago Digital Refractometers) and the density ρ (using the Paar Density Meter), both at 20 °C. Additionally, determine the densities at ambient temperature by weighing 25 mL of the liquid (apply temperature correction and buyoancy correction), also calculate the estimated uncertainty.

Vapour pressure measurements: Measure the boiling temperature of the pure solvent ethanole at pre-setted pressures, according to chapter 1.2.2 in the praktikum book. At least 30 points have to be taken. Record all data clearly in the lab journal.

Transient evaporation cooling: Following the instructions carefully inject 5 μL of liquid on the temperature sensor of the TREVAC apparatus to obtain a transient cooling curve. Measure at least 3 curves of both liquids ethanole and n-hexane and additional at least 4 curves of the reference liquid methanol.

Data processing and graphs

1. Verify your experimental data of refractive index and density of ethanole and n-hexane with literature data by drawing them in the n_D,ρ data sheet. Briefly describe in your report the principles that have been used to determine these data.

2. Using your experimental pressure-temperature data of the solvents calculate, with nonlinear regressions, the substance parameters $\Delta_v H$ and T_0 and further A, B and C in both of the model functions

- $p = 1013.25\,\text{mbar} \cdot e^{\Delta_v H/(RT_0)} e^{-\Delta_v H/(RT)}$ (Clausius-Clapeyron equation)
- $p = 1\,\text{mbar} \cdot 10^{A-B/(\theta+C)}$ (Antoine equation)

including standard deviations. Good starting values for the regression parameters have to be provided when using the `nls()` regression function of R. Calculate $S = 95\%$ confidence intervals to report the parameters.

3. With the Clausius-Clapeyron model parameters calculate the molar entropy of vaporization $\Delta_v S = \Delta_v H/T_0$ of both solvents.

   In a table, summarize the quantities T_0, $\Delta_v H$ and $\Delta_v S$ of both solvents with their respective $S = 95\%$ confidence intervals and with literature data. Be aware of a correct presentation of the results! Explain what exactly is meant by the term enthalpy of vaporization!

   (Note that the choice of $p_0 = 1013.25\,\text{mbar}$ (= 1 atm, 'normal pressure') in the Clausius-Clapeyron model yields directly the normal boiling temperature T_0.)

4. Prepare graphs that show the experimental boiling data p/mbar vs. $\theta/\,^\circ\text{C}$ of the solvents. Add the calculated vapour pressure curves to these figures, according to the Clausius-Clapeyron fit and the Antoine fit. Add the normal boiling point as determined above.

5. Prepare a graph that shows the linearized experimental boiling data, *i.e.* $\ln(p/1013.25\,\text{mbar})$ vs. $1/T$ (in K^{-1}), of both solvents. Draw the appropriate straight lines, according to the Clausius-Clapeyron equation, through the data. What is the significance of the slope?

6. Plot the cooling curves of all TREVAC experiments (with identical time and temperature scales for mutual comparison) and determine the area under each peak. Evaluate the enthalpy of vaporization of ethanole and n-hexane as explained in the handout. Give a description of the cooling curves and discuss peculiarities.

Literature

[1] E. Meister, Grundpraktikum Physikalische Chemie, 2. Aufl., vdf Hochschulverlag AG, an der ETH, ZÃ¼rich, 2012

[2] References with liquid-vapour data compilations see practicum book [1] on page 40. These references are accessible at the D-CHAB infocenter.

Lab report

Write a report that should not exceed 6 pages. Additional figures and tables can be added in the appendix. Please add to your report: This task list, copies of your lab journal, program codes used to evaluate the data.

Deadline of submission: 5 June 2021.