UNIVERSITI PUTRA MALAYSIA

TTHERMAL EFFUSIVITY AND REFRACTIVE INDEX OF OIL-ALCOHOL MIXTURES

FIRAS KAMEL MOHAMAD AL-ASFOOR

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By

FIRAS KAMEL MOHAMAD AL-ASFOOR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

May 2009

DEDICATION

To my dearest parents, my wife and my son

for their supports and concern……

To my supervisors

Prof. Dr. W. Mahmood Mat Yunus, Prof. Dr. Mohd. Maarof Moksin
and
Assoc. Prof. Dr. Azmi Zakaria

for their guidance and kindly advice…

To all my Family and friends

for their assistance and supports…

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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May 2009

Chairman: Professor W. Mahamood Mat Yunus, PhD

Faculty: Science

The open photoacoustic cell technique has been used for thermal effusivity measurements on pure liquids and liquid mixtures. The thermal effusivity was determined from the captured photoacoustic signal amplitude as a function of modulated frequency. The chosen samples for liquids were ethanol, methanol, glycerol, virgin olive oil, virgin coconut oil and distilled water. The thermal effusivity values which were obtained for these liquids were in the range from 0.0524 W $s^{1/2}$ K^{-1} cm^{-2} to 0.1522 W $s^{1/2}$ K^{-1} cm^{-2} with acceptable error about (± 0.041).

For oil- alcohol mixtures, two kinds of alcohol (ethanol and methanol) were mixed separately with two types of virgin oils and eleventh different percentages for each oil- alcohol mixture sets were obtained. Thermal effusivity values and the density of virgin olive oil-ethanol mixtures decreased with the increasing of ethanol composition in the mixture. The thermal effusivity values for virgin oil- ethanol mixture varied from 0.0524 W $s^{1/2}$ K^{-1} cm^{-2} to 0.0589 W $s^{1/2}$ K^{-1} cm^{-2}, and the density

By using the minimum deviation method, the refractive index was determined for the samples. Distilled water was used to calibrate the experimental setup. The experiment was carried out at room temperature and a laser source with 632.8 nm wavelength was used. The refractive index of distilled water was 1.332 which is in good agreement with literature. Using the same laser source, the refractive indices of the mixture samples were measured. Virgin olive oil-ethanol mixtures has refractive index varied from 1.3597 to 1.4652. The refractive indices of virgin olive oil-methanol mixture varied from 1.3266 to 1.4564. The same method was used to measure the refractive index of virgin coconut oil-ethanol mixtures and it was found that these values varied from 1.3597 to 1.4524. The refractive index measurements were carried for virgin coconut oil-methanol mixtures and it was found that the refractive index values were varied from 1.3266 to 1.4524. In this study it was found that the refractive index for all the mixture samples decreased gradually while the alcohol percentage increased in the mixture.

The FTIR measurements ranging from 600 cm^{-1} to 4000 cm^{-1} were carried out to determine functional groups of the mixtures using Fourier Transform Infrared. Generally the FTIR spectra for all mixtures shows that the five important peaks explaining the stretching absorption due to aldehyde (C= O) and esters (C-O), bending absorption (methylene (CH_2) and methyl (CH_3) groups) and double bond absorptions (C= O) are strong in pure oils and oil- alcohol mixtures.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

EFUSIVITI TERMA DAN INDEK BIASAN CAMPURAN MINYAK-ALKHOL

Oleh

FIRAS KAKEL MOHAMAD AL-ASFOOR

May **2009**

Pengerusi: Professor W. Mahamood Mat Yunus, Ph. D.

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Teknik fotoakustik sel terbuka telah digunakan untuk mengukur efusiviti terma cecair tulen dan campuran cecair. Efusiviti terma ditentukan daripada penangkapan amplitud signal fotoakustik sebagai fungsi kepada frekuensi modulasi. Sampel yang dipilih ialah etanol, metanol, gliserol, minyak zaitun dara, minyak kelapa dara dan air suling. Nilai efusiviti terma yang diperolehi untuk cecair tersebut adalah dalam julat dari 0.0524 (W $s^{1/2}$ K^{-1} cm^{-2}) hingga 0.1522 (W $s^{1/2}$ K^{-1} cm^{-2}).

Bagi cecair campuran, dua jenis alkohol (etanol dan metanol) dicampur dengan dua jenis minyak secara berasingan dan sebelas campuran bagi setiap set campuran minyak-alkohol yang berbeza dalam peratusannya didapati. Nilai efusiviti terma dan ketumpatan campuran minyak zaitun dengan etanol berkurang dengan pertambahan komposisi etanol dalam campuran. Nilai efusiviti terma untuk campuran tersebut berubah dari 0.0524 (W $s^{1/2}$ K^{-1} cm^{-2}) hingga 0.0589 (W $s^{1/2}$ K^{-1} cm^{-2}) dan ketumpatan berubah dari 0.779 (g. cm^{-3}) hingga 0.921 (g. cm^{-3}). Kadar langsung dari

efusiviti terma dan ketumpatan bagi campuran minyak zaitun dara dan etanol diperhatikan. Ketumpatan campuran minyak zaitun dangan metanol berkurangan sementara efusiviti terma bertambah. Nilai efusiviti terma berubah dari 0.589 (W $s^{1/2}$ K^{-1} cm^{-2}) hingga 0.0643 (W $s^{1/2}$ K^{-1} cm^{-2}) dan nilai ketumpatan berubah dari 0.786 (g. cm^{-3}) hingga 0.921 (g. cm^{-3}). Campuran ketiga diperolehi dengan mencampurkan minyak kelapa dara dengan etanol. Pertambahan kepekatan etanol dalam campuran mengakibatkan ketumpatannya berkurang. Pengurangan ketumpatan menyebabkan efusiviti terma campuran berkurang. Julat efusiviti terma campuran minyak kelapa dara dengan etanol adalah dari 0.0524 (W $s^{1/2}$ K^{-1} cm^{-2}), hingga 0.0851 (W $s^{1/2}$ K^{-1} cm^{-2}) dan julat ketumpatannya adalah dari 0.779 (g. cm^{-3}) hingga 0.916 (g. cm^{-3}). Minyak kelapa dara telah bercampur dengan metanol dan efusiviti terma bagi campuran ini diukur dan nilainya berubah dari 0.0643 (W $s^{1/2}$ K^{-1} cm^{-2}) hingga 0.0851 (W $s^{1/2}$ K^{-1} cm^{-2}) dengan ketumpatannya berubah dari 0.786 (g. cm^{-3}) hingga 0.925 (g. cm^{-3}).

Dengan menggunakan kaedah serakan minimum, indeks biasan untuk sampel yang dipilih ditentukan. Air suling digunakan untuk tujuan kalibrasi set ujikaji. Ujikaji dilakukan pada suhu bilik dan sumber cahaya laser dengan panjang gelombang 632.8 nm digunakan. Nilai indeks biasan bagi air suling ialah 1.332 di mana ia bersetuju dengan litratur. Dengan menggunakan sumber laser yang sama, indeks biasan sampel campuran diukur. Campuran minyak zaitun dara- etanol mempunyai indeks biasan yang berubah dari 1.3597 hingga 1.4562. Indek biasan bagi campuran minyak zaitun dara-metanol berubah dari 1.3266 hingga 1.4564. Kaedah yang sama adalah digunakan untuk mengukur indeks biasan campuran minyak kelapa dara-etanol dan didapati nilainya berubah dari 1.3597 hingga 1.4524. Pengukuran indeks biasan juga dilakukan pada campuran minyak kelapa dara dengan metanol dan didapati bahawa nilai indeks biasannya berubah dari 1.3266 hingga 1.4524. Dalam kajian ini, didapati bahawa indeks biasan untuk semua sampel campuran semakin berkurang apabila peratusan alkohol dalam campuran bertambah.

Pengukuran FTIR dari 600 cm^{-1} hingga 4000 cm^{-1} digunakan adalah untuk menentukan kelompok fungsional bagi campuran dengan menggunakan Fourier Transform Inframerah. Secara umumnya, spektra FTIR untuk semua campuran menunjukkan bahawa lima puncak penting menjelaskan regangan penyerapan yang disebabkan oleh aldehyde (C= O) dan esters (CO), tekukan penyerapan (methylene (CH_2) dan methyl (CH_3) kelompok) dan penyerapan ikatan ganda dua (C= O) adalah kuat dalam minyak tulen dan campuran minyak-alkohol.

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Special thanks to my friend Assoc. Prof. Muhammed Mizher Radhi for his help during my study.

Finally, may all of them who have helped and supported me live in peace, happiness and prosperous.

I certify that an Examination Committee met on 4th May 2009 to conduct the final examination of Firas Kamel Mohamad on his Master of Science thesis entitled "Thermal Effusivity and Refractive Index of Oil-Alcohol Mixtures" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981.

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Date: 8 June 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

FIRAS KAMEL MOHAMAD

Date: 7 May 2009

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LIST OF ABBREVIATIONS

Co_2	Carbon Dioxide
N_2	Nitrogen Gas
R-G theory	Rosencwaig-Gersho theory
PAS	Photoacoustic Spectroscopy
VOO	Virgin Olive Oil
VCO	Virgin Coconut Oil
PA	Photoacoustic
Hg-Xe	Mercury-Xenon
H^+	Ion Hydrogen
PT	Photothermal
PE	Pyroelectric
PPE	PhotoPyroelectric
TWRC	Thermal Wave Resonant Cavity
PVDF	Polyvinlidene Difluoride
TWC	Thermal Wave Continuous
OTTER	Optotheraml Transient Emission Radiometry
OPC	Open Photoacoustic Cell
Ar-ion	Argon Ion
He-Ne	Helium- Neon Laser
d-PMMA	Deuterated Polymethylmethacylate
API	The American Petroleum Institute
FTIR	Fourier Transform Infrared Spectroscopy
SEM	Scanning Electron Microscope

EDX	Energy Dispersion X-ray
IR	Infrared
Al	Aluminum

LIST OF SYMBOLS

ρ	Density
f	Modulation frequency
α	Thermal diffusivity
α_g	Thermal diffusivity of gas
I_o	The incident monochromatic light flux (W/cm^2)
a_g	Thermal diffusion coefficient of the gas
a_s	Thermal diffusion coefficient of the sample
c	Speed of electromagnetic waves in vacuum
c_n	Specific heat capacity of layer *n*
d	Photoacoustic cell diameter
ε	Thermal effusivity
H	Heat density
I_h	Heat intensity
k_n	Thermal conductivity of layer *n*
k_s	Thermal conductivity of the sample
L	Photoacoustic cell length
l_β	Optical length
n	Refractive index
P	The pressure
P_o	Ambient pressure
Q	Photoac oustic signal
v	Speed of wave
V	Gas volume in the cell

V_o	Cell volume
x	Depth into the sample, x < 0.
α_i	Complex thermal diffusion coefficient of material i
α_s	Thermal diffusivity of the sample
β	The optical absorption efficient
γ	Ratio of the specific heats
δp	Pressure in the PA air chamber
δV	Incremental volume
Θ	The temperature
θ_{ac}	Periodic temperature change in the gas
θ_{av}	Average temperature of gas
θ_{dc}	Average dc temperature of the gas boundary layer
θ_g	Temperature at the gas
θ_o	Temperature at the solid-gas boundary (x =0)
θ_s	Temperature at the sample
λ	Wavelength
μ	Thermal diffusion length
ω	Modulating angular frequency of the incident light
l_b	Thickness of backing material
l_g	Length of gas column
l_s	Sample thickness
α	Thermal diffusivity
η	The efficiency at which the absorbed light at wavelength λ is