Experiment f: a raoult's law experiment essay sample

Objective:

The purpose of this experiment is to study the total vapour pressure of ideal or non-ideal mixtures of two volatile liquids as a function of chemical composition. Introduction:

For ideal mixtures of volatile liquids the vapour pressure of any given mixture may be obtained by applying Raoult's Law to each of the components of the mixture. If, for example, pA* and pB* are the vapour pressures of pure compound A and B respectively, and $\square$A and $\square$B are their mole fractions in a particular mixture, then the partial vapour pressures of each component over that mixture at a given temperature are: pA = $\square$A pA* and pB = $\square$B pB* and the total vapour pressure is given by the sum of these partial vapour pressures: pT = pA + pB.

Liquid mixtures that obey Raoult's Law essentially define an ideal solution. This means that the presence of A in B has no effect on the vapour pressure of B except by diminishing the number of moles of B present in each unit volume. This can only result when the forces between molecules of A and B are essentially the same as those between A molecules themselves, and B molecules themselves. If the attractive forces between A and B are greater than those between A – A and B – B, then both A and B will exhibit partial pressures PA and PB less than those expected from Raoult's Law. This results in a negative deviation (from that calculated with Raoult's Law) in the total pressure. On the other hand, if the attractive forces between A and B are less than those between A – A and B – B, then both A and B will exhibit partial pressures PA and PB greater than those expected from Raoult's Law. This results in a positive deviation in the total pressure. These deviations can

be quite small, but for some mixtures are large enough that the total vapour pressure curves pass through a maximum or minimum.

In this experiment, there two mixture solutions, one is ideal (Hexane-Heptane) and the other is non-ideal (Hexane-Ethanol) behaviour. The diagram below represents the behaviour of the mixtures. In addition, the thin lines represent the ideal behaviour, and the curve lines are for non-ideal behaviour. The curves are due to intermolecular forces.

As the curves approach the extremes of the pure components, molecules of the minor component are surrounded by molecules of the major component. Thus the departures from the ideal give information about the interaction of the components. According to guiding questions #3, there are two pairs of volatile liquids exhibiting both ideal and non-ideal behavior. The ideal pair is Hexane-Heptane mixture and the non-ideal pair is Hexane-Ethanol mixture. Dalton's law of partial pressures states that the total pressure exerted by a gaseous mixture is equal to the sum of the partial pressures of each individual component in a gas mixture. $y_A = P_A/P_{tot} = x_A P_A*/P_{tot}$ (4)

$y_B = P_B/P_{tot} = x_B P_B*/P_{tot}$ (5)

According to guiding question #7, the total vapor pressure of binary solutions could be like below:

The total vapour pressure and the two partial When a component (the solvent) is nearly vapour pressures of an ideal binary mixture pure, it has a vapour pressure that is are proportional to the mole fractions of the

proportional to the mole fraction with a components. slope p*B

(Raoult's law).

When it is the minor component (the solute),

its vapour pressure is still proportional to the

mole fraction, but the constant of

proportionality is now KB(Henry's law).

For guiding question #8, the mole percent of hexane in 30mL of a mixture of

hexane and heptane of 20% hexane by volume is shown below (assume

room temperature which is 25ºC); Volume of hexane = 30mL * 0. 2(20%) =

6mL

Mole of hexane = 6mL(volume) * 0. 65483g/mL(density) = 0. 0456mol

86. 18 g/mol(molar mass)

The mixture solution compositions (percentage by volume of A and B used to

study the total vapor pressure of each system is as follows: A :

0%20%40%60%80%100%

B : 100%80%60%40%20%0%

Volume of solutions used to record the vapor pressure is about 30mL, and

the temperature for recording the vapour pressure is 15°C.

Experimental Procedures:

In this experiment, a plot of the total vapour pressure (p) of a volatile liquid

mixture as a function of its composition will be plotted. This will be done for

an ideal system, a system that exhibits negative deviation from Raoult's Law

and one that shows positive deviation. Ideally, measurements will be made

with the vapour at constant temperature. Measurements of the vapour

pressure of the following mixtures will be taken: hexane-heptane, hexane-ethanol and acetone-chloroform. Apparatus description

This apparatus consists of a manifold that connects a vacuum pump to a probe that measures the pressure inside the manifold and a port to which a round bottom flask (also called the glass bulb) containing the sample will be attached. There are 3 valves (labelled A, B and C) that determine which parts of the manifold are exposed to the vacuum. Valve C is the main valve that controls exposure of the whole manifold to the vacuum – when it is closed the pump is not connected to the manifold. Valve B controls the connection between the pump and the manometer. It is usually kept open and allows the pressure inside the manifold to be measured – the pressure measurement is displayed in the attached digital unit. Valve A determines whether the sample is exposed to the vacuum. There are 3 main valve combinations that are used in this experiment: i) Evacuating the manifold: close the sample valve (A), and open B and C. ii) Evacuating the manifold and bulb: all valves open (with round bottom flask attached). iii) Measuring vapour pressure: close valve C from evacuated manifold, open valve A. B should already be open.

Apparatus preparation

Ensure that:

a) The round bottom flask is clean, and all ground joints are clear of debris and have been well greased with vacuum grease. Joints must be re-greased for each trial. b) The vacuum pump is on and evacuating the manifold (valves B and C open). c) The $N_2(l)$ trap for the vacuum line is filled.

Check for leaks

Before starting the experiment, attach the empty glass bulb to the manifold port just below valve A. Use the springs provided in the locker to keep the bulb in place. This bulb has an additional joint where the thermometer must be attached before the evacuation can begin. Evacuate the manifold and bulb (valves A, B, and C open). Close valve C. Watch the manometer to ensure that there is no pressure change with time. Leaks around the greased joints are most common, and result in large pressure changes. Once you are satisfied that there are no leaks open valve C and close valve A to allow the manifold to evacuate. Attach the sample

While the manifold is evacuating remove the glass bulb place 30 ml of the solution into the round bottom flask taking care not to allow the solvent to touch any surfaces coated with vacuum grease. (Solvents will dissolve the grease.) Ensure that there is adequate grease on all the ground glass joints. Re-attach the bulb to the apparatus, again using the springs provided. Install the thermometer making sure that the probe is not touching the bottom of the flask. Degas the sample

Degas each solution for which you want to measure the vapour pressure. For this you will need a dewer with liquid nitrogen. Submerge the bulb in the N2(l) to freeze the sample until solid, then open valve A to allow the sample to evacuate. Leave the sample frozen while evacuating the bulb. Close valve A, and warm the sample to near room temperature. You can submerge the bottom of the bulb in water bath to speed this process. Refreeze the sample, evacuate, and thaw twice more. Record the vapour pressure

After the final freeze-pump-thaw cycle, warm the solution up to 15 oC. It is important to reach this temperature by warming, and NEVER by cooling, the sample. This temperature must be used for ALL readings for a particular solution composition series. Once the temperature of interest is reached, close valve C, and open valve A. Record the pressure. Measure the vapour pressure in the above manner for solutions of components A and B consisting of 0%, 20%, 40 %, 60%, 80% and 100% A (by volume). Data Work-up

Plot the vapour pressure as a function of solution composition (in mole percent) for each mixture. Draw a straight line representing ideal behaviour (between pA* and pB*). Draw the best smooth curve through the data points.

Results:

Table 1: Uncertainty of Instruments

Instrument| Uncertainty|

Burette| ± 0. 01mL|

Thermometer| ± 0. 05°C|

Manometer| ± 0. 05torr|

Figure 1-Ethanol-Hexane

| Ethanol (mL)| Hexane (mL)| Pressure (Torr)|

0%| 15| 15| 138. 1|

20%| 6| 24| 86. 7|

40%| 18| 12| 278. 2|

60%| 12| 18| 345. 4|

80%| 24| 6| 200. 8|

100%| 30| 0| 448. 8|

| 0| 30| 167. 2|

Figure 2-Heptane-Hexane

| Heptane (mL)| Hexane (mL)| Pressure (Torr)|

0%| 15| 15| 142. 0|

20%| 6| 24| * 103. 0| 40%| 18| 12| * 95. 7| 60%| 12| 18| * 103. 7| 80%| 24| 6|

* 57. 6| 100%| 30| 0| * 31. 2|

Figure 3-Chloroform-Acetone

| Chloroform (mL)| Acetone (mL)| Pressure (Torr)|

0%| 15| 15| * 279| 20%| 6| 24| * 282| 40%| 18| 12| * 287| 60%| 12| 18| * 285|

80%| 24| 6| * 292| 100%| 30| 0| * 299|

Figure 4-Density and Molar Mass of the solutions used

Solution| Density @ 15ºC (kg/L= g/mL)| Molar Mass (g/mol)| Hexane| 0. 663|

86. 18|

Heptane| 0. 687| 100. 21|

Ethanol (Ethyl Alcohol)| 0. 780| 46. 068|

Calculations

Used equations:

$n(mol) = V(mL) * d(g/mL) / MW(g/mol)$

$x_A = n_A / (n_A + n_B)$

Sample calculations:

For Hexane-Heptane:

$P_{Hexane}^{o} = 167. 2 torr$

$P_{Heptane}^{o} = 31. 2 torr$

For mixture 15mL of Hexane and 15mL of Heptane

nHexane = (15mL) * (0. 663g/mL) / (86. 18g/mol) = 0. 115mol

xHexane = (0. 115mol) / (0. 115mol + 0. 103mol) = 0. 527

nHeptane = (15mL) * (0. 687g/mL) / (100. 21g/mol) = 0. 103mol

xHeptane = (0. 527mol) / (0. 115mol + 0. 527mol) = 0. 821

Ptotal calculated = (PHexane^o * xHexane) + (PHeptane^o * xHeptane)

= (167. 2torr * 0. 527) + (31. 2torr * 0. 821)

= 113. 7296 torr ≈113. 73 torr

Partial Pressure:

PHexane = PHexane^o * xHexane = 167. 2torr * 0. 527 = 88. 11torr PHeptane

= PHeptane^o * xHeptane = 31. 2torr * 0. 821 = 25. 6torr

For Hexane-Ethanol:

PHexane^o = 167. 2torr

PEthanol^o = 86. 7torr

For mixture 24mL of Hexane and 6mL of Ethanol

nHexane = (24mL) * (0. 663g/mL) / (86. 18g/mol) = 0. 186mol

xHexane = (0. 186mol) / (0. 186mol + 0. 102mol) = 0. 646

nEthanol = (6mL) * (0. 780g/mL) / (46. 068g/mol) = 0. 102mol

xEthanol = (0. 102mol) / (0. 186mol + 0. 102mol) = 0. 354

Ptotal calculated = (PHexane^o * xHexane) + (PEthanol^o * xEthanol)

= (167. 2torr * 0. 646) + (86. 7torr * 0. 354)

= 195. 0652torr ≈ 195. 06torr

Partial Pressure:

yHexane = (xHexane * PHexane^o) / [PEthanol^o + {(PHexane^o – PEthanol^o) *

xHexane}] = (0. 646 * 167. 2) / [86. 7 + {(167. 2 – 86. 7) * (0. 646)}] = 0.

779

yEthanol = 1 – yHexane = 1 – 0. 779 = 0. 221

yHexane = PHexane / Ptotal(measured)=> PHexane = yHexane *

Ptotal(measured)

= 0. 779 * 86. 7

= 67. 5393≈ 67. 54torr

Graphs:

Figure 5-Pressures of the different mixtures

Discussion:

The goal of this experiment was to study the total vapour pressure and the partial vapour pressure of the solution mixtures, hexane-heptane, hexane-ethanol, and chloroform-acetone, and to compare them with each other and to determine the difference of the ideal and non-ideal behaviours. For the results part, the mixture solution Hexane-Heptane got the value which is linear graph because this solution has ideal behavior. However, the mixture solution Hexane-Ethanol got the curve value since this solution has non-ideal behavior. So, it means that these two mixture solutions have different ways for getting partial pressures. Ideal solution used Raoult's law which is:

PA(partial) = xA(mole fraction) * PA(initial or total)º

On the other hand, for non-ideal solution, Dalton's law for a binary solution was used which is: yA = PA / Ptotal, yB = PB / Ptotal

yA = (xA* PAº) / [PBº + {(PAº – PBº) * xA}], yB = 1 – yA Other examples of solvent systems which give:

(a) an ideal behavior are CCl4 & SiCl4

(b) a negative deviation from Raoult's law are chloroform & acetone

(c) a positive deviation from Raoult's law are carbon disulfide & acetone

A block of common ice will float in a tub of water because solid water is less dense than liquid water. But at 4 °C, just above freezing, water reaches its maximum density, and as water cools further toward its freezing point, the liquid water, under standard conditions, expands to become less dense. Thus, the reason that the common form of ice is less dense than water is a bit non-intuitive and relies heavily on the unusual properties inherent to the hydrogen bond. The D. N. A. double helix is stabilized by hydrogen bonds between the bases attached to the two strands. So, Hydrogen bonds influence the D. N. A. structure, base pair is connected by two hydrogen bonds (non-covalent). As hydrogen bonds are not covalent, they can be broken and rejoined relatively easily. There could be several errors for the experiment. First of all, when we measured solutions by using the burettes, uncertainty was ± 0. 01mL.

Also, equipments have accuracy range themselves, which are thermometer has ± 0. 05ºC range and manometer has 0. 05torr. Second of all, during the procedure, when remove the warm water beaker which heated the glass bulb, if it was late like at 13~14ºC, it did not have enough time to stabilize the temperature at 15ºC. Or, if it was too early, it would take a lot of time, also, it could be different value like too low results of pressures. Last of all, during using the vacuum pump, the procedure was long and complex like open big black valve, and close green valve, so on. Therefore, we must

concentrate on the procedure and follow as procedure said while using it.

Conclusion:

Hexane-Heptane mixtures show pressure, Pmeasured, was linear value, increased regularly. owever, Hexane-Ethanol solution mixture got a different value, a curve line. These results showed Hexane-Heptane was ideal behavior solution (followed Raoult's law) and Hexane-Ethanol was non-ideal behavior solution (followed Dalton's law for a binary solution).

References

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