Solutions to Exercises from Absorption Chillers and Heat Pumps

# Chapter 3

## 3.1. Derive equations 3.20 and 3.21 from 3.19.

Let us follow the math. Based on the total mass, we must have

We will need a conversion from mole quantities to mass fraction. This is obvious:

Now we can start differentiating. First let us observe that

Note that partial molal Gibbs free energy in equation 3.19 should be denoted with an overbar, and deriving partial mass quantities requires the equations shown in example 3.1. So we have

And similarly

## 3.2. Evaluating chemical potential of NH3 in mixture with water.

We follow Example 3.1. However, note that using a fundamentalgleichung, er, equation of state as discussed in section 3.1.3, it may not be necessary to compute a numerical derivative, if an analytic derivative exists.

To proceed using open software, we now need to implement the mixture properties. The IAPWS offers a formulation and guidelines in [1], based on Tillner-Roth and Friend [2]. These require also an implementation of IAPWS pure water properties, which have already been implemented in an open manner by a number of projects.

Meanwhile, an alternative is to borrow some existing properties from EES’s external library, NH3H2O, or REFPROP9. Here are some outputs. Here, is for ammonia, for water. As can be seen, although the mass fraction is quite different, the chemical potentials are very similar at both points, which are in equilibrium. There difference is probably due to the numerics at the saturated vapor point, because the forward difference method used to evaluate fetches a superheated state. Reducing the quality of the second point to 0.999 brings the potentials into very close agreement.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | T | P | x | h | s | u | v | Qu |
|  | K | bar |  | kJ/kg | kJ/kg-K | kJ/kg | m^3/kg |  |
| sat liquid | 373.15 | 10.00 | 0.31568 | 240.46 | 1.2693 | 239.2 | 0.00122 | 0.0000 |
| sat vapor | 373.15 | 10.00 | 0.92988 | 1563.20 | 5.1263 | 1391.5 | 0.17168 | 1.0000 |
| almost sat vapor | 373.15 | 10.00 | 0.92926 | 1561.88 | 5.1224 | 1390.4 | 0.17151 | 0.9990 |
|  |  |  |  |  |  |  |  |  |
|  | g | dgdx | mu1 | mu2 |  |  |  |  |
|  | kJ/kg | kJ/kg | kJ/kg | kJ/kg |  |  |  |  |
| sat liquid | -233.18 | -189.683 | -362.983 | -173.301 |  |  |  |  |
| sat vapor | -349.68 | -195.733 | -363.408 | -167.674 |  |  |  |  |
| almost sat vapor | -349.57 | -189.683 | -362.983 | -173.301 |  |  |  |  |

## 3.3. Evaluating chemical potential of H2O in mixture with ammonia.

See previous.

## 3.4. Properties as mole fraction.

Not really useful, but we need to derive equation 3.51 anyway. First derive equation 3.50. From equation 3.14,

Now, assuming an ideal gas model, is constant and , so

Integrating,

The first equality in equations 3.51 can be assumed (as definition of partial entropies). Partial pressures are given by Dalton’s law, and . Then expanding the pressure terms shows how to obtain the second equality and definition of :

## 3.5. Expression for mixture molecular weight (trivial).

a. This is given in example 3.1 as

b. Equation 3.53 (also used in example 3.1, just renaming ) converts from mass fraction to mole fraction and makes it clear that

## 3.6. Mixture Enthalpy