Physical Chemistry I. mock tests

1. a) Give the area under the function e^{1-2x} between the points -1 and 1!

   b) Calculate the exact differential of the function $\Psi(x,t) = e^{-x^2+i\omega t}$ (i and ω are constants)!

   (a: 9.8588)

   (b: $\mathrm{d}\Psi = -2x \cdot \Psi(x,t) \cdot \mathrm{d}x + i\omega \cdot \Psi(x,t) \cdot \mathrm{d}t$)

(2 points)

2. We have a cylinder with a piston, which is adiabatically isolated and keeps 30 *bar* constant pressure. At start it has 1000 *mol* liquid water in it at its boiling point, and the same amount of steam at 380 °C temperature.

   a) Consider the gas to be real. Illustrate the process in which the system reaches equilibrium on a T-s diagram! Determine the equilibrium temperature, and the change in entalphy and entropy.

   b) Consider the gas to be ideal. Determine the same values as in a)! The heat of vaporization is 1800 k*J*/k*g*, the average specific heat capacity of the steam is 2,67 k*J*/k*gK*. Read the boiling point temperature from the T-s diagram.

   (a: $T_{eq} = 235°C, \Delta H = 0\ J, \Delta S = 1,26\ \frac{\mathrm{k}J}{K}$)

   (b: $T_{eq} = 235°C, \Delta H = 0\ J, \Delta S = 1,65\ \frac{\mathrm{k}J}{K}$)

(8 points)

3. Estimate the equilibrium vapor pressure of toluene at 75 °C, if its boiling point temperature at standard pressure is 110 °C, and the latent heat of vaporization for toluene is 38,1 k*J*/*mol*!

   ($0,3017\ bar$)

(4 points)

4. We have a closed system consisting of 25°C, 5 *mol* *n*-heptane – *n*-hexane mixture in which the molar fraction of *n*-heptane is 0,4. How many *mol*s of substance will be in vapor phase if we set the pressure to 9 k*Pa*? The equilibrium vapor pressure of *n*-hexane at 25°C is 13 k*Pa*, and 5,2 k*Pa* for *n*-heptane.

   For what molar fractions is an *n*-heptane – *n*-hexane mixture in two phases at 25 °C temperature and at 10 k*Pa* pressure?

   ($n_g = 2,605\ mol$; $0,6153 \leq z_{hex} \leq 0,7999$)

(7 points)

5. We expand a 5 *mol*, 520 *K*, 2 M*Pa* hydrogen gas in adiabatic circumstances to 6 *bar*. After this we perform and isobaric, and then an isochor process, after which the gas returns to its original state. Illustrate the processes on a p-V diagram! Determine the missing temperature and pressure values! Calculate the heat, work, change in entropy and change in internal energy for each step and for the complete process, and give them in tabular form! The molar heat capacity of hidrogen at constant volume is 20,54 *J*/*molK*.

   ($T_2 = 367,5\ K, T_3 = 156\ K$.

   For the three subprocesses and the whole process:

   $Q: 0\ \mathrm{k}J, -30,5\ \mathrm{k}J, 37,4\ \mathrm{k}J, 6,9\ \mathrm{k}J; W: -15,7\ \mathrm{k}J, 8,8\ \mathrm{k}J, 0\ \mathrm{k}J, -6,9\ \mathrm{k}J;$

   $\Delta S: 0\ J/K, -123,6\ J/K, 123,6\ J/K, 0\ J/K; \Delta U: -15,7\ \mathrm{k}J, -21,7\ \mathrm{k}J, 37,4\ \mathrm{k}J, 0\ \mathrm{k}J$)

(9 points)

1. a) Differentiate the function $\frac{1}{2x+1}$! ($\frac{-2}{(2x+1)^2}$)

   b) Express the variable x from the equation $ln(\frac{1}{2x+1}) = 0$! ($x = 0$)

   c) Integrate the function $\frac{1}{2x+1}$ between 0 and 1! ($\frac{ln3}{2}$)

   d) Calculate the $\frac{\partial^2 f}{\partial x \partial y}$ partial derivative of the function $f(x,y)$ which has the exact differential $\mathrm{d}f = \frac{1}{y^2}\mathrm{d}x - 2\frac{x}{y^3}\mathrm{d}y$. ($-\frac{2}{y^3}$)

   (4 points)

2. We expand 2 g, 10 dm^3, 160 °C water steam to 10 kPa in an isothermal process, then we compress it in an adiabatic reversible process, finally we make it return to its original state through a process with constant pressure. Calculate the change in the internal energy, in the entropy, and the heat for the three subprocesses and for the complete process. Solve the prolem assuming the steam to be a real gas, and also as an ideal gas. Illustrate the processes on a T-s and on a p-V diagram. How would the calculated values during the first process (real gas) change if we expanded the gas through an adiabatic throttle instead of an isothermal process?

   (10 points)

   (Real:

   $Q: 563\,J, 0\,J, -700\,J, -137\,J; \Delta S: 1{,}3\,J/K, 0\,J/K, -1{,}3\,J/K, 0\,J/K; \Delta U: 0\,J, 500\,J, -500\,J, 0\,J$

   Ideal:

   $Q: 555\,J, 0\,J, -705\,J, -150\,J; \Delta S: 1{,}28\,J/K, 0\,J/K, -1{,}28\,J/K, 0\,J/K; \Delta U: 0\,J, 470\,J, -470\,J, 0\,J$

   Real adiabatic throttle: for this system basically also an isotherm on the T-d diagram, no change)

3. Acetone and acetonitrile compose a mixture that can be treated as ideal. The eq. vapor pressure of acetone and acetonitrile at 20 °C is 24,8 kPa and 9,3 kPa, respectively. If we put a mixture with 1:1 molar ratio into a 5 l vessel the ressure will be 15 kPa. What was the amount of substance we put into the vessel? (Treat the vapor as an ideal gas, neglect the volume of the liquid.)

   (6 points)

   (0,056 mol)

4. The eq. vapor pressure of methanol doubles as we heat it from 30 °C to 45 °C. What is the methanol's latent heat of evaporation? (Treat it as an ideal gas.)

   (3 points)

   (37,054 kJ/mol)

5. We put a 250 °C metal plate weighting 25 g into 10 g toluene with 90 °C temperature. The system is adiabatically isolated and keeps constant pressure. What is the equilibrium state (phases, temperature) ? What is the entropy change during the process?

   The boiling point of toluene is 110 °C, its specific heat capacity is 1,68 $\frac{kJ}{kgK}$, its heat of evaporation is 356 $\frac{kJ}{kg}$. The specific heat capacity of the metal plate is 0,46 $\frac{kJ}{kgK}$.

   (7 points)

   (Eq. state: solid metal, liquid and gaseous toluene, 110 °C

   $\Delta S = 0{,}645 J/K$)

1. a Integrate the function $(1-2x)^{-3}$ between 1 and 2! ($-\frac{2}{9}$)

   b Calculate the derivative of the function $e^{-(1-2x)^2}$! ($e^{-(1-2x)^2} \cdot (-2) \cdot (1-2x) \cdot (-2)$)

   c Calculate $\frac{\partial^2 h}{\partial p \partial q}$ if $\mathrm{d}h = p^3 q \cdot \mathrm{d}p + \frac{1}{4} p^4 \cdot \mathrm{d}q$. (p^3)

   (4 points)

2. We expand 6 *mol* of ideal gas from 40 °C and 5 *bar* in an isothermal process till its volume becomes three times its original. After this we make it return to its original state through an adiabatic reversible and an isochor process. What is the change in enthalpy, in entropy, and the work for the complete process and the subprocesses? Would the work increase or decrease if we returned to the originial state from the second state through an adiabatic reversible and an isobaric process? Illustrate all processes on a p-V diagram and give your results in tabular form! $\kappa = 1,3$.

   (10 points)

   ($\Delta H: 0$ k$J, 26,4$ k$J, -26,4$ k$J; \Delta S: 54,8\ J/K, 0\ J/K, -54,8\ J/K; W: -17,16$ k$J, 20,3$ k$J, 0$ kJ

   The work decreases in the alternative route, from 3,15 kJ to 2,35 kJ)

3. We cool down 2 *mol* 250 °C saturated water vapor on constant volume, and then with an adiabatic reversible compression we take it to its critical point. What is the pressure and the temperature at this point? What is the work and the change in internal energy in the whole process and in the steps? Give your results in tabular form and illustrate the process on the T-s diagram!

   (8 points)

   ($T = 375°C, p = 22$ M$Pa, \Delta U: -29,7$ k$J, 9,2$ k$J, -20,5$ k$J; W: 0$ k$J, 9,2$ k$J, 9,2$ kJ)

4. We put 10 *mol* benzene-toluene mixture, with 65% benzene, into a cylinder with piston. At 20 °C we set the pressure so that the molar fraction of benzene in the vapor phase is 0,7. What is the volume of the vapor phase if we neglect the volume of the liquid and we treat the vapor as an ideal gas? How much do we need to increase the pressure for the vapor phase to disappear?

   The eq. vapor pressure of benzene and toluene at 20 °C is 9960 *Pa* and 2973 *Pa*, respectively.

   (8 points)

   ($3,45\ m^3, 7515\ Pa$)

First test
Problem 2: see practice_6.pdf
Problem 3: see practice_6.pdf
Problem 4: see practice_6.pdf
5: see Problem practice_6.pdf

Second test

Problem 2:

real gas:
First identify the three points on the T-s diagram

For each point you need two pieces information with which you can associate a line. The crossing point of the lines is the point you're looking for.

- point 1: 160 °C→ one line is the horizontal line belonging to 160 °C; m=2g, V=10dm^3 → the other line is the constant specific volume line belonging to 5 m^3/kg

- point 2: since the step 1 → 2 is isothermal we have 160 °C→ one line is the horizontal line belonging to 160 °C; p=10kPa → the other line is the constant pressure line belonging to 0,01 MPa

- point 3: we got here from point 2 in an adiabatic reversible process → one line is the vertical line belonging to the same specific entropy as for point 2; since we reach point 1 from point 3 in an isobaric process, the pressure has to be the same as in point 1, that is, 0,04 MPa → the other line is the constant pressure line belonging to 0,04 MPa

After we have found the points we write up the equations to calculate ΔU, ΔS and Q in each of the subprocesses (ΔS is always $m \cdot \Delta s$)

To calculate these we have to, for each point, read the s, h, v, and p values from the diagram: for example, to get h_1, we determine which constant specific enthalpy line goes through point 1. If there is no such line explicitly drawn on the diagram, we have to guess the value based on where we are in between two lines: if we're halfway between to h lines, our h_1 value is halfway between the values for those lines. (see more help in the solution for the 3rd problem in the third test)

An adiabatic throttle is a process in which $\Delta H = 0\ J$, but our first process happens to be like this anyway, so nothing changes in this case

ideal gas: see practice_2.pdf

Problem 3:

$n = n_g + n_l$
$n_g = \frac{pV}{RT}$
$\frac{n_l}{n_g} = \frac{z_{Ac} - y_{Ac}}{x_{Ac} - z_{Ac}}$
$z_{Ac} = 0,5$
$x_{Ac} = \frac{p - p^*_{An}}{p^*_{Ac} - p^*_{An}}$ (see practice_5.pdf)
$y_{Ac} = \frac{p^*_{Ac} x_{Ac}}{p}$

Problem 4:

Clausius-Clapeyron: $ln\frac{p^*_2}{p^*_1} = -\frac{\lambda}{R}(1/T_2 - 1/T_1)$
We know the ratio of p^*_2 and p^*_1, also T_1 and T_2, question is λ

5: see practice_6.pdf

Third test

Problem 2:

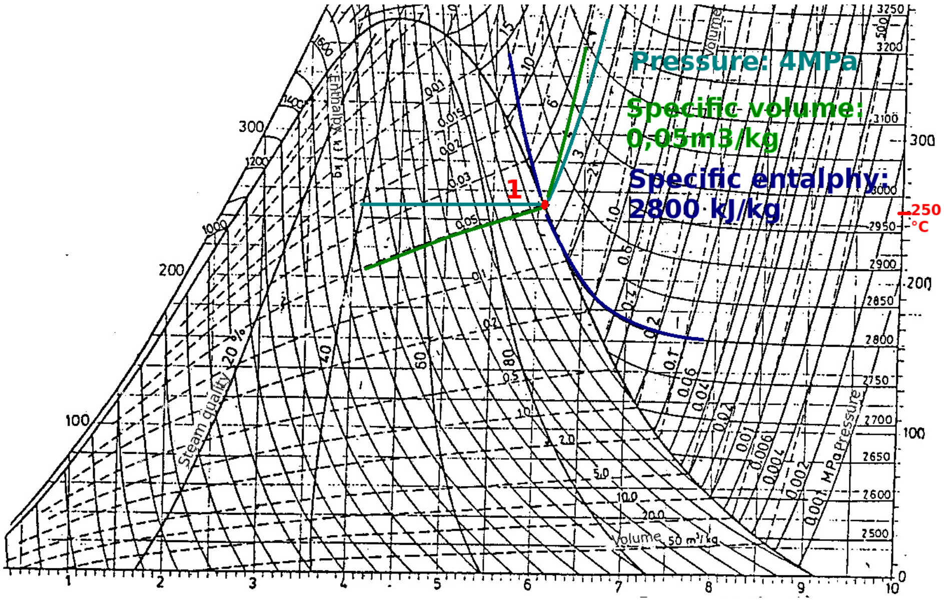
- 1→2: $\Delta H = 0\ J$ (isothermal); for ΔS and W we need p_2/p_1, which is $V_1/V_2 = 1/3$
- 2→3: $\Delta S = 0\ J/K$ (ad. rev.); for ΔH and W we need $(T_3 - T_2)$, $c_{m,p}$, and $c_{m,v}$; $T_3 = T_2\left(\frac{V_2}{V_3}\right)^{\kappa-1}$, $V_2 = 3V_1$, $V_3 = V_1 \rightarrow T_3 = 435{,}22\ K, \Delta T_{2\rightarrow3} = 122{,}2\ K$; $\frac{c_{m,p}}{c_{m,v}} = \kappa = 1{,}3$, $c_{m,p} = c_{m,v} + R \rightarrow c_{m,v} = 27{,}71\ J/molK, c_{m,p} = 36{,}03\ J/molK$
- 3→1: $W = 0\ J$ (isochor); we have every info for ΔH and ΔS too

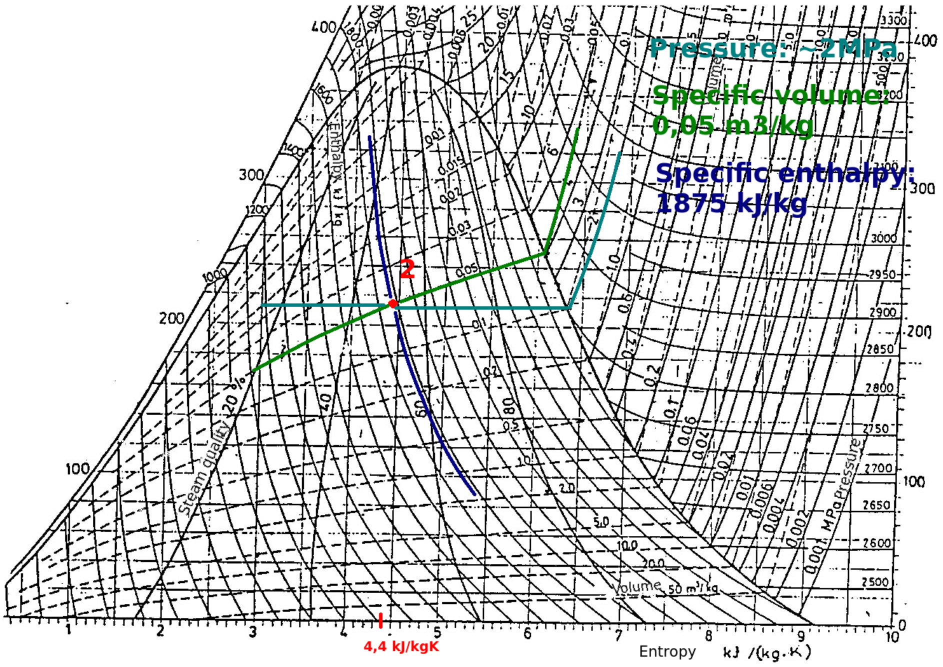
Alternative route:
- 1→2: same
- 2→4: $\Delta S = 0\ J/K$ (ad. rev.); for ΔH and W we need $(T_4 - T_2)$; $T_4 = T_2\left(\frac{p_2}{p_4}\right)^{\frac{1-\kappa}{\kappa}}$; $p_4 = p_1 = 5\ bar$, $p_2 = p_1\frac{V_1}{V_2} = \frac{5}{3}\ bar \rightarrow T_4 = 403{,}33\ K, \Delta T = 90{,}33\ K$
- 4→1: $W = 0\ J$ (isochor); we have every info for ΔH and ΔS too

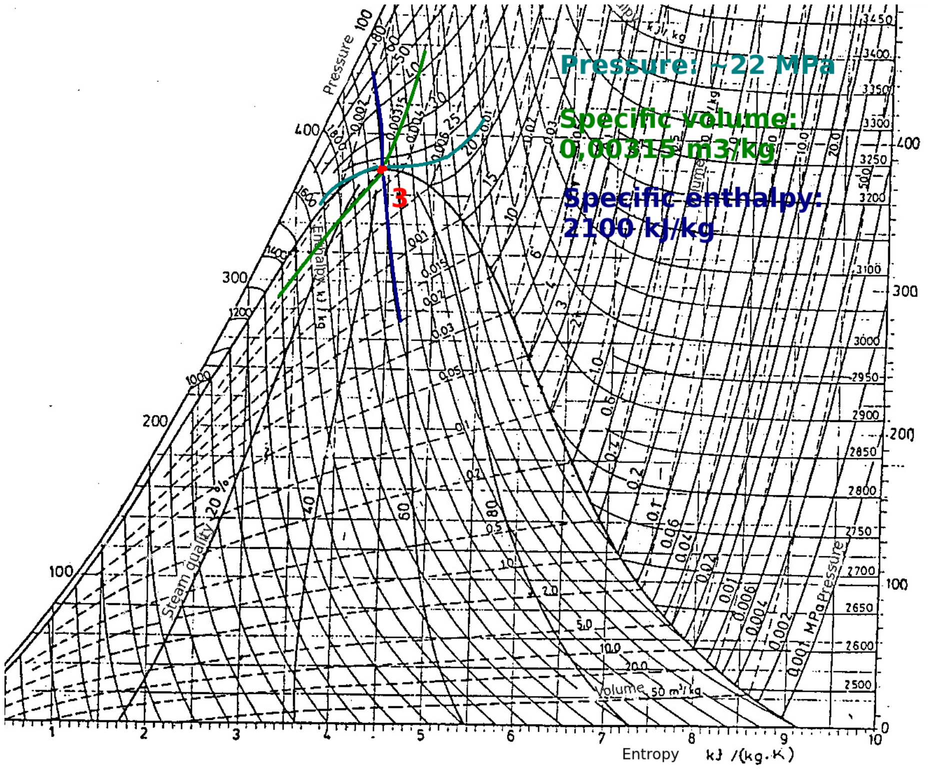
Problem 3:

critical point: top point of the bell curve
- point 1.: saturated vapor → one line is the right side of the bell curve; 250°C → the other line is the horizontal line belonging to 250°C
- point 2.: same specific volume as in point one, that is, 0,05 m^3/kg → one line is the specific volume line belonging to 0,05 m^3/kg; we get to the critical point from point 2 in an ad. rev. process, that is, the s will not change → other line is the vertical line belonging to the critical point
- point 3.: critical point

We need the h, v, and p values for each of the points







Problem 4: see practice_6.pdf