Principles of Physical Chemistry CHEM-C1230 exam 3 22.1.2024 (start at 13:00)

The exam where the exercises are counted. You will have 3 h + 0.5 h time for the exam (unless you have special permission for 4 h exam). The 0.5 h extra is to return the exam to MyCourses. (it need to be in the folder latest at 16.30)

The filename (or files) need to have your name in it. Your name and student number should be in the file too. Most common file types, like .doc .pdf are OK. The answers can be hand written and scanned but pay attention to the clarity of the output file. Try to send a single file.

You can use any material you find but do not copy it directly to the answers. The use of AI-tools like Chat-GPT, Bard etc. are NOT allowed. The points will be reduced if I find a direct copy from e.g. Correction Notes, Wikipedia or the textbook. The answers need to be in English.

The book's appendix tables are needed in the exam. In any case, **quote the data source**.

1) Hydrogen is a possible energy storage molecule. It can be made by dissociating some molecules. How much heat is needed to make 1 kg of H_2 from water molecules or from methane? In the latter, you can assume that the C will form graphite. Last, if methane reacts with O_2 and produces H_2 and CO_2. Explain in detail what you compute. (Extra: if electricity costs 0.1 eur/kWh, what is the minimum cost of 1 kg of H_2 in the two first cases? This ignores the other production costs. You get 1 extra point of this.)

2) Investigate the boiling of a liquid at constant pressure. What happens to systems volume, enthalpy and entropy when the temperature changes from a bit below the boiling point to a bit above it? Explain qualitatively why. Use 1 mol of water or methanol at 1 atm and at the boiling point temperature as an example and give numerical values to these quantities. (The volume change does not need to be very accurate.)

3) You can use a constant pressure calorimeter to measure enthalpies. Explain the calorimeter and what you can measure with it. You calibrate a calorimeter by measuring dissolution heat of 2.72 g Na_2SO_4(s). The calorimeter contains 150 g of water and it heats 0.05 K. From table data, what is the Na_2SO_4(s) dissolution reaction enthalpy? Water molar heat capacity is 75.3 J/(K mol). Then you dissolve 3 g of NaCl and the calorimeter above cools 0.02 K. What is the enthalpy of dissolution of NaCl?
4) The van der Waals equation of state parameters for O_2 are a=1.38 dm^6 bar /mol^2 and b=0.0319 dm^3/mol. Explain what the vdW equation describes and to what phenomena the parameters or equation terms are linked. What is the compression factor? Comment on the ideality of O_2 using numbers in the table below. The compression factor is a bit difficult to compute. You can estimate it by computing the $P_{vdw}(V_{id})/P$, where the V_{id} is the ideal gas molar volume, $P_{vdw}(x)$ is the vdW pressure equation. Do this comparison at 200 K, 50 bar and at 400 K, 150 bar (two z values). Compare your numbers to the values below.

z (T,P)	200 K	300 K	400 K
50 bar	0.8696	0.9735	0.9998
100 bar	0.7905	0.9633	1.0076
150 bar	0.8304	0.9747	1.0240

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5) What the reaction Gibbs energy will tell you of a reaction? Are the following reactions in equilibrium and if not, in which directions the reactions will go (toward reactants or products). Explain your conclusions.
a) $H_2O(l) \leftrightarrow H_2O(g)$ and the partial pressures are 1.0 atm (liq) and 0.0323 atm (gas). T = 298.15 K
a) $H_2O(l) \leftrightarrow H_2O(g)$ and the partial pressures are 1.0 atm (liq) and 0.155 atm (gas). T = 298.15 K

6) CO_2 is the most important greenhouse gas. It will dissolve in water with Henry's constant of $1.65*10^3$ atm (The textbook definition). How many moles of CO_2 are in 1 L of water if the CO_2 partial pressure is 400 ppm = $4.0*10^{-4}$ atm. You can assume that the concentration is small. In water, CO_2 will react with water and form carboxylic acid H_2CO_3. This is a weak acid and part of it will dissociate $H_2CO_3 \rightarrow HCO_3^- + H^+$. The equilibrium constant of CO_2 (aq) and $HCO_3^- + H^+$ is $4.3*10^{-7}$ mol/L. What is the proton concentration in water. You can assume that $[HCO_3^-] = [H^+]$. What is the pH.

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