


To be filled with the student: First name: Last name: <hr/> Warning: <ul style="list-style-type: none"> • For problems marked with an icon  give your calculation or reasoning which lead to your solution! • For tasks with variant answers a), b), c), ... more than one answer item can be correct! 	To be filled with the examiner: Score from the exam test: Score from the credit tests: Average score: Grade: Date: Signature:
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1. 

Mark intensive quantities:

- a) temperature
- b) molar entropy
- c) work
- d) molar amount

2. 

We mix 1 liter of ethanol and 4 liters of water. Calculate the volume fraction of ethanol in the mixture.

3.

Transform units: molar volume $1 \text{ m}^3\text{mol}^{-1} = \dots\dots\dots \text{ cm}^3\text{mol}^{-1}$.

4.

The process during which a system does not exchange heat with its surroundings is denoted as

- a) isochoric
- b) isothermal
- c) isobaric
- d) adiabatic

5.

Heat is expressed in the same units as

- a) mechanical work
- b) non-mechanical work (e.g. electric)
- c) power (i.e. work per a unit of time)
- d) temperature change per a unit of time
- e) energy

6.

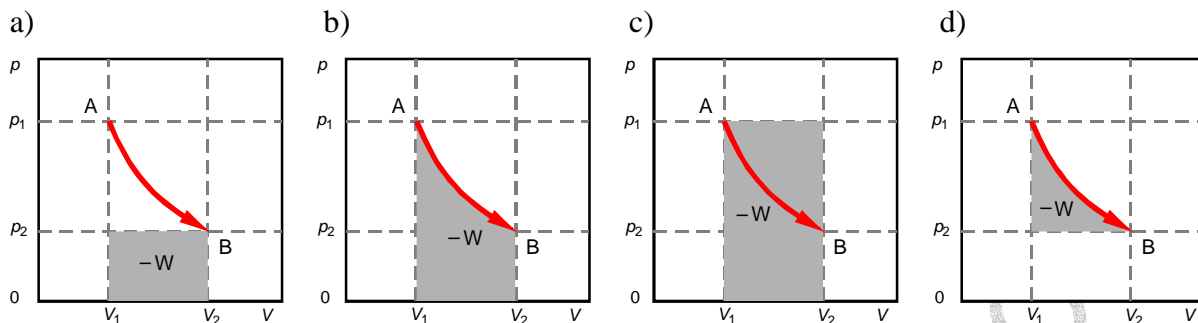
To denote a certain thermodynamic function a symbol A is often used in the literature. Which function is meant if it holds $A = U - TS$? (U , T and S are internal energy, temperature and entropy.)

7. 

The total pressure exhibited by a mixture of ideal gases was 8 kPa. In the mixture, the partial pressure of the water vapor was 400 Pa. What was the mole fraction of water in this mixture?

8. 

A system passed reversibly from state A to state B, the path being shown in the p - V diagram. Select the variant in which the area marked in the diagram corresponds to the mechanical work the system exchanged with its surroundings.



9. 

For the total differential of the internal energy of a closed system the following relation holds

$$dU = T dS - p dV$$

From here it can be inferred that

a) $\left(\frac{\partial U}{\partial S}\right)_V = T$

b) $\left(\frac{\partial U}{\partial S}\right)_V = -p$

c) $\left(\frac{\partial U}{\partial V}\right)_S = -p$

d) $\left(\frac{\partial U}{\partial V}\right)_S = T$

10. 

The standard reaction enthalpy ($\Delta_r H_m^\ominus$) of the reaction $2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\text{g})$ has a value that

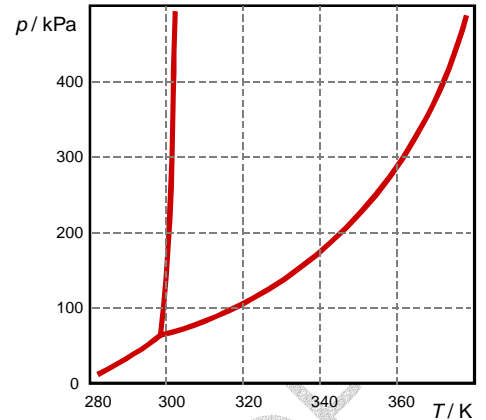
- a) is the same as that of the standard combustion enthalpy of hydrogen
- b) is a half of that of the standard combustion enthalpy of hydrogen
- c) is twice of that of the standard combustion enthalpy of hydrogen
- d) none of the previous variants is correct

11. 

By mixing 9 mol of hexane with 1 mol of cyclohexane a solution is prepared the behavior of which can be considered to be ideal. What is the activity of cyclohexane in this solution provided the standard state is that of "the pure liquid component"? Molar masses of hexane and cyclohexane are 86 and 84 g mol^{-1} , respectively.

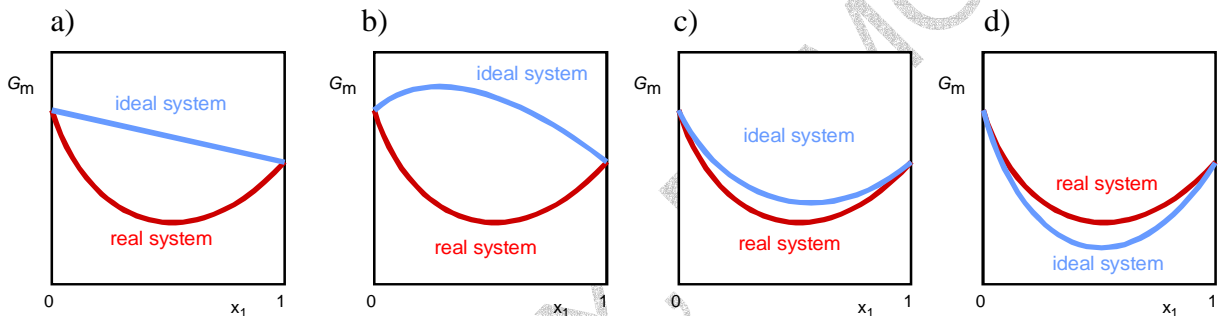
12. 

Using the phase diagram of a pure substance, determine its normal boiling temperature.



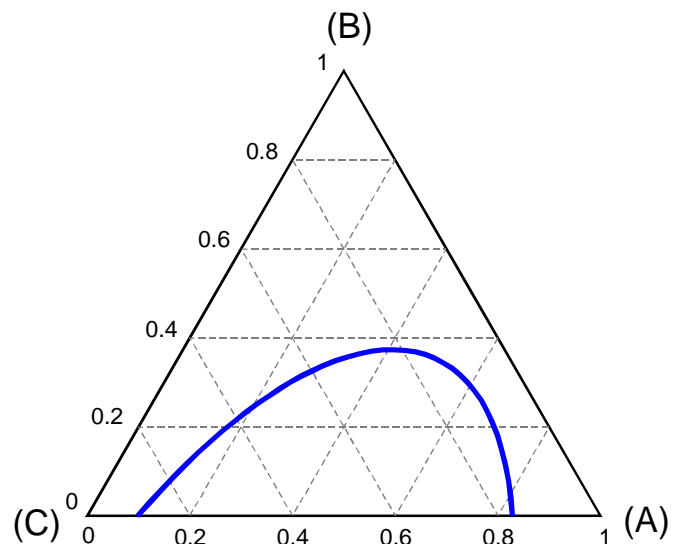
13. 

Which of the variants depicts in a qualitative way correctly the dependence of the molar Gibbs energy on composition of a binary mixture for the case, that this real mixture exhibits negative deviations from ideality (i.e. the excess Gibbs energy $G^E < 0$)?



14. 

Using a given ternary diagram depicting the liquid-liquid phase equilibrium, decide whether two liquid phases emerge if we mix at a given temperature 4 mol of substance A, 8 mol of substance B, and 8 mol of substance C. Justify your decision briefly.



15.

The following relation holds for the reaction Gibbs energy $\Delta_r G_m = \Delta_r G_m^\ominus + RT \ln \prod_{i=1}^k a_i^{v_i}$

Explain the meaning of the term $\prod_{i=1}^k a_i^{v_i}$.

16.

Write down the reaction occurring in the galvanic cell which is symbolically recorded as follows
 $\text{Ni (s)} \mid \text{NiCl}_2 \text{ (aq)} \mid \text{Cl}_2 \text{ (g)} \mid \text{Pt (s)}$

17. 

The nuclide ^{11}C has a decay half-life of 20 minutes. How much of this nuclide remains in the sample after 24 hours?

- a) unmeasurably small amount
- b) about 1 % of the original amount
- c) half of the original amount
- d) about 99 % of the original amount

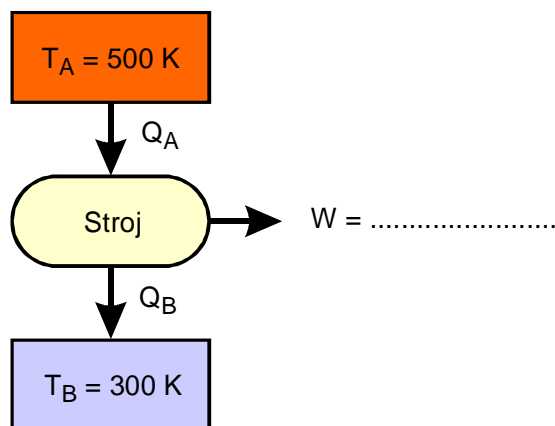
18. 

Which of the statements is correct? (Justify!)

- a) The isotherm for an ideal gas connects points having the same enthalpy.
- b) The isotherm for an ideal gas connects points having the same entropy.
- c) The isotherm for an ideal gas connects points having the same internal energy.
- d) The isotherm for an ideal gas connects points having the same Gibbs energy.

19. 

What will be the maximum work yielded by a cyclic heat engine working between the temperatures $T_A = 500 \text{ K}$ and $T_B = 300 \text{ K}$, if the respective heats exchanged are $Q_A = 500 \text{ kJ}$ and $Q_B = -300 \text{ kJ}$?



20. 

It was found by calorimetric measurements that for warming 200 g of CaCO_3 ($M = 100 \text{ g mol}^{-1}$) from $20 \text{ }^\circ\text{C}$ to $30 \text{ }^\circ\text{C}$ at constant pressure a heat of 1640 J is needed. Determine the specific heat capacity and the molar heat capacity of CaCO_3 .

21. 

In the tables that give thermodynamic properties of water, the molar enthalpy of ice at the triple point is set to zero. The enthalpies of fusion and vaporization at the triple point of water ($T = 273,16 \text{ K}$) are 6000 J mol^{-1} and 45000 J mol^{-1} , respectively. Calculate the molar enthalpies of liquid and gaseous water at the triple point.

22.

The second law of thermodynamics states that

- a) a body immersed into a liquid is lifted by a force that is equal to the weight of the liquid expelled by the body
- b) it is impossible to construct a cyclic heat engine that would convert all the heat supplied completely to work
- c) the efficiency of the heat engine increases if the temperature of its cooler increases
- d) is impossible to construct a cyclic heat engine that would convert work to heat

23. 

The department that is engaged in the electrolysis of NaCl received an order for the production of 40 kg NaOH ($M = 40 \text{ g mol}^{-1}$) and 40 kg liquid chlorine ($M = 71 \text{ g mol}^{-1}$). What will be the minimum electrical charge needed?

24. 

For a certain process with an ideal gas the mechanical work is given by the following formula

$W = -nR(T_2 - T_1)$. Thus, the process in question is

- a) adiabatic
- b) isothermal
- c) isobaric
- d) isochoric

25. 

Water at 293 K and a certain pressure is saturated by air (20 mol. % O_2 , 80 mol.% N_2). The mole fraction of nitrogen in water is roughly 2× greater than the mole fraction of oxygen in water. What is the ratio of the Henry's law constants of both gases in water (i.e. the ratio $K_{\text{H}}(\text{N}_2)/K_{\text{H}}(\text{O}_2)$)? Justify!

Solutions:

1.

a) temperature, b) molar entropy

2.

$$\varphi_{\text{ethanol}} = 0.2$$

3.

$$1 \text{ m}^3 \text{ mol}^{-1} = 10^6 \text{ cm}^3 \text{ mol}^{-1}$$

4.

d) adiabatic

5.

- a) mechanical work
- b) non-mechanical work
- d) energy

6.

Helmholtz energy

7.

$$x_{\text{H}_2\text{O}} = 0.05$$

8.

b)

9.

a) $\left(\frac{\partial U}{\partial S}\right)_V = T$

c) $\left(\frac{\partial U}{\partial V}\right)_S = -p$

10.

c) is twice of that of the standard combustion enthalpy of hydrogen

11.

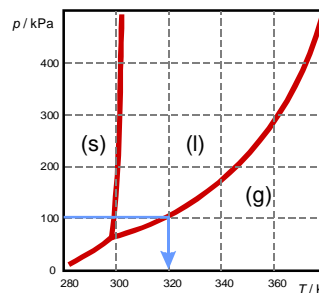
$$a_{\text{cyclohexane}} = 0.1$$

12.

$$T_{\text{NBP}} = 320 \text{ K}$$

13.

c)



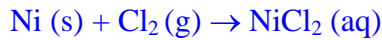
14.

The resulting solution will contain just one liquid phase. It will have the composition $x_A = 0.2$, $x_B = 0.4$, $x_C = 0.4$ which corresponds to the homogenous region.

15.

$\prod_{i=1}^k a_i^{v_i}$ is the product of the activities of the reaction components raised to their respective stoichiometric coefficients. Unless $\Delta_r G_m = 0$, this product is not equal to the equilibrium constant of the reaction.

16.



17.

a) unmeasurably small amount of nuclide

18.

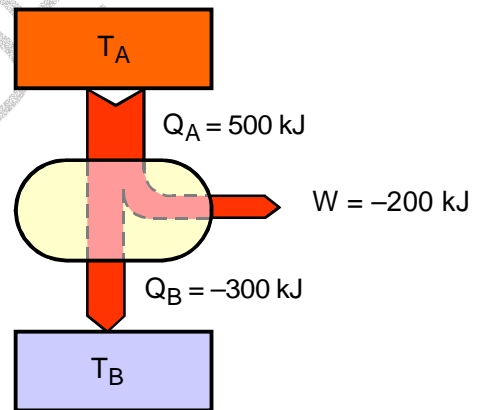
a) The isotherm for an ideal gas connects points having the same enthalpy.

c) The isotherm for an ideal gas connects points having the same internal energy.

For an ideal gas the enthalpy and the internal energy are functions of temperature only. The entropy as well as the Gibbs energy depend on temperature and pressure.

19.

$$W = -200 \text{ kJ}$$



20.

$$C_{pm} = 82 \text{ J K}^{-1} \text{ mol}^{-1}, C_{psp} = 0.82 \text{ J K}^{-1} \text{ g}^{-1}$$

21.

$$H_m(\text{H}_2\text{O}, \text{l}) = 6000 \text{ J mol}^{-1},$$
$$H_m(\text{H}_2\text{O}, \text{g}) = 51000 \text{ J mol}^{-1}.$$

22.

b) it is impossible to construct a cyclic heat engine that would convert all the heat supplied completely to work

23.

The charge needed is $Q = 1.1 \cdot 10^3 \text{ F} = 106\,150 \cdot 10^3 \text{ C}$.

24.

c) isobaric

25.

$$K_H(\text{N}_2)/K_H(\text{O}_2) = 2$$