JURY ONLY
Total points:_____
Theory:_____ Experiment:_____
Checked by: _____

THEORETICAL PROBLEMS

(Write down the solutions and answers to the problems at the designated places!
Results/solutions out of the frame will not be checked!)

1) A reaction cylinder contains a mixture of gases with the following mole fractions: 18 % CO, 11 % H_2O, 8 % H_2, the rest being argon. Upon heating the mixture to 1000 °Ca chemical reaction is initiated given by the following equation: $CO + H_2O \rightleftharpoons CO_2 + H_2$. An equilibrium is reached characterized by$K_c = 1.6$. (15 points)

(I) For each of the gases in the vessel show the equilibrium mole fraction as a function of the reaction extent and the total quantity of gases present. (4 points)

Solution:

(II) Using the data given, calculate the equilibrium mole fractions for each gas. (9 points)

Solution:

(III) Is it possible to calculate the rate of the chemical reaction taking place in the vessel, given the data in the problem? Explain please. (2 points)

Answer:

2) 15 mL of NaOH solution with concentration of 0,015 mol/L are mixed with 85 mL solution of phosphoric acid with a concentration of 0.0144 mol/L. (10 points)

(I) Write down the reaction equation and calculate the pH value of the resulting solution. Consider phosphoric acid as a monoprotic one (that is the dissociation is $HA + H_2O = H_3O^+ + A^-$) and the equilibrium constant, $K_a(HA)$, is given by $K_a(HA) = \frac{c(H_3O^+)c(A^-)}{c(HA)} = 7.1 \cdot 10^{-3}$ mol L^{-1}. (7 points)

Solution:

(II) Phosphoric acid is, actually, a triprotic acid and dissociates in three steps. Write the corresponding equations describing these three steps:

1.

2.

3. (1,5 points)

(III) Write down the expressions for the equilibrium constants relevant for each of the three steps of dissociation:

1.

2.

3. (1,5 points)

3) The following chemical equation is given: (7 points)

$$FeO{\cdot}Cr_2O_3 + O_2 + Na_2CO_3 = Na_2CrO_4 + Fe_2O_3 + CO_2$$

(I) Mark the oxidizing and the reducing agent within the above equation: (4 points)

Answer:
The oxidizing agent is _____, while the reducing one is_____.

(II) Balance the above equation (with the least all-integer coefficients), using electron-balance scheme (3 points)

Solution:

4) Energy is needed in order to break bonds in a molecule, while energy is released during formation of the same bond (that is, ΔH is negative). Values for the reaction enthalpy (in kJ/mol) are given in the table below, for breaking the bond signed with the dash. Thus, for breaking the bond between carbon and oxygen (in ethanol) the reaction enthalpy is 380 kJ/mol. (8 points)

H–H	436
H–I	298
$CH_3CH_2O–CH_3$	339
$CH_3CH_2–OH$	380
$CH_3–I$	234
$CH_3CH_2O–H$	436

(I) Determine which bonds are broken, and which are formed in a chemical reaction described by the following equation: (2 points)

$$CH_3CH_2OCH_3 + HI = CH_3CH_2OH + CH_3I$$

Answer:
The following bonds are broken: _____,
The following bonds are formed: _____.

(II) Calculate the reaction enthalpy of the above equation using the data from the table. Is the reaction exothermic or endothermic? (4 points)

Solution:

The reaction is (encircle): a) exothermic b) endothermic

(III) The quantity of hydrogen iodide in the beginning of a reaction (in a vessel) is 0,345 mol. After equilibrium is reached it equals 0,025 mol. Calculate the enthalpy change (in kJ) during the reaction. (2 points)

Solution:

IMAGINED EXPERIMENT

A technician has prepared 7 solutions planned to be used in a field analysis. During the transport of the chemicals, the bottle with hydrochloric acid leaked and damaged the labels. Could you help the technician in determining the content of the bottles, having at your disposal (apart from the unlabeled solutions) only a set of test-tubes and the bottle that (you know) contains hydrochloric acid? The solutions were: $Na_2CO_3(aq)$, $AgNO_3(aq)$, $Ba(NO_3)_2(aq)$, $NaCl(aq)$, $K_2SO_4(aq)$ and $NH_4NO_3(aq)$. Propose the easiest approach that is to be used, to be able to unequivocally solve this problem. Note: you can use nothing but the above chemicals and equipment! Write down the relevant reaction equations that you would use in the course of solving the problem.

Solution**:**