Test in chemistry for the follow-up master's study

Model test with results

Study field: Nuclear chemistry

The exam is considered to have been successfully passed if the candidate has obtained at least 20 points (i.e. 50 % of the maximum number of points).

1. The density of a natural isotopic mixture of unknown gas at a temperature of 293.15 K and a pressure of 101325 Pa is ρ = 1330.1 g.m^{-3}. What gas is it? Assume ideal gas behavior.
(4 points)
Result: It's oxygen.

2. An important product of the chemical processing of uranium ores is insoluble diammonium diuranate, which precipitates from uranyl sulfate solution via ammonia solution. Write the stoichiometric equation of the reaction. For the purposes of stoichiometry, aqueous ammonia solution may be regarded as "ammonium hydroxide".
(4 points)
Result: $2\ (UO_2)SO_4 + 6\ NH_4OH \rightarrow (NH_4)_2U_2O_7 + 2\ (NH_4)_2SO_4 + 3\ H_2O$

3. Fill in the missing substance marked with a question mark in the equation *(c)* and determine the stoichiometric coefficients:
a) $Ag + O_2 + KCN + H_2O \rightarrow K[Ag(CN)_2] + KOH$
b) $Cr_2O_3 + NaNO_3 + Na_2CO_3 \rightarrow Na_2CrO_4 + NaNO_2 + CO_2$
c) $MnO_2 + KClO_3 + KOH \rightarrow K_2MnO_4 + KCl + ?$
d) $Fe_2O_3 + KNO_3 + KOH \rightarrow K_2FeO_4 + KNO_2 + H_2O$
(4 points)
Result:
a) $4\ Ag + O_2 + 8\ KCN + 2\ H_2O \rightarrow 4\ K[Ag(CN)_2] + 4\ KOH$
b) $Cr_2O_3 + 3\ NaNO_3 + 2\ Na_2CO_3 \rightarrow 2\ Na_2CrO_4 + 3\ NaNO_2 + 2\ CO_2$
c) $3\ MnO_2 + KClO_3 + 6\ KOH \rightarrow 3\ K_2MnO_4 + KCl + 3\ H_2O$
d) $Fe_2O_3 + 3\ KNO_3 + 4\ KOH \rightarrow 2\ K_2FeO_4 + 3\ KNO_2 + 2\ H_2O$

4. Substance A with an unknown molar concentration of c_1 is dissolved in the solution. 2 mL of this solution were made up with distilled water to a total volume of V = 100 mL. For analysis, a 500 μL sample was taken from the diluted solution, which was made up to the mark with distilled water in a 10 mL volumetric flask. The concentration of substance A in the sample thus prepared was C_3 = 3.8.10^{-4} mol.L^{-1}. What was the concentration of substance c_1 in the starting solution?
(4 points)
Result: c_1 = 0.38 mol.L^{-1}

5. Oxidation of copper with nitric acid proceeds according to the following equation:
$3\ Cu + 8\ HNO_3 \rightarrow 3\ Cu(NO_3)_2 + 2\ NO + 4\ H_2O$.
What must be the mass of copper introduced into the reaction if the amount of $Cu(NO_3)_2$ is to be equal to 0.75 mol? What volume of HNO_3 solution with a density of 1376.9 g.L^{-1} and a weight fraction of 0.62 should be used, and what will be the volume of NO formed under normal conditions (T = 273.15 K, P = 101325 Pa)?
(4 points)
Result: 47.7 g; 148 mL; 11.2 dm^3

6. The standard heat of combustion of methane during the formation of liquid water is equal to -891 kJ.moL^{-1}. Assume that we have burned in excess oxygen *a)* 1 g of methane, *b)* such an amount of methane, the volume of which at a temperature of 25 ° C and a pressure of 0.0987 MPa is just $1\cdot 10^{-3}$ dm^3. Calculate how much heat ΔH the reaction system transfers to the surroundings in both cases.
   (5 points)
   Result: a) -55.5 kJ; b) -0.035 kJ

7. The equilibrium degree of conversion of ethane in the reaction C_2H_6 (g) ↔ C_2H_4 (g) + H_2 (g) at a temperature of 1000 K was α = 0.485. The equilibrium system pressure was equal to the standard pressure. Pure ethane was introduced into the reaction and the reaction mixture behaved ideally. Calculate the value of the equilibrium constant K_a at the given temperature and the molar fractions of the components in the equilibrium mixture.
   (5 points)
   Result: K_a = 0.308; x (C_2H_6) = 0.341; x (C_2H_4) = x (H_2) = 0.327

8. Calculate the pH of these aqueous solutions: *a)* KOH solution with a total (analytical) concentration of $5\cdot 10^{-4}$ mol.L^{-1}; *b)* HCl solution with a total concentration of $2\cdot 10^{-8}$ mol.L^{-1}. Can activity coefficients be considered as unit? Use the value of the ionic product of water K_W = $1.01\cdot 10^{-14}$.
   (5 points)
   Result: pH(KCl) = 10.69; pH(HCl) = 6.96

9. The reaction 2 HI → H_2 + I_2 belongs at temperatures 629 K and 700 K to the rate constant $3\cdot 10^{-5}$ and $1.2\cdot 10^{-3}$ L.mol^{-1}.s^{-1}, resp. Calculate the value of the activation energy and the frequency factor.
   (5 points)
   Result: E_a = 190.2 kJ.mol^{-1}; A = $1.9\cdot 10^{11}$ L.mol^{-1}.s^{-1}