ENTRANCE EXAMINATION AT THE UNIVERSITIES OF TECHNOLOGY IN FINLAND (HELSINKI, TAMPERE, LAPPEENRANTA, OULU, ÅBO)

Chemistry Exam 26 May 2004

1. a) When water solutions of sodium phosphate (Na_3PO_4) and calcium chloride ($CaCl_2$) are mixed together a deposit which contains calcium phosphate is formed. Write the reaction equation for the formation of the deposit.

   b) Complete the following reaction equation: $Mg(OH)_2\,(aq) + HClO_4\,(aq) \rightarrow$

   c) Balance the following oxidation-reduction reaction which occurs in acidic solution:

   $Cr_2O_7^{2-}\,(aq) + Cl^-\,(aq) + H^+\,(aq) \rightarrow Cr^{3+}\,(aq) + Cl_2\,(g) + H_2O\,(l)$

   Which element oxidizes and which reduces in the reaction?

2. The solubility product of silver chromate, $K_s(Ag_2CrO_4)$, is $1.3 \cdot 10^{-12}$ $(mol/dm^3)^3$ at 25 °C. Calculate the solubility of silver chromate (mg/dm^3)

   a) in pure water.

   b) in a 0.010 mol/dm^3 $AgNO_3$ solution.

3. a) Calculate the pH of a 0.01 mol/dm^3 sodium hydroxide solution.

   b) Calculate the pH of a 0.01 mol/dm^3 acetic acid solution.

   c) Calculate the pH of a 0.01 mol/dm^3 sodium acetate (CH_3COONa) solution.

   The acid dissociation constant of acetic acid, K_a (CH_3COOH), is $1.8 \cdot 10^{-5}$ mol/dm^3 and the ion-product constant of water, K_w, is 10^{-14} $(mol/dm^3)^2$.

4. Methane gas is burned with air in a small combustion chamber. Methane flows into the chamber at a rate of 200.0 dm^3/min in a tube where the pressure is 152 kPa and the temperature 25 °C. Air is introduced into the chamber in another tube where the pressure is 101 kPa and the temperature 25 °C.

   a) Write the reaction equation when methane burns completely to carbon dioxide and water.

   b) To ensure as complete combustion as possible three times as much air as is theoretically necessary is introduced into the chamber. Calculate the amount of air introduced into the chamber in units dm^3/min. (You can assume that air contains 21 volume percent O_2 and 79 volume percent N_2).

   c) Calculate the composition of the exhaust gas mixture of part b) (O_2, N_2, CO_2 and H_2O) in terms of mole percent assuming that combustion of methane is complete and that the nitrogen in air does not react in this combustion system.

5. a) Write the structural formulas of all those alcohols with the formula $C_5H_{12}O$. Name also these alcohols.

   b) Write the structural formula for *cis*-2-butene.

   c) Write the structural formula for *o*-chlorophenol.

6. a) Write the reaction equation when 2-methyl-2-pentene reacts with water. Name the product.

   b) Write the monochlorinated reaction products for the reaction:

   $$\text{2,3-dimethylbutane} + Cl_2 \xrightarrow[-\ HCl]{hv}$$

   c) Write the reaction equation using structural formulas when 2-aminobutanoic acid reacts with 2-aminopropanoic acid.

Molar masses of the elements:

Element:	Ag	Cr	O
M / g mol^{-1}	107.90	52.00	16.00

Constants:

R = 8.314 J mol^{-1} K^{-1}