COMPETITION OF FIVE SCHOOLS

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CHEMISTRY PROBLEMS

Nõo Reaalgümnaasium, 9.–10. january 2008

1. Mart was in laboratory where he could use calcium, calcium hydrogen carbonate, muriatic acid, sodium carbonate, dolomite ($CaCO_3 \cdot MgCO_3$) and water. He could also use Kipp gas generator, gas-burner, crucible and glass-ware from the laboratory apparatus. Considering the existing equipment propose as many equations of reaction to get $CaCO_3$ as possible. (5)
NB! Some of the initial substances (five) must be synthesized from starting substances which Mart had. Give also equations of reaction for these syntheses. (5) **10 p**

2. There are five possible ways to get oxygen for example: thermal decomposition of $KMnO_4$, thermal decomposition of $KClO_4$, decomposition of H_2O_2 (30 % water solution) in the presence of catalyst, electrolysis of water and fractional distillation of liquefied air.

a) Sort these oxygen containing compounds in the increasing order of **i)** atom and **ii)** mass percent of oxygen. (5)

b) In which case ($KMnO_4$, $KClO_4$, H_2O_2 30 % water solution, water, air) the mass of the initial substance in grams is the lowest for getting exactly 1 dm^3 of oxygen (at normal conditions, *nc*). The volume percent of oxygen in air is 20.7. V_m = 22.4 dm^3/mol (4)

c) Industry consumes only oxygen that is preserved in the atmosphere. Therefore the content of the oxygen is decreasing slowly with the rate of 3,8 ppm per year (1 ppm = parts per million). How much (in dm^3 at *nc*) atmospheric oxygen is consumed in one year? At the present atmosphere contains $1175 \cdot 10^{15}$ tons of oxygen.
Source: Eesti Loodus Nr. 2007/10. (2) **11 p**

3. In the textbook there is written: „The ionic reactions trend toward the formation of weak electrolyte“. But at the same time no reaction is completely irreversible.

a) Calculate the concentration (M) of the hydrogen ions in the solution if 20 cm^3 of 0.15 M KOH solution reacts with **i)** 20 cm^3 and **ii)** 15 cm^3 of 0.20 M HCl solution (**1**); and **iii)** estimate the concentration of the hydrogen ions (< 10^{-7}, = 10^{-7}, > 10^{-7} M) if the alkali is in excess. **iv)** Is this reaction (**1**) partially reversible or completely irreversible? (6)

b) Write the equation of dissociation reaction for water and calculate the degree of dissociation of water ($\alpha = N_d/N$, $\rho(H_2O)$ = 0.9989 g/cm^3). Why does the reaction (**1**) take place? (2,5)

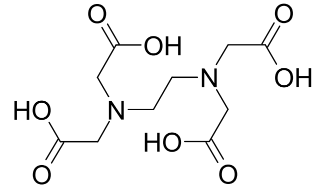
c) Reaction occurs also between CH_3COONa and HCl (**2**). **i)** Write the equation of this reaction. **ii)** Why does this reaction (**2**) take place? (1)

d) The acetic acid divides into ions in the solution and the degree of dissociation, α, depends approximately on the concentration of acetic acid, c, in the following way $\alpha = \sqrt{1.8 \cdot 10^{-5} / c}$.
i) Draw the dependence between α and the concentration on the enclosed graphic using the concentrations in the table.

c / M	0.5	0.1	0.03	0.01	0.003	0.001	0.0005
α						0.125	0.173

ii) Find the concentration (M) of the H^+ ions in the solution if 12 cm^3 of 0.010 M CH_3COONa solution reacts with 10 cm^3 of 0.012 M HCl solution. **iii)** Is the reaction (**2**) partially reversible or completely irreversible as compared with reaction (**1**)? **iv)** Estimate which should be the concentration of the acetic acid solution to ensure that the reaction is mainly shifted towards the products. (5,5)
NB! The concentration of hydrogen ions in neutral solution is 10^{-7} M (mol/dm^3). The densities of the solutions are equal to one. **15 p**

4. In the analytical chemistry EDTA (in figure) is used as the complexing agent.



a) The number of protons given up by EDTA depends on pH of the solution. **i)** Mark the acidic hydrogens in the EDTA structure. **ii)** Write the stepwise equations of the dissociation for EDTA. H_4Y stands for the neutral form of EDTA. (3)

b) EDTA can be used to determine the total hardness of the tap-water by complexation titration. The disodium salt of EDTA (Na_2H_2Y) is used for this purpose. Na_2H_2Y reacts with all water-soluble alkali and alkaline-earth metal ions in a 1 : 1 ratio. The total hardness of the water is equal to the millimoles of Na_2H_2Y used to titrate exactly 1 dm^3 of the water. For titration, 100.0 cm^3 of the tap-water is pipetted into the flask. 2 cm^3 of ammonium buffer (to keep pH in range 9-10) and a little amount of indicator (eriochrome black T) is also added to the flask. At the end-point of titration the colour of the solution changes from reddish-purple to blue.
i) 13.48 cm^3 of 0.05105 M Na_2H_2Y solution was used for titration. Calculate the total hardness of the water. **ii)** Write the equation of reaction between Ca^{2+} and Na_2H_2Y. **iii)** Estimate the pH change of the solution during the titration. **iv)** What is the difference between temporary and permanent hardness of the water? (4) **7 p**

5. a) Write the names, constitutional formulas and the functional group classes of the organic compounds formed in the reaction between primary C_3H_7I and **i)** KOH, **ii)** sodium ethanolate, **iii)** NH_3 (reacts 1:1), **iv)** $CH_3CH_2C{\equiv}CNa$, **v)** sodium propanoate and **vi)** NaCN. What is the reaction mechanism of these reactions. (5)

b) Write the equation of the hydrogenation reaction of the oleic acid (cis-9-octadecenoic acid). The melting temperature of the oleic acid is 14 °C. How do the melting temperature and the state of the product, stearic acid (octadecanoic acid), change compared to initial substance. (2) **7 p**