CENTRALE COMMISSIES VOORTENTAMEN

CHEMISTRY EXAM

Example exam 1

Time	: 3 hours
Number of questions	: 5

Start every question on a new sheet of paper (because each question is marked by a different corrector).

State your name on every sheet you hand in.

Do not write in pencil and do not use Tipp-Ex or any similar product.

Answers without argumentation will not be honored.

Additional data can be found in the BINAS science data reference book (5th or 6th edition).

The maximum scores are:

Question 1	: 19 points
Question 2	: 18 points
Question 3	: 9 points
Qqestion 4	: 14 points
Question 5	: 12 points

$$\text{mark} = \left(\frac{\text{number of scored points}}{72}\right) * 9 + 1$$

Information concerning the procedure and progress of the proces of marking: www.ccvx.nl

QUESTION 1 - ammonia

For this question, assume T=298 K and $p = p_o$

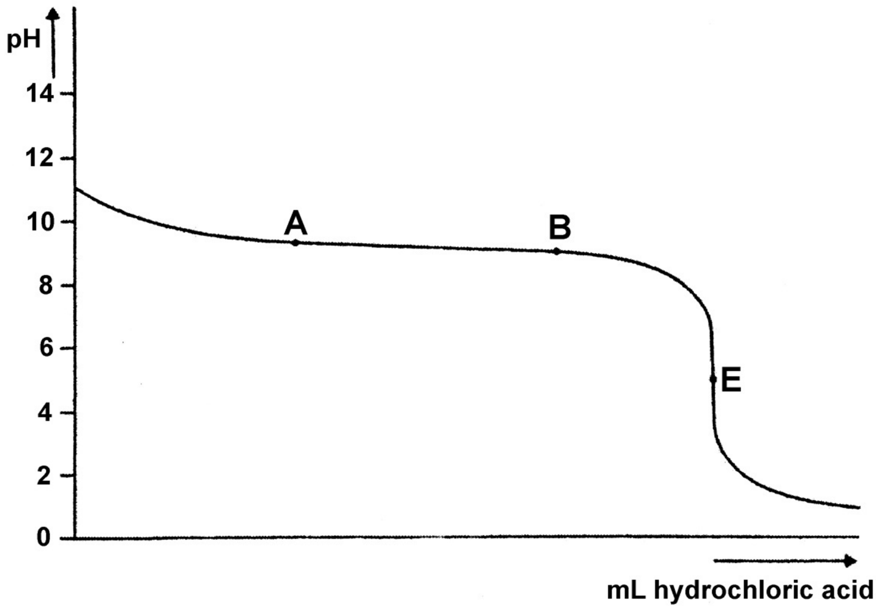
Uncle Twan, a chemistry teacher, while doing a cleaning job tells his niece Nina that ammonia gas dissolves remarkably well in water: ‘In one liter of water, more than 100 liters of ammonia gas may be dissolved’. Nina answers that you would then have 101 liters of solution. ‘No’, says uncle Twan to his astonished niece, ‘no, the volume remains one liter’.

a. Explain how it is possible to dissolve 100 liters of ammonia gas in 1 liter of water while the volume of the final solution is still about 1 liter.

You have a 0.100 M solution of ammonia in water.

b. Show by calculation that the pH of this solution is 11.1

You transfer 25.0 mL of this solution into a beaker and you titrate the solution using diluted hydrochloric acid. During the titration, the pH of the solution is monitored continuously. The results of these measurements are depicted in the diagram below:



In this diagram the pH is drawn against the number of added mL hydrochloric acid. The end- or equivalence point E is at a pH value below 7.

c. Explain that this was to be expected.

It took 20.0 mL of diluted hydrochloric acid to reach E.

d. Calculate the molarity of the hydrochloric acid solution that was used.

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The line between points A and B in the diagram is virtually horizontal.

e. Explain why the pH is almost constant here although a solution of strong acid was added.

From the diagram, one might read the pH value at the moment that 10.0 mL of the hydrochloric acid solution had been added, exactly halfway the titration. The solution then has a particularly special composition.

f. Explain what is special about the composition of the solution being titrated at that moment in comparison to other moments during the titration.

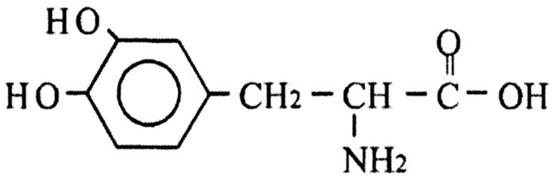
Halfway the titration, the pH value turns out to be 9.3.

g. Using <u>this pH value</u>, and your answer in f, calculate the acid constant (K_a) of the NH_4^+-ion.

QUESTION 2 - Parkinson

Dopamine is produced by certain cells in the brain. Dopamine plays a role in the transfer of pulses from the brain to the spine. The death of a large number of these dopamine producing cells results in the neurologic disease known as Parkinson's disease.

The brain cells synthesize dopamine in two successive reactions. In the first reaction, L-DOPA is formed from L-tyrosine with the help of a specific enzyme.
The structural formula of L-DOPA is:



In the second reaction, dopamine is formed from L-DOPA by the enzyme L-DOPA decarboxylase. In this reaction, L-DOPA is split up to yield dopamine and carbon dioxide. The indication 'L' in L-tyrosine and L-DOPA gives information about the spatial structure of the molecules of these compounds. In the name 'dopamine', the indication 'L' is not necessary.

a. Give the reaction equation for the decomposition of L-DOPA to dopamine and carbon dioxide. Use structural formulas for L-DOPA and dopamine.

b. Explain why the indication 'L' is necessary in L-DOPA, yet unnecessary in dopamine. Use structural formulas.

Research has shown that a point mutation in the gene for a protein called DJ-1 may be the cause for the development of Parkinson's disease. All members of a family, in which the disease is common, appearered to have a point mutation in the gene that codes for DJ-1. As a consequence, amino acids 165-166-167 of the DJ-1 protein now read Ala-Pro-Ala instead of the normal Ala-Leu-Ala.

c. Draw the fragment ~ Ala – Pro – Ala ~ in structural formula.

d. Explain, also on the basis of your drawing in c, how the presence of Pro instead of Leu may disturb the alpha helix structure of the protein at this point. Also mention the name of the type of binding that plays a role in keeping the alpha helix structure intact.

e. Assuming continuous coding of DJ-1 on the DNA (no introns) with nucleotide 1 being the first nucleotide of the first coding triplet, what are the numbers of the nucleotides coding for the amino acid mutated in the DNA of affected family members?

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f. Using Binas-table70E (5th edition) or 71G (6th edition) and the above data about the point mutation, what is the number and nature of the 'normal' base pair and of the mutated base pair? Be sure to show both coding and complementary strand of the DNA, so base pairs and which one of the pair is in the coding strand. (use the 1-letter abbreviations for nucleotides in DNA sequences).

QUESTION 3 - chlorine gas - water vapor equilibrium

Chlorine gas and water vapor may react with each other under certain conditions.
The following equilibrium forms:

$$2\ Cl_2(g) + 2\ H_2O(g) \rightleftarrows 4\ HCl(g) + O_2(g)$$

The reaction to the right is endothermic.

In order to determine the equilibrium constant K at a given temperature, 2.0 moles of chlorine gas and 2.0 moles of water vapor are led into a closed vessel of 5.0 dm^3. After reaching equilibrium, 1.2 moles of chlorine gas remain.

a. Give the equation for the equilibrium.

b. Calculate the content of the vessel in equilibrium (numbers of moles of all gases).

c. Calculate K.

Subsequently, the temperature of the vessel is changed. After the new equilibrium has been reached, only 1.0 moles of chlorine gas remain.

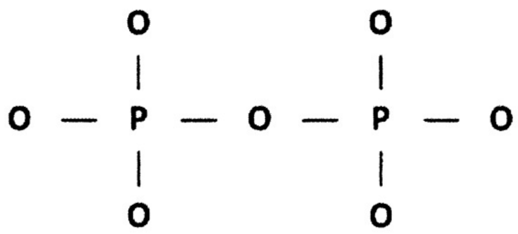
d. Has the temperature of the vessel been increased or decreased? Explain your answer!

QUESTION 4 - two vanadium salts

$V_2O_2P_2O_7$ and $V_2OP_2O_7$ can be regarded as compounds build from vanadium-ions, oxide-ions and $P_2O_7^{4-}$-ions. All vanadium-ions in $V_2O_2P_2O_7$ have the same charge. All vanadium-ions in $V_2OP_2O_7$ also have the same charge, yet different from the charge of the vanadium-ions in $V_2O_2P_2O_7$

a. From the given formulas of the vanadium salts, deduce the charge of the vanadium ions in $V_2O_2P_2O_7$ and in $V_2OP_2O_7$

The spatial structure of the $P_2O_7^{4-}$-ion resembles that of two tetrahedrons with one common vertex corner. In projection, this looks like the figure.

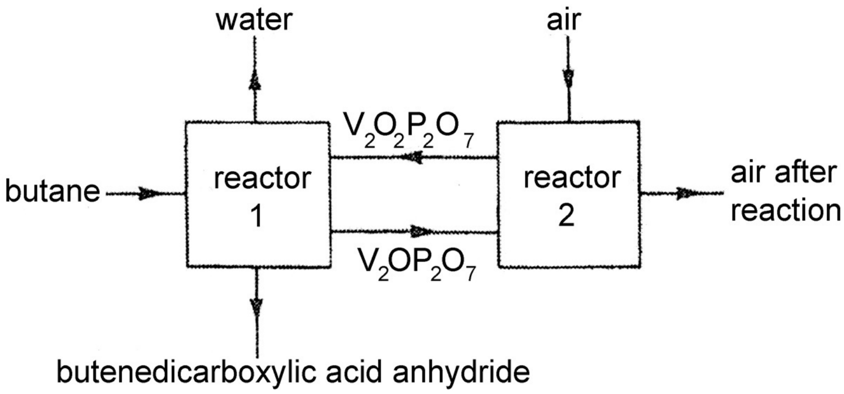


b. From this projection, construct the Lewis structure of the $P_2O_7^{4-}$-ion. Show the location of the charges.

$V_2O_2P_2O_7$ is used in certain industrial processes; it is used for instance in the production of butenedicarboxylic acid anhydride ($C_4H_2O_3$) from butane. This is a redox reaction, in which $V_2OP_2O_7$ is formed.

c1. Give the half reaction for the conversion of $V_2O_2P_2O_7$ to $V_2OP_2O_7$ and explain whether $V_2O_2P_2O_7$ acts as an oxidator or as a reductor.
c2. Give the half reaction for the conversion of butane to butenedicarboxylic acid anhydride. Use molecular formulas for organic compounds.
c3. Give the overall reaction of $V_2O_2P_2O_7$ with butane.

The way butenedicarboxylic acid anhydride is synthesized in a chemical plant is shown in the scheme.

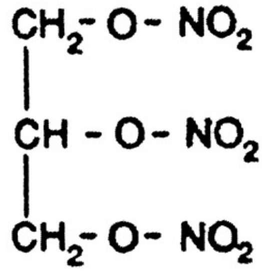


In reactor 1, butane and $V_2O_2P_2O_7$ react. $V_2OP_2O_7$ that is formed in this reaction reacts with oxygen from air in reactor 2 and is reconverted to $V_2O_2P_2O_7$, which is taken from reactor 2 and re-used in reactor 1. Two students, Michiel en Gijs, have different opinions about the role of $V_2O_2P_2O_7$ in the process. Michiel says that it functions as a catalyst, but Gijs disagrees.

d1. Explain what makes Michiel think of $V_2O_2P_2O_7$ as a catalyst.
d2. Explain what makes Gijs think differently.
d3. Explain who is right, Michiel or Gijs.

QUESTION 5 - explosive

Glyceryltrinitrate is a well-known explosive:



On explosion, glyceryltrinitrate decomposes as follows:

$$4\ C_3H_5N_3O_9(l) \rightarrow 12\ CO_2(g) + 10\ H_2O(g) + 6\ N_2(g) + O_2(g)$$

A lot of energy is released in this reaction.

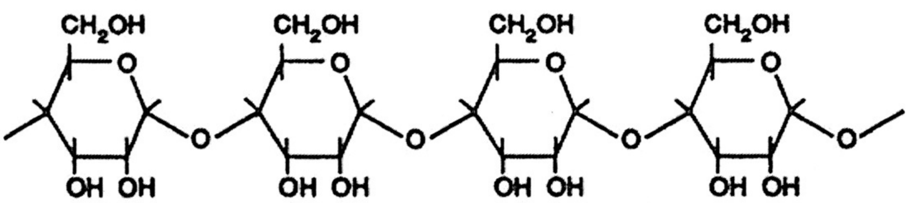
a. Calculate the energy change (298 K, $p = p_o$) of this reaction per mole of glyceryltrinitrate. Use data in Binas and the fact that the energy of formation of glyceryltrinitrate is **–**$3{,}56 \cdot 10^5$ J mol^{-1} (298 K, $p = p_o$).

Glyceryltrinitrate is synthesized by esterification of glycerol (propane-1,2,3-triol) with nitric acid. Nitric acid is added in excess. The esterification takes place in the presence of sulphuric acid.
A reactor is filled with 100 kg glycerol, 250 kg nitric acid and 150 kg sulphuric acid. Only glyceryltrinitrate and water are formed and all substances involved are fluids under the reaction conditions. After full conversion of the glycerol, the content of the reactor is emptied.

b. Calculate the mass percentage of glyceryltrinitrate in the mixture from the reactor.

The decomposition of glyceryltrinitrate can be looked upon as an internal combustion. The oxygen needed for its combustion is present within the compound itself. The internal combustion of glyceryltrinitrate is complete; sufficient oxygen is present for full combustion, there is even a surplus of oxygen.

Guncotton or ‘nitrocotton’ is an explosive compound as well.
It is produced by complete esterification of cellulose using nitric acid.
The structural formula of cellulose is depicted in part below:



Upon explosion, guncotton decomposes. This decomposition may also be viewed upon as an internal combustion.

c. Give the molecular formula of guncotton.

d. Explain on the basis of the molecular formula whether guncotton decomposes fully or only partially by internal combustion.

END