CENTRALE COMMISSIES VOORTENTAMEN

CHEMISTRY EXAM

Example exam 1

time	: 13.30 to16.30
number of questions	: 6

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	: 9 points
Question 2	: 10 points
Question 3	: 16 points
Qqestion 4	: 10 points
Question 5	: 11 points
Question 6	: 20 points

$$\text{mark} = \left(\frac{\text{number of scored points}}{76}\right) * 9 + 1$$

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

QUESTION 1 - chrome alum

Chromium (III) potassium sulphate dodecahydrate is the systematic name for chrome alum. The meaning of numerical prefixes is given in table 66C of BINAS.

This salt is highly soluble in water.

a. Give the number of protons and electrons of the chromium(III)-ion in chrome alum.

b. Name the three bond types that occur in chrome alum and name the particles between which these bonds occur.

c. Draw the Lewis structure (electron formula) for the sulphate ion. In this structure, indicate the formal charges and determine which spatial arrangement the ion takes as a result.

d. Write down the equation for the solution of chrome alum in water.

QUESTION 2 - deodorant

When merging a potassium bromate solution ($KBrO_3$), a solution of potassium bromide and hydrochloric acid the following reaction occurs:

$$BrO_3^- + 5\ Br^- + 6\ H^+ \rightarrow 3\ Br_2 + 3\ H_2O$$

a. Calculate the amount of bromine (in mmol) created when 7.00 mmol of potassium bromate reacts with excess potassium bromide and sufficient hydrochloric acid.

If oxine (C_9H_7NO) is added to the resulting solution, a reaction that exclusively produces dibromo-oxine ($C_9H_5Br_2NO$) as a carbon bond will occur. Oxine and dibromo-oxine are both molecular substances that are relatively easily soluble in water. The mole ratio for the reaction of oxine and bromine is oxine : bromine = 1: 2

b. Write down the equation for the reaction that occurred and indicate the different states of matter.

Some deodorants contain an Al^{3+} solution. The above reaction can be used to determine the levels of Al^{3+} in these types of solutions.

Assume you are testing the Al^{3+} level in a deodorant by adding a solution of excess sodium oxinate ($Na^+C_9H_6NO^-$) to 10.0 mL of the deodorant in question. Sodium oxinate is a salt of oxine, which is a weak acid. Following the addition of this sodium salt solution, aluminium oxinate, which is a poorly soluble salt, forms a sediment.

c. Write down the equation for this sediment reaction.

The aluminium oxinate is filtered and subsequently converted into Al^{3+} and oxine using hydrochloric acid. Next, 7.00 mmol of a potassium bromate solution is added, as well as the necessary amount of potassium bromide to convert all bromate into bromine. The oxine fully reacts with the bromine created in the above process (in a mole ratio of 1 : 2). The remaining amount of bromine is determined by titration, producing an outcome of 0.660 mmol.

d. Calculate the amount of Al^{3+} in 1.00 mL of the deodorant.

QUESTION 3 - pectin

The third structural formula shown in table 67F1 of BINAS (6th edition) or table 67A1 (5th edition) is of D-galactose.

a. Explain what the capital D in the name of this substance stands for.

Replacing the CH_2OH group bound to carbon 5 in this structure with a carboxylic acid group will produce the structural formula of D-galacturonic acid.

With a simple alkanol, this change can be achieved by reacting with an oxidising agent. For example, one of the substances resulting from a reaction of propan-1-ol with a potassium dichromate ($K_2Cr_2O_7$) solution in an acid medium will be propanoic acid. In this reaction, the orange colour that is caused by the dichromate ion will change to green.

b. Write down the equations for the two half reactions and the full reaction for the conversion of propan-1-ol into propanoic acid using an acidic solution of potassium dichromate. Use molecular formulas for the organic substances.

The conversion of D-galactose into D-galacturonic acid cannot be achieved by adding an acidic solution of potassium dichromate. The orange colour will change to green, but the required reaction product will not be generated.

c. Explain why D-galacturonic acid will not be the reaction product when a D-galactose solution is mixed with an acidic solution of potassium dichromate.

D-galacturonic acid is a major component of pectin, which is a building block of plant cell walls. To produce pectin, a conversion of D-galactose into D-galacturonic acid takes place in living cells.

d. Explain how the conversion of D-galactose into D-galacturonic acid works in living cells.

e. Work out a method by which this conversion could be achieved outside of living cells.

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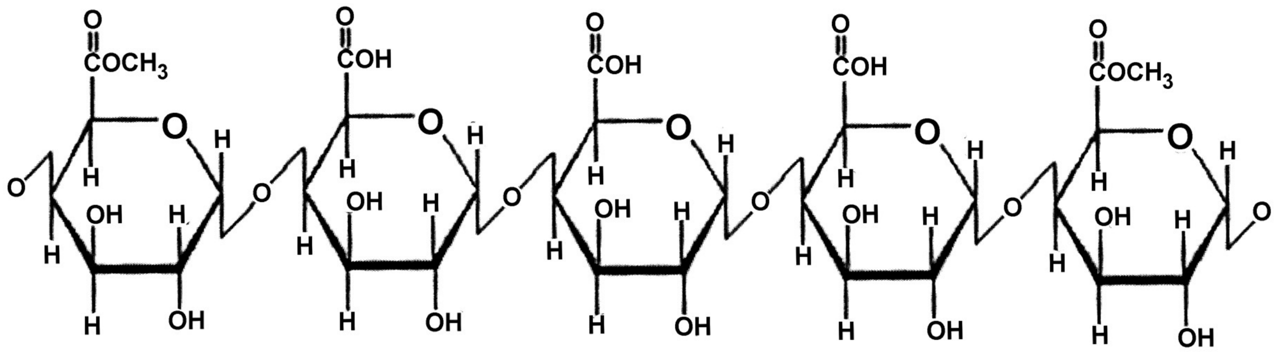
Glucose can be polycondensed into starch or amylose (see BINAS 67F3 or 67A3). Galacturonic acid can be polycondensed in a similar way, and pectin can be produced following an additional process. The structure of pectin can be represented as follows:



Apparently, the additional process the polygalacturonic acid has undergone is partial esterification.

f. Using structural formulas, write down the equation for the esterification of propanoic acid by analogy with the esterification of polygalacturonic acid, and provide the name of the product.

One of the properties of pectin is that it can bind the walls of different cells. Polysaccharides are a major component of these walls.

g. Explain how this bond is achieved.

Depending on the circumstances, the carboxylic acid groups of pectin may emit a proton. The K_z associated with this process is $5{,}0 \cdot 10^{-3}$. Assume you have a solution of pectin in which 40% of the initially present carboxylic acid groups have esterified. The pH of the solution is 4.0.

h. Calculate the percentage of the initially present carboxylic acid groups that have protolysed.

QUESTION 4 - oxides and water

The solubility of the oxides of sodium, potassium, calcium, barium, magnesium and zinc are shown in table 45A of BINAS.

a. Write down the equation for the reaction of potassium oxide and water.

There is an “s” next to the oxides of magnesium and zinc in the table, meaning less than ca. 0.01 mmol of the substance is dissolved per litre of water. A bit of these oxides will therefore dissolve. However, solutions of these oxides do not contain any O^{2-}.

b. Explain which ions do occur in a saturated solution of magnesium oxide.

The solubility products of calcium, magnesium and zinc hydroxides are shown in table 46.

c. Using a calculation, demonstrate that the “s” in table 45A is correct for the amount of solubility product of magnesium oxide.

Milk of lime is a common name for a suspension of calcium oxide in water.

The suspension of magnesium oxide in water is commonly known as milk of magnesia (N.B.: a solution of a suspension is always a saturated solution).

d1. Explain whether milk of lime has a higher or lower pH level than milk of magnesia.
d2. Explain whether a suspension of zinc oxide in water has a higher or lower pH level than milk of magnesia.

e. Explain what happens to the pH level of milk of magnesia if extra magnesium oxide is added.

QUESTION 5 - 4-methylpent-2-ene

a. Draw the structural formula of 4-methylpent-2-ene.

b. Explain whether there are any stereoisomers, and if so, how many.

Assume bromine is added to 4-methylpent-2-ene.

c. Provide the name of the substance produced by this reaction.

A polymer can be synthesised using 4-methylpent-2-ene as a monomer.

d. Draw the structural formula of part of this polymer, which includes at least three monomer units.

It is also possible to use 4-methylpent-2-ene in the synthesis of a copolymer. In this case, a second alkene such as ethylene is required.

e. Describe briefly how the structure of such a copolymer looks like.

QUESTION 6 - alkane through electrolysis

When phenylacetic acid ($C_6H_5CH_2COOH$) reacts with persulfate ($S_2O_8^{2-}$), the products formed include carbon dioxide and 1,2-diphenylethane ($C_6H_5CH_2CH_2C_6H_5$); the $S_2O_8^{2-}$ is converted into SO_4^{2-}. This reaction of phenylacetic acid with persulfate is a redox reaction.

a. Write down the equation for each of the two half reactions.

Assume another conversion takes place by electrolysing a solution of an alkane carboxylic acid and the salt of the same alkane carboxylic acid, resulting in the production of hydrocarbon and carbon dioxide. The liquid is continuously stirred during this electrolysis. Octane can thus be produced by electrolysis of a solution of pentanoic acid (C_4H_9COOH) and sodium pentanoate ($C_4H_9COO^-Na^+$) in ethanol. To prepare this solution, a little sodium is added to a solution of pentanoic acid in ethanol first. This results in a conversion, which is assumed to occur via two partial reactions:

partial reaction 1:	sodium reacts with ethanol to produce ethanolate ions ($C_2H_5O^-$), among other substances.
partial reaction 2:	the ethanoate produced in partial reaction 1 reacts further with pentanoic acid molecules, producing ($C_4H_9COO^-$) ions, among other substances.

Both of the partial reactions are complete reactions.

b1. Write down the equations for the two partial reactions and use these to determine the equation of the total reaction.
b2. Explain why partial reaction 2 is a complete reaction.

During electrolysis, the $C_4H_9COO^-$ produced in the previous process reacts at the positive electrode. Octane and carbon dioxide are produced as a result. It can be assumed that radicals are also formed in the process. The reaction mechanism can be seen as follows:

Step 1: $CH_3(CH_2)_3COO^- \rightarrow CH_3(CH_2)_3COO\bullet + e^-$
Step 2: $CH_3(CH_2)_3COO\bullet \rightarrow CH_3(CH_2)_3\bullet + CO_2$
Step 3: $2\ CH_3(CH_2)_3\bullet \rightarrow CH_3(CH_2)_6CH_3$

This reaction mechanism has been tested by carrying out the electrolysis in the presence of styrene (phenylethylene). At the end of the experiment, it becomes apparent that some polystyrene has also been formed.

c. Based on the mechanism described above, explain how the production of polystyrene from styrene has occurred in this experiment.

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During electrolysis of a solution of pentanoic acid and sodium pentanoate in ethanol, pentanoic acid reacts at the negative electrode to produce $C_4H_9COO^-$ and hydrogen. When the pentanoic acid runs out, ethanol reacts at the negative electrode.

d1. Determine the maximum amount of octane (in mol) that can be produced through electrolysis of a solution of 0.20 mol pentanoic acid and 0.020 mol sodium pentanoate in ethanol.
d2. Calculate how much dm^3 CO_2 (298K,p_o) is produced at the positive electrode at the same time.

Similar types of reaction occur when solutions of other organic acids and their salts are electrolysed in ethanol, and it can be assumed they follow the same mechanism. It should therefore be possible to produce octane through electrolysis of a mixture, dissolved in ethanol, of two alkanoic acids other than pentanoic acid and the sodium salts of these two alkanoic acids.

e. Write down the structural formulas for two carboxylic acids other than pentanoic acid that can be used to produce octane through electrolysis.

f. Based on the mechanism described above, explain whether the amount of octane (in mol) produced per mol of CO_2 using the latter method is greater than, smaller than or equal to the amount of octane (in mol) produced using the former method (assuming a solution of pentanoic acid and sodium pentanoate is used).

END