Supplement 1: An example of student worksheets and teacher notes used in the school year 2017/2018

MTA-ELTE Research Group on Inquiry-Based Chemistry Education
Content Pedagogy Research Program of the Hungarian Academy of Sciences

It is important to note that the student sheets are not intended to be stand alone. They were used in class with an accompanying dialogue from the teacher. In other words, the teachers talked students through the sheets. Each following student sheet and teacher notes was part of a teacher guide file that contained detailed instructions for teachers how to prepare and guide the students through the activities. Those files are available in Hungarian at the following links:

Student sheet 7: **Jamie Oliver's perfect salad dressing** 7. feladatlap: Jamie Oliver tökéletes salátaöntete

Student sheet 8: **The fight of metals** 8. feladatlap: Fémek harca

Student sheet 9: **How much iron is in the water?** 9. feladatlap: Mennyire vasas az ivóvíz?

Student sheet 10: **The "ancient enemy"** 10. feladatlap: Az "ősi ellenség"

Student sheet 11: **Lime in the limelight** 11. feladatlap: Nem ettünk meszet!

Student sheet 12: **Milk, the complete food** 12. feladatlap: A tej, mint teljes értékű élelmiszer

The English translations of the first 18 student sheets and teacher guides are available on the website of the project: http://ttomc.elte.hu/publications/90:

1-6. Student sheets and teacher notes (piloted in school year 2016/2017)
7-12. student sheets and teacher notes (piloted in school year 2017/2018)
13-18. student sheets and teacher notes (piloted in school year 2019/2020)

7. Student sheet: Jamie Oliver's perfect salad dressing

(type 1: 'step-by-step' version for Group 1 students)

Jamie Oliver, the famous English cook prepares many different salad dressings. He praises the one with sardella paste, and you can watch a video in Hungarian about its preparation on the internet.[1] Jamie uses two tablespoons of wine vinegar for this recipe. The characteristic flavours of wine vinegars are due to their different ingredients. (For instance, there is raspberry flavoured vinegar too.) The vinegars made by fermentation contain 3-15% acetic acid in aqueous solutions. If there is not the type of vinegar at home what you would need according to the recipe, it can be replaced with one that has got different concentration, but you will obviously need a different volume of that. However, how do you think the amount of acetic acid in a vinegar is determined? You will get know about it by filling in this worksheet.

Experiment 1: Pour a little sodium hydroxide solution into a test tube. Add 1 drop of phenolphthalein solution to it and shake the content of the tube.

Observation: After adding phenolphthalein, the colourless solution became …… colour.

Explanation: The phenolphthalein indicates with this colour that the sodium hydroxide solution is ……

Experiment 2: Pour a little water into a test tube. Add 1 drop of white wine vinegar to it. Add 1 drop of phenolphthalein solution to it and shake the content of the tube.

Observation: After adding phenolphthalein, the colour of the solution became ……..

[1] https://www.youtube.com/watch?v=gOakIi6aKEA (last accessed: 28 October 2020)

Explanation: The acetic acid in the vinegar (white vine vinegar, salad vinegar) is ……..

Experiment 3: Add sodium hydroxide solution drop-by-drop to the test tube containing the mixture of vinegar solution and phenolphthalein left after finishing Experiment 2 until the change of colour remains.

Observation: The colour of the solution changed from …….. to ……..

Explanation: sodium hydroxide (an alkali / a base) reacted with acetic acid (an acid), while sodium acetate (salt) and water formed: **acid + base = salt + water**. This reaction is called **neutralisation**. After

all the acetic acid had reacted, the excess of the …… sodium hydroxide added is indicated

by the …… colour of the phenolphthalein.

Experiment 4: There are vinegar solutions in both glasses, labelled "A" and "B". These were prepared by pouring the same volume of water into both glasses, then adding 1 drop of 6% white wine vinegar into one glass and 2 drops of 6% white wine vinegar into other glass. Determine, **in which of the glasses are the 2 drops of vinegar**! Add 1 drop of phenolphthalein to the content of both glasses. Add sodium hydroxide solution drop-by-drop into the glass labelled "A", counting the number of drops until the change of colour remains. Stir the solution after adding each drop of sodium hydroxide solution. Then repeat this with the solution being in the glass labelled "B".

Observation: ……. drops of sodium hydroxide solution had to be added to the content of glass labelled "A"

until the changed colour remained. ……. drops of sodium hydroxide solution had to be added to the content of glass labelled "B" until the changed colour remained.

Explanation: More acetic acid was in the glass labelled ……., because **more/less sodium hydroxide solution** had to be added until the colour changed. Therefore, the 2 drops of 6% white wine vinegar was in the

glass labelled ……. Twice as much acetic acid needs ……..sodium hydroxide. If the concentration of sodium hydroxide solution is known, then the concentration of acetic acid solution can be calculated.

What would you observe if there were 3 drops of 6% white wine vinegar in a glass, and you would do Experiment 4 with it?

……

7. Student sheet: Jamie Oliver's perfect salad dressing
(type 2: 'step-by-step' version + explanation of experiment-design for Group 2 students)

It is the same as the type 1 student sheet ('step-by-step' version for Group 1 students), but after Experiment 4 the worksheet also contains the text below that the students have to read and discuss with their teacher.

While doing the Experiment 4, we had to follow **exactly the same process in case of both glasses**:

- the same amount of phenolphthalein was added to both solutions, by the same dropper;
- the same concentration sodium hydroxide solution was added to them, by the same dropper;
- both solutions were stirred after each drop of alkali solution;
- the sodium hydroxide solution was added until the same change of colour.

While designing the experiment, the principle called "**how to vary one thing at a time**" was applied. Only the amount of acetic acid was different in the glasses labelled "A" and "B", the other parameters were the same. This way, only the different amount of the acetic acid could cause that more drops of sodium hydroxide solution were needed to reach the same change of colour in the case of the 2 drops of vinegar. Therefore, the **amount of the acetic acid** was **the only changing variable that was different**. **The volume of sodium hydroxide solution needed only depended** on that, because **the other parameters were held constant**.

7. Student sheet: Jamie Oliver's perfect salad dressing
(type 3: experiment-designing version for Group 3 students)

It is the same as the type 1 student sheet ('step-by-step' version for Group 1 students), except Experiment 4 that goes as follows.

Experiment 4: There are vinegar solutions in both glasses, labelled "A" and "B". These were prepared by pouring the same volume of water into both glasses, then adding 1 drop of 6% white wine vinegar into one glass and 2 drops of 6% white wine vinegar into the other glass. Design an experiment to determine which of the glasses contains the 2 drops of vinegar!

You have to do **exactly the same in the case of both glasses labelled "A" and "B".** You have to use the **same equipment and materials (solutions)** and accomplish the **same operations** with them. Therefore, while designing the experiment, you apply the principle called "**how to vary one thing at a time**". If only the **amount of acetic acid** is different, then this is **the only variable that changes**, therefore this **causes the different observations in the cases of the two glasses**. All the other **parameters have to be constant**. Based on Experiment 1-3, **what could be the different observation (experience) that only depends on the amount of acetic acid**?

Plan of the series of experiment:……

……

……

Observations:……

……

Explanations:……

……

7. Student sheet: Jamie Oliver's perfect salad dressing[2]

(teacher notes)

Jamie Oliver, the famous English cook prepares many different salad dressings. He praises the one with sardella paste, and you can watch a video in Hungarian about its preparation on the internet[3]. Jamie uses two tablespoons of wine vinegar for this recipe. The characteristic flavours of wine vinegars are due to their different ingredients. (For instance, there is raspberry flavoured vinegar too!) The vinegars made by fermentation contain 3-15% acetic acid in aqueous solutions. If there is not the type of vinegar at home what you would need according to the recipe, it can be replaced with one that has got different concentration, but you will obviously need a different volume of that. However, how do you think the amount of acetic acid in a vinegar is determined? You will get know about it by filling in this worksheet.

Experiment 1: Pour a little sodium hydroxide solution into a test tube. Add 1 drop of phenolphthalein solution to it and shake the content of the tube.

Observation: After adding the phenolphthalein, the colourless solution became **purple/pink** colour.

Explanation: The phenolphthalein indicates with this colour that the sodium hydroxide solution is **alkaline**.

Experiment 2: Pour a little water into a test tube. Add 1 drop of white wine vinegar to it. Add 1 drop of phenolphthalein solution to it and shake the content of the tube.

Observation: After adding the phenolphthalein the colour of the solution became **colourless**.

Explanation: The acetic acid in the vinegar (white vine vinegar, salad vinegar) is **acidic**.

Experiment 3: Add sodium hydroxide solution drop-by-drop to the test tube containing the vinegar solution and the phenolphthalein left after finishing the Experiment 2 until the change of colour remains.

Observation: The colour of the solution changed from **colourless** to **purple/pink**.

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[2] The basic idea of this student sheet was found in the *Inquiry in Action* (Third Edition, Copyright 2007, American Chemical Society), pp. 285-297. (http://www.inquiryinaction.org/download, last visited: 10.07.2017). The context of Jamie Oliver's salad dressing was a pre-service chemistry teacher student's (called Mónika Bak) idea, who used it for a lesson plan at the time of her training.

[3] https://www.youtube.com/watch?v=gOakIi6aKEA (last accessed: 28 October 2020)

Explanation: The sodium hydroxide (an alkali / a base) reacted with the acetic acid (an acid), while sodium acetate (salt) and water formed: **acid + base = salt + water**. This reaction is called **neutralisation**. After all the acetic acid had reacted, the excess of the **alkaline** sodium hydroxide added is indicated by the **purple/pink** colour of the phenolphthalein.

Experiment 4: [Only for type 1 and 2 student sheets.] There are vinegar solutions in both glasses, labelled "A" and "B". These were prepared by pouring the same volume of water into both glasses, then adding 1 drop of 6% white wine vinegar into one glass and 2 drops of 6% white wine vinegar into other glass. Determine, **in which of the glasses are the 2 drops of vinegar**! Add 1 drop of phenolphthalein to the content of both glasses. Add sodium hydroxide solution drop-by-drop into the glass labelled "A", counting the number of drops until the change of colour remains. Stir the solution after adding each drop of sodium hydroxide solution. Then repeat this with the solution being in the glass labelled "B".

Observation: (E.g.) **16** drops of sodium hydroxide solution had to be added to the content of glass labelled "A" until the changed colour remained. **8** drops of sodium hydroxide solution had to be added to the content of glass labelled "B" until the changed colour remained.

Explanation: More acetic acid was in the glass labelled **„A"**, because **more/~~less~~ sodium hydroxide solution** had to be added until the colour changed. Therefore, the 2 drops of 6% white wine vinegar was in the glass labelled **„A"**. Twice as much acetic acid needs **twice as much** sodium hydroxide. If the concentration of the sodium hydroxide solution is known, then the concentration of the acetic acid solution can be calculated.

What would you observe, if there was 3 drops of 6% white wine vinegar in a glass, and you would do the Experiment 4 with it?
24 drops of sodium hydroxide solution should be added until the changed colour would remain.

[Only for type 2 student sheets.]
While doing the Experiment 4, we had to follow **exactly the same process in case of both glasses**:

- the same amount of phenolphthalein was added to both solutions, by the same dropper;
- the same concentration sodium hydroxide solution was added to them, by the same dropper;
- both solutions were stirred after each drop of alkali solution;
- the sodium hydroxide solution was added until the same change of colour.

While designing the experiment, the principle called "**how to vary one thing at a time**" was applied. Only the amount of acetic acid was different in the glasses labelled "A" and "B", the other parameters were the same. This way, only the different amount of the acetic acid could cause that more drops of sodium hydroxide solution were needed to reach the same change of colour in the case of the 2 drops of vinegar. Therefore, the **amount of the acetic acid** was **the only changing variable that was different**. **The volume of sodium hydroxide solution needed only depended** on that, because **the other parameters were held constant**.

[Only for type 3 student sheets.]
It is the same as the type 1 student sheet ('step-by-step' version for Group 1 students), except the Experiment 4 that goes as follows.

Experiment 4: There are vinegar solutions in both glasses, labelled "A" and "B". These were prepared by pouring the same volume of water into both glasses, then adding 1 drop of 6% white wine vinegar into one glass and 2 drops of 6% white wine vinegar into the other glass. Design an experiment to determine which of the glasses contains the 2 drops of vinegar!

You have to do **exactly the same in the case of both glasses labelled "A" and "B".** You have to use the **same equipment and materials (solutions)** and accomplish the **same operations** with them. Therefore, while designing the experiment, you apply the principle called "**how to vary one thing at a time**". If only the **amount of acetic acid** is different, then this is **the only variable that changes**, therefore this **causes the different observations in the cases of the two glasses**. All the other **parameters have to be constant**. Based on Experiment 1-3, **what could be the different observation (experience) that only depends on the amount of acetic acid**?

Plan of the series of experiment: E.g.: **1 drop of phenolphthalein has to be added to the content of both glasses. Sodium hydroxide solution should be added drop-by-drop into the glass labelled "A" until the change of colour remains, counting the number of drops. The solution has to be stirred after adding each drop of sodium hydroxide solution. Then this has to be repeated with the solution being in the glass labelled "B".**

Observations: **(E.g.) 16 drops of sodium hydroxide solution had to be added to the content of glass labelled "A" until the changed colour remained. 8 drops of sodium hydroxide solution had to be added to the content of glass labelled "B" until the changed colour remained.**

Explanations: The 2 drops of vinegar was in the **glass labelled "A", because more sodium hydroxide solution had to be added to that until the changed colour remained**

END OF THE 7. STUDENT SHEETS AND TEACHER NOTES

Supplement 2.

Test 2

Number of school:…… Number of teacher:….. Number of group:…….. Number of student: …….

The aim of our research is to make the teaching of chemistry as interesting and effective as possible. Thank you for completing this test according to the best of your knowledge, because you help our work. Please, write your answers only on this sheet of paper and do not use any other piece of paper.

1. a) What **gas** develops when magnesium and hydrochloric acid react?.....**...** AQ

1. b) Does lead (Pb) deposit from the aqueous solution of a lead compound, if zinc is placed in it? **Explain your answer** using the reactivity series of metals (see below). AR

K Ca Mg Al Zn Fe Co Ni Sn Pb H Cu Ag Au

……

2. a) The aqueous solution of copper(II) sulphate is blue. How could you decide which one is the more concentrated by looking at a very dilute and a very concentrated copper(II) sulphate solution?

Explain your answer!..... AS

……

2. b) There is 6% vinegar and 20% vinegar in two identical looking plastic bottles. The labels have fallen off from both bottles. You must decide, by doing an experiment, which bottle contains the more concentrated vinegar. (Smelling does not give a satisfactory answer and you must not taste the vinegar.) The following materials and equipment are available: 2 empty glasses (you can only use both of them once), 2 spoons, 4 droppers (with a scale on them showing the volume), aqueous solution of an alkaline caustic drain cleaner, red cabbage juice. (Vinegar is acidic and red cabbage juice indicates the changes of pH by its change of colour.)

What materials would you put into one glass and what into the other glass?.....

…… AT

In what order would you put the materials into one glass and into the other glass? AU

……..

How much would you put of the different materials into one glass and how much into the other glass?

…… AV

……

What different experiences would you expect in the case of each glass?..... AW

……

Based on your experiences, how could you decide which bottle contains the more concentrated vinegar? …… AX

3. a) A piece of eggshell and a piece of limestone were both held in flame and then they were put separately into water containing phenolphthalein. Why did the indicator show that both solutions are alkaline? …… AY

3. b) Write down the equation of the calcination.

…… AZ

4. The labels of two washing powders („**X**" és „**Y**") show that they contain the following ingredients:

- „**X**" washing powder: *5-15% anionic surfactants, <5% nonionic surfactants, polycarboxilates, zeolits, enzymes, fragrance materials.*
- „**Y**" washing powder: *sulphate: more than 30%, phosphate and carbonate: 15-30%, anionic surfactants, chloride, silicate: 5-15%, polymers, anionic surfactants below 5%. It contains enzymes. It only contains active ingredients that are biologically easily degradable.*

Which one would you buy, the „**X**" or the „**Y**" washing powder? (Assuming their price is the same.) Based on what you learnt about water softeners, explain **why you would not use the other** washing powder!

…… BA

5. 5 cm^3 of **fatty** milk is shaken with 2 cm^3 petrol in a test tube. 5 cm^3 of **skimmed** milk is also shaken with 2 cm^3 petrol in another test tube. Then we take 3 identical size drops of liquid from the upper layers of the content of both test tubes (from the solutions in petrol) and drop them on a piece of filter paper. In the case of the fatty milk or in the case of the skimmed milk is a bigger patch left on the paper after the evaporation of petrol? **Why?**

…… BB

……

6. a) What is the formula of the magnesium chloride?…… BC

b) Which of the materials listed below should be added to a dish of food that has got too much vinegar in it to improve its flavour? **Why?** *salt, alcohol, citric acid, sodium bicarbonate, starch, cooking oil*

…… BD

……

7. There are three test tubes. One contains silver ions (Ag^+), another aluminium ions (Al^{3+}), and the third zinc ions (Zn^{2+}). All are colourless aqueous solutions. (There is about 1 cm^3 dilute solution in each.)

There are two labelled bottles beside them, one contains ammonia (NH_3) solution and the other sodium hydroxide (NaOH) solution. The table below shows what would be seen if a little (a few drops) or much more (several cm^3) ammonia solution or sodium hydroxide solution was added to the test tubes containing the solutions of the different ions.

ion	+ little NH_3 solution	+ much NH_3 solution	+ little NaOH solution	+ much NaOH solution
Ag^+	brown precipitate	brown precipitate, dissolves	brown precipitate	brown precipitate
Al^{3+}	white precipitate	white precipitate	white precipitate	white precipitate, dissolves
Zn^{2+}	white precipitate	white precipitate, dissolves	white precipitate	white precipitate, dissolves

a) What is the **fewest** number of tests needed to decide which solution of metal ions is in each of the three test tubes? **Explain your answer.** .....

……

b) Only one of the solutions (NH_3 or NaOH) can be used to determine which ion is in which test tube. Which one? **Explain your answer**.

..... BF

……

c) How should your chosen solution (NH_3 or NaOH) be added to the solutions in the test tubes?

…… BG

d) What would you see when your chosen solution (NH_3 or NaOH) is added to the test tube containing the solution of aluminium ions (Al^{3+})?

BH

……

Please, give us the following information!

The end-of-semester grade you got in chemistry: BI

- The larger the number you circle, the more you like chemistry: (0: you do not like it at all, 4: you really like it): 0 1 2 3 4 BJ
- The bigger the number, the more you consider it is important to test ideas in sciences by experiments (0: not important at all; 4: very important): BK
  0 1 2 3 4
- The bigger the number, the more you agree with the following statement: "I prefer the step-by-step experiments to the ones that I have to design." BL
  0 1 2 3 4
- How important was it for you to fill in this test? (0: not important at all; 4: you worked as hard as you could): BM
  0 1 2 3 4

Instructions given to the teachers to mark the students' answers of the Test 2

Teachers correcting the test can judge whether the particular answer is accepted, since that should be determined by the meaning of the answer.

Please fill in the columns of the Excel spreadsheet with the marks obtained from following the instructions below. A student's marks should be written in the appropriate row of the Excel spreadsheet.

Columns 'AQ'-'BH' contain marks for students' answers.
Columns 'BI' contains the student's end-of-semester grade in chemistry.
Columns 'BJ'-'BM' contain students' attitude responses.

Column 'AQ' (task 1.a)
Hydrogen or H_2 or H or Mg + 2HCl = $MgCl_2$ + H_2.
Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column 'AR' (task 1.b)
Alternative answer I.: Yes, because zinc is more reactive (than lead).
Alternative answer II.: Yes, because zinc can reduce lead.
Alternative answer III.: Yes, because zinc can replace lead in its compounds.
Alternative answer IV.: Yes, because zinc is on the left (or in front) of lead in the reactivity series.
Marks: 1
In any other case. Marks: 0
1 item: application (DCK task)

Column 'AS' (task 2.a)
The deeper blue the solution is the more concentrated it is, since the deeper blue the solution is, the more blue solute is in it. Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column 'AT' (task 2.b, question 1)
Alternative answer I.: Vinegar, red cabbage juice and aqueous solution of the caustic drain cleaner in both glasses.

Alternative answer II.: Vinegar and red cabbage juice in both glasses.
Alternative answer III.: Red cabbage juice and aqueous solution of the caustic drain cleaner in both glasses. *(Note: This answer is only acceptable, if the student wants to add the two types of vinegar to the content of the glasses later.)*
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'AU' (task 2.b, question 2)
Alternative answer I.: 1. vinegar 2. red cabbage juice (or 1. red cabbage juice 2. vinegar) 3. aqueous solution of the caustic drain cleaner.
Alternative answer II.: 1. aqueous solution of the caustic drain cleaner 2. red cabbage juice (or 1. red cabbage juice 2. aqueous solution of the caustic drain cleaner) 3. vinegar.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'AV' (task 2.b, question 3)
Alternative answer I.: The same amount of the two types of vinegar in the two glasses and the same amount of red cabbage indicator into both glasses. The aqueous solution of the caustic drain cleaner should be added drop by drop to both solutions until the colour of one of the liquids changes.
Alternative answer II.: The same amount of the two types of vinegar in the two glasses and the same amount of red cabbage indicator into both glasses. The aqueous solution of the caustic drain cleaner should be added drop by drop to both solutions until the colours of both liquids change in the same way.
Alternative answer III.: The same amount of the aqueous solution of the caustic drain cleaner and the same amount of red cabbage indicator into the two glasses. The two types of vinegar should be added drop by drop to the content of the two glasses until the colours of one of the liquids change.
Alternative answer IV.: The same amount of the aqueous solution of the caustic drain cleaner and the same amount of red cabbage indicator into the two glasses. The two types of vinegar should be added drop by drop to the content of the two glasses until the colours of both liquids change in the same way.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'AW' (task 2.b, question 4)
Alternative answer I.: Less (or more) aqueous solution of the caustic drain cleaner should be added to the content of one glass than to the other until the colour of one of the liquids changes.
Alternative answer II.: Less (or more) aqueous solution of the caustic drain cleaner should be added to the content of one glass than to the other until the colours of both liquids change in the same way.
Alternative answer III.: Less (or more) aqueous solution of one type of vinegar should be added to the content of one glass than of the other type of vinegar to the content of the other glass until the colour of one of the liquids changes.
Alternative answer IV.: Less (or more) aqueous solution of one type of vinegar should be added to the content of one glass than of the other type of vinegar to the content of the other glass until the colours of both liquids change in the same way.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘AX’ (task 2.b, question 5)
Alternative answer I.: The more concentrated acid is in that glass, in which the colour of the liquid has not changed until the colour of the liquid changed in the other glass, if the same number of drops were added of the aqueous solution of the caustic drain cleaner to the content of both glasses.
Alternative answer II.: The more concentrated acid is in that glass, in which more drops had to be added of the aqueous solution of the caustic drain cleaner until the same change of colour.
Alternative answer III.: The more concentrated acid is the one, which changes the colour of the same amount of aqueous solution of the caustic drain cleaner first, if the same number of drops of vinegar are added to the content of both glasses.
Alternative answer IV.: The more concentrated acid is the one, of which less number of drops changes the colour of the same amount of aqueous solution of the caustic drain cleaner in the same way.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘AY’ (task 3.a)
Alkaline (calcium hydroxide) solution was formed in both cases.
Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column ‘AZ’ (task 3.b)
$CaCO_3 = CaO + CO_2$
Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column ‘BA’ (task 4)
Alternative answer I.: I would choose the washing powder “X”, because there is no phosphate in it (since that causes environmental pollution).
Alternative answer II.: I would choose the washing powder “Y”, because it contains phosphate, which is a water softener.
Marks: 1
In any other case. Marks: 0
1 item: application (DCK task)

Column ‘BB’ (task 5)
fatty milk, because it contains more fat (in the same volume than the skimmed milk). Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column ‘BC’ (task 6.a)
$MgCl_2$ Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column ‘BD’ (task 6.b)
Alternative answer I.: Sodium bicarbonate should be added, because that reacts with the vinegar.
Alternative answer II.: Sodium bicarbonate should be added, because carbon dioxide evolves from sodium bicarbonate by vinegar.

Alternative answer III.: Sodium bicarbonate should be added, because an alkaline solution reacts with an acidic solution.
Alternative answer IV.: Sodium bicarbonate should be added, because that is used when there is too much acid in the stomach.
Marks: 1
In any other case. Marks: 0
1 item: application (DCK task)

Column 'BE' (task 7.a)
Alternative answer I.: 2, because then those 2 ions could be excluded in the case of the third test tube.
Alternative answer II.: 2, because then the content of the third test tube could be concluded.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'BF' (task 7.b)
Alternative answer I.: With ammonia solution, because then the experiences would be different in the cases of the three test tubes.
Alternative answer II.: With ammonia solution, because the experiences would be different in the case of aluminium ion and zinc ion containing solutions too.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'BG' (task 7.c)
Alternative answer I.: First only a little and then a lot (of the ammonia solution).
Alternative answer II.: Drop by drop (or in small quantities (of the ammonia solution).
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'BH' (task 7.d)
White precipitate would form that would not be dissolved in the excess of ammonia solution.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'BI'
The student's end-of-semester grade in chemistry.

Column 'BJ'
Insert the number circled by the student.

Column 'BK'
Insert the number circled by the student.

Column 'BL'
Insert the number circled by the student.

Column 'BM'
Insert the number circled by the student.

END OF EVALUATION OF THE TEST 2

Supplement 3.

Test 3

Number of school:…… Number of teacher:….. Number of group:…….. Number of student: …….

The aim of our research is to make the teaching of chemistry as interesting and effective as possible. Thank you for completing this test according to the best of your knowledge, because you help our work. Please, write your answers only on this sheet of paper and do not use any other piece of paper.

1. a) What kind of chemical processes are called reduction?

…… BN

1. b) Alkali metals have got low electronegativity. Are they usually oxidising or reducing agents? **Explain your answer!**…… BO

2. Does the catalyst participate in the chemical reaction? **Explain your answer!**

…… BP

3. The equation of the reaction that takes place between the bromine water and the methanoic acid:

$$Br_2 + HCOOH = 2\ HBr + CO_2$$

Bromine water is yellow. The other reactant and products are colourless. Your task is to show that the rate of reaction depends on the concentrations of the starting materials. The following are available: methanoic acid solution (in a glass bottle), bromine water (in a glass bottle), distilled water (in a flask), 4 beakers (50 cm^3, with a scale on their side to show the volume), 4 eyedroppers (without a scale), 4 Pasteur pipette (with a scale on their side to show the volume), 4 measuring cylinder (10 cm^3, with a scale on their side to show the volume), stopwatch.

a) What equipment and **how many pieces** of them are needed among the above listed ones for the experiment?……

…… BQ

b) Which materials and how much of them would you put into the chosen equipment at the time of the **preparation** of the experiment?

…… BR

c) How would you **start** the experiment?

…… BS

d) What **experiences** would you expect by the end of the experiment?

…… BT

e) Based on your experiences, how could you **decide**, how the rate of reaction depends on the concentrations of the starting materials?

…… BU

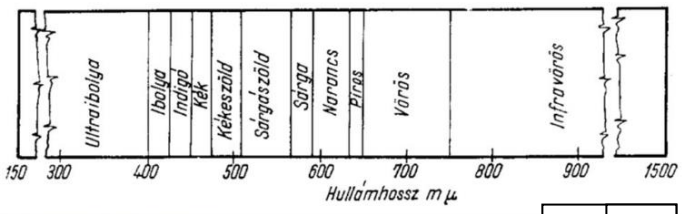
4. a) What happens between the system and its environment at the time of an endothermic reaction?

…… BV

4. b) You read the following on the internet how a feeding-bottle warmer works: *There is a very fine aluminium powder in it. If the outside wrapping is torn, the aluminium powder that has no protective oxide layer, is contacted with the air and begins to oxidise. This ensures the heat that warms up the content of the feeding-bottle.* What data or information would you need to determine whether this process really causes warming?

…… BW

5. The longer the wavelength of the light, the smaller the energy that its photons have. Explain, using this figure, whether the red colour flame test of lithium or the violet colour flame test of potassium indicates higher excitation energy!



…… BX

6. a) We measured the volumes of the drops of two liquids that have similar density. In which liquid has got stronger interactions among the particles: the liquid with a smaller or a larger volume of drop?

Explain your answer!…… BY

……

6. b) Why does a drop of water got a spherical shape in space, where gravitation is negligible?

…… BZ

7. Which substances are called acids?……

…… CA

8. You want to identify the following three water samples, with the help of acid-base indicators:
   A) Rainwater that is only slightly acidic because of the carbon dioxide dissolved in it, and its pH is 5.6.
   B) Acid rainwater that was collected in a polluted area and its pH is 2.8.
   C) A water sample collected from the Lake Balaton that has got a pH 8.0, because the waterbed is made of alkaline rocks.

You can do no more than two experiments, and you can choose indicators from the following table. (Between the two pH values belonging to the two colours, the transition colour of the indicator could be seen that changes depending on the pH.)

Name of the acid-base indicator	One colour of the indicator	The other colour of the indicator
phenolphthalein	colourless, if pH≤8.2	purple, if pH≥10.0
bromothymol blue	yellow, if pH≤6.0	blue, if pH≥7.6
crystal violet	green, if pH≤0.8	blue, if pH≥2.6
litmus	red, if pH≤5.0	blue, if pH≥8.0
methyl orange	red, if pH≤3.1	orange, if pH≥4.4

a) Which indicator would you use for Experiment 1? What colour change would you **expect** for each of the water samples? …… CB

……

b) Which indicator would you use for the Experiment 2? What colour change would you **expect** for each of the water samples?…… CC

……

c) Would false result be obtained if identical amounts of the water samples, but different amounts of indicators were used in the experiments that you have described? **Explain your answer.**

…… CD

……

d) Would you get a different result in the experiments that you described, if we replaced (as a model)

CE

the water sample "B" by 0.1 mol/dm^3 acetic acid that has got a pH 2.7? **Why?** …….

……

Please, give us the following information!

- The end-of-semester grade you got in chemistry: ☐ CF ☐
- The larger the number you circle, the more you like chemistry:
  (0: you did not like it at all, 4: you really liked it): 0 1 2 3 4 CG ☐
- The bigger the number, the more you consider it is important to test ideas in sciences by experiments (0: not important at all; 4: very important): CH ☐
  0 1 2 3 4
- The bigger the number, the more you agree with the following statement:
  "I prefer the step-by-step experiments to the ones that I have to design." CI ☐
  0 1 2 3 4

Instructions given to the teachers to mark the students' answers of the Test 3

Teachers correcting the test can judge whether the particular answer is accepted, since that should be determined by the meaning of the answer.

Please fill in the columns of the Excel spreadsheet with the marks obtained from following the instructions below. A student's marks should be written in the appropriate row of the Excel spreadsheet.

Columns 'BN'-'CE' contain marks for students' answers.
Columns 'CF' contains the student's end-of-semester grade in chemistry.
Columns 'CG'-'CI' contain students' attitude responses.

Column 'BN' (task 1.a)
Alternative answer I.: Gain of electron(s).
Alternative answer II.: Loss of oxygen (or gain of hydrogen).
Alternative answer III.: Decrease of oxidation number.
Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column 'BO' (task 1.b)
Alternative answer I.: They are reducing agents, since they give off electrons easily (while their reaction partner gains electrons and therefore it is reduced).
Alternative answer II.: They are reducing agents, since they give off electrons easily, while they are oxidised (and therefore they reduce their reaction partner).
Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column 'BP' (task 2.)
Alternative answer I.: Yes, because it accelerates the reaction (or increases the rate of reaction) by opening a new reaction route (or decreasing the activation energy).
Alternative answer II.: Yes, because that is how it starts the reaction.
Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column ‘BQ’ (task 3.a)
Alternative answer I.: 2 beakers, 1 measuring cylinder and a stopwatch.
Alternative answer II.: 2 beakers, 1 Pasteur pipette and a stopwatch.

Alternative answer III.: 2 beakers, 2 measuring cylinders.
Alternative answer IV.: 2 beakers, 2 Pasteur pipettes.
Alternative answer V.: 3 beakers, 1 measuring cylinder and a stopwatch, etc.
(Note: Any combination is good which the student correctly uses later while describing a fair test.)
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘BR’ (task 3.b)
The same volume, but different concentration of one of the solutions (formic acid or bromine water).
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘BS’ (task 3.c)
By adding one of the solutions to the other (or adding one of the solutions to the other solution and starting the stopwatch, if the experiments are not done in parallel with the solutions that have different concentrations).
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘BT’ (task 3.d)
Alternative answer I.: One of the solutions get colourless sooner than the other(s).
Alternative answer II.: It becomes colourless (and/or it gets fizzy).
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘BU’ (task 3.e)
Alternative answer I.: If the more concentrated solution gets colourless earlier (than the more dilute), then the rate of reaction increases by the increase of concentration.
Alternative answer II.: If the more dilute solution gets colourless later (than the more concentrated), then the rate of reaction decreases by the decrease of concentration.
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘BV’ (task 4.a)
Alternative answer I.: The system gets heat from its environment.
Alternative answer II.: The environment gives off heat to the system.
Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column ‘BW’ (task 4.b)
Alternative answer I.: Whether the reaction enthalpy (of the oxidation of aluminium) is positive or negative.

Alternative answer II.: Whether the reaction (i.e. the oxidation of aluminium) is exothermic or endothermic.
Marks: 1
In any other case. Marks: 0
1 item: application (DCK task)

Column 'BX' (task 5)
That of the potassium, because the energy of the photons of the violet light is higher (since the wavelength of the violet light is shorter).
Marks: 1
0: If the calculation is not correct.
1 item: application (DCK task)

Column 'BY' (task 6.a)
In the case of the liquid that has got the bigger drops, because it has got a higher surface tension (since the surface tension is higher, if there are stronger interactions among the particles).
Marks: 1
In any other case. Marks: 0
1 item: application (DCK task)

Column 'BZ' (task 6.b)
Alternative answer I.: Because the particles on the surface of the liquid are attracted to the center of the drop by the same strength of forces (as an avarage).
Alternative answer II.: Because the resultant force points into the inner part of the liquid (and the spherical shape has got the smallest surface, if the volume of the liquid remains the same).
Marks: 1
In any other case. Marks: 0
1 item: understanding (DCK task)

Column 'CA' (task 7)
Alternative answer I.: Substances that give away proton/hydrogen ion/H^+.
Alternative answer II.: Substances that increase the concentration of hydrogen ion/H^+/oxoniumion/H_3O^+ (in the solution).
Marks: 1
In any other case. Marks: 0
1 item: recall (DCK task)

Column 'CB' (task 8.a)
Alternative answer I.: With litmus and if it is red, then the sample is **B)**, if it is blue, then the sample is **C)**, if it shows a transition colour (lilac) than the sample is **A)**.
Alternative answer II.: With methyl orange, and if it is red, then the sample is **B)**, if it is orange, then the sample is **A)** or **C)**.
Alternative answer III.: With bromothymol blue, and if it is blue, then the sample is **C)**, if it is yellow, then the sample is **A)** or **B)**.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column 'CC' (task 8.b)
Alternative answer I.: See above (at task 8.a).
Alternative answer II.: With methyl orange, and if it is red, then the sample is **B)**.
Alternative answer III.: With bromothymol blue, and if it is blue, then the sample is **C)**.

Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘CD’ (task 8.c)
No, because the intensity of the colour of the indicator does not influence the result in this case (only its colour is important).
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘CE’ (task 8.d)
No (i.e. we could get to the same conclusion), because there is not any indicator among the listed ones that changes colour between pH 2.8 and 2.7.
Marks: 1
In any other case. Marks: 0
1 item: higher order cognitive skills (EDS task)

Column ‘CF’
The student’s end-of-semester grade in chemistry.

Column ‘CG’
Insert the number circled by the student.

Column ‘CH’
Insert the number circled by the student.

Column ‘CI’
Insert the number circled by the student.

END OF EVALUATION OF THE TEST 3