# Mathematics in school chemistry

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## 1 Introduction

In this unit we want to look closer at usage of mathematics in everyday life. For all these estimations and calculations we will use elementary mathematics to overcome the prejudice of “hard math” in lower secondary school chemistry. This helps us to uncover the basic principles of science and can support the engagement of the reader to keep discovering the world around him in more scientific way.

## 2 Making your own soap

Our earth’s crust contains different kinds of elements, minerals and rocks. One of these elements is sodium. If we look closer at it than we find out that we are using it quite often in our everyday life.

**Q:** How is it possible that you cannot find the element sodium in nature, but you can find it in a laboratory?

**A:** It is because of sodium reactivity. That is why it is found in nature only as a compound and never as the free element. Sodium makes up about 2.6% by weight of the Earth's crust, making it the sixth most abundant element overall and the most abundant alkali metal. We can find sodium in many different minerals. The most common is ordinary salt (sodium chloride). [1]

**Q:** Why do you think sodium is dangerous (Fig.1)?

**A:** www.km.fpv.ukf.sk/math2earth/video/natrium.AVI

*Comment:* Sodium as the element can be fitted into the dark glass bottle with petroleum.(Fig. 2) Because sodium is hygroscopic.

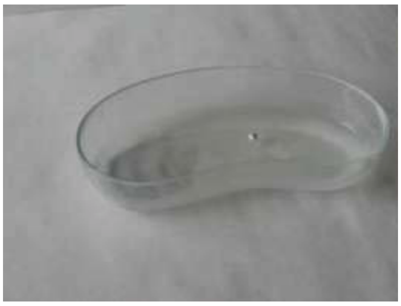

**Fig.1 Chemical reaction Na + $H_2O$**


**Fig. 2 Sodium in petroleum**

From salt (NaCl) we can get in laboratory conditions other compounds that contain sodium. Many of them we are using in our everyday life. Try to discover which of them are used the most! The compound that we will use for our soap production is sodium hydroxide (NaOH).

*Problem 1:* Prepare 200 grams of 20% sodium hydroxide (Fig. 3).

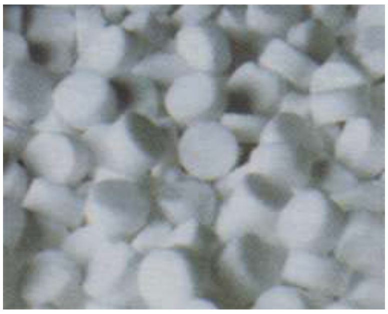

**Fig. 3 Sodium hydroxide (NaOH)**

You need to calculate how many grams of sodium hydroxide you need to mix with the water.

## 2.1 Curriculum content needed for this part

### 2.1.1 Chemical knowledge needed

- Mass fraction of the compound in solution
- We can calculate a mass fraction for the compound in solution with the following formula:

$$w = \frac{m(\text{substance})}{m`(\text{solution})} \cdot 100\ \%$$

w – a mass fraction of the compound in solution
m – a mass of the dissolved substance
m`– a mass of the whole solution

### 2.1.2 Mathematical knowledge needed

- Percentage
- Decimals
- Fractions
- Proportion

### 2.1.3 Calculation using decimal fraction

(Šedivý, 2004, s.56) [2]

Base...200g aqueous solution

$\frac{1}{100}$ of the base ... $\frac{200g}{100}$ = 2 g aqueous solution

$\frac{20}{200}$ of the base ... 2 g . 20 = 40 g sodium hydroxide

*Answer:* Mass of sodium hydroxide is 40 grams.

### 2.1.4 Application of chemical formula

(Adamkovič, 2000, s.23) [3]

$w = 20\ \% \Rightarrow 0{,}2$  $w = \frac{m(\text{substance})}{m`(\text{solution})} \cdot 100\ \%$

m`= 200 g of the solution

m = ? g sodium hydroxide  $0{,}2 = \frac{m(\text{sodium hydroxide})}{200\ \text{g}}$

$$0{,}2 \cdot 200\ \text{g} = m(\text{sodium hydroxide})$$

$$40\ \text{g} = m(\text{sodium hydroxide})$$

*Answer:* Mass of sodium hydroxide in its 20% aqueous solution is 40g.

### 2.1.5 Logical solution

If 10 % is $\frac{10}{100}$ of the base, which is $\frac{1}{10}$, then 20 % is $2 \cdot \frac{1}{10} = \frac{1}{5}$. Then 200 g. $\frac{1}{5}$ = 40 g.

*Answer:* Mass of sodium hydroxide is 40 grams.

### 2.1.6 Using 1%

Base ... 200 g aqueous solution

Percentage ... 20 % sodium hydroxide

We have to calculate the percentage = how many grams of sodium hydroxide is in 200 g of its aqueous solution

Base  100 % ... 200 g

 1 % ... 200 g : 100 = 2 g

Rate (percentage)  25 % ...  2 g . 20 = 40 g … part of the base

*Answer:* 200 g aqueous solution contains 40 g of sodium hydroxide.

### 2.1.7 Proportion method

(Šedivý, 2004, s.69) [2]

Let's name the given values

200 g is base 100 %  100 % ...........200 g

20 % percentage  20 % .............x g

We have to calculate the part (of the base)

$$x = \frac{20}{100} \cdot 200\ \text{g}$$

We have to calculate the part (of the base)

$$x = 40\ \text{g}$$

*Answer:* Mass of sodium hydroxide in its aqueous solution is 40 g.

### 2.1.8 Geometrical solution

(Vallo, 2009) [4]

1. Draw the isosceles triangle ABC with the right angle at vertex B and the $|AB|$ = 200 units. 2. Diagonal $|ED|$ is perpendicular to $|AB|$ and $|AD|$=100 units

3. On diagonal $|ED|$ find the point If you know that $|EG|$ = 20 units. The half-line $|\overrightarrow{AG}|$ will intersect side $|BC|$ in the point F.(Fig.4)

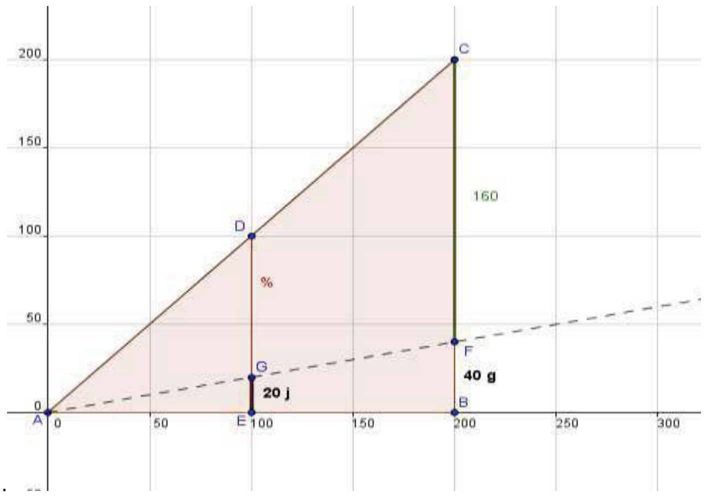


**Fig.4** Graphical solution of the problem

A mass of the sodium hydroxide is length $|BF|$, because length $|FC|$ is a mass of the water in the whole solution.

*Answer:* A mass of sodium hydroxide we can find in the Figure 4, because it is length $|BF|$.

### 2.2 Soap production

Materials and chemicals needed:

45 g vegetable fat, 28 g second vegetable fat,30 ml olive oil, 40 ml *20 % sodium hydroxide*, few drops of aromatic oil, balance, graduated cylinder, small bin, metal kettle,

If we have done the calculation, now prepare enough NaOH solution that we will use in producing our home-made soap. **www.km.fpv.ukf.sk/math2earth/video/hydroxide.AVI**

!!! For your safety follow the instructions:
Slowly add lye to water (best done outside), stirring gently (Fig.5). It is very important to add the Lye to the water and not the other way around, otherwise the reaction is too quick and it is dangerous! The lye will heat the water and release fumes. The fumes dissipate quickly, but turn your face away so as not to inhale the fumes. Set aside and allow the lye to cool.

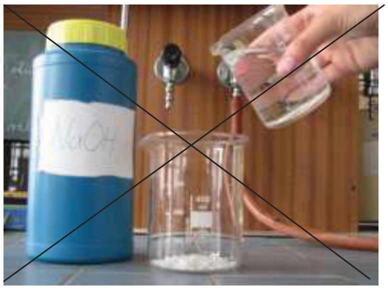


**Fig. 5 Water to lye**


**Fig. 6 Lye to water**

**Procedure:**

1. Weigh out 45 grams of vegetable fat and 28 grams of second vegetable fat and put them into the metal kettle. Melt these fats over low heat and stir frequently. Remove from heat after oils have melted and add the 30 ml of olive oil.
2. When your lye has reached a range of 35-36 degrees Celsius and your oils are at the same temperature, add the lye ( 40 ml of 20% sodium hydroxide solution) in a slow steady stream to the oils. Use the metal whisk to stir the mixture. After about ten minutes you will notice a change in your mixture. This is called saponification.
3. Add your fragrance when tracing occurs. The mixture will appear like thin cream, and droplets of soap will stand up on the surface. Stir well. Be ready to pour natural soap in your mould.
4. Cover your shoe box with the two towels and set aside undisturbed for eighteen hours. The soap will go through a gel stage and a heat process. At the end of this period uncover the soap and allow to sit for another 12 hours. If you measured accurately and followed the directions, there should be no problems. But if your soap has a deep oily film on top the natural soap cannot be used because it has separated. It is disappointing if this happens. This will occur if your measurements were not accurate.
5. Take your natural soap from the mould. Turn the box over and allow the soap to fall on a towel or clean surface. Cut your soap into bars. Allow the natural soap to cure in a cool dry place for approximately four to six weeks before using. With this process you can prepare different flavour of soaps. [5]
6. You can use the rest of the sodium hydroxide solution to prepare another flavour of soap using the same procedure.

**Q:** Can you estimate how many ml of salt water do we need to produce 50g of sodium soap?

Hint: The sea water contains 3,5% of salt (Fig. 7). If we want to get only the pure salt (sodium chloride) than we can round the amount of salt to 2,5% of the sea water. The whole process is too complex and requires deeper chemical knowledge and more information.

Try to aproximate the effectiveness of NaOH production from hydrolysis of NaCl and than calculate the amount of soap

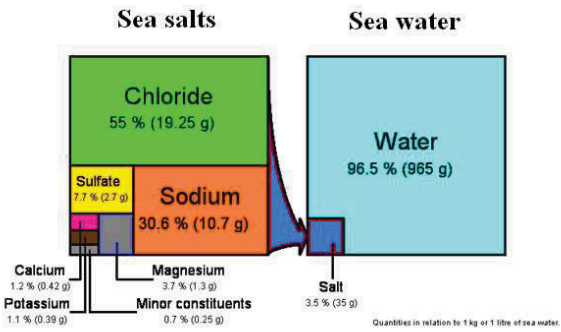


**Fig.7.** Graphical representation of salt percentage in the sea water

## 3 Make your own lemonade

*Problem:* It is 30° C outside and you want to refresh yourself by making the lemonade. Choose your favourite syrup and mix it with water. Can you describe what we got by mixing water and syrup? If you drink the whole volume of lemonade how many ml of water will it be? What is the mass fraction of syrup in the solution*?*

**Q:** Think about this problem more scientifically and try to make your own predictions. Let's use the scientific inquiry to find the satisfactory answer.

*Procedure:* First measure the amount of water that you mixed with syrup. Add the appropriate amount of syrup to make your drink tasty (for further calculation use producer's recommendation of the ratio). How can we measure this amount of syrup? What is the most practical unit to express it, for our further investigation?

Is it all we need? If so test your hypothesis by calculating the correct answer.
Let's look closer to our problem using information that people have already discovered. What information can help us to figure out this problem? Remember what you have learnt and find out more information about it.
Check the following solution and discuss how accurate the answers are.
For your calculation use 900 g of water and 100 g of syrup. (syrup contain 20 % of water)(Fig. 8)

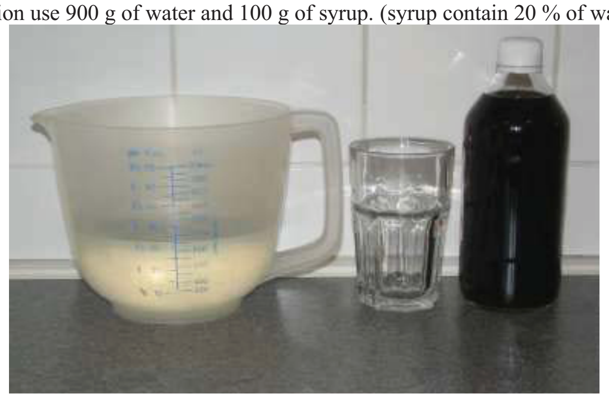

**Fig. 8** Material needed for the experiment

### 3.1 Solution 1

w =? % $$w = \frac{m(\text{compound})}{m`(\text{solution})} \cdot 100\ \%$$

m = 100 g of syrup

m`= 900 g of water $$w = \frac{100\ g}{900\ g} \cdot 100\ \%$$

w = 11, 11 % of syrup

*Answer*: So we must have 88,89% of water, which equals to 888,9 g or 888,9 ml of water.

*Comment:* As we can see, the mistake has occurred at the beginning, when we have not added the amount of syrup to the volume of water to get the volume of the whole solution.

### 3.2 Solution 2

w =? % of syrup $$w = \frac{m(\text{compound})}{m`(\text{solution})} \cdot 100\ \%$$

m = 100 g of syrup

m`= (900 + 100)g of the aqueous solution $$w = \frac{100\ g}{1000\ g} \cdot 100\ \%$$

w = 10 % is syrup in the solution

*Answer:* Is this the real amount of water in the solution?

*Comment*: Check the label of the syrup you are using and look for the ingredients. Does the syrup contain any water? What does it mean for our calculation?

Check the following solution and discuss how accurate the answers are.
For your calculation use 900 g of water and 100g of syrup. We have found out that the syrup contains 20% of water.

### 3.3 Correct mathematical solution

base ... 100 g syrup with water

base percentage... 20 % water

We can calculate the part – how many grams of water does the syrup contain:

Base 100 % ... 100 g

1 % ... 100 g : 100 = 1 g

percentage10 % 1 g . 20 = 20 g … part of the base

It means that 100g of syrup contains 20 g of water and (100 – 20)g of pure syrup.

Base ... 1000 g syrup solution

Part of the base ... 80 g pure syrup

<u>need to calculate ... percentage</u>

100 % ... 1000 g

1 % ... 1000: 100 = 10 g

10 g it is 1 %

80 g will be 80: 10 = 8 %

*Answer:* There is 8% of pure syrup in syrup solution and 92% of the water which is 920 ml.

## 3.4 Correct chemical solution

If the syrup contains 20% of water, then pure syrup is 80% of the syrup. Considering 100 g of the syrup, 80% of it equals to 80 g which is pure syrup. Total mass of the solution will be 1000g as we will mix 100g of the syrup (80 g of pure syrup and 20g of water) and 900 g of water. Mass fraction is as following :

$$w = \frac{m_{(puresyrup)}}{m_{(solution)}} = \frac{80}{1000} = 0,08$$

Result in percentage: Mass fraction of syrup in the solution is 8%, and the mass fraction of water is 92%, which equals to 920 ml of water.

*Discussion:*

Can we test the amount of water in syrup experimentally? How? Make a suggestion about the best procedure. How ecological and economical is it?

What is the volume of the syrup solution?

What will change if we use sherbet instead to prepare our drink?

What will change if we consider the water evaporation?

**Further problems**

1) Find the mass of potassium sulphate and water for a preparation of 400g of 30% aqueous solution of potassium sulphate. $[120g, 280g]$
2) Find the mass of glucose and water needed for a preparation of 200g of 5% solution. $[10g, 190g]$
3) We add 25 g of potassium nitrate to 125g of water. Calculate the mass fraction of potassium nitrate. $[17\%]$

4) What is the mass of 2,5% aqueous solution of silver nitrate, which can be prepared from 10g of silver nitrate? $[400g]$
5) In what amount of water do we have to dissolve 12,5g of potassium iodide in order to get 5% solution? $[250g]$
6) Calculate the mass of $FeSO_4.7H_2O$ which we need for preparation of 3,5% solution. $[28g]$
7) Prepare 450 g of 10% aqueous solution sodium chloride. How many grams of sodium chloride do we need? $[45g]$
8) Prepare 1500 g of 25% aqueous solution of potassium hydroxide. Calculate the mass of hydroxide and water needed for a preparation of this solution. $[375g, 1125g]$
9) How many grams of water do we need for dissolving 45g of sodium carbonate to prepare 20% solution? $[180g]$
10) How many grams of sodium hydroxide and water do we need to weigh if we want 800 g of 15% solution? $[120g, 680g]$

## Conclusion

Chemistry, as well as the rest of natural science, is awfully complicated – because it is Nature. [6] The use of mathematical methods in natural science, especially in chemistry, is an integral part of complex and specialized study. We want to show easier methods, how to find results. We are hoping that our article can help carry out this idea.

**References**

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[6] Jacob, M., Andersson, S., *THE NATURE OF MATEHEMATICS AND THE MATHEMATICS OF NATURE,* Netherlands, 1998