The 8th International Young Naturalists' Tournament

Problem № 11
«Hydrogen release»

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Condition of the problem:

A simple method to produce gaseous hydrogen is the reaction between metal aluminum and two salts in aqueous solution (e.g. copper sulphate and sodium chloride). Investigate how the reaction rate depends on the concentration of each salt and other relevant conditions. What salts react with aluminum to release hydrogen?

Hypothesis

If we use different salts contained in the water solution, change their concentration or temperature conditions of the experiment, the rate of hydrogen production will change.

Purpose of the study:

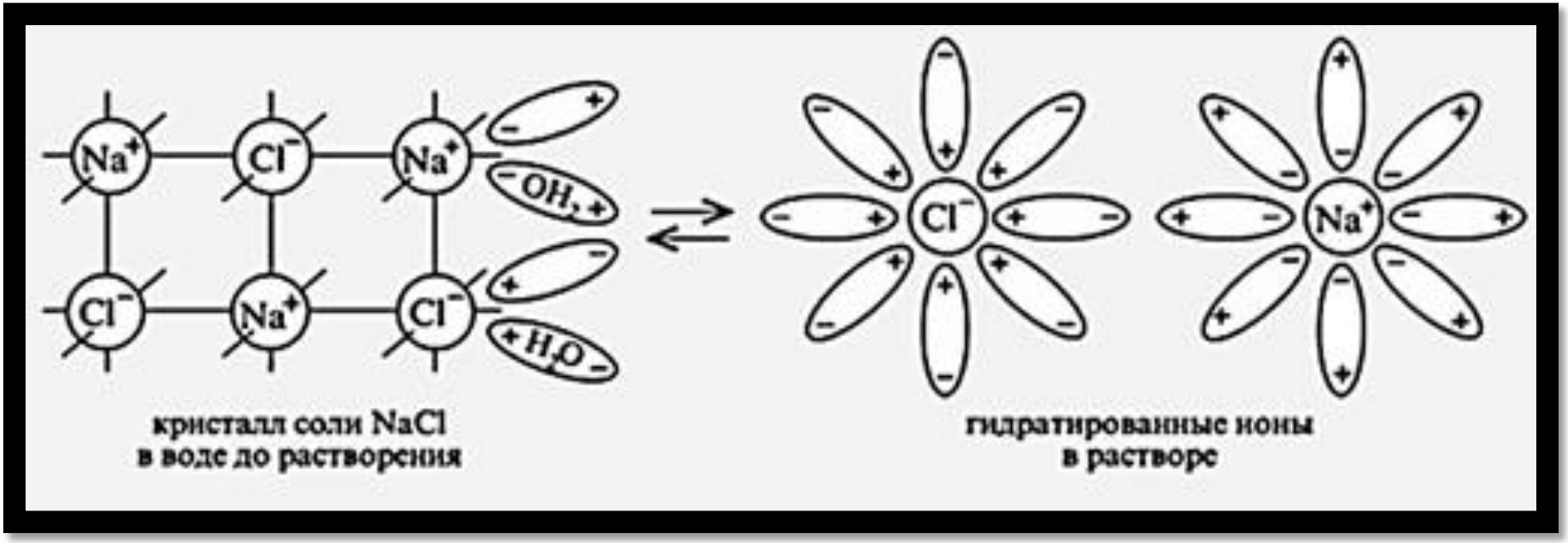
To offer the most effective way to obtain hydrogen within the condition of the task.

Research objectives:

1. To study theoretical material containing data on hydrogen and its production methods.
2. To study the dependence of the rate of hydrogen production on the concentration of salts contained in the solution.
3. To study the dependence of the hydrogen production rate on the type of salt contained in the solution.
4. To study the dependence of the rate of hydrogen production on temperature conditions.
5. To prove that the product of our reaction is hydrogen.

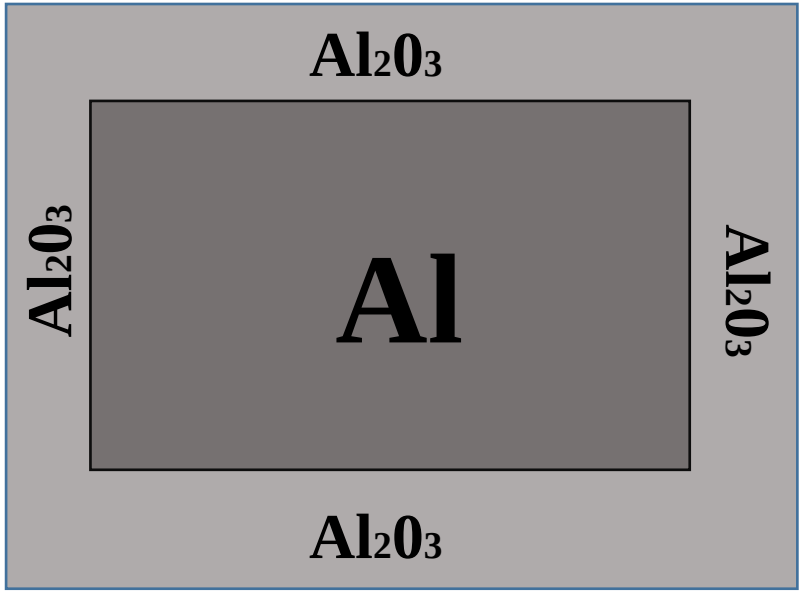
Theory

Dissociation is a reaction in which the compound molecules break down into smaller constituent parts.

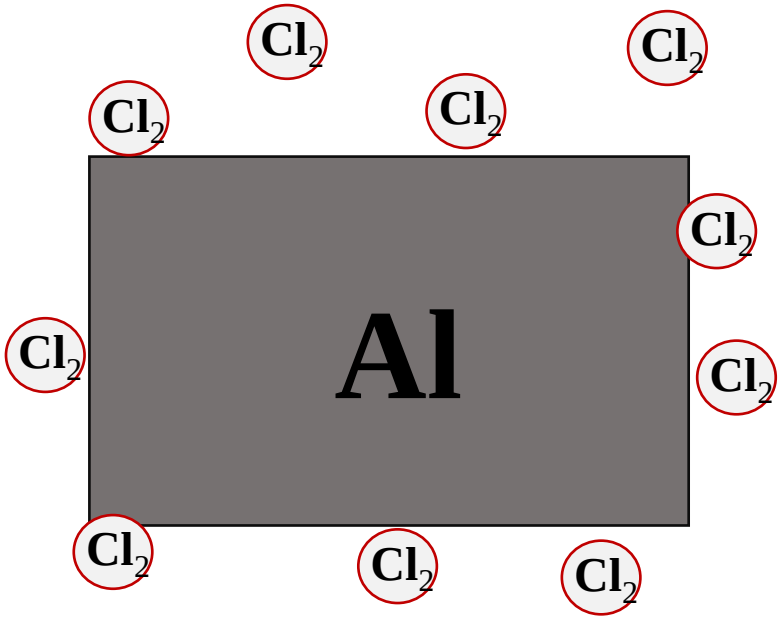


Theory

- Aluminum is a light and ductile white metal, matte silver thanks to a thin oxide film that immediately covers it in air.



$4Al+3O_2=2Al_2O_3$

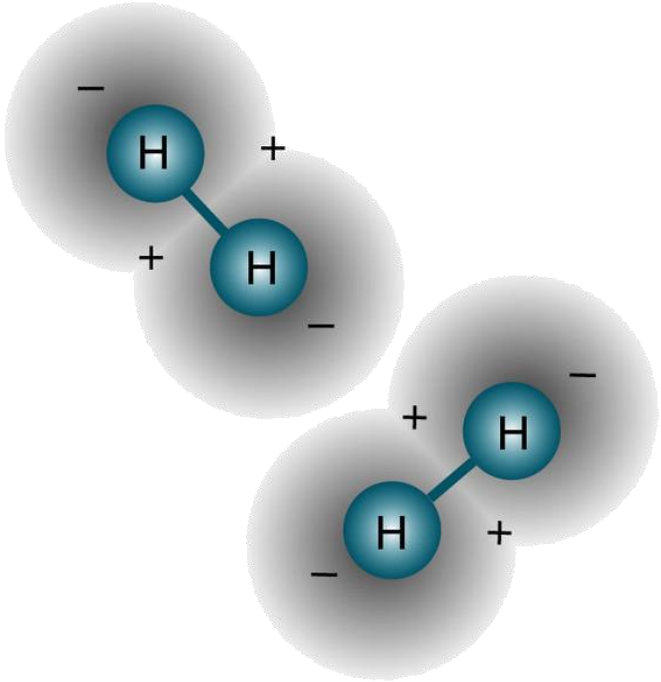


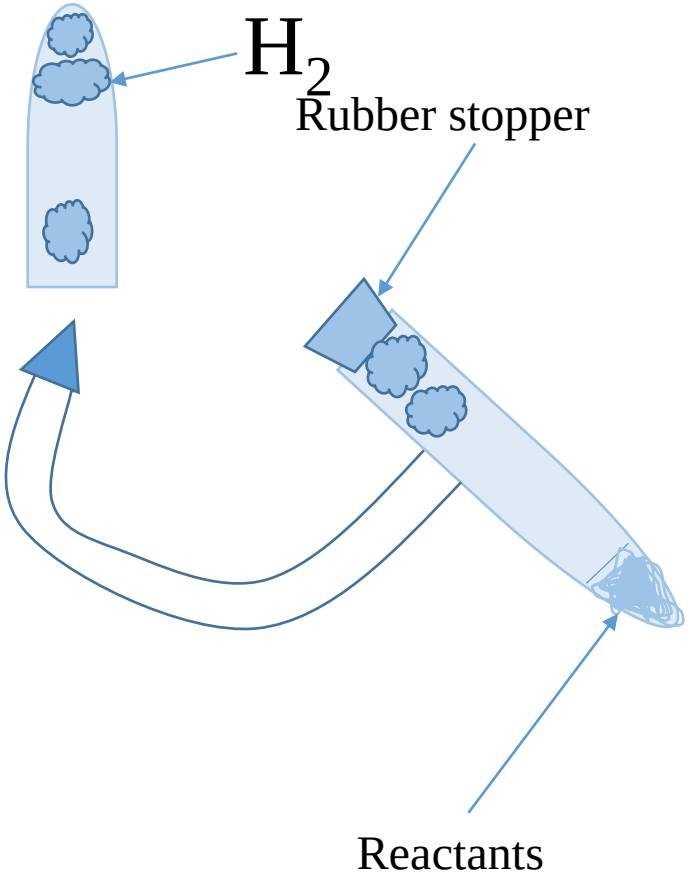
$Al_2O_3 + \mathbf{6}NaCl = \mathbf{3}Na_2O + \mathbf{2}AlCl_3$

$2\ \mathbf{AlCl_3} \rightarrow 2\ \mathbf{Al} + 6\ \mathbf{Cl}$

Theory

- Hydrogen is a colorless, odorless and tasteless gas, the lightest substance of all known, explosive. Part of natural gas, it is also lighter than air





Experimental part

Experiment 1. Purpose : to conduct the proposed experiment in laboratory conditions (reaction between metallic aluminum and two salts in aqueous solution)

Devices and materials: salt solutions: CuSO4, NaCl. A metallic aluminum, test tubes.

Proceeding reactions:

$CuSO_4 + 2NaCl \leftrightarrow CuCl_2 + Na_2SO_4$

$Al_2O_3 + 6NaCl = 3Na_2O + 2AlCl_3$

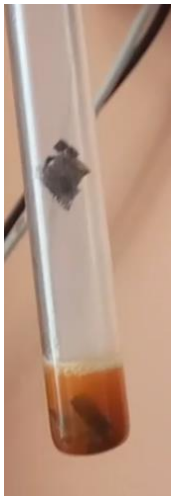
$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu\downarrow$

$2Al + 3CuSO_4 \rightarrow Al2(SO4)3 + 3Cu\downarrow$

$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2\uparrow$

Aluminum

Aluminum, copper-coated



m(Al)=2g

$V(H_2)$=?

$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2\uparrow$

n(Al)=2g/27g/mol=0,074mol

$2n(Al)=3n(H_2)$

$n(H_2)$=0,074mol*1,5=0,111mol

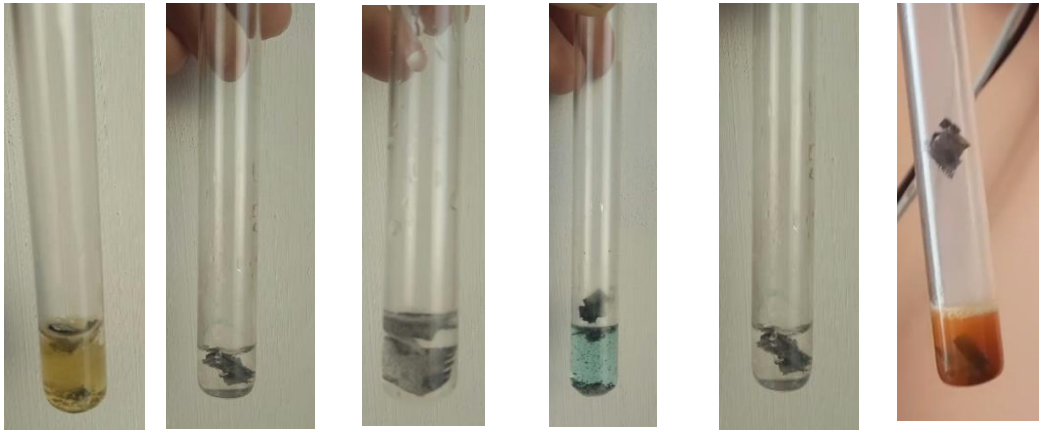
$V(H_2)$=0,111mol*22,4L/mol= **2,4864L**

Conclusion: aluminum does not react with CuSO4 solution, because it is covered with an oxide film (Al2O3), but if sodium chloride solution is added, then chlorine ions will destroy the protective film, and hydrogen evolution will become possible when aluminum interacts with water.

Experimental part

Experiment 2. Purpose: to establish the dependence of the rate of hydrogen production on the type of salt contained in the solution.

Devices and materials: salt solutions: CuSO4, NaCl, FeSO4, ZnSO4, Na2C03. a metallic aluminum, test tubes.



$FeSO_4$ $ZnSO_4$ Na_2CO_3 $CuSO_4$ NaCl $CuCl_2$

$$\mathbf{Al_2O_3 + 6NaCl = 3Na_2O + 2AlCl_3}$$

$2Al+3ZnSO_4=3Zn+Al_2(SO4)_3$

no hydrogen evolution

Al+Na2CO3 no reaction

$Al + CuSO_4 \rightarrow AlSO_4 + Cu$

$2Al + 3CuCl2 \rightarrow 2AlCl3 + 3Cu\downarrow$

$2Al+3FeSO_4+6H_2O=Al2(SO4)_3+3Fe(OH)_2+3H_2$

$V(H_2)=2.5L$

$2Al + 6NaCl + 6H2O \rightarrow 3H_2 + 2AlCl_3 + 6NaOH$

V(H2)=2.5L

Conclusion: due to the fact that chlorine ions destroy the oxide film faster, the hydrogen production reaction proceeds faster in the presence of chloride salts in the solution. However, not all salts react with aluminum. An example of this is Na2C03.

Experimental part

Experiment 3. Purpose: to establish the dependence of the rate of hydrogen production on the concentration of salts contained in the solution.

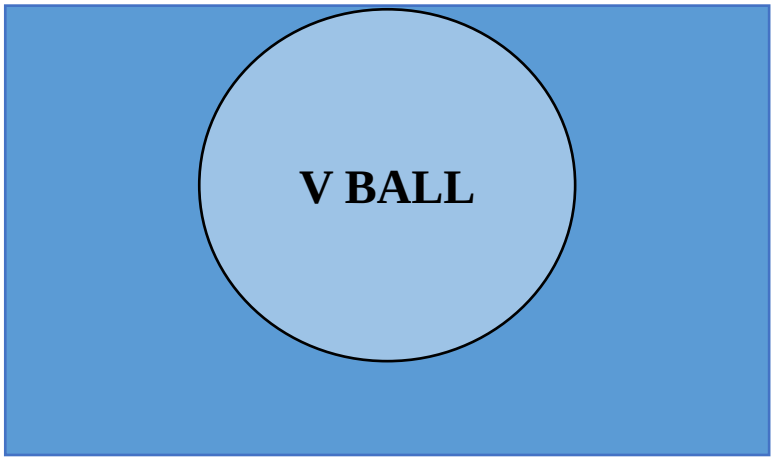
Devices and materials: $FeSO_4$ solutions, in concentrations of 0.3 and 0.15. a metallic aluminum, test tubes.

At a concentration of 0.15:

$$v = 0{,}4\frac{L}{hour}$$

At a concentration of 0.3:

$$v = 0{,}5\frac{L}{hour}$$



V ball = V displaced water

V2 (H2) practical = 0.8 L

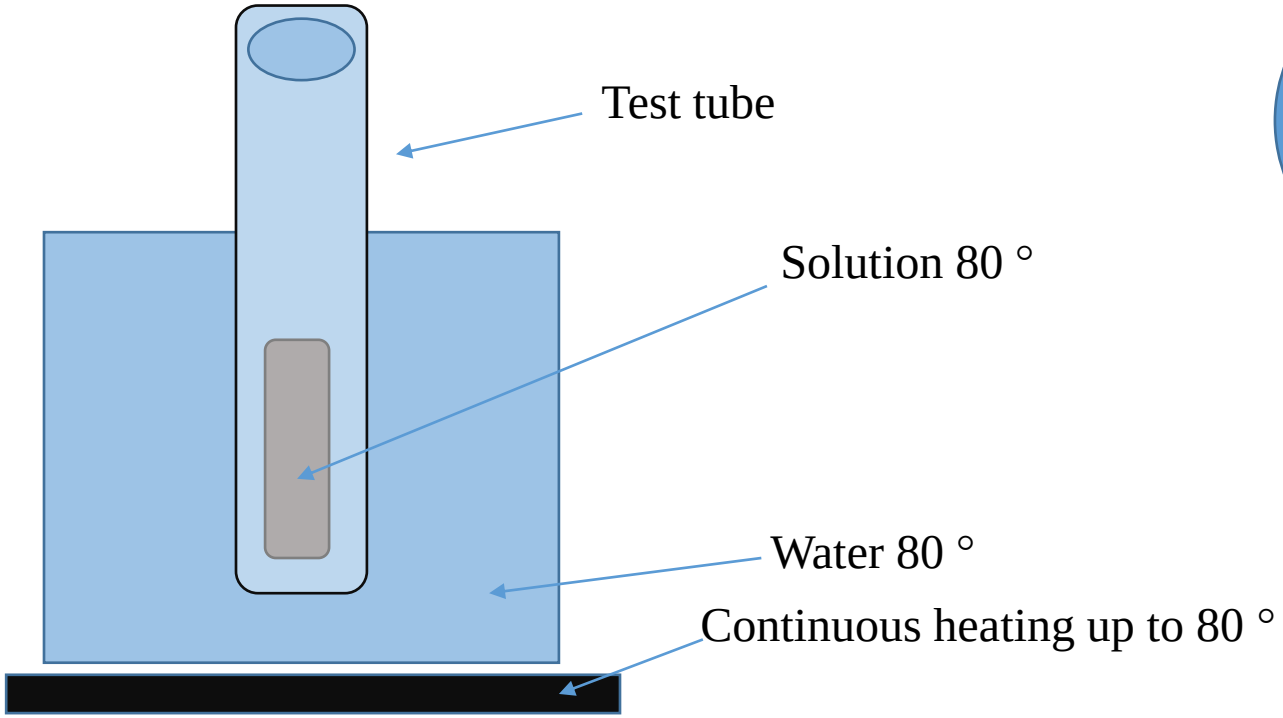
V1 (H2) practical = 1 L

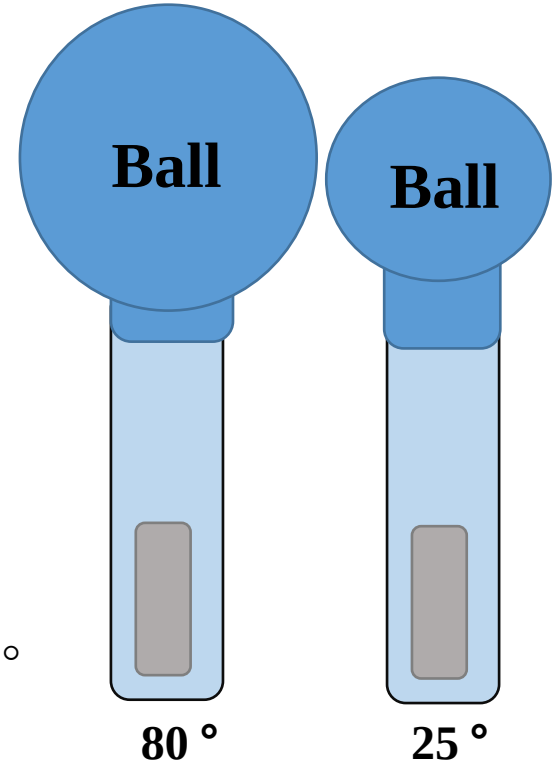
Conclusion: The higher the concentration of salts in an aqueous solution, the faster the reaction of producing hydrogen proceeds. This is due to the fact that with an increase in the concentration of reactants, the reaction rate increases.

Experimental part

Experiment 4. Purpose: to establish the dependence of the rate of hydrogen production on temperature conditions.

Devices and materials: a FeSO4 solution. a metallic aluminum, test tubes.



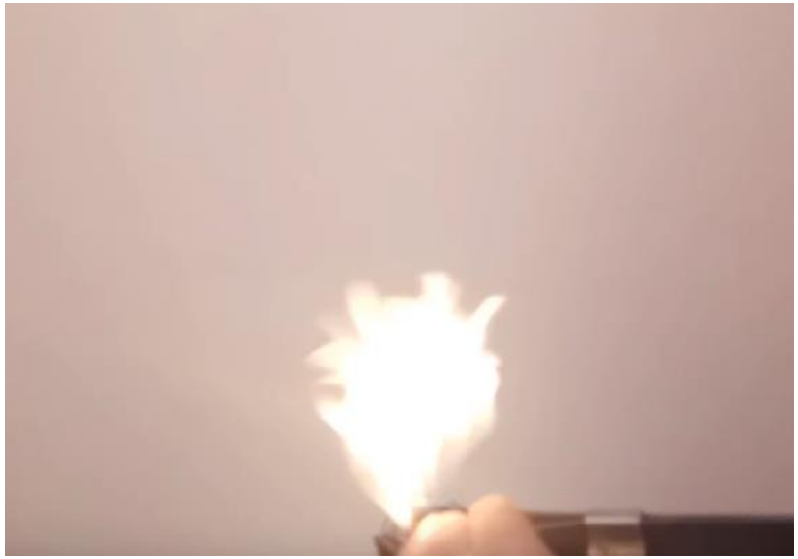


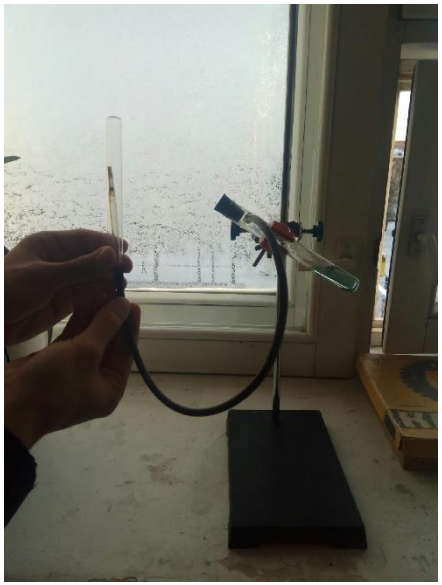
Conclusion: The speed of our chemical reactions directly depends on temperature conditions. The higher the ambient temperature, the higher the speed.

Experimental part

Experiment 5. Purpose: to prove that the product of our reaction is hydrogen.

Devices and materials: a salt solutions: FeSO4, a metallic aluminum, test tubes, matches.





$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2\uparrow$$

Conclusion: when aluminum without an oxide film interacts with water, we get pure hydrogen.

Conclusions

1. The rate of hydrogen production increases in direct proportion to the increase in reagent concentration and temperature.
2. Not all salts react with aluminum.
3. The most effective way to produce hydrogen is the reaction of FeSO4 and NaCl at high temperature and concentration in solution.
4. We carried out a qualitative reaction, proving that the product of our reaction is hydrogen.

References

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