International Young Naturalists' Tournament

Problem no.12

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Table of Contents

1) The Problem

A Fireproof Handkerchief

This problem was suggested by the team of Moscow Suvorov Military School in the home stage of YNT-2012 and received the highest score from the Jury.

1) The Problem

The accessories needed to conduct the experiment:

- A handkerchief
- A metal container with water
- A aquarium, where the experiment will be conducted
- A plate
- 95% Alcohol
- Matches

1) The Problem

The experiment conduction:

- Wet handkerchief with water
- Wring out the handkerchief, but leave it wet
- Crumple handkerchief, put on the plate, pour with alcohol, and set on fire

Result:

- The handkerchief is burning, but it is not reduced to ashes. The handkerchief remained entire without any destruction

The question:

- Why fire has not any impact on the handkerchief?

2) Practical Solution

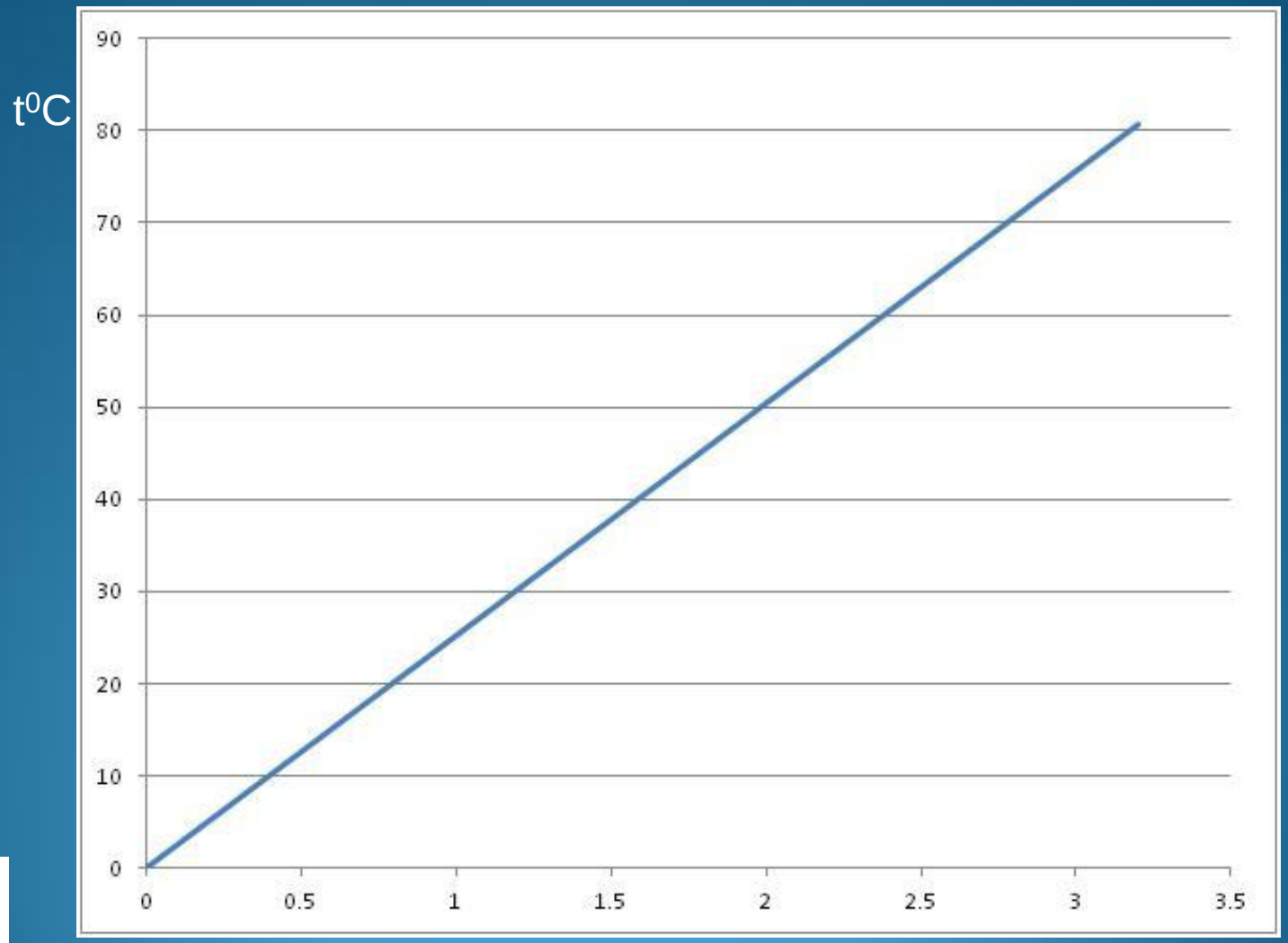
- The experiment

Equipment:

- ✓ Electronic scales (CAS MWP-300). Accuracy ± 0.01 g
- ✓ Thermocouple (Cu-Constantan (Cu-59%, Ni-39%, others – 2%)) with electrical tester
- ✓ Alcohol(95%), and acetone
- ✓ Water
- ✓ Plate
- ✓ Handkerchief

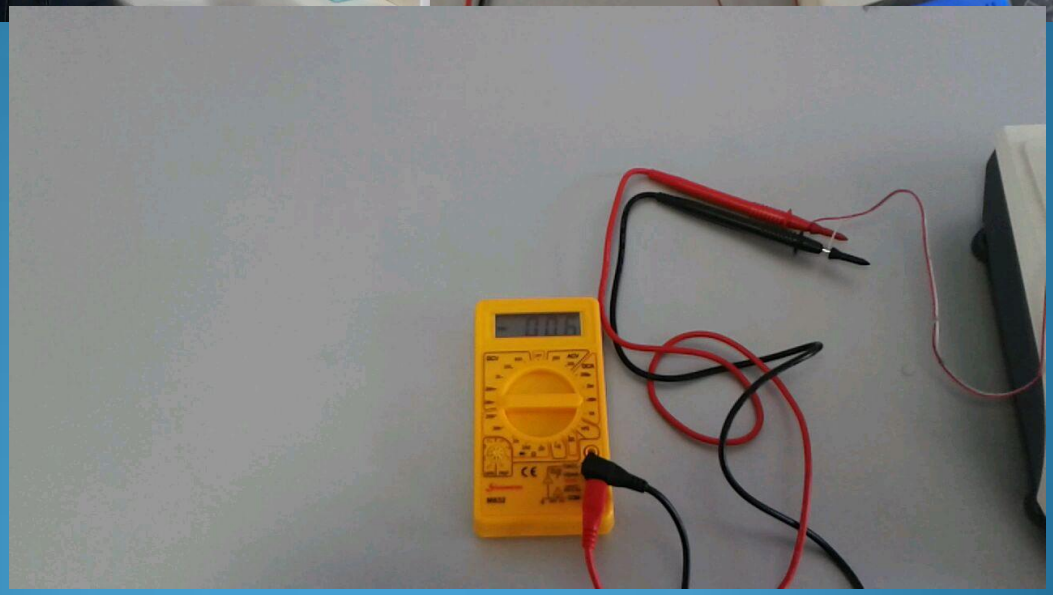
2) Practical Solution (Con'd)

This graph shows us how to deduce the temperature of a handkerchief from the voltage in the thermocouple's circuits



2) Practical Solution (Con'd)

The conduction of the experiment



- Data of experiments:

	The first experiment	The second experiment	The third Experiment	The fourth experiment
Mass of handkerchief, g	12.69	12.69	12.69	12.69
Initial mass of the water, g	9.79	11.94	11.87	16.62
Mass of the alcohol, g	7.3	2.49		
Mass of the acetone, g			3.96	1.08
Initial Temperature, °C	20	20	20	20
Average temperature, °C	37.8	45	25	31
Mass of the evaporated liquid	6.26	1.42	4.28	0.96

- Remarks:

✓ Some parts of the handkerchief may start burning while others still have water left in them.

✓ The acetone was burning at the temperature of 750^0C

2) Practical Solution

- Practical results:

✓ In the first two experiments only part of alcohol was evaporated. The other parts were probably dissolved in water.

✓ In the second two experiments mainly whole acetone was evaporated.

✓ Assuming that only alcohol (acetone) was burned during the experiments the freed energy can be assessed as:

181.54 KJ (First experiment)
411.80 KJ (Second experiment)
123.984 KJ (Third experiment)
27.804 KJ (Fourth experiment)

✓ Big amount of heat was distributed to the environment.

✓ Temperature distribution in the handkerchief was heterogenic

3)Theoretical Evolution and Solution

- Alcohol and acetone are combustible liquids.

- Water prevents burning of materials

✓ temperature by evaporation

✓ Isolates materials from air (oxygen)

- Theoretical assessment of the first way:

✓ The energy released by burning of alcohol

$Q=rm_1$

✓ 99.62% of energy is not transferred to water

✓ The heat absorbed by water can be counted as

$Q' = \eta r m_1$

$h \approx 0.0038$

- Theoretical assessment of the first way:

✓ The reaction of alcohol burning is:

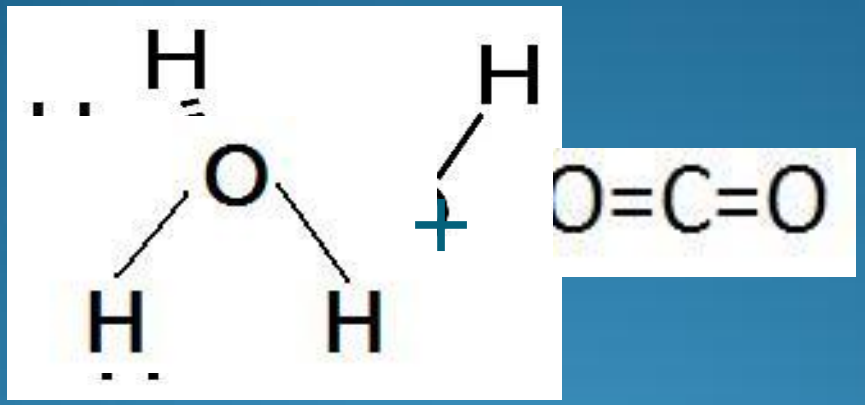
$$CO_2H_5OH+2O_2 \longrightarrow 2CO_2+3H_2O$$

✓ The reaction of acetone burning is:

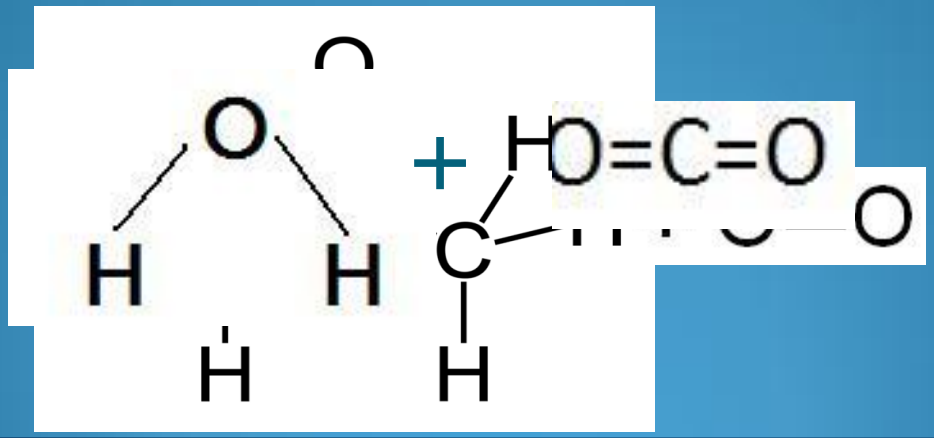
$$(CH_3)_2CO+4O_2 \longrightarrow 3CO_2+3H_2O$$

It is to be noted that same chemicals are unleashed in both reactions.

- The formula of alcohol:



- The formula of acetone:



✓ The energy needed for warming and evaporation of water:

$$Q=cm_2(t_2-t_1)+\lambda m_2$$

m_2 - mass of water
t_1 – water's initial temperature (20°C)
t_2 – water's boiling point (100°C)

Using mathematics we get that

$m_1/m_2=(c(t_2-t_1)+\lambda)/\eta r\approx 21.6$ (for alcohol)

$m_1/m_2=(c(t_2-t_1)+\lambda)/\eta r\approx 22155$ (for acetone)

Than all of the water is turned to gas.

If we consider densities of water and alcohol $\rho_1=1000 kg/m^3$, $\rho_2=790 kg/m^3$

$V_1/V_2=\rho_2 (c(t_2-t_1)+\lambda)/\rho_1\eta r\approx 17$

there is the volume of alcohol and is the volume of water than all the water is evaporated

4) Review of Results

Theoretical and practical assessments show:

- ✓ Heat sources are combustive liquids
- ✓ Water plays role for defender for handkerchief by two mechanisms.
- ✓ Great amount of heat was transferred to the environment. The amount depends on temperature gradient and time period of burning.

5) Conclusions

- The results given to us by practical and theoretical ways of solving the problem are about the same.
- Alcohol needs to be much more than water to burn the handkerchief.
- Temperature is unevenly distributed in the handkerchief.
- Most of the times all of the alcohol is not combusted.
- It must be noted that for different handkerchiefs the results were about the same