Teaching-learning materials compiled by the PARSEL consortium
as part of an EC FP6 funded project (SAS6-CT-2006-042922-PARSEL).

Cooperating Institutions and Universities within the PARSEL-Project:

For Students

Science in a Class of Its Own: Renewable Energy Sources – "My iPod Works with Energy from Bull Shit"

A Module for Science Instruction – especially Chemistry – for Grades 1o to 13

Outline

The PARSEL module **"Renewable energy sources – my iPod works with energy from bull shit"** focuses on the question of how biogas is produced and in how far the production of biogas can be used as an alternative to conventional energy production (e.g. fossil fuels). Working together in groups, you will have the opportunity to synthesise biogas. Afterwards, you will be able to determine the heating value of the biogas and analyse the explosiveness of air-biogas-mixtures. You may then want to compare the results of the heating value determination to the heating values and analysis results of other sources of energy. The following worksheets will help you to carry out the experiments necessary.

Developers: Birgit Kirschenmann, Claus Bolte (2007)
Institution: Department of Chemistry Education - Freie Universität Berlin, Germany

Science in a Class of Its Own: Renewable Energy Sources – "My iPod Works with Energy from Bull Shit"

These worksheets belong to: . . . . . .

1. Synthesising biogas

Equipment

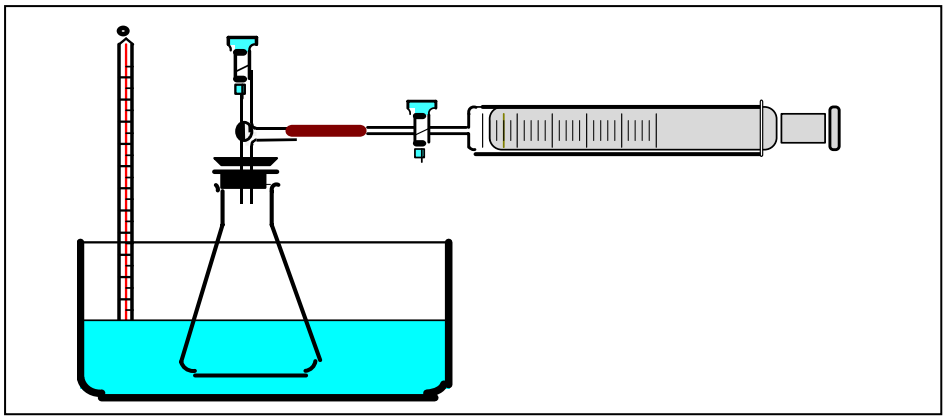
Erlenmeyer flask (300 ml) or plastic bottle (500 ml), funnel, spatula, scales, cotton wool balls, stoppers (bored), three-way stopcock, septum, rubber hose, syringe, measuring cylinder, water bath and thermometer

Chemicals

150 g fresh horse manure
NaCl solution (0.9 %)

Procedure

Construct the apparatus as shown. Fasten the syringe onto the stand. Fill 150 g horse manure into the flask and cover it with 130 ml of the 0.9 % NaCl solution. Cover everything with cotton wool and close the flask with the septum. The apparatus now has to remain unmoved for a minimum of two days.



Observations

2. Determining the Heating Value of Natural Gas and Biogas

Equipment

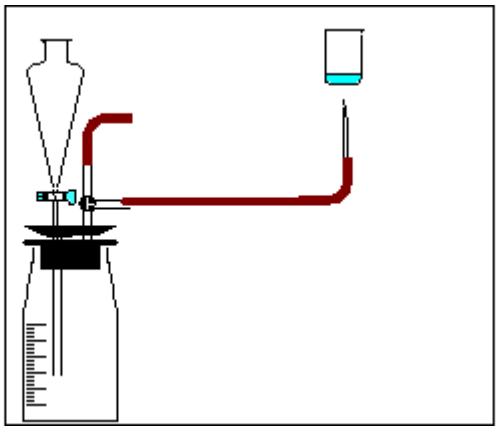
1 graduated baby flask (250 ml), 1 stopper with 2 holes, 1 three-way stopcock, 1 separating funnel as balancing container, 1 glass tube with capillary tip, 2 rubber hoses for connection, 1 long hose for connection to the gas mains, 1 glass angle with tip, 2 beakers (100 ml), 1 measuring cylinder (100 ml), 1 thermometer (0,1 K) or thermo-element, 3 stands with clamps and holders, glass grease, matches, stopwatch, 2 syringes, 2 rubber hoses for connection, 1 beaker (600 ml)

Chemicals

Biogas from gas sampling tube (methane: F+; R: 12; S: 9, 16, 33)
Natural gas from the mains (methane: F+; R: 12; S: 9, 16, 33)
Distilled water

Preparing the Experiment

Set up the apparatus as shown below. Fill the separating funnel with a little water (3 cm high). Weigh the beaker. Fill it with 75 ml of water and fasten it to the stand approx. 2 cm above the glass tip.



Experimental Procedure using Natural Gas

Flush the gas through the apparatus by leading it through the three-way stopcock (position: top-bottom-open) into the baby flask. Now carefully open the stopcock of the separating funnel (gas bubbles begin to form in the water). Completely fill the graduated baby flask with gas (you will smell gas in the separating funnel). Then first close the stopcock of the separating funnel (position: closed), secondly the three-way stopcock (position: top-right-open) and finally the gas mains stopcock. The gas is now enclosed in the apparatus.

Note down the water's starting temperature in the beaker and half fill the separating funnel with water.

One person now opens the three-way stopcock (position bottom-right-open) as well as the separating funnel's stopcock very carefully (position: top-bottom-open). At the same time a third person ignites the gas escaping through the glass tip using a match.
Note down the start time and regulate the height of the flame at approx. 1 cm by adjusting the three-way stopcock accordingly.

_____

Observe the water level in the baby flask. Close the three-way stopcock (position: top-right-open) as soon as a gas volume of 150 ml has been burned or when the water level is at 150 ml. Note down the time at which the mains gas supply is turned off.

_____

Observe the change in water temperature in the beaker until the temperature has reached a maximum. Note down the end temperature of the water.

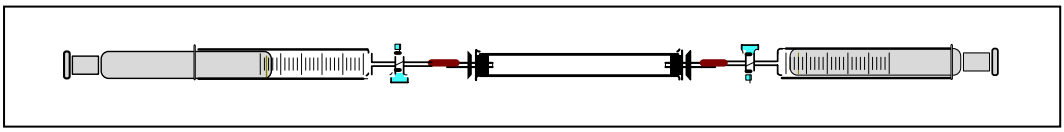
_____

Repeat the experiment.

Experimental Procedure using Biogas

Preparing the Experiment

Set up the apparatus as shown (not exactly horizontal, but ascending slightly on either side).



Gas syringe 1 Gas sampling tube Gas syringe 2

The biogas has to be transferred from the gas sampling tube to a syringe.

To do this, start by filling a beaker with distilled water. Then fill 100 ml of the distilled water into syringe 1. When the apparatus is sealed tightly, open the stopcocks in the following order: First the stopcock of syringe 1, then stopcocks 1 and 2 of the gas sampling tube as well as the stopcock of syringe 2. By gently pushing down on the plunger of syringe 1, push the water into the gas sampling tube, thereby forcing the biogas into syringe 2.

As soon as the 100 ml have been transferred to syringe 2, close all stopcocks. Now the biogas can be transferred through the three-way stopcock of the apparatus to determine its heating value. Repeat this procedure until the gas sampling tube is completely filled with water. Each time empty the syringe filled with gas into the apparatus through the three-way stopcock.

Continue with determining the heating value of biogas in the same way as described for natural gas; namely:

Experimental Procedure using Biogas

Flush the gas through the apparatus by leading it through the three-way stopcock (position: top-bottom-open) into the baby flask. Now carefully open the stopcock of the separating funnel (gas bubbles begin to form in the water). Completely fill the graduated baby flask with gas (you will smell gas in the separating funnel). Then first close the stopcock of the separating funnel (position: closed), secondly the three-way stopcock (position: top-right-open) and finally the gas mains stopcock. The gas is now enclosed in the apparatus.

Note down the water's starting temperature in the beaker and half fill the separating funnel with water.

One person now opens the three-way stopcock (position bottom-right-open) as well as the separating funnel's stopcock very carefully (position: top-bottom-open). At the same time a third person ignites the gas escaping through the glass tip using a match.
Note down the start time and regulate the height of the flame at approx. 1 cm by adjusting the three-way stopcock accordingly.

Observe the water level in the baby flask. Close the three-way stopcock (position: top-right-open) as soon as a gas volume of 150 ml has been burned or when the water level is at 150 ml. Note down the time at which the mains gas supply is turned off.

_____

Observe the change in water temperature in the beaker until the temperature has reached a maximum. Note down the end temperature of the water.

_____

Repeat the experiment.

3. Analysis of the Above Heating Value Experiments

Draw a temperature-time-diagram using your determined values. Establish the temperature differences graphically. Calculate the heating value using the following equations.

$$Q = -\Delta T \cdot (m_{water} \cdot c_{p\ water} + m_{glass} \cdot c_{p\ glasss})$$

$$H_u = \frac{Q}{m_{fuel\ probe}}$$

with: c_p : specific heat capacity
m_i : mass
Δ T: temperature difference
$c_{p\ water} = 4{,}19\ J\ g^{-1}K^{-1}$
$c_{p\ glass} = 0{,}85\ J\ g^{-1}K^{-1}$

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Possible Sources of Error

_____

_____

_____

_____

_____

4. Explosion Capability of a Methane-Air-Mixture

Equipment

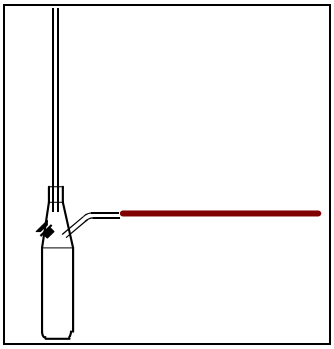
1.5 l plastic bottle without lid, 70-90 cm long glass tube (∅ 10 mm), textile tape, stopper, stopper with hole, knife, rubber hose, curved glass tube, stand with 2 clamps and holders, matches

Chemicals

Natural gas from mains (methane: F+; R: 12; S: 9, 16, 33)

Procedure

Carefully cut two stopper-size holes into the top part of the bottle. Cover one end of the glass rod with textile tape in such a way that that end snugly fits into the bottle opening and seals it tightly. Insert the glass rod into the upper bottle opening and fix it, as well as the bottle, to the stand (fume hood!). Loosely close one of the cut holes with the stopper. Connect the curved glass tube to the rubber hose and insert the glass tube into the stopper. Close the second cut hole with it. Connect the other end of the rubber hose to the gas mains stopcock.



Allow the gas to fill the apparatus until all of the air has been forced out of the bottle. Close the gas mains stopcock and ignite the gas immediately at the top end of the glass tube. As simultaneously as possible, remove the stopper with the gas inlet glass tube so that air can enter the bottle. Close the hood, switch off the light and wait.

Observations/Notes

5. Appendix/Extra Worksheet

Log for Heating Values of Natural Gas and Biogas

Time [min]	Water temperature [°C]			Time [min]	Water temperature [°C]		
	Nat. gas	Biogas			Nat. gas	Biogas	
0				8.30			
0.30				9			
1				9.30			
1.30				10			
2				10.30			
2.30				11			
3				11.30			
3.30				12			
4				12.30			
4.30				13			
5							
5.30							
6							
6.30							
7							
7.30							
8							

Time at which natural gas supply runs dry:	
Time at which biogas supply runs dry	

Natural gas consumption [ml]	
Biogas consumption [ml]	