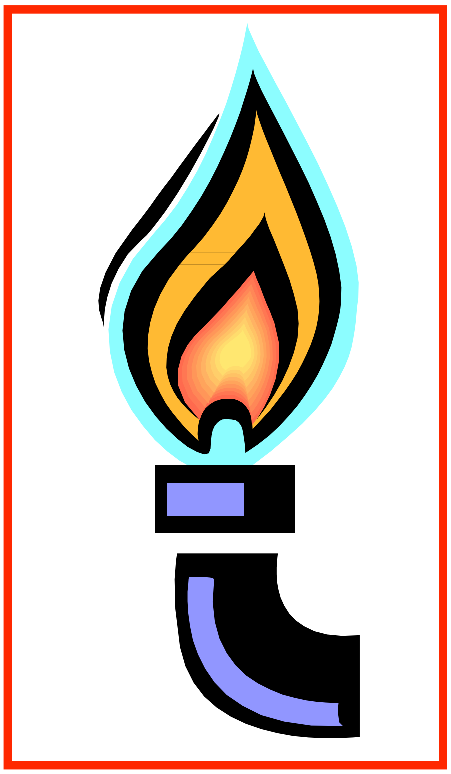
centre de développement pédagogique
pour la formation générale en science et technologie



BIOGAS

ANIMATOR'S GUIDE

WORKING DOCUMENT

Table of contents

Outline of the « Biogas » LES

> **NOTE : This LES was designed within the framework of training sessions for personnel in science and technology. It will require adaptation before being used with students.**

PREPARATION

1 Catalyst

- Context
- Presentation of 2 short video sequences and of the proposed challenge

2 Activation of previous knowledge

- Construction of a network of concepts
- Review of forms of energy
- Previous knowledge (p.15 of booklet)

REALISATION AND INTEGRATION

3 Learning activities

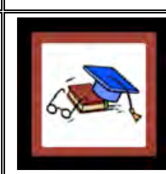
- Water pollution and methanogenesis
- Exothermic and endothermic reactions
- Greenhouse effect, ecological footprint
- Specific heat capacity
- Nomenclature, chemical equations and stœchiometry

4 Establishing a plan

- The student outlines the problem
- The teacher benchmarks the questioning and specifies the evaluation criteria for the experimental process as well as for the explanatory text

5 Complex task

- Elaboration of the experimental research process
    - Analysis of the elements of the context to benchmark the process
    - Transfer of knowledge in experimentation and in data gathering



6 Synthesis activity

- Synthesis document (text)
    - Consideration of all the parameters and environmental impacts
- Auto evaluation and esteem building
    - Critical analysis of your process
    - Taking stock of your learning

Evaluation of competency 1 in relation to the mandate proposed to the student

The students should:

Grasp the concepts touched by biogas, the ecological footprint and the greenhouse effect to be able to delimit the context of the proposed challenge. (C_d1 – Adequate representation of the situation)

The students must grasp the information presented in various forms (written, video, demonstrations and learning activities) in large groups, teams of two and individually, according to the suggested activities. They must call upon their previous knowledge to delimit the context of the problem.

Elaborate an experimental protocol (C_d1 – Elaboration of a pertinent action plan, adapted to the situation)

Starting from the proposed materials, from a base assembly and from techniques suggested in various learning activities, the students must get together in teams of two and plan their experimental process. It may be useful to work in conjunction with another team to obtain a greater range of data. Each team should submit its protocol for approval.

Carrying out the experimental process (C_d1 – Adequate implementation of an action plan)

Each team proceeds to experimentation while carrying out the necessary adjustments. The students gather the necessary data.

Concluding and reflecting upon possible repercussions of the exploitation of biogases. (C_d1 – Elaboration of pertinent conclusions, explanations or solutions)

Starting from the gathered data and the tendencies exhibited by these data, each student answers his initial questioning. He writes an explanatory text in relation to the challenge submitted to him.

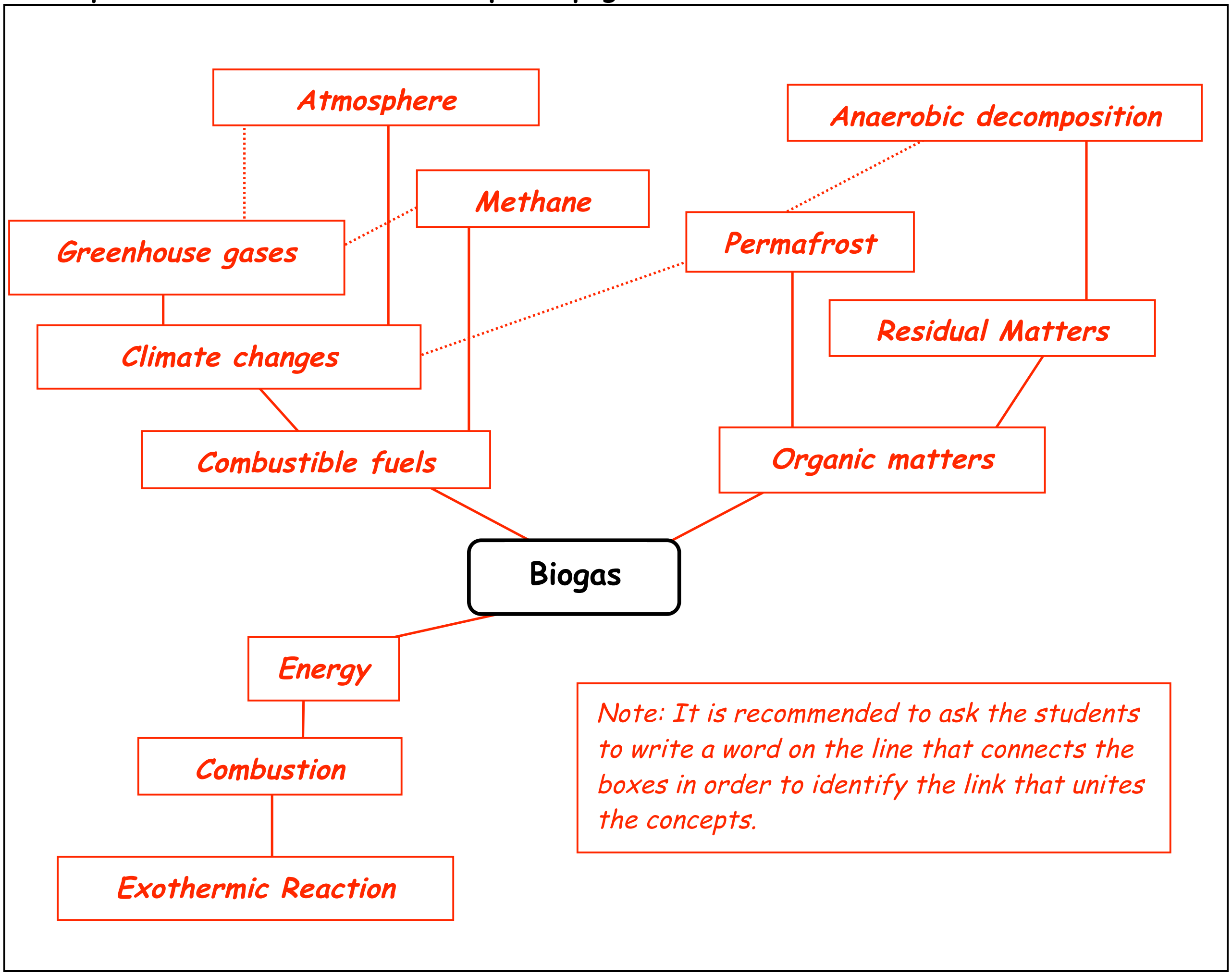
Suggested teacher planning

Total duration of the LES: 7 – 75 minute periods (homework)

Lesson	Summary description as regards the student booklet	To be foreseen
Lesson 1	• Catalyst: Methane released into the atmosphere! – page 3 • Showing 2 suggested short video sequences • Proposed challenge • Construction of a network of concepts • Homework: Individual calculation of the ecological footprint– pages 6 to 7 and annex 1	- Multimedia projector and accessibility to the suggested video sequences or foresee an alternative - Table (poster) to compile the individual ecological footprints.
Lesson 2	• Each student writes his ecological footprint in the prepared table • Demonstration on greenhouse effect – page 6 • Biogas and water pollution – pages 8 to 11 • Video sequence on anaerobic digestion and preparation of assemblies for fermentation – page 12	- Demonstration material for greenhouse effect; - Materials for fermentation assemblies.
Lesson 3	• The students complete the "results" section of the directed laboratory on fermentation - page 13 • Directed laboratory: Chemical and physical changes / Endothermic and exothermic reactions - pages 15 and 16 • Homework : pages 14 and 15	- Material for the identification of gases; - Laboratory materials: Chemical/physical, endo/exo.
Lesson 4	• Review of endothermic/exothermic phenomena and energy forms – page 17 • Directed laboratory: Specific heat capacity – pages 18 and 19 • Homework : pages 19 and 20	- Materials and assemblies for laboratory : Specific heat capacity
Lesson 5	• Review of the calculation of the ecological footprint of the group • Review of specific heat capacity and of question 6 of page 20 in a group discussion • Chemical nomenclature and the chemical equation – pages 21 to 26 • Homework: finish the exercises	
Lesson 6	• Review of the chemical equation and correction of the exercises • Formation of dyads and meeting in groups of two teams to plan the study of the output of biogas • Homework: planning the experimental process and beginning to write the explanatory text – page 32	- Presentation of the available materials and of the organisation of the biogas samples
Lesson 7	• Carrying out the experimental process – data gathering and sharing • Homework: Complete the report and the text	- Date for submitting the text and the output

Expected student booklet responses

Example of the networks of concepts - page 5



Demonstration: Greenhouse effect - page 6

In this demonstration, the Styrofoam spheres represent the Earth, the lights take the role of the Sun and the bowl illustrates the terrestrial atmosphere.

Protocol:

1. Note the initial temperature on the two thermometers.
2. Simultaneously light the heating lamps.
3. Note the temperatures on each thermometer every minute for five minutes.
4. Extinguish the lamps.
5. Note the temperatures on each thermometer every minute for five minutes.

We note that the initial temperature on each thermometer is identical. From the first minutes, the temperature of the assembly having an atmosphere increases more rapidly.

The difference tends to increase over time – the bowl creates a greenhouse effect in the same way that the terrestrial atmosphere imprisons a part of the sun's radiations.

Once the lamps are extinguished (analogy with what happens at night) the model with the atmosphere (the bowl) cools much more slowly. Indeed, the assembly without an atmosphere returns to its initial temperature much more quickly, while the other tends to conserve the retained heat. This allows for an analogy to be made with the variations in daytime/nighttime temperatures observed on planets without an atmosphere.

This demonstration allows for the appreciation of the benefits of the greenhouse effect for temperature regulation on the surface of the Earth.

Suggestions and information relating to the ecological footprint – page 7

- Calculate the average in hectares of the ecological footprints of the class.
- It is important to underline that the ecological footprint represents the surface of **« productive land and aquatic ecosystems… »** Now in a country like ours, the productive lands do not constitute the whole surface of the country.
- It is important to underline that this tool is not extremely precise and that it is built using estimations and statistical tools. It is nonetheless very useful to compare societies to one another. It also allows the participant to be sensitised to his role as citizen.
- The total surface of Canada is 9.98 billion hectares, but its inhabited surface, including the bulk of its productive lands, represents a narrow strip along the American border. This surface may be estimated at less than 10% of the country's total – a little less than 1 billion hectares.
- The productive capacity of the Earth is 11.4 billion hectares, because the deserts, polar ice caps and oceans must be excluded. This represents an ecological footprint of about 1.9 hectares per inhabitant.
- The population of Canada is around 33,000,000 inhabitants and its ecological footprint is estimated at about 8.84 hectares on average.
- The 25 % richest of the world's population consume 75% of the available resources.
- According to the resources consulted, the world's average ecological footprint is around 2.4 hectares. It has exceeded the biological capacity of the Earth since 1999.

- Some data gathered about the ecological footprint of various countries:

Footprint (hectares)	Country	Footprint (hectares)	Country
10,13	United Arab Emirates	5,26	France
9,70	United States	0,80	India
8,84	Canada	0,53	Bangladesh
7,58	Australia	0,47	Mozambique

Water pollution – pages 10 and 11

Question 1. What is eutrophication?

It is a natural enrichment process in an aquatic environment. It may be accelerated by human activity, particularly with the use of manure and fertilizers. It results in an important increase in phosphorus and nitrogen. This creates a proliferation of aquatic plants, algae, phytoplankton and cyanobacteria. The quantity of light available diminishes rapidly and the vegetable and animal matters deposit gradually on the bottom of the lake. Anaerobic bacteria proliferate. The lake gradually becomes transformed into a marsh.

Question 2. Why is polluted water detrimental to the environment?

The solids and micro organisms contained in the water continually attempt to consume the oxygen dissolved in the water, leaving nothing for aquatic life (algae, fish).

Question 3. How is the level of water pollution measured?

*A small quantity of polluted water is placed in a large quantity of well oxygenated water. Several days are allowed to elapse (5 or 20), then the quantity of oxygen that has been consumed is measured. This gives us a measure of pollution that is called **B**iochemical **O**xygen **D**emand (BOD_5 or BOD_{20})*

Manipulation : Fermentation – page 13

The gas collected is *carbon dioxide* because it clouds the *lime water.*

- This process is called **fermentation**. It is an anaerobic reaction, so it occurs *in the absence of oxygen.* It is a biochemical reaction of converted chemical energy contained in an organic molecule, in this case, *the grape or apple juice* in another energy form by mushrooms, bacteria or *yeast*. These organisms transform *the sugar of the fruit* into *carbon dioxide* and *alcohol*.
- The ideal temperature for fermentation is between 35°C and 40°C.

Manipulation: Specific heat capacity – page 19

NOTE: After numerous tries, we realise that the energy supplied by the combustion of a miniature marshmallow is constant when it is always lit the same way.

Average variations in temperature for 10.0 g. of liquid

Liquid	Δ Temperature (°C)
Water	*12*
Vegetable oil*	*23*
Antifreeze	*19*

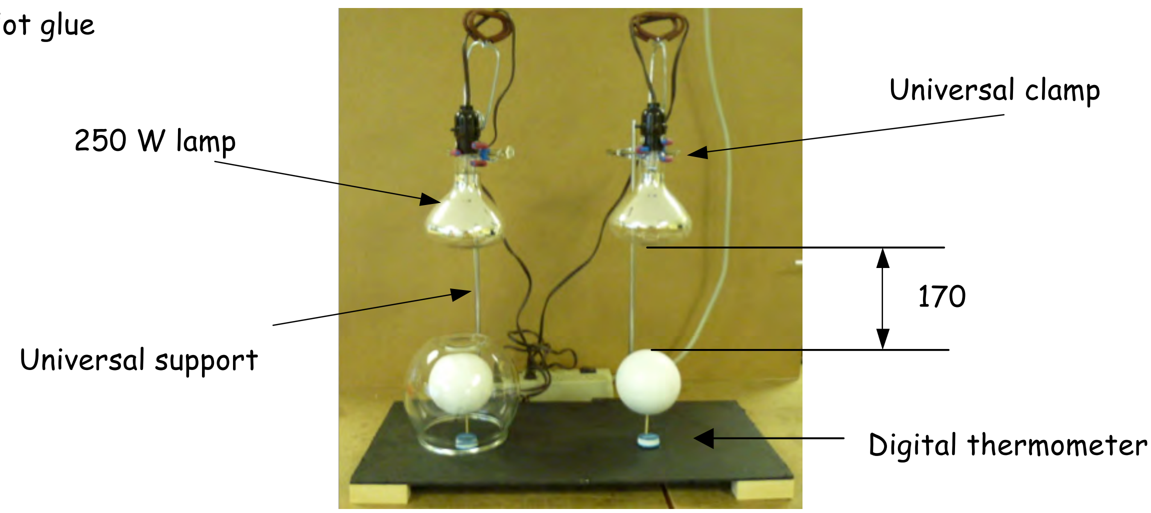
* We used canola oil. There will be a different variation depending on the type of oil used (olive or other) however the value of the variation should always be the greatest.

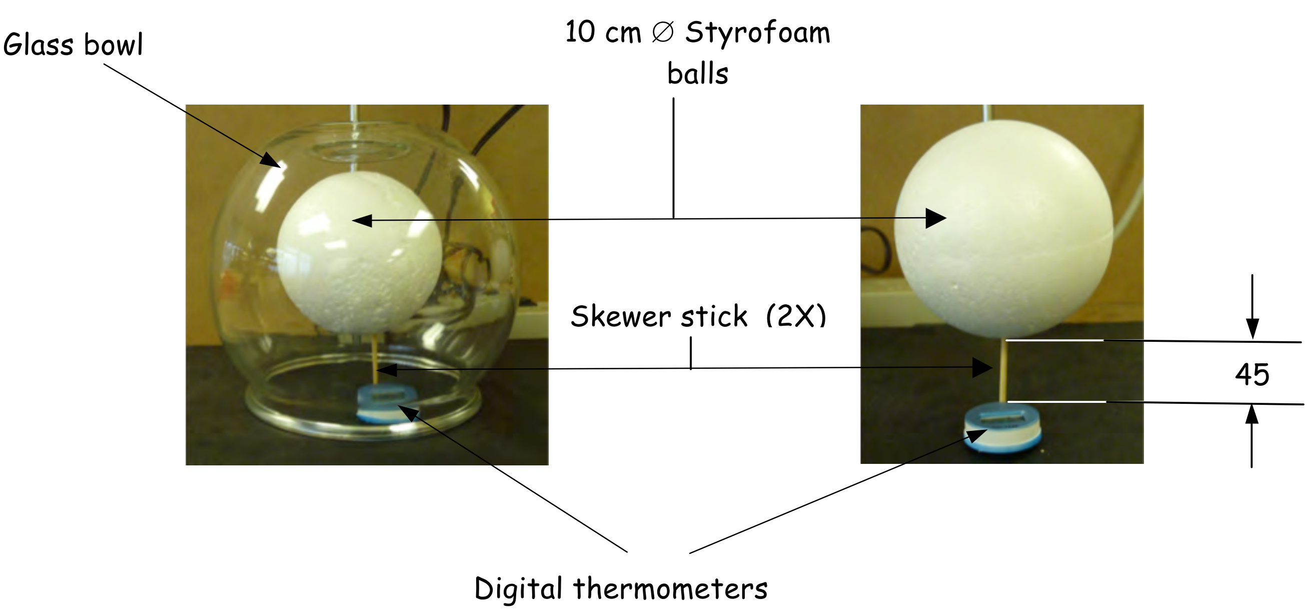
Section destined for practical work technicians for materials preparation and assemblies

Demonstration: « The greenhouse effect »

Required materials:

- 2 universal supports
- 2 universal clamps
- 2 digital thermometers
- 2 - 250W lamps
- Skewer stick
- 2 - 10 ∅ cm Styrofoam balls
- Glass fish bowl
- Foamcore support (605 mm x 290 mm)
- 4 wooden blocks (feet)
- Hot glue





Manipulation: « Fermentation »

Materials required per student (per work station):

- 500 mL graduated cylinder
- Eye dropper
- Scale (precise to tenths of grams)
- Weight
- Spatula
- Empty 500 mL water bottle or 500 mL Erlenmeyer flask
- « Stopper/Bag » set
- Grape or apple juice
- Traditional yeast

Material for the « Stopper/Bag » set:

- Retractable blade knife
- Glass cutter
- Tin snips
- Ruler
- Vice
- Glycerine
- 5mm ∅ glass tube (6 cm long)
- no.5 rubber stopper with one hole
- Plastic bag (« freezer bag with ties » type) (size : 20 cm x 33 cm)
- no.22 metallic wire (20 cm long) (or any other similar wire)

NOTE: The stopper number to be used depends upon the neck of the bottle used for the assembly. In addition, if you use an Erlenmeyer flask, you must be sure to have a stopper that ensures a good seal in the assembly.

Preparation for the « Stopper/Bag » set:

1	Affix the stopper in the vice (top edges outside the clamps of the vice). Using the retractable blade knife, groove the stopper 7mm from the top edge - the groove must be fairly deep (± 5mm).	
2	Insert the glass tube into the stopper (use a drop of glycerine to insert the glass tube).	

3	Cut 20 cm of metal wire. Solidly affix the plastic bag to the stopper using the metal wire. Ensure that the assembly is well sealed.	

Manipulation: « Specific heat capacity »

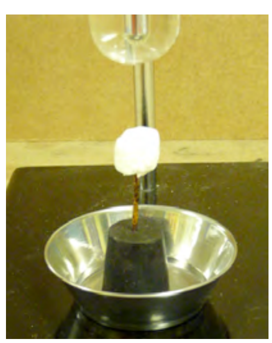
Material required for students (per work station):

- Universal support
- Universal clamp
- No. 4 stopper with copper rod or needle
- Test tube support
- 3 - 25 x 150 test tubes
- 3 - no. 4 stoppers with one hole + thermometer
- Scale (precise to tenths of grams)
- Eye dropper
- 3 weight containers
- 15 cm ruler
- Matches or lighter
- Small aluminum plate (optional)
  Note: It is preferable that the thermometers already be inserted into the stoppers. This manipulation should be done by the technical staff to avoid injury and thermometer breakage.

Substances required for the students (per work station):

- 3 miniature marshmallows
- 10.0 g of antifreeze
- 10.0 g water
- 10.0 g vegetable oil

Assembly of the marshmallow stopper:



Preparation of samples for experiments

We do not recommend that the students build bio-digesters in order to avoid contamination from the bacteria present in the organic material in decomposition. Also, the space necessary to store the bio-digesters, managing the organic residue (and the odors) as well as the time required to produce good quality biogas would impede the proper function of the LES. It could also entail some risk.

The samples are prepared using plastic bags that should not exceed 1000mL, filled ahead of time with natural gas (from the sources available in the laboratory or from a tank) and a CO_2 tank.

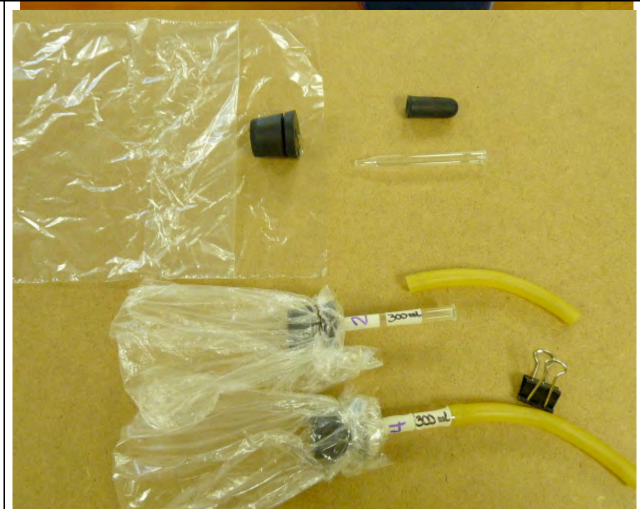
Recommendations:

- Work under the hood and respect the recommendations of the Toxicological repertory of the CSST: http://www.reptox.csst.qc.ca.
- Use a bag connected to a stopper then create the vacuum using a syringe.
- Do not exceed 1000mL of gas for methane or natural gas.
- Use sandwich bags without a zipper seal and cut the flap for the preparation of the samples.
- In order to avoid reaching the temperature at which water boils during the combustion of the sample, do not prepare samples exceeding 300 mL of gas.

Suggested samples:

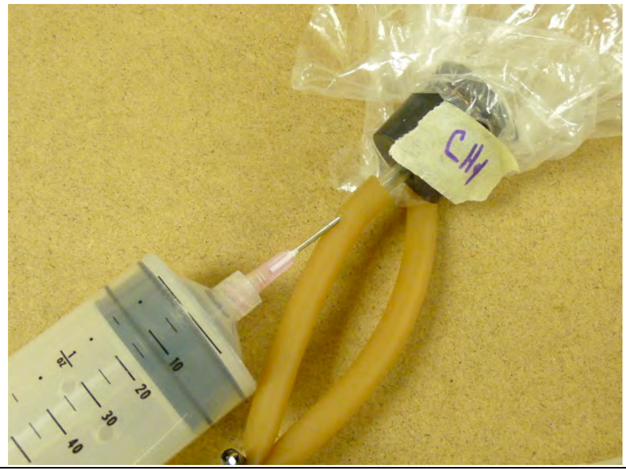
Sample #	Proportion of CH_4 (%)	Proportion of CO_2 (%)	Volume of CH_4 (mL)	Volume of CO_2 (mL)	Total volume of the bag (mL)
1	60	40	120	80	200
2	80	20	200	50	250
3	100	0	300	0	300
4	60	40	120	80	200
5	80	20	200	50	250
6	100	0	300	0	300
7	60	40	120	80	200
8	80	20	200	50	250
9	100	0	300	0	300

Preparation of the « Stopper / bag » for the experiment:

1	Affix the stopper in the vice (top edges outside the clamps of the vice). Using the retractable blade knife, groove the stopper 7mm from the top edge - the groove must be fairly deep (± 5mm).	
2	Insert a glass eye dropper into the stopper, tapered end in the stopper (use a drop of glycerine for insertion). Affix the sandwich bag with metal wire to the stopper (the flap of the bag should be cut off before affixing it). Identify the bag.	

Preparation of the « Sample / bag » for the experiment:

1	To prepare the sample bags, the following materials will be required: • 140 cc syringe with a sampling needle • 1000 mL gas bag (reservoir bag) • Rubber tubing • Tube clamp or paper clamp	

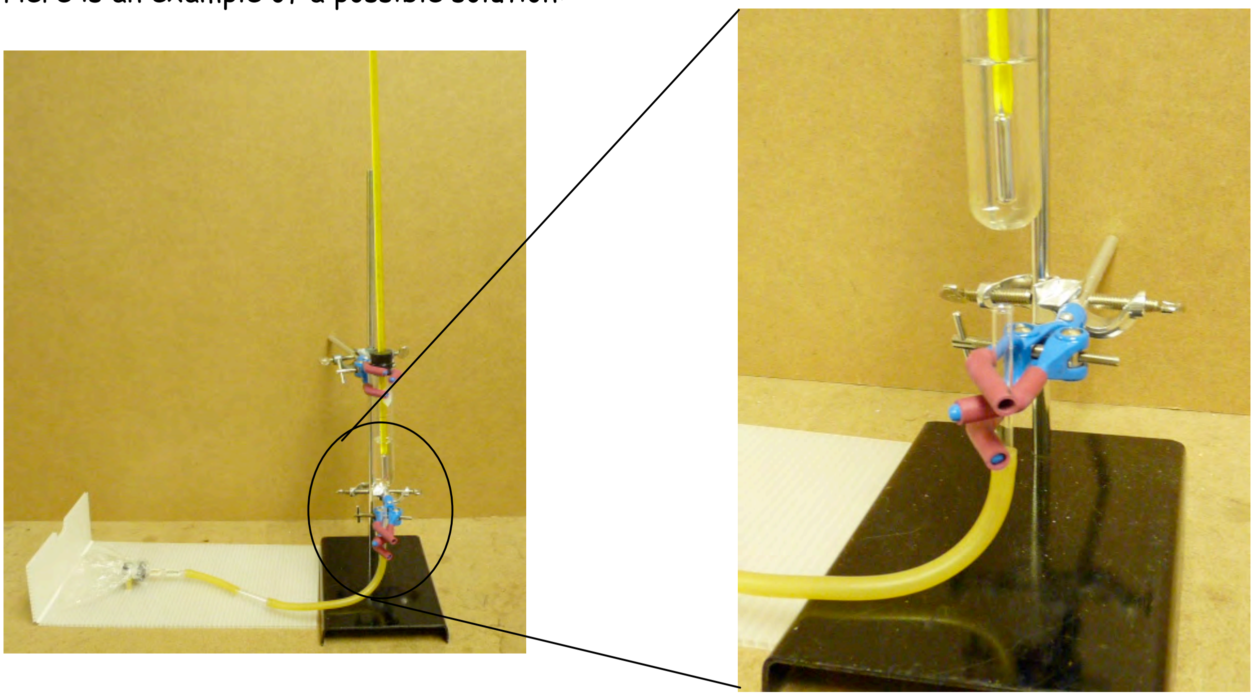
2	Fill a 1000mL bag with CH_4 and fill a second bag with CO_2. Withdraw the quantity of gas required according to the "suggested samples" table.	
3	Inject the withdrawn gas into the sample bag. Mix the gases according to the desired sample.	

NOTE: When the gas is withdrawn, it is important to pull the piston slowly. This will allow a sufficient amount of gas. In addition, the reservoir bag should be well compressed when the sampling is carried out.

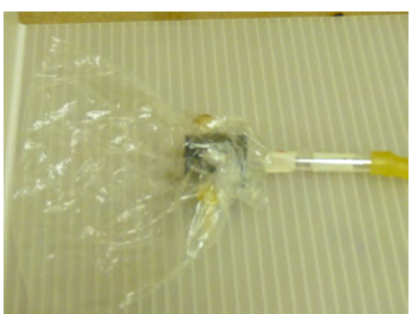
Preparation of the assembly for the experiment:

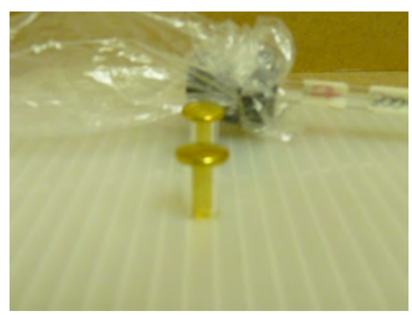
During the experiment, the student should make an assembly very similar to the one built for the manipulation about specific heat capacity. The materials list is therefore very similar.

Here is an example of a possible solution:



To compress the sample bag uniformly, it is preferable to have a small press. It is possible to make a rudimentary press. Here is an example:





Resources consulted and suggestions to learn more …

Webography

UCAR – The University Corporation for Atmospheric Research
www.ucar.edu/news/releases/

Méthanisation.info – French site of the Laboratoire de Biotechnologie de l'Environnement, INRA

http://www.methanisation.info/

ClimateChangeNorth.ca – Yukon conservation society web site.
http://www.climatechangenorth.ca/section-BGF/

Planète Terre – Web site of Mr. Pierre-André Bourque and the Département de géologie et de génie géologique of the Université Laval à Québec
http://www.ggl.ulaval.ca/personnel/bourque/intro.pt/planete_terre.html

Electrigaz - A company specialising in the study, design and realisation of biogas systems. Their offices are in Harrington, Quebec
www.electrigaz.com

La Recherche – French language scientific information magazine
http://www.larecherche.fr/content/recherche/

Green Teacher - Green Teacher is a non-profit organisation which publishes resources to help educators sensitise youths in primary and secondary schools to the environment.
http://www.greenteacher.com/francais.html

Natural Resources Canada
Research documents regarding arctic gas hydrates available.
http://gsc.nrcan.gc.ca/permafrost/arcticgas_f.php

Atlas du Canada
Maps available online regarding freshwater, hydrographical basins and watersheds
http://atlas.nrcan.gc.ca/site/francais/maps/archives/poster/watershed_bassin_versant
http://atlas.nrcan.gc.ca/site/francais/maps/freshwater/distribution/drainage

Natural Resources Canada
Reference document on water usage by the natural resources sector.
http://www.nrcan-rncan.gc.ca/com/resoress/publications/wateau/index-fra.php

Ministry of Sustainable Development, Environment and Parks
The voluntary lake supervision network of the Ministry of Sustainable Development, Environment and Parks. Reference document regarding eutrophication http://www.mddep.gouv.qc.ca/eau/rsv-lacs/methodes.htm

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WACKERNAGEL, Mathis. and REES, William, Our Ecological Footprint : Reducing Human Impact on the Earth, New Society Publishers, Philadelphia, Pennsylvania, 1996

Mc QUARRIE, Carole, Mc QUARRIE, Donald and ROCK, Peter A., Chimie Générale – Troisième édition, Éditions De Boeck Université, 1992

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