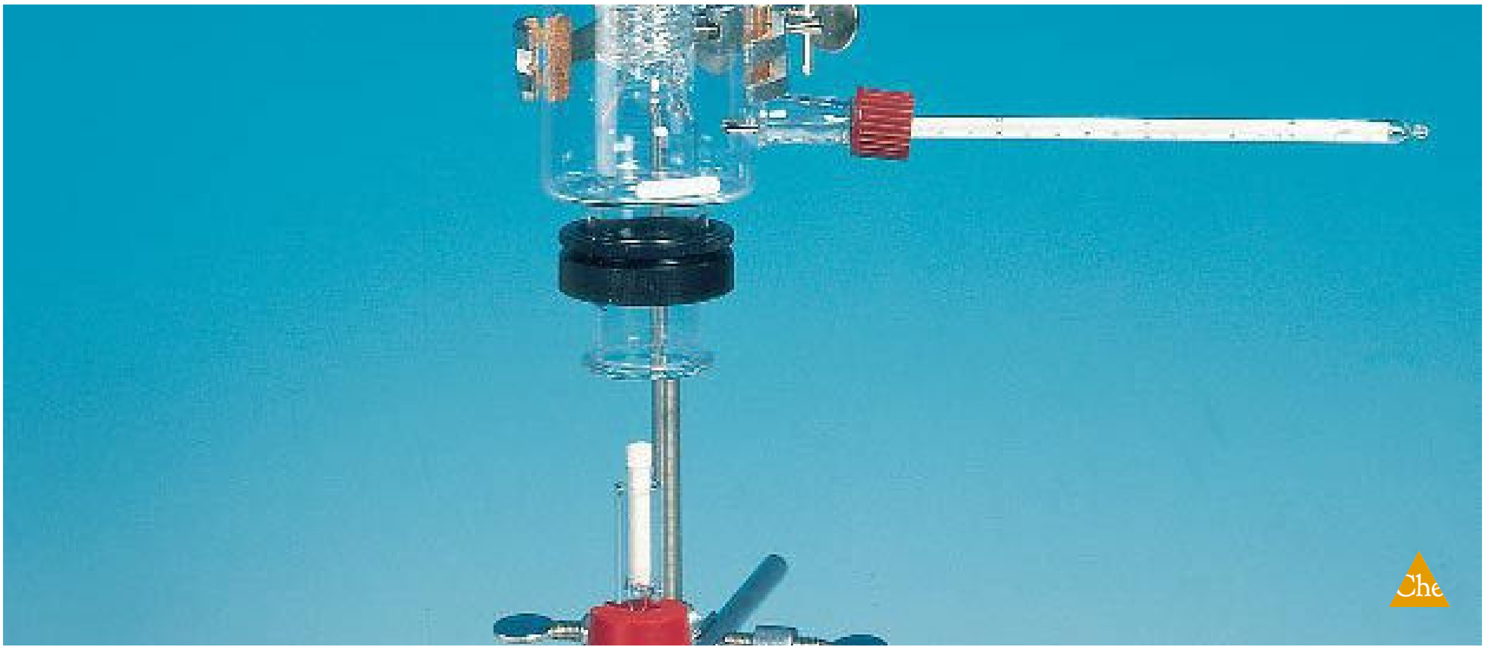
Determination of the heating value of fuel oil and of the calorific value of olive oil



Chemistry | Industrial Chemistry | Petrochemistry

Applied Science | Engineering | Renewable Energy | Basic Principles

Applied Science | Engineering | Photonics | Basic Principles

Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	20 minutes

General information

Application

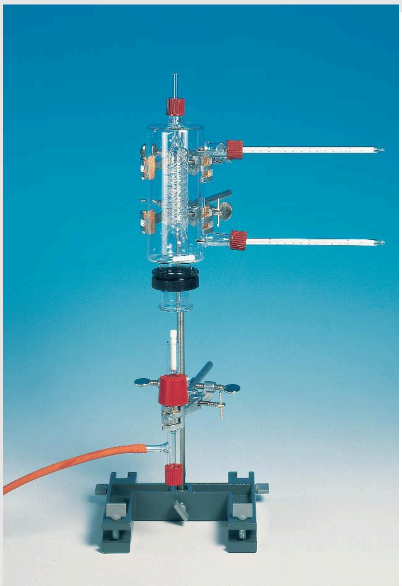


Fig.1: Experimental set-up

The calorific value of a product is used as a indicator of the energy residing in it and is as such used as an indicator for the nutritional value of a food product.

This experiment can be used to determine the heating value of fuel oil and the caloric value of olive oil.

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Other information (1/2)

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Prior knowledge

The prior knowlege required for this experiment is found in the theory section.

Main principle

The heat of reaction generated during the complete combustion of 1,000 g of solid or liquid fuel is known as the calorific value H. In the case of complete combustion of nutritional fats, the gross calorific value can also be determined. In order to ensure complete combustion, the reaction takes place under oxygen. The heat generated during the combustion of a specific amount of fuel is absorbed by a glass jacket calorimeter of known heat capacity. The calorific value of the test substance can be calculated from the temperature increase in the calorimeter.

Other information (2/2)

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Learning objektive

The goal of this experiment is to measure the calorific value of olive oil.

Tasks

Determine the calorific value of heating oil and the gross calorific value of olive oil.

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Safety instructions

Oxygen
H270: May cause or intensify fire; oxidizer.
H280: Contains gas under pressure; may explode if heated.
P220: Keep/Store away from clothing/…/combustible materials.
P403: Store in a well ventilated place.

Theory (1/2)

The calorimetric determination of heats of reaction consists of two tasks:

1. The determination of the chemical process that effects the temperature change in the calorimeter.
2. The determination of the heat capacity of the system.

The reactions that are examined here are the complete conversion of heating oil and of olive oil under oxygen. The heat capacity of the system is made up of the heat capacity of the calorimeter C_{cal} together with that of the water C_W. It is usually measured by determining the amount of electrical energy that causes a certain increase in temperature. In this experiment the heat capacity C_{cal} is known, as the glass jacket calorimeter has been calibrated.

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Theory (2/2)

Calculate the mass m of combusted oil from the values m_3 and m_4 and determine the temperature difference ΔT from the temperature values T_1 and T_2. Use these values to calculate the calorific value (of fuels) and the gross calorific value (of foodstuffs) by application of the following equation:

$$H = \frac{(m_w \cdot C_w + C_{\text{cal}}) \cdot \Delta T}{m}$$

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Equipment

Position	Material	Item No.	Quantity
1	Support base DEMO	02007-55	1
2	Support rod, stainless steel, 500 mm	02032-00	1
3	Right angle boss-head clamp	37697-00	3
4	Universal clamp	37715-01	3
5	Glass jacket	02615-00	1
6	Calorimeter insert for glass jacket	02615-01	1
7	Combustion lance for gases	02613-00	1
8	Closure caps,10, GL18	41220-03	1
9	Rub.stop.d=38/31mm,1 hole 15mm	39260-19	1
10	Thermometer -10...+50 °C	38034-00	2
11	Magnet, d = 10 mm, l = 200 mm	06311-00	1
12	Magnetic stirring bar 30 mm, cylindrical	46299-02	1
13	Funnel, glass, top dia. 50 mm	34457-00	1
14	Graduated beaker with handle, 1000 ml, plastic (PP)	36640-00	1
15	Glass tube,d 10/8mm,l 300mm	45125-01	1
16	Beaker, Borosilicate, tall form, 50 ml	46025-00	1
17	Steel cylinder oxygen, 2 l, filled	41778-00	1
18	Reducing valve f.oxygen	33482-00	1
19	Table stand for 2 l steel cylinders	41774-00	1
20	Wrench for steel cylinders	40322-00	1
21	Rubber tubing, i.d. 6 mm	39282-00	2
22	Hose clip, diam. 8-16 mm, 1 pc.	40996-02	2
23	Teclu burner, DIN, natural gas	32171-05	1
24	Lighter f.natural/liquified gases	38874-00	1
25	Safety gas tubing, DVGW, sold by metre	39281-10	1
26	Hose clip f.12-20 diameter tube	40995-00	2
27	Crucible tongs, 200 mm, stainless steel	33600-00	1
28	Tweezers,straight,blunt, 200 mm	40955-00	1
29	Glass tube cutter	33185-00	1
30	Scissors,straight,blunt,l 140mm	64625-00	1
31	Paper,ceram.fibre,1.0x500x2000mm	38750-01	1
32	Pasteur pipettes, 250 pcs	36590-00	1
33	Rubber caps, 10 pcs	39275-03	1
34	Wood splints, package of 100	39126-10	1
35	Protective glasses, green	39317-00	1
36	Glycerol, 250 ml	30084-25	1
37	Olive oil,pure 100 ml	30177-10	1
38	Water, distilled 5 l	31246-81	1

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Setup and Procedure

Setup and Procedure (1/3)

Fit the calorimeter insert into the glass jacket as described in the instruction manual. Fill the graduated vessel with approximately 500 g of water and determine the mass of it on the balance (= m_1). Carefully pour the water into the glass jacket through one of the vertical tubular sleeves (using a funnel) and weigh the vessel again (= m_2). Calculate the mass of the water ($\mathrm{m(H_2O)} = m_2 - m_1$)

Put a magnetic stirrer bar into the glass jacket and insert the thermometers. Close the hose olive on the tubular sleeve with a rubber cap. Fix the thus-assembled calorimeter on the support rod (see Fig.1).

Unscrew the connection cap from the combustion lance, pull the metal tube out of the glass tube and seal the glass tube on the threaded side with a cap. Lubricate the glass tube with glycerol and push it into the hole of a rubber stopper (size 38/35 mm) from the side with the larger diameter. The tube should extend approximately 4 cm out of the other side. Connect the vertical gas inlet to the oxygen steel cylinder with a piece of rubber tubing. Fix the combustion lance vertically and exactly centred below the calorimeter so that the rubber stopper can seal the lower opening of the calorimeter when it is moved upwards.

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Setup and Procedure (2/3)

Prepare small tubes for the combustion of the oil in the following manner. Cut a glass tube (d = 10 mm) into pieces of 9 cm length using a glass tube cutter. Round off the sharp-edged ends in a Teclu burner flame. Now soften the centre of a piece over the flame holding the two ends and twist them in opposite directions while first pulling them slightly apart, then separate the pieces quickly. Melt the sharp edged to smoothness. It is recommended that a number of these 45 mm oil tubes be made at the same time. Cut out rectangles of ceramic paper (40×50 mm) and roll them to form 40 mm long wicks.

Add approximately 40 drops of the oil to be tested into one of the small oil tubes. Insert a ceramic paper wick into the tube and put a few more drops of oil onto it. The wick should protrude about 3 to 4 mm out of the oil tube. Use a 50 ml glass beaker as a weighing stand on the balance to determine the total weight of the oil tube (m_3). Following this, position it in the top of the glass tube of the combustion lance.

Setup and Procedure (3/3)

Record the initial temperature of the water in the calorimeter T_1. Put on the dark protective glasses. Adjust a gentle flow of oxygen and ignite the oil saturated wick with a wood splint. As soon as ignition has occurred, push the ‘burner’ upwards into the calorimeter and fix it into position with the help of the rubber stopper and the right angle clamp. The burner must not directly touch the glass wall of the calorimeter, otherwise this will become too hot. During combustion, adjust the flow of oxygen so that the flame is not sooty, and move the stirrer bar in the glass jacket using the magnet. When a temperature increase of approximately 5 K is shown, shut off the oxygen supply. The flame will continue to burn for a few seconds and then quickly extinguish. Continue stirring until temperature equilibrium has been established and record the final temperature T_2. Then remove the oil tube with the tweezers and immediately weigh it (m_4).

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Evaluation

Task 1

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$m_W = 500\,\text{g}$

$C_W = 4.19\,\text{J/gK}$

$C_{cal} = 410\,\text{J/K}$

$m_3 = 4.075\,\text{g}$

$m_4 = 3.648\,\text{g}$

$m = m_3 - m_4 = 0.427\,\text{g}$

$T_1 = 298.5\,\text{K}$

$T_2 = 305.4\,\text{K}$

$\Delta T = T_2 - T_1 = 6.9\,\text{K}$

$$H = \frac{(500 \cdot 4.19 + 410)6.9\ \text{J} \cdot \text{g}^{-1}}{0.427} = 40,479\ \text{kJ} \cdot \text{kg}^{-1}$$

Literature values:

Upper calorific value H_u = 42,300 to 43,570 kJ/kg

Lower calorific value H_l = 40,220 to 41,480 kJ/kg

The lower calorific value refers to combustion in which the water formed is present as vapour; the upper calorific value include the latent heat of condensation of water.

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Task 2

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$m_3 = 4.751\,\text{g}$

$m_4 = 4.358\,\text{g}$

$m = m_3 - m_4 = 0.393\,\text{g}$

$T_1 = 301.7\,\text{K}$

$T_2 = 307.55\,\text{K}$

$\Delta T = T_2 - T_1 = 5.85\,\text{K}$

$$H = \frac{(500 \cdot 4.19 + 410) 5.85 \text{ J} \cdot \text{g}^{-1}}{0.393 \text{ kg}} = 3,728.28 \text{ kJ} \cdot 100 \text{ g}^{-1}$$

Literature values:

The gross calorific value or energy content of olive oil is usually quoted in nutritional tables as 3,880 kJ / 100 g. This value corresponds to the physiological gross value because fatty oils are completely converted in the body to carbon dioxide and water.

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