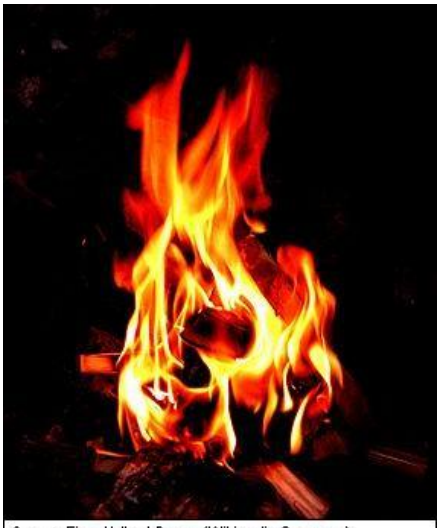
Heat of combustion

Woodburning fireplace generating heat. Source: Francisco Belard



Source: Einar Helland Berger (Wikimedia Commons)
Flame from combustion (burning) of a fuel.

The **heat of combustion** (ΔH_c^0) is the energy released as heatwhen a substance undergoes complete combustion with oxygen.
The chemical reaction for combustion is typically that of ahydrocarbon fuel reacting with oxygen derived from atmospheric air to form gaseous carbon dioxide, water vapor and heat. For example:

methane + oxygen ⇒ carbon dioxide + water vapor
$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$

The heat of combustion may be quantified with these units:

- energy per mole of fuel, such as kilojoule per mol (kJ/mol) or British thermal unit per pound-mol (Btu/lb-mol)
- per mass of fuel, such as megajoule per kilogram (MJ/kg) or British thermal unit per pound (Btu/lb)
- energy per volume of fuel, such as megajoule per cubic meter (MJ/m^3) or British thermal unit per cubic foot (Btu/ft^3)

The heat of combustion is usually measured with a bomb calorimeter. It may also be calculated as the difference between the heat of formation (ΔH_f^0) of the products and reactants.

Common expressions for the heat of combustion of fuels

The heat of combustion of a fuel is commonly referred to as the **heating value** or the **caloric value** and briefly defined as the amount of heat released when a unit amount of the fuel is completely combusted. The heating value is a unique characteristic of each specific fuel. The heating value of a fuel may be categorized as either the **higher heating value (HHV)** or the **lower heating value (LHV)**.[1][2] The HHV is also known as the **gross heating value** (**GHV**) or the **gross caloric value** (**GCV**) and the LHV is also known as the **net heating value** (**NHV**) or the **net caloric value** (**NCV**).

More completely defined, the HHV is the amount of heat released when a unit amount of fuel at a given initial temperature (usually 20 °C or 25 °C) is completely combusted at stoichiometric conditions and constant pressure with the combustion products being cooled to the initial temperature and any water vapor produced being condensed. Condensing any water vapor produced during determination of the HHV means that the HHV includes the heat of vaporization ($\mathbf{\Delta H_v^0}$ or more simply $\mathbf{H_v}$) of the water produced. Stoichiometric combustion means that the combustion products do not contain any oxygen (i.e., there was no excess combustion air during the combustion).

The LHV is similarly defined except that any water in the combustion products is not condensed and remains as a vapor. Thus, the LHV does not include the heat of vaporization of the water produced.

The relation between the HHV and the LHV may be simply expressed as:

$$\mathbf{LHV = HHV - H_v}$$

Fuel gases and fuel liquids usually contain little, if any, water. However, raw solid fuels like coal, wood orpeat do contain significant amounts of water. Coal, in particular, also contains significant amounts of non-combustible minerals that form ash when the coal is combusted.

More expressions for fuel heating values

Both the HHV's and LHV's of fuels (especially coal and other solid fuels) can be be further sub-categorized and expressed as:[3]

- **As Received** (**AR**): Indicates the the fuel heating value was measured with all inherent moisture and ash forming minerals present.
- **Moisture Free** (MF) or **Dry**: Indicates that the fuel heating value was measured after the fuel has been dried of all inherent moisture but still retained its ash forming minerals.
- **Moisture and Ash Free** (**MAF**) or **Dry and Ash Free** (**DAF**): Indicates that the fuel heating value has been measured in the absence of both inherent moisture and ash forming minerals.

Heating values of some common fuels

Table 1: Higher Heating Value (HHV) Of Various Common Fuels							
Fuel	**Phase**	**Molecular Weight]]**	**kJ/mol**	**MJ/kg**	**MJ/m^3**	**Btu/lb**	**Btu/ft^3**
Hydrogen [4]	gas	2.016	285.84	141.79	12.75	60,986	324
Methane [4][5]	gas	16.043	890.31	55.50	39.72	23,870	1,009
Ethane [4][5]	gas	30.069	1,559.88	51.88	69.59	22,313	1,768
Propane [4][5]	gas	44.096	2,220.05	50.35	99.05	21,654	2,516
Butane [4][5]	gas	58.122	2,878.52	49.53	128.43	21,301	3,263
Ethanol [6]	liquid	46.068	1,375.01	29.85		12,837	
Gasoline [6]	liquid	110	5,013.47	45.58		19,603	
Kerosene [7]	liquid	178	8,084.99	45.42		19,536	
Diesel oil [7]	liquid	225	10,124.99	45.00		19,355	
Coal [8]	solid			25.58		11,002	
Wood (dry) [9]	solid			21.14		9,093	
Peat (dry) [10]	solid			22.09		9,500	

-- The gas temperature and pressure for the values of MJ/m^3 are 0 °C and 101.325 kiloPascal.

-- The gas temperature and pressure for the values of Btu/ft^3 are 60 °F and 14.696 psia.

-- LPG is marketed as propane or butanes or a mixture of propane and butanes.

-- Natural gas, after removal of impurities and natural gas liquids (NGL), is essentially pure methane.

Table 2: Lower Heating Value (HHV) Of Various Common Fuels							
Fuel	Phase	Molecular Weight	kJ/mol	MJ/kg	MJ/m^3	Btu/lb	Btu/ft^3
Hydrogen [4]	gas	2.016	241.83	119.96	10.79	51,596	274
Methane [4]	gas	16.043	802.32	50.01	35.80	21,511	909
Ethane [4]	gas	30.069	1,427.84	47.49	63.70	20,424	1,618
Propane [4]	gas	44.096	2,044.00	46.35	91.19	19,937	2,317
Butane [4]	gas	58.122	2,658.45	45.74	118.61	19,673	3,013
Ethanol [6]	liquid	46.0684	1,241.66	26.95		11,593	
Gasoline [6]	liquid	110	4,675.00	42.50		18,280	
Kerosene [11]	liquid	178	7,519.05	42.24		18,169	
Diesel oil [11]	liquid	225	9,395.99	41.76		17,961	
Coal [11]	solid			24.429		10,507	
Wood (dry) [11]	solid			20.09		8,639	
Peat (dry) [11]	solid			20.65		8,883	

-- The gas temperature and pressure for the values of MJ/m^3 are 0 °C and 101.325 kPa.

-- The gas temperature and pressure for the values of Btu/ft^3 are 60 °F and 14.696 psia.

-- LPG is marketed as propane or butanes or a mixture of propane and butanes.

-- Natural gas, after removal of impurities and natural gas liquids (NGL), is essentially pure methane.

Sources of additional heating values

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Source:
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