

# Fundamental properties of Hydrogen gas

Gas density and electrical constants for fuel cell calculations

Iain Staffell - 2008

[woqone.com/ig/h2](http://woqone.com/ig/h2)

## Basic Constants for Hydrogen

				Ref
Atomic Mass	2.01588 g / mol	± 0.00014	(0.0069%)	[1]
Faraday	96485.34 As / mol	± 0.0024	(0.0000%)	[2]
Zero Degrees	273.15 °K			[3]
Molar Gas (R)	8.314472 Pa·m <sup>3</sup> / K / mol	± 0.000015	(0.0002%)	[3]

## Theoretical Hydrogen Density

Specify a given T and P, and calculate n (moles per litre) from PV = nRT

P 101.325 kPa  
T 25 °C

V 1 L  
R 8.3145 Pa·m<sup>3</sup> / K / mol

n 0.040874 mol / L

Get the density for this given combination and the (density x temperature) constant

ρ 0.082397 ± 0.000006 g / L  
ρT 24.567 ± 0.002 g°K / L

## H<sub>2</sub> Energy Density

HHV	Ref
141.86 kJ / g	[4]
141.86 kJ / g	[5]
141.79 kJ / g	[6]
141.90 kJ / g	[7]
141.85 ± 0.04	

LHV	Ref
119.93 kJ / g	[4]
119.93 kJ / g	[5]
119.96 kJ / g	[6]
120.10 kJ / g	[7]
119.98 ± 0.08	

## H<sub>2</sub> Conversion Factors

x 1.1823 LHV --> HHV  
x 0.8458 HHV --> LHV

## Measured Hydrogen Density

			ρT at 101.325 kPa	Ref
0.0837 g / L @	20 °C &	101.325 kPa	24.54 g°K / L	[4]
0.0838 g / L @	20 °C &	101.325 kPa	24.55 g°K / L	[5]
0.0850 g / L @	15 °C &	101.3 kPa	24.50 g°K / L	[8]
0.0834 g / L @	21 °C &	101.3 kPa	24.55 g°K / L	[8]
0.1968 g / L @	-150 °C &	100 kPa	24.56 g°K / L	[9]
0.1636 g / L @	-125 °C &	100 kPa	24.55 g°K / L	[9]
0.1399 g / L @	-100 °C &	100 kPa	24.55 g°K / L	[9]
0.1223 g / L @	-75 °C &	100 kPa	24.55 g°K / L	[9]
0.1086 g / L @	-50 °C &	100 kPa	24.55 g°K / L	[9]
0.0976 g / L @	-25 °C &	100 kPa	24.55 g°K / L	[9]
0.0887 g / L @	0 °C &	100 kPa	24.55 g°K / L	[9]
0.0813 g / L @	25 °C &	100 kPa	24.55 g°K / L	[9]
0.0750 g / L @	50 °C &	100 kPa	24.55 g°K / L	[9]
0.0696 g / L @	75 °C &	100 kPa	24.55 g°K / L	[9]
0.0649 g / L @	100 °C &	100 kPa	24.55 g°K / L	[9]
0.0609 g / L @	125 °C &	100 kPa	24.56 g°K / L	[9]
(note: ρT diverges outside the range of -150°C to +125°C)				
0.0899 g / L @	0 °C &	101.325 kPa	24.55 g°K / L	[10]
			24.549 ± 0.014	

## References

- [1] <http://www.webelements.com/webelements/elements/text/H/key.html>  
 [2] <http://physics.nist.gov/cgi-bin/cuu/Value?f>  
 [3] [http://en.wikipedia.org/wiki/Absolute\\_zero](http://en.wikipedia.org/wiki/Absolute_zero)  
 [4] [http://smad-ext.grc.nasa.gov/gso/manual/chapter\\_06.pdf](http://smad-ext.grc.nasa.gov/gso/manual/chapter_06.pdf)  
 [5] [http://www1.eere.energy.gov/hydrogenandfuelcells/tech\\_validation/pdfs/fcm01r0.pdf](http://www1.eere.energy.gov/hydrogenandfuelcells/tech_validation/pdfs/fcm01r0.pdf)

- [6] [http://www.tyndall.ac.uk/research/theme2/final\\_reports/it1\\_36.pdf](http://www.tyndall.ac.uk/research/theme2/final_reports/it1_36.pdf)  
 [7] [http://books.nap.edu/openbook.php?record\\_id=10922&page=240](http://books.nap.edu/openbook.php?record_id=10922&page=240)  
 [8] <http://encyclopedia.airliquide.com/Encyclopedia.asp?GasID=36#GeneralData>  
 [9] <http://hydrogen.pnl.gov/cocoon/morf/hydrogen/article/401>  
 [10] <http://en.wikipedia.org/wiki/Hydrogen>

Hydrogen Properties		
<b>HHV</b>		
Energy Density:	141.85 ± 0.044	MJ / kg
Atomic Mass:	2.01588 ± 0.00014	g / mol
Electron Density:	0.99212 ± 0.00007	mol / g
Faraday Const:	96485.3 ± 0.00240	As / mol
Charge Density:	95725.3 ± 6.6	As / g
From 1g / min flow rate:		
Power:	2364.23 ± 0.73	W
Current:	1595.42 ± 0.11	A
Voltage:	1.4819 ± 0.0005	V
Gas Density:	0.082397 ± 0.000006	g / L
<i>(at 25°C and 101.325 kPa)</i>		
From 1L / min flow rate:		
Power:	194.805 ± 0.062	W
Current:	131.458 ± 0.013	A
Voltage:	1.4819 ± 0.0005	V

Hydrogen Properties		
<b>LHV</b>		
Energy Density:	119.98 ± 0.081	MJ / kg
Atomic Mass:	2.01588 ± 0.00014	g / mol
Electron Density:	0.99212 ± 0.00007	mol / g
Faraday Const:	96485.3 ± 0.00240	As / mol
Charge Density:	95725.3 ± 6.6	As / g
From 1g / min flow rate:		
Power:	1999.68 ± 1.35	W
Current:	1595.42 ± 0.11	A
Voltage:	1.2534 ± 0.0009	V
Gas Density:	0.082397 ± 0.000006	g / L
<i>(at 25°C and 101.325 kPa)</i>		
From 1L / min flow rate:		
Power:	164.768 ± 0.112	W
Current:	131.458 ± 0.013	A
Voltage:	1.2534 ± 0.0009	V

Reference values:

Current: 131.5 A from 1L/min

[Handbook of Fuel Cells 6 - Ch 9]  
*(taken from 37.605g/hr required for 1kA)*

Open Circuit Voltage: 1.25 V LHV  
 1.48 V HHV

[Fuel Cell Systems Explained - Ch 2.4]  
*(calculated from  $E = (-\Delta g_f / 2F)$ )*