Battery Hydrogen Gas Emissions

Theory

If the voltage of a battery is high enough, so that the electrolysis potential of water is exceeded, water is decomposed continuously. The following chemical formula describes this reaction:

$$H_2O \quad + \quad 53.6029\frac{Ah}{mol} \quad \rightarrow \quad H_2 \quad + \quad \frac{1}{2}O_2$$

As 1 mol of water is exactly 2*1.00794 g + 1*15.9994 g = 18.01528 g, it is straight forward to be seen that 53.6029 Ah/mol / (18.01528 g/mol) = 2.9754 Ah per g water are needed for the decomposition. On the other hand, the reciprocal value of 1/(2.9754 g/Ah) = **0.336 g/Ah** means that 0.336 g water are decomposed when an electrical capacity of 1 Ah was used for the electrolysis.

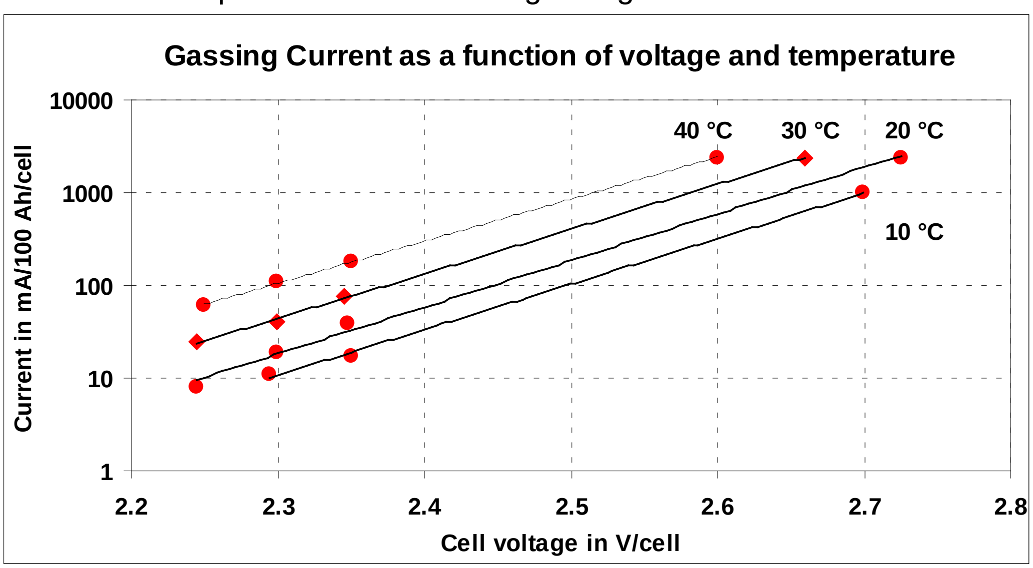
The formula shows also, that one mole of water produces one mole of hydrogen gas and half mole of oxygen gas. At ambient operating conditions, these gases can be considered as ideal gases which obey to ideal gas law:

$V \quad = \quad \frac{n \cdot R \cdot T}{P}$, where V is the volume in m³, n the number of moles, R the universal gas constant in Pa*m³/(mol*K), T the temperature in K and P the pressure in Pa. Involving standard values of n = 1 mol, R = 8.31447 Pa*m³/(mol*K), P = 101325 Pa and T = 273.15 K, one gets

V = 0.02241 m³, which are equal to **22.41 Liter of one mole Gas at standard conditions**.

Experimental results

Next diagram shows some experimental values for gassing currents in lead-acid batteries.



It can be seen that there are two main factors having an **influence** on the gassing current: **temperature** and **charging voltage**. Or, one can read a value he is interested in out of the diagram, or one models the dependencies by using exponential functions whose pre-exponential and exponential terms are expressed by functions of temperature.

Calculation method

1. calculation of electrical capacity which decomposes water
2. calculation of overall mass of decomposed water
3. calculate how many moles this mass correspond to
4. apply ideal gas law in order to get the corresponding gas volumes

1. $C_{el} = I \cdot 0.001 \cdot C_{10} \cdot 0.01 \cdot t \cdot N \cdot n \cdot S$
2. $m_{water} = 0.336g \cdot C_{el} \cdot c$
3. $n_{water} = m_{water} / 18.01528 \frac{g}{mol}$
4. $V_{Hydrogen} = \frac{n_{water} \cdot R \cdot T}{P}$

Where:

I	- Gassing current in mA/100 Ah/ cell
0.001	- The unit conversion factor from mA to A
C_{10}	- Nominal C_{10} capacity in Ah
0.01	- The conversion factor from 100 Ah to 1 Ah
t	- Time in hours (charging time or interval of interest, e.g. 1 hour)
N	- Number of blocks (or cells when there are no blocks)
n	- Number of cells per block (6 for a 12 V block, or 1 for a single cell)
S	- Number of parallel strings
c	- A design factor: 1 for vented and 0.1 for VRLA batteries
R	- R = 8.31447 Pa*m³/(mol*K),
P	- 101325 Pa (this his 1 atmosphere)
T	- Ambient temperature in K (Calculated by Celsius temperature: T/K = T/°C + 273.15, or by using Fahrenheit scale: T/K = (T/°F + 459.67)*5/9)

Example Gassing Calculations - Normal Conditions (End of Life) - BAE 2 OPzS 100

1 string of 130V 2 OPzS 100 is floated at 2.23 V/cell and a room temperature of 77 °F.

C_{el}	= 37.301 * 0.001 * 100Ah * 0.01 * 1h * 60 * 1 * 1	= 2.238 Ah
m_{water}	= 0.336 * 2.238 * 1 g	= .7520 g
n_{water}	= 0.7520 / 18.01528 mol	= 0.04174 mol
$V_{Hydrogen}$	= 0.04174 * 8.31447 * (273.15+25)/101325 m³	= 0.00102 m³/hr
$V_{Hydrogen}$	= **.03606 ft³/hr**	

(Note that the volume of oxygen is as half the volume of hydrogen)

Example Gassing Calculations - Worst Case Conditions (End of Life)- BAE 2 OPzS 100
1 string of 130V 2 OPzS 100 is equalized at 2.40 V/cell and room temperature of 77 °F..

C_{el}	= 259.598 * 0.001 * 100Ah * 0.01 * 1h * 60 * 1 * 1	= 15.5759 Ah
m_{water}	= 0.336 * 15.5759 * 1 g	= 5.2335 g
n_{water}	= 5.2335 / 18.01528 mol	= 0.2905 mol
$V_{Hydrogen}$	= 0.2905 * 8.31447 * (273.15+25)/101325 m^3	= .00711 m^3/hr
$V_{Hydrogen}$	= **.25099 ft^3/hr**	

(Note that the volume of oxygen is as half as the volume of hydrogen)