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Technical Note

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Subject: Calculating pH from Sulfuric Acid concentration

1. Introduction

Operation of SOx scrubber system generates effluent taking SO_x contents as the Sulfuric Acid (H_2SO_4). Due to the strong acidity of H_2SO_4 scrubber manufacturers consider special alloy with higher corrosion resistance performance especially against Sulfuric Acid.

STI has prepared for this document to explain shipyard designers and/or ship operators with the relationship between Sulfuric Acid concentration in weight (*WC*) and corresponding *pH* values.

2. Calculation example

2.1 pH calculation

pH is a simple measurement counting the number of H^+ ion within a solution.

$$pH = -\log(H^+) \tag{1}$$

For the case of 'strong acids' like Sulfuric Acid, $[H^+]$ is the same as $[HA]$, where $[HA]$ is concentration of the acid given as 'mole/liter'.

Sulfuric Acid, H_2SO_4, yields two $[H^+]$ ions when dissolved into water. It means that $[H^+]$ is two times of $[HA]$ for the case of H_2SO_4.

2.2 Concentration of Sulfuric Acid

Molecular weight of Sulfuric Acid, H_2SO_4, is 50 gram/mole.

$$50 = H\ x\ 2 + S + O\ x\ 4 = 1\ x\ 2 + 16 + 8\ x\ 2$$

Weight concentration (*WC*) of 1% of Sulfuric Acid in water is 1/5 mole/liter. (For the case of fresh water, 1 liter is 1kg in weight.)

$$1\%\, WC = 10\frac{g}{l} = \frac{1}{5}\frac{mole}{liter} \tag{2}$$

2.3 pH calculation example #1

A SOx scrubber uses 135 times of seawater compared to the fuel in weight.
When a diesel engine uses fuel oil with 3.5% sulfur contents in weight and all the sulfur contents in the exhaust gas flow (in the form of SO_2 and SO_3) dissolves into spray water, the *WC* becomes 0.026% (=3.5% / 135). This is an ideal case assuming that all the SO_2 in the exhaust gas dissolve in the spray water, and no spray water evaporates within the scrubber unit.

In this case, molecular concentration of the sulfuric acid becomes, 0.0052 mole/liter.
The amount of $[H^+]$ in the solution is 0.01, two (2) times of mole concentration.
pH value of this solution is 2 (= -log(0.01)).

2.4 pH calculation example #2

Calculate the pH values of a solution with 10% *WC* of sulfuric acid.

Weight of the sulfuric acid in the water is 100g per liter (of fresh water).
It is 2 mole/liter as shown in (2).
The amount of $[H^+]$ in the solution is 4.
pH value of this solution is -0.6 (= -log(4)).

2.5 pH calculation example #3

Calculate the Sulfuric Acid concentration from a given pH value of 3.5.

The calculation is to be made in a reverse process compared to the two examples shown in Sec. 2.3 and Sec. 2.4. Inverse of the *pH* equation, (1),

$$H^+ = 10^{-pH} = 10^{-3.5} \tag{3}$$

When the given *pH* is 3.5, then H^+ is 0.00032.
As the H^+ is 2 times of $[HA]$ for the case of Sulfuric Acid, H_2SO_4, $[HA]$ is 0.00016 mole/liter.

Using the equation (2), 0.00016 mole/liter of concentration is equivalent to 0.0008 (= 0.00016/0.2) gram/liter.
This is equivalent to 0.0008% of Sulfuric acid concentration.

3. Summary: *pH* vs. weight concentration (*WC*)

The relationship between *pH* and weight concentration of Sulfuric acid can be made by combining the two equations, (1) and (2). It should be noted that H^+ is 2 times of $[HA]$ for the case of Sulfuric Acid, H_2SO_4.

$$\begin{aligned} pH &= -\log(H^+) \\ &= -\log(2\,HA) \\ &= -\log(10\,WC) \end{aligned} \tag{4}$$

Graphical representation of equation (4) over a WC range of 10^{-6} % to 100% is as shown in Figure 1.

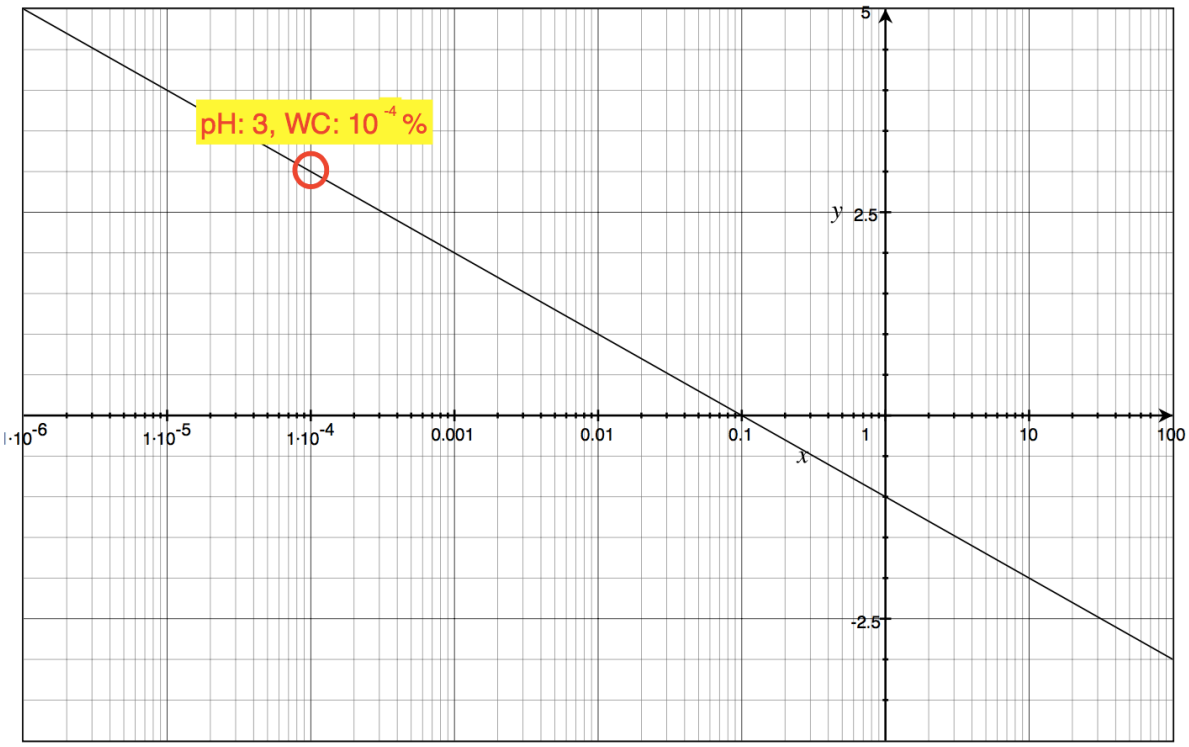

Figure 1. Weight concentration of Sulfuric Acid in % vs. pH value, WC={10^{-6} … 10^{2}}