Accurate Preparation of Chlorine Dioxide Solution

Presented is an analysis of the amount of chemical substances for the MMS solution and citric acid needed to get a stoichiometric accurate mix to produce chlorine dioxide. Wikipedia has for the definition of stoichiometry:

Stoichiometry (sometimes called reaction stoichiometry to distinguish it from composition stoichiometry) is the calculation of quantitative (measurable) relationships of the reactants and products in a balanced chemical reaction (chemicals). It can be used to calculate quantities such as the amount of products that can be produced with the given reactants and percent yield.

First we look at the molecular masses of sodium chlorite and citric acid (looked up at Wikipedia).

A molar mass M_{mol} is defined as the mass of one mole of substance in units of gm/mol; one mole has 6.022 *10^23 of molecules (or atoms), which is called the Avogadro constant N_A. More precisely, N_A is defined as the number of atoms in exactly 12 grams of the pure isotope ^{12}C.

The molar mass takes into account the fractions of natural isotopes found in nature.

Sodium Chlorite: $NaClO_2$ single valence

Molar mass:

$$M_{NaClO2} := (23 + 35.5 + 32)\frac{gm}{mol} \qquad M_{NaClO2} = 90.5 \cdot \frac{gm}{mol}$$

Citric Acid: $C_6H_8O_7$ triple valence

Molar mass:

$$M_{CitricAcid} := 210.14\frac{gm}{mol}$$

Ratio: $$\frac{210.14}{3 \cdot 90.5} = 0.774$$

The molar mass is for the monohydrate form, which means each citric acid molecule has a single molecule of water added to it.

Sodium Citrate: $C_6H_5Na_3O_7$ triple valence

Molar mass:

$$M_{SodiumCitrated} := 258.07\frac{gm}{mol}$$

Chemical reaction:

$3\ NaClO_2 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3\ ClO_2$

$ClO_2 + H_2O \rightarrow H_2ClO_3$

By molar mass, one needs therefore three times as much sodium chlorite than citric acid. **That means by actual weight, for each gram of sodium chlorite one would need about 0.77 grams of citric acid.**

The density of sodium chlorite is 2.5 gm/cm^3 and the density of citric acid is 1.665 gm/cm^3.

By volume for each cm^3 of sodium chlorite powder one would need 1.156 cm^3 of citric acid powder. So almost equal portions for each substance by volume.

MMS is made as a 22.4% solution by volume in water, the concentrated citric acid is made as a 50% solution by volume in water. Therefore this is a bit more citric acid than needed. The proper stoichimetric amount would be two drops of MMS solution for each drop of 50% citric acid. Since the MMS solution is 22.4% and not 25%, there is a little more citric acid by volume. The ratio 25%/22.4% is 1.12 vs. 1.156 for the optimum.

Within this accuracy two drops of MMS for each drop of concentrated (50%) citric acid should be fine.

Note that for the 10% citric acid solution one would need to mix two drops of MMS solution with 5 drops of 10% citric acid solution!

According to Wikipedia, natural lemon juice contains 47 gm/liter or 0.047g/cm^3 of citric acid. Bottled lemon juice is more concentrated. I think it is twice as concentrated as in the juice of a lemon, that is what I found on the web, so it should have about 0.1 gm/cm^3 citric acid.

I think that the recommendations of 5 times as much bottled lemon juice for each drop of MMS solution is on the low side. To calculate, we take the ratio of the concentration of MMS with that of the bottled lemon juice and multiply the result by the stoichiometric weight ratio of 1.3:

$$\frac{0.224 \cdot 2.5}{0.1} \cdot 1.3 = 7.28$$

You need 7-8 drops of bottled lemon juice per drop of MMS solution.

Quick check for the 50% citric acid solution:

MMS is 22.4% in water, so the concentration is 0.224*2.5gm/cm^3 = 0.56 gm/cm^3.
50% citric acid has 0.5*1.665 gm/cm^3 = 0.833 gm/cm^3.

The weight ratio of two parts of 22.4% MMS to one part of 50% citric acid is therefore:

$$\frac{2 \cdot 0.56\text{gm}}{0.833\text{gm}} = 1.345$$

The ideal weight ratio was 1/0.774 = 1.3 - close enough!