Chapter 6 - Chemistry

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Formulae

updated July 1999

Name	Formula	Description	Molar Mass or Formula Weight
Ammonium Citrate	$(NH_4)_2HC_6H_5O_7$	Developer	
Ammonium Dichromate	$(NH_4)_2Cr_2O_7$	Contrast Agent	
Ammonium Ferric Oxalate	$(NH_4)_3Fe(C_2O_4)_3{\cdot}3H_2O$	Sensitizer	428.06
Citric Acid	$HOC(COOH)(CH_2COOH)_2H_2O$	Clearing Agent	
EDTA	$(HOCOCH_2)_2NCH_2CH_2N(CH_2COOH)_2$	Clearing Agent	
Ferric Oxalate	$Fe_2(C_2O_4)_3{\cdot}6H_2O$	Sensitizer	483.84
Ferrous Oxalate	$Fe(C_2O_4)$	Exposed Sensitizer	
Hydrochloric Acid	HCl	Clearing Agent	
Hydrogen Peroxide	H_2O_2	Contrast Agent	
Lithium Chloride	LiCl	Salt	42.39
Oxalic Acid	$HOCOCOOH{\cdot}2H_2O$	Sensitizer Additive	
Palladium	Pd	Nobel Metal	
Palladium (II) chloride	$PdCl_2$	Metal Salt	177.31
Platinum	Pt	Nobel Metal	
Phosphoric Acid	H_3PO4	Clearing Agent	
Potassium Chloride	KCl	Salt	74.55
Potassium Chlorate	$KClO_3$	Contrast Agent	
Potassium Oxalate	$KOCOCOOK{\cdot}H_2O$	Developer	
Potassium Dichromate	$K_2Cr_2O_7$	Contrast Agent	

Potassium meta-Bisulfite	$K_2S_2O_5$	Clearing Agent	
Potassium tetrachloropalladium (II)	K_2PdCl_4	Double Metal Salt	326.42
Potassium tetrachloroplatinum (II)	K_2PtCl_4	Double Metal Salt (red)	415.11
Potassium hexachloroplatinum (IV)	K_2PtCl_6	Undesirable Slightly Soluble Double Metal Salt (yellow)	
Potassium Ferricyanide	$K_3Fe(CN)_6$	Sensitizer Testing Agent and clearing indicator	
Sodium Chloride	NaCl	Salt	58.44
Sodium Sulfite	Na_2SO_3	Clearing Agent	
Sodium tetrachloropalladium (II)	Na_2PdCl_4	Double Metal Salt	294.19
Water (Distilled)	H_2O		

Process Equations
updated December 2000

DOP - Ferric Oxalate
POP - Ammonium Ferric Oxalate

The process equations help provide an expression of the chemical reactions and an expectation of the materials necessary to provide for predicted outcomes. Unfortunately, the reactions and these equations are not fully understood. Future research may provide better understanding and insight as to the Pt/Pd process.

There are two primary processes to consider:

DOP - Develop Out Process employing the sensitizer Ferric Oxalate
POP - Printing Out Process employing the sensitizer Ammonium Ferric Oxalate

Current understanding seems to indicate that the metal salts behave similarly and each sensitizer gets to the same outcome by a different route.

The most useful information from the process equations for the process as described in this guide are the ratios of metal salts to sensitizer required. The ratios have been discerned empirically in the Empirical Verification of Process Equations.

Process Equations for Ferric Oxalate:

The sensitizer reacts to light, heat, or time as follows:

$$3Fe_2(C_2O_4)3 \bullet 6H_2O \text{ >exposure> } 6Fe(C_2O_4)) + 3(C_2O_4)) + 6H_2O$$

The metals are released by what is known as Brewster's Reaction described by Berkeley's equation:

$$6Fe(C_2O_4)) + 3K_2PtCl_4 => 2Fe_2(C_2O_4))_3 + 2(FeCl_3) + 6KCl + 3Pt$$

The same occurs for Palladium:

$$6Fe(C_2O_4)) + 3Na_2PdCl_4 => 2Fe2(C_2O_4))_3 + 2(FeCl_3) + 6NaCl + 3Pd$$

or

$$6Fe(C_2O_4)) + 3K_2PdCl_4 => 2Fe2(C_2O_4))_3 + 2(FeCl_3) + 6KCl + 3Pd$$

or

$$6Fe(C_2O_4)) + 3Li_2PdCl_4 => 2Fe2(C_2O_4))_3 + 2(FeCl_3) + 6LiCl + 3Pd$$

etc.

Every three $Fe_2(C_2O_4)_3$ will pair with three K_2PtCl_4 or Na_2PdCl_4 or K_2PdCl_4 or Li_2PdCl_4, a ratio of one-to-one (1 metal salt for 1 sensitizer.)

Process Equations for Ammonium Ferric Oxalate:

The sensitizer is thought to react generally as follows:

$(NH_4)3Fe(C\ C_2O_4)_3 \bullet 3H_2O$ >exposure> $Fe(C_2O_4)_2 + 3(NH_4) + 3H_2O + 2CO_2$

Some of the (C_2O_4) is changed into the $2CO_2$ gas as suggested by Mike Ware.
For a description of the reactions by Mike Ware click here.

The basic process reaction for AFO with Lithium is thought to be:

$3Fe(C_2O_4)_2 + 3Li_2PdCl_4 + 3(NH_4) + 3H_2O$ =>
$(NH4)3Fe(C_2O_4)_3 \bullet 3H_2O + 2(FeCl_3) + 6LiCl + 3Pd + 3(C_2O_4)$

Or other metallic salts could be substituted.

Every three sensitizer molecules will pair with three metallic double salt molecules, a one-to-one ratio (1 metal salt for 1 sensitizer.)

Formulas for Ferric Oxalate Sensitizer Solutions

created May 2000, updated April 2005

In order to achieve accuracy and consistency, it is important to begin with an accurately formulated sensitizer to which the metal solution will be balanced.

Summaries of Various Studies

The Initial Comparison of FO Powders Study provided estimates for the concentration of Ferric Oxalate (FO) in several tested FO Powders.

The Verification of FO Powder Composition study used the work of Dick Stevens to relate the percent concentration of Ferric Oxalate in a solution with its specific gravity. It was found that the Stevens' model and specific gravity information may not accurately relate to the concentration of Ferric Oxalate. However good comparisons could be achieved by comparing the resulting prints.

The Initial Threshold Study for FO Solutions determined an optimized sensitizer solution as having 26% ferric oxalate when optimally coated onto Cranes Parchment paper (CP). Further studies resulted in estimated purity and optimized sensitizer solutions as in the following table. It is currently speculated that a 100% pure FO powder will have an optimal solution strength between 24% and 25%.

FO	estimated purity	optimized solution strength assuming 100% pure
Ultra pure Vizcay powder	98% - 99.5% pure	25%
Artcraft powder*	~ 95% pure	26%
Bostic and Sullivan powder*	89% - 91% pure	27%

*Important Note:

The Artcraft and Bostic and Sullivan powders were from batches made in the 1990s. Current batches of these powders should have their threshold checked by making prints as per the Relative Comparison study.

The study of the Oxalic Acid Concentration in the FO Sensitizer determined a benefit of having Oxalic Acid in the sensitizer solution at a concentration between 2% and 5%.

The Clearing Study resulted in a recommendation for the addition of 0.04% EDTA (CAS: 60-00-4) and about 3% Oxalic Acid to the sensitizer solution to facilitate efficient clearing.

This information has been built into the FO Sensitizer Formula Calculator. Use this calculator or the Quick Formula Table to determine the formula for a FO based sensitizer solution.

Optimized Formulas for Metal Solutions

updated December 2000

Where the optimizations come from is in figuring the ratios of metal to sensitizer needed to balance the process equations. It can be demonstrated (see studies) that too little chemistry will adversely affect print quality and too much chemistry will go unused and be wasted. Also there is much better consistency of performance when interchanging solutions if those solutions are optimized.

To accomplish this balancing, the molar concentration of the sensitizer solution is calculated from the percent value of the solution and the molar mass (formula weight) of the material. With the mass being conserved, using the process equation ratio, the molar mass is calculated for the metal double salt (MDS). From the molar mass of the MDS is calculated the molar concentration, and then the percent of the MDS solution. (For an explanation of molar concentration and percent see Making a Percent Solution.)

The ratios for the process equations have been empirically verified to be 1:1.

The optimum solutions for the metal double salts (MDS) are calculated from the equation:

(% MDS solution)=(fw MDS)/(fw sensitizer)*(ratio)*(% sensitizer solution)

where,
fw = formula weight or molar mass
ratio = (molar mass MDS)/(molar mass sensitizer) from the process equation

NOTE: The molar mass for various chemicals are listed in the section, Formulae.

For the palladium (Pd) double salts, each molar equivalent of Pd MDS is mixed from one molar equivalent of $PdCl_2$ and two molar equivalents of the appropriate alkali-chloride salt (salt). The solution concentrations of $PdCl_2$ and whichever salt are calculated as follows.

(% $PdCl_2$ solution) = 1*(fw $PdCl_2$)/(fw sensitizer)*(ratio)*(% sensitizer solution)

(% salt solution) = 2*(fw salt)/(fw sensitizer)*(ratio)*(% sensitizer solution)

To begin calculations, a sensitizer and it's solution strength are required. Keep in mind that there is a threshold at which point the print has attained its threshold of maximum ability.

Ferric Oxalate (FO) has been traditionally mixed to a solution concentration of about 27%. Higher concentrations of FO may be mixed with the addition of EDTA to the solution as has been suggested by John Melanson and Richard Sullivan. FO solutions as high as 32% have been made with the addition of 4% EDTA(Na4). However, the higher concentrations along with the appropriate metal solutions do not provide for any further improvement in the print; as the threshold has been passed. Working through the Threshold for DOP Solutions Study can determine the concentration at which point prints show no further improvements.

Ammonium Ferric Oxalate (AFO) can readily be mixed to solution strengths of 60% but a threshold is also encountered of the maximum amount of metal that can be placed into the coating such that any additional amount will not result in a noticed benefit to the print. This threshold is also a function of the paper, coating efficiency, and technique. For the Crane's Parchment Business Card Stock (AKA: Cover-90 or CP) this threshold has been found to be the amount produced with a coating mixture based on a 35% solution of AFO as determined by the study Verification of Optimized Formulas (Threshold for POP solutions).

A further consideration is the purity of the FO powder. Adjustments should be made to reflect the accurate amount of FO involved. The FO Sensitizer Formula Calculator considers the purity of various FO powders based on studies identified in the section, Formulas for FO Sensitizer Solutions.

Some of the metal solutions will not stay dissolved at typical laboratory temperature and pressure, so heating of the solutions may be required. An optional half strength solution (which might not require heating) can be calculated and used with the double Quasi Muti-Coating Method.

Notes: Instructions for mixing are included in the section Preparing the Stock Solutions.

Be sure to label all solution bottles with the particular strength sensitizer they are optimized for as well as the name of the solution.

To determine the Sensitizer Solution Formula use the FO Sensitizer Formula Calculator.

To determine the Metal Solution Formula use the Metal Solution Formula Calculator.

Both calculators require a JavaScript capable browser.

Or, use the Quick Formula Table below.

The following Quick Formula Table has been created for some specific situations. Note that the 25% sensitizer solution column should be used for most DOP situations. The FO amounts to weigh out have been adjusted to account for the purity of the FO powder used. The sensitizer solution percent numbers assume 100% pure FO. The studies indicated that a 100% pure FO powder has a threshold sensitizer solution strength of 25%. The 26% and 27% solutions are provided if one wishes stronger solutions with more metal. It is not recommended to use less than a 25% solution strength FO. (Note: Even if the actual threshold is suspected to be between 24% and 25%, the 25% assures being at or past the threshold with the accuracies involved.)

For POP, 35% is the optimum solution strength for AFO.

Quick Formula Table

Sensitizer Solution Strength →		☆ 25% ☆	26%	27%	35%	35%
Material		grams to make 50 ml				
DOP Sensitizer[1]	98% FO powder	12.76	13.27	13.78		
	95% FO powder	13.16	13.68	14.21		
	90% FO powder	13.88	14.44	15.00		
	oxalic acid	1.00	1.00	1.00		
	EDTA CAS: 60-00-4	0.02	0.02	0.02		
Pt	K_2PtCl_4	10.72	11.15	11.58		
Pd[2]	$PdCl_2$	4.58	4.76	4.94		
	$LiCl_2$	2.19	2.28	2.37		
	KCl_2	3.85	4.01	4.16		
	$NaCl_2$	3.02	3.14	3.26		
POP Sensitizer	AFO ammonium ferric oxalate				17.50	half strength solutions[3]
Pt	K_2PtCl_4				16.97	8.49
Pd[2]	$PdCl_2$				7.25	3.63
	$LiCl_2$				3.47	
	KCl_2				6.10	3.05
	$NaCl_2$				4.78	

1) Only one FO is selected.

2) Only one of the salts is mixed with the $PdCl_2$. Li, K and Na salts can only be exchanged if their relative weight ratios are maintained.

3) Solutions which are not completely dissolved at the ambient temperature must be heated in a hot water bath to completely dissolve all material prior to each coating mixing operation. Do not heat the platinum solution above 140°F. An alternative half strength formula (which might not require heating) may be used with the double Quasi Muti-Coating Method.

Making a Percent Solution

A convenient way to express the mixture of a soluble chemical completely dissolved in water is as a percent solution. This is done by weighing out a desired amount of dry chemical and adding water to produce a total given volume.

The following excellent description of solution preparation may be found at the link below.
"Preparation of Solutions for the Clinical Laboratory: A Tutorial"
authored by Kereem M. D. Marlow
http://www.utmem.edu/allied/Solutions/Home.html

Do keep in mind that any material will only dissolve to a certain maximum percentage for a given temperature and pressure. Assuming adequate solubility, the following examples demonstrate how to make a percent solution. (Errors assume using a balance of accuracy 0.01 gram for the solid and a liquid measure accuracy of 0.05 ml.)

example A) To make a 20% solution, weigh 20 grams of soluble solid into a container, then add water to make a total volume of 100 ml.

example B) To make 60 ml of a 10% solution, weigh 6.00 grams of the soluble solid into a container, then water to make a total volume of 60 ml.

Accuracy:
For smaller quantities, it is more accurate to start with a stronger solution and dilute.

example C) To make 30 ml of a 0.5% solution, make a 10% solution, then add 1.50 ml of the 10% solution with 28.50 ml water.

30 ml of a 0.5% solution would require 0.15 grams. Weighed on a scale accurate to 0.01 grams, this would have an error of +-6.67%. In example C, a pipette accurate to .05 ml would produce an error of +-3.33%.

It would be even more accurate to work with larger quantities:

example D) To make 30 ml of a 0.5% solution, make a 10% solution, then make a dilution to 2% and then use that to dilute to 0.5%.

For example D, error to make 100 ml of a 10% solution is +-0.1%; error to then make 100 ml of a 2% solution is +-0.25%; error to then make 30 ml of a 0.5% solution is +-0.67%. Assuming cumulative error, the total error would be +-1.02%.

It is important to always label a bottle as to its contents and the % solution.

Weights and liquid measures and their symbols used in this document:

Liquid (volume) measure	Weight measure
ml = milliliter	g = gram
liter = 1000 ml	
oz = ounce = 30 ml	
gal = gallon = 128 oz	

Weighing Out Dry Chemicals

updated February 2001

General Information
for Coating Solutions
for Developers

General Information:
Dry chemicals must be accurately weighed in order to assure reliable and repeatable results. The accuracy depends of the sensitivity of the process to that particular aspect and the amount being prepared. The two procedures outlined below deal with small amounts (such as coating solutions) and large amounts (such as developers).

A scale capable of measuring .01 grams should be used for coating materials since the quantities are typically in the 1 - 10 gram range. This should allow for a accuracy of 1% or better.

The scale should have the ability to compensate for a large tare (the weight of an empty bottle). A good choice is the Ohaus Centogram balance scale.

Note: If one has a choice of a powder or a crystal, they should consider using the crystal as this will be less likely to get into the air and blow around the room.

PROCEDURE FOR WEIGHING COATING CHEMICALS:

The first time (optional):

- ✓ Balance the scale (empty, zero reading)
- ✓ Weigh the empty dropper bottle (complete with cap and dropper) and record as its weight. This information may be convenient if the weight of the contents needs to be measured later.

In every case:

- ✓ Place a small funnel into the top of a dropper bottle.
- ✓ Set the bottle with funnel onto the scale platform.
- ✓ Balance the scale by adjusting its weights. (This is the tare weight.)
- ✓ Adjust the scale weights to add the weight to be measured minus one gram.
- ✓ Scoop the dry chemical from its container with a CLEAN plastic spatula or spoon .
- ✓ Add the chemical to the bottle until the balance just swings over.
- ✓ Adjust the scale weights to add the one gram left out earlier.
- ✓ Add more chemical slowly until balanced, by tapping the spatula or spoon with a finger.

Notes: Be careful not to not go past the balance point because the chemical should not be returned to the stock bottle from the dropper bottle. If extra is to be removed, treat it as a spill (see below). Also be careful and add slowly, if this is an additional chemical to that already measured. The order of weighing and mixing the stock solutions should be followed as stated in this guide since the chemicals added last are the least likely to cause a problem if a bit too much is added. Return any chemical remaining on the spatula or spoon to its original container.

Most scales give a more accurate measurement when they are moving slightly back and forth around the balance mark.

- ✓ Tap the funnel to make sure all material has been delivered into the bottle.
- ✓ At this point one is ready to add the appropriate amount of another dry chemical or water.

SPILLS:

Do not return or use any chemical that has spilt. It may be contaminated and ruin the entire supply. If a large amount is spilt or valuable material is spilt, it can be placed into a separate storage bottle, labeled, and used to make a solution. This solution should be tested first to see if it works all right, otherwise dispose of properly or recycle to a manufacturer. Do not mix this solution with normal stock solutions.

NOTE: The platinum palladium process is an extremely sensitive process. Any contamination should be avoided.

PROCEDURE FOR WEIGHING DEVELOPER CHEMICALS:

- ✓ Place a cup (plastic or glass) large enough to contain the chemical onto the scale platform.
- ✓ Balance the scale by adjusting its weights. (This is the tare weight.)
- ✓ Adjust the scale weights to add the weight to be measured minus one gram.
- ✓ Scoop the dry chemical from its container with a CLEAN plastic spatula or spoon .
- ✓ Add the chemical to the cup until the balance just swings over.
- ✓ Adjust the scale weights to add the one gram left out earlier.
- ✓ Add more chemical slowly until balanced, by tapping the spatula or spoon on the handle with a finger.
- ✓ At this point one is ready to pour the chemical from the cup into a large mouth bottle and add the appropriate amount of water.

Preparing the Stock Solutions

updated December 2000, note added 8/2001

In order to efficiently coat and process a print, stock solutions are prepared from the bulk materials. The information below indicates the item, the component chemicals (listed in the order mixed), their weights or amount, and a procedure.

Water being of many qualities, the following notations have been chosen for this guide.

Water = Tap water filtered to 0.5 micron
H2O = Distilled Water (by steam distillation)

Note: A convenient way to view the contents of a amber bottle is with a sodium vapor lamp. Hold the bottle in front of the light and the bottle will seem to be clear.

Descriptions of the chemicals can be found in the Chapter 4, Chemicals.

Sensitizer Solutions:

The formula depends on the actual amount of ferric oxalate in the sensitizer powder discussed in the section on Sensitizer Formulas, the amount of Oxalic Acid from the Oxalic Acid Concentration Study, and the amount of EDTA from the Clearing Study.

The resulting formulas may be produced with the Sensitizer Solution Formula Calculator. More information on how an individual sensitizer effects the print can be found in the section Preparing the Coating Solution.

Warning: Dust may be harmful; wear protective mask and clean up any spills.
Sensitizers typically have a pH of 0.1 to 0.3 and may etch the skin of unprotected hands; avoid contact.

NOTE (added 8/2001): Further study of the "bleeding" of metal during processing has indicated that too much EDTA seems the culprit. It is now recommended that EDTA in the sensitizer be kept to a solution strength between 0.04% and 0.1%. The actual amount can vary with different papers, so the smallest amount of EDTA to add to the sensitizer to assist with clearing should be determined for each paper.

Contrast Agents:

A few on the agents are listed here. More information on how individual contrast agents effect the print can be found in the section Preparing the Coating Solution.

Warning: Powder of some contrast agents may present fire hazard; store properly and clean up any spills.

Metal Solutions:

The strength of the metal salt solutions depend on the sensitizer solution used and are to be determined by using the Metal Solution Formula Calculator. Some mixtures may be found in the section on Optimized Formulas. More information on how individual metal salt solutions effect the print can be found in the section Preparing the Coating Solution.

Warning: Dust may be harmful; wear protective mask and clean up any spills.

Developers:

Warning: Dust may be harmful; wear protective mask and clean up any spills.

Clearing Agents:

The agent and times for clearing should be found as necessary to pass the Clearing Test. More information on how individual clearing agents effect the print can be found in the Clearing Study.

Warning: The following acid strengths may etch the skin of unprotected hands; keep immersion time of hands limited and rinse hands in water immediately after immersion.

Solution	Abbreviation	Chemical Component	Amount	Directions to Mix
		SENSITIZER		
DOP Sensitizer	FO	Ferric Oxalate	*****	In Safe Light, Weigh out dry chemicals into bottle, Add H_2O & Shake well every 4 hours, Should be dissolved in 24-36 hours. Do not use until completely dissolved. Do NOT use high heat nor microwave.
		Oxalic Acid	*****	
		EDTA (CAS: 60-00-4)	*****	
		H_2O	*****	
POP Sensitizer	AFO	Ammonium Ferric Oxalate	*****	In Safe Light, Weigh out dry chemicals into bottle, Add H_2O & Shake well, Should sit for 24 hours before using. Do NOT heat nor microwave.
		H_2O	*****	
		CONTRAST AGENTS		
Contrast Agent	PC	Potassium Chlorate	☞	Make 15 ml of each of the solutions: 0.125%, 0.25%, 0.50%, 1.00%, 2.00% with H_2O in 1 oz dropper bottles.
		H_2O	☞	
Contrast Agent <internal control>	PD	Potassium Dichromate	☞	Make a 2.0% solution with H_2O, then Make 15 ml of each of the follow solutions with H_2O in 1 oz dropper bottles: 0.125%, 0.25%, 0.50%, 1.00%, 2.00%
		H_2O	☞	

Contrast Agent <external control>		Potassium Dichromate	☞	Make a 10.0% solution with H_2O, then mix with Potassium Oxalate developer to make these solutions in 32 oz wide mouth bottles: 0.20%, 0.10%, 0.05%, 0.02%, 0.01%
		Potassium Oxalate	☞	
		H_2O	☞	
Contrast Agent	AD	Ammonium Dichromate	☞	Make a 3.0% solution with H_2O, then Make 15 ml of each of the solutions with H_2O in 1 oz dropper bottles: 0.125%, 0.25%, 0.50%, 1.00%, 2.00%, 3.00%
		H_2O	☞	
Contrast Agent		Hydrogen Peroxide (3%)	☞	Dilute as needed immediately before using.
		H_2O	☞	
METAL DOUBLE SALT SOLUTIONS				
Platinum solution	Pt	K_2PtCl_4	*****	Weigh out chemicals into bottle, then add H2O. Heat in a warm water bath (<140oF) and shake.
		H_2O	*****	
Palladium solutions	K, Li, or Na	$PdCl_2$	*****	Weigh out chemicals into bottle, then add H_2O. Heat in a warm water bath (<140ºF) and shake.
		KCl_2, $LiCl_2$, or $NaCl_2$	*****	
		H_2O	*****	
DEVELOPERS				
Developer	PO	Potassium Oxalate	283 g	Warm H_2O in hot water bath, Put warm H_2O into a 32 oz wide mouth bottle, Add the Potassium Oxalate, and stir, Ready to use when fully dissolved.
		H_2O	30 oz	

CLEARING AGENTS				
Clearing Agent		Phosphoric Acid (ACS grade, 85%)	2 oz	Put 3 quarts water into a gallon bottle, Into 32 oz measuring cup put 30 oz water, Add 2 oz acid to water in cup, Add contents of cup to water in gal. bottle.
		water	1 gal.	
Clearing Agent		Muriatic Acid (20% HCl)	3 oz	Put 3 quarts water into a gallon bottle, Into 32 oz measuring cup put 29 oz water, Add 3 oz acid to water in cup, Add contents of cup to water in gal. bottle.
		water	1 gal.	
Clearing Agent		Citric Acid	20 g	Add Citric Acid to water, stir until mixed.
		water	1 litter	
Clearing Agent		EDTA(Na4)	20 g	Add EDTA(Na4) to water, stir until mixed.
		water	1 litter	
Clearing Agent		Sodium Sulfite	20 g	Add Sodium Sulfite to water, stir until mixed.
		water	1 litter	
Clearing Agent		Sprint Fixer Remover	1 part	Mix as per label instructions.
		water	9 parts	
Clearing Agent		Sodium Bisulphate	20 g	Add Sodium Bisulfate to water, stir until mixed.
		water	1 litter	

***** indicates to use data from the calculators or the Quick Formula Table.

Modifying an Existing Solution

created August 1999, updated December 2000

Make Stronger Make Weaker

It is advantageous to be able to modify a solution to a stronger or weaker concentration. The reason for this may be to recycle solutions to updated formulas or to fix incorrectly measured solutions. For a description of solution preparation see Making a Percent Solution.

To make a solution STRONGER:

Example: to modify a 10% solution to be a 12% solution.

✓ Measure the volume of the existing solution.

Example: 50.0 ml

✓ Calculate how much material is present in the solution using the following equation:
(grams in existing solution) = (% of existing solution) * (ml of existing solution)

Example: (5.00 g) = (0.10 g/ml) * (50.0 ml)

Note: The % is expressed as a decimal, such as 10% = 0.10

✓ Calculate how much material to add using the following equation.
(grams to add) =
[(% of desired solution) * (ml of existing solution) * (1.10)] - (grams in existing solution)

Example: (1.60 g) = [(0.12 g/ml) * (50.0 ml) * (1.10)] - (5.00 g)

Note: The 1.10 factor is used to create a larger volume thus compensating for any error caused by any increase in volume due to the material added. This factor should be fine in most instances. If the amount of material added is very substantial then this factor may be increased throughout this procedure. This factor may also be increased to produce a larger volume of the desired solution.

✓ Weigh out material. (see section on Weighing Out Dry Chemicals)

✓ Add material into the solution.

✓ Mix and wait for all material to be completely dissolved (warming if necessary.)

✓ Add H2O to bring the volume to 1.10 times the original volume and mix.

Example: Makes 55.0 ml final 12% solution for the factor of 1.10

The concentration of the solution is now that desired with a volume of 10% more.

To make a solution WEAKER:

Example: to modify a 10% solution to be an 8% solution.

✓ Measure the volume of the existing solution.

Example: 50.0 ml

✓ Calculate how much material is present in the solution using the following equation.
(grams in existing solution) = (% of existing solution) * (ml of existing solution)

Example: (5.00 g) = (0.10 g/ml) * (50.0 ml)

Note: The % is expressed as a decimal, such as 10% = 0.10

✓ Calculate how much H2O to add using the following equation.
(ml H2O to add) =
[(grams in existing solution) / (% of desired solution)] - (ml of existing solution)

Example: (12.5 ml) = [(5.00 g) / (0.08 g/ml)] - (50.0 ml)

Note: Since no solid material is being added, there is no offset in volume.

✓ Measure out the volume of H2O to add.

✓ Add H2O to the solution.

The concentration of the solution is now that desired.