chemical. But for our problem work, it is possible to express any of these "percentages" as fractions, as follows:

(a) $\frac{\text{5 gm. salt}}{\text{100 gm. soln.}}$ (b) $\frac{\text{5 gm. salt}}{\text{100 cc. water}}$ (c) $\frac{\text{5 gm. salt}}{\text{100 cc. soln.}}$

Lithographers often measure liquids, such as nitric or phosphoric acid, by volume instead of by weight. But the chemist is interested in the *weight* of active chemical in that volume. To convert from volume to the weight of active chemical in that volume, one must know two things—the density of the solution, and the percentage by weight of the active chemical in the solution. To solve the problem, "How many grams of nitric acid are there in 1000 cc. of a nitric acid solution?" one must know the density of that solution, and the percentage by weight of nitric acid in the solution. If the density is 1.42 grams per cc., and the solution contains 71% HNO_3 by weight (definition No. 1 of "percentage"), then the problem is worked as follows:

$$(1000\ \cancel{\text{cc. soln.}})\left(\frac{1.42\ \cancel{\text{gm. soln.}}}{1\ \cancel{\text{cc. soln.}}}\right)\left(\frac{71\text{ gm. }HNO_3}{100\ \cancel{\text{gm. soln.}}}\right) = 1008.2\text{ gm. }HNO_3$$

If you wanted to find the weight in *pounds* of HNO_3 (not the solution, but the HNO_3 in it), starting with 32 fl. oz. of the nitric acid solution, then you would operate as follows:

$$(32\ \cancel{\text{fl. oz. soln.}})\left(\frac{29.57\ \cancel{\text{cc.}}}{1\ \cancel{\text{fl. oz.}}}\right)\left(\frac{1.42\ \cancel{\text{gm. soln.}}}{1\ \cancel{\text{cc. soln.}}}\right)\left(\frac{71\ \cancel{\text{gm.}}\ HNO_3}{100\ \cancel{\text{gm. soln.}}}\right)\left(\frac{1\text{ lb.}}{453.6\ \cancel{\text{gm.}}}\right)$$
$$= 2.10\text{ lb. }HNO_3$$

The density conversion factor between the volume and the weight of the solution is based on cubic centimeters; so the fl. oz. must first be converted into the corresponding volume in cubic centimeters. When the weight of nitric acid is first obtained, it is expressed in grams; by the use of the conversion factor 1 lb. = 453.6 gm., the weight can finally be expressed in pounds.

It was necessary in the above problems to distinguish between grams of *solution*, and grams of nitric acid. It is the *solution*, and not the nitric acid in it, which has a density of 1.42 gm. per cc. So the density conversion factor is written $\frac{\text{1.42 gm. soln.}}{\text{1 cc. soln.}}$. The percentage conversion factor is really a fraction for converting from "grams of solution" to "grams of nitric acid" in that weight of solution. Since problems of this type are encountered often, it is possible to write a formula for this calculation. It is:

$$(\text{volume of soln. in cc.})\ (\text{density in gm./cc.})\ \frac{(\text{percentage by wt.})}{100}$$
$$= \text{weight in gm. of active ingredient in that volume.}$$

The reverse type of problem—calculating the volume which must be used to contain a desired weight of active ingredient—may also be expressed by a formula, as follows:

$$\frac{(\text{wt. in gm. of active ingredient})\ (100)}{(\text{percentage by wt.})\ (\text{density in gm./cc.})} = \text{volume of soln. in cc.}$$

Changing a Conversion Factor From One Set of Units to Another. In all of the previous problems we have started the problem with the number which is not a conversion ratio. Then we have multiplied this number by as many conversion ratios as necessary in order to give the answer. In this case the answer is not a conversion ratio.

Occasionally you may want to change a conversion factor from one set of units to another. In this case you must start with this conversion factor after changing it to a conversion ratio. Then you multiply it by the required number of conversion ratios until you obtain the desired units of the answer. A conversion ratio has units both in the numerator and the denominator. It doesn't matter which of these you "change" first since one of the rules of arithmetic is that the order of multiplication and division is unimportant. For example, to solve the problem $\frac{2 \times 4 \times 6}{3 \times 5}$ you can multiply 2 by 4, then multiply the answer by 6, or you can multiply 2 by 6 and then multiply the answer by 4. You can also divide in any order. You can first get the answer of 2 x 4 x 6 and then get the answer of 3 x 5 and then divide the one into the other. Or you can first divide 3 into 6 to get a 2 in the numerator. Then multiply 2 x 4 x 2 and divide this answer by 5.

To illustrate the change of the units of a conversion factor, let's convert a density of 1.4 gm. per ml. into avoir. oz. per gal. This is done as follows:

$$\left(\frac{1.4\ \cancel{\text{gm.}}}{1\ \cancel{\text{ml.}}}\right)\left(\frac{1\text{ avoir. oz.}}{28.35\ \cancel{\text{gm.}}}\right)\left(\frac{3{,}785\ \cancel{\text{ml.}}}{1\text{ gal.}}\right) = \frac{186.9\text{ avoir. oz.}}{\text{gal.}}$$

or the new units are 186.9 avoir. oz. per gal.

Summary

You can see that the proper use of the "units method" can be very helpful in working even complex problems and avoiding mistakes in the method of calculation. But to do this you must write down the correct units of each number and cancel them out between the numerator and the denominator all the way down the line.

One of the beauties of the "units method" is that it is not necessary to get intermediate answers. You start with the number which