Percentage

The term percent and its corresponding sign (%) mean ‘‘by the hundred’’ or ‘‘in a hundred,’’ and percentage means ‘‘rate per hundred’’; so 50 percent (or 50%) and a percentage of 50 are equivalent expressions.

A percent may also be expressed as a ratio, represented as a common or decimal fraction. For example, 50% means 50 parts in 100 of the same kind, and may be expressed as 50⁄100 or 0.50.

Percentage is an essential part of pharmaceutical calculations. The pharmacist encounters it frequently and uses it as a convenient means of expressing the concentration of an active or inactive material in a pharmaceutical preparation.

Percentage preparation

The percentage concentrations of active and inactive constituents in various types of pharmaceutical preparations are defined as follows by the United States Pharmacopeia:

- Percent weight-in-volume (w/v) expresses the number of grams of a constituent in 100 mL of solution or liquid preparation and is used regardless of whether water or another liquid is the solvent or vehicle. Expressed as: % w/v.
- Percent volume-in-volume (v/v) expresses the number of milliliters of a constituent in 100 mL of solution or liquid preparation. Expressed as: % v/v.
- Percent weight-in-weight (w/w) expresses the number of grams of a constituent in 100 g of solution or preparation. Expressed as: % w/w.

The term percent, or the symbol %, when used without qualification means:

• for solutions or suspensions of solids in liquids, percent weight-in-volume;

• for solutions of liquids in liquids, percent volume-in-volume;

• for mixtures of solids or semisolids, percent weight-in-weight; and

• for solutions of gases in liquids, percent weight-in-volume.

Special consideration in percentage calculation

In most instances, use of percentage concentrations in the manufacture and labeling of pharmaceutical preparations is restricted to instances in which the dose of the active therapeutic ingredient (ATI) is not specific.

For example, the ATIs in ointments, lotions, external solutions, and similar products may commonly be expressed in percent strength (e.g., a 1% hydrocortisone ointment).

However, in most dosage forms, such as tablets, capsules, injections, oral solutions, and syrups, among others, the amounts of ATIs are expressed in definitive units of measure, such as milligrams per capsule, milligrams per milliliter, or other terms.

TABLE 6.1 EXAMPLES OF PHARMACEUTICAL DOSAGE FORMS IN WHICH THE ACTIVE INGREDIENT IS OFTEN CALCULATED AND EXPRESSED ON A PERCENTAGE BASIS

PERCENTAGE BASIS	EXAMPLES OF APPLICABLE DOSAGE FORMS
Weight-in-volume	Solutions (e.g., ophthalmic, nasal, otic, topical, large-volume parenterals), and lotions
Volume-in-volume	Aromatic waters, topical solutions, and emulsions
Weight-in-weight	Ointments, creams, and gels

Specific gravity may be a factor in a number of calculations involving percentage concentration. Many formulations are presented on the basis of weight, even though some of the ingredients are liquids.

Depending on the desired method of measurement, it may be necessary to convert weight to liquid or, in some instances, vice versa.

Thus, we should recall the equations from the previous chapter, namely:

$$g = mL \times sp\ gr$$

$$mL = \frac{g}{sp\ gr}$$

Percentage weight in volume

In a true expression of percentage (i.e., parts per 100 parts), the percentage of a liquid preparation (e.g., solution, suspension, lotion) would represent the grams of solute or constituent in 100 g of the liquid preparation.

Indeed, in weight-in-volume expressions, the ‘‘correct’’ strength of a 1% (w/v) solution or other liquid preparation is defined as containing 1 g of constituent in 100 mL of product.

This is based on an assumption that the solution/liquid preparation has a specific gravity of 1, as if it were water. So each 100 mL of solution/liquid preparation is presumed to weigh 100 g and thus is used as the basis for calculating percentage weight-in-volume (e.g., 1% w/v = 1% of [100 mL taken to be] 100 g = 1 g in 100 mL). We may prepare weight-in-volume percentage solutions or liquid preparations by the SI metric system if we use the following rule.

Volume (mL, representing grams) * % (expressed as a decimal) = grams (g) of solute or constituent

Examples of Weight-in-Volume Calculations

How many grams of dextrose are required to prepare 4000 mL of a 5% solution?

4000 mL represents 4000 g of solution
5% = 0.05
4000 g × 0.05 = 200 g, *answer.*

Or, solving by dimensional analysis:

$$\frac{5\ \text{g}}{100\ \text{mL}} \times 4000\ \text{mL} = 200\ \text{g, } \textit{answer.}$$

How many grams of potassium permanganate should be used in compounding the following prescription?

℞	Potassium Permanganate	0.02%
	Purified Water ad	250 mL
	Sig. as directed.	

250 mL represents 250 g of solution
0.02% = 0.0002
250 g × 0.0002 = 0.05 g, *answer.*

How many grams of aminobenzoic acid should be used in preparing 8 fluidounces of a 5% solution in 70% alcohol?

8 fl. oz. = 8 × 29.57 mL = 236.56 mL
236.56 mL represents 236.56 g of solution
5% = 0.05
236.56 g × 0.05 = 11.83 g, *answer.*

What is the percentage strength (w/v) of a solution of urea, if 80 mL contains 12 g?

80 mL of water weighs 80 g

$$\frac{80\ (\text{g})}{12\ (\text{g})} = \frac{100\ (\%)}{x\ (\%)}$$

$$x = 15\%, \textit{ answer.}$$

How many milliliters of a 3% solution can be made from 27 g of ephedrine sulfate?

$$\frac{3\ (\%)}{100\ (\%)} = \frac{27\ (\text{g})}{x\ (\text{g})}$$

x = 900 g, weight of the solution if it were water
Volume (in mL) = 900 mL, *answer.*

Percentage volume in volume

Liquids are usually measured by volume, and the percentage strength indicates the number of parts by volume of an ingredient contained in the total volume of the solution or liquid preparation considered as 100 parts by volume.

Examples of Volume-in-Volume Calculations

How many milliliters of liquefied phenol should be used in compounding the following prescription?

℞	Liquefied Phenol	2.5%
	Calamine Lotion ad	240 mL
	Sig. For external use.	

Volume (mL) × % (expressed as a decimal) = milliliters of active ingredient

240 mL × 0.025 = 6 mL, *answer.*

Or, solving by dimensional analysis:

$$\frac{2.5 \text{ mL}}{100 \text{ mL}} \times 240 \text{ mL} = 6 \text{ mL, } \textit{answer.}$$

In preparing 250 mL of a certain lotion, a pharmacist used 4 mL of liquefied phenol. What was the percentage (v/v) of liquefied phenol in the lotion?

$$\frac{250 \text{ (mL)}}{4 \text{ (mL)}} = \frac{100 \text{ (\%)}}{x \text{ (\%)}}$$

$$x = 1.6\%, \textit{ answer.}$$

What is the percentage strength v/v of a solution of 800 g of a liquid with a specific gravity of 0.800 in enough water to make 4000 mL?

800 g of water measures 800 mL

800 mL ÷ 0.800 = 1000 mL of active ingredient

$$\frac{4000 \text{ (mL)}}{1000 \text{ (mL)}} = \frac{100 \text{ (\%)}}{x \text{ (\%)}}$$

$$x = 25\%, \textit{ answer.}$$

Peppermint spirit contains 10% v/v of peppermint oil. What volume of the spirit will contain 75 mL of peppermint oil?

$$\frac{10\ (\%)}{100\ (\%)} = \frac{75\ (\text{mL})}{x\ (\text{mL})}$$

$$x = 750\ \text{mL},\ \textit{answer.}$$

If a veterinary liniment contains 30% v/v of dimethyl sulfoxide, how many milliliters of the liniment can be prepared from 1 lb of dimethyl sulfoxide (sp gr 1.10)?

1 lb = 454 g
454 g of water measures 454 mL
454 mL ÷ 1.10 = 412.7 mL of dimethyl sulfoxide

$$\frac{30\ (\%)}{100\ (\%)} = \frac{412.7\ (\text{mL})}{x\ (\text{mL})}$$

$$x = 1375.7 \text{ or } 1376\ \text{mL},\ \textit{answer.}$$

Percentage weight in weight

Percentage weight-in-weight (true percentage or percentage by weight) indicates the number of parts by weight of active ingredient contained in the total weight of the solution or mixture considered as 100 parts by weight.

Examples of Weight-in-Weight Calculations

How many grams of phenol should be used to prepare 240 g of a 5% (w/w) solution in water?

Weight of solution (g) × % (expressed as a decimal) = g of solute

240 g × 0.05 = 12 g, *answer.*

How many grams of a drug substance are required to make 120 mL of a 20% (w/w) solution having a specific gravity of 1.15?

120 mL of water weighs 120 g
$120 \text{ g} \times 1.15 = 138 \text{ g}$, weight of 120 mL of solution
$138 \text{ g} \times 0.20 = 27.6 \text{ g}$ plus enough water to make 120 mL, *answer.*

Or, solving by dimensional analysis:

$$120 \text{ mL} \times \frac{1.15 \text{ g}}{1 \text{ mL}} \times \frac{20\%}{100\%} = 27.6 \text{ g, } \textit{answer.}$$

Sometimes in a weight-in-weight calculation, the weight of one component is known but *not* the total weight of the intended preparation. This type of calculation is performed as demonstrated by the following example.

How many grams of a drug substance should be added to 240 mL of water to make a 4% (w/w) solution?

$100\% - 4\% = 96\%$ (by weight) of water
240 mL of water weighs 240 g

$$\frac{96\ (\%)}{4\ (\%)} = \frac{240\ (\text{g})}{\text{x}\ (\text{g})}$$

$$\text{x} = 10 \text{ g, } \textit{answer.}$$

If 1500 g of a solution contains 75 g of a drug substance, what is the percentage strength (w/w) of the solution?

$$\frac{1500\ (\text{g})}{75\ (\text{g})} = \frac{100\ (\%)}{\text{x}\ (\%)}$$

$$\text{x} = 5\%, \textit{ answer.}$$

If 1000 mL of syrup with a specific gravity of 1.313 contains 850 g of sucrose, what is its percentage strength (w/w)?

1000 mL of water weighs 1000 g
1000 g × 1.313 = 1313 g, weight of 1000 mL of syrup

$$\frac{1313\ (g)}{850\ (g)} = \frac{100\ (\%)}{x\ (\%)}$$

x = 64.7%, *answer.*

Percentage Concentration

The amounts of therapeutically active and/or inactive ingredients in certain types of pharmaceutical preparations are expressed in terms of their percentage concentrations.

Unless otherwise indicated:

(a) Liquid components in liquid preparations have *volume-in-volume* relationships with calculations following the equation:

mL of preparation × % concentration[a] = mL of component

(b) Solid components in liquid preparations have *weight-in-volume* relationships with calculations following the equation:

mL of preparation × % concentration[a] = g of component

The terms of this equation are valid due to the assumption that the specific gravity of the preparation is 1, as if it were water, and thus each milliliter represents the weight of one gram.

(c) Solid or semisolid components in solid or semisolid preparations have *weight-in-weight* relationships with calculations following the equation:

g of preparation × % concentration[a] = g of component

[a] In these equations, "% concentration" is expressed decimally (e.g., 0.05, *not* 5%).

Ratio strength

The concentrations of weak solutions are frequently expressed in terms of ratio strength.

Because all percentages are a ratio of parts per hundred, ratio strength is just another way of expressing the percentage strength of solutions or liquid preparations (and, less frequently, of mixtures of solids).

For example, 5% means 5 parts per 100 or 5:100. Although 5 parts per 100 designates a ratio strength, it is customary to translate this designation into a ratio, the first figure of which is 1; thus, 5:100 = 1:20.

When a ratio strength, for example, 1:1000, is used to designate a concentration, it is to be interpreted as follows:

• For solids in liquids = 1 g of solute or constituent in 1000 mL of solution or liquid preparation.

• For liquids in liquids = 1 mL of constituent in 1000 mL of solution or liquid preparation.

• For solids in solids = 1 g of constituent in 1000 g of mixture.

The ratio and percentage strengths of any solution or mixture of solids are proportional, and either is easily converted to the other by the use of proportion.

Example Calculations Using Ratio Strength

Express 0.02% as a ratio strength.

$$\frac{0.02\ (\%)}{100\ (\%)} = \frac{1\ (\text{part})}{x\ (\text{parts})}$$

$$x = 5000$$

$$\text{Ratio strength} = 1{:}5000, \textit{ answer.}$$

Express 1:4000 as a percentage strength.

$$\frac{4000\ (\text{parts})}{1\ (\text{part})} = \frac{100\ (\%)}{x\ (\%)}$$

$$x = 0.025\%, \textit{ answer.}$$

Note: To change ratio strength to percentage strength, it is sometimes convenient to "convert" the last two zeros in a ratio strength to a percent sign (%) and change the remaining ratio first to a common fraction and then to a decimal fraction in expressing percent:

$$1:100 = \tfrac{1}{1}\% = 1\%$$
$$1:200 = \tfrac{1}{2}\% = 0.5\%$$
$$3:500 = \tfrac{3}{5}\% = 0.6\%$$
$$1:2500 = \tfrac{1}{25}\% = 0.04\%$$
$$1:10{,}000 = \tfrac{1}{100}\% = 0.01\%$$

A certain injectable contains 2 mg of a drug per milliliter of solution. What is the ratio strength (w/v) of the solution?

$$2 \text{ mg} = 0.002 \text{ g}$$

$$\frac{0.002 \text{ (g)}}{1 \text{ (g)}} = \frac{1 \text{ (mL)}}{x \text{ (mL)}}$$

$$x = 500 \text{ mL}$$

Ratio strength = 1:500, *answer.*

What is the ratio strength (w/v) of a solution made by dissolving five tablets, each containing 2.25 g of sodium chloride, in enough water to make 1800 mL?

$$2.25 \text{ g} \times 5 = 11.25 \text{ g of sodium chloride}$$

$$\frac{11.25 \text{ (g)}}{1 \text{ (g)}} = \frac{1800 \text{ (mL)}}{x \text{ (mL)}}$$

$$x = 160 \text{ mL}$$

Ratio strength = 1:160, *answer.*

In solving problems in which the calculations are based on ratio strength, it is sometimes convenient to translate the problem into one based on percentage strength and to solve it according to the rules and methods discussed under percentage preparations.

How many grams of potassium permanganate should be used in preparing 500 mL of a 1:2500 solution?

$$1:2500 = 0.04\%$$
$$500 \text{ (g)} \times 0.0004 = 0.2 \text{ g, answer.}$$

Or,

1:2500 means 1 g in 2500 mL of solution

$$\frac{2500 \text{ (mL)}}{500 \text{ (mL)}} = \frac{1 \text{ (g)}}{x \text{ (g)}}$$

$$x = 0.2 \text{ g, answer.}$$

How many milligrams of gentian violet should be used in preparing the following solution?

℞	Gentian Violet Solution 1:10,000	500 mL
	Sig. Instill as directed.	

$$1:10{,}000 = 0.01\%$$
$$500\ (g) \times 0.0001 = 0.050\ g \text{ or } 50\ mg, \textit{ answer.}$$

Or,
1:10,000 means 1 g of 10,000 mL of solution

$$\frac{10{,}000\ (mL)}{500\ (mL)} = \frac{1\ (g)}{x\ (g)}$$
$$x = 0.050\ g \text{ or } 50\ mg, \textit{ answer.}$$

In using a ratio strength in a calculations problem, there are two options: (a) convert it to a percentage strength and perform calculations in the usual manner, or (2) use the ratio strength directly in a problem-solving proportion.

(a) To convert a ratio strength to a percentage strength; for example, 1:10,000 w/v:

$$\frac{1\ g}{10{,}000\ mL} = \frac{x\ (g)}{100\ mL}$$

Solving for x yields percent, by definition (parts per hundred).

(b) Problem-solving proportion, for example:

$$\frac{1\ g}{10{,}000\ mL} = \frac{x\ g}{(\text{given quality, mL});}; x = g \text{ in given mL}$$

Simple conversions of concentration to mg/ml

Occasionally, pharmacists, particularly those practicing in patient care settings, need to convert rapidly product concentrations expressed as percentage strength, ratio strength, or as grams per liter (as in IV infusions) to milligrams per milliliter (mg/mL).

These conversions may be made quickly by using simple techniques. Some suggestions follow.

To convert *product percentage strengths to mg/mL*, multiply the percentage strength, expressed as a whole number, by 10.

Example:

Convert 4% (w/v) to mg/mL.

4×10	= 40 mg/mL, *answer.*
Proof or alternate method: 4% (w/v)	= 4 g/100 mL
	= 4000 mg/100 mL
	= 40 mg/mL

To convert *product ratio strengths to mg/mL*, divide the ratio strength by 1000.

Example:

Convert 1:10,000 (w/v) to mg/mL.

$10{,}000 \div 1000$	= 1 mg/10 mL, *answer.*
Proof or alternate method: 1:10,000 (w/v)	= 1 g/10,000 mL
	= 1000 mg/10,000 mL
	= 1 mg/10 mL

Example:

Convert a product concentration of 1 g per 250 mL to mg/mL.

$1000 \div 250$	= 4 mg/mL, *answer.*
Proof or alternate method: 1 g/250 mL	= 1000 mg/250 mL = 4 mg/mL

Parts per million (PPM) and parts per billion (PPB)

The strengths of very dilute solutions are commonly expressed in terms of parts per million (ppm) or parts per billion (ppb), i.e., the number of parts of the agent per 1 million or 1 billion parts of the whole. For example, we are all familiar with fluoridated drinking water in which fluoride has been added at levels of between 1 to 4 parts per million (1:1,000,000 to 4:1,000,000) for the purpose of reducing dental caries.

Also the presence of trace amounts of contaminants in our drinking water and food which can pose a risk to our health and safety.

Among the concerns are the levels of contaminants found in sources of drinking water and how those levels compare with the standards set by the United States Environmental Protection Agency (EPA). The EPA has established maximum contaminant levels (MCLs) which quantify the highest level of a contaminant that is allowed in drinking water below which there is no known or expected risk to a person's health or safety.

Such levels are established for copper, lead, fluoride, chlorine, total organic compounds, and other trace constituents. These levels generally are expressed either in parts per million or parts per billion.

Example Calculations of Parts per Million and Parts per Billion

Express 5 ppm of iron in water in percentage strength and ratio strength.

5 ppm = 5 parts in 1,000,000 parts = 1:200,000, ratio strength, *and*
= 0.0005%, percentage strength, *answers.*

The concentration of a drug additive in an animal feed is 12.5 ppm. How many milligrams of the drug should be used in preparing 5.2 kg of feed?

12.5 ppm = 12.5 g (drug) in 1,000,000 g (feed)

Thus,

$$\frac{1{,}000{,}000 \text{ g}}{12.5 \text{ g}} = \frac{5{,}200 \text{ g}}{\text{x g}}$$

$$\text{x} = 0.065 \text{ g} = 65 \text{ mg, } \textit{answer.}$$

The drinking water in a community has detected lead in its drinking water at a level of 2.5 ppb. The EPA's MCL is set at 15 ppb. Express the difference between these two values as a ratio strength.

15 ppb − 2.5 ppb = 12.5 ppb = 12.5:1,000,000,000 = 1:80,000,000, *answer.*