

TREATMENT PLANT OPERATOR TRAINEE
Examination Study Guide



These tables will be made available to examinees when taking the math section of the test.

Unit Conversions

Length

1 inch (in.) = 2.54 centimeters (cm)
10 millimeters (mm) = 1 centimeter (cm)
100 centimeters (cm) = 1 meter (m)
1 meter (m) = 3.28 feet (ft.)
1 mile (mi.) = 5,280 feet (ft.)

Volume

1 cubic meter (m³) = 35.31 cubic feet (ft³)
1 cubic foot (1 ft³) = 7.48 gallons (gal)
1 gallon (gal.) = 3.785 liters (L)
1 cubic centimeter (cm³) = 1 milliliter (mL)
1 liter (L) = 1,000 milliliters (mL)
1,000 cubic centimeters (cm³) = 1 liter (L)
1.75 pint (pt.) = 1 liter (L)

Weight

1 gallon (gal) of water = 8.34 pounds (lbs.)
1 kilogram (kg) = 2.2 pounds (lbs.)
1 gram (g) = 1,000 milligrams (mg)
1 kilogram (kg) = 1,000 grams (g)

Concentration

1 milligram per liter (mg/L) = 1,000 micrograms per liter (µg/L)
1 milligram per liter (mg/L) = 1 part per million (ppm)
1 microgram per liter (µg/L) = 1 part per billion (ppb)
1 percent (%) solution = 10,000 milligrams per liter (mg/L)

Equations

Volume of a cylinder = $.785 \times \text{Diameter}^2 \times \text{Height}$
Feed Rate (lbs./day) = Dosage (mg/L) \times Flow rate (mgd) \times 8.34
Chlorine Dosage (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)
Concentration₁ \times Volume₁ = Concentration₂ \times Volume₂
Concentration₁ \times Volume₁ + Concentration₂ \times Volume₂ = Concentration₃ (Volume₁ + Volume₂)

Study Guide for Treatment Plant Operator Trainee

As you will need to study on the job, it is necessary to test your ability to study and perform on a test. This study guide was constructed to help measure your ability to study and then apply the information and pass a test. As such, it is highly recommended that you study this document and become familiar with all the calculations and vocabulary terms presented here.

Mathematics for Treatment Plant Operator Trainees

One of the essential requirements of this job is “Knowledge of mathematics to include addition, subtraction, multiplication, division, algebra, and geometry to include calculation of averages, volume, and area.” This guide assumes that you already know how to add, subtract, multiply, and divide. If you come across a term that you do not understand, you should find a mathematics reference text or use other resources (such as an online search tool) to learn about the term before taking the test. Furthermore, a large part of the job of a Treatment Plant Operator Trainee is to study and learn the chemistry and mathematics needed to pass a certification exam for Treatment Plant Operators. After studying this part of the guide, you should be able to do the following:

- Volume
 - Calculate the volume of a cylinder given its height and diameter
- Conversions
 - Convert values from one unit into another unit using algebra
 - Convert values from one unit into another unit using a shortcut method.
 - Convert values from one unit into another unit using dimensional analysis
- Feed Rate
 - Calculate the feed rate of a chemical if given the effective dosage and the flow rate
 - Calculate the flow rate if given the feed rate and effective dosage of a chemical
 - Calculate the effective dosage of a chemical if given the feed rate and flow rate
- Dosage
 - Calculate the chlorine dosage if given the chlorine demand and chlorine residual
 - Calculate the chlorine demand if given the chlorine dosage and chlorine residual
 - Calculate the chlorine residual if given the chlorine dosage and chlorine demand
- Solutions
 - Calculate starting volume if given starting concentration, ending concentration, and ending volume
 - Calculate ending concentration if given starting concentration, starting volume, and ending volume
 - Calculate ending volume if given starting concentration, starting volume, and ending concentration
 - Calculate starting concentration if given starting volume, ending concentration and ending volume.
 - Calculate the final concentration of a mixture of two solutions given their respective concentrations and volumes.

It is important to note that many questions will require you to do more than one of the above calculations in order to come to the correct answer.

Volume

Treatment Plant Operators work with water and other fluids and their work requires them to know how to calculate how much water or other fluids they are working with. Particularly important are cylinders, as many pipes, tanks, and other vessels used to hold water and other fluids are cylinders.

For Example: An operator needs to know how many gallons of water are in a full tank of water. He knows the height and diameter of the tank in feet and he can look up the equation for the volume of a cylinder, which is:

$$\text{Volume} = .785 \times (\text{Diameter})^2 \times \text{Height}$$

So if the Tank is 20 feet tall and has a 5-foot radius, how many gallons can it hold? Remember that diameter is $2 \times$ radius, so a 5-foot radius is 10ft diameter.

$$\text{Volume} = .785 \times (10\text{ft})^2 \times 20\text{ft}$$

According to the order of operations for mathematics, we know to solve the exponent first because there is nothing in parentheses to solve that would come first, remember the order of operations is Parentheses, Exponents, Multiplication and Division, Addition and Subtraction. A useful mnemonic device to help you remember this is Please Excuse My Dear Aunt Sally (PEMDAS).

When working with units, you treat units like variables in algebra.

For example: $(10\text{ft.})^2$ must be treated the same as $(10x)^2$

With this in mind, we know we must use the distributive law of multiplication and division (a.k.a. the distributive property) to square both items inside the parentheses:

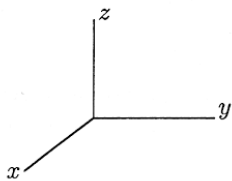
$$(10x)^2 = (10)^2 (x)^2 = 100 x^2$$

$$(10\text{ft})^2 = (10)^2 (\text{ft.})^2 = 100 \text{ft}^2 \text{ or one hundred square feet}$$

Then we put that term back into the equation

$$\text{Volume} = .785 \times 100 \text{ft}^2 \times 20 \text{ft.}$$

Remember, volume is calculated in three dimensions.



If we measure 1 foot in each dimension we get $1 \text{ft.} \times 1 \text{ft.} \times 1 \text{ft.}$

Remember that when multiplying variables with the same base (x , or in this case “ft.”) you add the exponents together, and that no exponent is the same as “to the power of one” i.e., x is the same as x^1

$$\text{For example } 1y \times 1y^2 \times 1y^3 = 1y^{1+2+3} = 1y^6$$

In this case, we are multiplying square feet by feet, $(\text{ft.}^2 \times \text{ft.}^1)$ which results in ft.^3 or cubic feet $(\text{ft.}^{2+1} = \text{ft}^3)$

$$.785 \times 100 \text{ft.}^2 \times 20 \text{ft.}, = 1,570 \text{ft.}^3$$

There are 1,570 cubic feet of water in the tank. However, the question asked for *gallons*!

Conversions

Treatment plant operators need to know how to convert one unit into another because they are often given problems expressed in one unit that must be solved using another unit. Remember that a unit is a definite magnitude of a quantity, defined and adopted by convention or by law, which is used as a standard for measurement of the same kind of quantity. Any other quantity of that kind can be expressed as a multiple of the unit. For Example: pound (lbs.), foot (ft.), inch (in.), gallon (gal.), liter (L), and gram (g). They are also asked to express answers in specific units of measurement that may not match the units used to solve the problem.

Take the previous example that was not completely solved. Because the units in the equation do not match the units asked for in the question, we have to convert the answer from cubic feet to gallons. Looking at the Unit Conversion Chart on the first page of this study guide, we can see that 1 cubic foot is equal to 7.48 gallons. If 1 cubic foot of water is 7.48 gallons, how many gallons are in 1,570 cubic feet of water?

Using algebra, we can treat the units like variables. For the moment, let us call cubic feet “x” and call gallons “y”.

We know that $1x = 7.48y$

If we have 1,570 x that means we multiplied the left side of the equation by 1,570

We know that in Algebra, whatever happens to the left side of the equation must happen to the right, so we have to multiply the right side of the equation by the same number

$$(1,570) \times (1x) = (7.48y) \times (1,570)$$

If we put “cubic feet of water” back in for “x” and “gallons” back in for “y” we can see that:

If there are 1,570 cubic feet of water, there are $1,570 \times 7.48$ gallons of water

$$1,570 \times 7.48 = 11,743.6 \text{ gallons of water}$$

The tank holds 11,743.6 gallons of water

Let us say you had a tank that could hold 8,345 gallons of water in it. How much water is that in cubic feet?

$$1 \text{ ft}^3 = 7.48 \text{ gal}$$

Can we just multiply as we did before?

$$(8,345) \times (1\text{ft}^3) = 7.48 \text{ gal} \times (8,345)$$

$$8,345 \text{ ft}^3 = 7.48 \text{ gal} \times (8,345) = 62,420.6$$

Now we have 8,345 cubic feet in 62,420.6 gallons. That is not the amount of gallons we were given though, so this is not helpful. Before changing the equation, we need to make sure that the side we are changing with our initial value is alone. Remember that in algebra you can remove a term from one side of an equation by transposing it. In order to do this to terms that are being multiplied you multiply by its reciprocal (a.k.a. dividing by that number). In other words, when you take something that is being multiplied or divided from one side of the equation and put in on the other it goes from top to bottom, or if it starts on the bottom it ends up on top.

For example:

$$(F) = (M) \times (A)$$

If we want to get “A” by itself we simple move “M” to the left side by dividing both sides by “M”

$$\frac{(F)}{(M)} = \frac{(M) \times (A)}{(M)}$$

Because $\frac{(M)}{(M)} = 1$ the “M”s on the right side of the equation cancel each other out

$$\frac{(F)}{(M)} = \frac{\cancel{(M)} \times (A)}{\cancel{(M)}}$$

This leaves us with: $\frac{(F)}{(M)} = (A)$

So if we have $1\text{ft}^3 = 7.48 \text{ gal}$. and we want to get 1 gal alone on the right side all we need to do is divide both sides by 7.48

$$\frac{1\text{ft}^3}{7.48} = \frac{7.48 \text{ gal}}{7.48} \rightarrow \frac{1\text{ft}^3}{7.48} = \frac{7.48 \text{ gal}}{7.48} \rightarrow \frac{1\text{ft}^3}{7.48} = \text{gal}$$

Now that we have gallons by itself, we can simply multiply that (and thus the other side) by the number of gallons we have

$$(8,345) \times \frac{1\text{ft}^3}{7.48} = \text{gal} \times (8,345)$$

Which is the same as:

$$\frac{8,345 \text{ ft}^3}{7.48} = 8,345 \text{ gal}$$

$$8,345 \text{ ft}^3 \div 7.48 = 1,115.64 \text{ ft}^3$$

Therefore 8,345 gallons = 1,115.64 cubic feet. There are 1,115.64 cubic feet in 8,345 gallons of water.

This is easy enough for simple conversions, but Treatment Plant Operators often need to make several conversions in a row in order to make sense of a problem.

Let us say that you have 45 cubic feet of water and you are asked how many grams it weighs. How would you make this conversion?

If we look at the Unit Conversions table, we can see that:

$$1 \text{ ft}^3 = 7.48 \text{ gal} \quad 1 \text{ gal} = 8.34 \text{ lbs.} \quad 2.2 \text{ lbs.} = 1 \text{ kg} \quad 1 \text{ kg} = 1000 \text{ g}$$

Using Algebra to solve:

First, we choose a unit conversion based on the information that we have, and the information that we need:

We know how many cubic feet we have and we know that we eventually need to get to grams, which is a unit of weight. The only volume conversion we have that goes from volume to weight is gallons to pounds so we know that we need to get to gallons.

First, cubic feet (what we have) to gallons (a step closer to what we need):

$$(1 \text{ ft}^3) = (7.48 \text{ gal.})$$

We have 45 cubic feet of water, so we have to multiply the left side by 45, and then we have to multiply the right by the same.

$$(45) \times (1 \text{ ft}^3) = (7.48 \text{ gal}) \times (45)$$

$$7.48 \text{ gal.} \times 45 = 336.6 \text{ gal.}$$

Now we know we have 336.6 gallons of water. Now we choose a unit conversion based on the information that we have, and the information that we need, namely a unit conversion that brings us closer to grams from gal. We need our gallon to weight conversion.

$$1 \text{ gal. (of water)} = 8.34 \text{ lbs.}$$

Since we have 336.6 gallons of water we need to multiply the left side by 336.6, and then we need to multiply the right by the same.

$$(336.6) \times (1 \text{ gal}) = (8.34 \text{ lbs.}) \times (336.6)$$

$$8.34 \text{ lbs.} \times 336.6 = 2,807.24 \text{ lbs.}$$

We know we have 2,807.24 lbs., but the next equation starts with 2.2 lbs. Before we multiply the left side of the equation by 2,807.24, we need to get pounds by itself so that when we multiply by 2,807.24 we get the right number of pounds.

$$(2.2 \text{ lbs.}) = 1 \text{ kg}$$

Divide both sides by 2.2 in order to get pounds by itself.

$$\frac{2.2 \text{ lbs.}}{2.2} = \frac{1 \text{ kg}}{2.2}$$

The 2.2 on the top of the left side of the equation cancels out the 2.2 on the bottom of the left side of the equation.

$$\frac{\cancel{2.2} \text{ lbs.}}{\cancel{2.2}} = \frac{1 \text{ kg}}{2.2}$$

$$2.2 \div 2.2 = 1$$

$$1 \text{ lbs.} = \frac{1 \text{ kg}}{2.2}$$

Moving on with our algebraic conversions, we know we have 2,807.24 lbs. Therefore, we multiply both sides by 2,807.24

$$2,807.24 \times 1 \text{ lbs.} = \frac{1 \text{ kg}}{2.2} \times 2,807.24$$

$$2,807.24 \text{ lbs.} = \frac{2,807.24 \text{ kg}}{2.2}$$

$$2,807.24 \text{ kg} \div 2.2 = 1,276.02 \text{ kg}$$

This means that we have 1,276.02 kilograms. This still is not the information we were asked for, so we need a conversion factor between kilograms and grams.

$$1 \text{ kg} = 1000 \text{ g}$$

Since we have 1,276.02 kilograms of water we need to multiply the left side by 1,276.02, and then we have to multiply the right by the same.

$$(1,276.02) \times (1 \text{ kg}) = (1000 \text{ g}) \times (1,276.02)$$

$$1000 \text{ g} \times 1,276.02 = 1,276,020 \text{ g}$$

Therefore:

$$45 \text{ cubic feet} = 336.6 \text{ gal.}$$

$$336.6 \text{ gal.} = 2,807.24 \text{ lbs.}$$

$$2,807.24 \text{ lbs.} = 1,276.02 \text{ kg}$$

$$1,276.02 \text{ kg} = 1,276,020 \text{ g}$$

Therefore:

$$45 \text{ cubic feet} = 336.6 \text{ gal} = 2,807.24 \text{ lbs.} = 1,276.02 \text{ kg} = 1,276,020 \text{ g}$$

Therefore: 45 cubic feet = 1,276,020 g. This gives us our answer, 45 cubic feet of water weighs 1,276,020 grams.

For simple conversions, here is a helpful shortcut. If you are going from a bigger unit to a smaller unit (Feet to Inches), you know you have to multiply by the factor given in the unit conversion chart because you know you have to have more inches to cover the same amount of feet (1 foot = 12 inches). If you are going from a smaller unit to a bigger unit (Feet to Miles), you know you must divide because you need fewer of the larger unit to describe the same distance (1 mile = 5,280 feet).

Using shortcuts to solve the same problem:

We start with 35 ft³ and we need to convert it to gallons. We can see from the unit conversion table that there are 7.48 gallons in 1 ft³ of water. So which unit is bigger? Counterintuitively, the unit in the equation with the smaller number must be the larger unit because it takes more of the smaller unit to equal the same amount of whatever we are working with. Since it takes 7.48 gallons to equal 1 ft³, the ft³ is the larger unit. This means that we are going from a larger unit to a smaller unit, which means we need to multiply:

We start with 45 cubic feet.

$$45 \times 7.48 = 336.6$$

Now we have 336.6 gallons

Next, we need to go from gallons to pounds. Because there are 8.34 pounds in every single gallon, a gallon is the larger unit. Because we are going from larger to smaller, we multiply again.

$$336.6 \times 8.34 = 2,807.24$$

Now we have 2,807.24 pounds

Next, we have to get from pounds to kilograms. Because there are 2.2 pounds in every kilogram, we know that a kilogram is the bigger unit. This means we are going from smaller unit to bigger, which means we divide.

$$2,807.24 \div 2.2 = 1,276.02$$

Now we have 1,276.02 kilograms.

Finally, we need to convert kilograms into grams. Because there are 1,000 grams in every kilogram, the kilogram is the larger unit. This means that we are going from a larger unit to a smaller unit, which means we need to multiply.

$$1,276.02 \times 1,000 = 1,276,020$$

This finally gives us the number of grams in 45 cubic feet of water, which is 1,276,020.

You will notice the calculations made here are identical to the calculations made when doing the algebra; you are just using a shortcut to tell you whether you are multiplying or dividing by the conversion factor. This is a very effective method of converting simple units but it is far less useful when trying to convert compound units that have more than one unit in them such as mgd (millions of gallons/day), ppm (parts/million), and psi (pounds/in²). Treatment Plant Operators

routinely work with these type of units and, thankfully, there is a tool that can help you solve these types of problems easily.

Dimensional Analysis is a quick method (also known as the factor-label method, or the unit-factor method) of doing the algebra covered previously. When applied correctly it is faster even than the shortcut method mentioned above, especially when dealing with multiple conversions, or when working with compound units. It works by multiplying what you have by a conversion factor that is equal to one.

For example:

$$1 \text{ foot} = 12 \text{ inches}$$

This can create two conversion factors

$$\frac{1 \text{ ft.}}{12 \text{ in.}} \text{ or } \frac{12 \text{ in.}}{1 \text{ ft.}}$$

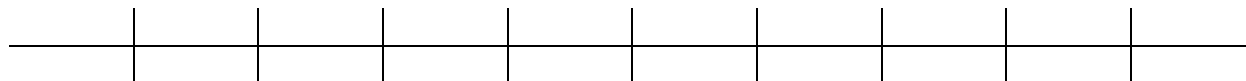
It is easy to see that both of these conversion factors are equal to one because we know that 1 foot is the same length as 12 inches. If you have 12 inches of rope, it will be the same length as a 1-foot long ruler.

Why would you multiply anything by 1? Because you do not want to change the value, just the units!

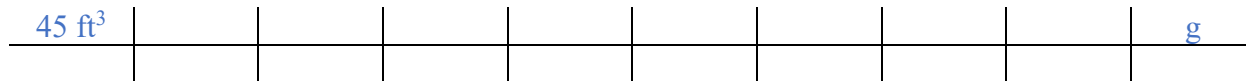
Let us say you have that same 45 cubic feet of water, how do you get to grams using dimensional analysis?

Dimensional Analysis Steps

1. Decide what you have: 45 cubic feet
2. Decide what you need: grams
3. Draw the *unit* Conversion Grid: Each vertical line represents a multiplication operator; the horizontal line separates the numerator from the denominator and so represents a division operator



4. Fill in what you have at the beginning, and what you need at the end



5. Now, we are going to put unit conversion factors into this line. What we're trying to do is connect the beginning of the equation to the end by using conversion factors that equal one in such a way to eliminate the units we don't want and get to the units we do want.

Feed Rate

Early in the water treatment process, chemicals such as Dry Alum are used to gather together fine, light particles to form larger particles, called floc, which can be removed from the water in the sedimentation process. The amount of Dry Alum that needs to be added to the water (in pounds per day) is equal to the dosage of the chemical (in milligrams per liter) multiplied by the flow rate of the water treatment plant (in millions of gallons per day) multiplied by a conversion factor of 8.34.

This is the formula used to calculate how many pounds of chemical should be used per day in order to treat the water.

$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{flow rate (mgd)} \times 8.34$$

Notice that 8.34 does not have any units. Why not?

8.34 is a shortcut that helps turn mg/L into lbs./day when multiplying by a flow rate in millions of gallons per day. The long form of this factor follows:

mg	1 g	1 kg	2.2 lbs.	3.79 L	1,000,000 gallons
L	1,000 mg	1,000 g	1 kg	1 gallon	day

mg	1 g	1 kg	2.2 lbs.	3.79 L	1,000,000 gallons
L	1,000 mg	1,000 g	1 kg	1 gallon	day

	1	1	2.2 lbs.	3.79	1,000,000	=	lbs.
	1,000	1,000	1	1	day		day

$$2.2 \times 3.79 \times 1,000,000 \div 1,000 \div 1,000 = 8.34 \text{ lbs./day}$$

The formula includes 8.34 so that the conversions between mg to g, g to kg, kg to lbs., and liters to gallons does not need to be done repeatedly. It does not have any units stated because it is the number that when multiplied by a dosage in mg/L and a flow rate in mgd will give you pounds per day (lbs./day).

For example: If the dosage of Dry Alum needed to treat the water is 12 mg per liter and the water treatment facility treats 3 million gallons of water per day how many pounds of Dry Alum per day would need to be added to the water in order to cause the suspended and colloidal matter to floc?

$$\text{Feed Rate} = \frac{12\text{mg}}{1 \text{ liter}} \times 3 \text{ mgd} \times 8.34$$

$$\frac{12\text{mg}}{1 \text{ liter}} \times 3 \text{ mgd} \times 8.34 = \frac{300.24 \text{ lbs.}}{\text{day}}$$

300.24 pounds of Dry Alum would need to be added to the water per day

In order for this equation to work, the units in the problem must match the units in the equation. If they do not, you need to convert any units that do not match before you work the equation.

For Example:

Chlorine can be added to the water at multiple points in the water treatment process in order to kill disease-causing organisms in the water. If the chlorine dosage rate is 2 mg/L and the flow rate of the water treatment plant is 700,000 gallons per day, how many pounds of chlorine need to be added to the water per day?

If we were to multiply the numbers as they are without regard to units, we would get the following **WRONG ANSWER:**

$$2 \times 700,000 \times 8.34 = 11,676,000$$

11,676,000 pounds of Chlorine at a 2 mg/L dosage would be enough chlorine to disinfect 700,000,000,000 gallons of water not 700,000 gallons of water. That is a million times more chlorine than we need!

The mistake here is that the flow rate must be expressed in terms of “millions of gallons” per day (mgd) in order to work in the equation. Because the problem specifies the flow rate in gallons per day (gal./day), one must convert 700,000 gallons per day to mgd.

There is no conversion factor listed to go from “gallons” to “millions of gallons”. So how do we figure out many “millions of gallons” are in 700,000 gallons? We can logically deduce a conversion factor. How many gallons are in a million gallons? The answer should be obvious. 1 million. There are 1 million “gallons” in a “million gallons”.

$$1 \text{ million gallons} = 1,000,000 \text{ gal.}$$

Let us solve this using the three methods discussed above.

Using Algebra:

$$1,000,000 \text{ gal./day} = 1 \text{ mgd.}$$

We are given how many gallons per day we have, so we will want gallons per day by itself on one side of the equation so we divide both sides by 1,000,000

$$\frac{1,000,000 \text{ gal./day}}{1,000,000} = \frac{1 \text{ mgd}}{1,000,000}$$

$$\frac{\cancel{1,000,000} \text{ gal./day}}{\cancel{1,000,000}} = \frac{1 \text{ mgd}}{1,000,000}$$

$$1 \text{ gal./day} = \frac{1 \text{ mgd}}{1,000,000}$$

We have 700,000 gallons so we multiply both sides by 700,000

$$700,000 \times 1 \text{ gal./day} = \frac{1 \text{ mgd}}{1,000,000} \times 700,000$$

$$700,000 \text{ gal./day} = \frac{700,000 \text{ mgd}}{1,000,000}$$

$$700,000 \div 1,000,000 = .7 \text{ mgd}$$

So in 700,000 gallons per day there are .7 “million gallons” per day (mgd)

Using the shortcut:

We know that a “million gallons” is larger than a “gallon” because there are 1,000,000 gallons in 1 “million gallons”.

$$1,000,000 \text{ gal./day} = 1 \text{ mgd}$$

We are starting with 700,000 gallons

We are going from gallons to “millions of gallons” so we are going from a small unit to a big unit therefore we must divide.

$$700,000 \div 1,000,000 = .7$$

Both of these methods work because we are given gallons per day and we need millions of gallons per day. Only the gallons unit is changing, the day part of the compound unit is staying the same. However, this is not always the case. When more than one unit needs changing, dimensional analysis is a far more effective tool.

Using Dimensional Analysis:

We start by filling in what we start with and what we want in the end

$$\frac{700,000 \text{ gallons}}{\text{day}} \quad | \quad | \quad | \quad | \quad \frac{\text{million gallons}}{\text{day}}$$

$$1,000,000 \text{ gal.} = 1 \text{ million gallons}$$

We already have days in the denominator so we don't want to take it out, but the unit we have at the beginning is “gallons” while the unit we need for the equation is “million gallons”. This means we need a conversion factor with gallons on the bottom and millions of gallons on top

$$\frac{1,000,000 \text{ gallons}}{1 \text{ million gallons}} \quad \text{or} \quad \frac{1 \text{ million gallons}}{1,000,000 \text{ gallons}}$$

$$\frac{700,000 \text{ gallons}}{\text{day}} \quad | \quad \frac{1 \text{ million gallons}}{1,000,000 \text{ gallons}} \quad | \quad | \quad | \quad \frac{\text{million gallons}}{\text{day}}$$

We make sure the units we do not want are canceled out and that units we want are kept

$$\frac{700,000 \text{ gallons}}{\text{day}} \bigg| \frac{1 \text{ million gallons}}{1,000,000 \text{ gallons}}$$

Now we multiply the top and divide by the bottom

$$700,000 \times 1 \div 1,000,000 = .7 \text{ millions of gallons per day}$$

This is the number we need to insert into our equation that calls for “flow in millions of gallons per day”.

Therefore, the **RIGHT ANSWER** is as follows:

$$2 \times .7 \times 8.34 = 11.676$$

We need 11.676 pounds of Chlorine per day.

Usually, the feed rate is what you are trying to find using this equation:

$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{flow rate (mgd)} \times 8.34$$

However, it can also be used to find the flow rate in millions of gallons per day.

For example: suppose that you have 23 lbs. of Chlorine left in storage. What is the highest flow rate you could effectively treat today if you used all the chlorine available to you? The effective dosage is still 2 mg/L. Express your answer in mgd.

Let us fill in what we know:

$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{flow rate (mgd)} \times 8.34$$

$$23 \text{ lbs./day} = 2 \text{ mg/L} \times \text{flow rate (mgd)} \times 8.34$$

First, we isolate flow rate on one side of the equation by dividing both sides by everything we don't want on that side of the equation

$$\frac{23 \text{ lbs./day}}{(2 \text{ mg/L}) (8.34)} = \frac{2 \text{ mg/L} \times \text{flow rate (mgd)} \times 8.34}{(2 \text{ mg/L}) (8.34)}$$

Now we cancel out

$$\frac{23 \text{ lbs./day}}{(2 \text{ mg/L}) (8.34)} = \frac{\cancel{2 \text{ mg/L}} \times \text{flow rate (mgd)} \times \cancel{8.34}}{(\cancel{2 \text{ mg/L}}) (\cancel{8.34})}$$

This leaves us with:

$$\frac{23 \text{ lbs./day}}{(2 \text{ mg/L}) (8.34)} = \text{flow rate (mgd)}$$

$$23 \div 2 \div 8.34 = 1.378896882494005.$$

The maximum flow rate that could be treated with 23 lbs./day of chlorine, if the effective dosage is 2 mg/L is about 1.38 mgd.

In addition to needing to perform unit conversions before solving, sometimes a Treatment Plant Operator needs to perform unit conversions afterwards in order to solve other problems.

For Example: Suppose the chemical feeding machine that doses the water is broken at the facility. The water still needs to be chlorinated! Someone needs to manually dose the water with solid chlorine until the machine can be repaired. How many grams of dry chlorine need to be added to the water every minute to ensure the water remains properly chlorinated? The feed rate is 11.676 pounds per day and the effective dosage of chlorine is 2 mg/L, the flow rate is .7.

1. Decide what you have: 11.676 pounds per day
2. Decide what you need: grams per minute
3. Draw the unit Conversion Grid:

--	--	--	--	--	--	--	--	--

4. Fill in what you have at the beginning, and what you need at the end

11.676 lbs. day								grams minute
--------------------	--	--	--	--	--	--	--	-----------------

5. Start inserting conversion factors. We can see that we are going from days to minutes. Since we know how many hours are in a day, and how many minutes are in an hour we are going to insert factors for this first.

$$\frac{24 \text{ hours}}{1 \text{ day}} \text{ or } \frac{1 \text{ day}}{24 \text{ hours}} \quad \text{and} \quad \frac{60 \text{ min}}{1 \text{ hour}} \text{ or } \frac{1 \text{ hour}}{60 \text{ min}}$$

Since we are starting with days on the bottom, we choose the factor that will cancel it:

$\frac{24 \text{ hours}}{1 \text{ day}}$ or $\frac{1 \text{ day}}{24 \text{ hours}}$

11.676 lbs. day	1 day 24 hours					grams minute
--------------------	-------------------	--	--	--	--	-----------------

11.676 lbs. day	1 day 24 hours					grams minute
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If we stopped here, multiplied across, and then divided by the bottom it would tell us how many pounds of chlorine would need to be added every hour. However, that would not properly distribute the chlorine, someone needs to sit by the water and add dry chlorine every minute until the chemical feeding machine is fixed. We need to know how much to add every minute so we

need to get hours out of our equation. Since hours are currently on bottom, we need hours on top to cancel it.

$$\frac{60 \text{ min}}{1 \text{ hour}} \quad \text{or} \quad \frac{1 \text{ hour}}{60 \text{ min}}$$

11.676 lbs.	1 day	1 hour				grams
day	24 hours	60 min				minute

11.676 lbs.	1 day	1 hour				grams
day	24 hours	60 min				minute

This gets us what we wanted on the bottom, but if we stopped here and did our calculations, it would tell us what?

11.676 lbs.	1 day	1 hour				lbs.
day	24 hours	60 min				min

$$11.676 \times 1 \times 1 \div 24 \div 60 = .008108333 \text{ pounds per minute.}$$

That is not a very useful number for the person who has to feed chlorine into the water. Remember that the question asked for grams per minute.

Now we need to convert the pounds to grams

$$1 \text{ kg} = 2.2 \text{ pounds} \quad 1 \text{ kg} = 1,000 \text{ g}$$

Conversion factors we will need:

$$\frac{2.2 \text{ lbs.}}{1 \text{ kg}} \quad \text{or} \quad \frac{1 \text{ kg}}{2.2 \text{ lbs.}} \quad \text{and} \quad \frac{1000 \text{ g}}{1 \text{ kg}} \quad \text{or} \quad \frac{1 \text{ kg}}{1000 \text{ g}}$$

Since we have pounds, we need to start by canceling those out. Because lbs. are on top, we need the conversion factor with lbs. on the bottom.

$$\frac{2.2 \text{ lbs.}}{1 \text{ kg}} \quad \text{or} \quad \frac{1 \text{ kg}}{2.2 \text{ lbs.}}$$

11.676 lbs.	1 day	1 hour	1 kg			grams
day	24 hours	60 min	2.2 lbs.			minute

This cancels out the pounds

11.676 lbs.	1 day	1 hour	1 kg			grams
day	24 hours	60 min	2.2 lbs.			minute

Finally, we can get grams on top by inserting our last conversion factor

$$\frac{1000 \text{ g}}{1 \text{ kg}} \text{ or } \frac{1 \text{ kg}}{1000 \text{ g}}$$

11.676 lbs.	1 day	1 hour	1 kg	1000 g		grams
day	24 hours	60 min	2.2 lbs.	1 kg		minute

6. Double check to make sure that all the units that you do not want are canceled out; units that are not canceled out are carried to the end.

11.676 lbs.	1 day	1 hour	1 kg	1000 g		grams
day	24 hours	60 min	2.2 lbs.	1 kg		minute

7. Multiply all the numbers on top then divide by all the numbers on the bottom

$$11.676 \times 1,000 \div 24 \div 60 \div 2.2 = 3.69 \text{ grams per minute}$$

In practice, this whole problem would be solved like this: Suppose the first step I take is in red, the next is orange; the next is yellow, then green, then blue, then purple.

11.676 lbs.	1 day	1 hour	1 kg	1000 g		grams
day	24 hours	60 min	2.2 lbs.	1 kg		minute

$$11.676 \times 1,000 \div 24 \div 60 \div 2.2 = 3.69 \text{ grams per minute}$$

Chlorine Dosage

When one adds chlorine to water containing other substances, it will combine and react with these substances and form chlorine compounds. If you continue to add chlorine, you will eventually reach a point where the reaction stops. When this happens, one has satisfied what is known as “chlorine demand”. The total amount of chlorine compounds present in the water after this point is known as the “chlorine residual” or “residual chlorine”. The amount of chlorine that needs to be added to the water in order to disinfect the water is called the “chlorine dosage” or “chlorine dose.”

The relationship between “chlorine demand”, “chlorine residual”, and “chlorine dose” is as follows:

$$\text{Chlorine Dosage (mg/L)} = \text{Chlorine Demand (mg/L)} + \text{Chlorine residual (mg/L)}$$

The lab has determined that due to the level of contaminants in the water, the pH of the water, and the temperature of the water, the chlorine demand of the water is 4 mg/L. The tests also show that the residual chlorine in the water is .6 mg/L. At what dosage (in mg/L) should Chlorine be added to the water if the plant is flowing at 2 million gallons per day?

$$\text{Chlorine Dosage (mg/L)} = 4 \text{ mg/L} + .6 \text{ mg/L} = 4.6 \text{ mg/L}$$

You may have noticed that there was information in the question that was not needed to answer the question. On the job as a Treatment Plant Operator, you are often provided with a lot of information. It is important that you are able to select the information you need in order to answer the questions you need to answer. It is also important to note that the State exam that one needs to pass in order to be a certified Treatment Plant Operator is notorious for providing details and numbers in the question that may or may not be necessary to answer the question.

Given the Chlorine dosage, you should also be able to find the residual if given the demand, or the demand if given the residual.

For example: If the chlorine dosage is 3.2 mg/L and the chlorine residual is .3 mg/L, what is the chlorine demand in mg/L?

$$\text{Chlorine Dosage (mg/L)} = \text{Chlorine Demand (mg/L)} + \text{Chlorine residual (mg/L)}$$

Insert what we know.

$$3.2 \text{ mg/L} = \text{Chlorine Demand (mg/L)} + .3 \text{ mg/L}$$

Solve for chlorine demand by getting it alone on one side of the equation. Remember that in algebra, when we transpose a term from one side of the equation to the other we multiply by its reciprocal when working with terms that are being multiplied or divided, but when terms are being added or subtracted we simply move it to the other side and change its sign. That is, if something is being added on the right, we need to subtract it from the right and subtract it from the left as well.

If we have:

$$3.2 \text{ mg/L} = \text{Chlorine Demand (mg/L)} + .3 \text{ mg/L}$$

We want to move the “+.3 mg/L”

In order to do this, we subtract it from both sides

$$3.2 \text{ mg/L} - .3 \text{ mg/L} = \text{Chlorine Demand (mg/L)} + .3 \text{ mg/L} - .3 \text{ mg/L}$$

$$.3 \text{ mg/L} - .3 \text{ mg/L} = 0$$

$$3.2 \text{ mg/L} - .3 \text{ mg/L} = \text{Chlorine Demand (mg/L)} + 0$$

$$3.2 \text{ mg/L} - .3 \text{ mg/L} = 2.9 \text{ mg/L}$$

$$2.9 \text{ mg/L} = \text{Chlorine Demand}$$

If the chlorine dosage is 5.7 mg/L and the chlorine demand is .65 mg/L, what is the chlorine residual in mg/L?

$$\text{Chlorine Dosage (mg/L)} = \text{Chlorine Demand (mg/L)} + \text{Chlorine residual (mg/L)}$$

Insert what we know.

$$5.7 \text{ mg/L} = .65 \text{ mg/L} + \text{Chlorine residual (mg/L)}$$

Solve for chlorine residual by getting it alone on one side of the equation.

$$5.7 \text{ mg/L} - .65 \text{ mg/L} = .65 \text{ mg/L} + \text{Chlorine residual (mg/L)} - .65 \text{ mg/L}$$

$$5.7 \text{ mg/L} - .65 \text{ mg/L} = \text{Chlorine residual (mg/L)} + 0$$

$$5.7 \text{ mg/L} - .65 \text{ mg/L} = 5.05 \text{ mg/L}$$

$$5.05 \text{ mg/L} = \text{Chlorine residual}$$

However, sometimes you are not given residual or demand, what can you do then in order to find Chlorine Dose?

Suppose that there has been a lot of rain lately and the flow of the plant has increased substantially. The lab calls and asks what dosage the machine is feeding into the water because they do not trust it. You know that 15 pounds of chlorine are being fed into the water every day according to the meter on the chemical feeding device. The flow rate has increased to 1.5 million gallons. What is the dosage? The lab personnel did not tell you what the Chlorine demand or chlorine residual is.

Because we do not know what the chlorine demand or chlorine residual is, we **cannot** use the following equation from our equation table:

$$\text{Chlorine Dosage (mg/L)} = \text{Chlorine Demand (mg/L)} + \text{Chlorine residual (mg/L)}$$

The equation we must use here is:

$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{flow rate (mgd)} \times 8.34$$

Let us fill in what we know:

$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{flow rate (mgd)} \times 8.34$$

$$15 \text{ lbs./day} = \text{Dosage (mg/L)} \times 1.5 \text{ mgd} \times 8.34$$

Because we need to know what the dosage is, we move the flow rate and the conversion factor of 8.34 to the other side of the equation by dividing both sides by those factors.

$$\frac{15 \text{ lbs./day}}{(1.5)(8.34)} = \frac{\text{Dosage} \times 1.5 \times 8.34}{(1.5)(8.34)}$$

$$\frac{15 \text{ lbs./day}}{(1.5)(8.34)} = \frac{\text{Dosage} \times \cancel{1.5} \times \cancel{8.34}}{\cancel{(1.5)}\cancel{(8.34)}}$$

$$\frac{15 \text{ lbs./day}}{(1.5)(8.34)} = \text{Dosage}$$

Remember that if you have two numbers on the bottom of an equation you have to divide the numerator by both separately or you have to multiply them together before dividing the top by their product.

For example:

$$15 \div 1.5 \div 8.34 = 1.19904076738... \text{ mg/L}$$

Or

$$(1.5 \times 8.34) = 12.51$$

$$15 \div 12.51 = 1.19904076738... \text{ mg/L}$$

NOT:

$$15 \div 1.5 \times 8.34 = 83.4$$

We can check our answer by inserting it into our equation. Leaving the long decimal number on our calculator's screen, we can multiply it by the other two factors that should equal 15 pounds per day.

$$1.19904076738... \times 1.5 \times 8.34 = 15$$

15 is what we started with, so our answer is correct.

On the other hand, if we did the calculation **wrong**:

$$83.4 \times 1.5 \times 8.34 = 1,043.33$$

1,043.33 is not what we started with, we must have done something wrong.

Solutions

Treatment Plant Operators commonly measure water samples using spectrophotometry in order to check on relative levels of chemicals in the water at different stages in the water treatment process. Spectrophotometry is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength. More simply, it measures how much light from a range of colors the water sample absorbs or reflects. In order to calibrate devices like the DR 6000 Spectrophotometer commonly used by Treatment Plant Operators, you must be able to calculate standard solutions. A standard solution is a solution with precisely known values.

In order to make a standard solution you will need to know how to create a certain amount of solution at certain concentrations. The relationship between concentration and volume of solutions is as follows: The concentration that you are starting with multiplied by the volume that you are starting with must be equal to the concentration that you have at the end multiplied by the volume that you have at the end:

$$C_1 \times V_1 = C_2 \times V_2$$

Where:

C_1 is the concentration that you are starting with

V_1 is the volume that you are starting with

C_2 is the concentration that we have at the end

V_2 is the volume that we have at the end

For example, in order to find out the amount of ammonia that is in the water an operator needs to create a 20 mg/L standard. If the stock solution of the ammonia reagent is 500 mg/L how many mL of stock solution do you need in order to fill the 3.5 mL cuvette (the vessel that holds the water sample for testing) assuming that the cuvette will be filled the rest of the way with distilled water?

First, we look at what we started with.

C_1 is the concentration that we are starting with. This is the 500 mg/L solution of ammonia reagent that we have to use.

V_1 is the volume we are starting with. In this question, it is the amount of ammonia reagent that we put into the cuvette before diluting to 3.5 mL. This is the question; we do not have this yet.

Then we define what we have at the end.

C_2 is the concentration that we have at the end. In this problem, we need a 20 mg/L concentration of ammonia reagent.

V_2 is the volume that we have at the end. The cuvette is 3.5 mL, so this is the final volume we are looking for.

Let us fill these values into our equation.

$$C_1 \times V_1 = C_2 \times V_2$$

$$500 \text{ mg/L} \times V_1 = 20 \text{ mg/L} \times 3.5 \text{ mL}$$

Since we know the concentration, what we need to find is the volume of reagent we need in order to create a 20 mg/L concentration of 3.5 mL of reagent. At this point, we are working with basic algebra. We are solving for V_1 , so first we need to get it by itself on one side of the equation

$$\frac{500 \text{ mg/L} \times V_1}{500 \text{ mg/L}} = \frac{20 \text{ mg/L} \times 3.5 \text{ mL}}{500 \text{ mg/L}}$$

$$\frac{500 \text{ mg/L} \times V_1}{500 \text{ mg/L}} = \frac{20 \text{ mg/L} \times 3.5 \text{ mL}}{500 \text{ mg/L}}$$

$$V_1 = \frac{20 \times 3.5 \text{ mL}}{500}$$

$$20 \times 3.5 \text{ mL} = 70 \text{ mL}$$

$$V_1 = \frac{70 \text{ mL}}{500}$$

$$70 \text{ mL} \div 500 = .14 \text{ mL}$$

The amount of ammonia reagent we need to add to the cuvette is .14 mL. The rest of the 3.5 mL volume will be filled with water and we will end up with a standard 20 mg/L solution that is 3.5 mL in volume.

Concentrations are not always given in milligrams per liter (mg/L). They can also be given in micrograms per liter ($\mu\text{g/L}$), parts per million (ppm), parts per billion (ppb), or percent solution (%).

$$1 \text{ mg/L} = 1,000 \text{ } \mu\text{g/L} \quad 1 \text{ mg/L} = 1 \text{ ppm} \quad 1 \text{ } \mu\text{g/L} = 1 \text{ ppb} \quad 10,000 \text{ mg/L} = 1\%$$

In the example above, we solved for volume, but sometimes a Treatment Plant Operator knows the volume and needs to know the concentration instead. The equation is the same.

For example, let us say that you are working with another Treatment Plant Operator Trainee and he did his math wrong and added 1.4 mL of reagent. What is the resulting concentration in $\mu\text{g/L}$, assuming that he also filled the rest of his 3.5 mL cuvette with distilled water?

First, we look at what we started with.

C_1 is the concentration that we are starting with. This is the 500 mg/L solution of ammonia reagent that the other guy used.

V_1 is the volume we are starting with. In this problem, it is the 1.4 mL of ammonia reagent that the other guy put into the cuvette before diluting to 3.5 mL.

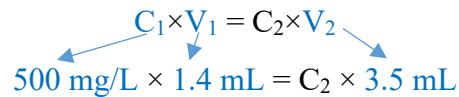
Then we define what we have at the end.

C_2 is the concentration that we have at the end. This is the question; we do not know this yet.

V_2 is the volume that we have at the end. The cuvette is 3.5 mL, so this is the final volume he ended up with.

Let us fill these values into our equation.

$$C_1 \times V_1 = C_2 \times V_2$$



$$500 \text{ mg/L} \times 1.4 \text{ mL} = C_2 \times 3.5 \text{ mL}$$

Since we know the volume, what we need to find is the concentration of reagent in the 3.5 mL sample created by adding 1.4 mL of 500 mg/L concentration reagent and diluting to fill the cuvette. At this point, we are again working with basic algebra. We are solving for C_2 , so first we need to get it by itself on one side of the equation

$$\frac{500 \text{ mg/L} \times 1.4 \text{ mL}}{3.5 \text{ mL}} = \frac{C_2 \times 3.5 \text{ mL}}{3.5 \text{ mL}}$$

$$\frac{500 \text{ mg/L} \times 1.4 \text{ mL}}{3.5 \text{ mL}} = \frac{C_2 \times \cancel{3.5 \text{ mL}}}{\cancel{3.5 \text{ mL}}}$$

$$\frac{500 \text{ mg/L} \times 1.4}{3.5} = C_2$$

$$500 \text{ mg/L} \times 1.4 = 700 \text{ mg/L}$$

$$\frac{700 \text{ mg/L}}{3.5} = C_2$$

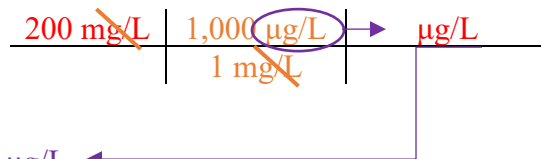
$$700 \text{ mg/L} \div 3.5 = 200 \text{ mg/L}$$

However, the question asked for $\mu\text{g/L}$ so we need to convert our answer into $\mu\text{g/L}$ from mg/L.

$$1 \text{ mg/L} = 1,000 \mu\text{g/L}$$

$$\frac{1 \text{ mg/L}}{1,000 \mu\text{g/L}} \quad \text{or} \quad \frac{1,000 \mu\text{g/L}}{1 \text{ mg/L}}$$

We pick the factor with mg/L on bottom to cancel out the mg/L that we have, and get $\mu\text{g/L}$



$$200 \times 1,000 \div 1 = 200,000 \mu\text{g/L}$$

The resulting solution that the other Treatment Plant Operator Trainee created was 200,000 µg/L.

How much water would you have to add to his solution in order to dilute it to the proper concentration so that it is not wasted?

We now have a 3.5 mL cuvette filled with a 200 mg/L solution of ammonia reagent. We need a 20 mg/L solution. If we transfer the solution to a flask, how much water would we need to add in order for the resulting solution to have the correct concentration?

First, we look at what we started with.

C_1 is the concentration that we are starting with. This is the 200 mg/L solution of ammonia reagent that resulted from the other guy's mistake.

V_1 is the volume we are starting with. In this problem, it is the 3.5 mL of solution that the other guy ended up with.

Then we define what we have at the end.

C_2 is the concentration that we have at the end. We know that we want the concentration to be the standard 20 mg/L.

V_2 is the volume that we have at the end. If we dilute the solution so that it is the correct concentration, how much will we have? More importantly, if we take his solution and put it into a flask how far should we fill the flask so that the resulting solution is the correct concentration?

Let us fill these values into our equation.

$$C_1 \times V_1 = C_2 \times V_2$$

$$200 \text{ mg/L} \times 3.5 \text{ mL} = 20 \text{ mg/L} \times V_2$$

We are solving for V_2 so we can start by getting that on one side of the equation by itself.

$$\frac{200 \text{ mg/L} \times 3.5 \text{ mL}}{20 \text{ mg/L}} = \frac{20 \text{ mg/L} \times V_2}{20 \text{ mg/L}}$$

$$\frac{200 \text{ mg/L} \times 3.5 \text{ mL}}{20 \text{ mg/L}} = \frac{20 \text{ mg/L} \times V_2}{20 \text{ mg/L}}$$

$$\frac{200 \times 3.5 \text{ mL}}{20} = V_2$$

$$200 \times 3.5 = 700 \text{ mL}$$

$$\frac{700 \text{ mL}}{20} = V_2$$

$$700 \text{ mL} \div 20 = 35 \text{ mL}$$

The resulting solution will have to be 35mL in total in order for the solution to have the correct concentration of 20 mg/L. The easiest way to do this would be to pour the 3.5 mL solution of 200mg/L into a flask and then simply add water until it was full up to the 35 mL mark, but the questions asked “how much water”.

If we already have 3.5 mL of solution in the flask, we simply subtract that amount from 35 mL in order to determine how much water was added.

$$35\text{mL} - 3.5\text{mL} = 31.5 \text{ mL}$$

In order to fix his mistake we need to add 31.5 mL of water to the solution. We can then fill a 3.5mL cuvette with the resulting solution in order to use it as a standard in the spectrophotometer.

The next day, your supervisor comes to you and informs you that someone has left out a flask of reagent. It has been evaporating. Based on the results from the spectrophotometer, the current concentration is 13.5% and there is 7.407 mL of the reagent left in the flask. By the stain left on the glass, you can see that the solution began as 10 mL. What concentration did the reagent have before it started evaporating? There are four different concentrations that the lab has, and in order to keep track of how much of each are on hand at any given time you need to know if it was the 5% solution, the 10% solution, the 15% solution, or the 20% solution.

First, we look at what we started with.

C_1 is the concentration that we are starting with. This is what we are trying to find.

V_1 is the volume we started with. In this case, 10 mL

Then we define what we have at the end.

C_2 is the concentration that we have at the end. In this case, the spectrophotometer is telling us the concentration is at 13.5%.

V_2 is the volume that we have at the end. In this case, we have 7.407 mL left.

Let us fill these values into our equation.

$$C_1 \times V_1 = C_2 \times V_2$$

$$C_1 \times 10 \text{ mL} = 13.5\% \times 7.4 \text{ mL}$$

We are solving for C_1 so we can start by getting that on one side of the equation by itself.

$$\frac{C_1 \times 10 \text{ mL}}{10 \text{ mL}} = \frac{13.5\% \times 7.4 \text{ mL}}{10 \text{ mL}}$$

$$\frac{C_1 \times \cancel{10 \text{ mL}}}{\cancel{10 \text{ mL}}} = \frac{13.5\% \times 7.4 \text{ mL}}{10 \text{ mL}}$$

$$C_1 = \frac{13.5\% \times 7.4}{10}$$

$$13.5\% \times 7.4 = 99.9\%$$

$$C_1 = \frac{99.9\%}{10}$$

$$99.9\% \div 10 = 9.99\%$$

The original solution had a concentration of 9.99%. If the options are 5%, 10%, 15%, or 20%, the best answer is that a flask of 10% solution was left out.

The equation we have been using ($C_1 \times V_1 = C_2 \times V_2$) is used when we are diluting one solution with water. (Or when the solution gets stronger in relation to the content of water, through evaporation). However, when mixing two solutions together you need a different formula.

Concentration₁ × Volume₁ + Concentration₂ × Volume₂ = Concentration₃ (Volume₁ + Volume₂)

$$C_1 \times V_1 + C_2 \times V_2 = C_3 \times V_3$$

Where:

C₁ is the concentration of the first solution

V₁ is the volume of the first solution

C₂ is the concentration of the second solution

V₂ is the volume of the second solution

C₃ is the concentration of the combined solution

V₃ is the volume of the combined solution (is equal to V₁ + V₂)

Let's say you have a 20 mL raw water sample that is .0022% solids, if you add this to another raw water sample that is 35 mL and .0073% solids, what concentration of solids do you have in the combined solution? Express your answer in mg/L.

C_1 is the concentration of the first solution: For this problem, it would be .0022%

V_1 is the volume of the first solution: For this problem, it would be 20 mL

C_2 is the concentration of the second solution: For this problem, it would be .0073%

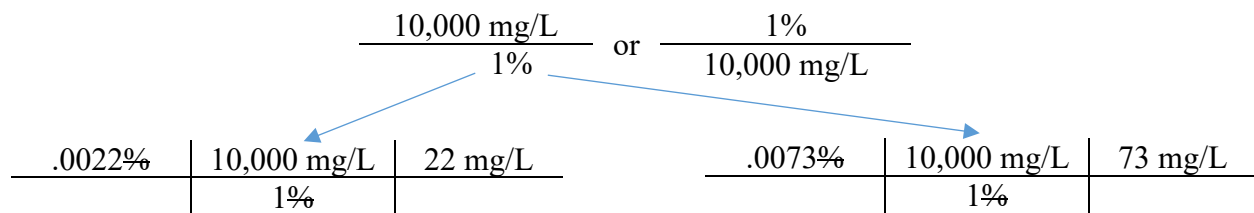
V_2 is the volume of the second solution: For this problem, it would be 35mL

C_3 is the concentration of the combined solution: This is what the question asked.

V_3 is the volume of the combined solution (is equal to $V_1 + V_2$): 20mL + 35mL = 55mL

Because the question asked us for the concentration in mg/L, we might as well convert the percentages we have into mg/L now. We could also do this at the end but it might be a good idea to convert first so that one does not forget to do so at the end.

From our conversion chart, we can see that 10,000 mg/L = 1%



Let us plug in what we have

$$C_1 \times V_1 + C_2 \times V_2 = C_3 \times V_3$$

$$22 \text{ mg/L} \times 20 \text{ mL} + 73 \text{ mg/L} \times 35 \text{ mL} = C_3 \times 55 \text{ mL}$$

For now, let us substitute mg/L as "y" and mL as "z"

$$22 y \times 20 z + 73 y \times 35 z = C_3 \times 55 z$$

$$440 yz + 2,555 yz = C_3 \times 55 z$$

$$2,995 yz = C_3 \times 55 z$$

Now we need to get C_3 by itself

$$\frac{2,995 yz}{55 z} = \frac{C_3 \times 55 z}{55 z}$$

The "z" in the denominator cancels out the "z" in the numerator

$$\frac{2,995 y}{55} = C_3$$

$$2,995 y \div 55 = 54.45 y$$

Now we can put mg/L back in for "y". The resulting concentration is 54.45 mg/L

In summary, here are the calculations that you should be able to do at this point:

- Volume
 - Calculate the volume of a cylinder given its height and diameter
 - $\text{Volume} = .785 \times (\text{Diameter})^2 \times \text{Height}$
- Conversions
 - Convert values from one unit into another unit using algebra
 - What happens on one side happens on the other
 - Can move terms from one side to another by
 - Multiplying or Dividing
 - Adding or Subtracting
 - Convert values from one unit into another unit using a shortcut method.
 - Bigger unit to a smaller unit: Multiply
 - Smaller unit to a bigger unit: Divide
 - Convert values from one unit into another unit using dimensional analysis
 - Unit conversion factors that equal 1 can be used to transform one even compound units into other units
- Feed Rate
 - Calculate the feed rate of a chemical if given the effective dosage and the flow rate
$$\text{Feed Rate (lbs./day)} = \text{Dosage (mg/L)} \times \text{Flow Rate (mgd)} \times 8.34$$
 - Calculate the flow rate if given the feed rate and effective dosage of a chemical
$$\text{Flow Rate (mgd)} = \frac{\text{Feed Rate (lbs./day)}}{\text{Dosage (mg/L)} \times 8.34}$$
 - Calculate the effective dosage of a chemical if given the feed rate and flow rate
$$\text{Dosage (mg/L)} = \frac{\text{Feed Rate (lbs./day)}}{\text{Flow Rate (mgd)} \times 8.34}$$
- Dosage
 - Calculate the chlorine dosage if given the chlorine demand and chlorine residual
$$\text{Chlorine Dosage (mg/L)} = \text{Chlorine Demand (mg/L)} + \text{Chlorine Residual (mg/L)}$$
 - Calculate the chlorine demand if given the chlorine dosage and chlorine residual
$$\text{Chlorine Demand (mg/L)} = \text{Chlorine Dosage (mg/L)} - \text{Chlorine Residual (mg/L)}$$
 - Calculate the chlorine residual if given the chlorine dosage and chlorine demand
$$\text{Chlorine Residual (mg/L)} = \text{Chlorine Dosage (mg/L)} - \text{Chlorine Demand (mg/L)}$$

- Solutions

$$C_1 \times V_1 = C_2 \times V_2$$

- Calculate starting volume if given starting concentration, ending concentration, and ending volume

$$V_1 = \frac{C_2 \times V_2}{C_1}$$

- Calculate ending concentration if given starting concentration, starting volume, and ending volume

$$C_2 = \frac{C_1 \times V_1}{V_2}$$

- Calculate ending volume if given starting concentration, starting volume, and ending concentration

$$V_2 = \frac{C_1 \times V_1}{C_2}$$

- Calculate starting concentration if given starting volume, ending concentration and ending volume.

$$C_1 = \frac{C_2 \times V_2}{V_1}$$

- Calculate the final concentration of a mixture of two solutions given their respective concentrations and volumes.

$$C_1 \times V_1 + C_2 \times V_2 = C_3 \times (V_1 + V_2)$$

$$C_3 = \frac{(C_1 \times V_1) + (C_2 \times V_2)}{(V_1 + V_2)}$$

Vocabulary for Treatment Plant Operator Trainees

Treatment Plant Operator trainees are required to either have some knowledge or have the ability to readily acquire some knowledge of the following:

- Chemical composition, structure, and properties of substances and of the chemical processes and transformations they undergo
- Physical principles, laws, and their interrelationships
- Hydraulics and fluid dynamics
- Materials and equipment used in water/wastewater treatment plants
- Mechanical and electrical maintenance processes and procedures
- Tools and equipment used for mechanical and electrical maintenance
- Chemistry to include acids, bases, buffers, and electrical charge

In order to demonstrate your ability to acquire job-related knowledge, please study and memorize the following terms and definitions before taking the test.

Actuator: A component of a machine that is responsible for moving and controlling a mechanism or system, for example, by opening a valve

Air binding: The clogging of a filter, pipe, or pump due to the presence of air released from water

Algae: Microscopic plants which contain chlorophyll and live floating or suspended in water

Alkalinity: The capacity of water to neutralize acids

Amperage: The amount of electric current flow, similar to the flow of water in gallons per minute

Aerator: A treatment device that brings air into contact with water for the purpose of transferring gases from the air into the liquid phase

Ambient Temperature: The temperature of the surrounding air

BOD (Biochemical Oxygen Demand): The rate at which organisms use the oxygen in water while stabilizing decomposable organic matter under aerobic conditions

Backwashing: The process of reversing the flow of water through the filter media to remove entrapped solids

Bacteria: Living organisms, microscopic in size, which usually consist of a single cell

Bearing: A machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts

Brownian Motion: The random movement of particles suspended in a fluid medium resulting from molecular bombardment

Buffer Capacity: A measure of the capacity of a solution or liquid to neutralize acids or bases

Centrifuge: A mechanical device that uses centrifugal or rotational forces to separate solids from liquids

Circuit: The complete path of an electric circuit

Clarifier: A large circular or rectangular tank or basin in which water is held for a period of time during which the heavier suspended solids settle to the bottom

Coagulation: The clumping together of very fine particles into larger particles caused by the use of chemicals

Conductivity: A measure of the ability of a solution to carry an electric current

Coupling: A device for connecting parts of machinery

Cross Connection: The physical connection of a safe or potable water supply with another water supply of unknown or contaminated quality or such that the potable water could be contaminated or polluted

Direct Current: An electric current flowing in one direction only

Drain: A pipe, conduit, or receptacle in a building that carries liquids by gravity to waste

Drought: A prolonged period of dry weather that causes a serious or prolonged deficiency or shortage of water

Electric Motor: An electrical machine that converts electrical energy into mechanical energy

Gear: A rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque

Hydrogen Sulfide: A toxic gas that has a very noticeable rotten-egg odor

Impeller: A rotating set of vanes in a pump or compressor designed to pump or move water or air

Jogging: The process of frequently starting or stopping an electric motor

Mechanical Seal: A method of containing fluid within a vessel (typically pumps, mixers, etc.) where a rotating shaft passes through a stationary housing or occasionally, where the housing rotates around the shaft

pH: A measure of acidity or alkalinity of water soluble substances (**pH** stands for 'potential of hydrogen')

Pump: A device that moves fluids, or sometimes slurries, by mechanical action

Range: The spread from minimum to maximum values over which an instrument is designed to measure

Starter (motor): A device used to start up large motors gradually to avoid severe mechanical shock to a driven machine and to prevent disturbance to the electrical lines

Stator: The stationary portion of an electric generator or motor, especially of an induction motor

Turbidity: The cloudy appearance of water caused by the presence of suspended and colloidal matter

Valve: A device that regulates, directs or controls the flow of a fluid by opening, closing, or partially obstructing various passageways

Viscosity: A measure of the capacity of a substance to internally resist flow

Voltage: The electrical pressure available to cause a flow current when an electric circuit is closed

Volute: A spiral casing for a centrifugal pump

Weir: A wall or plate placed in an open channel and used to measure the flow of water

After studying this guide you should be able to define any of the above terms or identify the term given its definition or a description of the term.

For example you may be asked, “**What is Brownian Motion?**”

To which, you will have to select the correct definition: “**The random movement of particles suspended in a fluid medium resulting from molecular bombardment**”.

You may, alternatively be given the definition: “**What is the random movement of particles suspended in a fluid medium resulting from molecular bombardment?**”

To which, you would be required to select the correct term: “**Brownian Motion**”.

You may also be given a description of the term: “**Solids suspended in water often move randomly due to molecular bombardment, what is this random movement called?**”

To which you would have to select the term: “**Brownian Motion**”