Drinking Water Operator Certification Training

Basic Math

Revised February 2017

Topical Outline

I. Describe principles and rules for solving equations.

II. Review unit cancellation steps.

III. Perform calculations for the following types of situations:

   A. Pressure/Height conversions

   B. Temperature conversions

   C. Unaccounted for water

   D. Area/Volume

IV. Quiz #1

V. Perform calculations for the following types of situations:

   A. Davidson Pie Feed Rate Equation (100% strength)

   B. Davidson Pie Dosage Equation (100% strength)

   C. Davidson Pie Flow Equation (100% strength)

VI. Quiz #2

VII. Practice Problems

VIII. Perform calculations for the following types of situations:

   A. Feed Rate Using Flow for % Strength Solutions

   B. Feed Rate Using Volume for % Strength Solutions

   C. Calculating “Active Ingredient” weight

   D. Using “Active Ingredient weight to convert from lbs to gal/day

IX. Quiz #3

X. Perform calculations for the following types of situations:

   A. Calculating the weight of a solution

   B. Calculating the “Active Ingredient” weight of a Drum

XI. Math Question Exam Tips

XII. Math Concept Exercise

XIII. Summary Dosage Math Tables (Gas and Hypochlorite)

XIV. Math Key Points

XV. Math Final Exam

Here are a few basic math rules that apply to all equations.

Rules for Solving for an Unknown Variable (such as *X*)

When solving for the unknown variable (***X***), there are 2 basic objectives:

1. ***X*** must be in the numerator, **AND**
2. ***X*** must be by itself (on one side of the equation).

To accomplish these objectives, **only diagonal movement of terms across the equal sign is permissible in multiplication and division problems.**

$$\frac{(5)}{(3)} = \frac{(3)}{(5)}$$

Here's how we apply the diagonal movement principle. It's the same concept of keeping the equation balanced by doing the same math function (addition, subtraction, multiplication, or division) to **both sides** of the equation.

Explanation of diagonal movement and an example.

An equation is a mathematical statement in which the terms or calculation on one side = the terms or calculation on the other side. To keep both sides equal, any multiplication, division, addition, or subtraction done to one side, must be done to the other. This keeps the equation balanced.

Example:

$5X = 20$

Question #1 regarding Example #1: Is the ***X*** in the numerator? ______

Question #2 regarding Example #1: Is the ***X*** alone on one side of the equation? _____

How do we use diagonal movement to place ***X*** alone on one side of the equation?

Answer:

- Divide both sides by "5" to get ***X*** alone and **treat both sides of the equation equally**.
  Notice that the 5 was moved from the top of the left side to the bottom of the right side of the equation **– a diagonal move.**

$\frac{\cancel{5}\mathbf{X}}{\cancel{5}} = \frac{20}{5}$ **FINAL ANSWER**: ________

There are a few rules for doing the various mathematical functions like multiplication, division, addition and subtraction.

Order of Operation for Multiplication, Division, Addition and Subtraction
To solve for ***X*** when multiplication and division as well as addition and subtraction of terms is indicated, use the following steps: 1. Simplify as many terms as possible, using the order of operation: • If **brackets or parentheses** contain any arithmetic, **simplify within these groups first** by: o Completing the multiplication or division, **THEN** o Complete the addition or subtraction. • Complete all **multiplication and division** from left to right, **THEN** • Complete all **addition and subtraction** from left to right. 2. Verify that the ***X*** term is in the numerator. If it is not, move the ***X*** term to the numerator, using a diagonal move. 3. Verify that ***X*** is by itself, on one side of the equation.

In addition to reviewing basic math rules, we'll review how you use unit cancellation to convert units of measurement.

Problem Solving Using Unit Cancellation:

We give it that name because you cancel units until the problem is solved.

- Unit cancellation involves canceling units in the numerator and denominator of unit fractions to obtain the desired units of measurement.

- Unit cancellation can be used to make conversions or to solve problems.

There are three basic rules for using unit cancellation on the next page.

Basic rules for using unit cancellation:

Unit fractions should be written in a vertical format. A unit fraction has one unit in the numerator (above the line) and one unit in the denominator (below the line).

1. A fraction is structured like this: $\frac{\text{numerator}}{\text{denominator}}$

   For example, gallons per minute (GPM) should be written as $\frac{\text{gal}}{\text{min}}$

2. Any unit which appears in the numerator of one unit fraction and the denominator of another unit fraction is canceled.

   The following is an example of how units are canceled:

   $$20\ \frac{\text{gal}}{\cancel{\text{min}}} \times 60\ \frac{\cancel{\text{min}}}{\text{hr}} = 1200\ \frac{\text{gal}}{\text{hr}}$$

3. It may be necessary to invert data and the corresponding units.

   $$10\ \frac{\text{gal}}{\text{min}} \text{ is the same as } \frac{1\ \text{min}}{10\ \text{gal}}$$

Example Problem: An operator has determined it takes 30 lbs/day as a feed rate for a 12.5% hypochlorite solution. This solution provides 1.2 available lbs of chlorine/gallon of hypochlorite solution. How many gal/day of 12.5% solution are needed to accomplish this feed rate?

Problem Set Up

List all known and unknown data.

Unknown: $? \frac{\text{gal}}{\text{day}}$ Known: $30 \frac{\text{lbs}}{\text{day}}$ $\frac{1.2 \text{ lbs of chlorine}}{1 \text{ gallon of 12.5\% solution}}$

Steps to solving problems using unit cancellation

Step 1: List unknown data including units in vertical format followed by an equal sign.

Example: Unknown data: $? \frac{\text{gal}}{\text{day}} =$

Step 2: Find data (known or a conversion) that has the same numerator unit as the unknown numerator. Place it to the right of the equal sign. Add a multiplication sign.

Example: $? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gal of 12.5\% solution}}{1.2 \text{ lb of chlorine}} \times$

Positions your numerator unit

Known data that was inverted

Steps 3 and 4: To cancel unwanted denominator unit, find data (known or a conversion) that has the same numerator unit. Place it to the right of data used in Step 2. Place a multiplication sign between each piece of data. Continue to place data (known or a conversion) into equation to systematically cancel all unwanted units until only the unknown denominator units remain.

Example: $? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gal of 12.5\% solution}}{1.2 \text{ \sout{lb of chlorine}}} \times \frac{30 \text{ \sout{lbs of chlorine}}}{\text{day}}$

Known data, cancel unwanted units that match

Note 1: All units must cancel, leaving only the units you are solving for in the unknown data. If all units except the unknown units are not crossed out, check the list of known data to see if all relevant known data was used to solve the problem and all necessary conversions were made.

Note 2: If you need to invert the known data or conversion values and units to cancel, remember to move the appropriate units with the value.

Step 5: Multiply the values of all numerators and place this value in the numerator of the answer. Multiply the values of all denominators and place this value in the denominator of the answer. Divide to calculate the final answer.

Example: $? \frac{\text{gal}}{\text{day}} = \frac{30 \text{ gal of 12.5\% solution}}{1.2 \text{ day}} = \frac{25 \text{ gallons of 12.5\% solution}}{\text{day}}$

Final denominator unit matches unknown denominator unit

Important: Check the answer to verify that the value is reasonable.

Let's practice doing unit cancellation on a simple conversion that we know.

Practice Problem: How many minutes are there in a day?

Problem Set Up

List all known and unknown data.

Unknown: $? \frac{\text{min}}{\text{day}}$ Known: $60 \frac{\text{mins}}{\text{hr}}$ $24 \frac{\text{hrs}}{1}$

Step 1: List unknown data including units in vertical format followed by an equal sign.

$$? \frac{\text{min}}{\text{day}} =$$

Step 2: Find data (known or a conversion) that has the same numerator unit as the unknown numerator. Place it to the right of the equal sign. Add a multiplication sign.

$$? \frac{\text{min}}{\text{day}} = \_\_\_\_$$

Insert data that has "mins" in the numerator unit

Steps 3 and 4: To cancel unwanted denominator unit, find data (known or a conversion) that has the same numerator unit. Place it to the right of data used in Step 2. Place a multiplication sign between each piece of data. Continue to place data (known or a conversion) into equation to systematically cancel all unwanted units until only the unknown denominator units remain.

$$? \frac{\text{min}}{\text{day}} = \frac{60\ \text{min}}{1\ \cancel{\text{hr}}} \times \_\_\_\_\_\_$$

Insert data that has "hrs" in numerator in next data set to cancel unwanted unit

Step 5: Multiply the values of all numerators and place this value in the numerator of the answer. Multiply the values of all denominators and place this value in the denominator of the answer. Divide to calculate the final answer.

$$? \frac{\text{min}}{\text{day}} = \frac{60\ \text{min}}{1\ \cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hrs}}}{1\ \text{day}} = \frac{\_\_\_\_\_\ \text{min}}{1\ \text{day}}$$

These are the correct units in both numerator and denominator

Unit Cancellation Steps

Step 1: List ? unknown data including units followed by an = sign

Step 2: Place data with same numerator unit to the right of the equal sign followed by a multiplication sign. This positions your numerator.

Step 3: To cancel unwanted denominator unit, next place data with same numerator unit.

Step 4: Continue to place data into equation to systemically cancel all unwanted units until only the unknown denominator units remain.

Step 5: Do the math (Multiply all numerator values, multiply all denominator values, then divide numerator by the denominator.)

Example:

The density of a liquid is 1 gm/mL in the Metric system. **What is the density in the English system (lbs/gal)?**

Notice that this conversion proves that the density of water = 8.34 lbs/gallon.

$$\frac{?\ \text{lbs}}{\text{gal}} = \frac{1\ \text{lb}}{454\ \cancel{\text{gm}}} \times \frac{1\ \cancel{\text{gm}}}{1\ \cancel{\text{mL}}} \times \frac{3785\ \cancel{\text{mL}}}{1\ \text{gal}} = 8.34\ \frac{\text{lbs}}{\text{gal}}$$

Helpful Hints:

$\frac{\text{Numerator}}{\text{Denominator}}$

Vertical format: 5 gal = $5\ \frac{\text{gal}}{1}$

1 gm = 1000 mg is written: $\frac{1\ \text{gm}}{1000\ \text{mg}}$ OR $\frac{1000\ \text{mg}}{1\ \text{gm}}$

"per" means divided by: Ex. 5 gpm = $5\ \frac{\text{gal}}{1\ \text{min}}$

Inverting: $5\ \frac{\text{gal}}{1\ \text{min}} = 1\ \frac{\text{min}}{5\ \text{gal}}$

Pressure/Height Conversions

Pressure - the force per unit of area. Pressure is commonly expressed in units of **pounds per square inch** (**psi**).

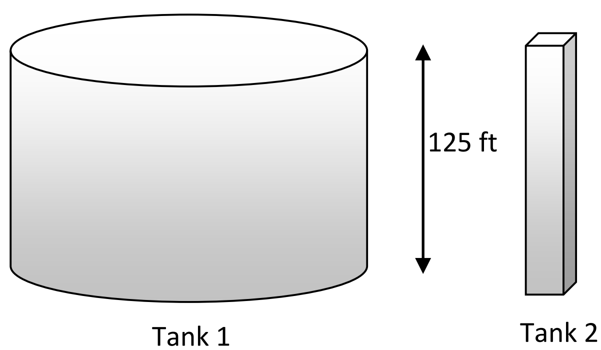
Pressure Head - the vertical distance from a free water surface to a point below the surface (i.e., pressure increases with increasing depth). Pressure head is commonly expressed in units of feet of water (**ft)**.

Relation between Head and Pressure

1 psi = 2.31 ft

Pressure is a function of the height of water. Every 2.31 feet of water exerts 1 pound of pressure at the bottom of the base of the container.

For example, an operator may be required to calculate how much pressure an elevated water tank may generate for his system.



Example Problem Calculating psi: How much pressure does water exert on both tanks if they are filled to the top (psi)?

Note: pressure is not affected by the volume of the tank, only the height. Both tanks are the same height, therefore both tanks will exert the same amount of pressure on 1 square inch. (psi)

$$?\text{psi} = \frac{1\ \text{psi}}{2.31\ \cancel{\text{ft}}} \times 125\ \cancel{\text{ft}} = \frac{125\ \text{psi}}{2.31} = \mathbf{54.1\ psi}$$

Practice Problem calculating psi: The water level at the top of a fully filled water standpipe is 150 feet above the elevation of a water tap. The tank contains 50,000 gallons of water. What is the approximate pressure at the tap?

$$? \text{ psi} = \frac{1 \text{ psi}}{2.31 \cancel{\text{ft}}} \times \frac{150 \cancel{\text{ft}}}{} = \frac{150 \text{ psi}}{2.31} = \_\_\_\_\_\_\_ \text{psi}$$

Note: Remember pressure is not affected by volume, only **height**.

You can also calculate the height of water in a tank (in ft) if you have the psi.

Example Problem calculating height in ft: If the pressure is 14 psi, what is the height of water in the tank?

To calculate **height in ft** from psi:

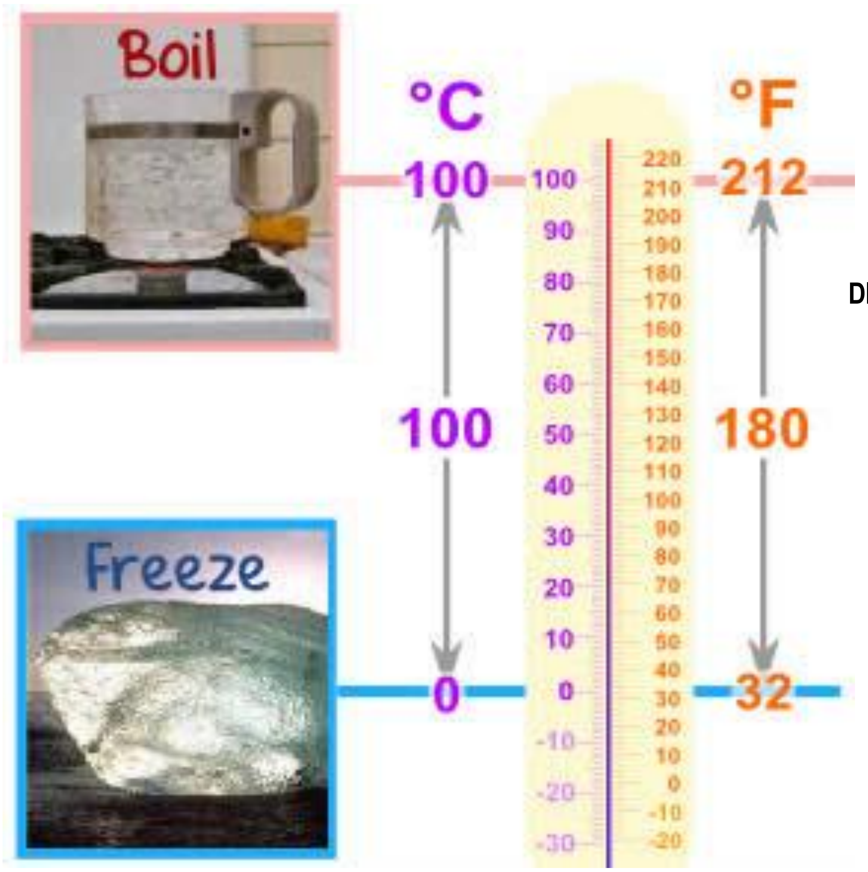
$$? \text{ ft} = \frac{2.31 \text{ ft}}{1 \cancel{\text{psi}}} \times 14 \cancel{\text{psi}} = 32 \text{ ft}$$

Practice Problem calculating height in ft: An elevated tank records a pressure of 25 psi, what is the height of water in the tank?

To calculate **height in ft** from psi:

$$? \text{ ft} = \frac{2.31 \text{ ft}}{1 \cancel{\text{psi}}} \times 25 \cancel{\text{psi}} = \_\_\_\_\_\_ \text{ ft}$$

Temperature Conversions (°F and °C)



DIFFERENCES IN SCALING

- 180ºF versus 100ºC from freezing to boiling
- Freezing point of water is 32ºF versus 0ºC

The Celsius scale reads from 0°, which corresponds to 32 ° F to 100ºC which corresponds to 212° F. The conversion formulas are as follows:

ºC = (º F – 32) x (5/9)

°F = (º C x 1.8) + 32

Example Problem: Convert 39º F to ºC.

ºC = (º F – 32) x (5/9)

ºC = (39 – 32) x (5/9)

$°C = 7 \times \frac{5}{9} = \frac{35}{9} = 3.88$ °C (rounds to 3.9 °C)

If you want to avoid doing math with the 5/9 fraction, here's a way to rearrange the equation to solve for °C:

°F= 1.8 x °C + 32

Step 1: To get °C alone on one side of the equation, subtract 32 from each side of the equation

°F**-32** =1.8 x °C + 32**-32**

Step 2: To get °C alone on one side of the equation, divide by 1.8 from each side of the equation

$\frac{°F-32}{\mathbf{1.8}} = \frac{1.8 \times °C}{\mathbf{1.8}}$

Step 3: Divide 1.8 by 1.8 to equal 1 °C on the right side of the equal sign

$\frac{°F-32}{1.8} = \frac{\cancel{1.8} \times °C}{\cancel{\mathbf{1.8}}}$

$$\mathbf{°C = \frac{°F-32}{1.8}}$$

To solve for °C, there are 2 equations you can use.

Equation 1: °C = (°F – 32) x (5/9)

OR

Equation 2:

$$°C = \frac{°F-32}{1.8}$$

Example: Convert 39° F to °C using equation 2:

$°C = \frac{°F-32}{1.8} = 39-32 = \frac{7}{1.8} = 3.88$ °C (rounds to 3.9)

Practice Problem Solving for °C: Convert 60ºF into °C

$$°C = \frac{°F-32}{1.8} \qquad \frac{60-32}{1.8} = \underline{\qquad} = \underline{\qquad\qquad} °C$$

Now let's convert from °C to ˚F

Example Problem: Convert 4° C to ºF:

ºF = (ºC x 1.8) + 32

ºF = 4 x 1.8 = 7.2 + 32 = 39.2 ˚F

Practice Problem Solving for °F: Convert 20ºC into °F

°F = (ºC X 1.8) +32

ºF = 20 X 1.8 = 36 + 32 = _____˚F

Unaccounted Water Calculation

Terms and Definitions

Consumption—refers to actual (metered) or estimated water uses within a distribution network. Consumption includes metered or estimated customer usage and can also include authorized uses that can be estimated such as firefighting, main flushing, and street cleaning.

Unaccounted-for Water— is the difference between the amount of water produced and the amount of water metered for billing purposes. It generally refers to water used or lost from the distribution network that cannot be estimated such as water lost through leaks, inaccurate meters, or theft of water. Other examples may be sites that never had meters installed such as libraries, schools, and churches. It is recommended that unaccounted-for water should not exceed 15%.

Examples to determine the amount of unaccounted for water are provided below:

Example Problem #1:

ABC water treated 96,000,000 gallons of water during December of 2012. Records indicate that ABC billed 88,673,249 gallons for December of 2012. What is their percent of water loss?

$$96{,}000{,}000 \text{ gallons} - 88{,}673{,}249 \text{ gallons} = 7{,}326{,}751 \text{ gallons}$$

$$\frac{7{,}326{,}751 \text{ gallons}}{96{,}000{,}000 \text{ gallons}} \times 100 = 7.6\,\% \text{ or } 8\% \text{ Unaccounted for water loss}$$

Note: A better term for evaluating and describing water loss is '**non-revenue water**' which is defined as the distributed volume of water that is not reflected in customer billings, specifically the sum of Unbilled Authorized Consumption (water for firefighting, flushing, etc.) plus Apparent Losses (customer meter inaccuracies, unauthorized consumption and systematic data handling errors) plus Real Losses (system leakage and storage tank overflows).

Example Problem #2:

The master meter for a system shows a monthly total of 700,000 gallons. Of the total water, 600,000 gallons were used for billing. Another 30,000 gallons were used for flushing. On top of that, 15,000 gallons were used in a fire episode and an estimated 20,000 gallons were lost to a main break that was repaired that same day. What is the total unaccounted for water loss percentage for the month?

Step 1: Add total gallons accounted for (billed, fire protection, flushing and leaks) as follows:

600,000 + 30,000 + 15,000 + 20,000 = 665,000 gallons accounted for.

Step 2: Subtract "accounted for" from total produced to find "Unaccounted for"

700,000 Master Meter Reading - 665,000 Accounted for Through System = 35,000 Unaccounted for

Step 3: Divide "Unaccounted for" by total produced and multiply by 100 to equal the % unaccounted for

35,000 Unaccounted For = 0.05 x 100 = 5% Unaccounted for
700,000 Master Meter

Practice Problem: In one month a water system produced 5,500,000 gallons of water. Of the total water, 4,500,000 gallons were billed, 250,000 were used for fire protection and 200,000 gallons were used for flushing. What is the total unaccounted for water loss percentage for this month?

Step 1: Add total gallons accounted for (billed, fire protection and flushing)

Gallons Accounted for = ____________(billed) + ________ (fire protection) + _______ (flushing) = ____________

Step 2: Subtract "accounted for" from total produced to find "Unaccounted for"

5,500,000 – __________ (Step 1 Accounted for) = _____________ (Unaccounted for)

Step 3: Divide "Unaccounted for" by total produced and multiply by 100 to equal the % unaccounted for

__________ (Step 2 Unaccounted For) = _____ X 100 = ____% Unaccounted for
5,500,000 (Total Produced)

Area of a Rectangle

Area of a rectangle = Length (L) X Width (W)

Example Problem: The area of a package plant filter unit is 10ft. long by 10 ft. wide. What is the area in square feet?

Area = (L) X (W) = 10 ft. X 10 ft. = 100 ft^2

Practice Problem: The sedimentation basin for the filtration plant is 25 ft. x 15 ft. What is the area in square feet?

Area = (L) X (W) = 25 ft. X 15 ft. = ______ ft^2

Area of a Rectangle – Converting inches to feet

Practice Problem: The filter unit at the plant is 15 ft. 6 inches long, and 15ft. 6 inches wide. What is the area of the filter?

Step 1: Convert inches to feet

The first step in solving this problem is to change the inch units to feet units. The tank is 15 feet. 6 **inches** long, by 15 feet 6 **inches** wide.

$$? \text{ ft} = \frac{1 \text{ ft}}{12 \text{ \sout{inches}}} \times 6 \text{ \sout{inches}} = \frac{6}{12} = \_\_\_\_\_ \text{ ft}$$

Step 2: Add 0.5 ft to the **length** and the **width** and insert into equation and multiply L X W.

Area = (L) X (W) = 15.5 ft X 15.5 ft = **_______** ft^2

Area of a Circle

Area = (0.785) X $(\text{Diameter})^2$

Example Problem: The storage tank for the plant is 30 feet in diameter. What is the area of the tank?

Area = $(0.785)(\text{Diameter})^2 = (0.785)(30\ \text{ft})(30\ \text{ft}) = 706.5\ \text{ft}^2$

Practice Problem: The day tank for the coagulant is 4 feet in diameter, what is the area in square feet?

Area = $(0.785)(\text{Diameter})^2 = (0.785)(4\ \text{ft})(4\ \text{ft})$ = ________ ft^2

Area of a Circle – Converting inches to feet

Practice Problem: The chemical feed tank is 20 inches in diameter, what is the area of the chemical feed tank?

Step 1: Convert inches to feet

$$? \text{ ft} = \frac{1 \text{ ft}}{12 \text{ inches}} \times 20 \text{ inches} = \_\_\_\_\_\_ \text{ ft}$$

Step 2: Insert diameter (in ft) into area formula and do the math.

Area = $(0.785)(D)^2 = (0.785)(1.67\ \text{ft})(1.67\ \text{ft})$ = ______ ft^2

Volume of a Rectangle in ft^3

The formula for volume of a rectangle is length X width X height or depth, or (L)(W)(H or D)

Note: For this equation, the terms “height” and “depth” are interchangeable.

Example Problem: What is the volume of a sedimentation basin that is 25 feet long, 15 feet wide, and 10 feet deep?

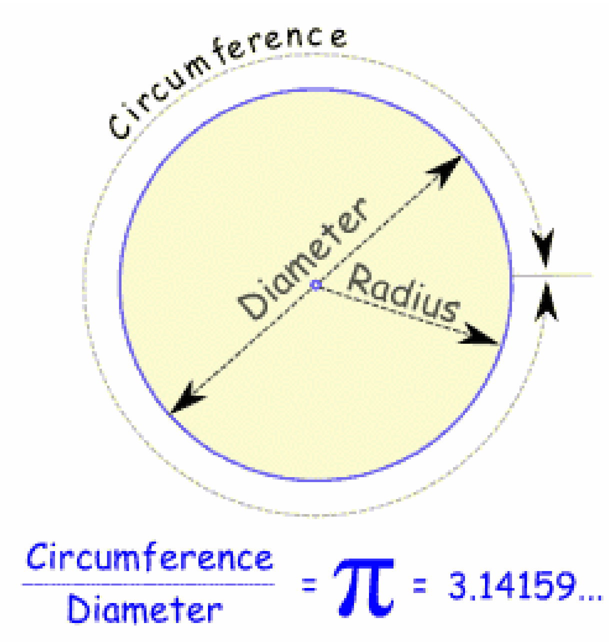
V= (L)(W)(D) = $(25\ \text{ft})(15\ \text{ft})(10\ \text{ft}) = 3750\ \text{ft}^3$

Practice Problem: What is the volume of a clearwell that is 40 feet long, by 40 feet wide, by 12 feet deep?

V = (L)(W)(D) = $(40\ \text{ft})(40\ \text{ft})(12\ \text{ft})$ = ________ft^3

Volume of a Circular Tank in ft^3

Here's the explanation to how we derive the volume calculation for a circular tank.



$$\text{Tank Volume} = \frac{\pi D^2}{4} \times h$$

$$\frac{\pi}{4} = \frac{3.14}{4} = 0.785$$

This is the final equation:

$V = 0.785(DIA)^2(H)$

Example Problem: What is the volume in cubic feet of a tank that is 22 feet in diameter, and filled to 8 feet deep?

$V = 0.785(Dia)^2(H)$

V= 0.785(22 ft)(22 ft)(8 ft)

V= 3039.5 ft^3 or 3040 ft^3

Volume of a Circular Tank in ft^3 – Converting inches to feet

Practice Problem: What is the volume of a day tank that is filled to 3 feet, and is 20 inches wide?

Step 1: Convert inches to feet

$$?ft = \frac{1\ ft}{12\ \cancel{inches}} \times 20\ \cancel{inches} = \_\_\_\_\_\_\ ft$$

Step 2: Insert diameter (in ft) into volume formula and do the math.

$V = 0.785(1.67\ ft)(1.67\ ft)(3\ ft) = \_\_\_\_\_\_\ ft^3$

Volume of a Rectangular Tank – Converting ft^3 to gallons

The problems in the previous examples requested the volume measured in units of cubic feet. More often, the volumes are measured in gallons. The conversion factor to go from cubic feet to gallons is:

$1\ ft^3 = 7.48$ gallons

To convert ft^3 to gallons, use this equation:
Gallons = volume in ft^3 X 7.48

$$\frac{1\ ft^3}{7.48\ gallons}$$

Therefore, if we were asked to calculate the volumes in the previous problems in gallons instead of cubic feet, the solution would require one extra step.

Example Problem: What is the volume in **gallons**, of a sedimentation basin that is 25 feet long, 15 feet wide, and 10 feet deep?

Step 1: Solve the volume equation in ft^3:

$V = (L)(W)(D) = (25\ ft)(15\ ft)(10\ ft) = 3750\ ft^3$

Step 2: Convert ft^3 into gallons:

$$?\ gal = \frac{7.48\ gal}{1\ \cancel{ft^3}} \times \underline{3750\ \cancel{ft^3}} = 28{,}050\ gallons$$

Practice Problem: What is the volume, in gallons, of a tank 40 feet square and filled to 12 feet deep?

Step 1: Solve the volume equation in ft^3:

V= (L)(W)(D) = (40 ft)(40 ft)(12 ft) = _________ ft^3

Step 2: Convert ft^3 into gallons:

$? \text{ gal} = \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \times$ ________ ft^3 = _________gallons

Volume of a Circular Tank – Converting ft^3 to gallons

Example: What is the volume in gallons, of a tank that is 22 feet in diameter, and filled to 8 feet deep?

Step 1: Solve the volume equation in ft^3:

$V = 0.785(Dia)^2(H)$

V=0.785(22 ft)(22 ft)(8 ft)

$V = 3039.5 \text{ ft}^3 = 3040 \text{ ft}^3$

Step 2: Convert ft^3 into gallons:

$? \text{ gal} = \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \times 3040 \text{ ft}^3 = 22{,}739 \text{ gallons}$

Practice Problem: What is the volume, in gallons, of a day tank that is filled to 3 feet, and is 20 inches wide?

Step 1: Convert inches to feet

$?\text{ft} = \frac{1 \text{ ft}}{12 \text{ inches}} \times 20 \text{ inches}$ = _______ft

Step 2: Insert diameter (in ft) into volume formula and do the math.

V = 0.785(1.67 ft)(1.67 ft)(3 ft) = ______ ft^3

Step 3: Convert ft^3 into gallons:

$? \text{ gal} = \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \times 6.6 \text{ ft}^3$ = _________gallons

QUIZ # 1

1. What is the **volume in ft^3**, of a sedimentation basin that is 22 feet long, and 15 feet wide, and filled to 10 feet?

2. What is the **volume in gallons** of a clear well that is 35 feet long, 30 feet wide, and filled to 18 feet?

3. What is the **volume in gallons** of a storage tank that is 20 feet in diameter, and filled to 18 feet?

4. What is the **volume in gallons** of a clear well that is 40 feet 8 inches square, and filled to 12 feet deep?

5. What is the **volume in ft^3** of an elevated clear well that is 17.5 feet in diameter, and filled to 14 feet?

6. What is the **pressure (psi)** at the bottom of an elevated tank filled to 60 feet of water?

7. Convert 80 º F to **ºC**.

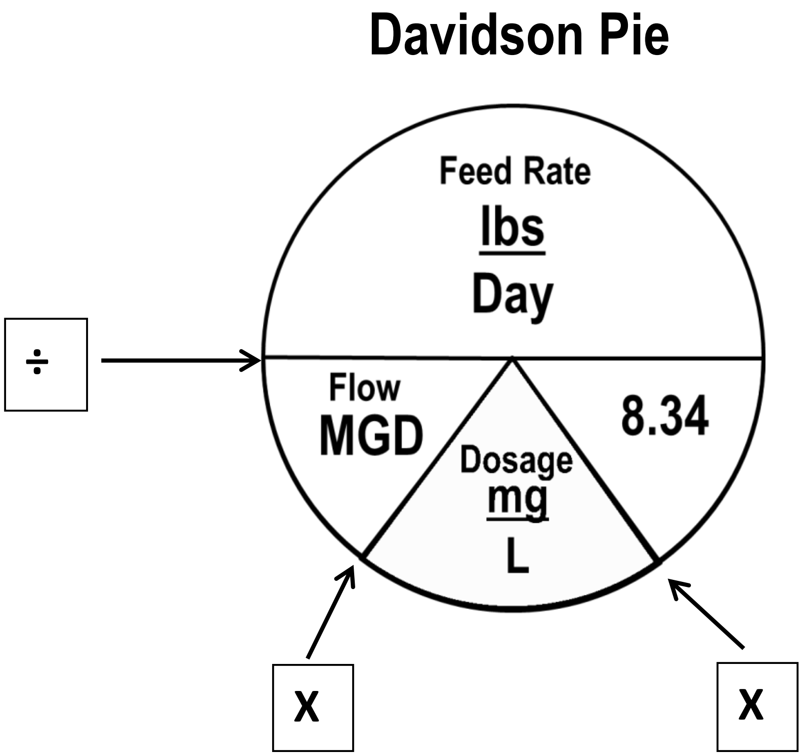
Feed Rate/Dosage/Flow Calculations

Operators need to determine feed rate, dosage and flow calculations. They can do this by using the following equations.

Equation #1: Solving for lbs/day using the Feed Rate Formula

$$\frac{?\text{lbs}}{\text{day}} = \text{Flow(MGD)} \times \text{Dose(mg/L)} \times (8.34)$$

This feed rate formula is represented in the following diagram called the Davidson Pie which was created by Gerald Davidson, Manager, Clear Lake Oaks Water District, Clear Lake Oaks, CA.



Key Acronyms: MG = million gallons or MGD = million gallons per day

Davidson Pie Diagram Interpretation and Formulas

This diagram can be used to solve for 3 different results: dosage, feed rate, and flow (or volume).

As long as you have 2 of those 3 variables, you can solve for the missing variable.

Davidson Pie Interpretation

Middle line = divided by (÷)

Bottom diagonal lines = multiply by (x)

In other words, here are the 3 equations that can be used with these variables:

1. **Feed Rate, lbs/day = Flow (MGD) or Volume (MG) x Dosage (mg/L) x 8.34** (which is the density of water)

2. Flow (MGD) = lbs/day ÷ (Dosage, mg/L x 8.34)

   Vertical Format: Flow(MGD) = <u>Feed Rate (lbs/day)</u>

   [Dosage (mg/L) x 8.34]

3. Dosage (mg/L) = lbs/day ÷ (Flow, MGD x 8.34)

   Vertical Format: Dosage (mg/L) = <u>Feed Rate (lbs/day)</u>

   [Flow(MGD) x 8.34]

Example Problem: If a water treatment plant produces 3 MGD, and uses soda ash to raise the pH, dosed at 7 mg/L, you can calculate how many pounds per day the plant will use.

$\frac{?lbs}{day}$ = Flow(MGD) X Dose(mg/L) X (8.34)

? $\frac{lbs}{day}$ = 3 x 7 x 8.34 = 175 pounds per day

Practice Problem: If a water treatment plant is putting out 14 MGD, and dosing soda ash at the rate of 5 mg/l, how many pounds will they use every day?

$\frac{?lbs}{day}$ = Flow(MGD) X Dose(mg/L) X (8.34)

$\frac{?lbs}{day}$ = 14 X 5 X 8.34 = _______ lbs/day

Practice Problem: If a water treatment plant is making 0.150 MGD, and the chlorine dose is 1.2 mg/l, how many pounds of gas chlorine will they use?

$\frac{?lbs}{day}$ = Flow(MGD) X Dose(mg/L) X (8.34)

$\frac{?lbs}{day}$ = (0.15)(1.2)(8.34) = _____ lbs/day

Converting from GPD to MGD before solving with the formula

Example Problem: If a water treatment plant is making water at the rate of 150,000 gallons per day, and the chlorine dose is 0.8 mg/L, how many pounds of gas chlorine will they use daily?

Step 1: Convert gallons per day into million gallons per day (MGD) using unit cancellation.

$$\frac{?MG}{day} = \frac{1\ MG}{1{,}000{,}000\ \cancel{gallons}} \times \frac{150{,}000\ \cancel{gallons}}{day} = 0.15\ MGD$$

Step 2: Use MGD in feed rate formula to solve for lbs/day

Feed Rate, lbs per day = Flow(MGD) x Dose(mg/L) x 8.34

0.15 x 0.8 x 8.34 = 1 lb/day

Practice Problem: If a water treatment plant is making water at the rate of 300,000 gallons per day, and the chlorine dose is 2.0 mg/l, how many pounds of gas chlorine will they use daily?

Step 1: Convert gallons per day into million gallons per day (MGD) using unit cancellation.

$$?\frac{MG}{day} = \frac{1\ MG}{1{,}000{,}000\ \cancel{gallons}} \times \frac{300{,}000\ \cancel{gallons}}{day} = \_\_\_\_\_\_\_\ MGD$$

Step 2: Use MGD in feed rate formula to solve for lbs/day

Feed Rate, lbs per day = Flow(MGD) x Dose(mg/L) x 8.34

0.30 x 2.0 x 8.34 =_____ lb/day

Converting from GPM to MGD before solving with the formula

Example: A water treatment plant operates at the rate of 75 gallons per minute. They dose soda ash at 14 mg/L. How many pounds of soda ash will they use in a day?

Step 1: Convert gallons per minute into million gallons per day (MGD) using unit cancellation.

$$?\frac{MG}{day} = \frac{1\ MG}{1{,}000{,}000\ \cancel{gallons}} \times \frac{75\ \cancel{gal}}{\cancel{minute}} \times \frac{1440\ \cancel{minutes}}{day} = 0.108\ \frac{MG}{day}$$

Step 2: Use MGD in feed rate formula to solve for lbs/day

Feed Rate, lbs per day = Flow(MGD) x Dose(mg/L) x 8.34

0.108 x 14 x 8.34 = 12.6 lb/day

Practice Problem: A water treatment plant operates at the rate of 200 gallons per minute. They dose soda ash at 5 mg/L. How many pounds of soda ash will they use in a day?

Step 1: Convert gallons per minute into million gallons per day (MGD) using unit cancellation.

$$?\frac{MG}{day} = \frac{1\ MG}{1{,}000{,}000\ \cancel{gallons}} \times \frac{200\ \cancel{gal}}{\cancel{minute}} \times \frac{1440\ \cancel{minutes}}{day} = \_\_\_\_\_\_\ \frac{MG}{day}$$

Step 2: Use MGD in feed rate formula to solve for lbs/day

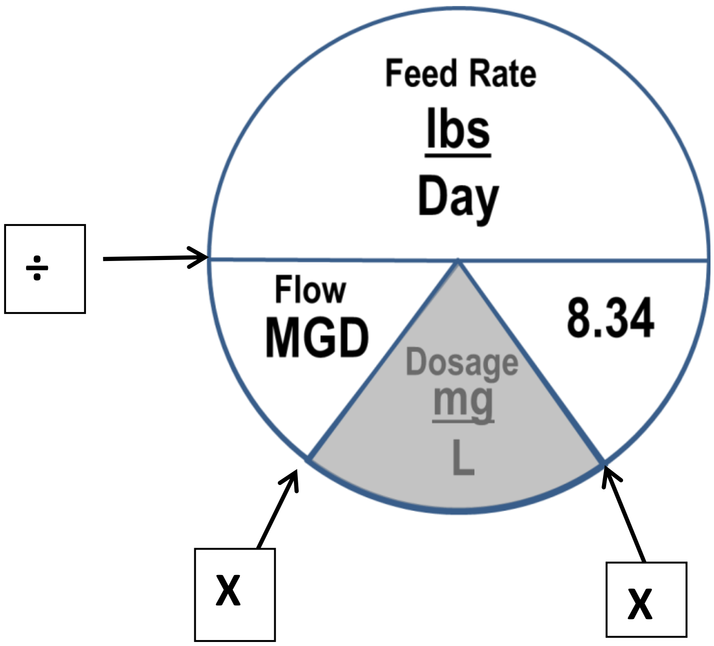
Feed Rate, lbs per day = Flow(MGD) x Dose(mg/L) x 8.34

0.288 x 5 x 8.34 =_______lb/day

Equation #2: Solving for Dose (mg/L) using the Feed Rate Formula

An operator can also use the pie chart formula to calculate the dose if the known factors are the feed rate in pounds per day, and the flow rate.

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate, (lbs/ day)}}{\text{Flow(MGD)(8.34)}}$$



Example Problem: A water treatment plant is producing 1.5 million gallons per day of potable water, and uses 38 pounds of soda ash for pH adjustment. What is the dose of soda ash at that plant?

Step 1: Set up the variables in vertical format and insert known values

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate, lbs/day}}{\text{(Flow, MGD)(8.34)}} = \frac{38 \text{ lbs/day}}{(1.5)(8.34)}$$

← **Known feed rate** (38 lbs/day)

Known Flow (MGD) (1.5)

Step 2: Multiply 1.5 x 8.34 in the denominator = 12.51 (basic math rule)

Step 3: Perform the **DOSE** division: $\frac{38 \text{ (numerator)}}{12.51 \text{ (denominator)}} = 3.03 \frac{mg}{L}$

Practice Problem: A water treatment plant produces 150,000 gallons of water every day. It uses an average of 2 pounds of permanganate for iron and manganese removal. What is the dose of the permanganate?

Step 1: Set up the variables in vertical format.

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate, lbs/day}}{\text{(Flow, MGD)(8.34)}}$$

Step 2: Insert known values into equation.

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate, lbs/day}}{\text{(Flow, MGD)(8.34)}} = \frac{\text{(2) lbs/day}}{(0.15)(8.34)}$$

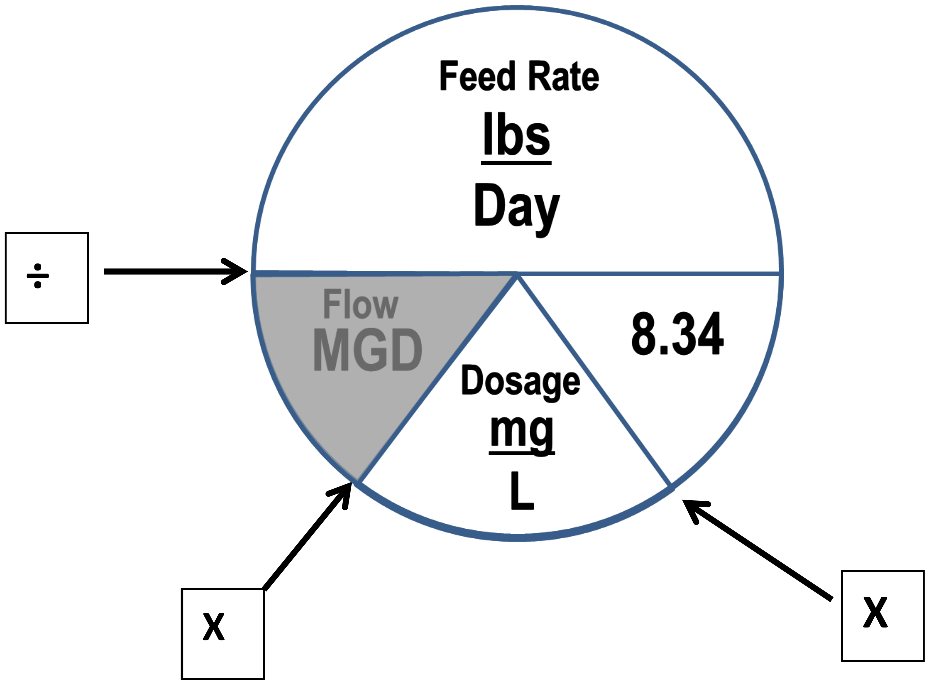
Step 3: Multiply 0.15 x 8.34 in the denominator = _______ (basic math rule)

Step 4: Perform the **DOSE** division: $\frac{\text{2 (numerator)}}{\text{1.25 (denominator)}} =$ _____ $\frac{mg}{L}$

Equation #3: Solving for Flow (MGD) using the Feed Rate Formula

Lastly, the pie chart formula can be used to calculate the flow if the dose and feed rate in pounds per day are known factors.

Example Problem: A water treatment plant uses 14 pounds of chlorine gas to treat their water daily. The chlorine dose is 1.5 mg/l. What is their flow rate in MGD?



Remember: Middle line represents a division sign (÷)
Bottom diagonal lines = multiply by (x)

Vertical Format: **Flow, MGD =** $\dfrac{\textbf{Feed Rate, lbs/per day}}{\textbf{(Dose, mg/L)(8.34)}}$

Example Problem: A water treatment plant uses 14 pounds of chlorine to treat their water daily. The chlorine dose is 1.5 mg/l. What is their flow rate in MGD?

Step 1: Set up the variables in vertical format and insert known values

? Flow (MGD) = $\frac{\text{Feed Rate, lbs/day}}{(\text{Dose})(8.34)}$ = $\frac{\text{14 lb/day}}{(1.5)(8.34)}$ ← **Known feed rate**

↑ **Known Dose**

Step 2: Multiply 1.5 x 8.34 in the denominator = 12.51 (basic math rule)

Step 3: Perform the **FLOW** division: $\frac{\text{14 (numerator)}}{\text{12.51 (denominator)}}$ = 1.1 MGD

Practice Problem: A water treatment plant uses 8 pounds of chlorine daily and the dose is 17 mg/l. How many gallons are they producing?

Step 1: Set up the variables in vertical format and insert known values

? Flow (MGD) = $\frac{\text{Feed Rate, lbs/day}}{(\text{Dose})(8.34)}$ = $\frac{\text{(8) lb/day}}{(\underline{17})(8.34)}$

Step 2: Multiply 17 x 8.34 in the denominator = _______ (basic math rule)

Step 3: Perform the **FLOW** division: $\frac{\text{8 (numerator)}}{\text{141.78 (denominator)}}$ = ________ MGD

Unit Cancellation Steps to solve for gallons/day

? $\frac{\text{gallons}}{\text{day}}$ = $\frac{\text{1,000.000 gallons}}{\text{1 } \cancel{\text{MG}}}$ x $\frac{0.056425\ \cancel{\text{MG}}}{\text{day}}$ = $\frac{\text{56,425 gallons}}{\text{day}}$

Quiz # 2

1. How many **pounds per day** will be required if the dose is 13 mg/L, and the flow treated is 1 MGD?

2. How many **pounds per day** will be required if the dose is 13 mg/L, and the flow is at the rate of 695 gpm?

3. How many **pounds per day** will be needed to dose 335,000 gallons of water at 4 mg/L?

4. What is the **dose** if 2.5 MGD were treated with 31 pounds of chlorine?

5. How many **pounds** will be required if the flow is 95 gpm, and the dose is 7 mg/L, and the plant runs for 12 hours per day?

Practice problems:

1. How many **pounds per day** will be used when the dose is 5 mg/L, and the flow rate is 350 gpm?

2. How many **pounds per day** will be needed if the flow rate is 80,000 gpd, and the dose is 25 mg/L?

3. How many **pounds per day** will be used if the flow rate is 47 gpm through each filter, and there are 2 filters, and the dose is 7 mg/L?

4. How many **pounds per day** will be used if the flow rate is 50 gpm, the dose is 4 mg/L, and the plant operates for 16 hours each day?

5. What is the **dose** if the total water treated is 650,000 gallons, and 22 pounds of chemical was used?

6. What is the **dose** if the plant uses 120 pounds of chemical each day to treat 1,350,000 gallons daily?

7. What is the **dose** if the operator uses 18 pounds of chemical to treat 650,000 gpd?

Feed Rate Calculations Using Flow with a % Strength (i.e., % pure) Solution

Unlike chlorine gas, sodium and calcium hypochlorite solutions are not 100 percent pure. For example, the sodium hypochlorite typically used is 12.5% pure. That means that out of every gallon of hypochlorite, only 12.5% is the chlorine component, and the other material (87.5%) is not chlorine.

Example Problem: A water plant uses sodium hypochlorite (12.5%) to disinfect the water. The target dose is 1.2 mg/L. They treat 0.25 million gallons per day. How many pounds of sodium hypochlorite will need to be fed?

Step 1: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

Using the formula pounds per day = flow x dose x 8.34 = (0.25)(1.2)(8.34) = 2.5 pounds of chlorine is required.

Step 2: Calculate # of pounds of 12.5% solution needed to achieve Step 1 feed rate.

Since they are using hypochlorite, and only 12.5 % of the hypo is chlorine, we need to calculate how many pounds of hypo are required to get 2.5 pounds of chlorine. To do that we need to change the percent to a decimal, and divide that into the pounds required.

a) Convert % purity of solution into a decimal:

$$\frac{12.5\ \%}{100\%} = 0.125$$

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$$\frac{2.5\ \text{pounds}}{0.125\ (\%\ \text{purity as a decimal})} = 20\ \text{pounds of}\ 12.5\ \%\ \text{hypochlorite.}$$

TIP: Answer will always be more pounds than Step 1 result because solution is not 100% pure.

Practice Problem: A water plant uses 15% sodium hypochlorite to disinfect the water. The dose is 1.2 mg/L. They treat 0.25 million gallons per day. How many pounds of sodium hypochlorite will need to be fed?

Step 1: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

? Pounds per day = flow x dose x 8.34 = (0.25)(1.2)(8.34) = 2.5 pounds of chlorine is required.

Step 2: Calculate # of pounds of 15% solution needed to achieve Step 1 feed rate.

a) Convert % purity of solution into a decimal:

$\frac{15\%}{100\%}$ = _______

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$\frac{\text{2.5 pounds}}{\text{0.15 (\% purity as a decimal)}}$ = ______ lbs of 15% hypochlorite.

TIP: Answer will always be more pounds than Step 1 result because solution is not 100% pure.

Practice Problem: A water plant doses liquid alum at 5 mg/L and treats 1.5 MGD. How many pounds of liquid alum will be required daily to do this? Liquid alum is 48½% pure.

Step 1: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

? Pounds per day = flow x dose x 8.34 = (1.5)(5)(8.34) = _____ lbs of alum.

Step 2: Calculate # of pounds of 15% solution needed to achieve Step 1 feed rate.

a) Convert % purity of solution into a decimal:

$\frac{48.5\%}{100\%}$ = _______

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$\frac{\text{62.55 pounds}}{\text{0.485 (\% purity as a decimal)}}$ = ________ lbs of 48.5 % liquid alum.

Feed Rate Calculations Using Volume with a % Strength (i.e., % pure) Solution

Notice that you can also use this first equation and substitute **volume** for flow. Let's look at a problem that uses volume instead of flow. **In addition, the feed rate is determined in pounds, rather than pounds per day.**

Example Problem: How many pounds of 65% calcium hypochlorite will be required to disinfect a 5,000 gallon tank with a residual of 50 mg/l?

Step 1: Convert volume (in gallons) into MG so that the feed rate formula can be used.

$$?MG = \frac{1\ MG}{1,000,000\ \not{gal}} \times 5,000\ \not{gal} = 0.005\ MG$$

Step 2: Solve for pounds (feed rate) for 100 % pure chemical (no impurities).

? lbs = volume(MG) x dose(mg/L) x 8.34 = (0.005)(50)(8.34) = 2.085 pounds of chlorine is required.

Step 3: Calculate # of pounds of 65% solution needed to achieve Step 2 feed rate.

a) Convert % purity of solution into a decimal:

$$\frac{65\%}{100\%} = 0.65$$

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$$\frac{2.085\ \text{pounds}}{0.65\ (\text{\% purity as a decimal})} = 3 \text{ pounds of 65\% hypochlorite.}$$

Practice Problem: Calculate the amount of calcium hypochlorite to dose a 500,000 gallon storage tank to a dose of 25 mg/L using granular calcium hypochlorite that indicates it is 65% chlorine.

Step 1: Convert volume (in gallons) into MG so that the feed rate (lbs) formula can be used.

$$?MG = \frac{1\ MG}{1{,}000{,}000\ gal} \times (500{,}000)\ gal = \_\_\_\_\_\_\ MG$$

Step 2: Solve for pounds per day (feed rate) for 100 % pure chemical (no impurities).

? lbs = volume(MG) x dose(mg/L) x 8.34 = (0.5)(25)(8.34) = ________ lbs of chlorine is required.

Step 3: Calculate # of pounds of 65% solution needed to achieve Step 2 feed rate.

a) Convert % purity of solution into a decimal:

$$\frac{65\%}{100\%} = \_\_\_\_\_\_$$

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$$\frac{104.25\ pounds}{0.65} = \_\_\_\_\_\_\ \text{lbs of 65\% calcium hypochlorite.}$$

Summary of Steps for Solving Feed Calculations (in lbs/day) for % Strength (i.e., % Purity) Solutions (using either volume or flow rate)

Example: Calculate the amount of calcium hypochlorite required to dose a 500,000 gallon storage tank to a dose of 25 mg/L using granular calcium hypochlorite that indicates it is 65% chlorine.

Step 1: Convert volume (in gallons) into MG **or** flow in gallons (per day or per minute) into MGD so that the feed rate (lbs or lbs/day) formula can be used.

$$?MG = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \text{volume of tank } (\cancel{gal})$$ **OR**

$$?MGD = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \frac{\text{volume of flow } (\cancel{gal})}{1\ day}$$ **OR**

$$?MGD = \frac{1\ MG}{1{,}000{,}000\ \cancel{gal}} \times \frac{\text{volume of flow } (\cancel{gal})}{1\ \cancel{min}} \times \frac{1440\ \cancel{min}}{day}$$

Step 2: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities). (104.25 pounds for this example)

? lbs = volume (MG) x dose (mg/L) x 8.34 = pounds of chlorine that are required.

Step 3: Calculate # of pounds of % solution needed (in this example, 65%) to achieve Step 2 feed rate.

a) Convert % purity of solution into a decimal:

$$\frac{65\%}{100\%} = 0.65$$

b) Then divide the pounds needed (feed rate of 100% pure chemical) by the % purity of the solution (as a decimal).

$$\frac{104.25 \text{ pounds}}{0.65} = 160.39 \text{ pounds of 65\% calcium hypochlorite.}$$

TIP: Answer will always be more pounds than Step 2 result because solution is not 100% pure.

Calculating "Active Ingredient" Weight

In addition to knowing that solutions are not 100% pure (i.e. 100% active), we also need to determine the weight of the active strength ingredients within that solution.

Active ingredient weight is the number of pounds of "active ingredient" per gallon of a % solution that cause a chemical reaction.

- This "active ingredient" weight value is then used in a calculation with the 100% pure "lbs/day" feed rate to determine the "gal/day" feed rate.

We need the specific gravity of the solution which is found on the SDS sheet to calculate the weight of a solution.

Calculating the Weight of the "Active Ingredient" of a % Solution Chemical

EXAMPLE: How many pounds of chlorine are there in a gallon of sodium hypochlorite that is 12.5% pure that has a specific gravity of 1.15?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.15 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = 9.59 \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the "active ingredient" weight of the solution based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{12.5}{100} = 0.125$$

b) Multiply the weight of a gallon (from step 1) by the % purity of the product (as a decimal).

$9.59 \frac{\text{pounds}}{\text{gallon}} \times 0.125 = 1.2$ pounds of available chlorine in a gallon of 12.5 % sodium hypochlorite

This active ingredient weight provides the pounds of available chlorine that is found in each gallon of 12.5% sodium hypochlorite solution. Within the 9.59 pounds of 12.5% sodium hypochlorite, there are **1.2 pounds of available chlorine (i.e., active ingredient).**

Calculating the Weight of the "Active ingredient" of a % Solution Chemical

Practice Problem: How many pounds of caustic soda are there in a gallon of caustic soda that is 25% pure that has a specific gravity of 1.28?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.28 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = \underline{\qquad} \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the "active ingredient" weight of the caustic soda based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{25\%}{100\%} = \underline{\qquad}$$

b) Multiply the weight of a gallon (from step 1) by the % purity of the product (as a decimal).

$10.67 \frac{\text{pounds}}{\text{gallon}} \times 0.25 = \underline{\qquad}$ pounds of caustic soda in a gallon of 25% caustic soda solution

This "active ingredient" weight provides the pounds of available caustic soda that is found in each gallon of 25% caustic soda solution. Within the 10.67 pounds of 25% caustic solution, there are 2.66 pounds of active ingredients.

Now that we know the active ingredient weight of the solution, we can use this information to determine how many gallons we need to feed. We'll use unit cancellation to determine the number of gallons/day from the lbs/day feed rate.

Using "Active Ingredient" Weight to Convert Feed Rate from lbs/day to gal/day

Example: A water plant uses sodium hypochlorite (12%) to disinfect the water which provides 1.2 lbs/gal of available chlorine ("active ingredient" weight). The required dosage is 2.5 mg/L. They treat 118,000 gallons per day. How many **gallons** of sodium hypochlorite will need to be fed?

Step 1: Convert flow in gallons (per day) into MGD so that the feed rate (lbs/day) formula can be used.

$$? \text{ MGD} = \frac{1 \text{ MG}}{1{,}000{,}000 \not{\text{gal}}} \times \frac{118{,}000 \ (\not{\text{gal}})}{1 \text{ day}} = 0.118 \text{ MGD}$$

Step 2: Solve for pounds per day (feed rate) for 100% pure chemical (no impurities).

? Pounds per day = flow x dose x 8.34 = (0.118)(2.5)(8.34) = 2.46 pounds of chlorine is required.

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gals/day**

Active Ingredient Weight of 12% hypo solution

Feed Rate of 100% pure chlorine

NOTE: Inverted weight so that gallon unit was in numerator to position the numerator

$$? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gallon}}{1.2 \text{ lbs}} \times \frac{2.46 \text{ lbs}}{\text{day}} = 2.05 \frac{\text{gal}}{\text{day}}$$

NOTE: When you are given the "active ingredient" weight of a solution to solve a feed rate problem, you do not need to use the % purity factor because it was used derive the active ingredient weight.

Practice Problem: A water plant uses sodium hypochlorite (12.5%) to disinfect the water which provides 1.2 lbs/gal of available chlorine ("active ingredient" weight). The chlorine dosage is 1.6 mg/L. They treat 600,000 gallons per day. How many **gallons** of sodium hypochlorite will need to be fed?

Step 1: Convert flow in gallons (per day) into MGD so that the feed rate (lbs/day) formula can be used.

$$? \text{ MGD} = \frac{1 \text{ MG}}{1{,}000{,}000 \ \cancel{\text{gal}}} \quad \text{X} \quad \frac{600{,}000 \ (\cancel{\text{gal}})}{1 \ \text{day}} = \_\_\_\_ \text{MGD}$$

Step 2: Solve for pounds per day (feed rate) for 100 % pure chemical (no impurities).

? pounds per day = flow x dose x 8.34 = (0.6)(1.6)(8.34) = ____ pounds of chlorine is required.

Step 3: Use "active ingredient" weight with unit cancellation steps to convert lbs/day to **gal/day**

Active Ingredient Weight of 12.5% hypo solution

Feed Rate of 100% pure chlorine

$$? \frac{\text{gal}}{\text{day}} = \frac{1 \text{ gallon}}{1.2 \text{ lbs}} \quad \text{x} \quad \frac{8 \ \text{lbs}}{\text{day}} = \_\_\_\_\_ \ \frac{\text{gal}}{\text{day}}$$

NOTE: When you are given the "active ingredient" weight of a solution to solve a feed rate problem, you do not need to use the % purity factor because it was used to derive the active ingredient weight.

Quiz: 3

1. How many **pounds** of alum (48.5 %) are required to treat 0.75 MGD with a dose of 12 mg/L?

2. How many **pounds** of calcium hypochlorite (65 %) are needed to treat 500,000 gallons per day with a dose of 2 mg/L?

3. How many **pounds** of sodium hypochlorite (12½ %) are needed to treat a flow of 150 gallons per minute at a dose of 0.7 mg/L?

4. How many **pounds** of caustic soda are needed to dose water at 17 mg/L if you are treating 1,400,000 gallons per day? The caustic soda concentration is 50 percent.

5. How many **pounds** of chlorine gas are required to treat 750,000 gallons of water to a dose of 50 mg/L for a 24 hour period?

6. A treatment plant uses 12.5% hypochlorite to disinfect the water. The required hypochlorite dosage is 2 mg/L and the plant flow is 300,000 gpd. How many **gallons** of 12.5% hypochlorite are required (12.5% hypo has 1.25 lbs/gal available chlorine)?

Calculating the Weight of a Solution

Another consideration in water chemistry calculations is the weight of the product being used. For example, the weight of a gallon of water is 8.34 pounds. We learned earlier that there are 7.48 gallons in a cubic foot of water.

Example Problem: What would be the weight of a cubic foot of water?

$$? \frac{lbs}{ft^3} = 8.34 \frac{lbs}{\cancel{gal}} \times 7.48 \frac{\cancel{gal}}{ft^3} = \frac{62.4 \text{ lbs}}{ft^3}$$

Practice Problem: What would be the weight of 100 gallons of water?

$$? \text{ lbs} = 8.34 \frac{lbs}{gal} \times 100 \text{ gal} = \_\_\_\_\_\_ \text{ lbs}$$

Using Specific Gravity to calculate the weight of a solution

To calculate the weight of various chemicals we need to factor in the specific gravity of the chemical being used. Specific gravity is the weight of a substance compared to the weight of a gallon of water. Specific gravity information is found on the Safety Data Sheets (SDS) and is used to calculate the weight of a substance.

Total Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

Example Problem: The specific gravity for liquid alum is 1.33. How much does a gallon of liquid alum weigh?

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$? \frac{lbs}{gal} = 1.33 \times 8.34 \frac{lbs}{gal} = 11.09 \frac{lbs}{gal}$$

The weight of a gallon of alum is 11.09 pounds.

Practice Problem: What is the weight of a gallon of sodium hypochlorite if the specific gravity is 1.11?

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$? \frac{lbs}{gal} = 1.11 \times 8.34 \frac{lbs}{gal} = \_\_\_\_ \frac{lbs}{gal}$$

Practice Problem: What is the weight of a gallon of crankcase oil if the specific gravity is 0.89?

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$? \frac{lbs}{gal} = 0.89 \times 8.34 \frac{lbs}{gal} = \_\_\_\_ \frac{lbs}{gal}$

Calculating the weight of a drum

If you want to determine the weight of a drum or tank of solution, you must include that volume in your calculation.

Drum Weight, lbs = (gallons of drum or tank) x (S.G.) x (8.34 lbs/gal)

Example Problem: What would be the weight of a 55 gallon drum of the coagulant Sternpac if the specific gravity of the product is 1.27?

Drum Weight, lbs = (gallons of drum or tank) x (S.G.) x (8.34 lbs/gal)

? Drum weight, lbs = 55 x 1.27 x 8.34 = 583 lbs

Practice Problem: What would be the weight of a 50 gallon drum of 50% caustic soda if the specific gravity of the product is 1.53

Drum Weight, lbs = (gallons of drum or tank) x (S.G.) x (8.34 lbs/gal)

? Drum weight, lbs = 50 x 1.53 x 8.34 = _____ lbs.

Remember during our feed rate section that we introduced the concept of calculating the weight of the "active ingredient" to then convert the lbs/day feed rate into a "gal/day" feed rate.

We'll practice calculating this active ingredient weight on another product on the next page.

Calculating the Weight of the "Active Ingredient" of a % Solution Chemical

EXAMPLE: How many pounds of chlorine are there in a gallon of sodium hypochlorite that is 12.5% pure that has a specific gravity of 1.15?

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.15 \times 8.34 \frac{\text{pounds}}{\text{gallon}} = 9.59 \frac{\text{pounds}}{\text{gallon}}$$

Step 2: Determine the "active ingredient" weight of the solution based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{12.5}{100} = 0.125$$

b) Multiply the weight of a gallon (from step 1) by the % purity of the product (as a decimal).

$9.59 \frac{\text{pounds}}{\text{gallon}} \times 0.125 = 1.2$ pounds of available chlorine in a gallon of 12.5 % sodium hypochlorite

This active ingredient weight provides the pounds of available chlorine that is found in each gallon of 12.5% sodium hypochlorite solution. Within the 9.59 pounds of 12.5% sodium hypochlorite, there are **1.2 pounds of available chlorine (i.e., active ingredient).**

Practice Problem: What is the active ingredient weight of 48.5% alum that has a specific gravity of 1.33.

Step 1: Solve weight equation (lbs/gal) for 1 gallon of chemical

Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water)

$$1.33 \times 8.34 \frac{\text{lbs}}{\text{gal}} = 11.09 \frac{\text{lbs}}{\text{gal}}$$

Step 2: Determine the "active ingredient" weight of the solution based on the % purity of solution

a) Convert % purity of solution into a decimal:

$$\frac{48.5}{100} = 0.485$$

b) Multiply the weight of a gallon (from step 1) by the % purity of the product (as a decimal).

$$11.09 \frac{\text{lbs}}{\text{gal}} \times 0.485 = \underline{5.37}$$ pounds of available alum in a gallon of 48.5 % alum

<u>Calculating the active ingredient weight of a drum of solution</u>

You can also calculate how many pounds of active ingredients there are in drum or tank of a liquid product.

? lbs of active ingredient within drum = drum volume (gal) x active ingredient weight (lbs/gal)

Example Problem: How many pounds of active ingredient are there in a 55 gallon drum of liquid alum if the product is 48½ percent pure with a specific gravity of 1.33 and the active ingredient weight is 5.37 lbs of alum/gal of product?

? lbs of active ingredient within drum = active ingredient weight (lbs/gal) X drum volume (gal)

? lbs of active ingredient within drum = $5.37 \frac{\text{lbs}}{\text{gal}} \times 55 \text{ gal}$

= <u>295.8</u> lbs of active ingredient (alum) within the 48.5% solution

Alternative Method of Calculating Active Ingredient Weight of a Drum:

Example Problem: How many pounds of active ingredient are there in a 55 gallon drum of liquid alum if the product is 48½ percent pure with a specific gravity of 1.33 and the active ingredient weight is 5.37 lbs of alum/gal of product?

Step 1: Solve weight equation (lbs/gal) for the drum

Drum Weight, lbs = (gallons of drum or tank) x (S.G.) x (8.34 lbs/gal)

? Drum Weight, lbs = 55 gal X 1.33 X 8.34

= 610 lbs

Step 2: Determine the "active ingredient" weight of the solution based on the % purity of solution

a) Convert % purity of solution into a decimal:

$\frac{48.5}{100} = 0.485$

b) Multiply the weight of the drum (from step 1) by the % purity of the product (as a decimal).

610 lbs X 0.485 = 295.8 lbs of active ingredient (alum) within the 48.5% alum solution

Now that you are familiar with many of the math calculations, we'll review some math question exam tips on the next page.

Math Question Exam Tips

- Read each question carefully and look for the following:

1. The **answer's units** (e.g., lbs, lbs/day, gal, gal/day). **Look at the units for each answer choice if you can't find the units in the question** to determine if you are solving for "lbs" or "gallons" so that you can use the appropriate equation and conversions.

2. **% solutions** (convert each % to a decimal) and use it in 2 different ways:

   - When solving for the lbs of "active ingredient" weight within a % solution in a drum that contains a specific gravity (SG), use this formula:

     Drum Volume X SG X 8.34 X % solution as a decimal. (same equation as 3b)

   - When solving for a feed rate (in **lbs or lbs/day**) of a % solution chemical, use this formula:

     $$\frac{\text{lbs of \% solution}}{\text{day}} = \frac{\text{100\% feed rate}}{\text{\% solution as a decimal}}$$ (using Davidson pie feed rate formula)

     TIP: This number of lbs of % solution/day will **ALWAYS be greater than the 100% feed rate** because the solution is less than 100%.

3. **Specific Gravity (SG)** is used in 2 ways:

   a. To determine the **total weight** (in lbs) of a gallon of product or of a drum of product:

   Total Weight of a liquid, lbs = gallons (single gallon or many gallons within a drum) X SG X 8.34

   b. To calculate the **"active ingredient"** weight of a single gallon or within a drum:

   Active Ingredient Weight within Drum = Drum Volume X SG X 8.34 X % solution as a decimal. (i.e., Total Weight X % solution as a decimal)

NOTE: Both ways start with solving for the total weight (Drum Vol X SG X 8.34). When solving for "active ingredient" weight, you have to then multiply by % solution as a decimal.

4. **Available lbs of chlorine/gal of solution** is used to convert the "100%" lb/day feed rate into its "gal/day" feed rate using this formula

   gal = "100%" lb feed rate (using Davidson pie feed rate formula)
   day   available Cl_2 lbs (e.g., 1.2 or 1.4 lbs of chlorine/gallon of hypochlorite)

5. Determine if the question is a **feed rate question** by looking for the necessary items:
Dose (given in mg/L or calculated by adding chlorine demand + chlorine residual) **AND**
Flow or Volume (given in gpm, gpd or MGD) **Remember to convert to MGD.**

You use the same Davidson pie feed rate formula when the problem is based on how much chlorine you add to disinfect a tank. (i.e., solving for a volume, not a flow)

6. Whether there are "**variations**" in the question like **partial tank volumes**, **partial days**, or **multiple days**.

- Don't be fooled by seeing an answer that looks correct; especially if you have **multiple calculation steps.**
  - **Example 1:** One of the answer choices reflects the "100%" **lb feed rate** value but the question involves a % solution which means you have to divide the "100" lb feed rate by % solution as a decimal.
  - **Example 2:** One of the answer choices reflects the "100%" **lb feed rate** value but the question is asking for the "**gal/day**" not lbs/day. To solve for gal/day, you have to divide the "100" lbs feed rate by the available lbs of chlorine/gal of product. (i.e, "active ingredient" weight).
  - **Example 3:** One of the answer choices reflects the correct answer in "**hrs**" but the calculation solves the problem in "**minutes**" so the correct answer needs to be multiplied by 60. (Calculating CT)
  - **Example 4:** One of the answer choices reflects the lbs/day feed rate but the question asks for lbs in **30 days** so the correct answer needs to be multiplied by 30.
  - **Example 5:** One of the answer choices reflects the lbs/day feed rate but the question asks for **lbs/hr** so the correct answer needs to be divided by 24.
  - **Example 6:** One of the answer choices reflects the lbs feed rate for the full tank volume but the question asks for a partial tank volume, like **½** or **¾ full** so the correct answer has to be multiplied by the partial tank volume.
  - **Example 7:** One of the answer choices reflects the total drum weight but the question is asking for the **"active ingredient" weight** so you have to multiply the total drum weight by % solution as a decimal.

Formula and Conversion Sheets

- Review each formula and place a checkmark beside each formula that you used in class or while doing math problems within the modules. This eliminates the formulas you don't need to use.

The following statements are made based on the **General Exam, Hypo, Gas, and Chem Add** subclass exams. As we review each page, record the **exam name** beside the correct formula.

Page 3:

- Area of a rectangle and circle.
- Volume of Rectangular Tank (ft^3) and the conversion from ft^3 to gallons is needed for **Chem Add.**
- Volume of a cylinder.
- Volume of a treatment vessel converts ft^3 into gallons.
- Chlorine Demand or Chlorine Dose is needed for **Hypo** and **Gas.**
- CT is needed for **Hypo** and **Gas.**
- Detention time formula is needed for **Hypo** and **Chem Add**.
- Dilution formula is needed for **Hypo.**
- Last formula on page 1 is for "**Dose**" which is one of the 3 formulas you can use with the Davidson Pie (last page of formulas) – Needed for **Gas**

Page 4:

- Dry chemical (lbs) is needed for **Chem Add.**
- Feed Rate (lbs/day) is the written formula pictured in the Davidson Pie diagram on the last page. - Needed for **Chem Add, Hypo & Gas.**
- Feed Rate (gal/day) is needed for **Hypo and Chem Add.**
- Weight of liquid (last formula) is needed for **General Exam and Chem Add**.
- Weight of active ingredient is needed for **Chem Add**.

Page 7:

- Review the conversion factors and place a checkmark beside each conversion you have used.
- 1 psi = 2.31 ft is needed for **General Exam**.

Page 8:

- 7.48 gal = 1 cu ft (ft^3) is needed in **Chem Add**
- 1 day = 1440 is needed to convert gpm to MGD in **Hypo and Chem Add**

Page 9:

- Ignore this page unless you need to be reminded of what **GPM**, **GPD** and **MGD** mean.

Page 10:

- Review the "Davidson Pie" on the last page if you are taking **Chem Add, Hypo or Gas** or any subclass exam that involves feed rate math (either as lbs/day or lbs for a tank volume).

Here are a few concepts you have to know when you are doing math calculations.

Formulas or Concepts You Must Memorize for Math Calculations:

Hypo, Chem Add or Gas Feed Rate Equations:

Converting gpm into MGD using this formula: $\frac{\text{gpm X 1440}}{\text{1,000,000}}$

Converting gpd into MGD using this formula: $\frac{\text{gpd}}{\text{1,000,000}}$

You don't need to memorize the *Detention Time (mins) = $\frac{\text{Volume of Tank (gallons)}}{\text{Influent flow (gpm)}}$

*However, be sure to convert MGD flow to **gpm** using this formula: $\frac{\text{MGD X 1,000,000}}{\text{1440}}$

Chlorine dose = chlorine demand + chlorine residual

When using the Dilution formula, here's the final step:

? gals = $\frac{\textbf{Known Gal X Known\% (whole \#)}}{\textbf{Unknown\% (whole \#)}}$

Determining a reduced feed rate when the flow decreases:

? Reduced Feed Rate = $\frac{\textbf{(Original Feed Rate)(Reduced Flow)}}{\textbf{Original Flow}}$

Completing final step for "lbs/day" of % solution:

$\frac{\text{lbs}}{\text{Day}}$ of % solution = $\frac{\text{lbs of 100\% feed rate}}{\text{\% solution as a decimal}}$ (using Davidson pie feed rate formula)

Math Concept Exercise

1. In order to use the Feed Rate formula which is lbs/day = Flow x Dosage x 8.34, name the units of measurement for the **flow**:

   a) MGD

   b) gpm

   c) gpd

   d) All of the above units can be used

2. If you have a flow in **gpm**, what calculation do you use to convert it to **MGD**?

   a) Multiply gpm X 24 and divide by 1,000,000

   b) Multiply gpm x 60 and divide by 1,000,000

   c) Multiply gpm x 1440 and divide by 1,000,000

   d) Divide flow in gpm by 1,000,000

3. If you have a flow in **gpd**, what calculation do you use to convert it to **MGD**?

   a) Divide flow in gpd by 100

   b) Divide flow in gpd by 10,000

   c) Divide flow in gpd by 100,000

   d) Divide flow in gpd by 1,000,000

4. When using "active ingredient" weight to solve for "gallons", what calculation do you use?

   a) ? gals = $\frac{1 \text{ gal}}{1.63 \text{ lbs}}$ X "lbs" (either needed to dilute day tank solution or as a % solution feed rate)

   b) ? gals = $\frac{1.63 \text{ lbs}}{\text{gal}}$ X "lbs" (either needed to dilute day tank solution or as a % solution feed rate)

Refer to the ***"Summary of Variations of Gas and Hypo Math Problems and Summary of Miscellaneous Math Problems"*** tables on pages 57 - 72. There are additional example problems that are not covered during this course.

Summary of Variations of Gas Chlorination Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Feed Rate: Solving for lbs/day of 100% gas chlorine **(Davidson Pie Equation #1)**	How many pounds of chlorine are needed for a plant flow of 2.2 MGD and a dose of 2.0 mg/L	?lbs/day = Flow (MGD) x Dose x 8.34 ?lbs/day = 2.2 x 2.0 x 8.34 = 37 lbs/day ?lbs/hr = lbs/day ÷ 24 hrs = $\frac{37}{24}$ = $\frac{1.54 \text{ lbs}}{\text{hr}}$?lbs/30 days = lbs/day X 30 days 37 lbs/day X 30 days = 1110 lbs/in 30 days	**1) Flow given in GPD:** Convert flow into MGD before using in feed rate equation: MGD = GPD ÷ 1,000,000 If **flow** is 350,000 gpd: 350,000 ÷ 1,000,000 = 0.35 MGD Then insert flow into feed rate equation **2) Solving for lbs/hr:** Divide feed rate for 1 day by 24 hours **3) Solving for lbs used in 30 days:** Multiply feed rate for 1 day by 30 days
Calculate chlorine dose	What is the chlorine dose in mg/L if the demand is 2.1 mg/L and the residual is 0.6 mg/L?	? Chlorine Dose = Demand + Residual ? Chlorine Dose = 2.1 + 0.6 = 2.7 mg/L	NONE

<table>
<tr><th colspan="4">Summary of Variations of Gas Chlorination Math Problems</th></tr>
<tr><th>Type of Problem</th><th>Example</th><th>Equation</th><th>Variations</th></tr>
<tr>
<td>Feed Rate: Solving for lbs/day of 100% gas chlorine when dose is calculated from chlorine demand and residual

(Davidson Pie Equation #1 with dose calculation)</td>
<td>How many pounds of chlorine gas will be required to treat 116,000 gpd with a desired residual of 0.5 mg/L and a chlorine demand of 2.0 mg/L</td>
<td>?lbs/day = Flow (MGD) x Dose x 8.34
?lbs/day = 0.116 X 2.5 X 8.34 = 2.42 lbs/day</td>
<td>1) Flow given in GPD:
Convert flow into MGD before using in feed rate equation:
MGD = GPD ÷ 1,000,000
If flow is 116,000 gpd:
116,000 ÷ 1,000,000 = 0.116 MGD

2) Not given dosage; calculate dose from chlorine demand and residual:
Dose = residual + demand
if demand = 2.0 mg/L
residual = 0.5 mg/L
Dose = 2.5 mg/L

Now insert this dose into feed rate equation</td>
</tr>
</table>

Summary of Variations of Gas Chlorination Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Dosage: Solving for a dose (mg/L) using a **flow** (MGD) and a **feed rate** (lbs/day) (**Davidson Pie Equation #3**)	A treatment plant produces 11,000,000 gallons of water each day. It uses 200 lbs/day of chlorine. What is the dose (mg/L) of chlorine?	? Dose (mg/L) = $\frac{\text{Feed Rate, lbs/day}}{\text{(Flow, MGD)(8.34)}}$?Dose (mg/L) = $\frac{\text{200 lbs/day}}{\text{11 MGD X 8.34}}$ Multiply 11 x 8.34 = 91.74 (denominator) Divide: $\frac{\text{200 (numerator)}}{\text{91.74 (denominator)}} = 2.18 \frac{mg}{L}$	NONE
Dosage Reduction Value when feed rate is decreasing	A chlorinator in a water treatment plant that produces 875,000 gallons per day is set to feed 20 lbs/day. If this feed rate is decreased by 5 lbs/day, the dosage will be reduced by how many mg/L?	? Dose (mg/L) = $\frac{\textbf{Feed Rate Difference,}\text{lbs/day}}{\text{(Flow, MGD)(8.34)}}$?Dose Reduction = $\frac{\text{5 lbs/day}}{\text{0.875 MGD X 8.34}}$ Multiply 0.875 x 8.34 = 7.29 (denominator) Divide: $\frac{\text{5 (numerator)}}{\text{7.29 (denominator)}} = 0.68 \frac{mg}{L}$	**1) Flow given in GPD:** Convert flow into MGD before using in feed rate equation: MGD = GPD ÷ 1,000,000 If **flow** is 875,000 gpd: 875,000 ÷ 1,000,000 = 0.875 MGD

Summary of Variations of Gas Chlorination Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Reduced Feed Rate when flow decreases	If a water treatment plant that produces 600,000 gallons per day decreases its flow to 500,000 gallons per day, the amount of chlorine fed will change from 18 lbs/day to how many pounds per day?	$\frac{\text{Original Feed Rate}}{\text{Original Flow(MGD)}} = \frac{\text{X(Unknown Feed Rate)}}{\text{Reduced Flow (MGD)}}$ $\frac{18}{0.6} = \frac{X}{0.5}$ To get the "X" alone: multiply 18 X 0.5 = 9 (in the numerator) then divide $\frac{9}{0.6}$ = 15 lbs/day	**1) Flow given in GPD:** Convert flow into MGD before using in feed rate equation: MGD = GPD ÷ 1,000,000 If **flows** are 600,000 and 500,000 gpd: 600,000 ÷ 1,000,000 = 0.6 MGD 500,000 ÷ 1,000,000 = 0.5 MGD
Calculate CT	If a free chlorine residual is 1.8 mg/L after 120 minutes of detention time, what is the CT value in mg-min/L?	CT = concentration x contact time (mins) CT = 1.8 x 120 = 216 mg-min/L	**Given detention time in hours:** Convert time from **hours** to **minutes**, then solve CT equation. Example: If a free chlorine residual is 1.8 mg/L after 2 hours of detention time, what is the CT value in mg-min/L? 60 min x hrs = minutes 60 x 2 = 120 minutes CT = 1.8 x 120 = 216 mg-min/L

Summary of Variations of Hypochlorite Math Problems

Type of Problem	Example	Equation	Variations
Calculating # of gallons with a different % solution	If 4.2 gallons of 12% hypochlorite is fed. How many gallons would you have to use if the concentration was 7%?	? gals of Unknown % = $\frac{\text{Known gal x Known\%}}{\text{Unknown \% solution}}$? gallons = $\frac{\text{4.2 gallons X 12\%}}{\text{7\%}}$ =7.2 gallons	NONE
Path 1 Feed Rate: Solving for lbs of 100% chlorine needed using a **volume** (lbs)	How many pounds of chlorine are needed to disinfect a 1,000,000 gallon tank with a dosage of 5 mg/L?	?lbs = Volume (MG) x Dose x 8.34 ?lbs = 1 x 5 X 8.34 = 41.7 lbs	Given a **partially full tank** instead of full: First, multiply tank volume by decimal that represents the partial tank (i.e., 3/4 = 0.75) Example of 1 MG tank that is ¾ full: 1,000,000 x 0.75 = 750,000 gal If solving for a **¾** full Tank: ?lbs = 0.75 x 5 x 8.34 = 31.3 lbs
Path 1 Feed Rate: Solving for lbs of 100% chlorine needed using a **flow**	How many pounds of chlorine are needed for a plant flow of 2.2 MGD and a dose of 2.0 mg/L	?lbs/day = Flow (MGD) x Dose x 8.34 ?lbs/day = 2.2 x 2.0 x 8.34 = 37 lbs/day	**Flow given in GPM or GPD:** Convert flow into MGD before using in feed rate equation: MGD = GPD ÷ 1,000,000 **OR**

Summary of Variations of Hypochlorite Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
			MGD = GPM x 1440 ÷ 1,000,000 Example: If **flow** is 350 gpm: 350 x 1440 ÷ 1,000,000 = 0.504 MGD If **flow** is 350,000 gpd: 350,000 ÷ 1,000,000 = 0.35 MGD Then insert flow into feed rate equation
Path 1 Feed Rate: Solving for lbs of a % Solution needed using a **volume or flow** (lbs or lbs/day)	How many pounds of 12% sodium hypochlorite are needed for a dose of 0.8 mg/L if they treat 250,000 gpd?	Step 1: ?100% lbs/day = 0.25 x 0.8 x 8.34 = 1.67 lbs/day Step 2: ?lbs of 12% hypo = $\frac{\text{lbs of 100\%}}{\text{\% purity of solution (as a decimal)}}$ $\frac{1.67}{0.12}$ = 13.9 lbs of 12% hypochlorite	**Not given dosage; Calculate dose from chlorine demand and residual:** Dose = residual + demand if demand = 1.4 mg/L residual = 0.5 mg/L Dose = 1.9 mg/L Now insert this dose into feed rate equation

Summary of Variations of Hypochlorite Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
			Given a partial day shift (i.e., 10 hrs) lbs/day ÷ 24 hours = lbs/hr lbs/hr x # of hours <u>Example:</u> Calculate lbs in 10 hours for example at left: 13.9 lbs (day) ÷ 24 hours = 0.579 lb/hr THEN 0.579 lbs/hr x 10 hours = 5.79 lbs in 10 hrs
Calculate chlorine demand	What is the chlorine demand in mg/L if the dose is 2.9 mg/L and the residual is 0.6 mg/L?	? Chlorine demand = Dose – Residual ? Chlorine demand = 2.9 - 0.6 = 2.3 mg/L	NONE

Summary of Variations of Hypochlorite Math Problems

Type of Problem	Example	Equation	Variations
Path 2 Feed Rate: Solving for Gallons of a % Solution using a **flow** (gals/day)	How many gallons of 15% sodium hypochlorite (1.4 lb/gal available chlorine) are needed to treat 750,000 gpd with a chlorine dose of 1.4 mg/L?	Step 1: ?100% lbs/day = 0.75 x 1.4 x 8.34 = 8.76 lbs/day Step 2: Convert lbs/day into gal/day using available chlorine data $\frac{\text{gals}}{\text{day}} = \frac{\text{100\% lbs}}{\text{available } Cl_2 \text{ lbs}}$ $\frac{\text{gal}}{\text{day}} = \frac{8.76}{1.4} = 6.25 \frac{\text{gal}}{\text{day}}$	**Not given dosage; Calculate dose from chlorine demand and residual:** Dose = residual + demand if demand = 0.6 mg/L residual = 0.8 mg/L Dose = 1.4 mg/L Now insert this dose into feed rate equation.
Calculate CT	If a free chlorine residual is 1.8 mg/L after 120 minutes of detention time, what is the CT value in mg-min/L?	CT = concentration x contact time (mins) CT = 1.8 x 120 = 216 mg-min/L	**Given detention time in hours:** Convert time from **hours** to **minutes**, then solve CT equation. Example: If a free chlorine residual is 1.8 mg/L after 2 hours of detention time, what is the CT value in mg-min/L? 60 min x hrs = minutes 60 x 2 = 120 minutes CT = 1.8 x 120 = 216 mg-min/L

Summary of Variations of Hypochlorite Math Problems

Type of Problem	Example	Equation	Variations
Calculate CT using flow and volume.	A plant's flow rate is 2 MGD. Water enters the clearwell that has a volume of 50,000 gallons. The chlorine residual of the outlet end of the tank is 0.9 mg/L. What is the CT in mg-min/L?	**Not given detention time; Determine detention time from flow and volume.** First, convert flow from **MGD** to **gpm** **Step 1:** Convert MGD to gpm: $\text{gpm} = \frac{\text{MGD X 1,000,000}}{1440}$ $\text{gpm} = \frac{2,000,000}{1440} = 1388.8 \frac{\text{gal}}{\text{min}}$ **Step 2:** Calculate detention time (mins) $\text{Detention time (mins)} = \frac{\text{Volume (gal)}}{\text{Flow (gpm)}}$ $\text{Time} = \frac{\text{Vol}}{\text{Flow (gpm)}} = \frac{50,000}{1388.8} = 36 \text{ mins}$ **Step 3:** Calculate CT CT = disinfection concentration X time CT = 0.9 mg/L X 36 mins = 32.4 mg-min/L	

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Pressure/Height conversions	The water level at the top of a fully filled water standpipe is 150 feet above the elevation of a water tap. The tank contains 50,000 gallons of water. What is the approximate pressure at the tap? If the pressure is 14 psi, what is the height of water in the tank?	$? \text{ psi} = \frac{1 \text{ psi}}{2.31 \text{ ft}} \times 150 \text{ ft} = 64.9 \text{ psi}$ **OR** $? \text{ ft} = \frac{2.31 \text{ ft}}{1 \text{ psi}} \times 14 \text{ psi} = 32 \text{ ft}$	NONE
Temperature Conversions	Convert 39 ºF to ºC Convert 20 ºC to ºF	$°C = \frac{°F-32}{1.8}$ $°C = \frac{°F-32}{1.8} = \frac{39-32}{1.8} = \frac{7}{1.8} = 3.88\ °C$ (rounds to 3.9) OR $°F = (°C \times 1.8) + 32$ $°F = 20 \times 1.8 = 36 + 32 = 68\ °F$	NONE

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Unaccounted for water calculation (Non-Revenue Water)	In one month a water system produced 5,500,000 gallons of water. Of the total water, 4,500,000 gallons were billed, 250,000 were used for fire protection and 200,000 gallons were used for flushing. What is the total unaccounted for water loss percentage for this month?	Step 1: Add total gallons accounted for (billed, fire protection and flushing) 4,500,000 + 250,000 + 200,000 = 4,950,000 Step 2: Subtract "accounted for" from total produced to find "Unaccounted for" 5,500,000 – 4,950,000 = 550,000 Step 3: Divide "Unaccounted for" by total produced and multiply by 100 to equal the % unaccounted for $\frac{550,000}{5,500,000}$ = 0.1 X 100 = 10 % Unaccounted for	NONE
Area of a rectangle	The area of a package plant filter unit is 10 ft. 6 inches long by 10 ft. wide. What is the area in square feet?	Area of a rectangle = Length (L) X Width (W) Area = (L) X (W) = 10.5 ft. X 10 ft. = 105 ft^2	Converting inches to feet: ? ft = 1 $\frac{ft}{12\ inches}$ x 6 inches = $\frac{6}{12}$ = 0.5 ft Add 0.5 to 10 ft = 10.5 ft (length)

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Area of a circle	The chemical feed tank is 20 inches in diameter, what is the area of the chemical feed tank?	Area = (0.785) X (Diameter)^2 Area = (0.785)(1.67 ft)(1.67 ft) = 2.19 ft^2	Converting inches to feet: ? ft = $\frac{1\ ft}{12\ inches}$ x 20 inches = 1.67 ft
Volume of a rectangular tank	What is the volume of a sedimentation basin that is 25 feet long, 15 feet wide, and 10 feet deep?	Vol = (L) X (W) X (H or D) **Note:** For this equation, the terms "height" and "depth" are interchangeable. V= (L)(W)(D) = (25 ft)(15 ft)(10 ft) = 3750 ft^3	If problem asks for volume in **gallons**: Converting ft^3 into gallons: ? gal = $\frac{7.48\ gal}{1\ ft^3}$ X 3750 ft^3 = 28,050 gal
Volume of a circular tank	What is the volume in gallons, of a tank that is 22 feet in diameter, and filled to 8 feet deep?	Vol = 0.785 X (Dia)^2 X (H) V=0.785(22 ft)(22 ft)(8 ft) V=3039.5 ft^3 = 3040 ft^3	If problem asks for volume in **gallons**: Converting ft^3 into gallons: ? gal = $\frac{7.48\ gal}{1\ ft^3}$ X 3040 ft^3 = 22,739 gal

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Calculating the total weight of a solution	The specific gravity for liquid alum is 1.33. How much does a gallon of liquid alum weigh?	Total Weight, lbs/gal = (Specific gravity of substance) x (weight of a gallon of water) $? \frac{lbs}{gal} = 1.33 \times 8.34 \frac{lbs}{gal} = 11.09 \frac{lbs}{gal}$	NONE
Calculating the drum weight of a solution	What would be the weight of a 55 gallon drum of the coagulant Sternpac if the specific gravity of the product is 1.27?	Drum Weight, lbs = (gal of drum or tank) x (SG) x 8.34 ? Drum weight, lbs = 55 x 1.27 x 8.34 = 583 lbs	NONE

Summary of Miscellaneous Math Problems

Type of Problem	Example	Equation	Variations
Calculating the weight of the "active ingredient" of a single gallon or drum	How many pounds of chlorine are there in a gallon of sodium hypochlorite that is 12.5% pure that has a specific gravity of 1.15? How many pounds of active ingredient are there in a 55 gallon drum of liquid alum if the product is 48½ percent pure with a specific gravity of 1.33 and the active ingredient weight is 5.37 lbs of alum/gal of product?	Weight, lbs/gal = (SG) x 8.34 x % solution (as a decimal) $? \frac{lbs}{gal} = 1.15 \times 8.34 \times 0.125 = 1.2 \frac{lbs}{gal}$ **OR** ? lbs = Drum Vol X SG X 8.34 X % solution (as a decimal) ? lbs = 55 X 1.33 X 8.34 X 0.485 = 295.8	NONE
Mixing a % solution	How many pounds of dry chemical must be added to a 35 gallon tank to produce a 2% solution?	? lbs = Weight of water X Tank volume (gals) X % Solution (as a decimal) ? lbs = 8.34 X 35 X 0.02 = 5.84 lbs	NONE

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Calculating theoretical pump output	What is the theoretical pump output for a 24 GPD pump that is set at 80% stroke length and 100% speed?	Pump Output =Max Pump Output x % Speed x % Stroke Pump output = $24.0\ \frac{gal}{day} \times 1.0 \times 0.80 = 19.2\ \frac{gal}{day}$	NONE
Calculating the % stroke and % speed setting for a liquid feed pump	An operator wants to estimate the approximate speed and stroke settings on a diaphragm pump that is rated to deliver a maximum pump output of 24 gallons per day. The system needs to deliver approximately 15 gallons per day of sodium hypochlorite. Where would the speed and stroke need to be set?	Pump Output =Max Pump Output x % Speed x % Stroke When choosing a pump for a facility, you want a pump that can maintain a stroke between 20% and 80% and keep the speed setting high. Let's calculate the theoretical pump output using 90% speed and 70% stroke to see if those settings can deliver 15 gal/day Pump Output = $24\ \frac{gal}{day}\ X\ 0.90\ X\ 0.70 = 15.1\ \frac{gal}{day}$	It's possible that other combinations of % speed and % stroke may also deliver 15 gal/day. For example: Using 80% speed and 80% stroke would deliver 15.3 gal/day. $24\ \frac{gal}{day}\ X\ 0.80\ X\ 0.80 = 15.36\ \frac{gal}{day}$

Summary of Miscellaneous Math Problems			
Type of Problem	**Example**	**Equation**	**Variations**
Determining mL/min for a liquid feed calibration table for 3 pump settings.	Alum Pumped (mL) / Time (sec) 65.6 / 55 141.9 / 59 249.1 / 61	To convert each pump speed setting into mL/min: $\frac{?mL}{min} = \frac{65.6\ mL}{55\ sec} \times \frac{60\ sec}{1\ min} = 71.56\ \frac{mL}{min}$ $\frac{?mL}{min} = \frac{141.9\ mL}{59\ sec} \times \frac{60\ sec}{1\ min} = 144.31\ \frac{mL}{min}$ $\frac{?mL}{min} = \frac{249.1\ mL}{61\ sec} \times \frac{60\ sec}{1\ min} = 245.02\ \frac{mL}{min}$	NONE

Summary of Miscellaneous Math Problems

Type of Problem	Example	Equation	Variations
Converting mL/min to gal/day to plot on a pump calibration curve	A 20% pump speed setting delivers 71.56 mL/min. Convert 71.56 mL/min into gal/day.	$?\frac{gal}{day} = \frac{1\ gal}{3785\ mL} \times \frac{71.56\ mL}{min} \times \frac{1440\ mins}{day} = 27.22\ \frac{gal}{day}$	Convert unchanging (i.e., static) fraction to a decimal: $\frac{1440}{3785} = 0.38\ \frac{gal}{day}$ Then multiply by mL/min for each pump setting: $\frac{mL}{min}$ of each pump setting X 0.38 = $\frac{gal}{day}$ 71.56 X 0.38 = 27.22 gal/day 144.31 X 0.38 = 54.83 gal/day 245.02 X 0.38 = 93.1 gal/day
Determining # of gallons that are fed from a pump setting that reads in mL/min	Determining # of gallons that are fed from a pump setting that delivers 71.56 mL/min if the plant ran for 8 hours	? Vol = $71.56\ \frac{mL}{min} \times 60\ \frac{mins}{1\ hour} \times 8\ hrs = 34{,}348.8\ mL$ Convert mL to gals: ?Vol (gal) = $\frac{1\ gal}{3785\ mL} \times 34{,}348.8\ mL = 9$ gallons	NONE

Math Key points

- Remember to perform math calculations using the order of operation steps listed in this unit.
- You can use unit cancellation steps to solve for the units you are seeking. Be sure to begin with positioning the numerator unit as your first data set. Then cancel unwanted units until only the unknown denominator units remain.
- You can use the following equation to calculate chlorine dose, chlorine demand or chlorine residual.
  - Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)
- The Davidson Pie diagram can be used to solve for feed rate (lbs or lbs/day), flow (MGD) or dosage (mg/L) by using the following formulas:

1. Feed Rate, lbs/day = Flow (MGD) x Dosage (mg/L) x 8.34 (which is the density of water)

2. Flow (MGD) = $\dfrac{\text{Feed Rate (lbs/day)}}{[\text{Dosage (mg/L)} \times 8.34]}$

3. Dosage (mg/L) = $\dfrac{\text{Feed Rate (lbs/day)}}{[\text{Flow(MGD)} \times 8.34]}$

In order to use any of these formulas, **all flows or volumes must be converted to either million gallons per day (MGD) or million gallons (MG).**

- **The specific gravity** of a liquid product is used in 2 ways:
  - To determine the weight (in lbs) of a gallon of product or of a drum of product using this formula:

    Weight of a liquid, lbs = gallons (single gallon or many gallons within a drum) X SG X 8.34

  - To calculate the ***"active ingredient"*** weight (lbs) of a liquid % solution using this formula:

Active Ingredient Weight within Drum = Drum Volume X SG X 8.34 X % solution as a decimal.
(i.e., Total Weight X % solution as a decimal)

NOTE: Both ways start with solving for the total weight (Drum Vol X SG X 8.34). When solving for "active ingredient" weight, you have to then multiply by % solution as a decimal.

- The **"active ingredient"** weight is used when determining:

  - The feed rate in **gallons/day** for % solutions following these steps:

Step 1: Solve for pounds (feed rate) for 100% pure chemical (no impurities).

$$? \frac{lbs}{day} = \text{Flow(MGD)} \times \text{dose(mg/L)} \times 8.34$$ = pounds of chlorine that are required.

Step 2: Convert lbs/day to **gals/day** by dividing Step 1 "lbs"/day by active ingredient weight

$$?gal = \frac{\text{lbs of pure chlorine (Step \#1 100\% feed rate)}}{\text{Active ingredient weight (lbs/gal)}}$$

.

Final Quiz :

1. What is the **volume in gallons** of a water tank that is 25 feet in diameter, and filled to a depth of 17 feet?

2. What is the **volume in gallons** in a sedimentation basin that is 50 feet long, 35 feet wide, and filled to a depth of 12 feet?

3. How many **pounds** of chemical will be fed if the dose required is 13 mg/L, and the amount of water to be treated is 175,000 gallons per day?

4. What is the **dose** if a water plant used 40 pounds of chemical, and treated 1.2 million gallons of water?

5. The target dose for a system is 1.2 mg/L. They are treating an average of 300,000 gallons each day. How many **lbs** of sodium hypochlorite (12½ %) will they need to feed?

6. The specific gravity of the hypochlorite is 1.11. If the system needs to feed 24 pounds of hypochlorite, how many **gallons** will that require?

7. How many **pound**s of chlorine will be needed to disinfect a 250,000 gallon tank if a 50 mg/L dose is required?

8. What is the **weight** of the water that is in a container one foot long, one foot wide, and filled to a depth of 1 foot?

10. How many **pounds** of aluminum sulfate (48.5%) are required to dose water at 21 mg/L if the amount of water treated is 2 MGD?

11. Convert a flow of 65 gallons per minute to the **MGD** unit.

12. How **high (in ft)** is the water column if the pressure at the bottom measures 40 psi?

13. Convert 17º C to **ºF.**

14. What is the **% unaccounted water** if a system records the following readings:
The master meter reading is 1,500,000 gallons.
The meter reading total is 965,000 gallons
Another 100,000 gallons were used for flushing, and 35,000 gallons were metered at a blow-off.

Reference

Joanne Kirkpatrick Price, *Basic Math Concepts for Water and Wastewater Plant Operators*.