# DW Module 24
# Gas Chlorination
# Answer Key

## Unit 1

### Unit 1 Exercise

1. Chlorine gas is **heavier**/lighter than air. (Underline the correct answer)

2. Vapor pressure is independent of volume.
   a. True___**X**___ b. False______

3. Vapor pressure decreases with increasing temperature.
   a. True______ b. False__**X**___

4. **HOCL**/OCl- is the stronger disinfectant. (Underline the correct answer)

5. The effectiveness of chlorine increases/**decreases** with decreasing temperature. (Underline the correct answer)

6. Cylinders contain both liquid and gas chlorine.
   a. True__**X**__ b. False______

## Unit 2

### Unit 2 - Chlorine Hazards

Using the sample SDS in the appendix, answer the following questions about chlorine hazards:

1. What effect does liquid chlorine have on the skin and eyes?

**Severely corrosive to the skin and eyes**

2. What effect does gaseous chlorine have on the nose, throat and lungs?

**Severely corrosive to the respiratory system including nose, upper respiratory tract and lungs**

## ☑ Unit 2 Exercise – Chlorine Handling and Storage

1. The quantity of chlorine that escapes from a leak is significantly less as a **gas**/liquid. (Underline the correct answer)

2. Chlorine feed room exhaust fans or a forced-air ventilation inlet must be near the floor.
   a. True___X___ b. False______

3. The chlorine feed room should be at least 60°F to facilitate chlorine discharge.
   a. True___X ___ b. False______

4. The fusible plug on a 100 pound cylinder will melt at 120°F.
   a. True______ b. False__X___

5. Where should the self-contained breathing apparatus be located?
   a. Inside the chlorine feed room
   **b. Near the door outside of the chlorine feed room**
   c. In the manager's office
   d. In the first-aid room

6. Repairing chlorine leaks in cylinders may include:
   a. Replacing the lead gasket at the discharge valve outlet
   b. Using the emergency repair "A" kit for cylinders
   c. Tightening the packing gland nut
   **d. All of the above**

7. When chlorine comes in contact with moisture, it turns into hydrochloric acid.
   a. True___X ___ b. False______

8. To detect a chlorine leak, a rag saturated in which type of solution is used to produce white fumes?
   a. Sodium thiosulfate
   b. Caustic soda
   **c. Ammonia**
   d. Saline solution

## Unit 3

### Unit 3 Exercise - Part 1

1. The amount of chlorine required to react with all the organic and inorganic material is known as the chlorine **demand**.

2. Breakpoint chlorination:
   a. Is the addition of chlorine until all chlorine demand has been satisfied.
   b. Occurs when no organic matter is available to react with the chlorine.
   c. Is used to determine how much chlorine is required for disinfection.
   d. Is the point at which further addition of chlorine will result in a free chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint.
   e. **All of the above**

3. Name the chemical used to neutralize all of the chlorine residual when collecting a bacteriological sample for coliforms. **Sodium thiosulfate**

4. The **MRDL** is the maximum permissible level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap without an unacceptable possibility of adverse health effects.

5. Chlorine residual samples are taken at representative points within the distribution system. These samples are taken at the same time and at the same location as the coliform samples are taken.

   a. True **X**  b. False_____

6. Surface water systems must maintain a **minimum** detectable disinfectant residual throughout their entire **distribution system**. What is the value of this minimum distribution disinfectant residual?

   a. 0.2 mg/L
   **b. 0.02 mg/L**
   c. 0.4 mg/L
   d. 4.0 mg/L

### Unit 3 Exercise - Part 2

1. A leaded gasket is used to seal the connection between chlorine cylinder yoke and the vacuum regulator inlet valve. Every time the connection is broken, the leaded gasket should be replaced..

   a. True **X**  b. False_____

2. A **rotameter** is a device used to measure the flow rate of gases and liquids.

3. A gas chlorine system problem may be due to:

    a. No ejector vacuum.
    b. Significant decrease in water pressure.
    **c. Both a and b.**
    d. None of the above

4. A 150 pound cylinder can provide chlorine at a maximum rate of about **1.6** pounds per hour.

5. Frost forms on a gas chlorine when the feed rate is too low.

    a. True_____ b. False **X**

6. Daily activities for chlorinators and ejectors include:
    a. Check ejector water supply pressure
    b. Check chlorinator vacuum
    c. Read and record chlorine feed rate
    d. Measure chlorine residual
    **e. All of the above**

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## Unit 4

### Explanation of diagonal movement and an example.

**Example:**

$5X = 20$

Question #1 regarding Example #1: Is the ***X*** in the numerator? **YES**
Question #2 regarding Example #1: Is the ***X*** alone on one side of the equation? **NO**
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.**

$$\frac{\cancel{5}X}{\cancel{5}} = \frac{20}{5}$$

**FINAL ANSWER**: $20 \div 5 = 4$

## Equation # 1: Feed Rate Calculation Using Flow

**Practice Problem:** If a water treatment plant has a flow rate of 0.55 MGD and a chlorine dosage of 3.9 mg/L, what is the feed rate in pounds/day?

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

? lbs/day = 0.55 X 3.9 X 8.34 = 17.88 lbs/day

**Solving for the lbs/hour:**

What if you need to calculate the feed rate in lbs/hour?

**Step 1:** Solve for feed rate for one day.

Lbs/day = Flow (MGD) X Dose (mg/L) X 8.34
? lbs/day = 0.55 X 3.9 X 8.34 = 17.88 lbs/day

**Step 2:** Divide feed rate for one day by 24 hours

17.88 ÷ 24 = 0.754 lbs/hour

**Solving for the Quantity of Chlorine Used in 30 Days**

What if you needed to calculate how much chlorine was used in 30 days?

**Step 1:** Solve for feed rate for one day.

Lbs/day = Flow (MGD) X Dose (mg/L) X 8.34
? lbs/day = 0.55 X 3.9 X 8.34 = 17.88 lbs/day

**Step 2:** Multiply feed rate for one day X 30 days

17.88 X 30 = 536 lbs/30 days

- ## Chlorine Demand or Dose Calculation

**Practice Problem:** You must maintain 0.5 mg/L chlorine residual in the finished water with a chlorine demand of 1.5 mg/L. What should the chlorine dose be?

? Dose = Chlorine Demand + Chlorine Residual
? Dose = 1.5 + 0.5
? Dose = 2.0 mg/L

- **Calculating Dose (from $Cl_2$ demand and residual) to Solve Feed Rate Calculation**

**Example:** 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?

**Step 1: Calculate the dose using the formula**

Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)

Dose = 2.0 + 0.5
= 2.5 mg/L

**Step 2: Convert gpd to MGD**

$\frac{116{,}000}{1{,}000{,}000}$ = 0.116 MGD

**Step 3: Use Feed Rate calculation to solve for lbs/day**

? lbs/day = flow x dose x 8.34 = (0.116)(2.5)(8.34) = 2.42 pounds of chlorine is required.

**Practice Problem:** How many lbs of chlorine gas will be required to treat 400,000 gallons per day with a desired residual of 0.6 mg/L and a chlorine demand of 2.2 mg/L?

**Step 1: Calculate the dose using the formula**

Chlorine Dose (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)

Dose = 2.2 + 0.6
= 2.8 mg/L

**Step 2: Convert gpd to MGD**

$\frac{400{,}000}{1{,}000{,}000}$ = 0.4 MGD

**Step 3: Use Feed Rate calculation to solve for lbs/day**

? lbs/day = flow x dose x 8.34 = (0.4)(2.8)(8.34) = 9.34 pounds of chlorine is required.

**Equation #2:** Note that Equation #2 (Solving for Flow Using the Feed Rate formula) is not practiced in this module.

## Equation #3: Solving for Dose Using the Feed Rate Formula

**Practice Problem:** A water treatment plant produces 11,000,000 gallons of water every day. It uses 200 lbs/day of chlorine. What is the dose (mg/L) of chlorine?

**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.

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate, lbs/day}}{(\text{Flow, MGD})(8.34)} = \frac{(200)\text{ lbs/day}}{(11)(8.34)}$$

**Step 3**: Multiply 11 x 8.34 in the denominator = 91.74 (basic math rule)

**Step 4:** Perform the **DOSE** division: 200 (numerator) ÷ 91.74 (denominator) = $\mathbf{2.18}\ \frac{\text{mg}}{\text{L}}$

- **Solving for Dosage Reduction Value when Feed Rate is Decreasing**

**Practice Problem:** A chlorinator in a water treatment plant that produces 600,000 gallons per day is set to feed 30 lbs/day. If this feed rate is decreased by 10 lbs/day, the dosage will be reduced by how many mg/L?

**Step 1**: Set up the variables in vertical format.

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

**Step 2:** Convert gallons per day into MGD and insert known values into equation.

$$? \frac{\text{MG}}{\text{day}} = \frac{1 \text{ MG}}{1{,}000{,}000 \cancel{\text{ gallons}}} \times \frac{600{,}000 \cancel{\text{ gallons}}}{\text{day}} = \mathbf{0.875} \text{ MGD}$$

$$? \text{ Dose (mg/L)} = \frac{\text{Feed Rate Difference, lbs/day}}{(\text{Flow, MGD})(8.34)} = \frac{(10)\text{ lbs/day}}{(0.6)(8.34)}$$

**Step 3**: Multiply 0.6 x 8.34 in the denominator = 7.29 (basic math rule)

**Step 4:** Perform the **DOSAGE** division of the **feed rate difference**:

10 (numerator) ÷ 5 (denominator) = **0.68** mg/L

- **Solving for a Reduced Feed Rate when Flow Decreases**

**Practice Problem:** If a water treatment plant that produces 990,000 decreases its flow to 850,000 gallons per day, the amount of chlorine fed will change from 20 lbs/day to how many pounds per day?

**Step 1:** Convert gallons per day into MGD for both original flow and reduced flow.

**a) Original Flow:**

$$?\frac{MG}{day} = 1\ \frac{MG}{1{,}000{,}000\ gallons} \times \frac{990{,}000\ gallons}{day} = \mathbf{0.99}\ MGD$$

**b) Reduced Flow:**

$$?\frac{MG}{day} = 1\ \frac{MG}{1{,}000{,}000\ gallons} \times \frac{850{,}000\ gallons}{day} = \mathbf{0.85}\ MGD$$

**Step 2**: Create the ratio of $\frac{\text{Original Feed Rate}}{\text{Original Flow}} = \frac{\text{X(Unknown Feed Rate)}}{\text{Reduced Flow}}$

$$\frac{20}{0.99} = \frac{X}{0.85}$$

**Step 3**: To get "X" alone, multiply 20 X 0.85 = 17 (in the numerator)

**Step 4**: Then divide numerator (17) by denominator (0.99) = 17.17 lbs/day

- **CT**

**Practice Problem:** If a free chlorine residual of 2.5 mg/L is measured at the end of the clearwell after 4 hours of detention time, what is the CT value in mg-min/L?

**Step 1:** Convert detention time from hours to minutes.

$$? \text{ Min} = 60\ \frac{min}{hr} \times 4\ \underline{hr} = \underline{240}\ \text{minutes}$$

**Step 2:** Insert disinfectant residual concentration and contact time (in minutes) into CT equation and multiply the values.

CT = disinfectant concentration (mg/L) x contact time (mins)

CT = 2.5 mg/L x 240 minutes = 600 mg-min/L

## Unit 4 Exercise

**1.** If your chlorine feed rate is 20 lbs/day, how much chlorine will you use in 28 days? **560 lbs.**

$$20\,\frac{\text{lbs}}{\cancel{\text{day}}} \times 28\,\cancel{\text{days}} = 560\text{ lbs}$$

2. If your chlorine feed rate is 50 lbs/day, what is the feed rate in lbs/hour? **2.08 lbs/hr**

$$?\,\frac{\text{lbs}}{\text{hr}} = 50\,\frac{\text{lbs}}{\cancel{\text{day}}} \times \frac{1\,\cancel{\text{day}}}{24\text{ hrs}} = \frac{50}{24} \qquad 2.08\,\frac{\text{lbs}}{\text{hr}}$$

3. When calculating the CT value, time is measured in what units?

a) Seconds
**b) Minutes**
c) Hours

4. In order to perform the feed rate/dosage calculations, the flow must be converted to million gallons per day. (MGD)

a. **True** False

5. Chlorine **Dose** = Chlorine demand + chlorine residual

6. Chlorine **Demand** = Chlorine dose – chlorine residual