

Wastewater Modules

WW Instructor Guides 21 – 26, 28-30 - Answer Key

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Module 21:
Rotating Biological Contactors
Instructor Guide – Answer Key



Exercise for Unit 1 – General Overview

1. Given the following information, calculate the percent removal:

Influent Total Suspended Solids = 200 mg/L

Effluent Total Suspended Solids = 19 mg/L.

Ans: Percent Removal (%) = $\frac{(\text{Influent Concentration, mg/L}) - (\text{Effluent Concentration, mg/L})}{(\text{Influent Concentration, mg/L})} \times 100$

$$\text{Percent Removal (\%)} = \frac{(200 \text{ mg/L}) - (19 \text{ mg/L})}{200 \text{ mg/L}} \times 100$$

$$\text{Percent Removal (\%)} = 90.5\%$$

2. The two types of RBC drive mechanisms are mechanical and air drives.
3. In a SBR, the drum rotates at approximately 1.5 RPM and about 40 % of the media surface is immersed in the wastewater.
4. Loping is the term used to describe uneven shaft rotation.
5. RBCs are typically designed to reduce total BOD to about 15 to 30 mg/L.
-



Calculation

1. Calculate the hydraulic loading of a RBC system with the following data:

8 Stage Systems

RBC Width (Per Stage) = 50 ft

RBC Length (Per Stage) = 200 ft

Influent Flow = 0.275 mgd

Ans: Hydraulic Loading (gpd/ft²) = $\frac{\text{Influent Flow, gpd}}{(\# \text{ of stages}) (\text{area per stage, ft}^2)}$

$$\text{Hydraulic Loading} = \frac{(275,000 \text{ gpd})}{(8) (50 \text{ feet}) (200 \text{ feet})}$$

Hydraulic Loading = 3.4 gpd/ft²



Calculation

1. What is the detention time of a 7,250,000 gallon RBC basin with an influent flow rate of 110,000 gallons per day?

Ans: Detention Time (days) = $\frac{\text{Basin Volume (gallons)}}{\text{Influent Flow (gallons/day)}}$

$$\text{Detention Time (days)} = \frac{7,250,000 \text{ gallons}}{110,000 \text{ gallons/day}}$$

$$\text{Detention Time (days)} = 65.9 \text{ days}$$



Calculation

1. Calculate the organic loading of a RBC with the following data:

Media Surface Area = 108,000 ft²

Influent Flow = 100,000 gpd

Influent BOD = 325 mg/L

Ans: Organic Load (lb BOD/day/1,000 ft²) = $\frac{(\text{BOD, mg/L}) \times (\text{Flow, mgd}) \times (8.34 \text{ lb/gallon})}{(\text{Area, ft}^2)}$

$$\text{Organic Load} = \frac{(325 \text{ mg/L}) \times (0.100 \text{ mgd}) \times (8.34 \text{ lb/gallon}) \times (1,000)}{(108,000 \text{ ft}^2)}$$

$$\text{Organic Load} = 2.5 \text{ lb BOD/day/1,000 ft}^2$$



Exercise for Unit 2 – General Operation and Maintenance

1. The length of detention time is a critical factor in determining which processes such as BOD and nitrification will occur in a RBC.
 - a. True
 - b. False
2. The highest removal efficiencies in an RBC will occur in:
 - a. cold weather

- b. warm weather
 - c. temperature has no effect
 - d. none of the above
3. When oxygen is not available, anaerobic bacteria can use nitrate (NO₃) or sulfate (SO₄) as alternative oxygen sources.
- a. True False
4. Bacteria in SBRs are generally grouped in two broad categories called aerobic which require DO and anaerobic which do not require DO for respiration.
5. List the six main RBC structures that were discussed in this unit:
- a. media
 - b. shaft
 - c. reactor basin
 - d. drive assembly system
 - e. orifice / weir
 - f. lines, valves and underdrains
6. In addition to testing required by your NPDES Permit, it may be important to periodically test for other parameters. Give two examples of additional test, how often they should be sampled and where the sample should be obtained (such as influent, primary clarifier, effluent, etc...)
- Answers may vary:
BOD, CBOD and TSS once per week influent, primary effluent and final effluent.
Test pH daily on plant influent and final effluent.
Test DO daily on final effluent.
Ammonia Nitrogen (NH₃-N) can be tested weekly or daily on influent and final effluent even if your NPDES Permit does not require it. This testing will provide a baseline in case action is needed in the future.



Exercise

1. List three problems associated with poor effluent quality and the solution(s) for each.

Ans: Low Temperatures – Cover RBC units to conserve heat.

Organic Overload – Install equalization tanks; place added treatment units in service; install supplemental aeration equipment; recirculate secondary clarifier effluent.

Hydraulic Overload – Install equalization tanks.

Short Circuiting – Install manifolds; provide multiple inlets and outlets; change location of inlets and outlets; keep inlets and outlets as far apart as possible; eliminate dead zones.

Toxic Influent Material – Sample the collection system; develop and implement sewer use ordinances; install equalization tanks; install supplemental aeration equipment; recirculate secondary clarifier effluent.

2. Under what conditions can pH increase sloughing?

Ans: If pH values are below 5 s.u. or above 10 s.u.

3. Explain how anaerobic conditions cause odor problems.

Ans: Influent wastewater containing toxic or inhibitory substances will stress the microorganisms on the media. The microbiological growth could even be completely killed off if the toxicity is severe.

4. Explain how the problem of excessive snail shells can be resolved.

Ans: Ensure adequate mixing in all basins to minimize the snail shell deposits; kill the snails via chlorination; increase the pH to 10 s.u. for a brief period to kill snails.

Module 22:
Industrial Pretreatment Programs
Instructor Guide – Answer Key



Exercise for Unit 1 – Introduction to the National Pretreatment Program

1. NPDES is an abbreviation for National Pollution Discharge Elimination System.
2. POTW is an abbreviation for Publicly Owned Treatment Works.
3. List the four objectives of the General Pretreatment Regulations
 - a. Minimizing the mass of pollutants that pass through a POTW into a receiving stream.
 - b. Preventing or minimizing any interference with a POTW's treatment processes.
 - c. Preventing or minimizing the mass of pollutants contained in sewage sludge.

d. Encouraging recycling of wastewaters and sludge.

4. List three discharges prohibited under the National Pretreatment Program.

Answers may vary. See page 1-4.



Exercise for Unit 2 – Regulatory Authority

1. Explain the difference between direct and indirect discharges.

Direct discharge is into a stream or other body of water. Indirect discharge refers to an industrial user that discharges wastewater through a POTW rather than directly to a receiving stream, such as a river.

2. Only state discharge limits that are more stringent than federal requirements take precedence over the federal requirements.

X True ____ False

3. Pollutants of concern are defined as

- ____ contaminants that interfere with POTW performance
- ____ adversely impact POTW sludge
- ____ cause the POTW to exceed its NPDES discharge limits
- ____ chemicals that can adversely impact workers
- X all of the above

4. MAHL is an abbreviation for Maximum Allowable Headworks Loading.

5. Explain the meaning of a significance industrial user.

- A user subject to categorical discharge requirements, OR

- An Industrial User contributing an average of 25,000 gallons per day of process wastewater, OR
 - An Industrial User contributing a process discharge with at least 5% of the total POTW dry weather influent flow or 5% of the organic load, OR
 - An Industrial User designated as a significant Industrial User by the control authority.
-



Exercise for Unit 3 – Identifying and Monitoring Industrial Users

1. List three general steps to follow in completing an inspection of industrial facilities.
 - a. preparation
 - b. on-site assessment
 - c. follow-up activities

2. What are some essential elements of a good sampling and analysis plan?

Answers may vary. See pages 3-6 and 3-7 for elements including sampling locations, sampling frequency and sample protocol.

Module 23
Wastewater Collection Systems
Part I
Instructor Guide – Answer Key



Exercise for Unit 1 – Overview of Wastewater Collection Systems.

1. List three types of collection systems and explain how they each operate.
 - a. Gravity – descriptions may vary.
 - b. Low Pressure – descriptions may vary.

- c. Vacuum – descriptions may vary.
2. List six types of appurtenances used in collection systems.
- a. manholes
 - b. backflow preventers
 - c. cleanouts
 - d. lateral
 - e. inverted siphon
 - f. flow regulators
3. A gravity sewer pipe or conduit is designed to carry wastewater flowing at 2 ft/sec.
- a. True
 - b. False
4. Act 537 is commonly called the Sewage Facilities Planning Act.
5. Backflow preventers are used in a sanitary sewer lateral to prevent the accidental backflow of wastewater into buildings.
- a. True
 - b. False
-



Exercise for Unit 2 – Flows, Regulatory Standards, & Layout.

- 1. It is important to use a peaking factor for residential flow volumes to ensure that the collection system is large enough to convey the flow.
 - a. True
 - b. False
- 2. Flow estimates for commercial land use are generally based on gallons per acre. The actual values used depend on the type and size of the business occupying the land in question.
- 3. Determine the peak residential flow for a subdivision of 75 acres with homes on 1 acre lots and assume 3 people per home.

$(75 \text{ acres})(1 \text{ home/acre})(80 \text{ gal/person/day})(3 \text{ person/home}) = 18,000 \text{ gpd}$

$\text{Peak residential flow} = 18,000 \times 2.5 = 45,000 \text{ gpd}$

4. The minimum size of a new sanitary sewer shall be
 - a. 6 inches
 - b. 8 inches
 - c. 10 inches
 - d. 12 inches
 5. If a sanitary sewer must cross under a water main, there must be at least 18 inches of vertical clearance.
 - a. True
 - b. False
 6. Which of the following statements are true?
 - a. An Erosion and Sedimentation (E&S) control plan is needed for earth moving activity.
 - b. Sanitary sewers should be 10 feet horizontally from existing or proposed water mains.
 - c. The slope of a sanitary sewer is often called Rise/Run.
 - d. All of the above.
 7. The minimum depth of a sanitary sewer is 4 feet.
 8. Sanitary sewers are often constructed to run in the middle of streets to provide easy access and manholes are typically placed about every 400 feet.
-



Exercise for Unit 2 – Installation, Construction Inspection & Testing.

1. The two major types of pipes used in collection systems today are rigid pipe and flexible pipe.
2. Pipe deflection is when the pipe has changed direction, either up, down, right or left from the direction it was originally laid.
3. When using rigid pipe, which class of bedding is typically not permissible?
 - a. Class A
 - b. Class B
 - c. Class C
 - d. Class D
4. An 8-inch diameter Vitrified Clay Pipe (VCP) has a standard strength of 2,000 pounds per foot, and is laid in a Class B trench. What is the total supporting strength?

$(2000 \text{ lb/ft}) \times (1.9) = 3800 \text{ lb/ft}$

5. The contract drawings provide a graphical representation of the work to be done.
 6. The qualitative requirements for a project covering topics like the material and workmanship involved in the manufacturing and installation of equipment can be found in the:
 - a. Legend
 - b. Index
 - c. Specifications
 - d. PA One Call
 7. Name the two types of reports that an inspector would normally write to keep track of progress and problems at a work site.
 - a. Daily reports
 - b. monthly reports
 8. Liquid leaking out of a collection pipe is called exfiltration .
 9. Liquid leaking into a collection pipe from the surrounding bedding material is called infiltration .
 10. A deflection test gage ball or mandrel can not be pulled through a sewer pipe if the pipe is deflected more than five percent of the pipe diameter.
 - a. True
 - b. False
-



Exercise

1. List the three types of collection system cleaning methods.
 - a. chemical
 - b. hydraulic
 - c. mechanical
2. What are the three methods of mechanical cleaning?
 - a. power buckets
 - b. power rodders
 - c. hand rods
3. List three of the six types of hydraulic cleaning and explain when each method is appropriate for use.
 - a. balling – grit and grease removal
 - b. high velocity cleaners – loose debris removal
 - c. flushing – floatable solids removal or sewer scooter, kites, bags, and poly pigs.

4. List three rehabilitation methods.
 - a. excavate and replace
 - b. chemical grouting
 - c. sliplining, or cured-in-place, deformed and re-shaped, and pipe bursting
5. Smoke testing can be useful in detecting:
 - a. illegal sump pump connections
 - b. cracks in sewer piping
 - c. storm sewers connected to sanitary sewers
 - d. all of the above
6. Lamping can be used to determine if a sewer is not straight or blocked.
 - a. True
 - b. False
7. Grouting is an excellent way to repair the structural integrity of a deteriorated manhole.
 - a. True
 - b. False

Module 24:
Wastewater Collection Systems – Part II
Instructor Guide – Answer Key



Exercise

1. List three types of pumping stations and explain when each is used.
 - a. wet well/dry well – for high flows.
 - b. submersible – for low flows and high heads.
 - c. vacuum – not typical in PA – used mostly in flat coastal areas of southern U.S.
2. What is the difference between a centrifugal pump and a positive displacement pump?

A centrifugal pump produces high velocity kinetic energy and converts it to pressure. A positive displacement pump produces pressure by applying force directly to the fluid.
3. List three types of valves and explain when each is used.

a. Gate valves are located immediately before and after pumps to facilitate maintenance by isolating the pump from the wet well and the force main.

b. Plug valves are less susceptible to clogging and are also used to isolate the pump from the wet well and the force main.

c. Check valves are typically installed in the discharge of each pump and prevent the force main from draining back into the wet well.



Exercise

5. Routine annual inspection of electrical equipment should include:
- a. an examination
 - b. replacement of worn and expendable parts
 - c. operational checks and tests
 - d. all of the above

6. List 4 items that should be part of the records for a sanitary sewer line.

a. answers may vary, see pages 2-4 and 2-5.

b. _____

c. _____

d. _____

3. A permit is required to install and operate a pump station.

a. True

b. False

4. List 4 important maintenance procedures for compressors and indicate how often they should be done.

a. answers may vary, see page 2-7

- b. _____
- c. _____
- d. _____

5. Pump bearing failure may be preceded by cavitation sounds, unusual noises or vibration.

- a. True
 - b. False
-



Exercise

1. Which of the following is not part of a traffic control zone?
 - a. A termination area.
 - b. An advance warning area.
 - c. An emergency pull-off.
 - d. A transition area.

2. Which of the following does not define a confined space?
 - a. It is large enough and so configured that a person can bodily enter it.
 - b. It is not designed for continuous occupancy.
 - c. It does not provide sufficient natural light.
 - d. It has limited or restricted means for entry.

3. Which of the following is a major hazard of entering a manhole?
 - a. Toxic exposure.
 - b. Physical injuries.
 - c. Psychological trauma.
 - d. Infection and disease.
 - e. All of the above.

4. No smoking is permitted inside or within 10 feet of a confined space.
 - a. True
 - b. False

5. Prior to beginning any excavation work, underground utilities need to be contacted and their respective lines located.
 6. Work on electrical equipment should only be done by qualified and trained workers.
 - a. True
 - b. False
 7. OSHA requires that a protective system be used in trenches 5 feet or deeper.
-

Module 25:
Introduction to Flowmeters
Instructor Guide – Answer Key



Calculation

1. If you have a channel that is 1 foot wide, the flow is 6 inches deep, and the velocity is 2.5 feet per second (fps), what is the volume in cubic feet per second and gallons per minute?

Ans: $(1 \text{ foot} \times 2.5 \text{ feet} \times 0.5 \text{ foot}) = 1.25 \text{ cfs}$

$$(1.25 \text{ cfs} \times 7.48 \text{ gals/cu ft} \times 60 \text{ second/minute}) = 561 \text{ gpm}$$

2. If you have an 8 inch diameter pipe and the velocity is 2.5 fps, what is the volume? (Hint: $A = \pi r^2$)

Ans: The area of a circle is expressed as $A = \pi r^2$, where π is the Greek letter pi (pronounced pie) and r is the radius. Pi is a constant that is used in many computations involving circles and is commonly approximated by the number 3.14

Remember to keep units the same, therefore, convert 8 inches to feet.

$$8 \text{ inches} / 12 \text{ inches} = 0.667 \text{ ft}$$

The radius is equal to half the diameter.

$$0.667 \text{ ft} / 2 = 0.333 \text{ ft}$$

Determine the area.

$$A = (3.14) (0.333 \text{ ft})^2 = 0.348 \text{ sq ft}$$

Now determine the volume.

$$Q = AV = 0.348 \text{ sq ft} \times 2.5 \text{ fps} = 0.87 \text{ cubic feet per second}$$

If we want to convert this to gallons, we multiply by 7.48 gallons per cubic feet.

$$Q = 0.87 \text{ cfs} \times 7.48 \text{ gallons} = 6.5 \text{ gallons per second}$$

3. Given a flow of 0.87 cfs conveyed in a 12 inch diameter sewer line, what would be the velocity?

Ans: Remember to keep units the same, therefore, convert 12 inches to feet.

$$12 \text{ inches} / 12 \text{ inches} = 1 \text{ ft}$$

The radius is equal to half the diameter.

$$1 \text{ ft} / 2 = 0.5 \text{ ft}$$

Determine the area.

$$A = (3.14) (0.5 \text{ ft})^2 = 0.78 \text{ sq ft}$$

Now determine the velocity.

$$V = Q/A = 0.87 \text{ cfs} / 0.78 \text{ sq ft} = 1.11 \text{ fps}$$



Exercise/Activity

We have an effluent flow that ranges from 10 gpm to 1,500 gpm from a well-operated WWTP. We do not anticipate an unacceptable amount of solids. What are possible V-notch weir options? Use Appendix D - ISCO Table 5-3A.

Ans: Either a 30 or 45 degree V-notch weir as shown in ISCO Table 5-3A.



Exercise/Activity

If we have a 2 ft rectangular weir without end contractions and the depth is 0.33 feet, what is the flow? Use Appendix D - ISCO Table 11-3.

Ans: From ISCO Table 11-3, the flow is 567 gallons per minute.



Calculation

If we have a pipe of 4 inch diameter, using the separation distance guidelines, what is the absolute minimum distance of straight pipe that is needed (excluding the width of the meter)?

Ans: $10 D = (10) (4 \text{ inches}) = 40 \text{ inches upstream}$

$$5 D = (5) (4 \text{ inches}) = 20 \text{ inches downstream}$$

$40 + 20 = 60 \text{ inches}$. We will need at least a 60 inch section or 5 feet of straight unobstructed pipe, excluding the width of the meter.



Calculation

Look at Appendix D and use Table 9-5 (90 degree V-notch weir). Compare how ½ inch makes a difference in flow reading. Compare 6 inch (0.50 feet) with 6.5 inch (0.54 feet).

Ans: The flow at 0.50 feet is shown as 198 gpm, but at a depth of 0.54 feet the depth is 240 gpm. For a day, the difference between 240 gpm and 198 gpm would result in a difference of 42 gpm or 60,480 gallons.



Exercise/Activity

1. We want to meter the effluent flow from a small wastewater treatment system that serves the community of King Village of approximately 200 homes. It is assumed that each home uses approximately 250 gpd, for a total daily flow of approximately 50,000 gpd. The discharge is temporarily stored within the system and discharged with a pump during a 12 hour period instead of continuously over a 24 hour period. Use Appendix D and look at tables 9-1 through 9-5 to select a V-notch weir which would be appropriate and state why. Do not allow more than a maximum of 1 foot of head over weir.

Ans: If the 50,000 gallons is going to discharge during 12 hours, the flow rate would be (50,000 gallons) divided by 12 hours divided by 60 min/hour; or about 69 gpm, if the rate would be constant.

Table	V-Notch size	Min flow @ head, ft	Depth of head at 69 gpm	Flow at 1 ft depth
9-1	22 ½ degree	3.99 gpm at 0.20 ft	0.63 ft	223 gpm
9-2	30 degree	5.43 gpm at 0.20 ft	0.56 ft	303 gpm
9-3	45 degree	8.31 gpm at 0.20 ft	0.47 ft	465 gpm
9-4	60 degree	11.58 gpm at 0.20 ft.	0.41 ft	648 gpm
9-5	90 degree	20.07 gpm at 0.20 ft.	0.33 ft	1,122 gpm

Discussion Items:

- ▶ The minimum flow rate for the larger V-notch is close to the anticipated flow rate and should not be used. As an example, the 90 degree V-notch minimum rate is 20 gpm and the probable flow is 69 gpm.
- ▶ The 22 ½ or 30 degree V-notch weirs provide much better coverage of the range.
- ▶ To make a decision, you would need to compare the accuracy of the 22 ½ degree V-notch weir and its associated higher maintenance requirements to the 30 degree V-notch weir and its lower maintenance requirements.
- ▶ If the 22 ½ degree weir is selected, it should be shielded from the sun to reduce growth of algae. It should also be easily accessible for cleaning.

2. Having taken this course, a WWTP operator measured the following depths at the proper location upstream of a 1 foot rectangular weir without end contractions. What are the flows? Use Appendix D - ISCO Table 11-1.

Ans:

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)	Reading (mgd)
2.40	0.200	133.7	0.19
2.52	0.210	143.9	0.21
2.76	0.230	164.9	0.24
3.00	0.250	186.9	0.27
3.60	0.300	245.7	0.35
4.32	0.360	322.9	0.46
4.92	0.410	392.5	0.56

Note: The readings in the mgd column have been rounded to the appropriate significant figure. Avoid creating false accuracy.



Exercise/Activity

The WWTP staff was able to measure the depth of the flow in a 6 inch Parshall flume at Ha with good accuracy and they determined the following depths. What are the flows? Should an instrumentation person be contacted to inspect the flume?

Ans:

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm) Table 13-4
1.2	0.10	24
3.0	0.25	103
4.5	0.38	200
6.0	0.50	309
7.5	0.62	434

Note that the depth of flow through the meter was able to be measured with good accuracy and all readings were within the ranges listed in the Table. Unless there are other concerns with the meter (e.g., the meter is due for its annual calibration), it does not appear an instrumentation person needs to be contacted.



Exercise/Activity



Display Slide 20—Potential Problem?

What potential problem exists in this picture? Which types of sensors would this problem affect?

Ans: There is a foaming problem.

An ultrasonic sensor is the sensor most affected by foam.



Exercise/Activity

Assume a 120 degree v-notch weir, with an average flow of 500 gpm. After initial operation, it was recognized that the flow could range from 20 gpm to 900 gpm. Is there a better v-notch weir for this application? Use Appendix D - ISCO Tables 9-3, 9-5, and 9-6.

Ans Using ISCO Table 9-5, a 90 degree v-notch weir has a range from 20 gpm to 1,122 gpm. This is a better v-notch weir for this application.

Module 26:
Advanced Flowmeters
Instructor Guide – Answer Key



Exercise/Activity

1. What is the normal flow for midday, which is about half way between each date stamp?

Ans: About 1600 to 1200 gpm.

2. There were 2 rain events when the intensity went above 0.06 inch. What was the affect to the flows?

Ans: Very little impact. Flowmetering indicates that I/I is not much of a problem.



Exercise/Activity

1. What is the normal flow for midday (look at the first two days)?

Ans: About 200 to 500 gpm.

2. What happens during rain events?

Ans: For the time period between the first Tuesday and Wednesday, the two events caused the peak flow to go up almost twice the normal range. Additionally, the flow took a long time to decrease which illustrates that the water continued to get into the system. A second rainfall event caused the flow to quadruple. In our previous discussion about how one municipality may use EDUs to report possible flows, the above data showing impact from a rainstorm would be missed.

I/I is a very bad problem in this system and must be corrected.



Calculation



For each calculation, ask a volunteer to share his or her answer. Record the correct calculation and answer on a flip chart or whiteboard.

1. If you have an 8 inch diameter pipe and the velocity is 2.5 fps, what is the flow rate? (Hint: $A = \pi r^2$)

Ans: 8 inch diameter pipe equals a radius of 0.33 feet.

Therefore, area = $\pi(0.33 \text{ ft})^2$.

Which calculates to 0.34 sq. ft.

If the velocity is 2.5 fps and the area is 0.34 sq. ft, the resultant flow is 0.85 cubic feet per second (cfs).

$0.85 \text{ cfs} \times 7.48 \text{ gals/cu. ft} \times 60 \text{ seconds/minute} = \text{a flow of about } 384 \text{ gpm.}$

Instructor Note: This illustrates how you can determine flow through a line without directly having a flowmeter.

Class Expansion of Problem (use if there is time available)

If the pipe is the force main from a pumping station and is 1,000 feet long, how long would it take 1 gallon of wastewater to travel through the force main if the flowrate is 384 gpm?

Ans: Since the flow rate has been determined based on an 8 inch diameter pipe and a velocity of 2.5 fps, divide the 1,000 feet by 2.5 fps and it would take 400 seconds. This could be confirmed by adding a dye directly to the pump suction, through a pressure gauge fitting, and timing it until it appears at the downstream manhole.

This might help you decide if an odor control chemical has sufficient time to react with the wastewater as it travels through the pipe at the calculated flow rate.

2. Given a flow rate of 0.87 cfs conveyed in a 12 inch diameter sewer line, what would be the velocity? (Hint: $A = \pi r^2$). If this is a sewer line, would settling of solids be a concern?

Ans: Remember to keep units the same, therefore, convert 12 inches to feet.
12 inches/12 inches = 1 ft

The radius is equal to half the diameter.
 $1 \text{ ft}/2 = 0.5 \text{ ft}$

Determine the area.
Area = $(3.14) (0.5 \text{ ft})^2 = 0.78 \text{ sq ft}$

Now determine the velocity.
 $V = Q/A = 0.87 \text{ cfs}/ 0.78 \text{ sq ft} = 1.11 \text{ fps}$

Typically, a sewer line should not have a velocity of less than approximately 2 fps. Therefore, solids may settle out unless flows increase. Settling of solids would be a concern.

This illustrates how knowing a flow rate can help you determine if other operational problems could exist.



Calculation

1. Find the hydraulic radius of a 12 inch diameter pipe, if the depth is 9 inches. Use the “Wetted perimeter in a pipe” figure in this unit and Table 6.2 in Appendix C.

Because most tables reference diameters in feet, we will convert inches to feet in the following calculation.

Ans: All units MUST be the same.
Depth of flow is 9 inches. Convert 9 inches to feet.
 $9 \text{ inches}/12 \text{ inches} = 0.75 \text{ foot}$

Diameter of pipe is 12 inches. Convert 12 inches to feet.
 $12 \text{ inches}/12 \text{ inches} = 1 \text{ foot}$

$d/D = 0.75 / 1 = 0.75$, refer to Table 6.2 which shows that the wetted perimeter factor is 0.3017 times the diameter of 1 foot.

2. What is the velocity if the wetted perimeter is 0.3017 ft, the slope is 0.007, and the pipe is a 12 inch diameter sanitary sewer line with a normal amount of internal slime, showing a Manning factor of 0.013?

Ans: $V = \frac{1.486 R^{2/3} S^{1/2}}{n}$

$$V = \frac{(1.486) (0.3017\text{ft}^{2/3}) (0.007^{1/2})}{0.013}$$

$$V = \frac{(1.486) (0.44987 \text{ ft}) (0.08367)}{0.013}$$

$$V = \frac{0.0559}{0.013}$$

Therefore the velocity is 4.3 feet per second (fps).

3. Determine the volume conveyed by the typical sewer line depicted in Problem 2 by using $Q=AV$ and ISCO Table 6.2 in Appendix C.

Ans: Since we know the velocity is 4.3 fps and we can find the area by using Table 6.2, we can use the $Q = AV$ formula to determine the volume conveyed by this typical sewer line.

Table 6.2 shows the area factor for a 0.75 depth of flow pipe is 0.6318. Multiply the area factor by the diameter (squared).

$$A = (0.6318) (1 \text{ ft})^2 = 0.6318 \text{ square feet.}$$

Multiplying the area of 0.6318 sq ft by the velocity of 4.3 fps yields a volume of 2.12 cubic feet per second.



Exercise/Activity

Compare the maximum flow capacity of a 10 inch Kennison versus a 10 inch Parabolic Nozzle. Look at Appendix C - ISCO Tables 3-8 and 3-9.

Ans A Kennison nozzle has a maximum capacity of 0.80 mgd and a parabolic nozzle has a 1.2 mgd capacity.



Exercise/Activity

A well-operated WWTP has an effluent flow that ranges from 10 gpm to 1,500 gpm. We do not anticipate an unacceptable amount of solids because the weir will be installed as a WWTP effluent flowmeter. What are the possible weir options? Use Appendix C - ISCO Table 5-3A.

- Ans
1. If you look at the table you will notice that only V-notch weirs are within this range. (This illustrates how concentrating the flow through a narrow opening, such as a V-notch, provides proper hydraulic conditions.)
 2. Within the V-notch ranges, at the lower flow rate of 10 gpm, there are only three possibilities of either a 22 ½, 30, or 45 degree notch weir.
 3. At the upper range of 1,500 gpm, the only one which fails to comply with a maximum of 1,500 gpm is the 22 ½ degree V-notch.
 4. Therefore, using the V-notch with the widest opening, to reduce potential problems when algae builds up in the notch, our choice would be the 45 degree.
-



Exercise/Activity

If we have a 2 ft rectangular weir without end contractions and the depth is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 11-3. Using Table 5-3, what is the flow range for this PHCE?

- Ans 566.6 gpm, 0.8159 mgd.
Approximately 400 gpm for a lower limit and approximately 4,000 gpm for an upper range.
-



Exercise/Activity

If we have a 2 ft Cipolletti weir and the depth of flow is 0.33 feet, what is the flow? Use Appendix C - ISCO Table 12-3.

- Ans Based on ISCO Table 12-3, the flow is 573 gpm.
-



Exercise/Activity

1. For a 12 inch Parshall Flume, where is the measuring point in relationship to the start of the throat? The throat is the size of the flume and is where the sides are parallel. Use Appendix C - ISCO Table 4.1A and the Parshall flume diagrams on the previous pages.

- Ans From ISCO Table 4.1A, column 2/3A, the answer is 3 feet.



Exercise/Activity

2. If we have a 6 inch flume and the depth of flow is measured to be 0.42 feet at the head, what is the flow rate in gallons per minute (gpm)? In million gallons per day (mgd)? Use Appendix C - ISCO Table 13-4.

Ans ISCO Table 13-4 shows the flows are 235 gpm or 0.3380 mgd.



Exercise/Activity

Select a flume that could be used for flows ranging from about 1 gpm up to 900 gpm. The type of material in the flow is normal fecal matter and paper most commonly present in domestic wastewater. Use Appendix C - ISCO Table 5-4.

Ans Look at various flow rates shown on ISCO Table 5-4. There are several H-type flumes and an extra large 60 degree trapezoidal flume that will work. Because we are not sure of the amount of solids that could clog the flume or settle out, we may want to consider the trapezoidal flume.



Calculation

If we have a pipe of 5 inch diameter, using the separation distance guidelines, what is the absolute minimum distance of straight pipe that is needed (excluding the width of the meter)?

Ans $10 D = (10) (5 \text{ inches}) = 50 \text{ inches upstream}$
 $5 D = (5) (5 \text{ inches}) = 25 \text{ inches downstream}$
 $50 + 25 = 75 \text{ inches. We will need at least a 75 inch section of straight unobstructed pipe, excluding the width of the meter.}$



Exercise/Activity

Using Appendix C Table 4-1a, find the sensor location for the following Parshall Flumes:

1 foot wide = Ans: $2/3 H_a$ is $9 \frac{17}{32}$ inches

2 foot wide = Ans: $2/3 H_a$ is $10 \frac{7}{8}$ inches



Calculation

Determine if a flowmeter needs calibration based upon comparing the flowmeter totalizer reading with calculations from the elapsed time meters for a pump station and a calibrated flow curve.

- The pumping station has two pumps. Refer to the pump performance curve from Gorman-Rupp on model S8A in Appendix E. Each pump was tested to provide 1,800 gallons per minute at a total dynamic head of 116 feet.
- The elapsed time meter for pump No 1 is 135 minutes, pump No. 2 is 140 minutes, and the simultaneous elapsed time meter had no run time.
- The discharge pressure on the pumps is normally 50 psi.
- Compare this with the flowmeter reading of 49,500 gallons per day.
- The flowmeter was calibrated by a new company who was not sure if there is a multiplier factor for the meter.

Ans: Pump No. 1 running for 135 minutes at 1,800 gpm conveys 243,000 gallons for the day.

Pump No. 2 running for 140 minutes at 1,800 gpm conveys 252,000 gallons for the day.

Pumps Nos. 1 and 2 do not run at the same time, therefore, there are no flow components for simultaneous operation of the pumps.

The total volume conveyed is 243,000 gallons plus 252,000 gallons for a total of 495,000 gallons for the day.

The flowmeter reading shows 49,500 gallons per day but the calculated flow is 495,000 gallons per day. The flowmeter is 1/10 of the calculated flow. It appears that when the flowmeter was calibrated, a factor of 10 was inadvertently missed.



Exercise/Activity

1. A 9 inch Parshall Flume on the raw wastewater line was checked by WWTP staff and the depths in inches are shown below, along with the depth converted to feet. Should an instrumentation person be contacted to inspect the flume? Refer to Appendix C - ISCO Table 13-5.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
1.2	0.10	10
3	0.25	165
4.5	0.38	310
6	0.50	477
7.5	0.62	663

Ans Although the meter shows a noticeable deviation from the table at the lowest flow, the other readings match the table. Since 4 of the 5 readings match the table, it is probable that the first reading was not done properly.

Note: ISCO Table 13-5 starts at 0.10 feet, so the first reading is at the lowest end of the table. This is not desirable and could have caused some of the meter inaccuracy.

2. A 2 foot Cippoletti Weir is used at the effluent end of a WWTP. What is your opinion of the meter readings? Use Appendix C - ISCO Table 12-3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	270
2.52	0.210	291
2.76	0.230	333
3.00	0.250	378
3.60	0.300	497
4.32	0.360	653
5.00	0.417	795

Ans The depth was measured very precisely based upon three significant figures. This allows for the correct calculation of three significant figures and the meter readings are acceptable.

3. There is a two foot wide board that an operator installed trying to fabricate a rectangular weir without end contractions. The operator measured directly above the weir with the following results. Was it measured properly and what are the flows? If measured properly, Appendix C - ISCO Table 11-3 can be used.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
0.5	0.04	
1.0	0.08	
1.5	0.12	
2.0	0.17	

Ans The readings are not valid because the flows were measured directly above the weir which is incorrect. Additionally, the board does not produce a sharp crested weir. Otherwise, you could use ISCO Table 11-3 if a sharp-crested weir was installed.

4. There is a sharp-crested 2 foot long rectangular weir without end contractions at a WWTP. Having taken this course, the operator measured at the proper location upstream of the weir. What are the flows? Use Appendix C - ISCO Table 11-3.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)
2.40	0.200	267
2.52	0.210	288
2.76	0.230	330

3.00	0.250	374
3.60	0.300	491
4.32	0.360	646
4.92	0.410	785

Ans The readings are valid because the flows were determined at the proper location. You could use ISCO Table 11-3. Correct readings are inserted in the table above.

5. Determine the amount of error an incorrect depth reading of ½ inch creates in a 120 degree V-notch weir if the perceived depth was 7 inches versus 7.5 inches. Determine its impact for a typical day at that rate. Use Appendix C, table 9-6.

Ans: At a depth of 7 inches (0.583 feet), the flow would be 498 gpm or a daily flow of 0.72 mgd but at 7.5 inches (0.625 feet), the closest value in the table is 0.62 feet and the flow at this depth is 588 gpm or a daily flow of 0.85 mgd.

The error of the average flow rate is $588 - 498 = 90$ gpm.

If the flow rate stayed constant throughout the day, the error would be approximately 0.13 million gallons per day in error.



Exercise/Activity

The average flow through a facility was estimated to be 200 gpm, based on water records. A 120 degree V-notch weir was installed. The staff reported a lack of flow detection sensitivity. The staff needed to interface a chemical feed disinfection system with the flowmeter and were able to determine that the minimum flow might be about 20 gpm and the maximum flow might be about 450 gpm. The metering point is the effluent from the WWTP, with suspended solids always below 30 mg/L, which allows the use of a V-notch weir. Use Appendix C - ISCO Tables 9-3, 9-5, and 9-6 to select a better V-notch weir.

Ans Either the 45 degree or 60 degree V-notch weir would work but the 45 degree V-notch is almost at its maximum range and would be operating at 1 foot of depth.

The 60 degree V-notch weir would only be operating at 0.87 feet (10 inches), which is better.

Select and use the 60 degree V-notch weir.

Emphasize that the 120 degree was too coarse of a measuring device.

Module 28:

Basic Math

Instructor Guide – Answer Key



Calculations

1. $6/10 - 2/5 =$

Ans: $2/10$, which can be reduced to $1/5$.

2. If a tank is $5/8$ filled with solution, how much of the tank is empty?

Ans: $3/8$ of the tank is empty. Since the whole tank would equal $8/8$, or 1, and $5/8$ of it is filled, then that means $3/8$ of it remains empty.

3. $1/2 \times 3/5 \times 2/3 =$

Ans: $6/30$, which can be reduced to $1/5$.

4. $5/9 \div 4/11 =$

Ans: $55/36$. You cannot reduce this fraction any further.

5. Convert $27/4$ to a decimal.

Ans: 6.75. This answer is arrived at by dividing 4 into 27.

6. Convert 0.45 to a fraction.

Ans: $45/100$, which can be reduced to $9/20$.

7. $4.27 \times 1.6 =$

Ans: 6.832

8. $6.5 \div 0.8 =$

Ans: 8.125

9. $12 + 4.52 + 245.621 =$

Ans: 262.141



Calculations

2. $(85 \times 17) + (22 \times 12)$

Ans: $1,445 + 264 = 1,709$

3.
$$\frac{(145 \times 9 \times 2) - (14 \times 9 \times 2) + 162}{(7 \times 5) - (10/2) + 150}$$

Ans: $\frac{2,610 - 252 + 162}{35 - 5 + 150} = \frac{2,520}{180} = 14$



Calculations

1. In Hampton City, the iron content of the raw water measures 5.0 mg/L. After treatment, the iron content is reduced to 0.2 mg/L. What is the percent removal of iron?

Ans: Step 1: $5.0 \text{ mg/L} - 0.2 \text{ mg/L} = 4.8 \text{ mg/L}$ (quantity of iron removed)

Step 2: $(4.8 \text{ mg/L} \div 5.0 \text{ mg/L}) \times 100\% = 96\%$ (percent removed)

2. Given a raw water turbidity of 18 NTU's and a finished water turbidity of 0.25 NTU's, calculate the percent removal.

Ans: $[(18 - 0.25) / 18] \times 100\% = 98.6\%$

[Note that these problems can be done in multiple steps (problem 1) or in a single step (problem 2).]



Calculations

1. Round 9.875 to two decimal points.

Ans: 9.88

2. Round 9,637 to the nearest thousand.

Ans: 10,000

4. Round 9,637 to the nearest hundred.

Ans: 9,600

5. Round 9,637 to the nearest tens.

Ans: 9,640



Calculations

1. 9 pounds x 3 pounds.

Ans: 9 pounds by 3 pounds = 27 square pounds.

2. 8 feet x 3 feet x 0.5 feet.

Ans: 8 feet x 3 feet x 0.5 feet = 12 cubic feet.



Unit 1 Review Exercise

1. Round 987.5321:

A.) To the nearest tens place.

Ans: 990

B.) To the nearest hundredths place.

Ans: 987.53

2. How many gallons of water would it take to fill a tank that has a volume of 6,000 cubic feet?

$$\text{Ans: } \frac{6,000 \text{ cu ft}}{1} \times \frac{7.48 \text{ gal}}{1 \text{ cu ft}} = 44,880 \text{ gal.}$$

3. $\frac{3}{4} - \frac{1}{8} =$

Ans: $\frac{6}{8} - \frac{1}{8} = \frac{5}{8}$

4. $25 + 101.53 + 0.479 =$

Ans: 127.009

5. We know that disinfection rates will increase as temperature increases. Assuming all else is equal, which tank would achieve disinfection first, Tank A at 40° F or Tank B at 15° C?

Ans: Tank B

In order to compare the temperatures to see which tank has the higher temperature, they must first be converted to the same units. You can either convert °F to °C or convert °C to °F. Let's look at both.

Step 1: Convert.

<u>Tank A</u>		<u>Tank B</u>
Celsius = $(^{\circ}\text{F} - 32^{\circ}) \times \frac{5}{9}$ = $(40^{\circ}\text{F} - 32^{\circ}) \times \frac{5}{9}$ = $(8^{\circ}\text{F}) \times \frac{5}{9}$ = 4.4°C		Fahrenheit = $(^{\circ}\text{C} \times \frac{9}{5}) + 32^{\circ}$ = $(15^{\circ}\text{C} \times \frac{9}{5}) + 32^{\circ}$ = $(27^{\circ}\text{C}) + 32^{\circ}$ = 59°F

Step 2: Compare.

<u>Tank A</u>		<u>vs.</u>		<u>Tank B</u>
4.4° C 40° F	\longleftrightarrow \longleftrightarrow			15° C 59° F

6. What is 0.22 expressed as a fraction?

Ans: $0.22 \times \frac{1}{1} = \left\{ \frac{0.22}{1} \times \frac{100}{100} \right\} = \frac{22}{100} = \frac{(11 \times 2)}{(11 \times 9.09)} = \frac{11}{11} \left\{ \frac{2}{9.09} \right\} = 1 \left\{ \frac{2}{9.09} \right\} = \frac{2}{9}$

Note: Once again, it is ok to drop the decimal point and decimal places from the 9.09 since 0.22 was only an approximation of 2/9 [2/9 = 0.2222...].

7. If you disinfect a storage tank with 150 mg/L of 100% strength chlorine knowing there is a chlorine demand of 5 mg/L, what percentage of the applied dose is being consumed by the chlorine demand?

Ans: $(5 \text{ mg/L} \div 150 \text{ mg/L}) \times 100\% = 3.3\%$

8. How much would the water in a 6,000 cu ft tank weigh in pounds? In kilograms?

$$\text{Ans: } \frac{6,000 \text{ cu ft}}{1} \times \frac{62.37 \text{ lbs}}{1 \text{ cu ft}} = 374,220 \text{ lbs} \quad \text{and} \quad \frac{374,220 \text{ lbs}}{1} \times \frac{1 \text{ kg}}{2.2 \text{ lbs}} = 170,100 \text{ kg}$$



Calculations

1. What is the surface area of an uncovered tank that is 100 feet long, 25 feet wide and 15 feet high and how many gallons of paint would be needed to paint the outside of the tank? One gallon of paint will cover 200 square feet.

Ans: To determine how much paint is required to paint the outside of a tank, the total area must first be calculated. Keep in mind that there are four sides to the tank. Two sides are 100 feet long by 15 feet tall. The area for these sides is calculated as follows:

$$A = L \times W$$

$$A = 100 \text{ feet} \times 15 \text{ feet} = 1500 \text{ square feet}$$

Because there are two sides with these dimensions, we add $1500 + 1500$ and get a total area of 3,000 square feet for the two largest sides.

There are also two other sides which are smaller. These two sides are 25 feet wide and 15 feet high. The area for these sides is calculated as follows:

$$A = L \times W$$

$$A = 25 \text{ feet} \times 15 \text{ feet} = 375 \text{ square feet}$$

Because there are two sides with these dimensions, we add $375 + 375$ and get a total area of 750 square feet for the two smaller sides.

To get the total surface area, we add the area of the two larger sides and the area of the two smaller sides:

$$\text{Surface area} = 3,000 \text{ square feet} + 750 \text{ square feet} = 3,750 \text{ square feet}$$

To determine how many gallons of paint are required:

We know that one gallon will cover 200 square feet, so we divide the total surface area of the tank by 200 square feet:

$$\text{Gallons of paint} = \frac{3,750 \text{ sq ft.}}{200 \text{ sq. ft. per gallon}}$$

$$200 \text{ sq. ft. per gallon}$$

$$\text{Gallons of paint} = 18.75 \text{ gallons of paint, or, } 19 \text{ gallons.}$$

2. If the tank had a cover, what would its area be?

Ans: If the tank has a cover, it would be 100 feet long by 25 feet wide. Its area would be:

$$A = L \times W$$

$$A = 100 \text{ feet} \times 25 \text{ feet}$$

$$A = 2,500 \text{ square feet.}$$



Calculations

- Find the area of a triangle with a base of 20 feet and a height of 16 feet.

Ans: The formula for calculating the area of a triangle is: $A = \frac{1}{2} B \times H$.

$$A = \frac{1}{2} (20 \text{ feet}) \times (16 \text{ feet})$$

$$A = \frac{320}{2} \text{ square feet}$$

$$A = 160 \text{ square feet}$$



Calculations

- Treatment Plant X is planning to build a new aerobic digester with a diameter of 80 feet and a height of 30 feet. Calculate the total surface area of the new tank.

Ans: Step 1: Calculate the area of the circle. Remember that the radius is equal to one half of the diameter, so in this problem, the radius is 40 feet.

$$A = \pi R^2$$

$$A = (3.14) (40 \text{ feet})^2$$

$$A = (3.14) (1600 \text{ ft}^2)$$

$$A = 5,024 \text{ square feet}$$

Step 2: Calculate the area of the sides of the tank.

$$A = \pi \times D \times H$$

$$A = (3.14) (80 \text{ feet}) (30 \text{ feet})$$

$$A = 7,536 \text{ square feet}$$

Now, add the values from Steps 1 and 2 to give the total surface area.

$$7,536 \text{ ft}^2 + 5,024 \text{ ft}^2 = 12,560 \text{ ft}^2$$

[Instructor note: if students use a calculator with π , the resultant numbers will be 5,026 square feet, 7,539 square feet, and 12,565 square feet.]



Calculations

- How many gallons of water could a 5 feet by 2 feet by 2 feet aquarium hold?

Ans: First, determine the volume of the aquarium using the formula $V = L \times W \times H$.

$$V = (5 \text{ feet}) (2 \text{ feet}) (2 \text{ feet})$$

$$V = 20 \text{ cubic feet}$$

To convert the volume into gallons, multiply the above answer by 7.48 since there are 7.48 gallons of water in one cubic foot. This will give us an answer of 150 gallons of water.



As a bonus question, can anyone tell me how much the 150 gallons of water would weigh?

Ans: One gallon of water weighs 8.34 pounds, so to determine how much the 150 gallons weighs, multiply 150 by 8.34 and you get 1,251 pounds as the weight of the water.

2. What is the volume, in cubic feet, of the bed of a dump truck measuring 15 feet long, 7 feet wide, and 6 feet deep?

Ans: The volume of the bed of the dump truck can be determined using the formula $V = L \times W \times H$.

$$V = (15 \text{ feet}) (7 \text{ feet}) (6 \text{ feet})$$

$$V = 630 \text{ cubic feet}$$

3. If a pump is filling a 10,000 gallon tank at the rate of 250 gpm, how long will it take to fill the tank?

Ans: Divide the volume of the tank (10,000 gallons) by the filling rate of 250 gallons/minute and you will get a fill time of 40 minutes.

4. If a flow of 10,000 gpm is going into a 500,000 gallon tank, what is the average detention time within the tank?

Ans: Detention time is sometimes compared to a fill time for a tank. Divide the volume of the tank (500,000 gallons) by the flow rate of 10,000 gpm, and you get a detention time of 50 minutes.



Calculations

1. A circular clarifier is 80 feet in diameter, a side water depth of 15 feet, and sloped towards a center depth of 19 feet. How much sludge would be in the 4 foot deep section of the tank bottom?

Ans: This requires using the formula for the area of a cone, which is: $V = \frac{\pi}{3} R^2 \times H$.

Since the diameter is 80 feet, we know the radius is 40 feet.

$$V = \frac{\pi}{3} R^2 \times H$$

$$V = (3.14) \frac{(40 \text{ feet})^2}{3} \times 4 \text{ feet}$$

$$V = (3.14) (1,600 \text{ square feet}) (4 \text{ feet})$$

$$V = \frac{20,096}{3} \text{ cubic feet}$$

$$V = 6,699 \text{ cubic feet}$$

To express this in gallons, multiply the volume in cubic feet by 7.48 gallons per cubic foot, and the answer in gallons is 50,108.

[Instructor note: if students use a calculator with π , the resultant numbers will be 6,702 cubic feet and 50,131 gallons.]



Calculations

1. A tank has a diameter of 100 feet and a depth of 12 feet. What is the volume in cubic feet and in gallons?

Ans: The diameter is 100 feet, so the radius is half of 100, or, 50 feet. The volume is determined by using the formula $V = \pi R^2 \times H$.

$$V = (3.14) (50 \text{ feet})^2 (12 \text{ feet})$$

$$V = (3.14) (2,500 \text{ square feet}) (12 \text{ feet})$$

$$V = 94,200 \text{ cubic feet}$$

To convert this to gallons, we multiply the 94,200 cubic feet by 7.48 gallons per cubic foot, and get a total of 704,616 gallons.

2. If the diameter is doubled, what is the tank capacity in cubic feet and gallons?

Ans: If the diameter is doubled, it becomes 200 feet and the radius becomes 100 feet. We still use the same formula used in the first calculation: $V = \pi R^2 \times H$.

$$V = (3.14) (100 \text{ feet})^2 (12 \text{ feet})$$

$$V = (3.14) (10,000 \text{ square feet}) (12 \text{ feet})$$

$$V = 376,800 \text{ cubic feet}$$

To convert this to gallons, we multiply the 376,800 cubic feet by 7.48 gallons per cubic foot, and get a total of 2,818,464 gallons.

3. How many gallons of chemical would be contained in a full drum that is 3 feet tall and 1.5 feet in diameter?

Ans: First you must compute the volume of the drum. Since the radius is equal to one half of the diameter, we know that the radius of the drum is 0.75 feet. Again, we calculate the volume using the equation $V = \pi R^2 \times H$.

$$V = (3.14) (0.75 \text{ feet})^2 (3 \text{ feet})$$

$$V = (3.14) (0.5625 \text{ square feet}) (3 \text{ feet})$$

$$V = 5.3 \text{ cubic feet}$$

To convert this to gallons, we multiply the 5.3 cubic feet by 7.48 gallons per cubic foot, and get a total of 40 gallons.



Calculations

1. How many mg/min are there in 1 lb/day?

Ans: Unknown Data: $\frac{? \text{ mg}}{\text{min}}$

Known Data: $\frac{1 \text{ lb}}{\text{day}}$

Steps: List unknown data including units. Place data with same numerator unit to the right of the equal sign followed by a multiplication sign. Continue to place data into equation to systemically cancel all unwanted units until only the unknown units remain.

$$\frac{? \text{ mg}}{\text{min}} = \frac{1,000 \text{ mg}}{1 \text{ g}} \times \frac{454 \text{ g}}{1 \text{ lb}} \times \frac{1 \text{ lb}}{\text{day}} \times \frac{1 \text{ day}}{1,440 \text{ min}} =$$

Now do the math (multiply all numerator values, multiply all denominator values, then divide numerator by the denominator.)

$$\frac{? \text{ mg}}{\text{min}} = \frac{454,000 \text{ mg}}{1440 \text{ min}} = 315.3 \frac{\text{mg}}{\text{min}}$$

2. How many hours will it take to empty a 55 gallon drum of a liquid chemical using a chemical feed pump that will pump at a rate of 30 ml/min?

Ans: Known Data: 55 gal and $\frac{30 \text{ ml}}{\text{min}}$

Unknown Data: ? Hours

$$\frac{? \text{ Hours}}{1} = \frac{\text{hr}}{60 \text{ mins}} \times \frac{\text{min}}{30 \text{ ml}} \times \frac{3785 \text{ ml}}{\text{gal}} \times \frac{55 \text{ gal}}{1} = \frac{208175}{1800} = 115.6 \text{ hrs.}$$

Note: The pump rate is rearranged to place the time unit in the numerator.



Calculations

- How many pounds per day of total phosphorus (TP) are discharged from a plant with a flow of 350,000 gallons per day (gpd) and an effluent TP concentration of 1.2 mg/L?

Ans: The formula is: Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
 First we need to convert the 350,000 gallons into MGD. 350,000 gallons is equal to 0.35 MGD.
 Next, we simply plug the numbers into our formula:
 Loading, lbs/day = (0.35 MGD) (1.2 mg/L) (8.34 lbs/gal)
 Loading, lbs/day = 3.5



Calculations

- If a well pump delivers 400 gpm, and the chlorine dose is 2.5 mg/L, determine the appropriate chlorinator setting in lbs/day.

Ans:
$$\text{Flow} = \frac{400 \text{ gal}}{\text{min}} \times \frac{1440 \text{ min}}{\text{day}} \times \frac{1}{1,000,000}$$

$$= 0.576 \text{ MGD}$$

Chemical Feed = (Flow, MGD)(Dose, mg/L)(8.34 lbs/gal)

$$= (0.576 \text{ MGD})(2.5 \text{ mg/L})(8.34 \text{ lbs/gal})$$

$$= 12 \text{ lbs/day}$$



Calculations

- What is the geometric monthly fecal coliform mean of a distribution system with the following FC counts: 24, 15, 7, 16, 31 and 23? The result will be inputted into a NPDES DMR, therefore, round to the nearest whole number.

Ans: Remember that the formula for geometric mean, as defined in the definition in the workbook is: $(X_1 \times X_2 \times X_3 \times \dots \times X_n)^{1/n}$ where X is the sample value and n is the number of samples. Using the nth root method, the answer is calculated as follows:

Step 1: Multiply all the values together.
 $(24 \times 15 \times 7 \times 16 \times 31 \times 23) = 28748160$

Step 2: Determine the number of tests done. In this example, the number of tests was 6, which becomes the n^{th} root, or, $1/6$, which equals 0.166666666.

Step 3: Take the n^{th} root of the final multiplied number.
 $(28748160)^{0.166666} = 17.5025$ or $\sqrt[6]{29748160}$

Remember that the geometric mean is representing a “life form” so round to the proper integer value, which in this case is 18.

[Instructor note: If participants get 19.3 as their answer, they most likely computed the average, not the geometric mean.]

2. What is the fecal coliform geometric mean of digested sludge with the following FC counts: 1502, 99, 460, 45, 590, 111 and 385?

Ans: Again, using the n^{th} root method, the answer is calculated as follows:

Step 1: $(1502 \times 99 \times 460 \times 45 \times 590 \times 111 \times 385) = 7.760884 \times 10^{16}$

Note: Due to the length of the answer in step one, it is best expressed as an exponent.

Step 2: In this example, the number of tests was 7, which becomes the n^{th} root, or, $1/7$, which equals 0.14285714.

Step 3: Take the n^{th} root of the final multiplied number.
 $(7.760884 \times 10^{16})^{0.14285714} = 258.729$ or $\sqrt[7]{7.760884 \times 10^{16}}$

Remember that the geometric mean is representing a “life form” so round to the proper integer value, which in this case is 259.



Exercise

1. What is the reading on the following meter? _____

Ans: 8642



Exercise 1

An operator wants to disinfect a round storage tank with a flat bottom. The tank is 120 feet in diameter and 15 feet deep. The intended task is to achieve a chlorine residual of 100 mg/l after a 24 hour detention period during which time no flow will be entering or exiting the tank.

6. How many cubic feet are in the tank?

Ans: The volume is determined by using the formula $V = \pi R^2 \times H$.

$$V = (3.14) (60 \text{ feet})^2 (15 \text{ feet})$$

$$V = (3.14) (3600 \text{ square feet}) (15 \text{ feet})$$

$V = 169,560$ cubic feet

7. How many gallons are in the tank?

Ans: Multiply 169,560 cubic feet by 7.48 gallons per cubic foot, and the answer is 1,268,309 gallons.

8. Assume there is a possible chlorine demand of 10 mg/l in addition to the 100 mg/l desired chlorine residual. What is the amount of 100% strength chlorine that should be fed into the tank?

Ans: If the chlorine demand is 10 mg/L and the desired concentration is 100 mg/l, we get a total dosage of 110 mg/L by adding these two numbers together.

In question 2, we calculated how many gallons are in the tank. Convert this to million gallons and it becomes 1.268 million gallons.

Chemical Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)

Chemical Feed, lbs/day = (1.268 MGD) (110 mg/L) (8.34 lbs/gal)

Chemical Feed, lbs/day = 1,163 pounds of 100% strength chlorine.

4. How much chlorine is consumed by the chlorine demand?

Ans: From question 3, we know that the chlorine demand is 10 mg/L.

To calculate the amount of chlorine consumed, use this formula:

Chemical Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)

Chemical Feed, lbs/day = (1.268 MGD) (10 mg/L) (8.34 lbs/gal)

Chemical Feed, lbs/day = 105.7 pounds.

5. If the operator wants to use sodium hypochlorite of 12% strength, how many gallons will be needed? Use a specific gravity of 1.168 for the sodium hypochlorite solution.

Ans: Most chlorine solutions do not weigh 8.34 pounds per gallon. As an example, sodium hypochlorite of 12% strength weighs approximately 10 pounds per gallon. This can be determined by multiplying the specific gravity of 1.168 times the normal weight of water (8.34 pounds), which yields a result of 9.74 pounds per gallon. This means that 9.74 pounds of the solution contains 1.168 pounds of chlorine per gallon.

In question 3, we determined the weight of 100% chlorine needed was 1,163 pounds. Since we are using a 12% solution in this problem, we must divide the 1,163 pounds by 12%, which yields 9,692 pounds of 12% solution. Next, we divide the 9,692 pounds of solution by its weight of 9.74 pounds and get 995 gallons.

6. In order to comply with maximum chlorine residual limits prior to discharge through the system, the tank effluent must be dechlorinated. The operator performs a chlorine residual test and determined it is 95 mg/L. Assume it requires 1 pound of dechlorination agent per 1 pound of chlorine, how much dechlorination agent will be required?

Ans: Dechlorination agent needed = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
 Dechlorination agent needed = (1.268 MGD) (95 mg/L) (8.34 lbs/gal)
 Dechlorination agent needed = 1,004.6 pounds

7. The tank is going to be emptied at a rate of 1,000 gpm (gallons per minute), how long will it take?

Ans: Rate = $\frac{1,268,309 \text{ gal}}{1,000 \text{ gpm}}$ = 1,268 min

8. The dechlorination process is going to be conducted at the same time the tank is being emptied. The dechlorination solution has an effective strength of 80% strength and a specific gravity of 1.0. What feed rate in gals/minute should the pump be set at to dose the 1,000 gpm flow out of the tank? How many gallons of the dechlorination agent will be used?

Ans: If the dechlorination agent is only 80% strength and we previously determined we would need 1005 pounds of dechlorination agent, then we need 1,256 pounds of solution. We know the solution weighs 8.34 pounds per gallon, so we can determine the total volume of solution by dividing 1,256 by 8.34. This gives a result of 151 gallons. From the information in question 7, we know the tank will empty in 1,268 minutes, so we divide the flow of 151 gallons by the time (1,268 minutes) and we get 0.119 gpm.

$$\begin{aligned} \text{Liquid Feed} &= (1005 \text{ lbs}) \div (8.34 \text{ lbs/gal} \times 80\% / 100\%) \\ &= (1005 \text{ lbs}) \div (6.67 \text{ lbs/gal}) \\ &= 151 \text{ gal} \end{aligned}$$

$$\begin{aligned} \text{Rate} &= \frac{151 \text{ gal}}{1,268 \text{ min}} \\ &= 0.119 \text{ gpm} \end{aligned}$$



Exercise 2

A treatment plant daily flow is 250,000 gpd. And the flow is split equally between two aeration tanks. Each aeration tank is 75 feet long, 15 feet deep and 15 feet wide. The laboratory testing indicates the following: influent BOD₅ = 150 mg/L, influent CBOD₅ = 120 mg/L, effluent CBOD₅ = 6 mg/L and the MLVSS in each aeration tank is 3,500 mg/L.

1. What is the volume in cubic feet and in gallons, of each aeration tank?

Ans: $V = L \times W \times H$
 $V = (75 \text{ feet}) (15 \text{ feet}) (15 \text{ feet})$
 $V = 16,875 \text{ cubic feet}$

To convert volume into gallons, multiply 16,875 cubic feet by 7.48 gallons per cubic foot, and you get 126,225 gallons.

2. What is the average detention time in the aeration basins?

Ans: The flow of 250,000 gpd is split between two tanks, which means each tank has a flow of 125,000 gallons. In question 1, we calculated the capacity of the tank as 126,225 gallons. To determine the detention time, divide the tank capacity of 126,225 gallons by the flow of 125,000 gallons per day, for a result of 1.01 days.

3. What is the organic loading to the facility in pounds of BOD₅ and also in CBOD₅?

Ans: BOD₅ Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)

Loading, lbs/day = (0.25 MGD) x (150 mg/L) x (8.34 lbs/gal)

Loading, lbs/day = 313 lbs/day

CBOD₅ Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)

Loading, lbs/day = (0.25 MGD) x (120 mg/L) x (8.34 lbs/gal)

Loading, lbs/day = 250 lbs/day

4. How many pounds of CBOD₅ are discharged from the facility?

Ans: CBOD₅ discharged = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)

CBOD₅ discharged = (0.25 MGD) (6 mg/L) (8.34 lbs/gal)

CBOD₅ discharged = 12.51 pounds per day. If rounded to the closest integer, the answer becomes 13 pounds per day.

5. What is the removal efficiency for the facility?

Ans: You can not, and must not, compare BOD₅ in the influent with CBOD₅ in the effluent; therefore, the only removal efficiency which can be calculated is for CBOD₅:

Removal efficiency, CBOD₅ = $\frac{\text{influent CBOD}_5 - \text{effluent CBOD}_5}{\text{Influent CBOD}_5} \times 100\%$

Removal efficiency CBOD₅ = $\frac{120 \text{ mg/L} - 6 \text{ mg/L}}{120 \text{ mg/L}} \times 100\%$

Removal efficiency CBOD₅ = 95%

6. How many pounds of biomass are in the two aeration tanks?

Ans: Previously the volume of 1 tank was determined to be 126,225 million gallons. First, multiply 126,225 by 2 to get a total volume of 252,450. Then convert that to MGD by dividing it by 1,000,000 and we get 0.252. Next we use the formula:

Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)

Loading, lbs/day = (0.252 MGD) (3,500 mg/L) (8.34 lbs/gal)

Loading, lbs/day = 7,356 pound

7. Based upon the organic loading and MLVSS concentration, calculate the F/M.

Ans: The food, as measured by BOD₅, is 313 pounds (this was calculated in Question 3). The microorganism is 7356 pounds, as determined in Question 6. Based on this information:

$$F/M = \frac{313}{7356}$$
$$F/M = 0.043$$

The food, as measured by CBOD₅, is 250 pounds (this was calculated in Question 3). The microorganism is still 7356 pounds, as determined in Question 6. Based on this information:

$$F/M = \frac{250}{7356}$$
$$F/M = 0.034$$

It is important to recognize the difference between using BOD₅ and CBOD₅ when evaluating organic loading. A substantial amount of operational guidelines and design information about F/M was developed using BOD₅ information.



Exercise 3

An operator runs 4 solids tests per week for every week of the year but available laboratory time is limited and at times he is behind schedule. The operator is evaluating the use of outside laboratory services.

- The operator is paid \$15/hour but also has fringe benefits that account for another 45% of his total labor cost. Currently the testing is conducted at the facility and requires 45 minutes per test. The laboratory supplies cost \$250 per year for the solids testing. The laboratory equipment cost \$2,000 when originally purchased 4 years ago. With proper care and maintenance the equipment has an expected service life of 20 years.
 - The operator obtained a price quote of \$15 per solids test from an outside contract laboratory. The laboratory can return the analytical results within 3-4 weeks.
1. Compare the total cost for the solids testing for either in house or the contract laboratory.

Ans: First we must determine the costs of testing in house, which will involve the labor costs, chemical cost and equipment cost, so we must calculate each of these.

Labor Cost

Step 1: \$15/hour + 45% for benefits

\$15/hour multiplied by 0.45 (which is the decimal representation of 45%) yields \$6.75 for benefits
\$15.00 + \$6.75 = \$21.75/hour

Step 2: 45 minutes equals 0.75 hours 45 minutes divided by 60 minutes = 0.75 hour
(0.75 hour/test) (4 test/week) = 3 hours/week for testing

Step 3: Yearly labor cost = (time per week for testing) (52 weeks/year) (hourly labor rate)

Yearly labor cost = (3 hrs/week) (52 weeks/year) (\$21.75/hour)

Yearly labor cost = \$3,393 labor cost for the year.

Chemical and Equipment Cost

As stated in the information supplied in the question, chemical costs are \$250/year. Next, we must calculate the annual cost of the equipment. We know that the equipment cost is \$2,000 and it is expected to last 20 years. Based on this information, the annual cost of the equipment is:

$$\text{Annual cost} = \frac{\text{Total cost of equipment}}{\text{Life expectancy of equipment}}$$

$$\text{Annual cost} = \frac{\$2,000}{20 \text{ years}}$$

$$\text{Annual cost} = \$100/\text{year}$$

Total Cost

The total cost is calculated by adding together the cost of labor, the cost of the chemicals and the cost of the equipment: $\$3,393 + \$250 + \$100 = \$3,743$ total annual cost.

Cost per test for in house

We know from the information supplied above that the operator performs 4 tests per week. To determine the total number of tests per year, we multiply 4 tests/week by 52 weeks/year and find that a total of 208 tests per year are done. Now we have to determine the cost per test, which is done as follows:

$$\text{Cost per test} = \frac{\text{Total annual cost}}{\text{Number of tests/year}}$$

$$\text{Cost per test} = \frac{\$3,743}{208}$$

$$\text{Cost per test} = \text{about } \$18.00 \text{ per test}$$

Cost of Using Contract Lab

We know that the contract lab provided a quote of \$15 per test. We will use this piece of information to calculate the cost of using the contract lab.

$$\text{Cost of contract lab} = (\text{number tests/week}) (52 \text{ weeks/year}) (\text{cost per test})$$

$$\text{Cost of contract lab} = (4 \text{ tests/week}) (52 \text{ weeks/year}) (\$15/\text{test})$$

$$\text{Cost of contract lab} = \$3,120 \text{ dollars}$$

2. Discuss the advantages/disadvantages of both options.

Ans: Let's compare the two options:

In house – This is more expensive but the results from the testing are known within 1-2 days. The information may be needed to make process control decisions and delay of a proper process adjustment by 3-4 weeks may result in a NPDES Permit violation. There is still about 16 years left on service life for the equipment; therefore, replacement is not needed in the immediate future.

Contract lab - Contract lab costs are about \$3.00 less per test ($\$18.00 - \$15.00 = \3.00). This means we are looking at an annual savings of \$623 per year ($\$3,743 - \$3,120 = \623). However, it takes almost a month to receive results from the lab. Can a process decision be delayed for this length of time? In some situations, if the operator is already overworked, it may be necessary to use contract lab services so the operator can catch up.

Summary - Once the operator is caught up, he must review his workload to determine how, or if, he can improve. Delaying process adjustments may result in penalties or fines of several thousand dollars per day.

In Question 1, part c, the labor cost shows 52 weeks per year testing. It is not expected that the operator works without any vacation or never has a sick day; however, the NPDES Permit may have a defined testing schedule which would require use of another person or lab. This may be a good choice for usage of the contract lab.

[To complete the Feed diagram:

- Step 1. Fill in the known data.*
 - Step 2. Put a question mark (?) for the value of any unknown data that you need.*
 - Step 3. If the unknown data is on the Metric system side, use the conversions provided to move each piece of known (English system) data across to the metric side. Likewise if the unknown data is on the English side, convert the known (Metric system) data to the English side.*
 - Step 4. Use unit cancellation to solve for the product feed rate.]*
-
-

Module 29:
General Chemistry
Instructor Guide – Answer Key



Periodic Table Exercise

1. What is the atomic number of an element that contains 11 protons?

Ans: Sodium

2. The element Carbon has the atomic number of 6. How many protons does Carbon contain?

Ans: 6

3. Indicate the atomic weight of an element that contains 7 protons and 7 neutrons.

Ans: 14



Physical and Chemical Changes

[Review the following statements and mark whether the change is physical or chemical.]

	PHYSICAL	CHEMICAL
1. Drinking water from ocean water by means of evaporation and condensation	✓	
2. Sodium from sodium chloride		✓
3. Pulverizing rock salt	✓	
4. Burning wood		✓
5. Dissolving sugar into water	✓	

WW Modules Answer Key

6. Rusting of Iron		✓
7. The evaporation of alcohol	✓	



Review Exercise

1. Define the term matter and list the three states of matter.

Ans: Matter occupies space and has mass. The air that surrounds us, the pencil that we write with and the water that we drink are all examples of matter. The three states of matter are solid, liquid and gas.

2. Differentiate between mass, weight, density and specific gravity.

Ans: Mass is the amount of matter present in a given object.

Weight is the mass of an object being acted upon by gravity.

Density is the mass of a substance per unit of volume of the substance.

Specific gravity is the density of a substance compared to the weight of the same volume of water.

3. Explain the difference between a physical and a chemical change in matter.

Ans: A physical change in matter is a change in the form of matter but not in its chemical identity. A chemical change in matter is a change in which one or more kinds of matter transform into a new kind of matter.

4. List and define three classes of matter.

Ans: Element – a substance that cannot be decomposed into simpler substances by any chemical reaction.

Compound – a substance that is composed of two or more elements that are chemically combined in fixed proportions.

Mixture – a material that can be separated by physical means into two or more substances.



Exercise

3. What is the molecular weight of H_2SO_4 (sulfuric acid)?

Ans: 2 H atoms = $1.0080 + 1.0080 = 2.016$
 1 S atom = 32.064
 4 O atoms = $15.9994 + 15.9994 + 15.9994 + 15.9994 = 63.9976$
 By adding the three molecular weights together, we get a total molecular weight of 98.0776 for H_2SO_4 .

4. What is the molecular weight of 2 molecules of CH_4 (methane)?

Ans: 1 C atom = 12.0112
 4 H atoms = $1.0080 + 1.0080 + 1.0080 + 1.0080 = 4.032$
 By adding the two molecular weights together ($12.0012 + 4.032$), we get a total molecular weight of 16.0432 for CH_4 , which is the weight of one molecule of CH_4 . Since we are asked to calculate the molecular weight of two molecules of CH_4 , we need to add $16.0432 + 16.0432$, which gives us a total molecular weight for the two molecules of 32.0864.



Calculations Using Moles

1. Calculate the number of moles in 80 grams of NaOH (sodium hydroxide, or caustic soda).

Ans: Step 1: To calculate the molecular weight of NaOH, reference the periodic table to determine the following atomic weights:
 1 Na atom = 22.9898
 1 O atom = 15.9994
 1 H atom = 1.00797
 By adding the three molecular weights, we get a total molecular weight of 39.99717 for NaOH.

Step 2: To calculate the number of moles, divide the molecular weight by the total number of grams.

$$\text{Moles} = \frac{39.99717}{80 \text{ grams}}$$

$$\text{Moles} = 0.50 \text{ moles}$$

2. Calculate the number of moles in 40 grams of H_2O_2 (hydrogen peroxide).

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Ans: Step 1: To calculate the molecular weight of H_2O_2 , reference the periodic table to determine the following atomic weights:
2 H atoms = $1.0080 + 1.0080 = 2.0160$
2 O atoms = $15.9994 + 15.9994 = 31.9988$
By adding the two molecular weights, we get a total molecular weight of 34.0040 for H_2O_2 .

Step 2: To calculate the number of moles, divide the molecular weight by the total number of grams.

$$\text{Moles} = \frac{34.0040}{40 \text{ grams}}$$
$$\text{Moles} = 0.85 \text{ moles}$$

3. Calculate the number of moles in 79 grams of KMnO_4 (potassium permanganate).

Ans: Step 1: To calculate the molecular weight of KMnO_4 , reference the periodic table to determine the following atomic weights:

$$1 \text{ K atom} = 39.0983$$

$$1 \text{ Mn atom} = 54.9381$$

$$4 \text{ O atoms} = 15.9994 + 15.9994 + 15.9994 + 15.9994 = 63.9976$$

By adding the three molecular weights, we get at total molecular weight of 158.0340 for KMnO_4 .

Step 2: To calculate the number of moles, divide the molecular weight, by the total number of grams.

$$\text{Moles} = \frac{158.0340}{79 \text{ grams}}$$
$$\text{Moles} = 2.0 \text{ moles}$$

4. Calculate the number of grams in 0.5 mol of HCl (hydrochloric acid).

Ans: Step 1: To calculate the molecular weight of HCl , reference the periodic table to determine the following atomic weights:

$$1 \text{ H atom} = 1.0080$$

$$1 \text{ Cl atom} = 35.4527$$

By adding the three molecular weights, we get at total molecular weight of 36.4607 for HCl .

Step 2: To calculate the number of grams, multiply the molecular weight by the total number of moles per molecule.

$$\text{Grams} = (36.4607) (0.5 \text{ mol})$$

$$\text{Grams} = 18.23$$

5. Calculate the number of grams in 1 mol of $\text{Fe}_2(\text{SO}_4)_3$ (ferric sulfate).

Ans: Step 1: To calculate the molecular weight of $\text{Fe}_2(\text{SO}_4)_3$, reference the periodic table to determine the following atomic weights:

WW Modules Answer Key

$$2 \text{ Fe atoms} = 55.847 + 55.847 = 111.694$$

$$3 \times 1 \text{ S atoms} = 32.066 + 32.066 + 32.066 = 96.198$$

$$3 \times 4 \text{ O atoms} = 12 \times 15.9994 = 191.992$$

By adding the three molecular weights, we get at total molecular weight of 399.884 for $\text{Fe}_2(\text{SO}_4)_3$.

Step 2: To calculate the number of grams, multiply the molecular weight by the total number of moles per molecule.

$$\text{Grams} = (399.884) \times (1 \text{ mol})$$

$$\text{Grams} = 399.88$$



Exercise

1. Calculate the Molarity of 12g of NaOH dissolved in 250 milliliters of deionized water.

Ans: Step 1: Convert grams of NaOH to moles.

$$1 \text{ atom of Na} = 22.9898$$

$$1 \text{ atom of O} = 15.9994$$

$$1 \text{ atom of H} = \underline{1.0080}$$

$$39.9972$$

$$\text{Moles of NaOH} = 12 \text{ grams} / 39.9972 = 0.30 \text{ moles}$$

Step 2: Calculate the molarity of the solution

$$\text{Molarity} = 0.30 \text{ mol} / 0.250 \text{ L} = 1.2 \text{ M}$$

Remember that since the definition of Molarity is the number of moles per 1 liter, we need to convert milliliters to liters so that the end result is in mol/Liter, or, M.

2. Calculate the grams of $\text{Na}_2\text{S}_2\text{O}_3$ (Sodium Thiosulfate) necessary to create a 10 ml solution of 0.6 M solution.

Ans: Step 1: Convert moles of $\text{Na}_2\text{S}_2\text{O}_3$ to grams.

$$2 \text{ atoms of Na} = 2 \times 22.9898 = 45.9796$$

$$2 \text{ atoms of S} = 2 \times 32.066 = 64.132$$

$$3 \text{ atoms of O} = 3 \times 15.9994 = \underline{47.9982}$$

$$158.1098$$

Step 2: Molarity = moles of solute/volume (L) of the solution

$$\text{Remember from earlier that Moles} = \frac{\text{Wt of substance in grams}}{\text{Molecular wt. in grams}}$$

$$\text{So Molarity} = \frac{\text{Wt of substance in grams}}{\frac{\text{Molecular wt. in grams}}{\text{L}}}$$

WW Modules Answer Key

$$0.6 \text{ M} = \frac{X \text{ (wt. of substance g)}}{\frac{158.1099 \text{ g MW}}{0.01 \text{ L}}}$$

Solving the equation for "x" we end up with the following formula:

$$M \times L \times MW = x$$

Step 3: Calculate the number of grams in the solution using the formula from Step 2.
(0.6 M) (0.01 Liters) (158.1098 g/mol) = 0.95 g

3. Calculate the Molarity of a solution of 81.1 grams of MgCl_2 , Magnesium Chloride, in 1.0 Liter of deionized water.

Ans: Step 1: Convert moles of MgCl_2 to grams.

$$1 \text{ atoms of Mg} = 1 \times 24.3050 = 24.3050$$

$$2 \text{ atoms of Cl} = 2 \times 35.4527 = \frac{70.9054}{95.2104}$$

$$\text{Moles MgCl}_2 = \frac{81.1 \text{ grams}}{95.2104 \text{ g/mol}}$$

$$\text{Moles MgCl}_2 = 0.85 \text{ mol}$$

Step 2: Calculate the molarity of the solution.

$$\text{Molarity} = 0.85 \text{ mol}/1.0 \text{ L} = 0.85 \text{ M}$$

Class Exercise:

- In Which section would you find information concerning the different hazards associated with handling caustic soda?
 - Section 3: Hazards Identification.
- What are the possible routes of entry?
 - Eye Contact: May cause tissue injury and loss of vision
 - Skin Contact: Corrosive to all tissue
 - Inhalation: concentrated mist May damage respiratory tract
 - Ingestion: Ingestion
- What information would you look for from the MSDSs, before repairing and metering pump or chemical feed system?
 - Exposure Controls and Protective equipment
 - Handling and Storage
 - First Aid

WW Modules Answer Key

- Fire Fighting Measures
- Physical and chemical properties

5. Where would you find information about storing Sodium Hydroxide? What are the storage recommendations?

- **Section 7 Handling and Storage**

Keep in a tightly closed container. Protect from physical damage. Store in a cool, dry, ventilated area away from sources of heat, moisture and incompatibilities. Always add the caustic to water while stirring; never the reverse. Containers of this material may be hazardous when empty since they retain product residues (dust, solids); observe all warnings and precautions listed for the product. Do not store with aluminum or magnesium. Do not mix with acids or organic materials

Module 30: Safety

Instructor Guide – Answer Key



Exercise

1. The three principal approaches to hazard control are: engineering controls, administrative controls and personal protective equipment.
 2. An individual inhales a high concentration of chlorine gas and develops an irritation of the eyes, nose, and throat, followed by coughing, wheezing, and chest pain. This is an example of acute exposure.
-



Exercise

1. What is aluminum sulfate used for?
Ans: As a coagulant.
2. How is sulfur dioxide usually shipped?
Ans: As a liquefied compressed gas.
3. What are the hazards and symptoms of exposure for sodium hypochlorite?

Ans: It causes irritation of the eyes, skin, mouth and lungs. Prolonged exposure can burn the skin and cause permanent eye and lung damage.



Calculation

A motor produces a sound level of 93 dBA and you have been provided with earplugs with an NRR of 25. What would the effective noise reduction from the earplugs be?

Ans: $25 \text{ (NRR)} - 7\text{dBA} = 18 \text{ dBA (NRR)}$
 $93 \text{ dBA} - 18 \text{ dBA} = 75 \text{ dBA effective NRR}$



There are also some less obvious consequences of fire. What do you think some of those consequences are?

Ans: Loss of production, destruction of business records, costs of reconstruction or clean-up, direct costs for losses not covered by insurance, increased insurance premiums and water and smoke damage to equipment and property.



What are some other examples of indirect promotion?

Possible answers can include:

Safety contests.

Incentive programs or reward programs.

Promotional items such as jackets, hats, t-shirts for good safety performance.

Monetary bonuses.

Large item prizes.

Lottery drawings or "safety Bingo" contests based on performance.