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ABSTRACT

This document is an instructional module package prepared in objective form for use by an instructor familiar with inorganic and general organic chemistry as applied to water and wastewater treatment. Included are objectives, instructor guides, and student handouts. The module contains material related to chemical reactions in water solutions, organic and inorganic compounds, coagulation, pesticides, heavy metals and radioactivity. (Author/RH)

ADVANCED CHEMISTRY FOR OPERATORS

Training Module 1.321.3.77

Prepared for the

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September, 1977

Handouts No. 3, 7 and 8 have been reprinted with permission from Applied Chemistry of Wastewater Treatment, a Programmed Learning, Mancy, McClelland, Pohland, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, 1973.

Module No:	Module Title: Advanced Chemistry for Operators
	Submodule Title: Reactions in Water Solutions, Organics and Inorganics, Coagulation, Pesticides, Heavy Metals, and Radiation
Approx. Time: 38.5 hours	Topic:

Objectives:

Upon completion of this module the participant should be able to examine reactions in water solutions, identify organic and inorganic compounds, explain coagulation, identify the various attributes of pesticides, examine heavy metals, and relate the various aspects of radioactivity.

Instructional Aids:

Handouts 1 - 10

Instructional Approach:

Discussion
Interpretation of Handouts
Lecture

References:

Chemistry Made Simple by Fred C. Hess.
Applied Chemistry of Wastewater Treatment, Ann Arbor Series, Mancy, McClelland, Pohland, 1974.
Chemistry for Sanitary Engineers, Sawyer and McCarty.
Chemistry for Laboratory Technicians, Stanley Cherim, 1971.
Modern Chemical Technology, Vol. 3, Chemical Technician Curriculum Project, 1971.
Manual of Instruction for Sewage Treatment Plant Operators, Health Education Service.
Water Supply and Pollution Control, Clark and Viessman, 1965.
Chlorinated Hydrocarbon Pesticides in Bottom Sediments, Don L. Kriens, Univ. of Iowa Library, 1972.

Class Assignments:

Review handouts and reading assignments as shown in module.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: ½ hour	Topic: Polarity - Nature of Water

Objectives:

Upon completion of this module, the participant should be able to:

1. State that the smallest part of water is the water molecule.
2. Indicate that hydrogen has 1 proton, 1 electron, oxygen, 8 protons, 8 electrons, and describe the hydrogen oxygen bond.
3. Illustrate polarity in a water molecule and describe the mechanism of polarity - indicate its electrical neutrality.
4. Describe that water molecules are held together by hydrogen bonds and the molecules move continuously as groups in solution.

Instructional Aids:

Handout No. 1 - Polarity of Water

Instructional Approach:

Discussion
Interpretation of Handout No. 1

References:

Chemistry Made Simple, Fred C. Hess, Doubleday and Co., 1955.
Applied Chemistry of Wastewater Treatment, Water and It's Impurities, Mancy, McClelland, Pohland, 1974, Ann Arbor Science Series.

Class Assignments:

Read Handout No. 1
Read P. 114, 115 Chemistry Made Simple

Module No:	Topic: Polarity - Nature of Water

Instructor Notes:	Instructor Outline:
P. 114, 115 Chemistry Made Simple - Water	**Objective 1** - Water Molecules The individual unit of water is H_2O but each have the fomula in sequence one should not necessarily think of a single molecule. Water is essentially in all life processes, is natures most important chemical compound. Other notable properties of water include its great solvent action and it's temperature of maximum density at 4° C. The relationship between temperature and density of water could be used to explain the fact that freezing takes place only on the surface of water and is responsible for spring and fall "turnovers" in natural water systems. Water is an important electrolyte and reacts with many compounds and elements.
Handout No. 1 - Polarity of Water PP. 55 - 74, Unit II, Water and It's Impurities, Ann Arbor Series - The Polarity of Water	**Objective 2 & 3** - Electrical Nature of Water and Polarity Briefly describe the electrical nature of water in terms of electrons in oxygen and hydrogen. Introduce polarity and nonpolarity of compounds and emphasize that like dissolves like. Molecules are neutral, and positive charges in them are canceled out by the negative charges; however, the charges in some molecules are separated so that one end is positive and the other negative, yielding polar compounds. Use magnetic polarity as a comparison.
Handout No. 1 - Polarity of Water	**Objective 4** - Water Molecules as Groups Interpretation of the Handout No. 1 should be discussed in detail but not to the extent that it is that extremely important. Emphasize water as a good solvent and polar compounds will not dissolve in nonpolar ones.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: ½ hour	Topic: Solvation of ions

Objectives:

Upon completion of this module, the participant should be able to:

1. Describe how water molecules in terms of polarity, dissolve solids into ions in solution.
2. Examine how ions are separated in solution by the water of hydration.
3. Indicate that as the ionic content is increased the water of hydration is "spread" thinner and thinner, eventually yielding saturation resulting in a condition of equilibrium for the particular ionic solid.

Instructional Aids:

PP. 177 - 225 Unit II, Ann Arbor Series

Instructional Approach:

Discussion

References:

Applied Chemistry at Wastewater Treatment, Unit II, Ann Arbor Series
Chemistry Made Simple, Fred C. Hess

Class Assignments:

Read PP. 177 - 225 Unit I, Ann Arbor Series
Answer questions

Module No:	Topic:
	Solvation of ions

Instructor Notes:	Instructor Outline:
PP. 177 - 225 Unit II, Water and It's Impurities, Ann Arbor Series - How Water Dissolves Impurities P. 78 Chemistry Made Simple Polarity of Water Causing Ionic Solutes to Dissociate	Objective 1 and 2 - Dissolving ionic solids and water of hydration In consideration of ionic solids or ionic solutes, it is the polarity of water which causes the ionic solutes to dissociate. The polar water molecules surround an ion and partially reduce the intensity of the attractive force between the ions, and float the individual ions off into solution. By using NaCl as an example one could illustrate this showing the polar H_2O molecule dissolving the solid into ions in solution. Describe water of hydration as wet molecules which effectively separate the ions in solution. Emphasize that we are speaking of ionic solids and true ionic solutions. Objective 3 - Saturation of ions Describe that as you increase the ions dissolved there is less H_2O molecules to separate the ions and eventually a point is reached where the water solution is saturated and any further addition of ions will cause the ions to precipitate "out" of solution. Reiterate that there may be several different types of ions in solution and some have a greater "solubility" than others and precipitation of solids may occur in varying degrees. Refer back to solubility products.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: ½ hour	Topic: Wastewater Solids - Dissolving Process

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain that water dissolves molecules of solids when the attraction between oppositely charged solute and solvent molecules is great enough to pull the solid/solute molecules apart.
2. Predict that a significant portion of organics in wastewater may dissolve to a lesser extent than inorganics due to their nonpolar nature.
3. Illustrate that CO_2 is more polar than O_2 and explain why CO_2 is more soluble than O_2 in water.

Instructional Aids:

Handout No. 2 - CO_2 and O_2 Solubilities in Water

Instructional Approach:

Discussion
Review graphically Handout No. 2

References:

Applied Chemistry of Wastewater Treatment, Unit II, Ann Arbor Series

Class Assignments:

Read Handout No. 2
Read P. 221, Unit II, Ann Arbor Series

Module No:	Topic: — Wastewater Solids - Dissolving Process
Instructor Notes:	**Instructor Outline:**
PP. 223 - 228 Unit II, Water and It's Impurities, Ann Arbor Series	<u>Objective 1</u> - Water dissolving molecules of solids Explain the 3 types of attraction involved in the dissolving process.
	<u>Objective 2</u> — Nonpolar nature of organics Give examples of organic compounds in wastewater and water in general and indicate the general nonpolar nature of most of the organics. Since nonpolar compounds will not dissolve to as great an extent in polar solvents organic compounds of wastewater are "less" dissolved.
Handout No. 2 - CO_2 and O_2 relative polarities P. 221 Unit II, Water and It's Impurities, Ann Arbor Series O_2 and CO_2 polarities	<u>Objective 3</u> - Relative Polarities of CO_2 and O_2 In oxygen gas the bond connects 2 atoms that are alike O_2. Oxygen is nonpolar. The carbon-oxygen bonds in CO_2 gas are polar; therefore CO_2 is more soluble in water than O_2 is. Note that nonpolar substances such as many organics do dissolve in water to some extent. The water can still form a cushion between the individual molecules, keeping them apart.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: 1½ hours	Topic: Carbonate Equilibrium

Objectives:

Upon completion of this module, the participant should be able to:

1. Examine by equation how CO_2 reacts in water to form carbonic acid and show ionization equations for carbonic acid.
2. Define the salts calcium carbonate and magnesium carbonate as sources of buffering capacity; describe by equation how CO_2 is neutralized by these salts.
3. Define bicarbonate as a main source of alkalinity in wastewater and indicate its formation by degradation of organic carbon to CO_2 and subsequent conversion to bicarbonate by the ionization of carbonic acid.
4. Explain how CO_2 increases the dissolving power of water and how the removal of CO_2 increases the pH during aeration and algae blooms.

Instructional Aids:

Handout No. 3 - PP. 10 - 16, Unit 8, Ann Arbor Series, Carbonate Equilibrium

Instructional Approach:

Discussion
Review Handout No. 3

References:

Applied Chemistry of Wastewater Treatment, Unit 8, Ann Arbor Series
Chemistry for Sanitary Engineers, Sawyer and McCarty, 1967.

Class Assignments:

Read Handout No. 3
Do Problem Set No. 1

Module No:	Topic: Carbonate Equilibrium

Instructor Notes:	Instructor Outline:
PP. 10 - 16, Unit 8, Inorganic Pollutants, Ann Arbor Series - CO_2 and Carbonate Equilibrium	Objective 1 - Formation of Carbonic Acid Describe sources of CO_2 in natural water systems such as absorption from air, microbial degradation and rocks containing CO_3 ions. Show by equation how CO_2 reacts with H_2O to form carbonic acid. $CO_2 + H_2O \rightleftharpoons H_2CO_3$. Also note that H_2CO_3 is a weak acid and will dissociate according to equations $H_2CO_3 \rightleftharpoons H^+ + HCO_3$ $HCO_3 \rightleftharpoons H^+ + CO_3$
Handout No. 3 - Carbonate Equilibrium	Objective 2 - Calcium carbonate, Magnesium carbonate Note that Ca CO_3 and Mg CO_3 are common salts in natural waters and wastewaters and H_2CO_3 can change the CO_3 ions of Ca-CO_3 and Mg CO_3 by an acid base reaction. In the reaction between H_2CO_3 and CO_3 ions, the CO_3 ions act as a base and in effect neutralize the acid $H_2CO_3 + CO_3^{-2} \rightleftharpoons 2\ HCO_3^{-1}$ Therefore these salts act as natural buffers neutralizing the acid H_2CO_3. Objective 3 - Bicarbonate as Alkalinity Define bicarbonate, HCO_3^{-1} ion and describe it as an alkalinity source. Define one method indirectly of bicarbonate formation in natural waters as degradation of organic carbons to CO_2 by biological decomposition and production of H_2CO_3 by CO_2 and H_2O and subsequent ionization of H_2CO_3 to HCO_3. Objective 4 - CO_2 Increases dissolving power of water In water containing CO_2, carbonate ions are changed to bicarbonate ions. As more CO_3 ions are changed to bicarbonates the equilibrium effectively causes more solid Ca CO_3 to dissolve. This usually applies mostly to $CaCO_3$ solid deposits and will vary with other solids.

Module No:	Topic: Carbonate Equilibrium
Instructor Notes:	**Instructor Outline:**
P. 338, 339 Chemistry for Sanitary Engineers - pH changes in the presence of algae blooms	Note: Also pH changes in algae blooms are caused by a reduction in "free" carbon dioxide concentrations below its equilibrium concentration with air and causes an increase in pH. Show how algae growths may extract CO_2 from bicarbonates and carbonates. Use the following equilibrium conditions: $2\ HCO_3^- \rightleftarrows CO_3^{-2} + H_2O + CO_2$ $CO_3^{-2} + H_2O \rightleftarrows 2\ OH^- + CO_2$ A review of general equilibrium situations and solubility equilibrium may be necessary at this point.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: ½ hour	Topic: Ionization of Water

Objectives:

Upon completion of this module, the participant should be able to:

1. Define proton and describe by equation how the exchange of a proton between "bumping" water molecules causes the production of hydronium and hydroxide ions.
2. Define the ionization constant of water and examine the equilibrium condition between water molecules and ions.
3. Describe pH as a "function" of hydronium ion concentration.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Laboratory Technicians, Stanley Cherim, W. B. Saunders Co., 1971.
Chemistry Made Simple, Fred C. Hess.
Modern Chemical Technology, Volume 3, Chemical Technician Curriculum Project, 1971.

Class Assignments:

Read P. 84, 85 Chemistry Made Simple

Module No:	Topic: Ionization of Water
Instructor Notes:	**Instructor Outline:**
	Objective 1 - Protons Describe protons simply as H^+ and also go through the production of H^+ and OH^- by normal bumping of water molecules in pure water. The simple equation $H_2O \rightleftarrows H^+ + OH^-$ is introduced. Again indicate the production of H^+ and OH^- ions as an ionization process.
	Objective 2 - Ionization constant Define the ionization constant of water K_w, as a mathematical expression for the degree of the ionization of water molecules into H^+ and OH^- ions: $H_2O \rightleftarrows H^+ + OH^-$ $K_w = \frac{(H)\ (OH)}{(H_2O)} = 1 \times 10^{-14}$
P. 84, 85 Chemistry Made Simple - pH	Objective 3 - pH Show the mathematical expression for pH: $pH = -\log (H_3O^+)$. However, do not emphasize the math treatment but merely state that pH is a function of the hydrogen ion concentration. Also note that it is a measure of the total H^+ ion content and not only from the ionization of water; may also include H^+ ion from acids which may be present.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: 1 hour	Topic: Acids - Ionization

Objectives:

Upon completion of this module, the participant should be able to:

1. Define strong acids and bases.
2. Given a weak acid describe by equation the equilibrium condition resulting from incomplete ionization.
3. Indicate that addition of an acid increases the number of hydronium ions, decreases hydroxide ions, and causes the pH to decrease.
4. Explain how a concentrated solution of a weak acid may still have a pH near 7.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry Made Simple, Fred C. Hess.
Manual of Instruction for Sewage Treatment Plant Operators, Health Education Service.

Class Assignments:

Read P. 78, 79 Chemistry Made Simple
Read P. 227 Manual of Instruction for Sewage Treatment Plant Operators

Module No:	Topic: Acids - Ionization

Instructor Notes:	Instructor Outline:
	Objective 1 - Strong Acids and Bases
P. 78, 79 Chemistry Made Simple - Strong and weak electrolytes	Redefine acids and bases and percent ionization.
	Objective 2 - Incomplete Ionization
	Show by equation and word form how a weak acid such as H_2CO_3 and HF, ionizes into an equilibrium condition.
	$HF \rightleftarrows H^+ + F^-$
	$H_2CO_3 \rightleftarrows HCO_3^- + H^+$
	$HCO_3^- \rightleftarrows H^+ + CO_3$
	Objective 3 - Addition of acid increases hydronium ions
	Define hydronium ions and equate with H^+. Indicate that acids will ionize, some greater then others, and introduce additional H^+ ions upset the $H_2O \rightleftarrows H^+ + OH^-$ equilibrium OH^- ions will decrease in order to maintain the K_w equilibrium content. Thus increased H^+ ions will cause a shift and result in a lowering of the pH. Show, using the mathematical expression, how this occurs.
	Objective 4 -
P. 227 Manual of Instruction for Sewage Treatment Plant Operators - Acids	Show that a pH near 7 may still occur in solution even though large amounts of acid (weak) have been added. Describe this as due to the poor ionization of the weak acid into its component ions. And since pH is a measure of the H^+ ion concentration this is the result. For example using the weak acid $HF \rightleftarrows H^+ + F^-$
	$K_w = 6.76 \times 10^{-4}$. Compare this with HCl, 100% ionized.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: 3/4 hour	Topic: Bases - Ionization

Objectives:

Upon completion of this module, the participant should be able to:

1. Define bases.
2. Given a base describe how it produces hydroxide ions in water through ionization.
3. Explain that adding a base to water increases OH ion concentration, decreases hydronium ion concentration, and increases the pH.
4. Diagram the pH scale, list basic and acidic areas.

Instructional Aids:

Handout No. 4 - pH scale

Instructional Approach:

Discussion
Review Handout No. 4

References:

Modern Chemical Technology, Volume 3, Chemical Technician Curriculum Project, 1971.

Class Assignments:

Study pH scale

Module No: _	Topic: Bases - Ionization

Instructor Notes:	Instructor Outline:
	Objective 1 and 2 - Bases and Ionization
PP. 437 - 441 - Modern Chemical Technology - The measurement of pH	Redefine bases as proton acceptors and show how bases ionize by ionization equation. Strong base Na OH, 100% ionized
	Na OH $\rightleftarrows$ Na^{+} + OH^{-} ions
	Weak base, K_b NH_3^{+} + OH^{-}
	Oh^{-} ions are thus introduced.
	Objective 3 - Increasing OH^{-} Concentration
	Show how addition of a base such as Na OH, introduces additional OH^{-} ions in water solutions and causes a shift in the equilibrium situation. H^{+} ions decrease and OH^{-} increase causing the pH to increase since pH is a negative log function of the hydrogen ion concentration. pH = - log (H).
	Objective 4 - pH Scale
Handout No. 4 - pH Scale	pH scale diagram.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: 3/4 hour	Topic: Acid Base - Reaction

Objectives:

Upon completion of this module, the participant should be able to:

1. Given an acid and base describe the neutralization reaction by equation, indicate proton transfer.
2. Define titration and explain, using the equation $N_1 \times V_1 = N_2 \times V_2$, how acidity can be determined by titration.
3. Explain why acidity or alkalinity is expressed in terms of calcium carbonate in wastewater analysis.

Instructional Aids:

Handout No. 5 - Titration example

Instructional Approach:

Discussion
Review Handout No. 5

References:

Chemistry for Sanitary Engineers, Sawyer and McCarty
Manual of Instruction for Sewage Treatment Plant Operators, Health Education Service.

Class Assignments:

Review Handout No. 5
Work 2 problems in handout

Module No:	Topic: Acid - Base Reaction

Instructor Notes:	Instructor Outline:
	Objective 1 - Acid Base Reaction Show a typical acid base reaction and indicate the transfer of protons. $HCl + Na\ OH \rightleftarrows NaCl + H_2O$
PP. 323 - 325 Chemistry for Sanitary Engineers - Method of Measurement	Objective 2 - Titrations Describe simple titrations, such as titration for alkalinity using a specified normality of of acid. Use the equation $N_1 \times V_1 = N_2 \times V_2$ to describe the mathematical treatment.
	Objective 3 - Expressing in terms of Calcium Carbonate
P. 226 Manual for Sewage Treatment Plant Operators - Determination of Alkalinity P. 69, 70 Chemistry for Sanitary Engineers - Calculations.	Indicate why alkalinity or acidity is expressed as mg/l $CaCO_3$ thus calling alkalinity, for alkalinity determinations, $CaCO_3$ the equation could be $H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2CO_3$. Review equivalents and equivalent weights. Show how the following equation is arrived at: mg/l active material in sample = $\frac{\text{ml titrant} \times N \times EW \times 1000}{\text{sample volume in ml}}$
Handout No. 5 - Titration Example	Results of alkalinity or acidity are expressed as $CaCO_3$ so they can be easily compared to each other and to other measurements which may be a result of other types of acids or bases.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Reactions in Water Solutions
Approx. Time: 3/4 hour	Topic: Oxidation - Reduction

Objectives:

Upon completion of this module, the participant should be able to:

1. Define oxidation state, valence, oxidation, reduction.
2. Given a reaction describe the oxidation reduction process, show half reactions and electrons transferred, define oxidizing and reducing agents.
3. State that oxygen is the oxidizing agent used in aerobic degradation of organic matter, a complicated process involving intermediate compounds ultimately producing carbon dioxide and water.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry Made Simple, Fred C. Hess
Chemistry for Sanitary Engineers, Sawyer and McCarty.

Class Assignments:

Read Chapter 10 Chemistry Made Simple

Module No:	Topic: Oxidation - Reduction

Instructor Notes:	Instructor Outline:
	<u>Objective 1</u> - Oxidation - reduction
Chapter 10 Chemistry Made Simple - Oxidation - reduction	Define oxidation and reduction and review valences and valence No. Oxidation - reduction should be, in my opinion, a brief section.
	<u>Objective 2</u> - Oxidation - Reduction Reactions
PP. 15 - 18 Chemistry for Sanitary Engineers - Oxidation Reduction Equations PP. 156 - 215, Unit 3, Ann Arbor Series - Electron Transfer, Oxidation and Reduction	Using an example, show how electrons are transferred according to each half reaction. Emphasize that not all reactions are oxidation reduction but that they represent only one type of general reactions. Show how reactions are balanced stoichiometrically in respect to electron transfer. $4Fe^{0} + 3O_2^{0} \rightarrow 2\ Fe_2^{+3}\ O_3^{-2}$ $2\ Fe^{++} + Cl_2^{0} \rightarrow 2\ Fe^{+3} + 2\ Cl^{-}$ $2\ I^{-} + Cl_2^{0} \rightarrow I_2^{0} + 2\ Cl^{-}$
	<u>Objective 3</u> - Oxygen in Aerobic Oxidation
	Briefly describe aerobic biological decomposition in which bacteria and other microbes utilize oxygen to decompose organic matter as food and ultimately produce CO_2 and H_2O. Organics + oxygen $\xrightarrow[\text{microbes}]{\text{aerobic}}$ CO_2 and H_2O eventually. Note that there are many intermediate compounds involved.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 1½ hours	Topic: Introduction to Organics

Objectives:

Upon completion of this module, the participant should be able to:

1. Define organic compounds and identify the major and minor elements in organic compounds.
2. Differentiate between general features of organics and inorganics: Combustibility, solubility in water, molecular or ionic reactions, molecular weight, bacterial food sources.
3. Explain the aerobic biological degradation process whereby aerobic bacteria use organics as a food source and oxidize organics into inorganics, ultimately forming CO_2 and H_2O.
4. Indicate that under anaerobic conditions, anaerobic bacteria may use oxidants other than oxygen to degrade organic compounds into CO_2, H_2O, CH_4, H_2S, NH_3, etc.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers, Sawyer and McCarty.

Class Assignments:

Module No:	Topic: Introduction to Organics
Instructor Notes:	**Instructor Outline:**
P. 86, 87 Chemistry for Sanitary Engineers - Introduction	Objective 1 - Organic Compounds Define organic compounds, indicate the major elements usually present, such as carbon, hydrogen, oxygen and the minor elements such as nitrogen, phosphorus, and sulfur. Organics may contain a variety of other elements.
P. 88 Chemistry for Sanitary Engineers - Properties	Objective 2 - Differentiation between organic and inorganic Differentiate between organic and inorganic in terms of combustibility, solubility in water, molecular or ionic reactions, molecular weights, and as bacterial food sources.
	Objective 3 and 4 - Aerobic and Anaerobic Decomposition Describe aerobic decomposition and differentiate between anaerobic decomposition. Show the various products which may result from each type.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 1 hour	Topic: Compounds - Aliphatic

Objectives:

Upon completion of this module, the participant should be able to:

1. Indicate that carbon will generally have 4 bonds attached to it - valence of 4.
2. Define hydrocarbons and identify methane as the simplest hydrocarbon.
3. Illustrate how methane and other hydrocarbons can be shown by graphic formula and condensed to one line.
4. Define alcohols and identify.
5. Define organic acids and indicate that organic acids are the last step before conversion to carbon dioxide and water in biological oxidation.

Instructional Aids:

Instructional Approach:

Discussion
Practice making graphic formulas

References:

Chemistry Made Simple, Fred C. Hess
Chemistry for Sanitary Engineers, Sawyer and McCarty.

Class Assignments:

Read Chapter 22, Chemistry Made Simple

Module No:	Topic: Compounds - Aliphatic
Instructor Notes:	**Instructor Outline:**
	Objective 1 and 2 - Carbon valence and Hydrocarbons
Chapter 22, Chemistry Made Simple - Organic chemistry	Describe the valence of carbon and indicate that it generally will have 4 bonds attached to it in a complete molecule. Define aliphatic hydrocarbons and graphically describe methane and others.
	Objective 3 - Graphic Descriptions
P. 90 - 98 - Chemistry for Sanitary Engineers - Aliphatic Compounds - Hydrocarbons	Illustrate aliphatic hydrocarbons by graphic representations. Depict CH_4, CH_3CH_3, $CH_3CH_2CH_3$, C_4H_{10} graphically as examples.
	Objective 4 - Alcohols
PP. 98 - 104 Chemistry for Sanitary Engineers - Alcohols	Define organic alcohols and identify several common ones, show graphically.
	Objective 5 - Acids
PP. 108 - 112 Chemistry for Sanitary Engineers - Acids	Define organic acids and identify the common ones, show graphically formic, acetic, propionic acids.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 3/4 hour	Topic: Compounds - Aromatic

Objectives:

Upon completion of this module, the participant should be able to:

1. Differentiate between aliphatic and aromatic compounds, illustrate the benzene ring.
2. Illustrate how groups may be attached to the benzene ring to form various aromatic compounds.
3. Illustrate phenol (carbolic acid) by graphic formula.

Instructional Aids:

Handout No. 6 - Aromatic hydrocarbons

Instructional Approach:

Discussion
Review handout No. 6

References:

Chemistry for Sanitary Engineers, Sawyer and McCarty
Chemistry Made Simple, Fred C. Hess

Class Assignments:

Review Handout No. 6

Module No:	Topic: Compounds - Aromatic
Instructor Notes:	**Instructor Outline:**
	Objective 1 - Aromatic compounds
PP. 118 - 122 - Chemistry for Sanitary Engineers - Aromatic Hydrocarbons	Illustrate the benzene ring and differentiate between aliphatic and aromatic organic compounds.
	Objective 2 - Groups attached
Handout No. 6 - Aromatic Hydrocarbons	Illustrate how groups are attached to the benzene ring. Show several types of functional groups.
	Objective 3 - Phenols
Handout No. 6 - Aromatic Hydrocarbons	Illustrate phenols and describe why they are among the most important aromatic compounds.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 1 hour	Topic: Effects on Treatment Process

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain that increased loads of organics require increased dissolved oxygen demands.
2. Indicate that organic acids may cause metal pipes and other structures to corrode.
3. Explain that increased organic loads make chlorination less effective, more chlorine is required to kill off microbial organisms.
4. Explain that certain organics may be toxic and kill off, or inhibit the reproduction of, treatment - microorganisms.
5. Explain that many organics, notably plastics, do not dissolve at all in water and are difficult to biodegrade.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry of Wastewater Treatment, Unit 6, Ann Arbor Series

Class Assignments:

Module No:	Topic: Effects in Treatment Processes

Instructor Notes:	Instructor Outline:
PP. 7 - 10 - Unit 6, Organic Pollutants, Ann Arbor Series - Effects of Organic Pollutants	Objective 1 - Organic and Oxygen Demands Point out that organics cause increased usage of oxygen by mieroorganism. Organics act as reducing agents. Objective 2 - Organic Acid Effects Note that organic acids may cause pipes and other metals to corrode. For example acetic acid, formic acid. Note that these organic acids are the result of anaerobic decomposition. Objective 3 - Chlorination - Organics. Explain the relationship between chlorination and organic quantities and that increased organic loads will make chlorination less effective and will increase the chlorine demand. Objective 4 - Toxic Organics. Explain that certain organics may be toxic to treatment microorganisms. An example may be phenols. Note that other organics are toxic to other types of aquatic life, various pesticides, PCB's etc. Objective 5 - Plastics Introduce plastics as organic compounds and note that they are very poorly biodegradable and will accumulate in natural systems. Also other organics, such as chlorinated hydrocarbon pesticides and PCB's are also poorly biodegradable and will accumulate in nature if introduced.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 3/4 hour	Topic: Greases, oils, surfactants

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain that greases and oils, though usually non-toxic, are slowly biodegradable, poorly settleable, cause foaming and may decrease the efficiency of the treatment of other organics by inhibiting dispersion of dissolved oxygen to microorganisms.
2. Define surfactants and indicate their sources.
3. Describe the problems surfactants may cause in wastewater treatment.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry of Wastewater Treatment, Unit 6, Ann Arbor Series
Chemistry for Sanitary Engineers, Sawyer and McCarty

Class Assignments:

Read Ch. 32 Chemistry for Sanitary Engineers

Module No:	Topic: Greases, Oils, Surfactants

Instructor Notes:	Instructor Outline:
Ch. 32 Chemistry for Sanitary Engineers - Grease P. 10, Unit 6, Ann Arbor Series - Grease and Oils P. 230 - 264, Unit 6, Ann Arbor Series - Grease and Oils	<u>Objective 1</u> - Greases and Oils Define greases and oils and examine the problems involved with these substances in wastewater treatment. Point out that they also decrease the efficiency of treatment of organics by microorganisms by inhibiting the dispersion of dissolved oxygen. Grease may coat the microorganisms.
P. 11, Unit 6, Ann Arbor Series - Detergents PP. 147 - 150 Chemistry for Sanitary Engineers - Detergents PP. 264 - 280, Unit 6, Ann Arbor Series - Surfactants	<u>Objective 2 and 3</u> - Surfactants Define surfactants and detergents as organic compounds and describe the problems associated with detergents in treatment. Define ABS, alkyl benzene sulfonate. And emphasize the slow biodegradation of these compounds.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: ½ hour	Topic: Phenols

Objectives:

Upon completion of this module, the participant should be able to:

1. Define phenol and indicate that phenols cause taste and odor problems and may be toxic to treatment microorganisms at high concentrations.
2. Describe extraction of organic compounds in terms of polarity, "like dissolves like".
3. Indicate that phenol may slightly ionize, in basic solutions, into an ionized polar form more soluble in water than the unionized molecular nonpolar form.
4. Explain that complete extraction of phenol by a nonpolar solvent will occur only in acidic solutions.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry of Wastewater Treatment, Unit 6, Ann Arbor Series

Class Assignments:

Module No:	Topic: Phenols

Instructor Notes:	Instructor Outline:
PP. 280 - 302, Unit 6, Ann Arbor Series - Phenols	Objective 1 Redefine phenols graphically and indicate that phenols cause taste and odor problems and may be toxic at high levels to microorganisms. Note that phenols are a group of waste products which contain the polar OH group attracted to nonpolar organic groups. The OH group of a phenol acts as a very weak acid, but is not polar enough to keep the un-ionized phenol part from dissolving in nonpolar solvents.
PP. 232 - 238, Ann Arbor Series, Unit 6 - Grease and Oils	Objective 2 - Extractions Define extractions and indicate that organic compounds, mostly nonpolar, will be extracted by nonpolar solvents. Thus in order to extract an organic compound such as DDT, an organic solvent such as benzene, hexane, or others will be used to extract DDT. Since DDT will be much more soluble in organic nonpolar solvents it is easily extractable from water, a polar solvent. "Like dissolves like". Likewise, ionic solids, polar compounds will be only very slightly soluble in organic solvents. Greases and oils are nonpolar compounds and are extracted from water solutions by nonpolar solvent such as hexane.
P. 279 - 282, Unit 6, Ann Arbor Series - Phenols	Objective 3 - Phenols Since the OH group of phenols is ionizable, phenols dissolve most readily in basic waters. In order to remove phenols from water an initial procedure would be to make the water acidic so the phenol molecule (OH) will be in the un-ionized form. Thus the un-ionized form is less soluble in water than the ionized (polar) form. A nonpolar solvent would be used to extract phenols from water only if the water is acidic.

Module No:	Topic: Phenols

Instructor Notes:	Instructor Outline:
	Objective 4 - Phenols Phenols are therefore only completely extractable by a nonpolar solvent if it is acidified previous to extraction.

Module No: 7	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 1 hour	Topic: Testing for Organics

Objectives:

Upon completion of this module, the participant should be able to:

1. Describe biochemical oxygen demand as a method for determining relative organic quantities in wastewater.
2. Define volatile solids testing and state how the loss of weight in the test gives an indication of the organic content of the sample.
3. Explain how total organic carbon is a measure of the degree of organic quantity by measuring the amount of CO_2 or CO formed when the organic material is oxidized.

Instructional Aids:

Handout No. 7 - BOD overview

Instructional Approach:

Discussion
Read Handout No. 7
Set up BOD's, run other tests if possible, volatile solids, TOC

References:

Applied Chemistry to Wastewater Treatment, Unit 6, Ann Arbor Series

Class Assignments:

Read Handout No. 7

Module No: —	Topic: Testing for Organics

Instructor Notes:	Instructor Outline:
	Objective 1 - Biochemical Oxygen Demand
PP. 100 - 189, Unit 6, Ann Arbor Series - Measurement by Oxygen Consumption Handout No. 7 - BOD - an Overview	Review BOD as a method for the determination of relative organic quantities and discuss why BOD is an accurate measure of oxygen demand under actual conditions. Review the methodology of the test.
	Objective 2 - Volatile Solids
PP. 33 - 66, Unit 6, Ann Arbor Series - Volatile Solids Test.	Review volatile solids as a method of measuring organic content. Review methodology of the test.
	Objective 3 - Total Organic Carbon
PP. 66 - 92, Unit 6, Ann Arbor Series, Total Organic Carbon	Review total organic carbon as a method of measuring organic content. Describe the methodology of the test.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: ½ hour	Topic: Inorganics in Wastewater

Objectives:

Upon completion of this module, the participant should be able to:

1. Define salinity as the presence of dissolved inorganic material in water.
2. Indicate that practically all inorganics which dissolve are present in the form of ions.
3. List 6 cations and 6 anions which may be present in water to cause salinity.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry to Wastewater Treatment, Unit 7, Ann Arbor Series

Class Assignments:

Module No:	Topic: Inorganics in Wastewater

Instructor Notes:	Instructor Outline:
PP. 17 - 25, Unit 7, Ann Arbor Series - Salinity	Objective 1 - Salinity Define salinity as the presence of dissolved inorganics in water. Objective 2 - Ions Explain that almost all inorganics that dissolve do so as ions in solution Objective 3 - Cations and anions List several types of cations and anions which may be in solution. Practically all ionic solids. Indicate sources of inorganic wastes, domestic, industrial, and natural.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Organics - Inorganics
Approx. Time: 1 hour	Topic: Inorganic Problems

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain that dissolved ions decrease the solubility of gases in water and high salinity may decrease the concentration of dissolved oxygen needed for biodegradation reactions in wastewater.
2. Indicate that high salinity may inhibit or kill the microorganisms in wastewater treatment.
3. Explain that high salinity may injure or kill fresh water fish.
4. Identify ammonia, ammonium ions, nitrates, and phosphates and explain how they may act as fertilizers and promote the undesirable growth of algae in streams.
5. Indicate that cations produced from metals such as mercury and lead, and anions such as cyanide, can be toxic to animals and people.
6. Identify hardness causing cations and cations of metals such as iron and manganese and the problems they cause.

Instructional Aids:

Handout No. 8 - Salinity

Instructional Approach:

Discussion
Review Handout No. 8

References:

Applied Chemistry of Wastewater Treatment, Unit 7, Ann Arbor Series.
Chemistry for Sanitary Engineers, Sawyer and McCarty.

Class Assignments:

Read Handout No. 8, do self-test I

Module No:	Topic: Inorganic Problems

Instructor Notes:	Instructor Outline:
	Objective 1 - Solubility of Gases vs. Dissolved Ions
PP. 17 - 25, Unit 7, Ann Arbor Series - Salinity	Explain the relationship between solubility of gases in water and dissolved ionic content. High salinity may cause a reduction in dissolved oxygen levels, for example, in a lagoon. During dry seasons this may become more of a problem.
	Objective 2 and 3 - High Salinity
Handout No. 8 - Salinity	Note that high salinity may also inhibit microbial action or kill the microorganisms. Also highly saline waters will kill or injure fresh water fish. Note the intrusion of salt water of estuaries into fresh water aquatic systems.
	Objective 4 - Nutrients
	Define NH_3, NH_4, NO_3, PO_4 as nutrients for algal growth which may, at times, promote undesirable growth of algal blooms, eventually resulting in an increased organic load on the system involved.
	Objective 5 - Toxic Ions
	Identify metallic cations such as Hg, Pb, As, Cd etc., as potential toxic substances (ions). Also note that some anions, such as CN^- are also toxic to microorganisms.
	Objective 6 - Hardness Cations
PP. 347 - 355, Chemistry for Sanitary Engineers - Hardness	Identify hardness causing cations and other ions of metals like iron and manganese and discuss the problems these ions cause.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Coagulation
Approx. Time: 2 hours	Topic: Colloids - Definitions

Objectives:

Upon completion of this module, the participant should be able to:

1. Define colloidal dispersions and the normal range of size for colloidal particles.
2. Indicate that much of wastewater suspended matter is colloidal, especially color and turbidity-causing substances.
3. Distinguish between true solutions and colloidal dispersions and indicate that both inorganic and organic materials may form colloidal suspensions.
4. Explain that surface area in relation to mass in colloids is great and that all colloids are electrically charged, the majority negatively.
5. Indicate that like charges repel, unlike charges attract.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers, Sawyer and McCarty.

Class Assignments:

Read Chapter 7, Chemistry for Sanitary Engineers - Colloid Chemistry.

Module No:	Topic: Colloids - Definitions

Instructor Notes:	Instructor Outline:
	Objective 1 - Colloidal Particles
P. 214, 215 Chemistry for Sanitary Engineers - Classes and graph for sizes	Define colloidal dispersions and relate their size to particles. Colloids are considered larger than individual atoms or molecules but small enough to possess properties very different from coarse dispersions. Colloids range from 1 to 100 millimicrons in size. Note that colloids are insoluble.
	Objective 2 - Color and Taste and Odor
P. 290, 291 Chemistry for Sanitary Engineers - Turbidity	Emphasize that much of the color and taste and odor causing substances are colloidal. The water systems will vary according to conditions and thus according to degree of colloidal dispersions.
	Objective 3 - True and Colloidal Dispersions
	Note that colloids, although almost molecular in size, are not true solutions. Also certain organic substances, such as soaps, that are usually considered soluble in water are not and actually form colloidal dispersions. Also inorganics such as bentonite clay, will not form a true solution.
	Objective 4 and 5 - General Properties of Colloids
P. 216, 217 Chemistry for Sanitary Engineers - General Properties	Discuss the general properties of colloids, especially the high surface area to mass ratio. Colloids thus have great adsorptive powers. Note that like charges repel, unlike attract.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Coagulation
Approx. Time: 2½ hours	Topic: Nature of Colloids

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain the fundamental basis for the stability of colloids as the repulsion of similarly charged colloidal particles with abnormally long settling times.
2. Define hydrophobic colloids and zeta potential.
3. Define Vander Waals force and indicate that as long as the zeta potential is great enough to produce repulsive forces in excess of Vander Waals force, the particles cannot coalesce.
4. Explain that the destabilization of colloids is brought about by counter-ion absorption by addition of ions of opposite charge until the Vander Waals attraction forces are stronger than the repulsive forces of the zeta potential and coagulation occurs.
5. Define the Schulze-Hardy rule.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers, Sawyer and McCarty.
Water Supply and Pollution Control, Clark and Viessman, 1965.

Class Assignments:

Ch. 7, Chemistry for Sanitary Engineers, do problems 7-1, 7-2

Module No:	Topic: Nature of Colloids

Instructor Notes:	Instructor Outline:
	Objective 1 - Stability of Colloids Examine the stability of colloids as a result of their inability to coagulate due to charge repulsion and therefore, their long settling times in sedimentation basins.
P. 218, 219. Chemistry for Sanitary Engineers - Hydrophobic Colloids PP. 341-343. Water Supply and Pollution Control - Zeta Potential	**Objectives 2 & 3** - Hydrophobic Colloids Define hydrophobic colloids and examine zeta potential. Limit mathematical treatment. Describe Vander Waal's force and discuss these opposing forces. Vander Waal's and zeta petential.
	Objective 4 - Destabilization of Colloids Discuss the theory of destabilization and the objectives of chemical coagulation. Briefly discuss the common four methods of destruction of hydrophobic colloids: (a) boiling, (b) freezing, (c) addition of electrolyles, and (d) mutual precipitation by addition of a colloid of opposite charge. Note that zeta potential may be reduced by adjustment of the pH.
P. 220. Chemistry for Sanitary Engineers - Destruction of Colloids	**Objective 5** - Schulze-Hardy Rule Define the Schulze-Hardy rule with respect to addition of electrolytes as a method for stabilization of colloids.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Coagulation
Approx. Time: 2 hours	Topic: Coagulation

Objectives:

Upon completion of this module, the participant should be able to:

1. List three areas of removal achieved by chemical coagulation.
2. Identify the two trivalents salts used in coagulation and illustrate the ionic valence states of the metal ions.
3. Illustrate how aluminum sulfate dissociates to yield sulfate, aluminum + 3 and various aluminum hydrolysis complexes.
4. Indicate that for a given coagulant, such as aluminum sulfate, lower pH values favor hydrolysis species of a more positive charge and that complexes with highest positive charge are most effective in coagulation.
5. Describe flash mixing and flocculation.

Instructional Aids:

Handout No. 9 - Coagulation

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers
Water Supply and Pollution Control

Class Assignments:

Read Handout No. 9
Read Chapter 18, Chemistry for Sanitary Engineers

Module No:	Topic: Coagulation
Instructor Notes:	**Instructor Outline:**
P. 341, 342. Chemistry for Sanitary Engineers - Purposes of Chemical Coagulation	Objective 1 - Object of Coagulation Redefine the objective of chemical coagulation - removal of colloidal dispersions and increase sedimentation rates. Note again that colloids impart color, tastes, and odors. Name areas of removal by coagulation and discuss (a) turbidity, inorganic and organic, (b) color, (c) bacteria, (d) algae, (e) taste and odor substances, and (f) phosphates. Note that coagulation previous to filtration is preferred.
Handout No. 9 - Chapter 18, Chemistry for Sanitary Engineers - Chemical Coagulation of Water	Objective 2 & 3 - Coagulant Salts Define the two primary coagulant salts used in coagulation as aluminum sulfate and ferric sulfate. Note that they both possess positive potentials and coagulate by mutual coagulation. Show how the salts dissociate in solution into their positively charges ions.
PP. 343-346. Water Supply and Pollution Control - Coagulation	Objective 4 - pH Dependence Discuss pH and its effect on coagulation and charged species. Objective 5 - Flash Mixing Describe the general mechanical features of coagulation.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Coagulation
Approx. Time: 2 hours	Topic: Polyelectrolytes in Coagulation

Objectives:

Upon completion of this module, the participant should be able to:

1. Define polymers and polyelectrolytes, indicate the origin of charges in polyelectrolytes.
2. Explain how polyelectrolytes, cationic type, destabilize hydrophobic colloidal systems by neutralization of colloidal charges and thus serve as coagulants.
3. Define hydrophilic colloids and state that most domestic sewage contains mainly hydrophilic colloids.
4. Indicate that counter ions alone are insufficient to destabilize hydrophilic colloids.
5. Explain how polymers may act to destabilize and agglomerate hydrophilic colloids by both charge neutralization and bridging principles.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers

Class Assignments:

Module No:	Topic: Polyelectrolytes in Coagulation
Instructor Notes:	**Instructor Outline:**
P. 345, 346. Chemistry for Sanitary Engineers - Coagulant Aids	Objective 1 & 2 - Polymers and Polyelectrolytes Generally discuss the features of polymers and polyelectrolytes and explain how polyelectrolytes act to stabilize hydrophobic colloids by charge neutralization.
P. 222. Chemistry for Sanitary Engineers - Hydrophilic Colloids	Objective 3 & 4 - Hydrophilic colloids Define hydrophilic colloids and discuss the reasons for their difficult removal by normal electrolytes. Indicate that much of domestic sewage will contrain hydrophilic colloids. Counter ions alone are insuffieient to destabilize hydrophilic colloids because their stability is dependent upon "love" for the solvent rather than the slight negative charge they carry.
	Objective 5 - Polymer Destabilization Relate how polymers destabilize by charge neutralization and also, very significantly by bridging pinciples. Polymers and polyelectrolytes should be examined as an introduction to this area of treatment.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Pesticides
Approx. Time: 2 hours	Topic: Introduction

Objectives:

Upon completion of this module, the participant should be able to:

1. Define pesticides according to biological usefulness and describe two instances where pesticides are used.
2. List the three major types of synthetic organic pesticides and name three organochlorine compounds.
3. Describe one way in which pesticides may be introduced into streams and water supplies.
4. Differentiate between the susceptibility to biological degradation of the three groups of pesticides.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry of Wastewater Treatment, Unit 6, Ann Arbor Series.
Chemistry for Sanitary Engineers

Class Assignments:

Module No:	Topic: Pesticides - Introduction
Instructor Notes:	**Instructor Outline:**
PP. 301-318. Unit 6, Ann Arbor Series - Pesticides	Objective 1- Biological Usefulness Discuss and define pesticides and the history behind them. Also describe various instances where pesticides are used for insect control, crop control, rodent control, fungicides, weed control, etc. Examine the economic relevance of pesticides.
P. 150-154. Chemistry for Sanitary Engineers - Pesticides	Objective 2 - Types Examine the three major synthetic pesticide types -- organophosphates, organochlorines, carbamates. Show graph representations of each. List several types of organochlorines, DDT, dieldrin, aldrin, DDE, heptachlor, etc. Note the similarities between organochlorines, and PCB compounds. Objectives 3 & 4 - Introduction to Environment and Toxic Effects Discuss ways that pesticides are introduced into the aquatic environments -- runoff, wind, leachates. Indicate the relative importance of each. Differentiate between toxic effects of pesticides on aquatic life in terms of the three synthetic classes of pesticides. Also differentiate between the susceptibility to biological degradation of the three classes and the significance of these differences.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Pesticides
Approx. Time: 2 hours	Topic: Pesticide Systems

Objectives:

Upon completion of this module, the participant should be able to:

1. Explain that organic pesticides are relatively insoluble in water and a significant portion are adsorbed on suspended solids or deposited in sediment of streams.
2. Indicate that during periods of agricultural runoff, pesticides fixed on soil particles may be transported into aquatic systems.
3. Describe how pesticides, especially organochlorides, may be concentrated or accumulated through food chains.
4. Indicate a method for degradation of pesticides.

Instructional Aids:

Instructional Approach:

Discussion

References:

Applied Chemistry of Wastewater Treatment; Unit 6, Ann Arbor Series

Chlorinated Hydrocarbon Pesticides in Bottom Sediments, thesis by Don L. Kriens, 1972, University of Iowa Library

Class Assignments:

Module No:	Topic: Pesticide Systems
Instructor Notes:	**Instructor Outline:**
Chlorinated Hydrocarbon Pesticides in Bottom Sediments Introduction and Summary	Objective 1 - Solubility in Water Note that organic pesticides are relatively nonpolar compounds and are relatively insoluble in water. Indicate that significant portions of pesticides may be adsorbed on suspended solids in streams or also attached to other organic solids or colloids. There is a variability of solubility of organic pesticides in water in respect to types of pesticides and individual compounds.
PP. 301-318. Unit 6, Ann Arbor Series - Pesticides	Objective 2 - Runoff Explain that agricultural land runoff contributes a major portion of pesticides into the aquatic environment. Objective 3 - Food Chains Discuss how pesticides, especially organochlorines, may accumulate through food chains due to their nonbiodegradable nature. Indicate that this biomagnification or concentration of pesticides may reach a point where it could be toxic to the organism in question. This is especially prevalent in regard to organochlorine pesticides. Chart out a food chain as an example. Objective 4 - Degradation of Pesticides Discuss how pesticides may be destroyed or changed through biodegradation, chemical decomposition, photo decomposition etc.

Module No:	Module Title: Advance Chemistry
	Submodule Title: Heavy Metals
Approx. Time: 2½ hours	Topic: Introduction

Objectives:

Upon completion of this module, the participant should be able to:

1. List four heavy metals by symbols.
2. Indicate that the most significant concentrations of heavy metals occur in industrial wastewaters.
3. Explain that heavy metals, which may dissolve in water to produce heavy metal cations, may be toxic or inhibitory to growth of microorganisms in waste treatment at significant concentrations.
4. Indicate that heavy metals may be in inorganic compound forms and this is a factor in determining toxicity to humans.
5. Discuss how heavy metals may accumulate through food chains and induce toxicity in man.

Instructional Aids:

Handout No. 10 - Heavy Metals

Instructional Approach:

Discussion
Interpret Handout No. 10

References:

Applied Chemistry to Wastewater Treatment, Unit 7, Ann Arbor Series

Class Assignments:

Read Handout No. 10

Module No:	Topic: Heavy Metals Introduction
Instructor Notes:	**Instructor Outline:**
PP. 279-304, Unit 7, Ann Arbor Series - Toxic Cations	Objectives 1 & 2 - Heavy Metals and Contributors List several heavy metals and indicate the major source of heavy metals in wastewater industry. Objective 3 - Toxic cations: Review the toxic effect that heavy metal cations can have on treatment microorganisms.
Handout No. 10 - Heavy Metals	Objective 4 - Form of Metals Explain that metals may take an organic or inorganic form in the environment. Generally state that its form, organic or inorganic, may determine its relative toxicity to humans. For example Hg mercury is usually more toxic as an alkyl mercury, usually methyl mercury, than its inorganic form, such as Hg vapor. This is an important factor when determining toxicity to humans and other organisms. List a few effects of metal poisonings on humans. For example, methyl mercury -- teratogenic or causes deformed children, Pb -- nervous system disorders, As - brain disorders and so on. Objective 5 - Food Chains Discuss accumulation of heavy metals through food chains and how toxicity may result.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Radioactivity
Approx. Time: 2½ hours	Topic: Introduction

Objectives:

Upon completion of this module, the participant should be able to:

1. Describe the classical atom picture consisting of a central nucleus made up of relatively massive protons and neutrons about which rotate a number of electrons in orbit.
2. State that certain atoms are radioactive, have nuclei that are unstable and emit energetic particles, a pulse of energy, or both.
3. Identify radiations emitted by the radioactive decay process as alpha and beta particles and gamma rays; indicate their relative penetrating powers.
4. Define curie and indicate its use in defining quantities of radioactive materials.

Instructional Aids:

Instructional Approach:

Discussion

References:

Chemistry for Sanitary Engineers
Water Supply and Pollution Control

Class Assignments:

Read Chapter 9, Chemistry for Sanitary Engineers

Module No:	Topic: Introduction - Radiation
Instructor Notes:	**Instructor Outline:**
Chapter 9, Chemistry for Sanitary Engineers - Radiochemistry	Objective 1 - Atomic Picture Evaluate the Bohr theory of the atom, show how protons, neutrons, electrons relate to each other and the nucleus of the atom. Objective 2 - Radioactive Atoms Examine naturally occurring radioactive elements, atoms which have nuclei that are unstable and emit energetic particles or a pulse of energy, or both.
P. 367. Water Supply and Pollution Control - Radioactivity	Objective 3 - Emissions Discuss the various emissions and their relative penetrating powers, and thus, their energy levels.
P. 247, 248. Chemistry for Sanitary Engineers - Nature of Radiations	Objective 4 - Curie Define nature of radiations and the unit of radioactivity, curie. Relate the use of curie in defining quantities of radioactive emissions.

Module No:	Module Title: Advanced Chemistry
	Submodule Title: Radioactivity
Approx. Time:	Topic: Sources of Radiation

Objectives:

Upon completion of this module, the participant should be able to:

1. State that there are over 40 kinds of atoms displaying natural radioactivity, most with atomic weights over 200.
2. Describe two sources of radioactive materials.
3. Indicate that uranium is the mother of a chain of naturally occuring radioisotopes and ultimately disintegrates into a stable form of lead.
4. Explain how nuclear reactors in power plants represent a potential source of radioactive waste in streams.
5. Indicate how radioactivity can be removed from water supplies. Give one example.

Instructional Aids:

Instructional Approach:

Discussion

References:

Water Supply and Pollution Control

Class Assignments:

Module No:	Topic: Sources of Radiation

Instructor Notes:	Instructor Outline:
	Objective 1 - Types of Radioactivity Indicate the types of radioactivity which occur in nature.
	Objective 2 - Sources
P. 368, Water Supply and Pollution Control - Radioactive Pollutants	Briefly explain various sources of radioactive pollutants.
	Objective 3 - Uranium Explain uranium as a natural radioactive ore which will ultimately decay into a stable form of lead. Radium is a significant waste product of uranium. Indicate the relative long halflives of radioactive sources, varying degrees.
	Objective 4 - Nuclear Reactors Explain how nuclear reactors represent a source of introduction of radioactive waste into the water and air environments. Major contaminants would be radioactive krypton, xenon, and tritium.
	Objective 5 - Removal
P. 369, Water Supply and Pollution Control - Removal of Radioactivity from Water	Indicate that lime-soda ash softening is an effective method of removing most radioactive wastes from water supplies. Filtration usually removes only wastes associated with suspended solids. Distillation is the most effective method of removal, but is most expensive. Discuss health problems associated with radiation exposure.

Polarity of Water
Handout No. 1

Molecules are neutral, and the positive charges in them are exactly canceled out by the negative charges. But charges in some molecules may be spaced so that they do not cancel each other out exactly, so that one end is positive and the other negative but the molecule as a whole is neutrally charged. Remember that like charges repel each other and unlike charges attract.

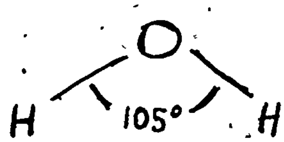
Water molecules are polar and account for much of the rather odd behavior of water.

A molecule of water H_2O contains 2 atoms of H and 1 atom of O.
Oxygen contains 8 electrons and 8 protons.
Hydrogen contains 1 electron and 1 proton.
Oxygen contains net negative charge of -2.
Hydrogen contains a net positive charge of +1.
A neutral water molecule contains 10 electrons.

The H_2O molecule may be illustrated as

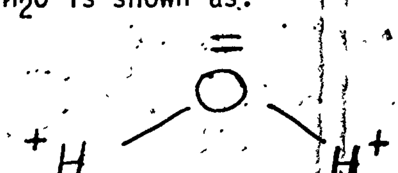
The bond between H and O may be represented as H:O where the electrons in the bond are shown as 2 dots. The nucleus of an oxygen atom pulls on its bonding electrons more strongly than a hydrogen nucleus does, thus the electron pair trapped between an O atom and an H atom will tend to be closer to the O atom. Because of the off-center position of this electron pair the O end of the bond is more negative than the H end. Therefore, the O-H bond will have electrical polarity, the hydrogen parts of the molecule having more positive charge and the oxygen end having more negative charge. The positive charges on the 2 hydrogens, hydrogen as a +1 charge, exactly balance out the negative charge on the oxygen, -2. The molecule is electrically neutral, but still remains polar. Why?

The water molecule, though neutral electrically, is a polar molecule because of the manner of orientation in space between the oxygen and hydrogen atoms. Examine again graphically:



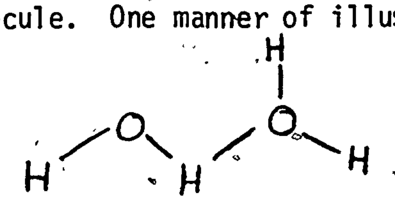
The angle between the molecule is 105°. This means that the H nuclei are not pulling in exactly the opposite directions. The molecule has positive and negative ends, H positive and O negative. This spatial orientation, caused by the off-center position of the electrons in the H-O bond accounts for the polar nature of water and is responsible for many of water's unique characteristics.

Note, that the positive charges on the H nuclei tend to keep the hydrogen atoms apart, like charges repel each other. Again in terms of charges the molecule H_2O is shown as:



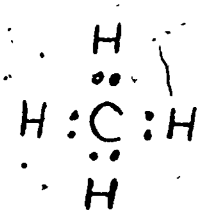
The charges balance each other but are spatially oriented so that the charges cause the molecule to be polar.

Polar molecules, like H_2O have attractions for each other. In water the oxygen end of the compound attracts the positive or hydrogen end of other water molecules. Remember that water solutions are combinations of many H_2O molecules. The proton in the hydrogen end of a water molecule can form a "weak" bond with an unused pair of electrons on the oxygen of a second water molecule. One manner of illustration may be:



Note that the bond within a water molecule is a bond of shared electrons, the bond between 2 water molecules is the single proton from a hydrogen nucleus, a hydrogen bond. This hydrogen bond is weaker than the H-O bond in the molecule itself.

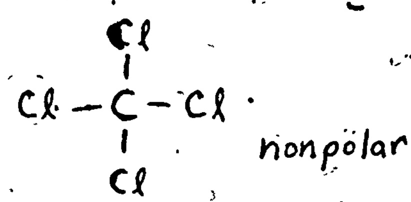
There are many other types of molecules that are nonpolar. For example:



The C and H nuclei have nearly the same equal attraction for the electrons. Since the C-H bond shares the electrons equally the bond is nonpolar. More so, the equal distribution of hydrogens arount the carbon tend to make it a nonpolar molecule.

The major significance of nonpolar and polar molecules is in the realm of solutions. Remembering the like dissolves like we understand then that a polar solvent like water will not be miscible in a nonpolar solvent like carbon tetrachloride or other nonpolar organic solvents. Also since water is a polar solvent it has great dissolving powers when it comes to dissolving ionic solids which carry charges.

Another example of a nonpolar compound is carbon tetrachloride ($C\ Cl_4$)



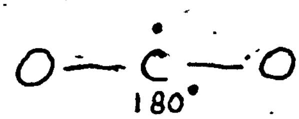
Most all organic solvents are nonpolar. Organic compounds are those which contain the element carbon within them.

CO_2 and O_2 Solubilities in Water

Handout No. 2

O_2 gas is nonpolar, so is Cl_2 or any other gas made up of 2 atoms that are alike. This is not necessarily to say that O_2 does not dissolve in water. Obviously it does, but it does so to a lesser degree due to its strictly nonpolar nature.

CO_2 is more polar than O_2 but does not act like a highly polar molecule. The C is the positive part, O the negative part.



Slightly polar

Due to the opposing pulls of the 2 polar C-O bonds the CO_2 molecule is not highly polar. It is not highly polar like H_2O because the opposing polar bonds are exactly oriented spatially 180° from each other.

However, CO_2 is more polar than O_2 and thus is more soluble in H_2O.

HANDOUT NO. 3 "Carbonate Equilibrium", PAGES 63-67 REMOVED PRIOR TO BEING SHIPPED TO EDRS DUE TO COPYRIGHT RESTRICTIONS.

pH Scale

Handout No. 4

	(H^+)	pH	$(OH)^-$	Examples
	1×10^{0}	0	1×10^{-14}	
Increasing	1×10^{-1}	1	1×10^{-13}	.1 M HCl
Acidity	1×10^{-2}	2	1×10^{-12}	.2 M HCl
	1×10^{-3}	3	1×10^{-11}	
	1×10^{-4}	4	1×10^{-10}	
	1×10^{-5}	5	1×10^{-9}	
	1×10^{-6}	6	1×10^{-8}	
Neutral	1×10^{-7}	7	1×10^{-7}	Distilled H_2O
	1×10^{-8}	8	1×10^{-6}	
	1×10^{-9}	9	1×10^{-5}	
Increasing	1×10^{-10}	10	1×10^{-4}	
Basicity	1×10^{-11}	11	1×10^{-3}	.3 M NaOH
	1×10^{-12}	12	1×10^{-2}	
	1×10^{-13}	13	1×10^{-1}	
	1×10^{-14}	14	1×10^{0}	

(H) and (OH) are in terms of molar concentrations.

Titration Example

Handout No. 5

The normality of acid solutions used to measure alkalinity (as $CaCO_3$) is usually:

1/50 = N/50 or .02 N

Thus in a titration to determine alkalinity a specified volume of sample is used and titrated with a specified normality of acid. The volume of acid used to titrate is determined at the end point. By using the equation:

$$\text{mg/l alkalinity as } CaCO_3 = \frac{\text{ml titrant} \times N \times EW \times 1000}{\text{Sample volume in ml}}$$

And alkalinity is thus determined.

As an example, 100 ml of sewage sample (effluent) is titrated with .02 N H_2SO_4 and the volume of titrant used is 12 ml, find the alkalinity.

$$\text{mg/l alk.} = \frac{12 \times .02 \times 50 \times 1000}{100 \text{ ml}}$$

$$= 120$$

50 is used as E.W. (equivalent weight) in order to express alkalinity as $CaCO_3$.

Problems

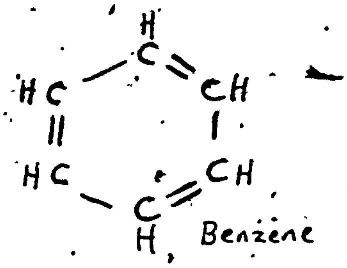
a. Find the alkalinity of a sewage sample (100 ml) in which 20 ml of a .02 N H_2SO_4 titrant is used. Express as mg/l $CaCO_3$.

b. Find the alkalinity of a sewage sample (50 ml) in which 30 ml of a .025 N H_2SO_4 titrant is used. Express as mg/l $CaCO_3$.

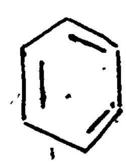
Aromatic Compounds

Handout No. 6

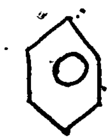
All aromatic compounds have groups of aromatic nature in their structure. The basic unit of aromatic compounds is the benzene ring.


Benzene

Simplified to



Sometimes represented as

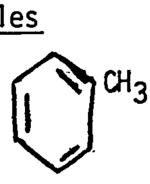


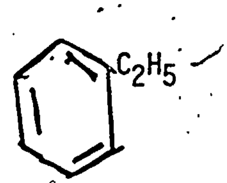
The formula shows double bonds between alternate carbon atoms in the ring.

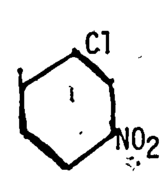
Functional groups added on to the benzene ring may include: As examples but not inclusive.

- $-CH_3$ methyl
- $-C_2H_5$ ethyl
- - Cl chloro
- - F fluoro
- - Br Bromo
- - I Iodo
- - OH alcoho (hydroxy)
- $-C(=O)H$ aldehyde
- $-C(=O)-$ Ketone
- $-C\equiv N$ nitrile
- $-NH_2$ amino
- $-NO_2$ nitro
- $-C(=O)OH$ acid

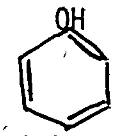
Examples


Tolvene


Ethylbenzene

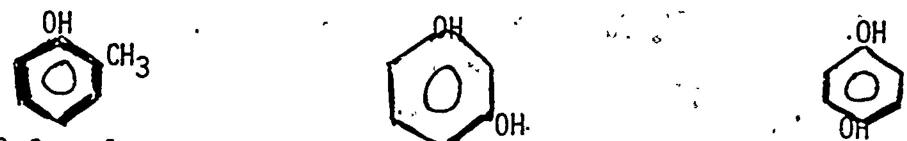

M-Chloronitobenzene

Phenols: Phenols are benzene rings with OH groups attached. The basic compound phenol is shown as:



Phenol

Others include added functional groups.



O-Cresol Resorcinol Hydroquinone

HANDOUT NO. 7 "Biochemical Oxygen Demand - Overview" PAGES 72-81 and HANDOUT NO. 8 "Salinity" PAGES 82-90 REMOVED PRIOR TO BEING SHIPPED TO EDRS FOR FILMING, DUE TO COPYRIGHT RESTRICTIONS.

Coagulation

Handout No. 9

Coagulant Salts

When aluminum sulfate $Al_2 (SO_4)3$ solutions are added to water the molecules dissociate to their various ions and also ionic complexes.

$Al_2(SO_4)_3 + H_2O \longrightarrow 2Al^{+++} + 3 SO_4$

In addition to Al^{+++} various hydrolysis complexes are formed with the OH^- of the water.

$Al(OH)^{++}$

$Al (OH)_2^+$

$Al (OH)_3$

Aluminum sulfate is usually called filter alum in engineering practice and may also be shown as $(Al_2 (SO_4)_3 \cdot 14 H_2O)$.

The various positively charged "species" formed may combine with the negatively charged colloids to neutralize part of the charge on the colloid and effectively reduce the zeta potential to a point at which the colloids will coagulate together

$Al^{+++} + \overline{-} \text{colloid} \overline{-} \longrightarrow Al \cdot \text{colloid}$

Ferric sulfate $Fe_2 (SO_4)_3$ likewise dissociates to yield: $Fe_2 (SO_4)_3 \longrightarrow 2Fe^{+++} + 3 SO_4^=$ and various hydrolysis complexes.

$Fe (OH)^{++}$

$Fe (OH)_2^+$

$Fe (OH)_3$

Chemistry Involved

It is notable that the species with the most positive charge is preferred. pH at lower values tend to favor those with a positive charge. pH values of 5 - 7.5 are considered the proper pH ranges. This is logical since lower pH values yield more H^+ ions, less OH^- ions, and therefore greater quantities of Al^{+++} ions, the more positive species.

Extreme pH depression, however, is undesirable and natural bicarbonates present act as buffers by this reaction.

$$HCO_3^- + H^+ \longrightarrow H_2CO_3 \rightleftharpoons CO_2 + H_2O$$

The zone of pH 5 - 7.5 is the zone of least solubility of floc and therefore the zone of greatest precipitation of floc or greatest coagulation. Residual alkalinity buffers the system at pH levels above 5 and guarantees total precipitation of coagulating ions.

Chemical coagulation is not fully understood and the chemistry involved is somewhat complex. It should also be noted that aluminum and iron salts (coagulants) have great advantages in that they remove, in addition to colloids, suspended matter and phosphates. However, a disadvantage is the addition of rather significant quantities of dissolved solids to the final effluent.

Heavy Metals

Handout No. 10

Heavy Metals

As - Arsenic

Cd - Cadmium

Be - Beryllium

Cr - Chromium

V - Vanadium

Mn - Manganese

Se - Selenium

Ni - Nickel

Pb - Lead

Hg - Mercury

Metals have varying effects according to source and form in the environment. A few are given here.

Arsenic - As

Sources - non ferrous metal smelting, seafood coal combustion, some natural waters.

Uses - insecticides, herbicides (organic), medicinals - potassium arsenite (Fowler's soln), anthelmintic.

Toxicology (effect on humans) - kidney malfunction and failures, central nervous system toxicity, dermatitis, cancer of skin, bladder, esophagus, liver.

Cadmium - Cd

Sources - lead and zinc smelting, silver soldering, electroplating battery manufacture, paint pigments, catalyst in plastics manufacture.

Toxicology - anemia, loss of calcium and phosphate in kidneys, damage to osteogenic tissue of bones.

Mercury - Hg

Sources - Mining of cinnabar, Hg is a minor component of many ores, distributed to environment in course of smelting.

Uses - Electrical and electronic devices, as slimicides, in paints, as seed protectant fungicides, in amalgam filling - dentistry, in laboratory and medical apparatus, as catalysts in plastics manufacture, as medicinals ($HgCl_2$ disinfectant, HgCl - calomel laxative, ammoniated Hg as a disinfectant.)

Penetration of human food chain: (a) Some uptake from soil into plant life - minimal. (b) Major source of penetration of human food chain is through marine sources of food. Mercury alkylated by bacterial metabolism - moved up through plankton to fish, eaten by humans. (c) Consumption of grain treated with Hg fungicide or of animals fed Hg treated grain.

Toxic actions - $HgCl_2$ extremely toxic, kidney damage, organic mercurys - nerve tissue damage, severe brain damage.

Lead - Pb

Sources - ores, storage batteries, non ferrous metal smelters - zinc, copper.

Uses - storage batteries, gasoline additive (tetraethyl lead), paint pigment, ammunitions, solder, shielding, caulking, several other uses.

Intake of Pb by U. S. resident =

Avg. daily ingestion (food, water) = .35 mg/day

Avg. daily exposure (air) = .15 mg/day

Total exposure = .50 mg/day

Highest absorption rate is in cities. Pb is stored mostly in bone tissue and is excreted primarily renal (kidney). Additional sources of lead for human consumption:

a. Lead paint chips

b. Smelter air sheds

c. Food grown near freeways

d. Lead chromate paint

e. Food eaten from lead-glazed pottery

Toxicology - nervous system disorders, anemia caused from impaired heme synthesis, kidney damage.

Manganese - Mn

Human exposure - mining, alloy manufacture, medicinals

Toxicology - Mn^{++} toxic to central nervous system.

Nickel - Ni

Human exposure - nickel carbonyl used in metallurgy is extremely toxic.

Toxicology - dermatitis, nickel carbonyl is very highly carcinogenic (cancer causing).

Problem Set No. 1 - Carbonate Equilibria

Fill in the following blanks:

1. H_2O + ________ $\rightleftharpoons$ H_2CO_3
2. H_2CO_3 $\rightleftharpoons$ ________ + HCO_3^- Show changes
3. $CaCO_3$ (solid) $\rightleftharpoons$ Ca^{++} + ________ Show changes
4. CO_2 increases the dissolving power of water by forming ________ acid.
5. The solid $CaCO_3$ dissolves in water into ions Ca^{++} and $CO_3^=$. When a solution of $CaCO_3$ is said to be saturated it has the ________ (maximum, minimum) amount of Ca^{++} and $CO_3^=$ ions allowed in solution.
6. In No. 5 above if Ca^{++} ions were introduced from an outside source would some $CaCO_3$ (solid) precipitate out of solution. ______ (yes, no).
7. True or false - Some CO_2 is picked up by our natural waters because of their contact with air above.
8. Which is more soluble at the same temperature and pressure ________ O_2 or CO_2. Is CO_2 (more or less) ________ polar than O_2.

Module No:	Module Title: Advanced Chemistry for Operators
Approx. Time:	Submodule Title:
	EVALUATION - Part A - Reactions in Water Solutions

Objectives:

Evaluation Questions

1. The water molecule is electrically ________.
2. Water molecules are ________ (polar, nonpolar).
3. Water molecules are held together by ________ bonds. Water molecules move continuously as groups in solution.
4. The smallest entity of water is the water ________. (ion, molecule)
5. Ions are separated in water solutions by the ________.
6. Increasing ionic content causing the water of hydration to be spread thinner and thinner will eventually result in ________ (saturation, insaturation) for the particular ionic solution.
7. Nonpolar substances will generally dissolve to a (lesser, greater) ________ extent in water, a polar substance.
8. Since carbon dioxide is more polar than oxygen, carbon dioxide will dissolve in water to a (greater, lesser) extent than oxygen.

Answer the following:

9. Show by equation form how CO_2 reacts in water to form carbonic acid.
10. Carbonic acid will ionize in water solutions. Show the ionization equations for carbonic acid.
11. Briefly describe how CO_2 increases the dissolving power of water (causes more $CaCO_3$ to dissolve).
12. Briefly explain how the removal of CO_2 during aeration and algal blooms will cause an increase in pH.

True or False

13. ____ Calcium carbonate and magnesium carbonate are sources of buffers.
14. ____ Bicarbonate is a main source of alkalinity in wastewater.

15. _____ Bicarbonates can be formed by bacterial degradation of organic carbon to CO_2 and CO_2 reacts in water to produce carbonic acid; carbonic acid then ionizes to produce bicarbonates.

16. _____ Hydronium ions (H^+) can be produced by the ionization of water.

17. _____ Hydronium ions (H^+) can be produced by the ionization of acids.

18. _____ pH is not a function of the hydrogen ion (hydronium ion) concentration.

19. _____ Increasing amounts of hydrogen ions in water solutions will cause an increase in pH.

20. _____ Hydroxide ions may not react with hydrogen ions to produce water molecules.

21. _____ Hydroxide ions can be produced by the ionization of water.

22. _____ Strong acids and weak acids ionize to the same degree (% ionization).

23. _____ Strong bases and strong acids will ionize (generally) 100%.

24. _____ Addition of a base to a water solution will cause an increase in hydrogen ions, a decrease in hydroxide ions, and cause the pH to decrease.

25. _____ A <u>weak</u> acid will ionize less than 100%.

26. _____ A <u>weak</u> base will ionize 100%.

27. _____ Adding an acid to a water solution will decrease in hydroxide ions, and a decrease in pH.

28. _____ pH 0 - 7 is considered the basic range of pH values.

29. _____ A base is a substance that will accept protons.

30. _____ Acidity and alkalinity are expressed in terms of $CaCO_3$ in wastewater analysis.

Answer the following:

31. Show, by equation form, how HCl acid dissociates into its component ions.

32. Show, by equation form, how NaOH base dissociates into its component ions.

33. Draw a diagram of the pH scale, list basic and acidic areas.

34. Given the acid HCl and the base NaOH, show by equation the neutralization reaction between these substances, show products.

35. Given 10 mls of .1 N HCl how many mls of .02N NaOH are required to neutralize or react with the HCl. Use $N_1 \times V_1 = N_2 \times V_2$ equation.

Evaluation - Part A - Answers

1. Neutral
2. Polar
3. Hydrogen
4. Molecule
5. Water of hydration
6. Saturation
7. Lesser
8. Greater
9. $CO_2 + H_2O \rightleftharpoons H_2CO_3$
10. $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

    $HCO_3^- \rightleftharpoons H^+ + CO_3^-$
11. In water containing CO_2 more H_2CO_3 is produced, thus according to the ionization equations, carbonate ions are changed to bicarbonate. As more carbonate ions are changed to bicarbonates the equilibrium effectively shifts causing more solid $CaCO_3$ to dissolve in order to replenish carbonate ions.
12. Aeration will cause CO_2 to be removed from solution in order to maintain the air-water CO_2 solubility equilibrium. Algae uptake also results in a decrease in CO_2 in water since CO_2 causes "acidity" through free CO_2 concentrations and production of H_2CO_3 loss of CO_2 will cause an increase in pH (less acidic).
13. T
14. T
15. T
16. T
17. T
18. F
19. F

20. F

21. T

22. F

23. T

24. F

25. T

26. F

27. T

28. F

29. T

30. T

31. HCl $\rightarrow$ $H^+ + Cl^-$

32. NaOH $\rightarrow$ $Na^+ + OH^-$

33. 14
13
12
11
10 Basic
9
8
7 Neutral
6
5
4 Acidic
3
2
1

34. HCl + NaOH $\rightarrow$ NaCl + H_2O

35. 10 x .1 = X x .02

50 mls. required

Module No:	Module Title: Advanced Chemistry for Operators
	Submodule Title:
Approx. Time:	EVALUATION - Part B - Organics, Inorganics

Objectives:

Evaluation Questions - 70%

Fill in the following blanks.

1. Organic compounds are compounds that always contain the element ______.
2. Organic compounds generally have (higher, lower) ______ molecular weight than inorganic compounds; organics are (combustible, non-combustible) ______ organics are (less, more) ______ sources of food for bacteria.
3. Carbon will almost always have (2, 3, 4) ______ bonds attached to it.
4. ______ is the simplest hydrocarbon and is a gas produced from anaerobic digestion.
5. Aliphatic and aromatic compounds are differentiated by the ______ ring.

True or False

6. ____ Aerobic bacteria may utilize organics as food sources and oxidize organics into inorganics, ultimately forming CO_2 and H_2O.
7. ____ CH_3 CH_2 OH, CH_3OH are known as alcohols.
8. ____ Methane's formula is CH_3.
9. ____ Increased loads of organics in treatment (secondary) systems will cause increased dissolved oxygen demands.
10. ____ Organic acids will not cause corrosion.
11. ____ Chlorination will become more effective in disinfection when higher organic quantities are present.
12. ____ Plastics are organic compounds which are very difficult to biologically degrade.
13. ____ Certain organics, such as phenols, may be toxic to treatment microorganisms.
14. ____ Greases and oils are quickly biodegradable.
15. ____ Greases and oils inhibit dispersion of oxygen to microorganisms.

16. ______ABS is known as alkylbenzene sulfonate.

17. ______Detergents are not organic compounds.

18. ______Phenols are substances which will cause taste and odor problems in water supplies.

Answer the following:

19. Illustrate the benzene ring graphically.

20. Illustrate phenol graphically

Fill in the following blanks:

21. Loss of weight in the volatile solids test gives an indication of the (organic, inorganic) ______________ content of the sample.

22. Biochemical oxygen demand is a method for determining the relative (organic, inorganic) ______________ quantities in wastewater.

23. ______________ (alkalinity, salinity) is known as the presence of dissolved inorganic substances in water.

24. Inorganics dissolve into ______________(molecules, ions).

True or False

25. ______Dissolved ions may decrease the solubility of gases in water.

26. ______Nitrates and phosphates act as nutrients for algae.

27. ______Low salinity may inhibit or kill microorganisms.

28. ______Sulfate and phosphate ions cause hardness.

29. ______Cations of mercury and lead may be toxic to animals.

Evaluation - Part B - Answers

1. Carbon
2. Higher, combustible, less, are
3. 4
4. Methane
5. Benzene
6. T
7. T
8. F
9. T
10. F
11. F
12. T
13. T
14. F
15. T
16. T
17. F
18. T
19.

20. OH

phenol

21. Organic
22. Organic
23. Salinity
24. Ions
25. T
26. T
27. F
28. F
29. T

Module No:	Module Title: Advanced Chemistry for Operators
Approx. Time:	Submodule Title:
	EVALUATION - Part C - Coagulation

Objectives:

Evaluation Questions - 70%

True or False

1. _____The basis for colloidal stability is the repulsion of similarly charged colloidal particles with abnormally long retention times.
2. _____Destabilization of colloids is brought about by counter-ion absorption.
3. _____If the Vander Waals forces are stronger than the repulsive forces of the zeta potential coagulation will occur.
4. _____Colloids are the size of ions.
5. _____Ferric sulfate and aluminum sulfate are the two main trivalent salts used in coagulation.
6. _____Particles (colloids) will not coalesce (coagulate) if the zeta potential produces repulsive forces in excess of Vander Waals force.
7. _____The objective of coagulation is the removal of colloidal dispersions causing an increase in sedimentation.

Answer the following:

8. Name 3 things that are removed by coagulation.
9. Illustrate, by equation, how aluminum sulfate dissociates to yield its various component ions.

True or False

10. _____Polyelectrolytes serve as coagulant aids by neutralization of colloidal charges.
11. _____Polymers act to destabilize hydrophilic colloids by both charge neutralization and bridging principles.
12. _____Domestic sewage contains mostly hydrophilic colloids.

Evaluation - Part C - Answers

1. T

2. T

3. T

4. F

5. T

6. T

7. T

8. Algae, tastes and odor, color, phosphates, organic and inorganic colloids, bacteria, turbidity, phosphates, some heavy metals, some radioactivity, etc.

9. $Al_2(SO_4)_3 + H_2O$ $Al^{+++} + 3\ SO_4^{-}$

$Al^{+++} + OH^-$ $Al(OH)^{++}$

$Al(OH)_2^{+}$ Various hydrolysis complexes

$Al(OH)_3$

10. T

11. T

12. T

Module No:	Module Title: Advanced Chemistry for Operators
	Submodule Title:
Approx. Time:	EVALUATION -- Part D - Pesticides, Heavy Metals, Radioactivity

Objectives:

Evaluation Questions - 70%

Answer the following briefly:

1. List the 3 major types of synthetic organic pesticides.
2. Name 3 ways pesticides can be introduced into streams.

True or False

3. _____ Organochlorines are less susceptible to biological degradation than organophosphates.
4. _____ Organochlorines will accumulate to a lesser degree in animal tissue than organophosphates.
5. _____ Runoff (agricultural) is responsible for a significant portion of pesticides deposited in streams.
6. _____ Organochlorines are relatively insoluble in water and a large portion can be adsorbed on suspended solids at various times.
7. _____ Pesticides cannot be bioconcentrated through food chains.
8. _____ Pesticides can be degraded through bacterial decomposition.

Answer the following:

9. List 4 heavy metals by symbol.
10. Heavy metals will occur mostly in (industrial, domestic) ____________ wastewater.
11. Heavy metals can (inhibit, promote) growth of treatment microorganisms.
12. Heavy metals (may, may not) accumulate through food chains and possibly induce toxicity in man.

True or False

13. _____ The form, organic or inorganic, of heavy metals is an important factor in determining toxicity to humans.
14. _____ Heavy metals can produce heavy metal cations in water.

15. _____Most heavy metals are non-toxic to treatment microorganisms at extremely large concentrations.

16. _____All atoms are radioactive.

17. _____The atomic nucleus is made up of electrons.

18. _____Gamma rays have much less penetrating power than alpha rays.

19. _____The classical atom consists of a central nucleus composed of protons and neutrons about which rotate electrons in distinct orbits.

20. _____The unit of radioactivity is defined as the curie.

21. _____Atomic weights of radioactive atoms (elements) are large.

22. _____Nuclear reactors in power plants are a potential source of radioactive waste in streams.

23. _____Xenon, tritium, krypton are radioactive environmental wastes from nuclear power plants.

24. _____Radioactive uranium will ultimately disintegrate into a stable form of lead.

Evaluation - Part D - Answers

1. Organochlorines (chlorinated hydrocarbon pesticides)

   Organophosphates

   Carbamates

2. Runoff - agricultural

   Runoff - industrial

   Wind - spraying

3. T

4. F

5. T

6. T

7. F

8. T

9. As, Cd, Be, Cr, V, Mn, Se, Ni, Pb, Hg

10. Industrial

11. Inhibit

12. May

13. T

14. T

15. F

16. F

17. F

18. F

19. T

20. T

21. T

22. T

23. T

24. T