Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

RQF LEVEL 5

GENAC502

ALL CONCERNED TRADE

Applied Chemistry

TRAINER'S MANUAL

APRIL 2025

Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

APPLY BASICS OF ANALYTICAL CHEMISTRY

2025

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LIST OF ABBREVIATIONS AND ACRONYMS

CBET: Competence Base Education and Training

RQF: Rwanda Qualification Framework

MS: Mass spectrometry

EMF: Electromagnetic Field

e.m.f: electromotive force

RTB: Rwanda TVET Board

TVET: Technical and Vocational Education and Training

INTRODUCTION

This Trainer's Manual encompasses all methodologies necessary to guide you to properly deliver the module titled: **Applied Chemistry** Trainees undertaking this module shall be exposed with practical activities that will develop and nurture their competences. The writing process of this training manual embraced competency-based education and training (CBET) philosophy by providing practical opportunities reflecting real life situations.

The Trainer's Manual is subdivided into Learning Outcomes, each learning outcome has got various topics. You will start guiding a self-assessment exercise to help trainees rate themselves on their level of skills, knowledge and attitudes about the unit.

The Trainer's Manual will give you the information about the objectives, learning hours, didactic materials, and proposed methodologies and crosscutting issues.

A discovery activity is followed to help trainees discover what they already know about the unit.

This manual will give you tips, methodologies and techniques about how to facilitate trainees to undertake different activities as proposed in their Trainee's Manuals. The activities in this training manual are prepared such that they give opportunities to trainees to work individually and in groups.

After going through all activities, you shall help trainees to undertake progressive assessments known as formative and finally facilitate them to do their self-reflection to identify your strengths, weaknesses and areas for improvements.

Remind them to read the point to remember section which provides the overall key points and takeaways of the unit.

APPLIED CHEMISTRY

Learning Outcomes	Learning Hours	Topic
1. Differentiate qualitative and quantitative chemical analysis	10	1.1 Explanation of qualitative chemical analysis
		1.2 Explanation of quantitative chemical analysis
		1.3 Applications of chemical analysis
2. Discuss solubility	10	2.1 Explanation solubility
		2.2 Identification of factors affecting solubility of salts
		2.3 Explanation of the solubility product
		2.4 Calculation of the solubility product
3. Describe the electrochemical cell reactions	10	3.1 Explanation of electrolysis
		3.2 : Illustrate electrochemical cell (galvanic cell)
		3.3 Determination of electromotive force of the cell

LEARNING OUTCOME 1: DIFFERENTIATE QUALITATIVE AND QUANTITATIVE CHEMICAL ANALYSIS

Learning outcome 1: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
   a. What do the illustrations show?
   b. What topics do you think will be covered under this unit based on the illustration?
2. After the discussion, inform trainees that this unit is intended to provide them with the knowledge, skills and attitudes to the qualitative and quantitative chemical analysis. They

will understand the methods used in qualitative chemical analysis, the factor considered and its application.

3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
   a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
   b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
   c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
   d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.

At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
1. Define analytical chemistry	1. Demonstrate proficiency in various analytical techniques	1. Uphold high ethical standards in all aspects of analytical work
2. Differentiate between qualitative and quantitative analysis	2. Accurately interpret observable phenomena to identify the presence of specific compounds	2. Demonstrate meticulous attention to detail in both qualitative and quantitative analyses to ensure accurate results.
3. Distinguish between inorganic and organic qualitative analysis	3. Accurately interpret observable reactions to deduce the presence of specific ions.	3. Demonstrate careful attention to detail in both inorganic and organic qualitative analyses to ensure

Knowledge	Skills	Attitudes
		accurate identification of compounds.
4. Identify and describe various qualitative methods	4. Identify and differentiate between flame colors produced by various metal ions accurately	4. Demonstrate meticulous attention to detail in preparing and mixing solutions to ensure accurate results
5. Explain the principle behind each qualitative method	5. Identify and differentiate between flames colors produced by various metal ions accurately.	5. Evaluate the effectiveness of different qualitative methods
6. Recognize and explain the factors influencing qualitative analysis	6. Demonstrate the ability to analyze and interpret the chemical composition of samples	6. Apply critical thinking to evaluate the factors influencing qualitative analysis and their potential impact on results.
7. Define quantitative analysis	7. Interpret quantitative data effectively	7. Clearly present quantitative findings
8. Describe various quantitative methods	8. Understand the basic principles of stoichiometry	8. Strive for high levels of accuracy and precision in calculations.
9. Identify and explain the factors that influence quantitative analysis	9. Selects appropriate analytical methods based on sample properties, desired sensitivity, and selectivity	9. Evaluate the suitability of the chosen method for the sample being analyzed.
10. Discuss the application of qualitative and quantitative analysis	10. Integrate qualitative and quantitative data to provide a comprehensive understanding of a sample	10. Be prepared to conduct multiple tests to confirm findings, especially in complex mixtures.

Steps:

Discovery Activity

Task 1

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to share their prior experience from their home area regarding the concept of analytical chemistry and its two main branches, qualitative and quantitative analysis under the **Task 1** in their Trainee's Manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are given.

2. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class. Encourage all trainees to give their views.

3. After the presentations/sharing session, inform trainees that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.

Topic 1.1: Explanation of qualitative chemical analysis

	Objectives: By the end of the topic, trainees will be able to: a. Explain clearly qualitative chemical analysis according to the analysis methods b. Differentiate correctly organic and inorganic qualitative analysis c. Explicate effectively the factors/criteria considered for qualitative analysis.
	Time Required: 4 hours
	Learning Methodology: Group discussion, Trainer guided, brainstorming

	**Materials, Tools and Equipment Needed:** Test-tube, Beaker, Conical flask, Distiller, measuring cylinder, washing bottle, Funnel, Retort stand, Burette, pipette, Pens/Pencils, Notebook, Papers, Marker, White/ Chalk, Boards, Chalks, Manufactured product having content label, teabag, Video, Projector, Computer, Books, Internet.
	**Preparation:** ❑ Prepare all material needed and describe their brief uses ❑ Checking the availability of equipment such as chalk, Flipchart and markers. ❑ Prepare some products with labels or labels of some products to share to trainees and observe what is on labels
	**Cross Cutting Issues:** ✓ Ensure gender balance while forming groups, allocating tasks and during presentation. ✓ Ensure inclusivity while allocating tasks to trainees and provide facilities that allow participation for all. ✓ Trainees might have limited prior knowledge of chemistry concepts like elements, compounds, and ions. ✓ They might have misconceptions about the meaning of "qualitative" and "quantitative" analysis.
	**Prerequisites:** ✓ Describe the structure of atoms, the periodic table, and the formation of ions. ✓ Explain chemical reactions, including types of reactions ✓ Observe and interpret changes in chemical solutions.

Activity 1: Problem-Solving

Task 2

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to read and analyze the scenario then answer the questions provided under **Task 2** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class. Write their responses for reference. Encourage all trainees to give their views.

3. After the sharing session, refer trainees to **Key facts 1.1** Qualitative chemical analysis and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.

Activity 2: Guided Practice

Task 3

1. Using an individual work methodology or in small group guide trainees to perform experiment provided under **Task 3** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in activity 1. Your role is to guide them by using probing questions such as why? what? How? To enable them to come to informed responses.
3. During the task, work collaboratively and discussing their findings, trainees will develop critical thinking and analytical skills essential for success in chemistry.
4. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class. Write their responses for reference. Encourage all trainees to give their views.

Activity 3: Application

Task 4

1. With a right methodology that require the trainee active participation like individual work, avail needed tool to assess trainees' understanding of the topic.
2. The trainer will provide task sheets to trainees in or ask them to go to **Task 4** in their trainee manual, and give clear and concise instructions on how the task will be done.
3. Make sure guidelines are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

4. This activity requires trainees to work independently in their respective groups with limited support from the trainer. During the task, trainees should be given a high degree of independence to apply the knowledge, skills and attitudes acquired to real life situations. Your role is to set clear instructions, methodology, and timeframe to finish the task.
5. Trainer can offer different instruction, such as providing additional exercises for fast learners and offering more hands-on support to struggling trainees

Checklist table for analyzing NPK fertilizer

SN	Criteria	Indicator	Yes	No
1	**Sampling is well performed**	NPK sample is collected with a clean tool		
		The sample is homogenised to ensure uniformity		
		The sample is well labelled		
2	**Flame test is well performed**	A burner burn is ignited for the flame test		
		A small amount of the sample is exposed to a Bunsen burner		
		A violet flame is observed		
		Flame color observation is recorded		

Topic 1.2: Explanation of quantitative chemical analysis

Objectives:

By the end of the topic, trainees will be able to:

a. Explicate properly chemical quantitative analysis according to the analysis methods
b. Explain correctly the titration method as used in chemical analysis
c. Explain clearly the gravimetric method as used in chemical analysis

Time Required: 3 hours

Learning Methodology: Group discussion, Trainer guided, Site visit, brainstorming and demonstration.

Materials, Tools and Equipment Needed: Test-tube, Beaker, Conical flask, measuring cylinder, Washing bottle, Funnel, Retort stand, Burette, Pipette, Analytical balance, Pens/Pencils, Notebook, Papers, Marker, White/ Chalk, Boards, Chalks, Acid and base, Table salt, Video, Projector, Computer, Books, Internet.

Preparation:

- ❑ Prepare diagrams showing the typical titration setup (burette, pipette, conical flask, etc.) and flow charts illustrating the steps in performing different types of titrations
- ❑ Prepare a flowchart of the gravimetric method, including precipitation, filtration, drying, and weighing.

Cross Cutting Issues:

- ✓ Ensure gender balance while forming groups, allocating tasks and during presentations
- ✓ Ensure inclusiveness while allocating tasks to trainees and provide facilities/environment that enable/allows participation of all
- ✓ Ensure Peace and values education are in place while trainees are interacting in groups and during role play

- ✓ Reinforce key concepts with clear, simple explanations and visual aids.
- ✓ Break down calculations into clear, manageable steps and walk trainees through example problems.
- ✓ Make the material more engaging by connecting it to real-world applications

Prerequisites:

- ➢ Explain the concepts of molarity and molality and how to calculate concentrations
- ➢ Identify chemical reactions, particularly acid-base reactions
- ➢ Distinguish Ionic, covalent, and metallic bonding.
- ➢ Solving algebraic equations and manipulating formulas

Activity 1: Problem-Solving

Task 5

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to read and analyze the scenario then answer the questions provided under **Task 5** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating.
2. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class.
3. Write their responses where it is easy for trainees to refer to them. Encourage all trainees to give their views during session sharing.
4. After the sharing session, refer trainees to **Key Facts 1.2a** Quantitative chemical analysis and **Key Facts 1.2b** Applications of chemical analysis then discuss them together while harmonizing their responses provided in the sharing session and clear any misconceptions that trainees may have answer any questions they have.

Activity 2: Guided Practice

Task 6

1. Using an appropriate methodology, such as individual work, in pair or in small group, guide trainees to perform the experiment provided under **Task 6** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating.

2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in activity 1. While conducting titration in groups, trainer moves around for guiding them where possible and provide any support by asking probing questions.

3. Using an appropriate methodology such as question and answer, large group discussion, pair presentations or small group presentations, trainee share their answers to the class. Write their responses for reference where it is easy for the trainees to refer to and encourage all trainees to give their views. The trainees have to refer to **Key Facts 1.2a and 1.2b** to complement their findings.

Activity 3: Application

Task 7

1. With a right methodology that require the trainee active participation like individual work, avail needed tool to assess trainees' understanding of the topic.
2. The trainer will provide the trainees with questionnaires or ask them to read the scenario provided under **Task 7** in their trainee's manual and give clear and concise instructions on how the task will be done.
3. Make sure guidelines are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

4. This activity requires trainees to work independently in their respective groups with limited support from the trainer. During the task, trainees should be given a high degree of independence to apply the knowledge, skills and attitudes acquired to calculation situations. Your role is to set clear instructions, methodology and timeframe for submitting the answer sheets
5. Make a summary of **Topic 1.2** by asking trainees to mention the main key points discussed.

Checklist of analyzing the hydrated salt sample

SN	Criteria	Indicator	Yes	No
1	**Sampling is well performed**	The analytical balance is well calibrated		
		50g of hydrated salt is accurately weighed		
		The sample is well labelled		
2	**The amount of volatile component is correctly determined**	The sample is heated until no further weight loss observed		
		The sample is allowed to cool in a desiccator		
		The mass of volatile components is calculated		
		The obtained mass is recorded		

Formative Assessment

1) **What is the main focus of qualitative chemical analysis?**

   a) **To determine the concentration of substances in a sample**

   b) **To identify the chemical components, present in a sample**

   c) **To measure the mass of an analyte**

d) To separate components of a mixture based on boiling points

Answer: b

2) **Which of the following is an example of a technique used in quantitative chemical analysis?**

a) Flame test

b) Distillation

c) Titration

d) Extraction

Answer: c

3) **Which of the following is not a factor considered in qualitative chemical analysis?**

a) Color

b) Melting point

c) Concentration

d) Odor

Answer: c

4) **What is the primary focus of qualitative chemical analysis in the context of testing fertilizers and pesticides?**

a) Measuring the exact concentration of active ingredients

b) Detecting the presence or absence of specific contaminants

c) Assessing the overall chemical composition of the product

d) Evaluating the environmental impact of the chemicals.

Answer: b

5) In pharmaceutical analysis, why is quantitative analysis crucial?

a) To detect impurities in the product

b) To ensure the presence of active ingredients at proper concentrations

c) To determine the chemical composition of the product

d) To separate the ingredients of the formulation

Answer: b

6) Fill in the blank spaces with the appropriate term among the following: the functional groups, ions, atoms, and molecules.

a) Organic qualitative analysis determines …… in the sample

b) Inorganic qualitative analysis frequently determines …… in the sample

Answer

a) Functional groups

b) Ions

7) The following are statements about qualitative and quantitative chemical analysis, answer by True if the statement is correct or by False if the statement is incorrect

a) Quantitative analysis is used to measure the concentration of specific substances in a sample.
b) The concentration of nitrogen in a fertilizer sample can be determined through titration in a quantitative analysis.
c) Gravimetric analysis involves measuring the mass of an analyte or precipitate formed during a chemical reaction.
d) The principle of the flame test is based on the phenomenon of atomic emission spectroscopy, where metal ions emit light at characteristic wavelengths when excited by heat.
e) Distillation is a separation process that separates components of a mixture based on differences in their melting points.

Answer

a) True

b) True

c) True

d) False

8) What does the principle of titration rely on?

Answer: The principle of titration relies on the stoichiometric relationship between the titrant (solution of known concentration) and the analyte (substance being analyzed).

9) Identify the primary technique used to determine the concentration of a substance in a solution

Answer: Titration

10) How can you use a precipitation reaction to determine the concentration of a metal ion in a solution?

Answer:

By adding a reagent that reacts with the metal ion to form a precipitate, the amount of precipitate formed can be used to calculate the concentration of the metal ion based on the stoichiometry of the reaction.

11) Explain clearly how reactivity can be used to distinguish different substances

Answer:

Different substances exhibit unique chemical reactions with various reagents. By observing the reactions (e.g., color changes, gas evolution, and formation of precipitates), it's possible to identify and differentiate between different substances

12) What volume of 0.75M HCl is required to neutralize 100ml of 0.01M Ca $(OH)_2$ solution.

Answer:

- ✓ **Balanced Equation: $2HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$**
- ✓ **Moles of $Ca(OH)_2$: 0.100 L X 0.01 mol/L = 0.001 moles**
- ✓ **Moles of HCl required: 0.001 moles $Ca(OH)_2$ X (2 moles HCl / 1 mole $Ca(OH)_2$) = 0.002 moles HCl**
- ✓ **Volume of HCl: 0.002 moles HCl / 0.75 mol/L = 0.00267 L = 2.67 Ml**

13) In petrochemical industry the operator, determine the following information; the melting and boiling point, functional group, structure and types of bonds. How does this be related to qualitative and quantitative analysis?

Answer:

This relates to qualitative analysis, as the determination of physical properties (like melting and boiling points) and the identification of functional groups, structure, and types of bonds help to identify the chemical composition of the petrochemical products. Quantitative analysis might be involved later to measure the concentrations of specific components.

14) If a fertilizer sample is tested and found to contain 25% nitrogen, what type of analysis has been performed?

Answer:

Quantitative analysis has been performed to determine the concentration of nitrogen in the sample.

15) Discuss the role of fertilizers and pesticides in modern agriculture and the need for chemical analysis to ensure their safety and effectiveness.

Answer:

Chemical analysis is necessary to ensure that these products contain the correct concentrations of active ingredients, are free of harmful contaminants, and meet safety standards. Analytical techniques such as qualitative and quantitative analysis are used to test these products for compliance, ensuring that they are both effective and safe for consumers and the environment.

Points to Remember

- While conducting chemical analysis you start with qualitative chemical analysis followed by quantitative chemical analysis.
- Always handle samples carefully to avoid contamination or loss of material.
- Ensure that all glassware and apparatus are clean and free from any previous chemicals.
- Follow the laboratory rules and regulation during laboratory experiments.
- When heating samples do so gradually and avoid overheating.
- For titrations involving pH-sensitive indicators (e.g., acid-base titrations), ensure that pH changes are carefully monitored to identify the equivalence point correctly.
- In titrations or other reactions, do not delay the observation of color changes, as some reactions can be time-sensitive.

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to identify their areas of strength, areas for improvement and actions to take to improve.

Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts.

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Relate qualitative with quantitative analysis to know the composition of any sample					
Explain the change in factors that would help to know the quality of a sample					
Differentiate qualitative and quantitative analysis					
Distinguish inorganic and organic qualitative analysis					
Identify the methods for qualitative and quantitative analysis					
Explain the principle behind each qualitative method					
Demonstrate the ability to analyze and interpret the chemical composition of samples					

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Recognize the quantitative methods of analysis					
Understand the basic principles of stoichiometry					
Identify the change in factors that would help to know the amount of substance					
Selects appropriate analytical methods based on sample properties, desired sensitivity, and selectivity					
Integrate qualitative and quantitative data to provide a comprehensive understanding of a sample					
Clearly present qualitative and quantitative findings					
Evaluate the effectiveness of					

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Different qualitative and quantitative methods					
Explain the application of chemical analysis					

Further Information for the Trainer

https://unacademy.com/content/neet-ug/study-material/chemistry/qualitative-and-quantitative-analysis/.

https://www.nagwa.com/en/explainers/712146764265/

Figure 2:

Learning outcome 2: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
    a. What does the illustration show?
    b. What do you think will be topics to be covered under this unit based on the illustration?
2. After the discussion, inform trainees that this unit is intended to provide them with the knowledge, skills and attitudes to discuss solubility. They will cover Solubility of sparingly soluble salts and Solubility product.
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:

a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.
b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.
c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?
d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.
e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
1. Define solubility and molar solubility	1. Interpret l data related to solubility and draw meaningful conclusions.	1. strong desire to explore the underlying principles of solubility
2. Differentiate soluble and insoluble salts	2. Apply the knowledge of solubility in explaining why some substances are soluble while others are not	2. Willingness to consider different perspectives and approaches to understanding solubility
3. List solubility rules for common ionic compounds,	3. Apply solubility rules to predict whether specific salts will dissolve in water	3. Paying close attention to the specific rules and exceptions
4. Explain the behavior of ionic compounds in solution	4. Apply knowledge of ionic bonding, intermolecular forces, and solution chemistry to solve problems	4. Have a strong desire to explore the behavior of ions in solution
5. Describe the dissociation equations	5. Write the dissociation equation	5. Persevere through complex chemical concepts

Knowledge	Skills	Attitudes
6. Distinguish types of solutions	6. Apply the concepts of solubility and saturation to prepare and analyze solutions.	6. Endure challenging experiments and problem-solving.
7. Discuss the factors that influence solubility	7. Observe changes in solubility under different conditions.	7. Willingness to consider different explanations for observed
8. Describe the relationship between solubility and solubility products	8. Apply the concept of Ksp to solve problems related to solubility.	8. Persevere through complex calculations and problem-solving.
9. Describe the ksp expression.	9. Solve equations involving Ksp expressions	9. Paying close attention to expressions.
10. Explain the procedures involved in calculating solubility product (Ksp) and solubility	10. Apply the steps involved in Ksp calculations to calculate solubility product (ksp) from solubility and vis versa	10. Persist through complex calculations and problem
11. Discuss the use of solubility	11. Analyze the role of solubility in various applications.	11. Strong desire to explore the uses of solubility.

Steps:

Discovery Activity.

Task 8

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to share their prior experience from their home area regarding solubility of salts under **Task 8** in their Trainee's Manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are given.

2. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class. Encourage all trainees to give their views.

3. After the presentations/sharing session, inform trainees that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit.

4. Using their answers, lead them to the topic discovery.

Topic 2.1: Solubility of sparingly soluble salts

Objectives:

By the end of the topic, trainees will be able to:

a. Identify properly the factors that affect solubility according to the nature of solution.
b. Describe correctly the types of solutions according to their solubility
c. Explain clearly solubility of a substance
d. Differentiate correctly soluble and insoluble salts

Time Required: 5 hours.

Learning Methodology: Lectures, demonstration and simulation, individual and group work, practical exercise, individualized, trainer guided and group discussion.

Materials, Tools and Equipment Needed:

Chemical salts, sugar, sand, Reference books, marker pen, flip chalks, chart, white/black board, projector, computer, chalkboard, DVD players, Internet connection, laboratory apparatus

Preparation:

- ❑ Prepare diagrams showing solute-solvent interactions, solubility curves, images, and videos to enhance understanding Focus on the most important concepts and avoid overwhelming trainees with too much detail.
- ❑ Gather salts, like NaCl, $CaCO_3$ and other that will help you to explain clearly the solubility of salts.
- ❑ Design simple experiments demonstrating solubility (e.g., dissolving different substances in water, observing the effect of temperature on solubility).
- ❑ Ensure access to basic laboratory equipment like beakers, stirring rods, thermometers, and possibly hot plates
- ❑ Prepare safety goggles and gloves for any experiments involving chemicals.

Cross Cutting Issues:

- ✓ Consider gender mainstreaming while teaching.
- ✓ Integration of inclusiveness in the learning and teaching process
- ✓ Consider the minimization of environmental impact during the teaching and learning

Prerequisites:

- ✓ Differentiating elements and compounds.
- ✓ Basic familiarity with the periodic table and the properties of different elements.
- ✓ Explain concentration and how it relates to the amount of solute in a solution.
- ✓ Describe simple calculations involving ratios and proportions.
- ✓ Main states of matter—solid, liquid, and gas—helps in understanding how solubility varies with these states.
- ✓ Differentiate ionic compounds and molecular compounds is key to knowing how solubility works, especially when considering the dissolution process.

Activity 1: Problem-Solving

Task 9

1. Using discussion in small groups, guide trainees to analyze the scenario and answer the questions provided under **Task 9** in their trainee's manuals. Inform them that each group will have a representative to present the findings. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used
2. Basing on the group presentations, ask trainees to share their answers to the class.
3. After the sharing session, refer to **Key facts 2.1** and discuss them together while harmonizing their responses provided in the sharing session and answer to any questions they encountered while performing task.

Activity 2: Guided Practice

Task 10

1. Using appropriate methodology, guide trainees to analyze the scenario and perform the experimental tasks provided under **Task 10** in their trainee's manuals. Make sure instructions are understood and all the trainees are actively participating and necessary materials/tools are provided and being used, so that will help them to be familiar with the solubility of salts

2. During the task, trainees should be given time to discuss and come up with findings on the given task. Monitor them so as they become more productive with intention to apply the knowledge and skills acquired in activity 1

3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusiveness, Ensure Environment and sustainability among others. Also attitudes and behavior changes should be handled during this activity.

Activity 3: Application

Task 11

1. Explain to trainees that the following task links them to the world of work and will require them to apply the knowledge, skills and attitudes acquired; and working independently to perform the task is required. Using an appropriate methodology that require the trainee active participation like individual work, avail needed tool to assess trainees' understanding of the topic.

2. The trainer will provide the trainees with questionnaires or ask them to go to **Task 11** In Trainee manual and give clear and concise instructions on how the task will be done. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

3. This activity requires trainees to work independently in their respective groups with limited support from the trainer. During the task, trainees should be given a high degree of independence to apply the knowledge, skills and attitudes acquired to real life situations. Your role is to set clear instructions, methodology and timeframe for submitting the answer sheets.

4. After the assessment of trainees' work, discuss with them the total performance/competence and use the individual forms to share and give feedback to the trainees in terms of clarity of the vision, mission, goals and objectives. Support those who may remedial activities.
5. Make a summary of Topic 2.1 by asking trainees to mention the main key points discussed.

Checklist for preparation and analysis of the salt solution

SN	Criteria	Indicator	Yes	No
1	**The salt is well dissolved**	the clean beaker is filled with 100 mL of water		
		The salt is gradually added in the beaker and stirred effectively		
		The amount of salt dissolved is recorded		

Topic 2.2: Solubility product

Objectives:

By the end of the topic, trainees will be able to:

a. Explain properly the solubility product based on the nature of salt.
b. Dissociate correctly a sparingly soluble salt and express its solubility product
c. Explain clearly the relationship between solubility and solubility product.
d. Calculate correctly solubility product and solubility
e. Explicate clearly the uses of solubility

Time Required: 5 hours

Learning Methodology: Demonstration and simulation, individual and group work, Lectures, practical exercise, individualized, trainer guided and group discussion

Materials, Tools and Equipment Needed:

Chemical salts, sugar, sand, Reference books, marker pen, flip chalks, chart, white/black board, projector, computer, chalkboard, DVD players, Internet connection, laboratory apparatus

Preparation:

- ❑ Design visual aids such as diagrams, flowcharts, and infographics that illustrate the concepts of dissociation and Ksp expressions.
- ❑ Plan and prepare laboratory experiments that allow trainees to observe the solubility of various salts in water
- ❑ Create worksheets with a variety of problems related to calculating Ksp and solubility from given data.
- ❑ Prepare a set of diverse worked examples for both calculating Ksp from solubility and calculating solubility from Ksp, including more complex salts and multi-step problems

Cross Cutting Issues:

- ✓ Ensure gender balance while forming groups, allocating tasks and during presentations
- ✓ Ensure inclusiveness while allocating tasks to trainees and provide facilities/environment that enable/allows participation of all
- ✓ Ensure Environment and sustainability while conducting the laboratory experiments

Prerequisites:

- ✓ Familiarity with ionic compounds, their structures, and how they dissociate into ions when dissolved in solvents
- ✓ Explain the principles of chemical equilibrium.
- ✓ Balance chemical equations and understand mole ratios.
- ✓ Familiarity with concentration units such as molarity (mol/dm^3) and how to convert between different units of concentration (e.g., g/dm^3 to mol/dm^3).

Activity 1: Problem-Solving

Task 12

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to read and analyze the scenario and then answer the questions provided under **Task 12** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. After answering the questions, guide trainees to share their answers to the rest of the class using an appropriate method such as pair-share or small group presentations. Motivate other trainees to give their contributions during the presentations. The answers should be pasted where trainees can easily refer to them during the session.
3. After the sharing session, ask trainees refer to **Key Facts 2.2a**: Definition of the solubility product and **2.2b**: Calculation of the solubility product in their trainee manual, read them together while comparing with their responses from the sharing session. Answer any questions trainees might have as well as clearing any misunderstandings they may have.

Activity 2: Guided Practice

Task 13

1. Using small manageable groups or in pair work methodology ask trainees to answer the questions provided under **Task 13** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in activity 1. Your role is to guide them by using probing questions such as why? What? How? to enable them to come to informed responses

3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, environment and sustainability among others. Also attitudes and behavior changes should be handled during this activity.

4. Using an appropriate methodology such as question and answer in a large group, pair presentations or small group presentations, trainees share their answers to the class. Write their responses for reference. Encourage all trainees to give their views.

5. Trainees have to refer to **Key Facts 2.2a**: Definition of the solubility product and **2.2b**: Calculation of the solubility product to complement their findings.

Activity 3: Application

Task 14

1. Using an appropriate methodology such as individual work, ask trainees to read the scenario provided in their Trainee Manual under **Task 14** and work individually by answering the related questions.

2. Explain to trainees that the following task links them to the world of work and will require them to apply the knowledge, skills and attitudes acquired; and working independently to perform the task required.

3. Give the trainees enough time and clear instructions to perform the task. This is a practical activity, so give trainees independence and freedom while they are performing the task.

4. After the assessment of trainees' work, discuss with them the total performance/competence and use the individual group forms to share and give feedback to the trainees in terms of the content presented. Support those who may need additional or remedial activities.

5. Make a summary of Topic 2.2 by asking trainees to mention the main key points

Formative Assessment

From questions 1 to 2 select the correct answer

1. A chemistry class is comparing the solubility of two salts: sodium chloride (NaCl) and calcium chloride ($CaCl_2$). They notice that NaCl is more soluble in water than $CaCl_2$.

   a) Which of the following salts is more soluble in water?

      i) Sodium chloride (NaCl)

      ii) Calcium chloride ($CaCl_2$)

      iii) Both have equal solubility

      iv) Neither is soluble in water

   b) What is the likely reason for the difference in solubility between NaCl and $CaCl_2$?

      i) NaCl has a higher molecular weight.

      ii) $CaCl_2$ has a higher molecular weight.

      iii) NaCl has a higher lattice energy.

      iv) $CaCl_2$ has a higher lattice energy

   c) Which of the following factors could potentially increase the solubility of $CaCl_2$ in water?

      i) Decreasing the temperature.

      ii) Increasing the pressure.

      iii) Adding more water.

      iv) All of the above.

Answer

a) Sodium chloride (NaCl)

b) $CaCl_2$ has a higher lattice energy

c) Adding more water

2. NaCl is mixed with 100ml water in three beakers according to the following ratios; first beaker adds 30g, 40g and 60g in second and third beaker respectively and relate findings with type of solution.
    a) When 30g of NaCl is added to 100ml of water, the solution is most likely:
        i) Unsaturated
        ii) Saturated
        iii) Supersaturated
        iv) Cannot be determined
    b) When 40g of NaCl is added to 100ml of water, the solution is most likely:
        i) Unsaturated
        ii) Saturated
        iii) Supersaturated
        iv) Cannot be determined
    c) When 60g of NaCl is added to 100ml of water, the solution is most likely:
        i) Unsaturated
        ii) Saturated
        iii) Supersaturated
        iv) Cannot be determined
    d) Which of the following is a saturated solution?
        i) A solution where no more solute can be dissolved at a given temperature.
        ii) A solution where more solute can be dissolved at a given temperature.
        iii) A solution that contains less solute than the maximum amount that can dissolve.
        iv) None of the above.
    e) A supersaturated solution is formed by:
        i) Adding more solute to a saturated solution.
        ii) Cooling a saturated solution.
        iii) Heating a saturated solution and then cooling it slowly.
        iv) All of the above.

Answer:

a) **Unsaturated**

b) **Saturated**

c) **Supersaturated**

d) **A solution where no more solute can be dissolved at a given temperature.**

e) **Heating a saturated solution and then cooling it slowly.**

3. Students are working in a laboratory, and your task is to investigate how different factors influence the solubility of a variety of substances. They have access to four main substances: sugar ($C_6H_{12}O_6$), salt (NaCl), carbon dioxide (CO_2), and oil (vegetable oil). From the given information answer the following questions by **True** or **False**

   a) Salt (NaCl) dissolves in non-polar solvents like vegetable oil

   b) Carbon dioxide (CO_2) is more soluble in water at higher temperatures

   c) Vegetable oil is soluble in water due to its non-polar nature

   d) Sugar will dissolve faster in warm water compared to cold water because solubility increases with temperature.

   e) The solubility of NaCl in water is unaffected by changes in pressure.

Answer

a) **False**

b) **False**

c) **False**

d) **True**

e) **True**

4. A chemist is trying to dissolve a non-polar organic compound in water. Why is the compound not dissolving?

Answer

The compound does not dissolve because "like dissolves like." Polar solvents (like water) dissolve polar solutes, while nonpolar solvents dissolve nonpolar solutes.

5. A soda can is opened. Explain why does the carbon dioxide fizz out?

Answer

When the soda can is opened, the pressure is released, decreasing the solubility of CO_2, which then escapes as gas bubbles, causing the fizz.

6. A chemist needs to dissolve a large amount of a solid salt in water. How can they increase the solubility of the salt?

Answer

Increasing temperature and stirring the solution can help increase the solubility of a solid salt in water.

7. You are conducting an experiment where you need to dissolve a salt (like potassium nitrate) in water. You have two beakers; one filled with cold water (5°C) and the other with hot water (60°C).
   a) Which beaker, the one with cold water or the one with hot water, do you think will dissolve more potassium nitrate? Why?
   b) What other factors, besides temperature, might affect the solubility of a salt in water?

Answer

a) The beaker with hot water (60°C) will dissolve more potassium nitrate because solubility generally increases with temperature for most salts.

b) Factors include pressure (for gases), the presence of other solutes, and the polarity of the solvent.

8. Trainees are comparing the solubility of two salts, sodium chloride (NaCl) and sugar (sucrose), in water. Both salts have similar polarities, but sucrose molecules are much larger than NaCl molecules. Predict will be more soluble in water? Why?

Answer

Sugar (sucrose) will be more soluble in water because it forms hydrogen bonds with water molecules, while NaCl dissociates into ions.

9. You're a beverage chemist tasked with creating a new, refreshing drink. You have a variety of ingredients, including sugars, flavorings, and carbonated water.
    a) How does temperature affect the solubility of sugars in water?
    b) How does pressure affect the solubility of carbon dioxide gas in water?
    c) Why do smaller molecules typically dissolve more easily in solvents compared to larger molecules?
    d) What happens to the solubility of carbon dioxide (CO_2) in water when the temperature is increased?

Answer

a) Sugar dissolves faster in warmer water because solubility typically increases with temperature.
b) Solubility of carbon dioxide increases with pressure, as described by Henry's Law.
c) Smaller molecules have a higher surface area to interact with solvent molecules, making it easier for them to dissolve
d) The solubility of CO_2 decreases as the temperature increases, which is why carbonated drinks lose their fizz when warm.

10. You are tasked with creating a new cleaning product. The goal is to dissolve vegetable oil (nonpolar) in a liquid solvent; water (polar), Hexane (nonpolar). Which one will dissolve vegetable oil effectively?

Answer

Hexane (nonpolar) will dissolve vegetable oil effectively because both are nonpolar, and "like dissolves like."

11. A student adds a spoonful of salt to a glass of water and stirs. The salt seems to disappear.
    a) Explain what happened to the salt.
    b) Relate the terms solute, solvent, and solution in this context.

Answer

a) The salt dissociates into its ions (Na^+ and Cl^-) and becomes dissolved in the water
b) The salt is the solute, the water is the solvent, and the resulting mixture is the solution

12. You are given a small amount of Calcium Carbonate ($CaCO_3$) and asked to dissolve it in water. After adding it to a beaker of water, you observe that only a small amount of the salt dissolves, and most of it remains as solid particles at the bottom.
    a) Why does Calcium Carbonate ($CaCO_3$) not dissolve completely in water?
    b) What does the term "sparingly soluble" mean in this context?

Answer

a) Calcium carbonate is sparingly soluble in water due to its high lattice energy, which makes it difficult to dissociate.

b) Sparingly soluble" means that the salt dissolves only to a small extent in water, forming a saturated solution at a low concentration.

13. Maliza is preparing saltwater solutions for a chemistry lab. She is using two beakers with equal amounts of salt (NaCl), but you change the conditions: Beaker 1: Cold water (5°C), Beaker 2: Hot water (60°C). Why would hot water (70°C) dissolve sugar more quickly than cold water (5°C)?

Answer

Higher temperatures increase the kinetic energy of molecules, leading to faster dissolution of sugar molecules.

14. Explain why does a carbonated drink go flat faster when it's warm?

Answer

Warm temperatures decrease the solubility of carbon dioxide in the liquid, causing the gas to escape more rapidly.

15. A carbonated beverage loses its fizz over time, even when the bottle is tightly sealed. Explain why this happens, referencing factors affecting gas solubility.

Answer

Over time, the solubility of CO_2 in the beverage decreases, and the gas escapes from the liquid, even if the bottle is sealed, due to changes in temperature or pressure

16. You have been given the following salts: Sodium Chloride (NaCl), Barium Sulfate ($BaSO_4$), Silver Chloride (AgCl), Potassium Nitrate (KNO_3), Calcium Carbonate ($CaCO_3$), Magnesium Sulfate ($MgSO_4$). Classify each salt as soluble, insoluble, or sparingly soluble based on your knowledge of solubility rules.

Answer

Soluble salts	**Slightly soluble**	**Insoluble salts**
Sodium Chloride (NaCl):	**Silver Chloride (AgCl)**	**Barium Sulfate ($BaSO_4$)**
Potassium Nitrate (KNO_3),	**Calcium Carbonate ($CaCO_3$)**	
Magnesium Sulfate ($MgSO_4$).		

17. The solubility of silver chromate, Ag_2CrO_4, is 1.3×10^{-4} mol/dm³. Calculate its solubility product, Ksp.
    a) Write the balanced dissociation equation for Ag_2CrO_4
    b) Determine the concentration of ions in terms of s
    c) Write the Ksp expression
    d) Calculate Ksp

    Answer

    a) $\mathbf{Ag_2CrO_{4(s)} \longleftrightarrow 2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}}$

    b) $\mathbf{[Ag^+] = 2s,}$

    $\mathbf{[CrO_4^{2-}] = s}$

    c) $\mathbf{Ksp = [Ag^+]^2[CrO_4^{2-}] = (2s)^2(s) = 4s^3}$

    d) $\mathbf{Ksp = 4s^3 = 1.3 \times 10^{-4} \rightarrow s \approx 3.28 \times 10^{-5}\ mol/dm^3}$

18. The solubility product of lead(II) iodide, PbI_2, is 1.4×10^{-8} mol³/dm⁹. Calculate its solubility in g/dm³. (Atomic masses: Pb = 207, I = 127).
    a) Write the balanced dissociation equation for PbI_2
    b) Determine the concentration of ions in terms of s
    c) Write the Ksp expression of PbI_2
    d) Calculate Ksp of PbI_2

Answer

a) $PbI_{2(s)} \longrightarrow Pb^{2+}_{(aq)} + 2I^-_{(aq)}$

b) $[Pb^{2+}] = s, \quad [I^-] = 2s$

c) $Ksp = [Pb^{2+}][I^-]^2 = s(2s)^2 = 4s^3$

d) $Ksp = 1.4 \times 10^{-8} \rightarrow s = 1.38 \times 10^{-3}\ mol/dm^3$

Points to Remember

- Solubility is the ability of a salute to dissolve in a solvent.
- Solutions can be categorized as unsaturated, saturated, and supersaturated.
- Factors include temperature (most solids dissolve better at higher temperatures), pressure (affects gas solubility), polarity (like dissolves like), and molecular size (smaller molecules generally dissolve more easily).
- When soluble salts dissolve in water, they dissociate into their constituent ions.
- To calculate Ksp from solubility, write the balanced dissolution equation, express ion concentrations in terms of solubility, and substitute into the Ksp expression.
- The solubility can be calculated from the following equation **s** = $\sqrt[m+n]{\frac{Ksp}{n^n m^m}}$

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Relate qualitative and quantitative analysis to know the composition of any sample					
Explain the change in factors that would help to know the quality of a sample					
Differentiate qualitative and quantitative analysis					
Distinguish inorganic and organic qualitative analysis					
Identify the methods for qualitative and quantitative analysis					
Explain the principle behind each qualitative method					
Demonstrate the ability to analyze and interpret					

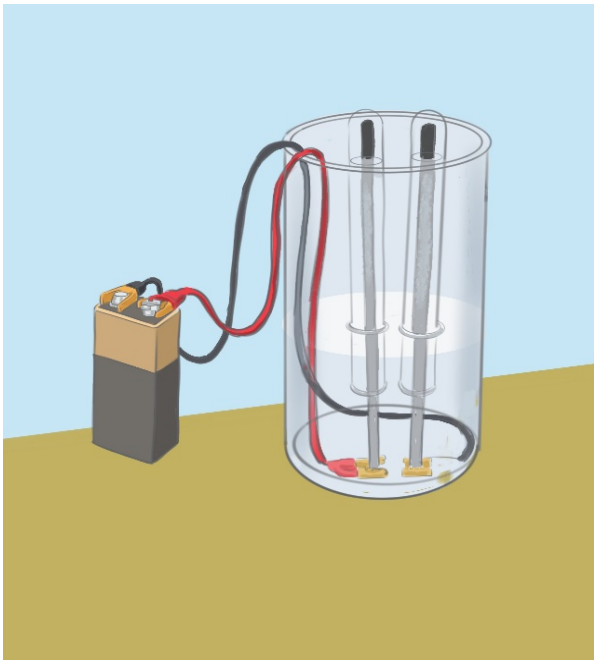
My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
the chemical composition of samples					
Recognize the quantitative methods of analysis					
Understand the basic principles of stoichiometry					
Identify the change in factors that would help to know the amount of substance					
Selects appropriate analytical methods based on sample properties, desired sensitivity, and selectivity					
Integrate qualitative and quantitative data to provide a comprehensive understanding of a sample					

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Present qualitative and quantitative findings					
Evaluate the effectiveness of different qualitative and quantitative methods					
Explain the application of chemical analysis					

Further Information for the Trainer

- ✓ *https://www.chemguide.co.uk/physical/ksp/introduction.html*
- ✓ *https://www.chemguide.co.uk/physical/ksp/introduction.html*
- ✓ *https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/solution-and-solubility*

LEARNING OUTCOME 3: DESCRIBE THE ELECTROCHEMICAL CELL REACTIONS



Learning outcome 3: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
   a. What does the illustration show?
   b. What do you think will be topics to be covered under this unit based on the illustration?

After the discussion, inform trainees that this unit is intended to provide them with the knowledge, skills and attitudes to describe the electrochemical cell reactions. They will cover electrolysis, galvanic cell and Electromotive force of the cell.

2. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:
   a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.

b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?

d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.

e. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
1. Explain the basic concepts of electrochemistry, such as oxidation, reduction, and redox reactions.	1. Calculate the oxidation state atoms in redox reaction and identify the oxidation or reduction reaction	1. Paying close attention to the rules and guidelines for assigning oxidation numbers to different elements and compounds
2. Describe the process of electrolysis	2. Conducting basic electrolysis experiments such as electrolysis of water	2. Prioritizing safety while conducting electrolysis experiment
3. Understand Faraday's first and second laws of electrolysis	3. Use Faraday's laws to calculate the amount of substance liberated at electrodes during electrolysis.	3. Pay close attention to units and throughout the calculations.
4. Recognize the industrial applications of electrolysis	4. Draw the electrolytic cell indicating the application of electrolysis and identify the reaction occurred	4. Be receptive to explore different types of electrolysis applications

Knowledge	Skills	Attitudes
5. Understanding the structure and function of galvanic (voltaic) cells	5. Illustrate the general representation of galvanic cell	5. Have willingness to consider new ideas about galvanic cell
6. Differentiate between galvanic (voltaic) and electrolytic cell	6. Representing electrochemical cells graphically, including electrodes, electrolytes, and electron flow	6. Persisting through the process of drawing and refining the diagram until it accurately represents the desired cell.
7. Differentiate primary and secondary cells	7. Identify various battery and classifying them as primary or secondary.	7. Have a strong interest in learning about different types of batteries and their characteristics.
8. Understand the concept of standard electrode potential	8. Predict which electrode will undergo reduction or oxidation in a redox reaction by using standard electrode potentials	8. Pay close attention to the signs and magnitudes of the standard reduction potentials.
9. Describe how to calculate and interpret the overall EMF of a cell	9. Calculating cell potential (EMF) using standard electrode potentials.	9. Persisting through challenging calculations and not giving up easily when encountering difficulties.
10. Interpret the diagram of an electrochemical cell	10. Writing the cell notation used to represent the electrochemical cell diagram	10. Striving for clear and precise notation that can easily be interpreted by others.

Steps:

Discovery Activity

Task 15

1. Using the interactive discussion, guide trainees to observe and reflect to presented materials and video, then brainstorm and share their views about that by using questions in the **Task 15** from their Trainee manual. Make sure instructions are understood and all the trainees are actively participating and necessary materials/tools are given.
2. After the presentations/sharing session, inform trainees that this activity was not intended for them to give the right answers but to give them a picture of what they will cover in the unit
3. Using their answers, lead them to the topic discovery.

Topic 3.1: Electrolysis

	Objectives: By the end of the topic, trainees will be able to: a. Explain clearly the electrolysis according to Faraday's Law b. Explicate correctly the components of electrolytic cells and working principles. c. Describe properly the application of electrolysis.
	Time Required: 4 hours
	Learning Methodology: Lectures, demonstration and simulation, individual and group work, practical exercise, individualized, trainer guided, group discussion

Materials, Tools and Equipment Needed:

NaCl, distilled water, marker pen, flip chalks, chart, White/black board, projector, computer, chalkboard, DVD players, Reference books, internet connection, laboratory apparatus, connecting wires, electrodes, electrochemical cell

Preparation:

- ❑ Prepare a demonstration of electrolysis using a simple setup with water and salt. Use a power supply, electrodes, and a beaker to visualize the process.
- ❑ Search for/prepare tutorial video about electrolysis
- ❑ Create a worksheet that allows trainees to explore the electrochemical series and predict the outcomes of electrolysis for different metal ions.
- ❑ Prepare real-life examples to help trainees understand how the laws apply, such as calculating the mass of a substance liberated during electrolysis
- ❑ Plan safe and effective laboratory experiments that demonstrate electrolysis.
- ❑ Be ready to guide trainees through worked examples, such as calculating the amount of electric charge needed to deposit a certain mass of a substance

Cross Cutting Issues:

- ✓ Consider gender mainstreaming while teaching and forming groups.
- ✓ Integration of inclusiveness in the learning and teaching process
- ✓ Consider the minimization of environmental impact during teaching and learning.

Prerequisites:

- ✓ Describe the structure of atoms, ions, and how they form molecules.
- ✓ Familiarize different types of chemical reactions
- ✓ perform stoichiometry calculation on amounts of substances involved in chemical reactions
- ✓ Describe ionic compounds and how they dissociate into ions in solution or when molten
- ✓ Explicate electric current, voltage, and how they relate.

Activity 1: Problem-Solving

Task 16

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to read the scenario, analyze and answer the questions provided under **Task 16** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

2. After answering the questions, guide trainees to share their answers to the rest of the class using an appropriate method such as pair-share or small group presentations. Encourage other trainees to give their contributions during the presentations. Responses can be put where trainees can refer to them during the session.

3. After the sharing session, ask trainees refer to **Key fact 3.1.** Explanation of electrolysis in their trainee manual, read them together while comparing with their responses from the sharing session. Answer any questions trainees might have as well as clearing any misconceptions they may have.

Activity 2: Guided Practice

Task 17

1. Using appropriate methodology, such as individual work small groups works and pair work, provide trainees with pre-laboratory tasks, such as reading instructions, predicting results, and reviewing relevant theoretical concepts to ensure they are prepared to perform tasks provided under **task 17** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

2. Give the trainees enough time to perform the task. While they are performing the task, Trainer should circulate around and provide guidance, answering questions, and ensuring

that trainees are following proper procedures. This helps maintain a safe and productive learning environment.

3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, environment and sustainability among others. Also attitudes and behavior changes should be handled during this activity.

4. After the trainees have finished the task, they should present their work with the rest of the class.

5. During the sharing session, encourage other trainees to ask questions and give their point of view using debriefing questions provided in under **Task 17** in trainee manual. You can ask trainees to refer to the **Key fact 3.1.** Explanation of electrolysis to complement their findings.

Activity 3: Application

Task 18

1. Explain to trainees that the following task links them to the world of work and will require them to apply the knowledge, skills and attitudes acquired; and working independently to perform the task required. Using an appropriate methodology such as individual work, pair work or small group work, trainees perform the tasks required under **task 18** and answer the related questions.

2. You can provide trainees with other materials, tools and equipment trainees may need to perform the task.

3. Give the trainees enough time and clear instructions to perform the task. This a practical application activity, so give trainees independence and freedom while they are performing the task.

4. After the trainees have finished the task, assess their work and discuss with them using debriefing questions provided under **task 18** in trainee manual and share their findings to the rest of the trainees. Support those who may need additional or remedial activities.

5. Make a summary of **topic 3.1** by asking trainees to mention the main key points

Checklist electrolysis experiment

SN	Criteria	Indicator	Yes	No
1	**Pencils for electrodes are well prepared**	Pencils are selected and checked for graphite content.		
		Erasers and metal sleeves are fully removed.		
		Both ends of the pencils are sharpened to expose graphite.		
2	**The electrolytic cell is well constructed**	The beaker is filled with warm water		
		The water level is sufficient for the electrodes to be submerged		
		The cardboard is properly cut and punched.		
		Pencils are securely placed through the holes and positioned in the water.		
		Pencils are not touching the bottom of the beaker.		
		Both pencils are connected to the battery securely.		
		Battery connections are intact and stable.		

Topic 3.2: Galvanic cell

	**Objectives:** By the end of the topic, trainees will be able to: a. Describe clearly the galvanic cell with the half-cell reactions b. Distinguish properly the types of battery (galvanic cell) c. Differentiate correctly galvanic cell and electrolytic cell
	**Time Required: 3** hours
	**Learning Methodology:** demonstration and simulation, individual and group work, Lectures, practical exercise, individualized, trainer guided and group discussion
	**Materials, Tools and Equipment Needed:** battery, marker pen, flip chalks, chart, White/black board, projector, computer, chalkboard, DVD players, Reference books, internet connection, laboratory apparatus, connecting wires, electrodes, electrochemical cell.
	**Preparation:** ❑ Prepare hands-on experiments or demonstrations that illustrate the principles of galvanic cells ❑ Search for/ prepare tutorial video about galvanic cell ❑ Explore the chemistry of various battery types (e.g., lithium-ion, lead-acid, fuel cells). ❑ Design visual aids such as diagrams, flowcharts, and 3D models of galvanic cells and their components ❑ Prepare case studies or examples of real-world applications of galvanic cells and batteries. Discuss how different types of batteries are used in everyday devices, such as smartphones, electric vehicles, and renewable energy systems

Cross Cutting Issues:

- ✓ Consider gender mainstreaming while teaching and forming groups.
- ✓ Integration of inclusiveness in the learning and teaching process
- ✓ Consider the minimization of environmental impact during the teaching and learning

Prerequisites:

- ✓ Familiarity with different types of chemical reactions.
- ✓ Explaining the concept of ions (cations and anions) and their formation
- ✓ Awareness with the basic principles of electrochemistry, including the concepts of electrodes, electrolytes.
- ✓ Describe the properties of acids and bases, as well as pH concepts.
- ✓ Discuss how stoichiometry is necessary for balancing redox reactions.
- ✓ Recognizing of safety protocols and proper handling of chemicals and electrical equipment.

Activity 1: Problem-Solving

Task 19

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to watch and analyze the video then answer the questions provided under **Task 19** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. After answering the questions, guide trainees to share their answers to the rest of the class using an appropriate method such as pair-share or small group presentations. Encourage other trainees to give their contributions during the presentations. Responses can be put where trainees can refer to them during the session.

3. After the sharing session, ask trainees refer to go to **Key fact 3.2.** Description of galvanic cell in their trainee manual, read them together while comparing with their responses from the sharing session. Answer any questions trainees might have as well as clearing any misconceptions they may have.

Activity 2: Guided Practice

Task 20

1. Using individual work methodology or in small groups, guide trainees to read the scenario and perform the tasks provided under **Task 20** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.
2. During the task, trainees should be given a degree of independence to apply the knowledge and skills acquired in activity 1. Your role is to guide them by using probing questions such as why? What? How? to enable them to come to informed responses.
3. During the task, use this opportunity to discuss or address any cross-cutting issues that may arise such as gender, inclusivity, environment sustainability among others. Also attitudes and behavior changes should be handled during this activity.
4. Using appropriate methodology ask trainees to answer the debriefing questions under the **Task 20** in their trainee's manual. Make sure that all trainees are actively participating. Allow trainees to share their answers to the class. Write their responses for reference. Encourage all trainees to give their views.

Activity 3: Application

Task 21

1. Explain to trainees that the following task links them to the world of work and will require them to apply the knowledge, skills and attitudes acquired; and working independently to perform the task required. Using an appropriate methodology such as individual work, pair work or small group work, trainees read the scenario and perform the tasks required under **Task 21**.

2. Give the trainees enough time and clear instructions to perform the task. This a practical application activity, so give trainees independence and freedom while they are performing the task.

3. After the trainees have finished the task, assess their work and discuss with them the total performance/competence in terms of the content shared to the rest of the trainees. Support those who may need additional or remedial activities.

4. Make a summary of topic 3.2 by asking trainees to mention the main key points.

Below is a checklist to be used when trainees are performing the given task:

SN	Criteria	Indicator	Yes	No
1	**Components of battery are identified**	Battery is disassembled in a well-ventilated area.		
		Battery is disposed of properly after disassembly.		
		Internal components are identified.		
2	**The battery performance is well measure**	Multimeter is set to the correct voltage range (DC)		
		Voltage is measured and recorded accurately.		
		Battery is connected securely to the bulb or circuit.		
		Current is measured and recorded accurately.		

SN	Criteria	Indicator	Yes	No
		Time is measured accurately using a stopwatch or timer.		
		Battery performance is monitored until the voltage drops significantly.		

Topic 3.3: Electromotive force of the cell

Objectives:

By the end of the topic, trainees will be able to:

a. Identify correctly oxidation and reduction reaction
b. Calculate properly the overall potential of the cell
c. Predict accurately the spontaneity of redox reactions

Time Required: 4 hours

Learning Methodology: demonstration and simulation, individual and group work, Lectures, practical exercise, individualized, trainer guided and group discussion

Materials, Tools and Equipment Needed:

battery, marker pen, flip chalks, chart, White/black board, projector, computer, chalkboard, DVD players, Reference books, internet connection, laboratory apparatus, connecting wires, electrodes, electrochemical cell.

Preparation:

- ❑ Prepare visual aids, such as diagrams and flowcharts, to illustrate the processes of oxidation and reduction, the construction of electrochemical cells, and the calculation of EMF
- ❑ Create a set of problem-solving exercises that require trainees to calculate the standard cell potential for various electrochemical reactions

	❑ Prepare a comprehensive table of standard electrode potentials for common half-reactions
	**Cross Cutting Issues:** ✓ Consider gender mainstreaming while teaching and forming groups. ✓ Integration of inclusiveness in the learning and teaching process ✓ Consider the minimization of environmental impact during the teaching and learning
	**Prerequisites:** ✓ Explain the basic chemistry concepts, including atoms, molecules, ions, and the nature of chemical reactions. ✓ Describe different types of chemical reactions. ✓ writing the electron configuration, particularly for transition metals and other elements that commonly participate in redox reactions ✓ Explain electrochemical cells and their components (electrodes, electrolytes). ✓ Explicate how stoichiometry is necessary for balancing redox reactions. ✓ Awareness of safety protocols and proper handling of chemicals and electrical equipment.

Activity 1: Problem-Solving

Task 22

1. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided discussions or large group discussion, guide trainees to analyze the scenario then answer the questions provided under **Task 22** in their trainee's manuals. Make sure instructions are understood, all the trainees are actively participating and necessary materials/tools are provided and being used.

2. After answering the questions, guide trainees to share their answers to the rest of the class using an appropriate method such as pair-share or small group presentations. Encourage other trainees to give their contributions during the presentations. Responses can be put where trainees can refer to them during the session.

3. After the sharing session, ask trainees refer to **Key fact 3.3.** Determination of electromotive force of the cell in their trainee manual, read them together while comparing with their responses from the sharing session. Answer any questions trainees might have as well as clearing any misconceptions they may have.

Activity 2: Guided Practice

Task 23

1. Using pairs or small groups, ask trainees to work on the questions provided under **Task 23** in their trainee manual.
2. This activity requires trainees to work independently with limited support from the trainer. During the task, trainees should be given a high degree of independence to apply the knowledge, skills and attitudes acquired to real life situations. Your role is to set clear instructions, methodology and timeframe for submitting the findings.
3. Give the trainees enough time to perform the task. While they are performing the task, move around and guide them, where possible by asking probing questions as well as providing necessary support.
4. Guide the agreement together with trainees about correct calculation and adjust errors.
5. During the sharing session, encourage other trainees to ask questions and give their contributions to the task. You can ask trainee to refer to **Key fact 3.3.** Determination of electromotive force of the cell to justify their findings.
6. Provide expert view as clarifications where necessary.

Activity 3: Application

Task 24

1. Explain to trainees that the following task links them to the world of work and will require them to apply the knowledge, skills and attitudes acquired; and working independently to perform the task required. Using an appropriate methodology such as individual work, pair work or small group work, trainees read the questions and perform the tasks required under **Task 24**.
2. Give the trainees enough time and clear instructions to perform the task. This a practical application activity, so give trainees independence and freedom while they are performing the task.
3. After the trainees have finished the task, assess their work and discuss with them the total performance/competence in terms of the content shared to the rest of the trainees. Support those who may need additional or remedial activities.
4. Make a summary of topic 3.3 by asking trainees to mention the main key points.

Steps for calculating e.m.f of the cell

1. Recall Formula for calculating e.m.f. $\mathbf{E^0_{cell} = E^0_{reduction} + E^0_{oxidation}}$
2. Identify the potentials for electrodes **B** and **C** from given table
3. Determine the cathode and anode: Electrode C has a more positive potential (+0.339 V), it will be the cathode. Electrode B, with a more negative potential (-0.762 V), will be the anode.
4. Replace the values of electrode potentials to find the emf.

Formative Assessment

For question 1, 2 and 4 select the letter corresponding to the right answer

1. Which of the following substances is an electrolyte?
    a. Mercury
    b. Copper
    c. Sodium sulphate
    d. Aluminium

Answer

c) Sodium sulphate

2. Which of the following substances is a weak electrolyte?
    a. Dilute hydrochloric acid
    b. Dilute sulphuric acid
    c. A solution of potassium bromide.
    d. Carbonic acid

Answer

d) Carbonic acid

3. Some cells, such as the nickel-cadmium cell used in calculators and electric shavers, can be recharged. Others, such as those used in watches and torches, cannot be recharged. Are rechargeable cells primary or secondary cells?

    Answer: Secondary cells

4. Which of these is a TRUE statement about galvanic cells?
    a) Galvanic cells convert chemical energy to electrical energy using an oxidation-reduction reaction.
    b) Galvanic cells convert electrical energy to chemical energy using an oxidation-reduction reaction.
    c) Galvanic cells convert chemical energy to electrical energy using a decomposition reaction.

d) Galvanic cells convert electrical energy to chemical energy using electrolysis.

Answer

Galvanic cells convert chemical energy to electrical energy using an oxidation-reduction reaction.

5. State two differences and two similarities between an electrochemical cell and an electrolytic cell.

Answer:

Differences:

- ✓ **Electrochemical cells convert chemical energy to electrical energy (galvanic cells), while electrolytic cells convert electrical energy to chemical energy.**
- ✓ **Electrochemical cells involve spontaneous reactions, whereas electrolytic cells require an external power source to drive non-spontaneous reactions.**

Similarities:

- ✓ **Both types of cells involve oxidation and reduction reactions.**
- ✓ **Both consist of two electrodes (anode and cathode) immersed in an electrolyte.**

6. What is the difference between electrolytic extraction of a metal and electroplating?

Answer:

Electrolytic extraction involves using electrolysis to separate a metal from its ore, while electroplating involves depositing a layer of metal onto a surface to enhance appearance or prevent corrosion.

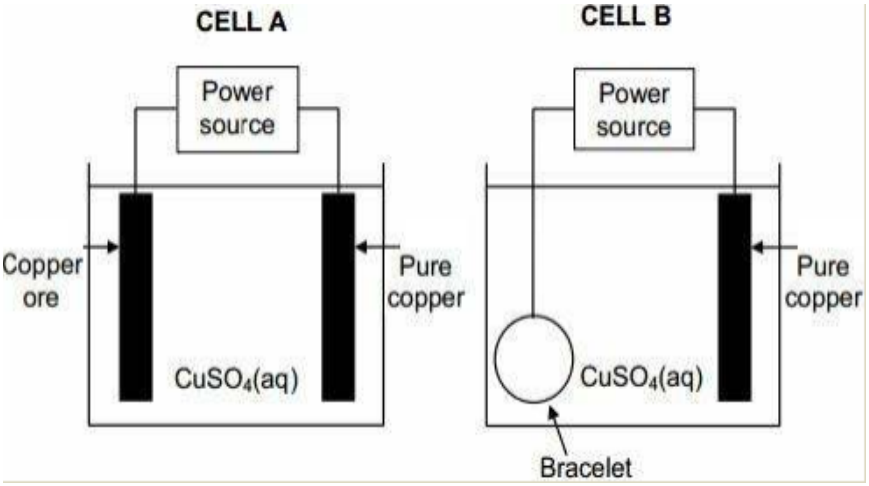
7. What is the material for cathode and anode during electro refining of impure copper? Potential contamination of nearby evaluating the environmental impact of the chemicals.

Answer:

Cathode: Pure copper (often a copper sheet)

Anode: Impure copper (the anode dissolves, and pure copper is deposited at the cathode

8. The simplified diagrams below represent two electrochemical cells, A and B, used in industry. Cell A is used in the purification of copper ore containing silver and platinum impurities. Cell B is used to electroplate a bracelet with a layer of copper.



a) Write down the name of the type of electrochemical cell of which the above two cells are examples.

b) Pure copper is used as one of the electrodes in each of the cells above. In which cell (A or B) is the pure copper?

Answer:

a) Both cells are examples of electrolytic cells.

b) i) Cell A (In the purification process, pure copper is the cathode.)

ii) Cell B (In electroplating, pure copper is the anode.)

9. Define standard electrode potential.

Answer:

The standard electrode potential is the measure of the tendency of a chemical species to be reduced, measured under standard conditions (1 M concentration, 1 atm pressure, and 25°C) relative to the Standard Hydrogen Electrode (SHE), which is assigned a potential of 0 V.

10. Is it possible to use another standard electrode than SHE? Justify your answer.

Answer:

Yes, it is possible to use other standard electrodes, but the SHE is the most commonly used reference because it provides a consistent baseline for measuring electrode

potentials. Other reference electrodes, such as the silver/silver chloride electrode, can also be used, but their potentials must be compared to the SHE.

11. Answer by True or False.

a) Hydrogen electrode which is the reference electrode can be used as Anode or Cathode.

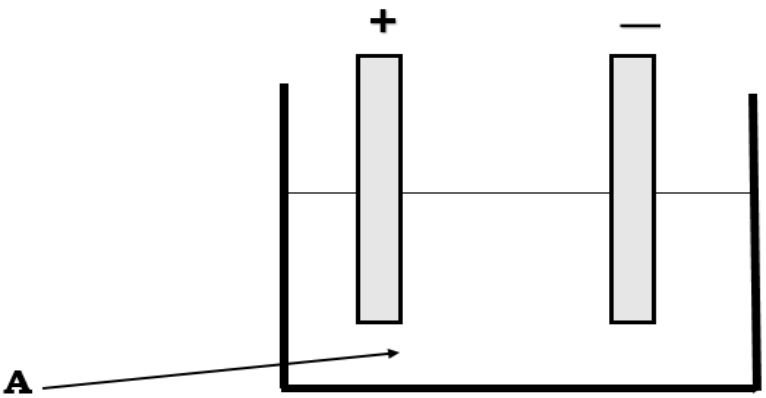
b) If hydrogen electrode acts as cathode, hydrogen is oxidised.

Answer

a) **True**

b) **False**

12. The chemical **A** is sodium chloride



a) What do you understand by electrolytic cell

b) Write the formula of **A**

c) When electricity is passed through **A**, what is produced at

i) The anode?

ii) The Cathode?

d) Write the half equation showing the reaction at

i) The anode.

ii) The cathode.

e) At cathode there is **……** (**Reduction, Oxidation**)

f) At anode there is **……** (**Reduction, Oxidation**)

Answer:

a) **An electrolytic cell is an electrochemical cell that uses an external electrical energy source to drive a non-spontaneous chemical reaction**

b) **NaCl**

c) **i) Chlorine gas (Cl_2)**

ii) Sodium metal (Na)

d) **i)** $2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$

ii) $2Na^+_{(aq)} + 2e^- \longrightarrow 2Na_{(s)}$

e) **Reduction**

f) **Oxidation**

13. The table below shows some values for standard electrode potentials.

Electrode	Electrode reactions	E^0/V
A	$Mn^{2+}_{(aq)} + 2e^- \rightleftharpoons Mn_{(s)}$	-1.18
B	$Zn^{2+}_{(aq)} + 2e^- \rightleftharpoons Zn_{(s)}$	-0.762
C	$Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$	+0.339
D	$2H^+_{(g)} + 2e^- \rightleftharpoons H_{2(g)}$	?
E	$Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(s)}$	-0.44

a) Give the name of electrode **D** and indicate its role in the determination of standard electrode potentials.

b) What is the value of the standard electrode potential for electrode **D**?

c) The electrochemical cell set up between electrodes **B** and **C** can be represented by the cell diagram:

$$Zn_{(s)} \mid Zn^{2+}_{(aq)} \parallel Cu^{2+}_{(aq)} \mid Cu_{(s)}$$

i. Calculate the e.m.f. of this cell.

ii. State, which would be the positive electrode.

iii. Write an equation to show the overall reaction in the cell

iv. Justify if the cell will produce energy

Answer:

a) Electrode D is likely the Standard Hydrogen Electrode (SHE), which serves as a reference point for measuring other electrode potentials.

b) The value of the standard electrode potential for electrode D is 0 V.

c) i) $E^\circ_{cell} = E^\circ_{reduction\ (C)} - E^\circ_{oxidation\ (B)}$ $E^\circ_{cell} = +0.339\ V - (-0.762\ V) = +1.101\ V$

ii) Electrode C (copper electrode)

iii) $Zn_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

iv) Yes, the cell will produce energy because the E°cell is positive, indicating that the reaction is spontaneous

14. Calculate the mass of silver deposited at the cathode when a current of 1.5 A is passed for 10 minutes in a silver nitrate solution.

Answer

- ✓ **First, calculate the charge passed:**
  - **Charge = Current × Time = 1.5 A × 10 × 60 s = 900 C.**
- ✓ **Moles of electrons = Charge / Faraday's constant = 900 C / 96500 C/mol = 0.00933 mol.**
- ✓ **The silver ion (Ag^+) accepts one electron to form solid silver (Ag), so 1 mol of electrons deposits 1 mol of silver.**
  - **Moles of silver deposited = 0.00933 mol.**
  - **Molar mass of silver = 107.87 g/mol.**

Mass of silver deposited = 0.00933 mol × 107.87 g/mol = 1.01 g

15. Suppose you electrolyze a solution of nickel (II) sulfate (NiSO4) and a solution of zinc sulfate ($ZnSO_4$) with the same quantity of electric charge, and if 15 grams of nickel are

deposited from the nickel sulfate solution, how much zinc will be deposited from the zinc sulfate solution?

Answer:

- ✓ **The molar mass of nickel (Ni) = 58.69 g/mol and the molar mass of zinc (Zn) = 65.38 g/mol.**
- ✓ **Nickel requires 2 moles of electrons for 1 mole of Ni to be deposited, and zinc requires 2 moles of electrons for 1 mole of Zn.**
- ✓ **The ratio of the masses deposited is proportional to the ratio of their molar masses.**
- ✓ **Mass of zinc deposited = (15 g × 65.38 g/mol) / 58.69 g/mol = 16.7 g of zinc.**

Points to Remember

- Electrolysis is a process of decomposing, ionic compounds into their elements by passing a direct electric current through the compound in a fluid form.
- Component of electrolytic cell are electrode and electrolyte.
- Cathode are negative while anode are positive electrodes
- Electrolysis found use in production of many chemicals, electroplating, metal extraction and purification
- Spontaneous reactions occur in galvanic (voltaic) cells; non-spontaneous reactions occur in electrolytic cells
- There are two types of electrochemical cells: galvanic (voltaic) cells and electrolytic cells.
- A galvanic (voltaic) cell is a device used to convert chemical energy of a redox reaction into electrical energy
- Electrolytic cell dissociate ionic compound into cation and anion when electric current is supplied through it.

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to identify their areas of strength, areas for improvement and actions to take to improve.

2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Explain the basic concepts of electrochemistry, such as oxidation, reduction, and redox reactions.					
Describe the process of electrolysis					
Understand Faraday's first and second laws of electrolysis					
Understanding the structure and function of galvanic (voltaic) cells					

My experience Knowledge, skills and attitudes	I do not have any experience doing this.	I know a little about this.	I have some experience doing this.	I have a lot of experience with this.	I am confident in my ability to do this.
Differentiate between galvanic (voltaic) and electrolytic cell					
Recognize the types of redox reactions					
Understand the concept of standard electrode potential					
Describe how to calculate and interpret the overall EMF of a cell					
Interpret the diagram of an electrochemical cell					
Differentiate primary and secondary cells					
Recognize the industrial applications of electrolysis,					

Further Information for the Trainer

1. http://hyperphysics.phy-astr.gsu.edu/hbase/Chemical/electrochem.html
2. https://www.google.com/url?sa=i&url=https%3A%2F%2Fchemistryclinic.co.uk%2Fwp-content%2Fuploads%2F2017%2F01%2Figcse-electrolysis.pdf&psig=AOvVaw1qOXdoX2Ci_AwSL305q5YL&ust=1735312842309000&source=images&cd=vfe&opi=89978449&ved=0CAQQn5wMahcKEwig2Mq13sWKAxUAAAAAHQAAAAAQBA
3. https://www.vssut.ac.in/lecture_notes/lecture1425072717.pdf

REFERENCES

1. Bb Dunn, S. M., & Aguiar, A. A. **(**2023). *Introduction to analytical chemistry: Principles and techniques*. Journal of Analytical Chemistry, 95(3), 121-134. https://doi.org/10.1016/j.janchem.2023.03.002
2. Smith, A. P., & Roberts, M. L. (2022). *Qualitative chemical analysis and its applications in organic and inorganic chemistry*. International Journal of Chemical Studies, 28(4), 210-222. https://doi.org/10.1002/ijcs.2022.28
3. Bennett, J. M., & Wilkins, C. E. (2021). Chemical analysis methods: Flame tests, distillation, extraction, and precipitation. Analytical Techniques in Chemistry, 40(2), 56-67. https://doi.org/10.1038/chemtech.2021.040
4. Brown, T. L., & LeMay, H. E. (2023). Principles of analytical chemistry: Quantitative analysis techniques. Journal of Chemical Education, 100(5), 1234-1245. https://doi.org/10.1021/acs.jchemed.3c00234
5. Jackson, M. W., & Lee, S. J. (2022). Applications of quantitative and qualitative analysis in environmental and water chemistry. Environmental Science and Technology, 58(9), 1420-1429. https://doi.org/10.1021/es301073a
6. Kumar, R., & Shah, P. N. (2021). Gravimetric and volumetric analysis in food and pharmaceutical testing. Analytical and Bioanalytical Chemistry, 413(4), 689-702. https://doi.org/10.1007/s00216-020-03138-1
7. Silverstein, R. M., & Webster, F. X. (2019). Spectrometric identification of organic compounds (8th ed.). Wiley.
8. Atkins, P., & de Paula, J. (2014). Atkins' physical chemistry. Oxford University Press.
9. Chang, R., & Goldsby, K. A. (2010). Chemistry. McGraw-Hill Education
10. Tro, N. J. (2020). Chemistry: A molecular approach (5th ed.). Pearson Education.

11. Thomas, H., & Morgan, D. (2018). Faraday's laws of electrolysis: Understanding the relationship between charge and chemical reactions. Journal of Electrochemical Science, 45(3), 157-164. https://doi.org/10.1016/j.jelchem.2017.10.001
12. Moore, C., & Patel, R. (2019). Electrolysis in chemical production: From chlorine to hydrogen. Industrial Chemistry Review, 34(6), 88-96. https://doi.org/10.1080/0252638X.2019.163001
13. Parker, M. L., & Adams, E. J. (2017). Applications of electrolysis in industry: Electroplating, metal extraction, and purification. Wiley-VCH.
14. Jenkins, L. R., & Smith, R. A. (2020). Electrolysis and electrochemical cells: Principles and applications. Springer Nature.
15. Miller, J. R., & Thomas, S. P. (2018). Redox reactions and their applications in galvanic cells. Journal of Electrochemical Research, 50(3), 120-128. https://doi.org/10.1016/j.jelchem.2018.01.005
16. Murphy, R. A., & White, P. L. (2016). A comparative study of galvanic and electrolytic cells: Energy conversion and practical uses. Electrochemical Science and Technology, 42(4), 256-264. https://doi.org/10.1080/0252638X.2016.1165647
17. Daves, G. S. (2009). Electrochemical cells and potentials: An introduction. Journal of Chemical Education, 86(8), 879-884. https://doi.org/10.1021/ed086p879

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