# Unit: Unit 1: Foundations of Chemistry

## Chapter: Chapter 1: The Language of Chemistry

# Lesson: Lesson 4: Scientific Inquiry and Experimental Design

Big Idea:  
Scientific inquiry and experimental design are fundamental to investigating and solving real-world problems, such as determining the authenticity of a bracelet using forensic chemistry.  
  
  
  
 Essential Questions:  
1. How can we design an experiment to determine if a bracelet is made of pure gold?  
2. What makes an experiment reliable and valid?  
3. How do independent and dependent variables influence the results of an experiment?  
  
  
  
 Phenomenon-Based Learning:  
  
 Phenomenon: The Mystery of the Stolen Bracelet   
In this lesson, we continue investigating the "Mystery of the Stolen Bracelet." The forensic chemist must design an experiment to determine whether the bracelet returned to the owner is the same as the one that was stolen. The chemist will measure the bracelet's density and compare it to the known density of gold, but how accurate does this measurement need to be to draw conclusions? How do we ensure the experiment is reliable and valid?

Vocabulary:  
  
- **Bias**: A preference or prejudice which can affect the outcome of an experiment.  
- **Causation**: A relationship where one event causes another to happen.  
- **Constant**: A factor that remains unchanged throughout the experiment.  
- **Control group**: A group in an experiment that does not receive the treatment being tested, used as a benchmark.  
- **Correlation**: A measure of the relationship between two variables.  
- **Data**: Information collected during an experiment.  
- **Dependent variable**: The variable that is measured or observed during an experiment.  
- **Experimental group**: The group in an experiment that receives the treatment or is exposed to the variable being tested.  
- **Hypothesis**: A testable prediction or explanation about what will happen in an experiment.  
- **Independent variable**: The variable that is changed or controlled in an experiment.  
- **Reliability**: Consistency in the results of an experiment across multiple trials.  
- **Replication**: Repeating an experiment to ensure the results are reliable.  
- **Validity**: The degree to which an experiment measures what it is supposed to measure.  
  
  
  
 SMART Lesson Objectives:  
1. **Distinguish** between observations (what we see) and inferences (what we think is happening based on the observations).  
2. **Identify** the independent and dependent variables in a forensic chemistry experiment.  
3. **Formulate** a testable hypothesis about the authenticity of the bracelet and design an experiment to test it.  
4. **Analyze** data collected during the experiment to determine if the bracelet is made of real gold.

Ignite (Engage):  
  
Imagine you are a forensic chemist tasked with solving the mystery of the stolen bracelet. You’ve been asked to confirm whether the bracelet returned by the police is the same one that was stolen. You know that pure gold has a density of 19.32 g/cm³, but the owner claims the returned bracelet is a fake. How can you use science to determine if the bracelet is made of pure gold?  
  
To pique your curiosity, think about this: What if the density of the bracelet is 18 g/cm³? Would that prove it’s not gold? What if it’s 19 g/cm³? What would you conclude if the density is 19.32 g/cm³? These are the questions a forensic chemist would ask before conducting experiments.  
  
Now, consider this: What role do computers and AI play in scientific experiments like this? Could they help us make more precise measurements or detect patterns we might miss?  
  
  
  
 Direct Instruction (Pre-Explore Section):  
  
Before we jump into designing an experiment, we need to understand how scientific inquiry works. When scientists investigate a mystery—like whether the bracelet is real gold—they follow a structured process called scientific inquiry. This process helps ensure their conclusions are accurate and reliable.  
  
# The Steps of Scientific Inquiry:  
1. **Ask a Question**: In our case, the question is, “Is this bracelet made of pure gold?”  
2. **Make Observations**: Observations can be anything from visual inspections to density measurements. The density of pure gold is a key observation.  
3. **Form a Hypothesis**: A hypothesis is a prediction based on observations. For example, “If the bracelet is pure gold, then its density will be around 19.32 g/cm³.”  
4. **Experiment**: You test your hypothesis by measuring the density of the bracelet. In this case, the independent variable (what you change) might be different materials you compare to gold, and the dependent variable (what you measure) is the density.  
5. **Analyze Data**: Are the results close to the density of gold? What do they tell you about the material’s authenticity?  
6. **Draw Conclusions**: Based on the data, you decide whether the bracelet is real gold or a fake.  
  
In forensic chemistry, **reliability** and **validity** are key. An experiment is reliable if it produces consistent results every time it’s repeated. It’s valid if it accurately measures what it’s supposed to—like whether the bracelet is gold.  
  
  
  
 Progress Check:  
  
1. What is the difference between an observation and an inference?  
2. Why is it important to identify the independent and dependent variables in an experiment?  
3. How can you ensure that an experiment is reliable?  
  
  
  
 Pathfinder (Explore):  
  
In this hands-on section, you’ll perform an experiment to determine the density of a metal bracelet. This is a key step in solving the mystery of whether the bracelet is made of real gold.  
  
Step-by-Step Instructions:  
1. **Gather Materials**: You’ll need a scale to measure mass, a graduated cylinder to measure volume, and a sample bracelet.  
2. **Measure the Mass**: Use the scale to measure the mass of the bracelet in grams.  
3. **Measure the Volume**: Fill the graduated cylinder with water to a specific level. Carefully place the bracelet into the water and note how much the water level rises. This will give you the volume of the bracelet in cubic centimeters (cm³).  
4. **Calculate the Density**: Use the formula for density, which is:

**Density=Volume/Mass**​  
  
 \[  
 \text{Density} = \frac{\text{Mass}}{\text{Volume}}  
 \]  
  
 Record your results. Compare the density you calculate to the known density of pure gold (19.32 g/cm³).  
  
5. **Discuss the Results**: In groups, discuss whether the bracelet’s density suggests it is real gold. What other tests could you perform to confirm the results?  
  
# Virtual Lab:   
If you don’t have the materials on hand, use the virtual lab simulation provided on your school’s chemistry platform. The simulation will allow you to measure the mass and volume of different materials and calculate their densities.  
  
# Retrieval Practice:   
1. What is the formula for calculating density?  
2. If the mass of the bracelet is 100 grams and the volume is 5 cm³, what is the density? Would this indicate real gold?  
3. What other properties could help you determine if the bracelet is real gold?  
  
  
  
 Lightbulb (Explain):  
  
In this section, let’s break down the key concepts you’ve explored so far.  
  
# **Scientific Inquiry and Experimental Design**   
Scientific inquiry is a systematic process used to investigate questions and test hypotheses. In our case, the question is whether the bracelet is made of real gold, and we are testing this by measuring its density.   
  
 **Why Density Matters**   
Density is a physical property that can help identify materials. It’s calculated by dividing a material’s mass by its volume. For pure substances like gold, the density remains constant. If the density of the bracelet is close to 19.32 g/cm³, it could be real gold. However, if the density is much lower, it’s likely made of a different material.  
  
 **Variables in an Experiment**   
In any experiment, you must correctly identify the independent variable (the one you change) and the dependent variable (the one you measure). In our experiment, the independent variable could be the material of the bracelet (gold, copper, brass, etc.), and the dependent variable is the density.  
  
 **Reliability and Validity**   
When performing experiments, scientists must ensure their results are reliable (consistent across multiple trials) and valid (accurately measuring what they are supposed to measure). For example, if you measure the density of the bracelet multiple times and consistently get the same result, your experiment is reliable. If the density you measure aligns with the known density of gold, your experiment is valid.  
  
  
  
 Progress Check:  
  
1. How can you determine if an experiment is valid?  
2. If you repeat an experiment and get the same results each time, what does that say about the experiment’s reliability?  
3. Why is identifying the independent variable important in an experiment?  
  
  
  
 Power Up (Elaborate):  
  
Let’s think critically about the results of your experiment. If your bracelet’s density is 18 g/cm³, does that mean the bracelet is definitely fake? Could there be other explanations, such as impurities in the gold?  
  
Consider this: What if you were testing a different material, like the diamonds on the bracelet? How would you design an experiment to test whether they are real diamonds or cubic zirconia?  
  
  
  
 Progress Check (Final Evaluation):  
  
1. What are some possible sources of bias in your experiment? How could you minimize them?  
2. If the density of the bracelet is 19 g/cm³, what conclusion can you draw? Is it enough to say the bracelet is real gold?  
3. What other tests might you perform to confirm the authenticity of the bracelet’s materials?  
  
  
  
 Beyond the Lesson (Extend):  
  
Now that you’ve learned how to design an experiment and analyze results, think about forensic chemistry in the real world. How do scientists use these techniques to solve crimes or verify the authenticity of valuable objects?  
  
For optional practice, research how forensic chemists test for other precious materials, like diamonds or platinum. How do their methods differ from testing gold?