# Unit 1: Foundations of Chemistry

## Chapter 1: The Language of Chemistry

# Lesson 4: Scientific Inquiry and Experimental Design

Big Idea:  
Scientific inquiry allows us to investigate the world, test ideas, and draw conclusions based on evidence.  
  
 Essential Questions:  
1. How can we use scientific inquiry to solve real-world mysteries, like identifying materials in a stolen bracelet?  
2. What makes an experiment reliable and valid in determining the authenticity of a material?  
3. How do independent and dependent variables help in designing a good scientific experiment?  
  
 Phenomenon  
  
Phenomenon: "The Mystery of the Stolen Bracelet"  
  
The owner of a prestigious bracelet claims that the one returned by the police is a fake. They believe that the original was made of pure gold, but the returned bracelet is gilded copper. The insurance company needs proof before paying out the claim. A forensic chemist is called to determine whether the bracelet is real or fake by conducting a series of tests, including calculating the density of the metal. Density will help decide whether the bracelet is pure gold or another material. Through scientific inquiry and experimental design, we will solve the mystery!  
  
 Vocabulary:  
- **Bias**: A tendency to favor certain outcomes in an experiment or investigation.  
- **Causation**: A relationship where one event causes another to happen.  
- **Constant**: A factor in an experiment that does not change.  
- **Control Group**: A group in an experiment that does not receive the experimental treatment, used for comparison.  
- **Correlation**: A connection between two variables, but it does not imply causation.  
- **Data**: Information collected during an experiment or investigation.  
- **Dependent Variable**: The variable that is measured in an experiment.  
- **Experimental Group**: The group in an experiment that receives the treatment or condition being tested.  
- **Hypothesis**: A testable statement or prediction about what will happen in an experiment.  
- **Independent Variable**: The variable that is changed or controlled in an experiment.  
- **Reliability**: The consistency of a set of measurements or an experiment.  
- **Replication**: Repeating an experiment to verify the results.  
- **Validity**: The extent to which an experiment measures what it is supposed to.  
  
 SMART Lesson Objectives:  
1. **Distinguish** between observations and inferences in a scientific context.  
2. **Identify** the independent and dependent variables in a given experiment.  
3. **Formulate** a hypothesis to explain a phenomenon and design an experiment to test it.  
4. **Analyze** the reliability and validity of an experimental design.  
  
  
  
 Ignite (Engage)   
Imagine you’re a forensic chemist tasked with solving the mystery of a stolen bracelet. The police have returned what they believe is the original bracelet, but the owner insists it's a fake. How can you prove whether the bracelet is real or not? You’d need to use scientific inquiry to figure it out!   
  
Let’s start with a simple question: **What is one way to tell if a metal is real gold?** A good option would be to measure its density. Pure gold has a density of **19.32 g/cm³.** If the metal in the bracelet has a much lower density, it’s likely not gold.  
  
Now, let’s think about how you could design an experiment to measure the density of the metal in the bracelet. What steps would you take? What variables would you need to control? How would you ensure your results are reliable and valid?  
  
In this lesson, you’ll learn how scientists design experiments to answer questions like these. You’ll also explore how biases can affect results and how to avoid them through careful planning.  
  
**AI Inquiry Task**: Imagine if you had access to an AI tool that could instantly analyze the density of any material. How would this change the way scientists conduct experiments? What would be the benefits and challenges of using AI in forensic investigations?  
  
  
  
 Direct Instruction (Pre-Explore Section):  
  
Before we dive into solving the mystery of the bracelet, let’s review some key concepts in scientific inquiry and experimental design.  
  
**Scientific Inquiry**: This is the process that scientists use to investigate natural phenomena. It involves asking questions, making observations, forming hypotheses, conducting experiments, and analyzing data.   
  
- **Observation**: This is when you gather information using your senses. For example, you might observe that the bracelet looks shiny.  
- **Inference**: This is when you draw a conclusion based on your observations. For example, you might infer that the bracelet is made of gold because gold is shiny.  
  
**Experimental Design**: To test a hypothesis, you need to design an experiment. A good experiment includes the following components:  
- **Independent variable**: The factor you change in the experiment (e.g., the material of the bracelet).  
- **Dependent variable**: The factor you measure (e.g., the density of the material).  
- **Constants**: Factors that stay the same throughout the experiment (e.g., the method used to measure density).  
- **Control group**: A group that does not receive the treatment, used for comparison.  
  
Proper experimental design is crucial for ensuring the experiment is **reliable** (consistent results) and **valid** (accurately tests what it’s supposed to).  
  
Let’s connect this to our phenomenon. The forensic chemist’s goal is to measure the density of the bracelet’s metal and compare it to the density of gold. If the density is close to **19.32 g/cm**³, the bracelet may be real gold. If the density is much lower, it’s likely a fake.  
  
  
  
 Progress Check (Evaluate):  
Let’s check your understanding before we move on:  
1. What’s the difference between an observation and an inference? (DOK 1)  
2. In the bracelet experiment, what is the independent variable? What is the dependent variable? (DOK 2)  
3. Why is it important to keep constants in an experiment? (DOK 3)  
  
  
  
 Pathfinder (Explore):  
  
**Activity: Investigating the Mystery of the Stolen Bracelet**  
  
You will now conduct an experiment to measure the density of different metals and compare them to the density of gold.  
  
**Materials**:  
- Three different metal samples (one could be gold, copper, or another metal)  
- A balance (to measure mass)  
- A graduated cylinder (to measure volume via water displacement)  
- Water  
- A ruler (optional, depending on the shape of the object)  
  
**Procedure**:  
1. **Weigh the Metal Samples**: Use the balance to measure the mass of each metal sample in grams. Record the mass.  
2. **Measure the Volume**: Fill the graduated cylinder with a known volume of water. Then, drop the metal sample in and record the new volume. The difference between the initial and final volume is the volume of the metal.  
3. **Calculate the Density**: Use the formula for density:   
 **Density = Mass / Volume** Record the density for each metal.  
4. **Compare to Gold**: Compare the density of your metal samples to the known density of pure gold (19.32 g/cm³). Which sample is closest to gold? Which one is likely to be a fake?  
  
**Virtual Lab**: If you don’t have access to physical materials, try our virtual lab where you can simulate the same experiment!  
  
**Discussion**:  
- In your groups, discuss the following:  
 - Which metal had the closest density to gold?  
 - How reliable are your results? Did you repeat the measurements?  
 - Could there be any sources of error in your experiment?  
  
  
  
 Lightbulb (Explain):  
  
In this section, we’ll break down the scientific process and explain how experimental design helps answer important questions, like whether a bracelet is real gold or not.  
  
 1. Scientific Inquiry  
Scientific inquiry is the process of exploring the natural world and asking questions. The steps of scientific inquiry include:  
- **Asking a question**: For example, “Is the bracelet made of real gold?”  
- **Forming a hypothesis**: A hypothesis is a testable statement. In this case, your hypothesis might be, “If the bracelet is real gold, then its density will be close to 19.32 g/cm³.”  
- **Conducting an experiment**: You can test your hypothesis by measuring the density of the bracelet’s metal.  
- **Analyzing data**: After collecting your data, you can analyze it to see if the results support or refute your hypothesis.  
  
 2. Experimental Design  
A good experimental design includes:  
- **Independent Variable**: This is the variable you change in the experiment. In our bracelet experiment, the independent variable is the type of metal being tested.  
- **Dependent Variable**: This is the variable you measure. In this case, the dependent variable is the density of the metal.  
- **Constants**: These are factors that stay the same throughout the experiment. For example, the method used to measure density should be the same for all metal samples.  
- **Control Group**: The control group is a baseline for comparison. In some experiments, you might need a control group, but in this case, we are directly comparing the density to the known value of pure gold.  
  
 3. Reliability and Validity  
- **Reliability**: This refers to the consistency of your results. For example, if you measure the density of the same metal three times, you should get roughly the same result each time. If your results vary widely, your experiment may not be reliable.  
- **Validity**: This refers to whether your experiment measures what it’s supposed to measure. In this case, we want to measure the density of the metal, so our method must accurately measure both mass and volume.  
  
 4. Bias and Error  
Bias can occur in an experiment if the scientist has expectations about the outcome. For example, if you expect the bracelet to be fake, you might unconsciously interpret the data in a way that supports your expectation. To avoid bias, it’s important to replicate the experiment and have other scientists review your work.  
  
Example Problem:  
A student measures the mass of a metal sample to be 38.6 grams and its volume to be 2 cm³. What is the density of the metal?   
**Solution**:

Density = Mass / Volume = 38.6 g / 2 cm³ = 19.3 g/cm³

Since 19.3 g/cm³ is very close to the density of gold (19.32 g/cm³), the metal is likely to be gold.  
  
Progress Check:   
If a different metal sample has a mass of 50 grams and a volume of 5 cm³, what is its density? Is it likely to be gold?  
  
  
  
 Progress Check

1. What is the purpose of a control group in an experiment? (DOK 1)  
2. How can an experiment be both reliable and valid? (DOK 2)  
3. Why is it important to repeat measurements in an experiment? (DOK 3)  
  
  
  
 Power Up (Elaborate) :  
  
Now that you understand how to design a scientific experiment, let’s apply these concepts to a new scenario. Imagine you’re investigating a different case: A famous painting is suspected to be a forgery. What kind of scientific tests might you perform to determine if the painting is real or fake?  
  
**Mini-Task**: In pairs, brainstorm a list of experiments you could design to test the authenticity of the painting. For example, you might test the paint’s chemical composition or the age of the canvas.  
  
**Open-Ended Question**: How would you ensure that your experiments are reliable and valid? What variables would you control, and how would you avoid bias?  
  
  
Progress Check (Final Evaluation):  
  
**Debate Question**:   
Imagine you are presenting the results of your bracelet experiment to the insurance company. Some people argue that the density of the bracelet (19.3 g/cm³) is close enough to the density of gold (19.32 g/cm³) to claim that the bracelet is real. Others argue that even small differences in density matter and the bracelet might still be a fake. What’s your position, and why?  
  
**Potential Arguments**:  
- **For**: The density is close enough to gold, and small differences could be due to measurement error.  
- **Against**: Even small differences in density could indicate that the bracelet is made of a different material.

Multiple-Choice Questions:  
  
1. What is the independent variable in the bracelet experiment?  
 a) The mass of the bracelet   
 b) The type of metal being tested   
 c) The volume of the bracelet   
 d) The density of the bracelet

Answer: b) The type of metal being tested  
  
2. Which of the following is a constant in the bracelet experiment?  
 a) The method used to measure density   
 b) The type of metal   
 c) The density of gold   
 d) The final conclusion

Answer: a) The method used to measure density  
  
3. Why is it important to replicate an experiment?  
 a) To prove the hypothesis wrong   
 b) To make sure the results are reliable   
 c) To change the independent variable   
 d) To reduce the number of constants

Answer: b) To make sure the results are reliable  
  
4. A student measures the mass of a metal to be 45 grams and the volume to be 3 cm³. What is the density of the metal?  
 a) 15 g/cm³   
 b) 13 g/cm³   
 c) 18 g/cm³   
 d) 19 g/cm³

Answer: a) 15 g/cm³  
  
 Long-Answer Questions:  
  
1. Explain the difference between an observation and an inference. Provide an example of each from the bracelet experiment.  
2. Design an experiment to test the validity of a suspected gold coin. Include the independent and dependent variables, constants, and how you would ensure reliability.  
3. Discuss the role of bias in scientific experiments. How can scientists minimize bias when conducting forensic investigations?  
4. In the bracelet experiment, why is it important to measure both the mass and the volume accurately? How would errors in these measurements affect the final conclusion?  
  
  
  
 Beyond the Lesson (Extend):  
  
Want to explore more forensic science? Research how forensic chemists use chemical reactions to test for the presence of different materials. For example, a common test for gold involves using nitric acid. If the metal dissolves, it’s not gold!  
  
**Challenge**: Design a test for another precious material, like diamonds, and explain how you would prove its authenticity using chemistry.  
  
**Spaced Practice**: Over the next week, review the steps of scientific inquiry by applying them to everyday situations. For example, if you observe that ice melts faster in one cup than another, ask why and design a simple experiment to test your hypothesis.