Unit 2: Atomic Structure and Bonding

Chapter 5: The Periodic Table and Chemical Trends

# Lesson 3: Managing Measurement Uncertainty and Data Visualization

1. Big Idea:  
Measurement uncertainty is always present in scientific experiments, and understanding how to calculate and report it is essential for accurate scientific conclusions.  
  
 2. Essential Questions:  
- How do we quantify and report the uncertainty in our measurements?  
 - We quantify uncertainty by identifying the precision of the measurement tool and calculating the uncertainty based on the precision. We report uncertainty using significant figures and error bars on graphs, which visually represent the uncertainty in data measurements.  
  
 3. Phenomenon-Based Learning:  
  
 Phenomenon:  
In cold northern countries, road salt is spread on icy streets to melt ice and prevent accidents. The ice and snow seem to disappear upon contact with the salt. But why doesn’t the salt dissolve metal street signs or lampposts? Additionally, there are different salts used for this purpose, such as sodium chloride, magnesium chloride, and calcium chloride. What causes these differences, and how can we predict the properties of these elements?  
  
 Connection to Lesson:  
Accurate measurements are critical when studying the effects of different salts on ice melting. However, in any scientific experiment, there’s always uncertainty in the measurements we collect. This lesson will focus on how to manage and report that uncertainty to ensure reliable conclusions about which salt works best for melting ice.

4. Vocabulary:  
  
- **Axis**: A reference line on a graph, typically representing the independent and dependent variables.  
- **Error Bars**: Graphical representations of the variability or uncertainty in data.  
- **Graph**: A visual representation of data, often used to show trends or relationships.  
- **Leading Zeroes**: Zeroes that appear before any nonzero digits in a number; they are not considered significant.  
- **Model:** A representation or simulation of real-world phenomena, often used in scientific experiments.  
- **Nonzero Digit**: Any digit that is not zero, which is always considered significant in a measurement.  
- **Rules of Significant Figures**: Guidelines for determining how many digits in a measurement are meaningful, based on the precision of the measuring instrument.   
 - \*Multiplication/Division\*: The result should have the same number of significant figures as the measurement with the fewest significant figures.  
 - \*Addition/Subtraction\*: The result should have the same number of decimal places as the measurement with the fewest decimal places.  
- **Significant Figures**: The digits in a measurement that are considered meaningful based on the precision of the measuring tool.  
- **Trailing Zeroes**: Zeroes that appear after a nonzero digit in a number; they are considered significant if they appear after a decimal point.  
  
  
  
 5. SMART Objectives:  
  
By the end of this lesson, students will be able to:  
1. Identify sources of error in measurements by analyzing data collection techniques.  
2. Calculate the uncertainty of a measurement based on the precision of the measuring instrument.  
3. Apply rules of significant figures in performing calculations involving addition, subtraction, multiplication, and division.  
4. Analyze how measurement uncertainty impacts scientific results, and report it using graphs with error bars.

6. Engage (Ignite):  
  
**Phenomenon-Related Question:**  
- Imagine you are testing the effectiveness of different salts in melting ice: sodium chloride, magnesium chloride, and calcium chloride. You measure the amount of ice melted by each salt, but your measurements have some uncertainty. How would you account for this uncertainty in your experiment?  
  
  
  
**Hands-On Experiment:**  
  
**Objective**: Measure the melting rate of ice with different salts while calculating and reporting the uncertainty of your measurements.  
  
**Materials:**  
- 3 beakers  
- Sodium chloride, magnesium chloride, and calcium chloride  
- Ice cubes  
- Digital scale (with precision to 0.01 grams)  
- Timer  
- Thermometer  
  
**Procedure:**1. Place an equal number of ice cubes in each beaker.  
2. Add 10 grams of sodium chloride to the first beaker, 10 grams of magnesium chloride to the second, and 10 grams of calcium chloride to the third.  
3. Measure the initial mass of each beaker using the digital scale.  
4. After 10 minutes, record the mass of the melted ice in each beaker.  
5. Repeat the experiment three times for accuracy.  
  
**Follow-Up Questions:**  
1. How do you think the precision of your scale affects your experiment results?  
2. What is the uncertainty in your mass measurements?  
3. How would you visually represent this uncertainty on a graph?  
  
  
 7. Pre-Explore (Direct Instruction):  
  
**Background Information:**  
- **Measurement Uncertainty**: In any experiment, measurements are not perfectly accurate. The instrument used to collect data (such as a scale or thermometer) has a limit to its precision. For instance, a scale that measures to 0.01 grams introduces uncertainty because the true value could be slightly above or below the recorded number.  
   
- **Significant Figures:** In science, we use significant figures to account for measurement uncertainty. The number of significant figures in a measurement tells us how precise a measurement is. For example, if you measure 10.00 grams, the "10.00" has four significant figures, meaning it’s precise to two decimal places.  
  
- **Error Bars on Graphs:** When you graph experimental data, you can add "error bars" to show the uncertainty in your measurements. These bars give a visual indication of how much the measured values might vary.  
  
**Interactive Elements:**  
- Ask the class: "Why do you think it’s important to report uncertainty in scientific data?"   
- Discuss how uncertainty could affect the outcome of experiments, especially when comparing the effectiveness of different salts in melting ice.  
  
  
  
 8. Evaluate (Progress Check) - Pre-Explore:  
  
1. What are some common sources of error in scientific experiments?  
2. How do leading and trailing zeroes in a number affect the number of significant figures?  
3. Why is it important to use significant figures when reporting the results of an experiment?  
  
  
  
 9. Explain (Lightbulb):  
  
**Core Concept 1: Identifying Sources of Error in Measurements**  
Every time we collect data in an experiment, there is some uncertainty involved. This uncertainty can come from:  
- **Instrument Error**: The precision of the tool you are using to measure (e.g., a scale or a thermometer).  
- **Human Error**: Mistakes made in reading measurements or recording data.  
- **Environmental Factors**: Changes in temperature, humidity, or other environmental conditions that can affect the results.  
  
For example, when measuring how much ice melts with different salts, the precision of the scale (0.01 grams) introduces uncertainty. If the scale reads “10.01 grams,” the real value might actually be between 10.00 and 10.02 grams. This range is the uncertainty.  
  
**Sample Problem**:  
If your scale has a precision of 0.01 grams and you measure the mass of melted ice as 5.24 grams, what is the uncertainty in your measurement?  
  
**Answer:**  
The uncertainty is ±0.01 grams.  
  
Progress Check:  
If you measure the mass of melted ice three times and get the following values: 5.24 grams, 5.25 grams, and 5.23 grams, what is the average mass and the uncertainty in your measurements?  
  
  
  
**Core Concept 2: Calculating Uncertainty Based on Precision**  
Uncertainty in a measurement is related to the precision of the tool used. The smaller the increments your tool can measure, the lower the uncertainty. For example:  
- If a ruler measures to the nearest millimeter, the uncertainty in a length measurement might be ±1 mm.  
- If a thermometer measures to the nearest tenth of a degree, the uncertainty in a temperature reading might be ±0.1°C.  
  
**Sample Problem:**You use a thermometer that measures to the nearest 0.1°C to record the temperature of a solution as 25.3°C. What is the uncertainty in this measurement?  
  
**Answer:**The uncertainty is ±0.1°C.  
  
Progress Check:  
If you measure the temperature of a solution several times and record the values as 25.3°C, 25.4°C, and 25.2°C, what is the average temperature and the uncertainty in your measurement?  
  
  
  
**Core Concept 3: Reporting Uncertainty with Significant Figures**  
Once you have calculated the uncertainty in your measurements, you need to report it correctly using significant figures. Significant figures tell us how many digits in a number are meaningful. Here are the basic rules:  
- Nonzero digits are always significant.  
- Leading zeroes are not significant.  
- Trailing zeroes are significant if there is a decimal point.  
  
**Example:**The number 0.00450 has three significant figures (the “4,” the “5,” and the trailing zero after the decimal point).  
  
**Sample Problem:**  
How many significant figures are in the measurement 0.00560 grams?  
  
**Answer:**There are three significant figures: the “5,” the “6,” and the trailing zero.  
  
Progress Check:  
How many significant figures are in the measurement 12.300 grams?  
  
  
  
**Core Concept 4: Using Error Bars to Visualize Uncertainty**In addition to calculating significant figures, scientists also use error bars on graphs to show uncertainty. Error bars represent the range of possible values for each data point, based on the uncertainty of the measurement.  
  
For example, if you measure the amount of ice melted by sodium chloride as 10.00 grams ±0.02 grams, you would plot a point at 10.00 grams on the graph and add an error bar extending from 9.98 to 10.02 grams.  
  
**Sample Problem:**If you measure the amount of ice melted by magnesium chloride as 12.00 grams with an uncertainty of ±0.03 grams, how would you represent this on a graph?  
  
**Answer:**You would plot a point at 12.00 grams and add an error bar that extends from 11.97 to 12.03 grams.  
  
**Progress Check:**  
How would you represent an uncertainty of ±0.05 grams for a measurement of 8.50 grams on a graph?  
  
  
  
 10. Elaborate (Deep Dive):  
  
After completing the hands-on activity, students should reflect on how uncertainty affects their conclusions. When comparing different salts for melting ice, the amount of ice melted is important—but so is the uncertainty in those measurements. If two salts melt the same amount of ice, but one has a larger uncertainty, we might have less confidence in that result.  
  
  
  
 11. Evaluate (Progress Check):  
  
1. Why is it important to calculate and report the uncertainty in your measurements?  
2. How do significant figures help scientists communicate the precision of their results?  
3. How do error bars on a graph help you visualize the uncertainty in data?  
  
  
  
Closing Reflection:  
Understanding and managing measurement uncertainty is essential in all areas of science. By calculating uncertainty and using significant figures, we can report our results more accurately. This helps us make better decisions, whether we are choosing which salt to use for melting ice or analyzing data in other scientific experiments.  
  
  
  
  
 10. Evaluate (Progress Check) - Explain  
  
Here are three scaffolded questions designed to assess your understanding of key concepts from the "Explain" section:  
  
**DOK Level 1: Recall and Reproduction**   
1. Question: What is an atom?   
 Answer: An atom is the smallest unit of matter that retains the properties of an element. It consists of protons, neutrons, and electrons.  
  
**DOK Level 2: Basic Application of Skills and Concepts**   
2. Question: How do protons, neutrons, and electrons differ in terms of charge and location within an atom?   
 Answer: Protons have a positive charge and are found in the nucleus, neutrons have no charge and are also in the nucleus, and electrons have a negative charge and orbit around the nucleus.  
  
**DOK Level 3: Strategic Thinking**   
3. Question: Predict what might happen to an atom if it gains or loses electrons.   
 Answer: If an atom gains or loses electrons, it becomes an ion. Gaining electrons makes it negatively charged, while losing electrons makes it positively charged.  
  
  
  
 11. Elaborate (Power Up)  
  
Let’s dive deeper! Here are some mini-tasks and open-ended questions to encourage deeper thinking.  
  
1. **Mini-Task 1**: Research how elements are arranged on the periodic table. Look for patterns in how the properties of elements change as you move across a row (period) or down a column (group).  
 **Expected Answer (DOK 2):** The elements in the same group (column) have similar chemical properties and the same number of valence electrons. As you move across a period (row), elements become more metallic to non-metallic in nature.  
  
2. **Mini-Task 2**: Imagine you are designing a new element. What would its properties be? How would you decide where to place it on the periodic table?  
 **Expected Answer (DOK 3):** The properties of the new element would depend on its atomic number (the number of protons). If it has properties similar to existing elements, it will likely be placed in the same group or period. For example, if it is reactive like fluorine, it might belong in Group 17, the halogens.  
  
3. **Open-Ended Question:** In what ways do you think the discovery of new elements could impact our everyday lives?  
 **Expected Answer (DOK 4):** The discovery of new elements could lead to new materials with unique properties, which might be used in technology, medicine, or energy production. For example, new elements might be more efficient in batteries or help create stronger, lighter materials.

12. Final Evaluation  
  
 Debate Question  
  
**Debate Topic**: Should scientists invest time and money into discovering new elements?   
**Arguments For**:   
- New elements could lead to advancements in technology, medicine, and energy.  
- They help expand our understanding of the universe and the fundamental building blocks of matter.  
  
**Arguments Against**:   
- The cost and effort might outweigh the benefits, especially since many new elements are unstable.  
- Resources could be better spent on more immediate global challenges like climate change or disease research.  
  
 Assessment Questions  
  
**Multiple Choice Questions (MCQs)**  
  
1. **Question**: What subatomic particle has no electric charge?   
 a) Proton   
 b) Electron   
 c) Neutron   
 d) Ion   
 **Answer: c) Neutron**   
 Explanation: Neutrons are neutral and have no charge, unlike protons (positive) and electrons (negative).  
  
2. **Question:** What happens when an atom loses an electron?   
 a) It becomes a neutron   
 b) It becomes a positive ion   
 c) It becomes a negative ion   
 d) It becomes unstable   
 **Answer: b) It becomes a positive ion**   
 Explanation: Losing an electron means the atom now has more protons than electrons, making it positively charged.  
  
3. **Question:** Elements in the same group of the periodic table have:   
 a) Similar atomic masses   
 b) The same number of protons   
 c) Similar chemical properties   
 d) The same number of neutrons   
 **Answer: c) Similar chemical properties**   
 Explanation: Elements in the same group have the same number of valence electrons, which gives them similar chemical properties.  
  
4. **Question:** Which part of the atom is responsible for most of its mass?   
 a) Electrons   
 b) Nucleus   
 c) Neutron Cloud   
 d) Electron Shells   
 **Answer: b) Nucleus**   
 Explanation: The nucleus contains both protons and neutrons, which make up nearly all the mass of an atom.  
  
**Long Answer Questions**  
  
1. **Question**: Explain how the discovery of isotopes has changed our understanding of atomic structure.   
 **Expected Answer**: Isotopes are atoms of the same element with different numbers of neutrons. This discovery showed that atoms of the same element can have different masses, which has important implications for fields like chemistry and physics, especially in nuclear reactions and dating methods like carbon dating.  
  
2. **Question**: Compare and contrast the properties of metals and non-metals on the periodic table.   
 **Expected Answer:** Metals are typically shiny, good conductors of heat and electricity, and malleable. Non-metals, on the other hand, are often dull, poor conductors, and brittle. Metals tend to lose electrons in reactions, while non-metals tend to gain or share electrons.  
  
3. **Question**: How does the arrangement of electrons in an atom determine its chemical properties?   
 **Expected Answer:** The chemical properties of an atom are determined by its valence electrons (the electrons in the outermost shell). Atoms with the same number of valence electrons behave similarly in chemical reactions. For example, elements in Group 1 all have one valence electron, which makes them highly reactive.  
  
4. **Question**: Describe how ion formation affects the chemical reactivity of elements.   
 Expected Answer: When elements form ions by gaining or losing electrons, they become more chemically stable. For instance, alkali metals (Group 1) easily lose one electron to form positive ions, making them highly reactive. Similarly, halogens (Group 17) gain one electron to form negative ions, also making them very reactive.  
  
  
  
 13. Extend (Beyond the Lesson)  
  
Here are some tasks and activities that will help you apply what you’ve learned to real-world situations:  
  
1. **Task 1**: Research how the periodic table has changed over time. How do you think it might change in the future?   
 **Goal**: Understand the history of scientific discoveries and predict how new discoveries could impact our understanding of the universe.  
  
2. **Task 2**: Look into how elements are used in modern technology. For example, how are rare earth elements used in smartphones or electric car batteries?   
 **Goal**: Connect the elements you’ve studied to everyday technologies and understand the real-world impact of chemistry.  
  
3. **Reading Suggestion**: Read about the life and contributions of Dmitri Mendeleev, the scientist who created the periodic table. How did he organize the elements, and what predictions did he make that were later found to be true?  
  
4. **Spaced Practice Activities**:  
 - Review the periodic table and quiz yourself on the properties of different groups every week.  
 - Create flashcards for key terms (such as "valence electron," "ion," or "isotope") and practice them over time.  
  
  
  
By completing these tasks and questions, you’ll have a stronger understanding of atoms, elements, and how the periodic table helps us make sense of the building blocks of everything around us! Keep exploring and asking questions – the world of chemistry is full of exciting discoveries!