Unit 12
Empirical Data Collection and Analysis

Descriptive Questions **taleemzone.com**

Q.1 (Ex. Q.4 (i)) What are our indigenous units of measurement of mass, volume and length?

Ans. Indigenous units of measurement can vary widely depending on the specific culture or region being discussed. Here are some common indigenous units of measurement for mass, volume, and length from various cultures:

Mass:

In many indigenous cultures, traditional units of mass might include items like "stone" or "pound." For example, in some cultures, a "stone" might be used to measure weight, which is equivalent to about 14 pounds (6.35 kg).

Volume:

Volume measurements might involve containers or natural resources. For example, a "basket" or "cup" could be used to measure liquids or grains. The actual volume would depend on the size of the container used.

Length:

Length might be measured by using body parts or traditional items. For example, a "foot" or "hand" could be used, where a foot might refer to the length of an actual foot (approx. 12 inches), and a hand could refer to the width of a hand, typically around 4 inches (10 cm).

Q.2. (Ex. Q.4 (ii)) Elaborate the difference between Accuracy and Precision.

Ans. Accuracy and precision are both ways to measure the correctness of results. They are used interchangeably in everyday life, but in science, they have distinct meanings.

i. Accuracy: Accuracy measures how close results are to the true or known value.

Example: The volume of a liquid is 26 cm^3. A student measures its volume three times and finds the result as 27 cm^3 each time. The student is not accurate because he has not measured the exact result.

ii. Precision: The closeness of two or more measurements to each other is called precision.

Example: If you weigh a given substance five times and every time you get a 3.2 kg reading, then your measurement is precise but not necessarily accurate.

Dependence:

Precision is independent of accuracy. A student may be precise but not accurate and vice versa. The exact mass of an object is 20 g. A student measures it and takes three readings as 17.3 g, 17.4 g, and 17.2 g. The student is considered precise but not accurate. Similarly, another student measures the mass of the same object and gets readings as 19.8 g, 20.5 g, and 19.6 g. The second student is more accurate but not precise.

Q.3 (Ex. Q.4 (iii)) How can you avoid systematic errors in your measurements?

Ans. Systematic Error:

Definition: When we use tools meant for measurement, we assume that they give correct results. However, these tools may not always be right. In fact, they have errors that naturally occur, and these errors are called systematic errors.

How to Avoid?

Systematic errors may be removed by adding or subtracting a constant adjustment to each measurement. Systematic errors affect the accuracy of the measurement. All measuring instruments contribute to systematic error, e.g., pipettes, burettes, and measuring cylinders may deliver a

volumeslightly different from the one indicated by their graduation. Regular calibration of instruments can also help minimize systematic errors. **taleemzone.com**

Q.4 (Ex. Q.4 (iv)) How do taking measurements in SI units ensure safety and reliability?
Ans. One of the most usual problems faced by the scientific community is the issue of units. If scientists in one country are measuring lengths in meters and in another country in feet, then we will have to face problems in converting them. Comparing quantities in different units is not only confusing but a waste of time as well.
SI Units:
Scientists have agreed to adopt standard and user-friendly units called SI or Système International Units. Things become a lot easier when we use these units.
Advantages of SI Units:
The adoption of SI units is important in all branches of science. It has the following advantages:

- It makes communication easy worldwide.
- It allows scientists to share data easily.
- SI units are preferred because they reduce the number of conversions needed to coordinate information among scientists.
- SI units use base 10, just like our number system. So, it is much easier to learn, remember, and convert these units.
- These units are based on definite and precise standards.
- SI units are interrelated in such a way that one unit is derived from other units without conversion factors.
- SI units are used almost everywhere in the world. It allows scientists to use a single 'standard' in exchanging scientific data. This fact brings accuracy, consistency, and universal understanding in scientific communication.
- A measurement taken in one part of the world can be easily understood and verified in another part without any confusion.

Q.5 (Ex. Q.4 (v)) Can a student be both inaccurate and imprecise in his measurements?
Ans. Yes, a student can be both inaccurate and imprecise. Precision is independent of accuracy. A student may be accurate but not precise and vice versa. Let's suppose the exact mass of an object is 20 g. A student measures it and takes three readings as 17.3 g, 17.4 g, and 17.2 g. The student is considered precise (readings are close to each other) but not accurate (readings are far from 20 g). If another student takes readings as 15.0 g, 25.0 g, and 18.0 g, these are neither precise (not close to each other) nor accurate (far from 20 g). **taleemzone.com**

Investigative Questions
Q.1. (Ex. Q.5 (i)) Elaborate the importance of using SI units in space exploration.
Ans. Using SI units in space exploration is crucial for several reasons:
Standardization: Space missions often involve collaboration among various countries and organizations. By using SI units, scientists and engineers ensure that everyone is on the same page regarding measurements. This standardization helps avoid misunderstandings that could arise from using different measurement systems, which is vital when dealing with complex technologies and systems.
Precision and Accuracy: SI units are based on decimal systems, which make calculations more straightforward and reduce the risk of errors. In space exploration, where precision is critical for navigation, communication, and data analysis, using a consistent and precise measurement system

is essential. For example, distances in space are often measured in kilometers or meters, which allows for accurate calculations when plotting trajectories or determining the positions of spacecraft.
International Collaboration: Space exploration is a global endeavor with many missions involving multiple countries. Using SI units facilitates international cooperation by providing a common framework for scientific communication. This is especially important in joint missions, such as the International Space Station, where teams from different nations work together.
Data Comparison and Sharing: The use of SI units allows for easier comparison of data collected from different missions. When data is reported in a standardized format, researchers can effectively analyze and share findings across various studies, enhancing the overall understanding of space phenomena.
Educational Consistency: SI units are taught in educational institutions worldwide, making them familiar to scientists and engineers entering the field. This consistency in education helps prepare future generations for careers in space exploration and related fields.

SLO Based Additional Long Question
Q.1. Compare SI units with the Imperial system of units.
Ans.

Measurement	SI Units	Imperial Units	Comparison
Length	Meter (m), Centimeter (cm)	Inch (in), Foot (ft), Yard (yd), Mile	1 m ≈ 39.37 in
Mass	Kilogram (kg), Gram (g)	Pound (lb), Ounce (oz)	1 kg ≈ 2.2046 lb
Volume	Liter (L), Milliliter (mL)	Fluid ounce (fl oz), Gallon (gal)	1 L ≈ 33.8 fl oz
Temperature	Kelvin (K), Celsius (°C)	Fahrenheit (°F)	°F = (°C × 9/5) + 32
Force	Newton (N)	Pound-force (lbf)	1 N ≈ 0.2248 lbf
Energy	Joule (J)	British Thermal Unit (BTU)	1 J ≈ 0.0009478 BTU

Exercise Short Questions
Q.1 What is consistency of results?
Ans. Consistency of results refers to the ability to obtain the same or similar measurements when an experiment is repeated under the same conditions. SI units are used almost everywhere in the world, allowing scientists to use a single standard in exchanging scientific data. This fact brings accuracy, consistency, and universal understanding in scientific communication. A measurement taken in one part of the world can be easily understood and verified in another part without any confusion.

Q.2 Why are SI units user-friendly?
Ans. When scientists belonging to different countries and cultures collaborate on research, they need a common language to share their results. Using SI units enables scientists to compare results, replicate experiments, and take benefit of each other's work. That's why SI units are user-friendly.

Q.3 Does systematic error affect accuracy?
Ans. Yes, systematic error affects the accuracy of the measurement. All measuring instruments contribute to systematic error, e.g., a pipette, burette, or measuring cylinder may deliver a slightly different volume from the one indicated by their graduation.

Q.4 What is the reason behind a random error? **taleemzone.com**
Ans. A random error is a type of error that a student commits during measurement. Random error causes one measurement to differ slightly from the next measurement. It comes from unpredictable changes during an experiment. The main reasons for random errors are limitations of instruments, environmental factors, and slight variations in procedure. For example, when taking a volume reading from a measuring cylinder, you may read the volume from a different angle each time. Measuring the mass of a sample on a balance may give you different values as the surrounding air affects the balance.

Q.5 Differentiate between Random Error and Systematic Error.
Ans.

Systematic Error	**Random Error**
When we use tools meant for measurement, we assume that they give correct results. However, these tools may not always be right. In fact, they have errors that naturally occur, and these errors are called systematic errors.	It is a type of error which a student commits during measurement. Random error causes one measurement to differ slightly from the next measurement. It comes from unpredictable changes during an experiment.
Systematic errors are consistent and reproducible.	Random errors vary unpredictably.
Systematic errors affect accuracy.	Random errors affect precision.

Q.6 Which other systems of measurements are used apart from SI units?
Ans. The following systems of units are commonly used in the world:

1. SI System (International System of Units)
2. CGS System (Centimeter-Gram-Second System of Units)
3. MKS System (Meter-Kilogram-Second System of Units)
4. Imperial System of Units

Q.7 Define meter.
Ans. It is the standard unit of length. The symbol "m" is used for meter. A meter is the distance travelled by light in a vacuum in about 1/299,792,458 of a second.

Q.8 Mention two benefits scientists get by using SI units.
Ans. When scientists belonging to different countries and cultures collaborate on research, they need a common language to share their results. Using SI units enables scientists to compare results, replicate experiments, and take benefit of each other's work. SI units allow scientists to work together effectively, advancing the frontiers of our knowledge. All of this ensures safety, reliability, reproducibility, and progress.

Practice Exercise Questions

Q.9 What is the difference between reliable and reproducible results?
Ans.

Reliable Results	Reproducible Results
Reliability refers to the consistency of results when the same experiment is repeated under the same conditions. If an experiment yields similar results every time it is conducted, it is considered reliable. This means that the measurement or observation is dependable and can be trusted to reflect what it is supposed to measure.	Reproducibility refers to the ability of other researchers to obtain the same results when they conduct the same experiment independently, using the same methods and conditions. This is crucial for validating findings in science.
For example, if a scientist measures the boiling point of water multiple times and consistently gets 100°C at sea level, those results are reliable.	**For example,** if another scientist takes the original experiment's procedure and performs it in a different lab and still finds that water boils at 100°C, then the results are reproducible.

Q.10 How have SI units brought harmony in the scientific community? taleemzone.com
Ans. SI units have brought harmony in the scientific community in several ways:
Universal Language: SI units serve as a universal language for scientists across the globe. By using a standardized system, researchers from different countries and disciplines can communicate their findings without confusion. This common ground fosters collaboration and understanding in a field that often involves complex data and measurements.
Consistency in Research: The use of SI units ensures that measurements are consistent and comparable. When scientists report their results in SI units, it allows others to replicate experiments and validate findings accurately. This consistency is crucial for building on previous research and advancing scientific knowledge.

Q.11 A student weighs a given substance three times, and each time he gets the reading 5.2 g. The true weight of the substance is, however, 5.0 g. Is the work done by the student (i) precise and accurate (ii) accurate but not precise (iii) precise but not accurate?
Ans. The student's work is **precise but not accurate**.
Explanation:
Precision refers to the closeness of repeated measurements to each other. In this case, the student consistently got a reading of 5.2 grams each time he weighed the substance, indicating precision. Accuracy refers to the closeness of a measurement to the true value. Since the true weight of the substance is 5.0 grams and the student consistently measured 5.2 grams, the measurements are not accurate. Therefore, the student's work is precise (consistent readings of 5.2 g) but not accurate (the measured value is not close to the true weight).

Q.14 How will you avoid systematic and random errors?
Ans.
Systematic errors may be removed by adding or subtracting a constant adjustment to each measurement. Systematic error affects the accuracy of the measurement.
Random errors can be minimized by:

- Taking multiple measurements.
- Using more precise instruments.
- Calibrating instruments regularly.

- Taking readings carefully (e.g., ensuring the eye is at the correct level when reading a meniscus).

SLO Based Additional Short Questions

Introduction

Q.12 Why was there a need to develop the SI unit system?

Ans. One of the most usual problems faced by the scientific community is the issue of units. If scientists in one country are measuring lengths in meters and in another country in feet, then we will have to face problems in converting them. Comparing quantities in different units is not only confusing but a waste of time as well. For the reasons mentioned above, scientists have agreed to adopt standard and user-friendly units called SI or Système International Units. Things become a lot easier when we use these units.

Q.13 What are the advantages of the SI unit system?

Ans. SI units are used almost everywhere in the world. It allows scientists to use a single standard in exchanging scientific data. This fact brings accuracy, consistency, and universal understanding in scientific communication. A measurement taken in one part of the world can be easily understood and verified in another part without any confusion.

SI Units in Chemistry

Q.15 How many SI units are used in Chemistry? Write their names.

Ans. There are seven base units in the SI system for physical quantities, out of which we use five in Chemistry. These physical quantities are length, time, amount of substance, mass, and temperature.

Quantity	Unit
Length	Meter (m)
Time	Second (s)
Amount of substance	Mole (mol)
Mass	Kilogram (kg)
Temperature	Kelvin (K)

Kilogram

Q.16 What do you know about "Kilogram"?

Ans. Its symbol is (kg) and it is the standard unit of mass. A platinum-iridium cylinder is kept in France, which is taken as the standard unit of mass. It is also defined as the mass of 1000 cm^3 of water at 4°C.

Second

Q.17 What do you know about "Second"?

Ans. It is the standard unit of time with a symbol (s). It is the time that elapses during 9,192,631,770 cycles of the radiation produced by the transition between two levels of the Cesium-133 atom.

Kelvin

Q.18 What do you know about "Kelvin"?
Ans. It is represented by (K) and it is the standard unit of temperature. It is 1/273.16th of the thermodynamic temperature of the triple point of water. It is a point at which all three states of water (solid, liquid, and gas) exist at the same time.

Mole
Q.19 What do you know about "Mole"?
Ans. It is the base unit of the amount of pure substance, and it is denoted by mol. It is defined as the amount of substance that contains exactly 6.022×10^{23} particles (Avogadro's number) of that substance.

SI Units in Chemistry
Q.20 Define SI (Système International) units.
Ans. The subject of chemistry needs a consistent way to measure and to communicate the quantities like mass, volume, temperature, amount, and time. To make sure that all of us can understand each other, scientists all over the world have adopted a common system of units which is based upon the metric system, and it is called SI units.

Q.21 What are derived units? Give examples.
Ans. Mathematically, these are derived from base units. Examples: The derived units used in chemistry are given in the following table.

Quantity	Unit
Volume	Cubic meter (m^3)
Density	kg per cubic meter (kg/m^3)
Area	Square meter (m^2)

In addition to derived units, there are other specific quantities commonly used in chemistry.

Quantity	**Unit**
Force	Newton (N) ($kg \cdot m/s^2$)
Pressure	Pascal (Pa) (N/m^2)
Energy	Joule (J) ($N \cdot m$)

Q.22 What is the advantage of the use of prefixes?
Ans. Since the SI system of units is a metric system, it is based around the number 10 for convenience. A set of prefixes has been developed which indicates whether the unit is a multiple or a fraction of the base ten. It allows the reduction of zeros of a very small number or a very large number. These SI prefixes also have a set of symbols that precede the unit symbol.

Q.23 Why is the gram (unit) used in Chemistry instead of Kilogram for measuring Molar mass?

Ans. In Chemistry, we measure the masses of the reactants in grams. It is essential because the unit of measurement of molar mass consists of grams per mole. Therefore, given a mass measured in grams as well as a corresponding molar mass, enables us to find the moles of a substance. Moreover, in Chemistry, the quantities involved in the laboratory are likely to be small. The choice of gram rather than kg is sensible and normal. Using grams provides more manageable numbers for calculation and prevents the need for excessively large or small values.

Q.24 Why is the Celsius scale often used to measure temperature in Chemistry rather than Kelvin?
Ans. The Celsius scale is most often used to measure temperature in Chemistry rather than Kelvin because it is more convenient to use. The Celsius scale has 100 divisions in total, which makes it more compatible with the base ten format of the SI system. Another reason is that it is easier to convert temperature on the Celsius scale into the Kelvin scale (K = °C + 273.15).

Q.25 Why is the unit of volume in Chemistry used as cubic centimeter instead of cubic meter?
Ans. The unit of measurement of volume in Chemistry is cubic centimeter instead of cubic meter because it is easy to measure and calculate with it, and it is precise. In the laboratory, we usually measure smaller volumes of liquids which are more manageable in cubic centimeters (or milliliters) rather than cubic meters.

Q.26 What are the two rules to write a symbol of an element?
Ans.

1. Symbols are not changed in plural forms (e.g., "1 kg" and "5 kg").
2. Use a space between units (e.g., "N m" not "Nm").

Tools and Techniques to Manage Accuracy and Precision

Q.27 Define error.
Ans. Every measurement carries a level of uncertainty which is known as error. An error may be defined as the difference between the measured value and the actual value. For example, if two students use the same tool or instrument for measurement, it is not necessary that both of them get similar results. The difference between the measurements is called an error.

Q.28 Why does an error occur?
Ans. An error may occur due to two factors:

1. The limitation of the measuring instrument.
2. The skill of the student making the measurement.

Q.29 What is the difference between precision and accuracy?
Ans.

Precision	**Accuracy**
The closeness of two or more measurements to each other is called precision.	Accuracy measures how close results are to the true or known value.
e.g. If you weigh a given substance five times and every time you get a 3.2 kg	**e.g.** The volume of a liquid is 26 cm^3. A student measures its volume three times and finds the result as 27 cm^3. The student is

Precision	Accuracy taleemzone.com
reading, then your measurement is precise.	not accurate. But if it measures 26 cm^3, then it would be accurate.

Constructed Response Questions

Q.1 (Ex. Q.3 (i)) Compare the units in the SI system with those in the MKS system.

Ans. The SI system and the MKS system are both metric systems used for measuring physical quantities, but they have some differences in their units.

SI System: In the SI (International System of Units), the base units are:

1. Meter (m) for length
2. Kilogram (kg) for mass
3. Second (s) for time
4. Ampere (A) for electric current
5. Kelvin (K) for temperature
6. Mole (mol) for the amount of substance
7. Candela (cd) for luminous intensity

MKS System:

The MKS system is a subset of the SI system, where MKS stands for Meter, Kilogram, and Second. It primarily focuses on these three units:

1. Meter (m) for length
2. Kilogram (kg) for mass
3. Second (s) for time

Q.2 (Ex. Q.3 (ii)) What are the five basic SI units which are used in chemistry?

Ans. There are seven base units in the SI system for physical quantities, out of which we use five in Chemistry. These physical quantities are length, time, amount of substance, mass, and temperature.

Basic Quantity	Basic Unit
Length	Meter (m)
Time	Second (s)
Amount of substance	Mole (mol)
Mass	Kilogram (kg)
Temperature	Kelvin (K)

Q.3 (Ex. Q.3 (iii)) Explain the three units derived from the basic SI units.

Ans.

Quantity	Unit
Volume	Cubic meter (m^3)

Quantity	Unit
Density	kg per cubic meter (kg/m^3)
Area	Square meter (m^2)

Q.4 (Ex. Q.3 (iv)) Explain why do we prefer to use smaller units of mass and volume in chemistry.

Ans. Mass: In Chemistry, we measure the masses of the reactants in grams. It is because the unit of measurement of molar mass consists of grams per mole. Therefore, given a mass measured in grams as well as a corresponding molar mass, enables us to find the moles of a substance.

Volume: The unit of measurement of volume in Chemistry is cubic centimeter instead of cubic meter because it is easy to measure and calculate with it, and it is precise. In the laboratory, we usually measure smaller volumes of liquids which are more manageable in cubic centimeters rather than cubic meters.

Q.5 (Ex. Q.3 (v)) What difficulties do we expect to encounter if we use different units of measurement in daily life?

Ans. If scientists in one country are measuring lengths in meters and in another country in feet, then we will have to face problems in converting them. Comparing quantities in different units is not only confusing but a waste of time as well. For the reasons mentioned above, scientists have agreed to adopt standard and user-friendly units called SI or Système International Units. Things become a lot easier when we use these units.

Multiple Choice Questions (Exercise)

1. Which of the following pairs of quantities may be measured in the same unit?
   (c) Heat and work ✔ (Both measured in Joules)
2. In which unit do we usually measure the energy present in food?
   (c) Calorie ✔ (or kilocalories)
3. What prefix is used for 10^{-12}?
   (b) Pico ✔
4. In SI, the unit of pressure is expressed in:
   (d) Pascal ✔
5. Which symbol is used for kilogram in SI units?
   (d) kg ✔
6. What does a mole represent?
   (a) Number ✔ (A specific number of particles)
7. Which unit of volume should usually be used in chemistry?
   (c) Cubic centimeter ✔ (or milliliter)
8. Express 0.000840 in scientific notation:
   (c) 8.40×10^{-4} ✔
9. In SI units, the prefix Nano is equal to:
   (a) 10^{-9} ✔
10. 65°C is equivalent to:
    (c) 149°F ✔ (°F = 65 × 9/5 + 32 = 149)

SLO Based Additional MCQs

Introduction

11. To change SI units by factors of ten into smaller or bigger units, they use:
    (a) Prefixes ✔
12. The standard form of 38,000,000,000 is:
    (c) 3.8×10^{10} ✔
13. The standard form of 0.00000000034 is:
    (c) 3.4×10^{-10} ✔
14. The eleventh general conference was held in Paris in:
    (d) 1960 ✔
15. The number 0.00580 in scientific notation is:
    (c) 5.80×10^{-3} ✔

Second

16. An interval of 200 ps is equivalent to:
    (c) 2×10^{-10} s ✔ ($200 \times 10^{-12} = 2 \times 10^{-10}$)

SI Units in Chemistry

17. What is the volume of the liquid in this graduated cylinder?
    (This question refers to an image that is not available. The student should read the meniscus correctly.)
18. How many cubic centimeters (cm^3) are there in one cubic decimeter (1 dm^3)?
    (b) 1000 cm^3 ✔
19. A distance of 1 kilometer means:
    (d) 1000 m ✔
20. In SI, the unit of mass is:
    (a) kilogram ✔

21. The number of base units in SI are:
    (c) 7 ✔
22. Which one of the following units is not a derived unit?
    (b) kilogram ✔
23. The amount of a substance in terms of numbers is measured in:
    (d) mole ✔
24. Which one of the following is the smallest quantity?
    (c) 100 µg ✔ (100 µg = 0.0001 g; 5000 ng = 0.000005 g, so 5000 ng is smaller. Let's check: 5000 ng = 5×10^{-6} g = 5 µg. So 100 µg is larger. The correct smallest is 5000 ng.)
25. A measuring cylinder is used to measure:
    (c) volume ✔
26. 1 micro (µ) =
    (b) 10^{-6} ✔
27. One cubic meter is equal to:
    (b) 1000 liter ✔
28. The base quantity is:
    (a) mass ✔
29. The scientific notation of the number 0.00235 is expressed as:
    (b) 2.35×10^{-3} ✔
30. One tera is equal to:
    (c) 10^{12} ✔

Accuracy and Precision

31. The property of a measuring instrument to give the output very close to the actual value is termed as:
    (b) Accuracy ✔
32. In measuring instruments, the degree of conformity and closeness to the true value is known as:
    (b) accuracy ✔