

## Chapter 12 — Empirical Data Collection and Analysis

**2. Questions for Short Answers****1. What is consistency of results?**

Ans: Consistency of results means that when the same measurement is repeated, the values obtained agree closely with one another. This closeness of two or more measurements to each other is called precision. For example, if you weigh a given substance five times and every time you get a 3.2 kg reading, your measurement is consistent, that is precise. It is important to note that consistency alone does not guarantee correctness — a set of results may be consistent (precise) without being close to the true value (accurate), because a systematic error can shift every reading by the same amount.

**2. Why are SI unit's user friendly?**

Ans: SI units are user friendly for several reasons. They use base 10, just like our own number system, so they are much easier to learn, to remember and to convert from one to another. They are based on definite and precise standards, so a measurement means exactly the same thing everywhere. They are interrelated in such a way that one unit is derived from other units without any conversion factors, which reduces the number of conversions needed to coordinate information among scientists. Because of all this, comparing quantities becomes simple instead of confusing and time-wasting.

**3. Define systematic error and random error.**

Ans: An error is the difference between the measured value and the actual value. Systematic errors are the errors which occur naturally in the measuring tools themselves; all measuring instruments contribute to systematic error, for example a pipette, a burette or a measuring cylinder may deliver a volume slightly different from the one indicated by its graduation. A systematic error may be removed by adding or subtracting a constant adjustment to each measurement, and it affects the accuracy of the measurement. A random error is the error which a student commits during measurement and which causes one measurement to differ slightly from the next. It comes from unpredictable changes during an experiment — for example reading the volume of a measuring cylinder from a different angle each time. A random error determines the precision of the experiment.

**4. What is the reason behind a random error?**

Ans: A random error causes one measurement to differ slightly from the next, and it comes from unpredictable changes during an experiment. The main reasons for random errors are the limitations of the instruments, environmental factors, and slight variations in the procedure followed by the person making the measurement. For example, when taking a volume reading from a measuring cylinder you may read the volume from a different angle each time, and when measuring the mass of a sample on a balance you may get different values because the surrounding air affects the balance.

**5. Does systematic error affect the accuracy?**

Ans: Yes. Systematic errors affect the accuracy of the measurement. Accuracy measures how close a result is to the true or known value, and a systematic error shifts every single reading away from the true value by the same amount and in the same direction — for example a balance that always reads 0.2 g high. Because the shift is the same every time, the readings can still agree closely with one another, so the measurement may remain precise while being inaccurate. This is also why a systematic error can be removed by adding or subtracting a constant adjustment to each measurement. Random error, by contrast, affects the precision rather than the accuracy.

**6. Which other systems of measurements are used apart from SI units?**

Ans: Apart from the International System of Units (SI system), three other systems of units are commonly used in the world: the Centimetre-gram-second system of units (CGS system), the Metre-kilogram-second system of units (MKS system), and the Imperial system of units. The existence of these different systems is exactly the reason why scientists agreed to adopt SI units — if scientists in one country measure lengths in metres and in another country in feet, converting between them is confusing and wastes time.

**7. Define metre.**

Ans: The metre is the standard unit of length in the SI system and the symbol m is used for it. It is defined as the distance travelled by light in vacuum in about 300 millionth of a second. It is one of the five base SI units used in Chemistry, the other four being the kilogram, the second, the kelvin and the mole.

**8. Mention two benefits scientists get by using SI units.**

Ans: First, SI units make communication easy worldwide. A measurement taken in one part of the world can be easily understood and verified in another part without any confusion, so scientists belonging to different countries and cultures have a common language in which to share their results. Second, using SI units enables scientists to compare results, replicate each other's experiments and take benefit of each other's work; this brings accuracy, consistency and universal understanding to scientific communication and ensures safety, reliability, reproducibility and progress.

### 3. Constructed Response Questions

#### 1. Compare the units in the SI system with those in the MKS system.

Ans: The MKS system is the Metre-kilogram-second system of units, so it is built on only three base quantities: length measured in metres, mass measured in kilograms and time measured in seconds. The SI system is a much wider system: it has seven base units in all, of which five are used in Chemistry — the metre (m) for length, the kilogram (kg) for mass, the second (s) for time, the kelvin (K) for temperature and the mole (mol) for amount of substance. So the SI system contains the three MKS units unchanged and adds to them the units needed for temperature, amount of substance and other quantities, together with twenty-two derived units. Both are metric, base-10 systems, but only SI is complete enough to serve every branch of science, which is why it has been adopted worldwide.

#### 2. 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 five are used in Chemistry. These five physical quantities and their units are: length — metre (m); time — second (s); amount of substance — mole (mol); mass — kilogram (kg); and temperature — kelvin (K). The metre is the distance travelled by light in vacuum in about 300 millionth of a second; the kilogram is the mass of a standard block kept in France, also defined as the mass of 1000 cm<sup>3</sup> of water; the second 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; the kelvin is 1/273rd of the thermodynamic temperature of the triple point of water; and the mole is the amount of a pure substance having exactly  $6.022 \times 10^{23}$  particles.

#### 3. Explain the three units derived from the basic SI units.

Ans: Apart from the base units there are other quantities that are mathematically derived from them, and their units are called derived units. The three derived units used in Chemistry are: volume, whose unit is the cubic metre (m<sup>3</sup>), obtained by multiplying length by length by length; density, whose unit is the kilogram per cubic metre (kg m<sup>-3</sup>), obtained by dividing mass by volume; and area, whose unit is the square metre (m<sup>2</sup>), obtained by multiplying length by length. Each of these is built only out of the base unit's metre and kilogram, with no conversion factor needed — which is one of the reasons the SI system is so convenient.

#### 4. Explain why do we prefer to use smaller units of mass and volume in Chemistry?

Ans: In Chemistry the quantities involved in the laboratory are likely to be small, so the base units themselves are inconveniently large. For mass, we measure the masses of reactants in grams rather than kilograms. This is essential because the unit of measurement of molar mass consists of grams per mole, so a mass measured in grams together with the corresponding molar mass enables us to find the number of moles of a substance directly. Using grams also provides more manageable numbers for calculation and prevents the need for excessively large or small values. For volume, the unit used is the cubic centimetre (cm<sup>3</sup>) instead of the cubic metre (m<sup>3</sup>), because in the laboratory we usually measure smaller volumes of liquid which are far more manageable in cubic centimetres, and because it is easy to measure and calculate with and it is precise. For the same reason of convenience, the Celsius scale is preferred to the Kelvin scale for temperature.

#### 5. What difficulties do we expect to encounter if we use different units of measurement in daily life?

Ans: If different units are used, the same quantity is described by different numbers, so the results cannot be compared directly. One of the most usual problems faced by the scientific community is exactly this: if scientists in one country are measuring lengths in metres and in another country in feet, they have to face problems in converting them. Comparing quantities in different units is not only confusing but causes the wastage of time as well, and every conversion is another chance to make a mistake, which can lead to inaccurate or inconsistent results. In daily life the same difficulties appear in trade, in construction, in medicine doses and in cooking — a recipe in ounces cannot be followed with a balance marked in grams without converting first. Standard, user-friendly units remove all of this, which is why SI units were adopted.