Significant Figures

Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called significant figures. Scientific calculations generally involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + One estimated figure (digit)

They are often expressed as "all of the digits known for certain plus one that is uncertain."

Significant Figure Rules:

(i) All non-zero digits are significant.

(ii) Zero Rules:

– Trailing zeroes (i.e., at the end to the right) of a measurement may or may not be significant.

(i)If it represents a measured quantity, it is significant. For example: 25.0 cm - the zero is significant (the decimal is clearly indicated)

(ii) If it is immediately to the left of the decimal, it is not a significant figure. For example: 250 cm or 2500 cm - the zeroes are not significant (there is uncertainity whether the zeroes were measured values)

- If the trailing zeroes in 250 cm and 2500 cm are significant, then the measurements should be written in scientific notation. For example: 2.50 × 102 cm or 2.500 $x10^3$ cm - the zeroes are significant

– A zero, between two non-zero digits in a measurement, is significant. For example: 9.04 cm - the zero is significant

– Leading zeroes (i.e., at the beginning to the left) are never significant (they do not represent a measured quantity), they merely locate the decimal point. For example: 0.46 cm and 0.07 kg - the zeroes are not significant

(Leading zeros never, trailing zeros only if decimal, trapped zeros always)

(iii) Rounding with Significant Figures

In reporting a calculated measured quantity, rounding an answer to the correct number of significant figures is important if the calculated measurement is to have any meaning. The rules for rounding are:

– If the figure to be dropped is less than 5, eliminate it. For example:
rounding 39.949 L to three significant figures results in 39.9 L
rounding 40.0 g to two significant figures results in 4.0×10^1 g

– If the figure to be dropped is greater than or equal to 5, eliminate it and raise the preceding figure by 1. For example:

rounding 39.949 L to four significant figures results in 39.95 L
rounding 39.949 L to two significant figures results in 4.0×10^1 L

(iv) Multiplying and Dividing with Significant Figures

In determining the number of significant figures in a measurement that is calculated by multiplying or dividing, the measurement with the least number of significant figures should be identified. The final calculated measurement should contain the same number of significant figures as the measurement with the least number of significant figures. For example:
$2.1 \text{ cm} \times 3.24 \text{ cm} = 6.8 \text{ cm}^2$

Since 2.1 cm contains two significant figures and 3.24 contains three significant figures, the calculated measurement should contain no more than two significant figures.

(v) Adding and Subtracting with Significant Figures

In determining the number of significant figures in a measurement that is calculated by adding or subtracting, the measurement with the least number of decimal places should be identified. The final calculated measurement should contain the same number of decimal places as the measurement with the least number of decimal places. For example:

42.56 g + 39.460 g + 4.1 g = 86.1 g

Since 4.1 g only contains one decimal place, the calculated measurement must be rounded to one decimal place.

(vi) Performing a Series of Calculations with Mixed Operations

When a series of calculations is performed, it is important to remember that multiplication/division and addition/subtraction are governed by separate significant figure rules. Rounding only occurs at the last step.

When calculations involve both of these types of operations, the rules must be followed in the same order as the operations. Rounding still only occurs at the last step of the calculation. For example:
$$\frac{(0.428 + 0.0804)}{0.009800}$$

The addition is first, 0.428 + 0.0804 = 0.5084. Following the rules for addition/subtraction, the answer should have three significant figures, but rounding is the last step. Therefore, 0.5084 is used in the next step, 0.5084/0.009800 = 51.87755. Following the rules for multiplication/addition, the answer should have four significant figures (but rounding is the last step). The sum of the numerator has three significant figures, and the denominator has four, so the final answer is rounded to three significant figures, 51.9.

(vii) Calculating with Exact Numbers

Sometimes numbers used in a calculation are exact rather than approximate. This is true when using defined quantities, including many conversion factors, and when using pure numbers. Pure or defined numbers do not affect the accuracy of a calculation. You may think of them as having an infinite number of significant figures. Calculating with exact numbers is important when dealing with conversions or calculating molar ratios in chemistry.