Chemistry 11

Unit II – Introduction to Chemistry

Notes

Because we are just starting out, we'll take it slow. Let's go over some of the easier concepts…

Rounding

Rounding off means finding a number that is closest to a given number but with fewer digits. The rules that we will use in chemistry 11 for rounding off a number are:

1. *The last digit to be retained is either kept or increased by one, whichever gives a value nearer to the original number.*

   For example, if the calculated answer was 158.2616, what would the rounded answer to 1 decimal place be? It would be 158.3 because 158.2616 is closer to 158.3 than 158.2. As a second example, the number 3.674 would become 3.67 if one digit is dropped and 3.7 if two digits were dropped.

2. *When the digits to be dropped are a five or a five followed by zeros, the last remaining digit is rounded up. If the digit to be dropped is a 4 or lower, the last remaining digit is kept the same.*

   The numbers 4.775 and 6.485, for example, would round off to 4.78 and 6.49. The number 6.984 would become 6.98.

Accuracy and Precision

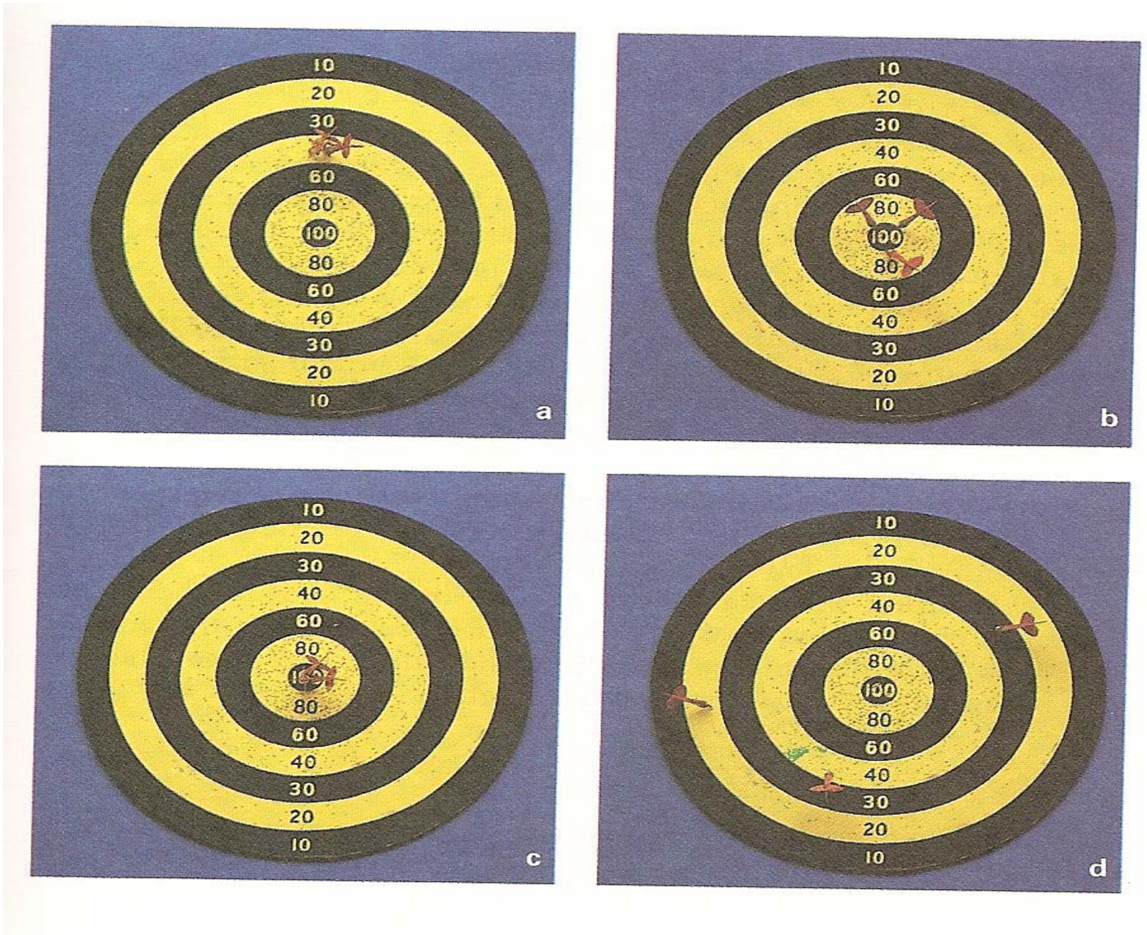
As scientists we need to show how accurate or precise a measurement or value is.

An ***ACCURATE*** measurement is a measurement that is close to the correct or accepted value. (The closer to the accepted/correct value, the more accurate the measurement.)

A ***PRECISE*** measurement is a reproducible measurement. A measurement will give about the same results again and again under the same conditions. ***Or***…precision refers to the uncertainty in a measurement, the less the uncertainty, the higher the precision.

Consider a ruler and a micrometer (used to measure thickness). A micrometer can measure to the nearest 0.001 cm. A ruler on the other hand can measure to the nearest 0.01 cm. Because the micrometer has less uncertainty, it is a more precise instrument.

This picture may help…



(a) Precise, NOT Accurate: The three shots are close together. Thus, the shooting was very precise, but the accuracy was low because the shots missed the centre of the target.

(b) Accurate, but NOT Precise: High accuracy because they are right on target. Low precision because they are scattered (in the centre).

(c) Accurate AND Precise: All in the centre, right on top of each other.

(d) Neither Accurate NOR Precise: All over the place… ☹

Scientific Notation

Numbers in science can be very large or very small. For example, there are 50,100,000,000,000,000,000,000 atoms in 1 g of carbon and the radius of each carbon atom is 0.000,000,000,077 m. Numbers in this form are difficult to work with, they are hard to read and even harder to write. Scientists have found it convenient to express such numbers using powers of 10

The basic form of scientific notation is as follows:

$$A \times 10^{n}$$

where A is greater than or equal to 1 but less than 10, and n is a positive or negative integer.

The following rules will help you to write numbers in scientific notation:

1. Find the number A by moving the decimal point from its original location to just after the first nonzero digit. (When the original number is written without a decimal point, for example, 168 or 1750 or 186,000, the decimal point is understood to follow the last digit.) Drop all zeros before the first nonzero digit.

2. Find n, the power of 10, by counting the number of places the decimal point has been moved. If the decimal point is moved to the left, the power of 10 is positive; if it moved to the right, the power of 10 is negative.

<u>Examples:</u>

Write the number 96,500 in scientific notation.

Write the radius of a carbon atom in scientific notation. (Radius is 0.000 000 000 077 m)

Try to put the following into scientific notation.

1.) 23 145 2.) 0.898 3.) 101.1 4.) 304 000

Density

Density is the mass contained in a given volume of a substance.

The equation is as follows…

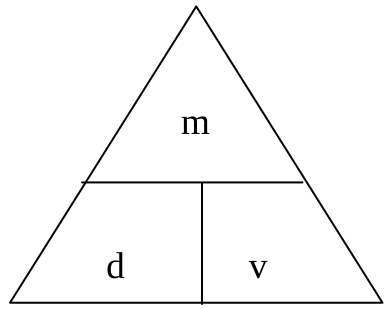
$$d = \frac{m}{v}$$

d = the density m = mass v = volume

units of density are g/mL OR g/L

Need to memorize the formula….if that is a problem, use the “Triangle of Laziness”

Triangle of Laziness



How to use → Cover the variable you want to solve for, what's left is the formula you need to use…now you will never have to remember how to use algebra ☹

Examples:

1.) A gold bar has a mass of 95,000 g and a volume of 3.75 L. What is the density of the gold bar?

2.) Mercury has a density of 13 600 g/L. What volume, in millilitres, is occupied by 715 g of mercury?

3.) The density of gold is 9500 g/L. What is the mass of a gold bar that has a volume of 625 mL?

Other things to remember…

Less dense liquids and objects will float on liquids have a greater density.

Objects will sink in a liquid if

$$d_{object} > d_{liquid}$$

Objects will float in a liquid if

$$d_{object} < d_{liquid}$$

For water at 4°C…

$$d = 1000.0 g/l \quad \text{OR} \quad d = 1.0000 g/mL$$

1 g = 1 mL is a popular conversion statement that can be used for water

OK, enough of this easy stuff, here's where it gets harder ☺

Significant Figures

Significant figures will be a term that you will become increasingly familiar with through out this course; which is why a solid foundation in this topic is very critical. So, what are significant figures (sig figs)?

Each non-zero digit obtained as a result of a measurement is called a significant figure (digit).

For example:

1.22 cm has ***3*** significant figures.
5 m has ***1*** significant figure.
5.69874523 mm has ***9*** significant figures.

What about 1000 cm. How many sig figs are present here?

The zeros in a number warrant special attention. A zero that is the result of a measurement is significant, but zeros that serve only to mark the decimal point are not significant. If this seems confusing, the three rules below will help you determine if a zero is significant or not.

1. *A zero between other significant figures is significant*. Example, 6.01 mL has 3 sig figs. 4001 L has four sig figs.
2. *Final zeros to the right of the decimal point are significant*. Example, a mass of 8.20g (recorded on a balance sensitive to 0.01 g) has 3 sig figs because the final zero is a result of a measurement. A mass of 12.00g has 4 sig figs.
3. *Initial zeros are not significant*. Initial zeros, such as the two zeros in 0.028 L, serve only to show the position of a decimal point. For example, 28 mL has two sig figs, expressed as 0.028 L it still has 2 sig figs. Similarly, 0.000601 m and 0.000610 m each have 3 sig figs.

Alternatively…Use the Atlantic-Pacific Rule

This rule divides measurements into two different categories, measurements with decimals and those without decimals. Imagine a map of North America, Pacific Ocean on the left, and Atlantic Ocean on the right.

Pacific Ocean

Atlantic Ocean

Here's how it works:

Pacific Ocean

Atlantic Ocean

Now write the measurement on the map itself.
If a decimal place is present, count sig figs from the "Pacific" side (From the left)
If there is not decimal point, count from the "Atlantic" Side (From the right)

In each case, start counting from the first nonzero digit you find. All digits from that point till the end will be significant, including any zeros**

Let's try a few examples. For each of the following determine the number of significant figures?

1.) 0.02 2.) 0.020 3.) 501 4.) 501.0 5.) 5,000

Significant figures in Calculations:

Now that we have some practice with sig figs, we can learn how to use them when doing calculations.

The number of sig figs in a calculated result depends on the number of significant figures in the data used for the calculation. If, for example, an employee with an actual income of $33,425 (five sig figs) were to file a tax return based on the rounded off income of $30,000 (1 sig fig), the Internal Revenue Service would quickly send a bill for the tax (and penalties) on $3425!!

When is it expectable to round off? Fortunately, there are rules that govern how many sig figs to use and when to use them.

Let's start with addition and subtraction. The following rule tells how to determine the number of significant figures in an addition and subtraction:

When adding or subtracting numbers, round the answer to the least significant, least accurate place. (In most cases, this will be the least number of decimal places)

Let's look at some examples:

1.) Add 94.02 g + 61.1 g + 3.1416 g, and determine the number of significant figures in the answer.

2.) Add 4780cm + 12 cm, and give the answer showing the right number of sig figs.

<u>More Examples:</u>

1. Subtract 2.30569 from 5.987
2. Add 987.984 and 3.6
3. Add 987,000 and 12
4. Add 1.234×10^6 and 6.45×10^4
5. Subtract 9.879 from 12
6. Add 967,987 and 1,000,234

The only other situation we need to cover is multiplication and division. The following rule is used to determine the number of significant figures in a multiplication or division:

A product (multiply) or quotient (divide) of two or more measurements has the same number of significant figures as the measurement with the least number of significant figures.

Let's try an example:

Multiply 5.6432 by 0.020 and determine the number of significant figures in the answer.

*****Important*****

Numbers obtained from counting or from a definition are exact. There are, for example, exactly 60 seconds in 1 minute, exactly 12 inches in 1 foot, and exactly 2.54 centimetres in 1 inch. There is no uncertainty in such numbers; therefore, ***exact numbers have no effect on the number of significant figures in a calculated result.***

Also, *Extra significant figures are carried through a calculation and rounded off at the end. Don't **EVER** clear your calculator!!!*

More examples:

1. 2.3569 x 4.0

2. 14.00 ÷ 2

3. 72.000 ÷ 8.00

4. $\dfrac{4.25 \times 99.000}{81}$

5. 4.0 x 3

6. 40.000 ÷ 2.0

4. 50.35 x 0.106 – 25.37 x 0.176 (Remember your BEDMAS!!!)

5. (0.865 – 0.800) x (1.593 + 9.04) CAREFUL!!!!

Unit Conversions

We will now discuss how to use a mathematical method called Unit Conversions, which will be used extensively in Chemistry 11 and 12. **Avoid the temptation to solve the problems by your own method. You need to learn the Unit Conversion method as the problems will get harder and your method may take to long.**

If you go to Tim Horton's and buy donuts it will cost you $4.60/dozen. However, you could also say that the donuts are 1 doz/$4.60. You can see that there are two different ways to state how much the donuts will cost.

The statement "$4.60 per dozen" allows us to RELATE or CONNECT one amount ($3.50) to another amount (1 dozen).

$$\frac{\$4.60}{1\ \text{doz}} \quad \text{and} \quad \frac{1\ \text{doz}}{\$4.60}$$

These two terms imply the same connection about how much donuts cost per dozen.

What we have just done here is made a **CONVERSION FACTOR** for the cost of donuts.

A **CONVERSION FACTOR** is a fractional expression relating or connection two different units.

Let's look at some examples:

Statement Form	Conversion Form
1 min = 60 seconds	$\frac{1\ \text{min}}{60\ \text{s}}$ and $\frac{60\ \text{s}}{1\ \text{min}}$
$1 = 100 ¢	$\frac{\$1}{100\ ¢}$ and $\frac{100\ ¢}{\$1}$

The general form of a unit conversion is shown below;

(UNKNOWN AMOUNT) = (INITIAL AMOUNT) X (CONVERSION FACTOR)

ALWAYS start with the initial value…..this is something you should remember for the whole course. ALWAYS start with what you have…

Let's look at some examples:

1. What is the cost of 3 dozen donuts if the donuts are $4.60/doz?
   What is the initial amount…what do we start with? What's the conversion factor?

2. If Mr.Simms can run 2.5 km in 7 minutes, how far can he run in 60 minutes?
   Again, what do I have…what's the conversion factor

3. Mr. Eckert drives an average speed of 85 km/hr. How long will it take Mr. Eckert to travel to Calgary, which is 1250 km's away.

Now you try these ones….

1) If a chemical costs $50 per gram, what is the cost of 100g of the chemical?

2) Computer disks cost $6.00 for 10 disks. How many disks can you buy for $36.00?

3) If Mr.Simms burns 250 calories every hour, how many calories will he burn in 8 hours?

Multiple Unit Conversions

All the problems we have done so far involve only one conversion factor. What happens if we have more than one conversion factor? It just so happens that you probably already have dealt with such a problem. Have you have ever figured out how many minutes there are in 1 day? If the answer is yes, then you are already well on your way to becoming a multiple unit converting machine!

Let's see if we can determine how many minutes are in 1 day.

Where do we start? What do we have? What about the conversions factors, what are they?

We need to RELATE and CONNECT a couple of things to solve this problem.

1. days to hours
2. hours to minutes

As you can see, we need two different conversion factors in order to solve the problem. Let's now determine what conversion factors we need.

1 day = 24 hours and 1 hour = 60 minutes

Our initial amount is in days, thus we will need to have days on the bottom of the conversion factor so it will cancel out. If we look above, there is only one choice, and that is 24 hours.

If we start to set up the equation it will look something like this:

Be sure to watch your units…make SURE they ALL cancel out

What about how many seconds in 1 year?

Metric Conversions

Metric conversions can be solved just like the multiple conversions above. Use the Metric system handout to get find the conversion statements and then set up the equation as you have been doing. Again, ***WATCH*** your units, they need to cancel out ☺

Examples:

1. How many g in 0.0235 kg?
2. Convert 5 cm to m?
3. How many ng in 0.0235 kg?
4. Convert 765 mm to µm?

Alright, now that we have a feel for those ones, let's try the tricky "***tops and bottoms***". These involve converting both the units on the top and bottom…wow ☺

Examples:

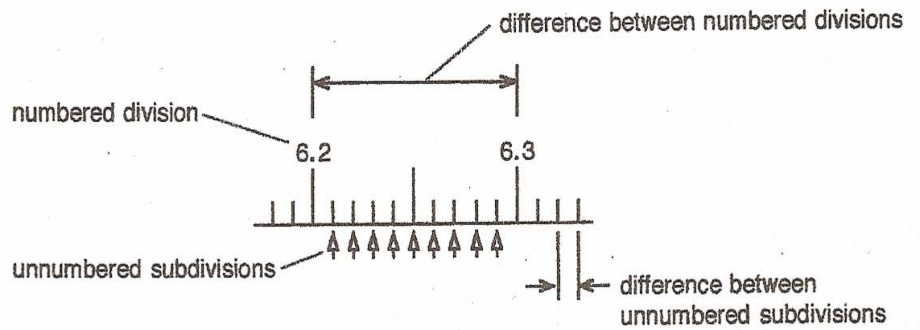
1. Convert 6 mg / L to kg / mL?
2. Convert 1 cm / ns to km / s
3. Convert 5 cg / ds to mg / s?
4. Convert 1 mg / dL to g / L

Uncertainty / How to read a Scale:

Last section ☺ The dreaded how to read a scale!!! As you may notice, I have taken this section right from textbook as they do an excellent job explaining the topic and I was a little lazy in scanning the pictures in ☺

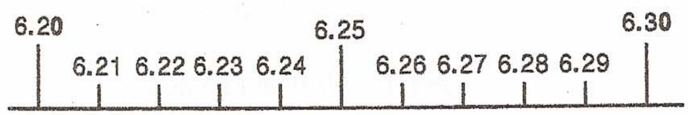
Before learning more about uncertainty, you must first be able to read a scale properly.

IMPORTANT: The following terms are used –



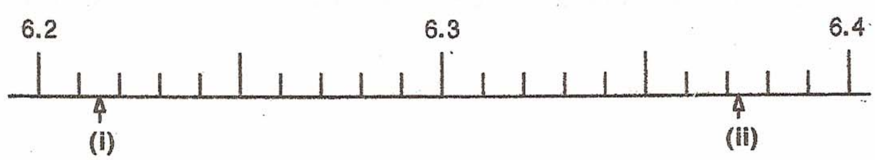
Both the numbered divisions and unnumbered subdivisions are **CALIBRATED** DIVISIONS because the overall scale has been "marked off" or "calibrated" at regular intervals.

If the unnumbered subdivisions ***were numbered***, they would be labelled as shown below.



The "numbered divisions" would then read "6.20" and "6.30", rather than "6.2" and "6.3". The unnumbered subdivisions allow two more decimal places to be read. For example, the numbered divisions above differ in the first decimal place and the unnumbered subdivisions allow a reading to the second decimal place. The estimated distance between unnumbered subdivisions allows a reading to the third decimal place.

EXAMPLES: **(a) What is the value of (i) and (ii) on the following centimetre scale?**



The first two digits of (i) are 6.2 and the first two digits of (ii) are 6.3. The problem is to read the next two digits for each point.

FIRST: Find the difference between each NUMBERED DIVISION.
In the above example: 6.3 – 6.2 = 0.1 cm.

SECOND: Find the number of unnumbered subdivisions between numbered divisions and calculate the value of each unnumbered subdivision. Each numbered division above has 10 subdivisions and each unnumbered sub–division is

$$\frac{0.1\text{ cm}}{10} = 0.01\text{ cm}.$$

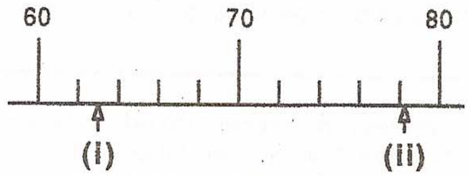
Since the unnumbered subdivisions have a value of 0.01 cm, the value at (i) is a little more than 6.21 cm and the value at (ii) is a little more than 6.37 cm.

THIRD: Estimate how far along their respective unnumbered subdivisions (i) and (ii) are; this gives a reading to the next decimal place, which is the uncertain digit.

Reading at (i): The 3 certain digits are "6.21". The pointer is half–way from 6.21 to 6.22, so the uncertain 4th digit is probably a "5". Therefore, the reading is **6.215 cm.**

Reading at (ii): The 3 certain digits are "6.37". The pointer is $^3/_{10}$ of the way from 6.37 to 6.38, so the uncertain 4th digit is probably a "3". Therefore, the reading is **6.373 cm.**

(b) What is the value of (i) and (ii) on the following centimetre scale?



The value of (i) lies between 60 and 70 cm; the value of (ii) lies between 70 and 80 cm.

FIRST: The difference between numbered divisions is 10 cm.

SECOND: There are 5 subdivisions between each numbered division, so each unnumbered subdivision is equal to

$$\frac{10\text{ cm}}{5} = 2\text{ cm}.$$

THIRD: Pointer (i) lies between 62 and 64, and pointer (ii) is between 78 and 80.

Reading at (i): The pointer is about half–way ($^5/_{10}$) between 62 and 64. Therefore the reading is more than 62 cm by $^5/_{10}$ of 2 cm (the subdivision value).

reading = 62 cm + 0.5 x 2 cm = **63.0 cm**

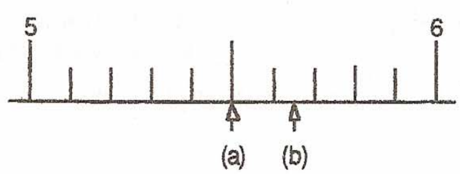
(The numbered divisions differ by "tens", the unnumbered subdivisions are read to the "ones" and an estimate between unnumbered subdivisions are read to "tenths".)

Reading at (ii): The pointer is about $^1/_{10}$ of the way from 78 to 80. Therefore the reading is more than 78 by $^1/_{10}$ of 2 cm.

reading = 78 cm + 0.1 x 2 cm = **78.2 cm**

There is one last problem associated with reading scales that must be examined: **what to do when the "pointer" is exactly on one of the markings.**

EXAMPLE: Look at the centimetre ruler and indicated values below.



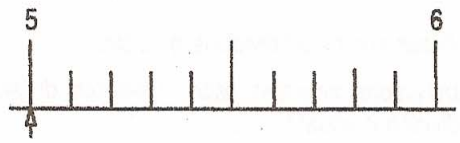
The pointer at (a) seems to indicate a value of 5.5 cm but that is ***not*** the correct value. Look at the pointer at (b). Since the value at (b) is about 5.65, both the value at (a) and (b) can be guessed to the nearest **0.01 cm.** The value for (a) must be given as **5.50 cm.**

BE VERY CAREFUL WHEN A VALUE APPEARS TO COINCIDE EXACTLY WITH A MARKING ON A MEASURING DEVICE. The following procedure should help when such a situation occurs.

THE PROCEDURE FOR CORRECTLY READING MEASURING SCALES WHEN A POINTER IS EXACTLY ON A NUMBERED DIVISION

- Determine the value that the measurement seems to have.
- Pretend you have a value in between two of the unnumbered subdivisions on your measuring device.
- Determine how many decimal places you could read off the measuring device at the "in–between value".
- Add a sufficient number of zeroes to the actual reading to give you the correct number of decimal places for your reading.

In the example above, the intervals between unnumbered subdivisions can be read to 0.01 cm; that is, to 2 decimal places. The reading appears to be 5.5, which is only 1 decimal place, so an extra zero is added to get the value: **5.50 cm.** Similarly, consider the value of the measurement below.



The value seems to be 5 cm, but the previous example shows that an "in–between value" can be read to 0.01 cm (2 decimal places) and so 2 extra zeroes are added to arrive at the final reading: **5.00 cm.**

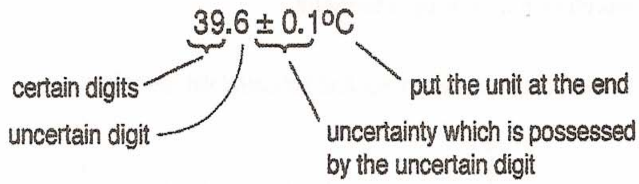
EXPERIMENTAL UNCERTAINTY

Having seen how to deal with significant figures and make proper readings, the next step is to learn about experimental uncertainty.

Definition: The experimental uncertainty is the estimated amount by which a measurement might be in error.

E. When adding an uncertainty to a measurement, the uncertainty goes after the measured value but before the unit.

EXAMPLE: Assume that a measured temperature is 39.6°C and the uncertainty in the measurement is ± 0.1°C (Part F shows how to estimate the uncertainty). The measurement and uncertainty are shown below.



NOTE: If the uncertain digit is in the first decimal place, the uncertainty will be in the first decimal place also.

INTERPRETATION OF UNCERTAINTIES

When a measurement is said to be 39.6 ± 0.1°C, this implies that the actual value most likely lies in the range from (39.6 – 0.1)°C to (39.6 + 0.1)°C; that is, from 39.5°C to 39.7°C.

Similarly the measurement 15.55 ± 0.02 mL implies a volume in the range from 15.55 – 0.02 = 15.53 mL to 15.55 + 0.02 = 15.57 mL.

If only the range of probable values is known, for example 88.0 g to 89.0 g, the uncertainty is simply one–half of the stated range.

range = 89.0 – 88.0 = 1.0 g
uncertainty = $^1/_2$(1.0) = 0.5 g

The measurement reported is the MIDPOINT of the range, plus/minus the uncertainty. The midpoint of the range is simply the AVERAGE of the endpoints of the range.

midpoint = $^1/_2$(88.0 + 89.0) = 88.5 g

Therefore, the reported measurement is **88.5 ± 0.5 g.**

Similarly, if the range is 15.0 g to 15.5 g then the midpoint of the range is 15.3 g (to one decimal point) and the uncertainty is $^1/_2$ (0.5) = 0.3 g (to one decimal point). [Yes, 15.3 ± 0.3 g predicts the range as 15.0 – 15.6 g, but the range, midpoint and uncertainty are all recognized as simply "good guesses".]

IMPORTANT: The place values (tens, units, first decimal, etc.) of the experimental uncertainty and the first uncertain digit of a measurement must agree with each other.

EXAMPLES: 15.5°C ± 0.01°C is ***wrong*** because the measurement is only read to the nearest 0.1°C, which means the first decimal place is uncertain. An uncertainty of 0.01°C implies the measurement can be read with at least partial certainty to the second decimal place.

5.52 ± 0.01 mL is ***correct*** because the last (uncertain) digit in the measurement and the uncertainty quoted are both to the second decimal place.

NORMALLY USE UNCERTAINTIES TO THE NEAREST 0.1 OF THE SMALLEST UNNUMBERED SUBDIVISION. ***If*** you can only estimate a value to the nearest ±0.2 or even ±0.5 of the smallest unnumbered subdivision, feel free to do so, but be prepared to justify your decision. (Sometimes values are hard to read.)

Now that you know HOW to read a scale, estimating the uncertainty is relatively easy.

EXAMPLE: Look at the centimetre scale below.

The pointer indicates a value of 6.214, and the last digit ("4") is somewhat uncertain. **The place value (third decimal place) of the experimental uncertainty and the first uncertain digit of a measurement must agree with each other.** Therefore the value and uncertainty are

6.214±0.001 cm .

EXAMPLE: The value on the scale below is 2.26 cm and $^1/_{10}$ of an unnumbered subdivision is 0.02 cm.

Therefore, the value and uncertainty are **2.26 ± 0.02 cm .**