Chemistry Review Section

Pages 3 to 33

"Quantum Chemistry"

Target Completion Date: October 1

About Slide Icons

Pages with a PINK background are supplementary . Not material for a test!

important information.

- You should either **note** or **highlight** items from this slide. Some items from this slide **WILL** be on tests!

Very Important Sample Problems

- **Always hand-copy** important sample problems in your note book, and refer back to them when doing assignments. Similar problems will be on tests!

Look at this! (usually charts, diagrams or tables)

- You don't need to copy or memorize this, but you **must** read and understand the diagrams or explanations here. Concepts **will** be tested, but not the details.

Information only. Don't copy!

- This is usually background information to make a topic more interesting or to fill in details, or to give examples of how to use a table. Not directly tested.

Review Stuff

- Not part of the material you will be tested on, but you are expected to remember this from grade 10. It may be indirectly tested.

Supplementary stuff

- Not material covered this year.

Conversions

- You must be able to do **<u>ALL</u>** standard metric conversions, especially:
  - Litres to millilitres, millilitres to litres
  - Grams to kilograms, kilograms to grams
- Other conversions you will learn during the course of the year:
  - Temperature: degrees celcius (°C) to kelvins (K)
  - Pressure: kilopascals (kPa) to millimetres (mmHg)

Quick Conversions

Prefix	means
mega (M)	million
…	100000
…	10000
kilo (k)	1000
hecto (h)	100
deca (da)	10
… unit	1
deci (d)	0.1
centi (c)	0.01
milli (m)	0.001
…	0.0001
…	$\times 10^{-5}$
micro (μ)	$\times 10^{-6}$

The table on the left gives the eight most commonly used prefixes in the metric system.

It also includes five rows that do not have prefixes.

The middle row is for the unit: metre, litre, gram, newton, or any other legal metric unit.

This table can be used to quickly convert from one metric amount to an equivalent. Make a copy of this table on the formula sheet, and learn how to use it.

Lets do an example. Let's find how many centimetres there are in 2.524 km

Conversion: 2.524 km → ? cm

2.52400 cm ←Add extra zeros if necessary

There are five steps in the table between "kilo" and "centi", so we have to move the decimal five places to the right. If we were going up the table we would move left.

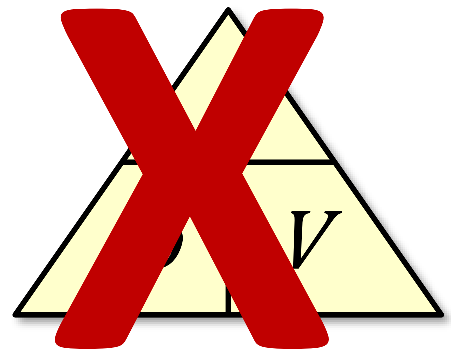
Answer: 2524 km = 252 400 cm

Density

- Density is the relationship between the volume of an object and its mass. Density is an important characteristic property of matter.
- This is a review formula from last year:

$$\boxed{\rho = \frac{m}{V}}$$

or



Where: $\rho =$ the density of the object, in g/cm^3 or g/mL
m = the mass of the object, in g
V = the volume of the object, in cm^3 or mL

$$\boxed{\rho_W = 1\,{}^{\mathrm{g}}/_{\mathrm{mL}} = 1\,{}^{\mathrm{g}}/_{\mathrm{cm}^3}}$$

The density of water is 1 g/mL. This is not true of other substances. Objects with less density than water will float. Objects with greater density will sink.

Solving Problems

- When solving Chemistry problems on a test or exam, it is important not only to find the correct answer, but to **justify it**. While solving the problem you should:
  1. Show your **data**, the information you used to solve the problem.
  2. Show your work, including the **formulas** you used and the **substitutions** you made.
  3. Write an **answer statement**, a sentence that clearly states your final answer.
  4. Include the correct **units** for your answer. Never just give a number—you must specify what the number means!

Suggested Solution Method

Problem: A block of material has a length of 12.0 cm, a width of 5.0 cm, and a height of 2.0 cm. Its mass is 50.0 g. Find its density.

Arrange your solution like this:

List all the information you find in the problem, complete with units, and the symbols.

Data:

l	= 12 cm.
w	= 5.0 cm
h	=2.0 cm
m	=50g
V	= ?

To Find:

ρ (density)

Write down all the formulas you intend to use:

Formulas: $V = lwh$ $\rho = \frac{m}{V}$

Show the substitutions you make, and enough of your calculations to justify your solution:

Calculations:

V =12cm x 5cm x 2 cm
= 120 cm^3

ρ = 50 g / 120 cm^3
= 0.42 g/cm^3

Always state your answer in a complete sentence, with appropriate units.

Answer: The density of the block is 0.42 g/cm^3 (or 0.42 g/mL)

Problems on Conversions and Density

1. Convert the following:
   a) 125 mL to L
   b) 450 g to kg
   c) 2.5 L to mL
   d) 30 mL to L
   e) 4500 mL to L
   f) 1.35 kg to g
   g) 75 mL to L
   h) 0.035L to mL
   i) 0.56L to mL
2. Find the density of a 4cm x 3cm x 2cm block that has a mass or 480 g. Justify your solution.
3. Find the width of a cube whose density is 5 g/cm^3 and whose mass is 135 g. Justify your solution.

Also: Do the worksheets entitled “Density” and “Metric Conversions”

Overview: Uncertainty
The Inherent Errors of Instruments

All measurements are made using instruments, and all instruments have imperfections that limit their precision. This is often called the "error" of the instrument, although I prefer the term "uncertainty", since this is not a mistake made by the observer, but rather an unavoidable reality of an imperfect world. Sometimes when we make measurements we are asked to record the error or uncertainty involved.

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Absolute Uncertainty (AU)

In math, numbers are considered pure, abstract things. In math, 2.00, 2.0 and 2 are considered the same, they all represent perfect number 2.

In science, numbers are considered to be measurements, and all measurements have some degree of uncertainty. They are seldom considered perfect!

In science, 2 mL, 2.0 mL and 2.00 mL are different!

All instruments that we use to make measurements have an inherent error or *absolute uncertainty*. On some instruments, the absolute uncertainty is marked, on other instruments we make the following assumption:

Assumption: The **absolute uncertainty** of a measurement is usually* one half of a measuring instrument's smallest graduation.

*at university level, or when using high-quality equipment AU measurements may be expected to be one fifth of the measure between the smallest marking instead of one half!

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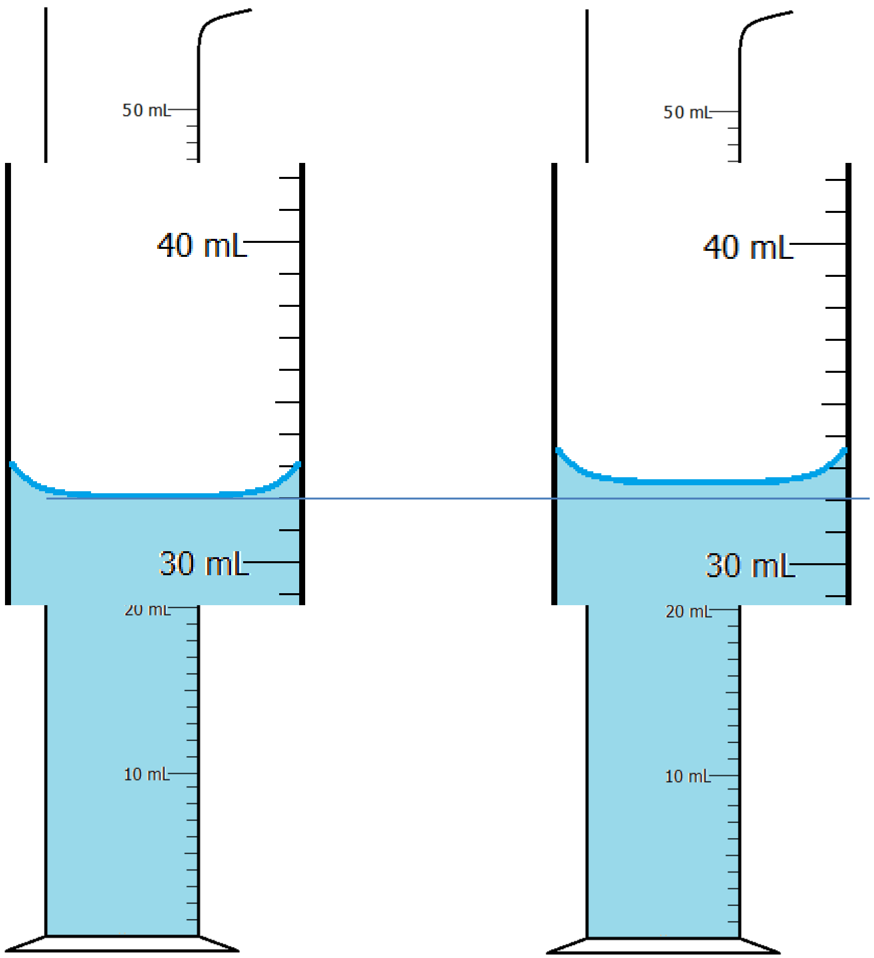
Example of Uncertainty.



- At first glance, the two graduated cylinders here seem identical, but look closer.
- The first one has a measurement of 32.0 ± 0.5 mL
- The second one 32.5 ± 0.5 mL
- It is NOT correct to say that the first measurement is just 32 mL!

How to Record Absolute Uncertainty

Plus-minus sign

Unit

(32.5 ±0.5)mL

A pair of parenthesis <u>may</u> be placed around the measurement.

Doubtful, but Significant digit

Absolute Uncertainty

- When you first look at the second graduated cylinder, it appears to contain 32 mL of liquid.
- Looking closer, you see it is about halfway between 32 and 33 mL, so you record the .5
  - If you had seen it was just below the 32 instead of just above it, you would record 31.5. If you still see it as exactly 32 even after a closer look, then record it as 32.0
- Then you write the **absolute uncertainty**, the allowable error of the instrument – usually* half the measure between the smallest markings.
  - In this case, the smallest markings represent one millilitre, so half the measure (0.5 mL) is the uncertainty.

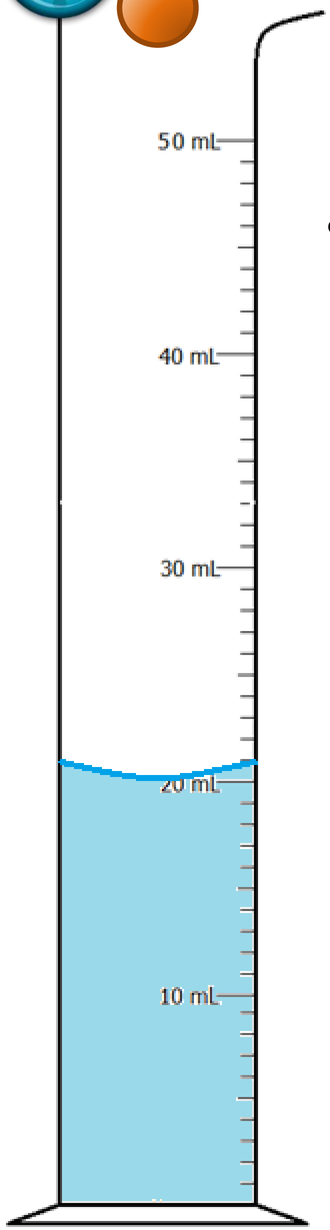
Notes! Please write!

Absolute uncertainty (AU)

- is the allowable error of the instrument. Unless stated otherwise we will assume it is ½ the measure between the smallest markings.

  eg. (32.5 $\pm$ 0.5) mL

- The 0.5 tells you that you must round to the 1st decimal place.



Adding & Subtracting with Absolute Uncertainties

- Frequently we make two measurements and subtract them to find a difference (*Δ*). When we subtract numbers that have an uncertainty we must <u>ADD</u> the absolute uncertainty values!
  - Eg. While doing a density experiment we add an object to a graduated cylinder. The reading of the cylinder changes from (20.5±0.5)mL to (24.0±0.5)mL. When adding two numbers with uncertainties, we also <u>ADD</u> the uncertainty.

$$AU_T = \Sigma AU \qquad \text{or} \qquad AU_T = AU_1 + AU_2 + \ldots$$

  - The volume difference (*Δ*V) is (3.5±1.0)mL but because the uncertainty is larger we write (4 ± 1)mL.

<u>Notes! Please write!</u>

<u>Absolute uncertainty</u> (AU)

- is the allowable error of the instrument. Unless stated otherwise we will assume it is ½ the measure between the smallest markings.

  eg. (32.5 ± 0.5) mL

- The 0.5 tells you that you must round to the 1st decimal place.
- When adding or subtracting #s with uncertainties, we must add the uncertainties.

  Eg. $(24.0 \pm 0.5)\text{mL} - (20.5 \pm 0.5)\text{mL} = (3.5 \pm 1.0)\text{mL}$

  $= (4 \pm 1)\text{mL}$

WS1

Due next class

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Relative Uncertainty

- Sometimes it is useful to know how much uncertainty we have compared to the original measurement. To do this we can calculate the relative uncertainty (RU).
- RU of a measurement equals the absolute uncertainty divided by the absolute value of the original measurement.
- The resulting decimal number is often converted to a percentage

$$\boxed{RU = \frac{AU}{|measurement|}}$$

Click here for details on UNCERTAINTY.

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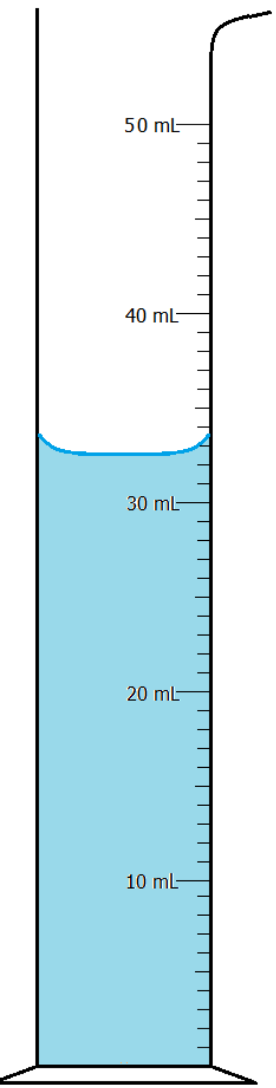
Example of Relative Uncertainty



- The graduated cylinder has a reading of (32.5±0.5) mL (absolute)
- To find its relative uncertainty, divide:

  $0.5 \div 32.5 = 0.01538461$
- Round off to a reasonable number of decimal places and convert to a percent:

  $0.015 \times 100 = 1.5\%$
- Write it like this:

  32.5 ml ±1.5%

Parenthesis is **NOT** used for Relative Uncertainty expressed in %

The nice thing about relative uncertainties it that they show you how small your error actually is.

Not in TEXT!

Multiplying and Dividing with Uncertainties

- When you multiply and divide measurements, you cannot use Absolute Uncertainties.
- Instead, we must **add** the Relative Uncertainties after we multiply or divide.
- We use the Relative Uncertainty to determine the Absolute Uncertainty!
- This will then tell us how to round our final answer!

Not in TEXT!

Multiplying & Dividing with Uncertainties

<u>Density example</u>: (58.3±1.0)g ÷ (32.5±0.5)mL.

- Step 1: Do the calculation: 58.3 ÷ 32.5 = 1.79385

(keep 4-6 digits!)

- Step 2: add the RU values.

$$(1.0/58.3 + 0.5/32.5) = ?$$

- Step 3: multiply the RU with your answer:

$$(1.0/58.3 + 0.5/32.5) \times 1.79385$$

$$= 0.0583670$$

Step 4: round to ONE significant digit.

The new AU is 0.06!

Final answer: 1.79 ± 0.06 g/mL

Notes! Please write!

Relative uncertainty (RU)

- RU of a measurement equals the absolute uncertainty divided by the absolute value of the original measurement.

$$RU = \frac{AU}{|\text{measurement}|}$$

eg. 32.5 $\pm$ 0.5 mL

RU = 0.5/32.5 = 0.0153846... Or 1.5%

- The RU allows you to determine the AU after a calculation involving multiplication or division.

Notes! Please write!

Density example: (58.3±1.0)g ÷ (32.5±0.5)mL.

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

$$= \frac{58.3}{32.5}$$

$$P = 1.79385$$

$$\Delta P = \left(\frac{\sigma m}{m} + \frac{\sigma v}{v}\right) P$$

$$= \left(\frac{1.0}{58.3} + \frac{0.5}{32.5}\right) \times 1.79385$$

$\Delta P = 0.0583670$ round to one significant digit

$\Delta P = 0.06$

Therefore you must round to two decimal places!

Final answer: 1.79 ± 0.06 g/mL

WS2 AU & RU calculations

Overview: Significant Figures

Knowing how much to round an answer.

In the sciences, we have an particular way of determining how much precision we need in the observations and answers we record.

The method of rounding is called **significant digits** or **significant figures**.

There is a detailed section in the appendix to your textbook on pages 394 to 397.

Correct precision

- It is considered **improper** in science to imply that a measurement is more precise than it really is.
    - If you have a graduated cylinder that is marked in 1 mL increments, you can record it to between the two smallest marks: eg. 32.0 ±0.5 mL or 32.5 ±0.5 mL are acceptable readings.
    - With the same graduated cylinder, it would be **wrong** to write 32 ±0.5 mL or 32. ±0.5 mL or even 32.00 ±0.5 mL
- In science 32 mL, 32.0 mL and 32.00 mL have <u>different</u> meanings with respect to precision.

Notes! Please write!

Significant Figures (or digits):

- Tell you how precise an observation is.
- They are a guide to how much we should round off a calculated answer.
- This is useful when you are doing calculation problems where the uncertainty is not provided, but instead needs to be inferred by the #s given!

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Notes! Please write!

Rules for Significant Figures :

1. All non-zero digits are **ALWAYS** significant
2. Zeros between significant digits are **ALWAYS** significant.
3. Zeros at the beginning of a number are **NEVER** significant.
4. Zeros at the end of a number **MAY** be significant.
5. Exponents, multiples, signs, absolute errors etc. are **NEVER** significant.

Examples of Rule 1, 2 and 3

Rule 1. Non-zero digits are **ALWAYS** significant.

1.234

145

19567.2

Rule 2. Zeros between significant digits **ARE** significant.

1001

5007.4

20000.6

Rule 3. Zeros at the beginning are **NEVER** significant.

007

0.0000005

0.025

Explaining Rule 4

Rule 4. Zeros at the end of a number **MAY** be significant.

Your textbook says that they are **ALWAYS** significant, but this is contrary to what most textbooks say.

If there is a **decimal point**, there is no problem. All textbooks agree, the zeros are **ALL** significant.

3.00000	has 6 significant digits
5.10	has 3 significant digits
10.00	has 4 significant digits

If there is **NO** decimal, the situation is **ambiguous,** and a bit of a **JUDGEMENT CALL**. If you trust the source to be precise, then you count all the zeros at the end. If you have reason to believe the person was estimating, then you don't count the zeros at the end.

5000	has 1 to 4 significant digits
250	has 2 or 3 significant figures
123 000 000	has 3 to 9 significant figures

In a test situation, assume the numbers are precise, unless something in the question states otherwise.

Estimated source

Trusted precise source

Rule 5

Rule 5: Exponents and their bases, perfect multiples, uncertainties (error values), signs etc. are **NEVER** significant.

6.02 x 10^{23} has 3 significant digits

504.1 mL x 3 has 4 significant digits (the 3 is not measured)

5.3 ±0.5 mL has 2 significant digits

– **5.432** x 10^{-5} has 4 significant digits

π x **3.54** cm has 3 significant digits (π is not a measurement)

In each case, the **blue** part is significant, the green part is **NOT** significant.

Note: The term Significance in this usage is not the same as importance. A digit may be “insignificant” but still very important. The significant digits guide you to the correct way of rounding numbers to show precision. The insignificant digits may serve as “placeholders”, making sure the decimal point is in the right place. An important job indeed, but not one that adds to the precision of the answer.

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Notes! Please write!

Rules for Significant Figures :

1. All non-zero digits are **ALWAYS** significant

   21 = 2 sig. figs

2. Zeros between significant digits are **ALWAYS** significant.

   2001 = 4 sig. figs

3. Zeros at the beginning of a number are **NEVER** significant.

   0.04 = 1 sig. figs

4. Zeros at the end of a number **MAY** be significant.

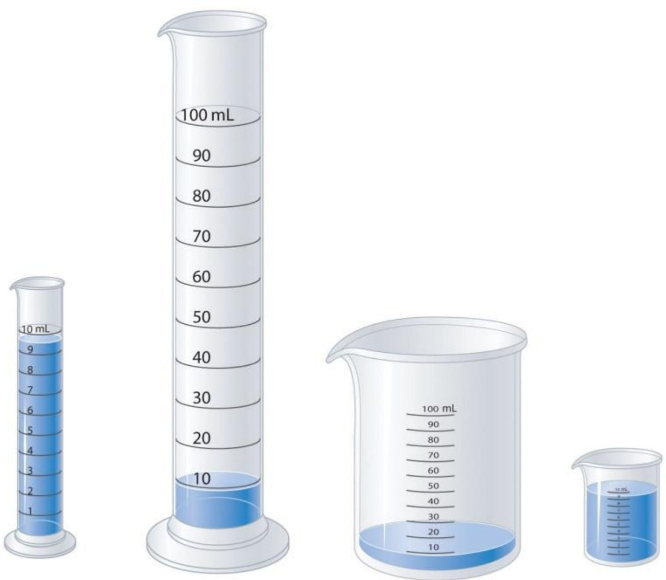
   21.0 = 3 sig. figs

5. Exponents, multiples, signs, absolute errors etc. are **NEVER** significant.

Not in TEXT!

Avoiding Ambiguity

- We mentioned before that measurements ending in zeros with no decimal were ambiguous. Their accuracy depends on how they were measured, and that doesn't always show up in the number.
- For example, if you measure 200 mL in a cylinder with markings of 1 mL it will be more accurate than if you measured it in one with markings 10 mL apart, and much better than a beaker whose markings were 100 mL apart.



How can we show someone reading our lab notes what degree of precision our 200 mL really means?

One answer is Scientific Notation!

Same Number, Different Precision

Number	Precise to
200.000	6 significant digits
200.00	5 significant digits
200.0	4 significant digits
200 *	**Ambiguous**, 1 to 3 SD*
2.00×10^2	3 significant digits
2.0×10^2	2 significant digits
2×10^2	1 significant digit

*This could represent one significant digit, or two significant digits, or three significant digits depending on how precise the measuring equipment was. If I am careless enough to write a number like this on a test, you should assume I mean 3 S.D., but you have my permission to point out my mistake!

Do not use numbers like **200 mL.** Instead write them in scientific notation.

2.0×10^2 mL means you measured it to the nearest 10 mL (2 S.D.)

2.00×10^2 mL means you measured it to the nearest 1 mL (3 S.D.)

2.0000×10^2 mL means you measured it to the nearest 0.01 mL… a very fine level of accuracy indeed!

Another way of showing the difference is to include the absolute uncertainty!

Math with Significant Figures

- Adding and Subtracting:
  - All units must be the same (can't add different units!)
  - Line up all the measurements at their decimal points.
  - Add or subtract as normal.
  - Round off all numbers to match the short
    decimals.

Decimals lined up

Round off

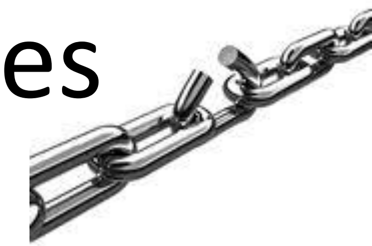
Example: add the following measurements.

This unit is not the same as the others!
(litres vs. millilitres)

~~5.34576 L~~	→	5345.76 mL
55.143mL	→	55.143mL
547.1 mL	→	547.1 mL
		5948.003 mL

The answer is 5948.0 mL. Note that the answer has 5 sig. digits, even though one of the measurements had only 4 sig. digits. This can happen with addition.

Math with Significant Figures



- Multiplication and Division:
  - Different units may be multiplied or divided if there is a formula to justify it.
  - The main rule in multiplying and dividing is that you cannot have an answer with more significant digits than your “weakest” measurement (the one with fewest significant digits)
  - After doing the math, round off your answer to match the weakest measurement.

Weakest measurement **only 3 S.D.**

Multiply 2.53 g/mL by 75.35 mL

2.53 x 75.35 = 190.6355

=191 g

Answer has only 3 S.D.

Justification: $m=\rho V$

About the unit: $\frac{g}{\cancel{mL}}$ x $\cancel{mL} = g$

You are the weakest link. Goodbye!

Math with Significant Figures

- Perfect numbers
  - Occasionally we consider a number to be perfect. For example, if you are told to "double a quantity" the 2 you multiply by is considered perfect. It does not affect the significant digits of your answer, neither increasing or decreasing them. Mole ratios in stoichiometry are also considered perfect, as are constants like pi. Perfect numbers have <u>no units</u>.
- Other operations
  - Generally, use the same rule as for multiplying for square roots, exponents etc. That is, your answer can have no more significant digits than your weakest measurement.
- Mixed operations
  - When doing mixed operations in science, you will usually do the additions or subtractions first (there should be brackets around them), then the other operations.

Notes! Please write!

- Adding and Subtracting:
  - All units must be the same (can't add different units!)
  - Line up all the measurements at their decimal points.
  - Add or subtract as normal.
  - Round off all numbers to match the shortest number of decimals.
- Multiplication and Division:
  - You cannot have an answer with more significant digits than your "weakest" measurement (the one with fewest significant digits)
  - After doing the math, round off your answer to match the weakest measurement.
- Combination
  - Follow BEDMAS
  - Trump #s before +/-!

- WS3
- Significant figures

Problems on Significant Figures

1. How many significant digits are in each measurement:
   a) 123.45 mL
   b) 4.500×10^3 mL
   c) 007 spies
   d) times 5
   e) 0.0023 m
   f) 4000 kg
2. A Coulter counter is a device which counts the blood cells in a sample as they pass through a beam of light. A laboratory technician records 20000 wbc in a blood sample. At a demonstration a reporter says there were 20000 protesters. Both numbers are the same, which one has more significant figures? Why?
3. Find the volume of a cube that measures 2.3 cm by 3.55 cm by 2.14159 cm.
4. Add the measurements: 2.500 kg, 354.2 g, 153.78 g

Also: Do the worksheet entitled "Significant Figures"