

Uncertainty

Answer the questions below.

A student measured the volume of hydrogen given off in the reaction between hydrochloric acid and magnesium. Their results are shown below.

- Identify an error in this results table.

The volume of hydrogen produced does not have a unit.

- Calculate the mean of these results.

$$\text{Mean} = \frac{(15.0 + 14.8 + 14.5 + 14.9)}{4}$$

$$\text{Mean} = 14.8$$

- Calculate the range of these results.

$$\text{Range} = 15.0 - 14.5$$

$$\text{Range} = 0.5$$

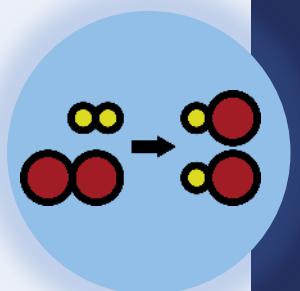
- Write a word equation for this reaction.

Magnesium + hydrochloric acid \rightarrow magnesium chloride + hydrogen

- Identify the reactants and products of this reaction.

Magnesium and hydrochloric acid are the reactants, magnesium chloride and hydrogen are the products.

Trial	Volume of hydrogen produced
1	15.0
2	14.8
3	14.5
4	14.9



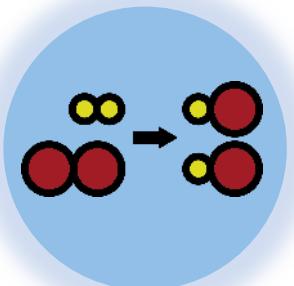
Uncertainty

C3.2.6

Science
Mastery

- C3.2.1 Prior Knowledge Review
- C3.2.2 Relative Formula Mass
- C3.2.3 Percentage by Mass
- C3.2.4 Conservation of Mass
- C3.2.5 Balancing Equations
- **C3.2.6 Uncertainty**
- C3.2.7 Introducing Concentration

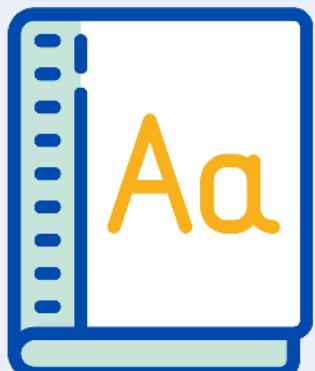
- C3.2.8 Concentration Calculations
- C3.2.9 Soluble Salts
- C3.2.10 Making Soluble Salts
- C3.2.11 Making Soluble Salts 2



Following this lesson, students will be able to:

- Describe the two ways of estimating uncertainty
- Estimate the uncertainty from a measuring instrument
- Estimate the uncertainty from a set of repeat measurements

Key Words:



uncertainty

instrument

repeat

resolution

range

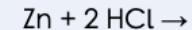
This is the fix-it portion of the lesson

The **fix-it** is an opportunity to respond to gaps in knowledge, especially those identified by the previous lesson's exit ticket.

- The teacher should customise this slide as needed, to facilitate
 - **reteach, explanation, demonstration or modelling** of ideas and concepts that students have not yet grasped or have misunderstood.
 - **practise** answering specific questions or of key skills.
 - **redrafting** or **improving** previous work.

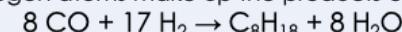
Answer the questions below.

1. Predict the products of the following equation:



- A. $\text{ZnCl}_2 + \text{H}_2$
- B. $\text{ZnCl} + \text{H}_2$
- C. $\text{ZnCl} + \text{H}$

2. How many hydrogen atoms make up the products of this reaction?



- A. 28
- B. 16
- C. 34

3. Which equation demonstrates the law of conservation of mass?

- A. $\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
- B. $\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$
- C. $\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$

What is uncertainty?

Scientific uncertainty means there is a **range of possible values** within which the **true value** of a measurement lies.

In any scientific investigation that involves a measurement, there is always some **uncertainty** about the result obtained.

A coach recorded the time taken for an athlete to run 100 metres 4 times.

The coach measured the following times:

We can calculate the **mean** time taken, and we can also **estimate** the **uncertainty**.



Trial	Time (s)
1	10.58
2	10.64
3	10.59
4	10.62

Repeated measurements

We can estimate uncertainty of measurements from the **range** of repeated measurements.

The uncertainty can be estimated as **half** the **range**.

Step 1: Calculate the mean.

Step 2: Calculate the range by subtracting the smallest value from the biggest value.

Step 3: Divide the answer by 2.

Step 4: Write the mean and the uncertainty after the plus or minus symbol.

Trial	Time (s)
1	10.58
2	10.64
3	10.59
4	10.62

$$\text{Mean} = \frac{(10.58 + 10.64 + 10.59 + 10.62)}{4}$$

$$\text{Mean} = 10.61 \text{ s}$$

$$\text{Range} = 10.64 - 10.58$$

$$\text{Range} = 0.06 \text{ s}$$

$$\text{Uncertainty} = \frac{0.06}{2}$$

$$\text{Uncertainty} = 0.03 \text{ s}$$

$$\text{Time} = 10.61 \text{ s} \pm 0.03 \text{ s}$$

Example 2

We can estimate uncertainty of measurements from the **range** of repeated measurements.

The uncertainty can be estimated as **half** the **range**.

Step 1: Calculate the mean.

Step 2: Calculate the range by subtracting the smallest value from the biggest value.

Step 3: Divide the answer by 2.

Step 4: Write the mean and the uncertainty after the plus or minus symbol.

Trial	Volume (cm ³)
1	15
2	16
3	18

$$\text{Mean} = \frac{(15+16+18)}{3}$$

$$\text{Mean} = 16.33 \text{ cm}^3$$

$$\text{Range} = 18 - 15$$

$$\text{Range} = 3 \text{ cm}^3$$

$$\text{Uncertainty} = \frac{3}{2}$$

$$\text{Uncertainty} = 1.5 \text{ cm}^3$$

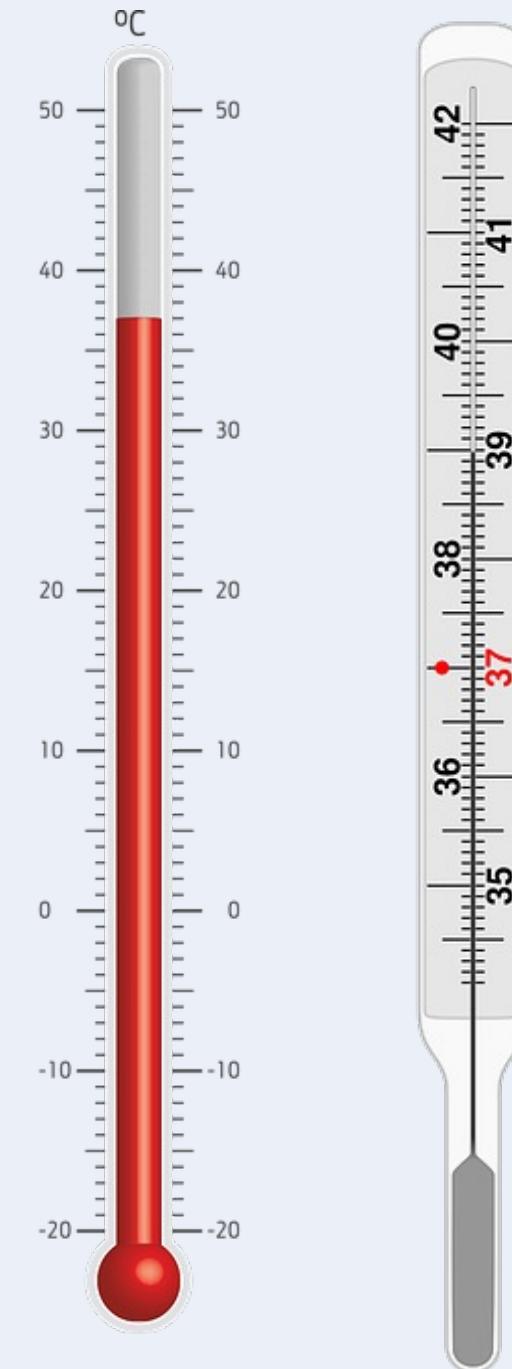
$$\text{Volume} = 16.33 \text{ cm}^3 \pm 1.5 \text{ cm}^3$$

Resolution of instruments

We can also estimate uncertainty of measurements from the **resolution** of the **instrument**.

The uncertainty can be estimated as **half** the **smallest interval**.

For a thermometer with resolution of 1 °C, the uncertainty is 0.5 °C.



Estimating the uncertainty

A student investigated the friction generated by different surfaces.

Calculate the mean and estimate the uncertainty of each set of data.

Carpet:

$$\text{Mean} = \frac{3.0+2.8+3.2}{3}$$

$$\text{Mean} = 3.0 \text{ N}$$

$$\text{Range} = 3.2-2.8$$

$$\text{Range} = 0.4$$

$$\text{Uncertainty} = \frac{\text{Range}}{2}$$

$$\text{Uncertainty} = 0.2 \text{ N}$$

$$\text{Mean} = 3.0 \text{ N} \pm 0.2 \text{ N}$$

Wood:

$$\text{Mean} = \frac{2.5+2.4+2.3}{3}$$

$$\text{Mean} = 2.4 \text{ N}$$

$$\text{Range} = 2.5-2.3$$

$$\text{Range} = 0.2$$

$$\text{Uncertainty} = \frac{\text{Range}}{2}$$

$$\text{Uncertainty} = 0.1 \text{ N}$$

$$\text{Mean} = 2.4 \text{ N} \pm 0.1 \text{ N}$$

Material	Repeats	Force (N)
Carpet	1	3.0
	2	2.8
	3	3.2
Wood	1	2.5
	2	2.4
	4	2.3
	1	1.2
Metal	2	1.2
	3	1.3

Carpet:

$$\text{Mean} = \frac{1.2+1.2+1.3}{3}$$

$$\text{Mean} = 1.23 \text{ N}$$

$$\text{Range} = 1.3-1.2$$

$$\text{Range} = 0.1$$

$$\text{Uncertainty} = \frac{\text{Range}}{2}$$

$$\text{Uncertainty} = 0.05 \text{ N}$$

$$\text{Mean} = 1.23 \text{ N} \pm 0.05 \text{ N}$$

Sources of Uncertainty

A group of students are investigating the effect of temperature on the number of spoons of sugar that can be dissolved in a cup of tea.

- 1. How could these students estimate the uncertainty of their measurements?**
- 2. What would the possible sources of uncertainty be in their investigation?**
- 3. How could students reduce the uncertainty in their investigation?**



Drill

1. Define uncertainty.
2. How do you calculate mean?
3. How do you calculate the range?
4. How do you calculate uncertainty?
5. What does 10 ± 0.5 mean?
6. What is resolution?
7. What is the resolution of this thermometer?
8. What is the uncertainty of this thermometer
9. How can you increase the accuracy of your measuring device?



Check for understanding

Drill answers

1. There are a range of possible values within which the true value of a measurement lies
2. Add up the values and divide by however many there are
3. Highest value - lowest value
4. Range divide by two
5. The true value lies somewhere between 9.5 and 10.5
6. How much a value goes up by on a measuring device
7. 0.1°C
8. 0.5°C
9. Have a greater resolution, so instead of going up in 1 go up in 0.1



Check for understanding

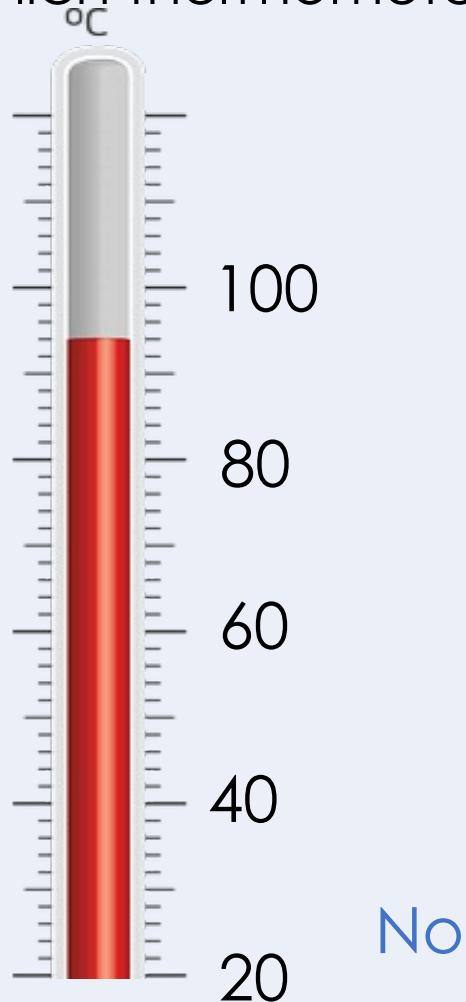
I : Uncertainty

A group of students are investigating the volume hydrochloric acid needed to neutralise calcium carbonate needed to neutralise. They are unsure about the apparatus needed to measure **20 cm³** of acid. Help them decide using the data below.

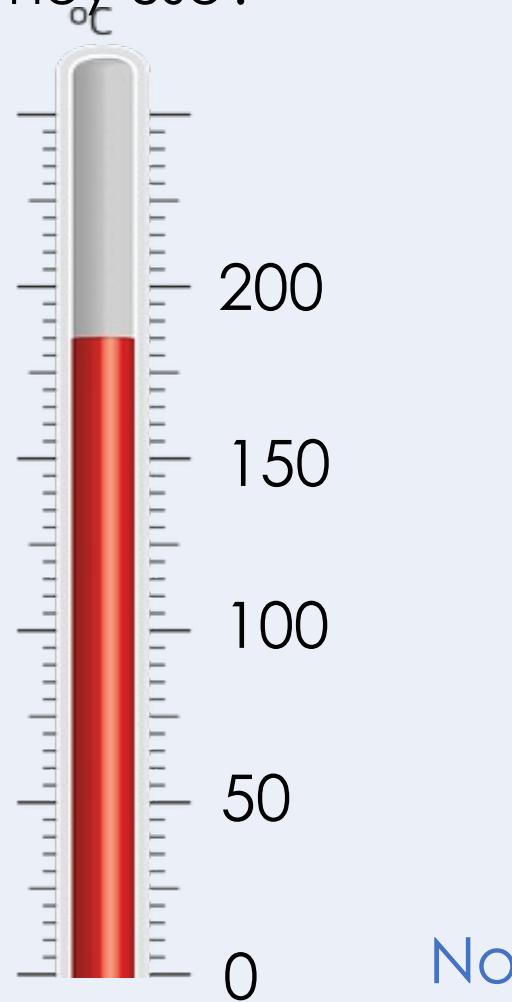
Apparatus	Uncertainty	Minimum value	Maximum value	Should they use this?
50 cm ³ Beaker	±10 cm ³	10	30	No
100 cm ³ measuring cylinder	5 cm ³	15	25	No
50 cm ³ measuring cylinder	1 cm ³	19	21	No
50 cm ³ burette	0.05 cm ³	19.95	20.05	Yes

We: Uncertainty

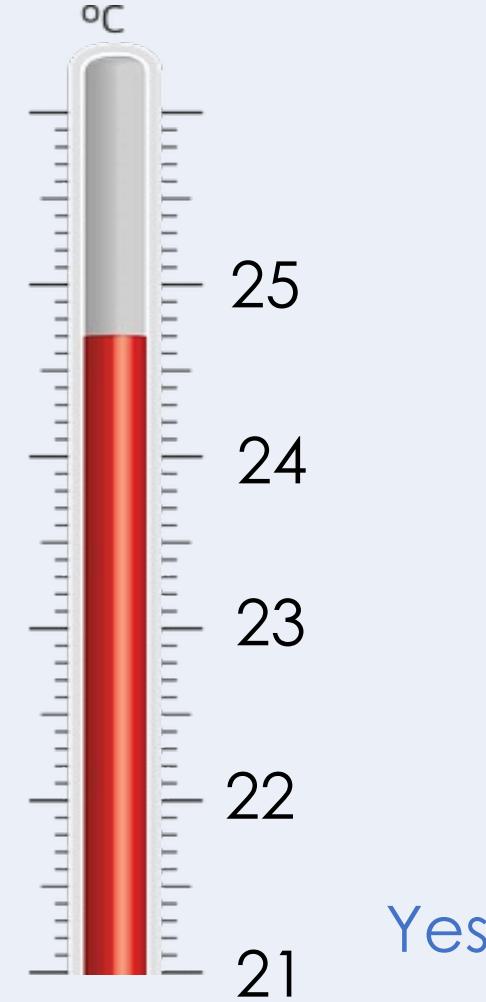
A group of students are investigating the temperature change in a reaction. The temperature change is $22.5\text{ }^{\circ}\text{C}$. Which thermometer should they use?



No



No



Yes

You: Uncertainty

A group of students are investigating the effect of concentration on the volume of hydrochloric acid needed to neutralise 1g of calcium hydroxide. They do repeat measurements to improve the repeatability.

Concentration of acid (mol/dm ³)	Volume needed to neutralise calcium hydroxide /cm ³				Range	Uncertainty
	Trial 1	Trial 2	Trial 3	Mean		
2	14.3	14.3	14.4	14.3	0.1	0.05
1.5	18.5	18.4	18.6	18.5	0.2	0.10
1	26.2	24.3	26.2	25.7	0.3	0.15
0.5	53.6	53.9	53.2	53.6	0.5	0.35
0.25	109.7	110.2	110.1	110.0	0.5	0.25

Calculate the means, the ranges and uncertainty of each
Decide the concentration with the lowest uncertainty.

2 mol/dm³

Answer the questions below.

1. Which is the best definition of uncertainty?
 A. The mean and the range of a data set
 B. The range of a data set divided by two
 C. The range of values within which the true value lies
2. Estimate the uncertainty of this data set.
 A. 3 g
 B. 6 g
 C. 105 g
3. Estimate the uncertainty of this instrument.
 A. 1 cm
 B. 0.1 cm
 C. 0.05 cm

Trial	Mass (g)
1	102
2	108
3	105



Lesson C3.2.6

What was good about this lesson?

What can we do to improve this lesson?

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Thank you!