

IB Chem Unit 1 Measurement and Uncertainties.ppsm - Guided Notes

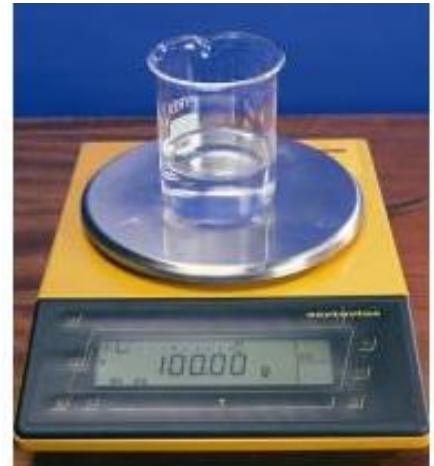
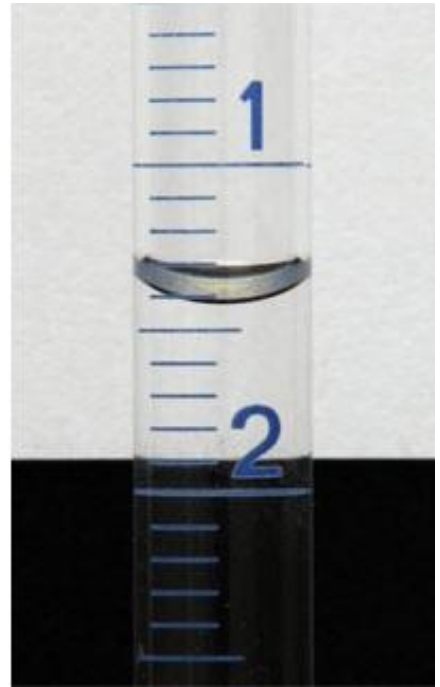
Slide 3: Why does reporting data accurately matter?

- Science is communal
- Science is open to scrutiny through peer review
- All measurements have uncertainties
- Uncertainties limit legitimate conclusions that are drawn from data
- Recognition of uncertainties allow science to progress
- Given the uncertainty within the practice of science, what behavior characteristics should scientists exhibit when conducting and publishing scientific research?
- **“One aim of the physical sciences has been to give an exact picture of the material world. One achievement...has been to prove that this aim is unattainable.” (J. Bronowski)**
- What are the implications of this claim for the aspirations of science?

Slide 4: Uncertainty in measurement

- Different laboratory _____ have different levels of uncertainty.
- The _____ of an **analogue** scale is (\pm) **half of the smallest division.**
- The last digit of a digital scale is _____.
- _____ of a **digital** scale is (\pm) **the smallest scale division.**
- 41.9 ± 0.5 mL
- Report to the tenths place
- 1.40 ± 0.05 mL
- Report to the _____ place
- * _____ **to read from the bottom of the meniscus**
- 100.00 ± 0.01 g
- Report to the _____ place





Slide 5: Other sources of uncertainty

- All _____ should be noted, even if not quantifiable
- Time measurements
- Changes in _____ colors
- Voltages of _____ cells
- Temperatures during _____ reactions

Slide 7: Significant figures in measurements

- Show the amount of _____ in a measurement.
- The digits in a _____ up to and including the first uncertain digit
- *Remember to use scientific notation to help report _____ to the correct number of sig figs.
- * _____ ALWAYS have units!

Slide 9: Experimental errors

- **Two categories:**
- **Random errors:**
- Have multiple causes, including changes in surroundings (e.g. temperature, air currents, etc.), _____ the measurement readings, insufficient data
- have an equal _____ of being too high or too low
- Can be reduced by repeating _____
- **2. _____ errors:**
- occur as a result of poor _____ design or procedure
- **Cannot** be reduced by repeating _____
- **Can** be reduced by changing _____ design
- **Occurs from the _____ between the recorded value and the literature (accepted) value**

Slide 10: Random error

- It is good practice to duplicate experiments in order for the results to be repeatable and reproducible.
- **The same person duplicates the experiment and obtains the same results.**
- **Several different experimenters duplicate the experiment and obtain the same results.**
- Example:
- The mass of a piece of magnesium ribbon is measured several times and _____ the following results obtained:
- 0.1234 g 0.1232 g 0.1233 g 0.1234 g 0.1235 g 0.1236 g
- Average mass Mg: $[0.1234 + 0.1232 + 0.1233 + 0.1235 + 0.1236]/5 = 0.1234$ g
- Average mass Mg: 0.1234 ± 0.0002 g
- **Why is the uncertainty ± 0.0002 g?**
- **Affects the precision of an experiment.**
- Uncertainty: Range/2
- $[0.1236 - 0.1232]/2 = 0.0002$ g
- **The range of data spans ± 0.0002 g from the average!**

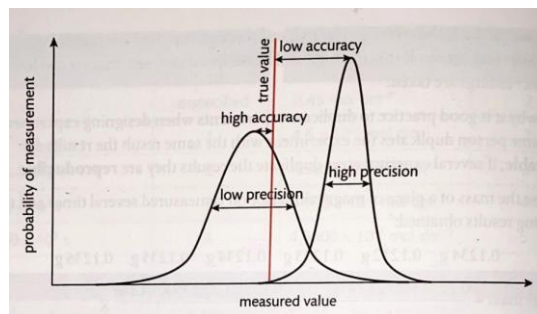
Slide 11: Systematic error

- Example:
- The mass of a piece of magnesium ribbon is measured several times and the following results obtained (however, the balance was not zeroed correctly):
- 0.1236 g 0.1234 g 0.1235 g 0.1236 g 0.1237 g 0.1238 g
- ***All values too high by 0.0002 g**
- Average mass Mg: $[0.1236 + 0.1234 + 0.1235 + 0.1237 + 0.1238]/5 = 0.1236$ g
- Average mass Mg: 0.1236 ± 0.0002 g
- **Examples of systematic errors:**
- Measuring liquids from the top instead of the bottom of the meniscus
- Consistently overshooting the volume of a liquid delivered in a titration

- Instruments not calibrated correctly
- **How do you know if you have a systematic error?**
- **Affects the accuracy of an experiment.**

Slide 12: Accuracy vs. Precision

- Smaller _____ error = greater accuracy
- Smaller random error = greater precision (_____)
- **How close a _____ is to the accepted value.**
- **How close _____ are to each other**



Slide 13: Percentage uncertainties and errors

- Uncertainty can be expressed using absolute, fractional, or percentage values.
- Absolute uncertainty: **actual uncertainty in raw data**
- Fractional uncertainty: $\frac{\text{absolute uncertainty}}{\text{measured value}}$
- **(aka Relative uncertainty)**
- Percent uncertainty: $\frac{\text{absolute uncertainty}}{\text{measured value}} \times 100\%$
- **percent uncertainty \neq percent error**
- Percent error: $\frac{|\text{accepted value} - \text{experimental value}|}{\text{accepted value}} \times 100\%$
- Example: Raw data: $23.4 \text{ mol dm}^{-3} \pm 0.2 \text{ mol dm}^{-3}$
- $0.2 \text{ mol dm}^{-3} = 0.0085$
- 23.4 mol dm^{-3}
- $= 0.85\%$ uncertainty
- ***Note: intermediate values in calculations should not be rounded in order to avoid imprecision**
- *** If calculated uncertainty is $\geq 2\%$, report to 1 sig fig. If calculated uncertainty is $< 2\%$, report to 2 sig figs.**

Slide 14: Propagation of uncertainties in calculated results

- _____ in raw data must be propagated in a consistent manner during data processing.
- **Addition and _____:**
- Two burette _____:
- _____ reading: $15.05 \pm 0.05 \text{ cm}^3$
- Final _____: $37.20 \pm 0.05 \text{ cm}^3$
- Reported value for volume _____: $22.15 \pm 0.10 \text{ cm}^3$
- }
- **Add absolute _____**

Slide 15: Propagation of uncertainties in calculated results

- _____ and Division:
- _____ uncertainty when determining density:
- _____: $12 \text{ g cm}^{-3} \pm 1 \text{ g cm}^{-3}$
- *You can add the individual % _____ to get the total % uncertainty, then use the result to calculate the absolute uncertainty

Slide 16: Propagation of uncertainties: Summary

- **Adding/Subtracting _____:**
- Total absolute uncertainty is the sum of the individual absolute _____
- **Multiplying/Dividing _____:**
- Total % uncertainty is the sum of the individual percent _____
- Use the total % _____ to calculate the total absolute uncertainty

Slide 17: Sig Figs: Addition/Subtraction

- **When adding/subtracting measurements, the number of decimal places determines the precision of the calculated value.**
- **Example 1:** adding the masses of 2 pieces of zinc
- **Mass 1:** $1.21 \text{ g} \pm 0.01 \text{ g}$
- **Mass 2:** $0.56 \text{ g} \pm 0.01 \text{ g}$
- **Total mass:** $1.77 \text{ g} \pm 0.02 \text{ g}$
- **Example 2:** calculation of a temperature increase
- **Temp. 1:** $25.2 \text{ }^\circ\text{C} \pm 0.1 \text{ }^\circ\text{C}$
- **Temp. 2:** $34.2 \text{ }^\circ\text{C} \pm 0.1 \text{ }^\circ\text{C}$
- **Temperature change:** $34.2 - 25.2 = 9.0 \pm 0.2 \text{ }^\circ\text{C}$
- When adding/subtracting: You cannot report a measurement with more precision than the measurement with the smallest number of decimal places (least precise measurement).
- Suppose a solution was made by adding 50 g of water to 1.00 g of sugar. $50 \text{ g} + 1.00 \text{ g} = 51 \text{ g}$
- The precision of the total mass is limited by the least precise measurement (the water).

Slide 18: Sig Figs: Multiplication/Division

- **% uncertainty:**
- Mass: $0.01/5.00 = 0.002 = 0.2\%$
- Volume: $0.1/2.3 = 0.0435 = 4\%$
- Add the uncertainties to get 4.2%
- Absolute uncertainty: $0.0455(2.1739) = 0.0989 \approx 0.1 \text{ g cm}^{-3}$
- **When multiplying/dividing measurements, the number of significant figures determines the precision of the calculated value.**
- **Example:** determining the density of sodium chloride
- **Mass:** $5.00 \text{ g} \pm 0.01 \text{ g}$
- **Volume:** $2.3 \text{ cm}^3 \pm 0.1 \text{ cm}^3$
- Density: $5.00/2.3 = 2.173913043 \text{ g cm}^{-3} \approx 2.2 \text{ g cm}^{-3} \pm 0.1 \text{ g cm}^{-3}$
- When multiplying/dividing: You cannot report a measurement with more precision than the measurement with the smallest number of sig figs (least precise measurement).

Slide 19: How can errors/uncertainties help your experimental design?

- One measurement with a much higher uncertainty will have the major effect on the uncertainty of the final result
- Thermometers often produce the most uncertain results (may require more repetitions of experiment)
- Enthalpy changes in exothermic reactions that are lower than literature values can be due to heat loss to surroundings (suggests systematic error and an alteration in experimental design may be necessary).

Slide 20: HOW TO GRAPH DATA

- SHOWS _____ BETWEEN VARIABLES

- **Independent Variable**
- **Dependent Variable**
- _____ Variable: on x-axis
- _____ Variable: on y-axis
- Correlation Coefficient (r): tells the magnitude and direction of the _____ between variables
- Trendline: _____ the general pattern and direction of the data.
- Equation of Trendline: can be used to _____ and extrapolate data.
- **99% OF THE TIME, GRAPHS IN _____ WILL BE A SCATTER PLOT**
- **EVEN axis _____ (can use different intervals on different axes)**
- **data takes up most of the space on the graph**
- Coefficient of _____ (R^2): tells the amount of variance in the dependent variable explained by the independent variable
- **r = 0.99**

Slide 21: Click the picture to go to the interactive whiteboard

- GROUP DISCUSSION

Slide 22: MORE GRAPH EXAMPLES

- **Strong, non-linear, positive correlation**
- **Moderate, linear, positive correlation**
- **Positive Correlation:** As the independent variable increases, the dependent variable increases (there is a positive relationship between variables)
- **Strong Correlation:** There is little variance in the dependent variable with respect to the independent variable; indicates a strong relationship between variables
- **Moderate Correlation:** There is moderate variance in the dependent variable with respect to the independent variable; indicates a moderate relationship between variables



Slide 23: MORE GRAPH EXAMPLES

- **Strong, non-linear, negative correlation**
- **Weak, negative correlation**
- **Negative Correlation:** As the independent variable increases, the dependent variable decreases (there is a negative relationship between variables).
- **Weak Correlation:** There is a large amount of variance in the dependent variable with respect to the independent variable; indicates a weak relationship between variables



Slide 24: MORE GRAPH EXAMPLES

- **Moderate, linear, negative correlation**
- **No significant correlation**
- **Negative Correlation:** As the independent variable increases, the dependent variable decreases (there is a negative relationship between variables).
- **No Correlation:** There is such a large amount of variance in the dependent variable with respect to the independent variable that no significant relationship exists

Slide 25: MORE ABOUT CORRELATION COEFFICIENTS

- **Strong Correlation**
- **No Correlation**
- _____ between r values are **subjective**
- **Moderate Correlation**
- **Weak Correlation**
- My _____ rule of thumb:
- -1
- 0
- +1
- **Perfect Correlation**
- **Perfect Correlation**
- **Strong Correlation**
- **Moderate Correlation**
- **Weak Correlation**
- -0.8
- -0.6
- -0.2
- -0.4
- +0.2
- +0.4
- +0.6
- +0.8
- **Negative Correlation**

- **Positive Correlation**
- TELLS HOW STRONGLY _____ ARE RELATED TO EACH OTHER
- R^2 VALUES CLOSER TO ZERO INDICATE OTHER _____ VARIABLES (OR ERROR) MIGHT BE CONTRIBUTING TO DEPENDENT VARIABLE (R^2 VALUES RANGE FROM 0 TO 1)

Slide 26: Not true— r^2 is the square of r , but if r is negative or less than 1, r^2 may be smaller.

- C. The coefficient of _____ is always greater than the correlation coefficient, regardless of the data.
- Both are _____ applied to linear models.
- This _____ their actual ranges— r ranges from -1 to $+1$, while R^2 ranges from 0 to 1.
- How is a correlation coefficient (r) different from the coefficient of _____ (R^2)
- A. The correlation coefficient measures the strength and direction of a linear relationship between 2 variables, while the coefficient of _____ indicates the proportion of variance in one variable explained by another.
- B. The correlation coefficient ranges from 0 to 1, while the coefficient of _____ ranges from -1 to 1.
- D. The correlation coefficient is used in nonlinear modeling, while the coefficient of _____ is exclusive to linear regression.

Slide 27: Click the picture to go to the interactive whiteboard

- GROUP DISCUSSION

Slide 28: A NOTE ABOUT DATA...

- **DATA DOES NOT “PROVE” _____**
- **THERE IS NO _____ “TRUTH” IN SCIENCE**
- **DATA SUPPORTS OR DOES NOT SUPPORT _____**
- **_____ DOES NOT EQUAL CAUSATION**
- **2 VARIABLES CAN HAVE A STRONG _____ BUT THAT DOES NOT MEAN ONE “CAUSES” THE OTHER**

Slide 29: Interpolate

Slide 30: Extrapolate

Slide 31: Correlation Coefficient (r)(Pearson’s)

- It's a number between -1 and $+1$, with numbers closer to each extreme indicating a stronger _____ between variables. A value of zero indicates no significant correlation between variables exists.

Slide 32: Coefficient of Determination (R^2) (Pearson’s)

- It's a number between 0 and $+1$, with numbers closer to 1 _____ a stronger fit and less variance between variables. A value of zero indicates the variance in the dependent variable is not explained by the model.

Slide 33: Trendline

Slide 34: Scatter Plot

Slide 35: Positive Correlation

Slide 36: Strong Correlation

- $r = 0.96$
- $r = -0.96$

Slide 37: Moderate Correlation

- $r = 0.79$
- $r = -0.78$

Slide 38: Negative Correlation

Slide 39: Weak Correlation

- $r = 0.47$
- $r = -0.47$

Slide 40: Negative Correlation

Slide 41: No Correlation