Uncertainties and Practical Work

1 A student recorded a value of 0.003050 in an experiment. The number of decimal places and significant figures in this value are

	Decimal places	Significant figures
A	6	3
B	4	3
C	6	4
D	6	6

2 A student recorded the following values for temperature in an experiment:

initial temperature / ^{o}C	21.0±0.5
maximum temperature / ^{o}C	48.0±0.5

The temperature change should be quoted as:

A 27±1 ^{o}C
B 27.0±0.5 ^{o}C
C 27.0±1.0 ^{o}C
D 27.0±1 ^{o}C

3 A student worked out the number of moles in a solution using the following data:

Volume of solution: 10.0±0.1 cm^3
Concentration of solution: $1.00\text{x}10^{-2}$±$1.00\text{x}10^{-4}$ mol dm^{-3}

The absolute uncertainty of the number of moles is:

A ±0.1001 mol
B ±2x10^{-6} mol
C ±2x10^{-3} mol
D ±2

4 A student carried out a calculation to determine the rate of reaction from data they obtained from a colorimetry experiment. Their data is shown in the table:

initial concentration of bromine /mol dm^{-3} ±0.0001	0.0200
final concentration of bromine /mol dm^{-3} ±0.0001	0.0100
time taken /s ±2	32

Determine the rate of reaction and the absolute uncertainty in mol dm^{-3} s^{-1} [4]

Rate of reaction = $\frac{\text{change in concentration}}{\text{Time}}$

Subtracting values, therefore add absolute uncertainties

Rate of reaction = $\frac{(0.0200-0.0100)}{32}$ = $3.125\text{x}10^{-4}$ mol dm^{-3} s^{-1}

Absolute uncertainty on change in concentration = 0.0001 + 0.0001 = 0.0002 mol dm^{-3}

Percentage uncertainty of change in concentration = $\frac{0.0002}{0.0100}$ x 100 = 2%

Percentage uncertainty of time = $\frac{2}{32}$ x 100 = 6.25%

Dividing values, therefore add percentage uncertainties

Percentage uncertainty of rate = 2 + 6.25 = 8.25%

Absolute uncertainty of rate = $3.125\text{x}10^{-4}$ x 8.25/100 = ±3x10^{-5} mol dm^{-3} s^{-1}

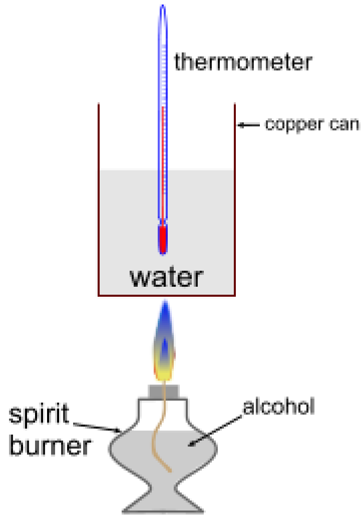
Absolute uncertainties quoted to 1 significant figure

Rate of reaction = 3.1x10^{-4}±3x10^{5} mol dm^{-3} s^{-1}

significant figures consistent with uncertainty (uncertainty in first decimal place

3.1x10^{-4}
3x10^{5}

5 A student designed an experiment to measure the standard enthalpy changes of combustion (ΔH_c) of propan-1-ol. They used the experimental set-up shown:



Their experimental data is shown below:

ALCOHOL	Volume of water /cm^3 ±0.5 cm^3	Initial mass of alcohol /g ±0.01g	Final mass of alcohol /g ±0.01g	Initial temperature of water /^{o}C ±0.5 ^{o}C	Maximum temperature of water /^{o}C ±0.5 ^{o}C
Propan-1-ol	100.0	233.61	232.57	19.0	44.0

(a) The student carried out the following calculation to work out the heat energy given out in the experiment

Energy = (233.61-232.57) x 4.18 x [(44.0-19.0) + 273] = 1295 J

Describe two major errors in this calculation. [2]

Energy = (233.61-232.57) x 4.18 x [(44.0-19.0) + 273] = 1295 J

Mass of water should be used instead of mass of alcohol burnt

273 should not be added to the temperature change – temperature change is the same in ^{o}C or K

(b) The student measured the volume of water using a measuring cylinder but a friend suggested that he would have had a smaller percentage error if he had used a different piece of apparatus. Suggest a suitable piece of apparatus he could have used to reduce the percentage uncertainty on the volume of water. [1]

Burette/pipette/volumetric flask/electronic balance

Measuring the mass of water using a 2 decimal place balance will be most precise

(c) (i) Using the data in the table calculate the enthalpy change of combustion of propan-1-ol. [2]

$q=mc\Delta T$ = 100.0x4.18x25 = 10450 J
moles of propan-1-ol = 1.04/60.11 = 0.0173 mol
Energy released per mol = 10450/0.0173 = 604000 J mol^{-1}
ΔH_c= -604 kJ mol^{-1}

(ii) Calculate the percentage uncertainty on the temperature change [2]

Subtracting values, therefore add absolute uncertainties

Absolute uncertainty on change in temperature = 0.5 + 0.5 = 1 ^{o}C
Percentage uncertainty of change in temperature = $\frac{1}{25}$ x 100 = ±4%

(iii) Calculate the percentage uncertainty on the energy released in this experiment [2]

Percentage uncertainty on mass of water = $\frac{0.5}{100}$ x 100 = 0.5%
Percentage uncertainty of q = 4 + 0.5 = ±4.5%

Multiplying values, therefore add percentage uncertainties

(iv) Calculate the absolute uncertainty for the enthalpy change of combustion of propan-1-ol [3]

Absolute uncertainty on mass of alcohol = 0.01 + 0.01 = 0.02 g

Percentage uncertainty on mass of alcohol = $\frac{0.02}{1.04} \times 100 = 1.9\%$

Percentage uncertainty on moles of alcohol = 1.9%

Molar mass of $MgCl_2$ assumed to be exact – 0% uncertainty

Percentage uncertainty on ΔH_c = 4.5 + 1.9 = 6.4%

Dividing values, therefore add percentage uncertainties

Absolute uncertainty on ΔH_c = 6.4/100 x 604 = ±40 kJ mol^{-1}

Absolute uncertainties quoted to 1 significant figure

(v) Use the values you obtained in (i) and (ii) to quote the enthalpy change of combustion to the appropriate number of significant figures. [1]

ΔH_c= -600±40 kJ mol^{-1}

significant figures consistent with uncertainty (uncertainty in 10s)

604 4 not quoted – negligible compared to uncertainty
40

(vi) The literature values for the enthalpy change of combustion is ΔH_c= -2021kJ mol^{-1}

Calculate the percentage error for the experiment and suggest sources of systematic error in the experiments. [5]

$\frac{|-2021-(-600)|}{|-2021|} \times 100 = 70.3\%$

Heat loss to the surroundings
Incomplete combustion of the alcohol
Evaporation of water
Evaporation of the alcohol

6 A student designed an experiment to measure the enthalpy change of solution of magnesium chloride. They followed the following procedure:

- measure out 25.0 cm^3 of water in a 100 cm^3 measuring cylinder and transfer it to a 250 cm^3 glass beaker.
- measure the initial temperature of the water
- add 2.00 g of magnesium chloride and stir rapidly
- measure the maximum temperature reached.

Their data is shown below.

Mass of $MgCl_2$/g ±0.01	Volume of H_2O /cm^3 ±0.5	Initial Temperature of water/°C ±0.2	Maximum Temperature of solution/°C ±0.2
2.00	25.0	19.0	36.0

(a) Suggest why the reaction mixture must be *stirred rapidly*. [1]

To make sure that the reaction occurs as quickly as possible to minimise heat loss /to get the maximum possible temperature rise

(b) The student calculate the enthalpy change of solution (ΔH_{sol}) using the following equation:

$$\Delta H_{sol} = -\frac{25.0 \times 4.18 \times 17.0}{(2.00/95.21)}$$

Suggest two assumptions that the student made when carrying out the calculation. [2]

The specific heat capacity of the solution is the same as that of water
The density of the solution is the same as that of water

(c) (i) Calculate the absolute uncertainty of the temperature change. [1]

Absolute uncertainty on change in temperature = 0.2 + 0.2 = ±0.4 ^oC

(ii) Calculate the percentage uncertainty of the enthalpy change of solution [3]

Percentage uncertainty of change in temperature = $\frac{0.4}{17} \times 100 = 2.4\%$

Percentage uncertainty on mass of water = $\frac{0.5}{25} \times 100 = 2\%$

Percentage uncertainty of q = 2 + 2.4 = 4.4%

Multiplying values, therefore add percentage uncertainties

Percentage uncertainty on mass of $MgCl_2$ = $\frac{0.01}{2.00} \times 100 = 0.5\%$

Percentage uncertainty on moles of $MgCl_2$ = 0.5%

Dividing values, therefore add percentage uncertainties

Percentage uncertainty on ΔH = 4.4 + 0.5 = ±4.9%

(d) The literature value for the enthalpy change of solution of magnesium chloride is -155 kJ mol^{-1}.

(i) Calculate the percentage error for the student's experiment [2]

ΔH_{sol} = -84.6 kJ mol^{-1}

Percentage error = $\frac{|-155-(-84.6)|}{|-155|} \times 100 = 45.4\%$

(ii) The student suggested the following improvements to the procedure:

I use a 25 cm^3 pipette instead of a measuring cylinder to measure the volume of water
II use an insulated cup instead of a glass beaker to reduce heat loss to the surroundings

Explain whether each suggestion would increase the accuracy or the precision of the student's results. [2]

I using a 25 cm^3 pipette would increase the precision – random errors would be reduced – smaller uncertainty on a pipette – final value could be known to more significant figures (depending on other measurements)

II using an insulated cup would increase accuracy – would reduce the systematic error of heat loss to the surroundings – the experimental value should be closer to the literature value.

(iii) The student also suggested that using 10 g of magnesium chloride instead of 2 g would reduce random errors. Discuss the student's suggestion with regard to both random and systematic errors. [3]

This would reduce random errors. The percentage error in the mass of $MgCl_2$ will now only be 0.1%. The greater temperature rise will also reduce the random error on the temperature change. Final value will be more precise.

Systematic errors would increase. The temperature change would be much larger (85 ^oC if boiling of water ignored) and would be sufficient to make the water boil meaning…

increase in heat loss to the surroundings / latent heat of vaporisation of water would have to be taken into account / more evaporation of water

The recorded value of the temperature rise would be less accurate and the final value of enthalpy change of solution would be less accurate