1. Planning

1.1 Defining the Problem [4]

- Identify:
  - the **independent variable** in the experiment
  - the **dependent variable** in the experiment
  - the quantities to be **controlled** – kept constant
- Formulate the aim in terms of a prediction or a hypothesis, and express this in words or in the form of a predicted graph
- Hypothesis is usually a short statement showing the relationship (e.g. proportional) between two variables.
- Explain your hypothesis using scientific knowledge
  - Rate of reaction = collision theory
  - Enthalpy of solution = ionic radii/ΔH_{hyd} and ΔH_{lat}
  - Group 2 = radii

1.2 Methods [8]

- Describe the methods to be used to vary the independent variable, and the means that you propose to ensure that you have measured its values accurately
- Describe how you will measure the dependent variable
- Describe how you will control each of the other variables
- Explain how you will use any control experiments to verify that it is the independent variable that is affecting the dependent variable and now some other factor
- Describe the arrangement of apparatus and the steps in the procedure to be followed
- Suggest appropriate volumes and conc. of reagents
- Assess the risks of your proposed methods
- Describe precautions that should be taken to keep risks to a minimum
- Draw up tables for data that you might wish to record
- Describe how the data might be used in order to reach a conclusion

2. Analysis, Conclusions and Evaluation

2.1 Dealing with Data [6]

- Identify the calculations and means of presentation of data that are necessary to be able to draw conclusions from provided data
- Use calculations to enable simplification or explanation of data
- Use tables & graphs to draw attention to the key points in quantitative data, including the variability of data

Calculations may include:

- Mean:

$$\bar{x} = \frac{\sum x}{n}$$

- Median: middle result when results in ascending order
- Mode: most common value
- Percentage Gain/Loss:

$$Percentage\ Gain/Loss = \frac{Actual\ Loss/Gain}{Original\ Amount} \times 100$$

2.2 Evaluation [4]

- Identify anomalous values in provided data and suggest appropriate means of dealing with such anomalies
- Suggest possible explanations for anomalous readings
- Identify the extent to which provided readings have been adequately replicated, and describe the adequacy of the range of data provided
- Use provided information to assess the extent to which selected variables have been effectively controlled

2.3 Conclusion [2]

- Draw conclusions from an investigation, providing a detailed description of the key features of the data and analyses, and considering whether experimental data supports the conclusion reached
- Make detailed scientific explanations of the data, analyses and conclusions that they have described
- Make further predictions, ask informed and relevant questions and suggest improvements

2.4 Tables

- Label each column with:
  - a description (e.g. concentration of acid in water)
  - a unit (e.g. /mol dm-3)
  - an expression to calculate the data (e.g. B x 0.1/20)
- Make sure values calculated is to s.f./d.p. required in question

2.5 Graphs

- Independent variable plotted on the x-axis and the dependent on the y-axis
- Appropriate scale; 1 large box = 1, 2, 4 or 5.
- Graph must cover at least half the grid in both directions
- If experiment/relationship shows origin (0, 0) is a valid point, scaling must include origin & line should include it as it is a definite point not subject to experimental errors
- When referring to anomalous result, clearly define the point before stating reason
- When calculating gradient, show construction lines and hypotenuse must be greater than half the line

3. Details and Methods

3.1 General Information

- Use burette/pipette to measure volumes as they have low % errors
- Using a 3 d.p. balance rather than a 2 d.p. balance reduces % error
- Percentage errors very high with very small volumes/masses
- Heating crystals strongly; use a crucible placed on a pipe clay triangle
- Allow crucible to cool on heat mat before placing on balance to measure mass
- Use sandpaper to clean surface of metal e.g. magnesium ribbon (remove oxide layer)
- Maximum temperature difficult to determine so instead, take readings at regular intervals
- The temperature of the solution is not uniform so stir the solution throughout the experiment
- No need to measure mass/volume of reagents in excess
- Flush out oxygen from a system using an inert gas (used in reduction experiment of metal oxides)
- To collect water vapour as liquid, collect in beaker placed in ice bath (Liebig condenser)
- Use a divided flask to keep reagents separate – shake to begin reaction & start time immediately; no gas escapes
- If syringe gives incorrect value, could be because it got stuck during the experiment
- If percentage difference between measured & true value
  - More than max apparatus error, experimenter's technique needs modification
  - Less than max apparatus error, due to error in apparatus or simply random error
- To improve accuracy of pH against volume curve, use data logger interface and computer to plot the graph

3.2 Volumes of Apparatus

- Always mention volume of apparatus being used
- Common volumes:
  - Test tube = 16cm^3
  - Gas syringe: 100cm^3 up to 500cm^3
  - Glass beaker = 250cm^3
  - Polystyrene cup = 150cm^3
- Calculate quantities and show volume would not exceed the apparatus used

3.3 Potential Risks and Solutions

- Oxygen: is an oxidant so remove any oxidisable material
- Nitrogen dioxide: is poisonous so carry out experiment in a fume cupboard
- When collecting gas over water: potential suck back so remove delivery tube from water when heating stops
- Solution boils over/sprays: use gloves, eye protection
- Corrosive nature of reagents: use gloves

3.4 Anomalous Points on the Graph

- A particular measurement is done before or after the moment it should be done
- Incomplete:
  - oxidation/reduction
  - decomposition
  - reaction
- Loss of water/chemical
- A compound has decomposed
- A solution has not been saturated
- Not all the water in the solution has been evaporated
- Crystals not adequately dried (propanone or water)
- Solid blown out of tube by not heating gently

3.5 Removing Moisture

- **From surface:**
  - Wash surface with stream of propanone
  - Propanone dissolves the water – repeat several times
  - Gently heat surface to evaporate propanone from surface
- **From vapours:** pass vapour through beaker containing a desiccant
  - Anhydrous sulphuric acid
  - Anhydrous calcium chloride
  - Silica gel
  - Can use soda lime: absorbs both water vapour and carbon dioxide

3.6 Forming Specific Conc. Solutions

From a given parent solution

e.g. 250cm^3 of 0.1 mol dm^{-3} using a 2.0 mol dm^{-3} solution

- Use $C_1V_1 = C_2V_2$

$$2.0 \times x = 250 \times 0.1$$
$$x = 12.5\text{cm}^3$$

- Add 12.5cm^3 of parent solution to a volumetric flask (250cm^3) using a burette

From a solid

e.g. 250cm^3 of 0.5 mol dm^{-3} solution of a crystal Mr = 50g

- Use $Conc = \frac{Mols}{Vol}$

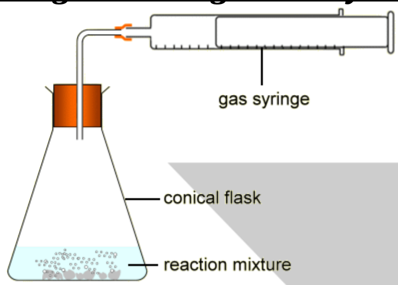
$$Mols = 0.5 \times 0.25 = 0.125$$

- Use $Mols = \frac{Mass}{Mr}$

$$Mass = 0.125 \times 50 = 6.25\text{g}$$

- Add 6.25g of solid to 50cm^3 of water in a beaker
- Stir well, add water gradually until fully dissolved
- Transfer solution from beaker to volumetric flask
- Rinse beaker with water and transfer back to volumetric flask
- Stopper the flask and shake properly
- Top off volumetric flask with distilled water to mark.

3.7 Measuring Gas using a Gas Syringe



- Take initial reading of the gas syringe
- Carry our procedure e.g. heating a solid or adding a reagent
- Take final reading of the gas syringe when volume is constant or take readings at regular time intervals
- If experiment heats reagent, wait until gas is at room temperature before measuring volume
- Calculate the maximum mass of solid/reagent that can be used by equating volume produced to volume of gas syringe used. Use samples smaller in size than that.

3.8 Measuring Solubility Experiments

Preparing a saturated solution

- Take a fixed volume of water in a beaker of appropriate volume
- Add the crystal to the water and stir continuously; allow some time for the crystal to dissolve
- After a few minutes of stirring, if no solid crystals appear, add further mass of crystal
- Repeat the process until solid appears in the beaker
- Filter the solution using a filter paper and funnel so that the saturated solution is collected in a beaker beneath the funnel

Preparing crystals:

- Place the beaker in a warm water bath.
- The water of the solution should evaporate and should have dry crystals ready.
- Inappropriate to apply heat directly as crystals could decompose

Measuring solubility:

- Measure mass of saturated solution = (Mass of Beaker + Solution) – (Mass of Beaker)
- Heat solution and evaporate all liquid to end up with dry crystals
- Measure mass of crystal = (Mass of Beaker + Crystals) – (Mass of Beaker)
- Calculate solubility of crystals

$$Solubility = \frac{Mass\ of\ Crystal}{Mass\ of\ Solution} \times 100$$

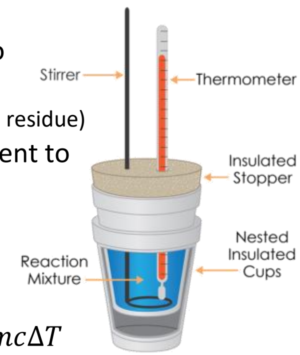
3.9 Measuring Enthalpy Experiments

Measuring enthalpy change of an experiment with a solid and a liquid or two liquids:

- Measure specific mass of solid to add using a balance

(mass of bottle + solid) – (mass of bottle + residue)

- Measure specific volume of reagent to add using burette/pipette
- Measure initial temperature of reaction mixture
- Record highest temperature
- Calculate enthalpy using $E = -mc\Delta T$

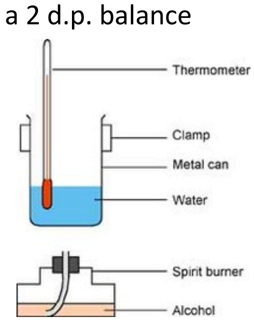


Disadvantages of using plastic cup to measure enthalpy changes and improvements:

- Heat loss to the surroundings from the beaker:
  - Cover the plastic cup with a lid
  - Place cup in a beaker; air acts a good insulator
  - Use multiple cups to thicken lateral layer of plastic
- Instability of the cup
  - Place the cup in a glass beaker
- For exothermic reactions, solution likely to spray
  - Use a larger beaker/cup to carry out the experiment
  - Put a lid on top of the beaker to minimize the spray

Measuring enthalpy change of combustion

- Measure mass of spirit burner using a 2 d.p. balance
- Add specific volume of water into metal can using measuring cylinder
- Take initial reading of water using a thermometer (1°C)
- Light spirit burner and burn for specific length of time
- Take final reading of water after a specific time
- Measure mass of spirit burner after burning
- Calculate mass of alcohol burned
- Use $E = -mc\Delta T$ and use ratios to calculate for 1 mole of alcohol



3.10 Titration Experiments

- Rinse burette and pipette with solution to be added before carrying out experiment
- Empty pipette into conical flask under gravity without forcing any drops to fall
- Remove funnel from burette before titration
- Add only two drops of indicator
- Swirl mixture during titration
- Titrate drop by drop when close to the end-point
- Keep eye-level perpendicular to burette when taking measurements
- Record burette reading to 2 decimal places

- **For better observation:**
  - Place a white tile under the conical flask
  - Illuminate the burette while taking the reading

- **Titrations are highly accurate because:**
  - Standard solution of acid/base is used
  - Able to obtain consistent titres (difference between two closest titres = 0.1 cm^3
  - % error in pipette and burette is very small
  - The end point of a titration is sharp