CIE Chemistry A-Level

4.2.2 Practical Skills for Paper 3 - Analysis, Conclusions and Evaluation

Notes

Analysis

Intro

It is necessary to perform analysis of the data after an experiment has been completed so that conclusions may be drawn from the experiment. We must analyse many aspects of the experiment, not just the obviously conclusive ones. Some important analyses may include determining the percentage uncertainty in some of our conclusive values, percentage purity of a solid, atom economy of a reaction and percentage yield. These latter calculations will not get us our main conclusive value, but will help us to confirm the validity and efficiency of our experiment.

Calculations

Some general calculations you may need to complete to evaluate an experimental procedure:

Determining percentage uncertainty

The percentage uncertainty is a way to calculate errors in the reaction, and how much they will affect the final calculated value.

$$100 \times \frac{absolute\ uncertainty}{calculated\ value}$$

Absolute uncertainty is the '±' range as shown in the examples below:

Example 1:

A 250 cm^3 volumetric flask has an error of ±0.10cm^3. What is the maximum percentage error of the volumetric flask?

$$= \frac{0.1}{250} \times 100$$

$$= 0.04\%$$

Example 2:

A burette has a percentage error of ± 0.05 cm^3. A titre was calculated to be 28.40 cm^3. What is the total percentage error of this measurement?

For this calculation the 0.05 uncertainty has to be doubled as two measurements are taken when a burette reading is calculated - the volume at the start and the volume at the end.

$$= \frac{2 \times 0.05}{28.4} \times 100$$

$$= 0.352\%$$

Percentage yield

The expected yield can be determined from the initial masses of the reactants and the overall equation of the reaction. The actual yield is measured by weighing of the final product produced.

$$percentage\ yield = \frac{actual\ yield}{expected\ yield} \times 100$$

Atom economy

To work out the efficiency at which our reaction produces the desired product of the experiment, we must calculate the atom economy of the reaction, there may be other routes to produce the desired product that are more efficient.

$$atom\ economy = \frac{relative\ formula\ mass\ of\ desired\ product}{total\ relative\ formula\ masses\ of\ reactants}$$

Example:

Hydrogen can be produced from methane in the following reaction.

$$CH_4 + H_2O \rightarrow 3H_2 + CO$$

What is the atom economy for the production of hydrogen?

$$= \frac{6}{34} \times 100$$

$$= 17.6\%$$

Finding the gradient of a straight line

To find the gradient of a straight line, the coordinates of two points on the line must first be known, let these two points be: (x_1, y_1) and (x_2, y_2). Thus:

$$change\ in\ y = y_2 - y_1$$

$$change\ in\ x = x_2 - x_1$$

$$gradient = \frac{change\ in\ y}{change\ in\ x}$$

The gradient of a straight line may need to be found in order to determine the constant of a rate equation, for example the gradient of a concentration-rate graph would give this value.

Percentage purity

It might be the object of an experiment to find the percentage purity of a given impure mixture, like an iron tablet, this is normally done by titration to find the actual mass of the desired substance present in the impure mixture. Finding the purity of reactants can be done on the side of the main experiment in order to better estimate the expected yield of the main experiment.

$$percentage\ purity = \frac{mass\ of\ desired\ substance}{mass\ of\ impure\ mixture} \times 100$$

Conclusions and Evaluation

Once all of your data has been collected and you have made your analysis, conclusions can be made. These may be drawn from the shapes of graphs that may show certain trends, or values given by the analysis. To make a successful conclusion, the results of the analysis must be looked at in the context of the experiment as a whole and this conclusion can then be interpreted in the context of our world. What impact does this conclusion have on our world? Is the experiment accurate enough for it's conclusion to be valid? Does the experiment need to be repeated or improved? These latter questions are asked in the evaluation part of the experiment. It is vitally important that all observations are written down in the experiment as it makes evaluating the method much easier.

Conclusion

An experiment is concluded, at A-Level, by comparing against known observations/values or by making judgements based on calculated results like percentage purity or the equation of a straight line. A calculated R_f value of an organic product from a synthesis would be compared to known R_f values of the expected product to assess if the correct product was made, this would then lead to the conclusion that the correct product was made, or that it was not.

Significant figures

It is also important that conclusive values are written to the correct number of significant figures. This is done by looking at the number that you have used in the calculation that has the least number of significant figures, this is the maximum number of significant figures you may use when presenting your conclusive value. Use the following calculation as an example:

$n = 0.709\ mol$

$p = 101400\ pa$

$T = 278.9\ K$

$V = ?$

$$pV = nRT$$

$$101400V = 0.709 \times 8.314 \times 278.9$$

$$V = 0.0162\ m^3$$

Although most of the values used in the equation are to 4 significant figures, the number of moles, n, is only to 3 significant figures, we must therefore present our final value to 3 significant figures.

Evaluation

Now it is time to assess our experiment, we must look at the whole of our experiment and identify any possible errors that have occurred, this may be to fix a particular issue like a very low percentage yield when synthesising organic solids. One example of an error is the false positive that may be obtained in ion tests from testing for sulphate ions first, where chloride ions could create a white precipitate and falsely indicate the presence of sulphate ions.

To fix a low percentage yield we must also balance how pure we would like our sample to be. Every time a solid is recrystallised it's purity increases, but some product is lost. The same is true for washing an organic liquid with water in a separating funnel. Other factors that could affect the yield would be that not all of the reactants reacted (incomplete reaction) or some product was lost when transferring between containers. Often, the yield is increased by using a different method which may involve changing the chemicals used in the reaction.

We must also identify all numerical errors in the experiment, like the error in each burette or thermometer reading. This value is normally half of the resolution of the instrument, for example a thermometer of resolution 1ºC would have an uncertainty of ±0.5ºC, or a burette with a resolution of 0.1 cm^3 would have an uncertainty ±0.05 cm^3. The percentage uncertainty of each measurement could therefore be reduced by increasing the value measured, like using a larger volume in a titration, or a larger mass in an enthalpy change experiment.