Lesson 14: Significant Figures in Calculations

*Read through the lesson notes. You can write them out, print them or save them.

*Once you have tried to understand the lesson answer the questions that follow and self-evaluate your work by checking the answers.

Learning Intention

-Practice giving answers to chemical calculations using the correct number of significant figures.

Background

You will have learned about the use of significant figures many years ago in Maths. This lesson will not set out to teach you again how to use or identify significant figures but to highlight them and use them when applied to chemical calculations.

The SQA Advanced Higher paper and project both dedicate 1 mark to the concept of significant figures. It is important to note that you can only be penalised ONCE in a test for expressing wrongly number of significant figures in an answer.

Significant Figures

A quick guide to significant figures is given below:

-non-zero numbers are always significant, e.g. 1·234 g has 4 significant figures and 1·2 g has 2 significant figures.

-zeros that are between non-zero numbers are always significant, e.g. 6007 kg has 4 significant figures and 5·08 cm^3 has 3 significant figures.

-zeros to the left of the first non-zero number are not significant, e.g. 0·005 m has 1 significant figure and 0·321 cm has 3 significant figures.

-zeros at the end of a number are always significant if the number contains a decimal point, e.g. 210·0 nm has 4 significant figures and 0·0600 mol l^{-1} has 3 significant figures.

-zeros at the end of a number may or may not be significant if the number does not contain a decimal point, e.g. does 200 g have 1, 2 or 3 significant figures? It is impossible to decide without further information about how the measurement was made. Suppose a balance measuring to the nearest 10 g was used then the number would have 2 significant figures but if a balance measuring to the nearest 1 g was used then the number would have 3 significant figures.

Quoting a number in scientific notation removes all doubt, e.g. $2{\cdot}0 \times 10^2$ g has 2 significant figures and implies that a balance reading to ±10 g had been used.

Worked Example 1

The first ionisation energy of sodium is 502 kJ mol^{-1}.
Calculate the wavelength of light, in nm, corresponding to this ionisation energy.

$$E = \frac{Lhc}{\lambda} \qquad \lambda = \frac{Lhc}{E}$$

$$\lambda = \frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8}}{502000}$$

502000 ⟵ convert to Jmol^{-1}

$\lambda = 2.385215139 \times 10^{-7}$ metres

$\Lambda = 238.5215139$ nm

The information given in the question (502 kJ mol^{-1}) is to three significant figures. Therefore the answer should ideally be expressed to three significant figures:

239nm

*When deciding the acceptable number of significant figures to use in your answer it should be one less and two more than the number of significant figures used in the question.

For example 1, the answer can be given in a range of two to five significant figures. In actual fact, the following answers would be credited as correct responses.

240nm (two significant figures)
239nm (three significant figures)
238.5nm (four significant figures)
238.52nm (five significant figures)

Worked Example 2

Ethene can be hydrated to produce ethanol.

$C_2H_4(g) + H_2O(\ell) \rightarrow C_2H_5OH(\ell)$

$\Delta G^\circ = -6.1 \text{ kJ mol}^{-1}$
$\Delta H^\circ = -44.2 \text{ kJ mol}^{-1}$

Calculate the standard entropy change, ΔS°, in J K^{-1} mol^{-1}.

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$$\Delta S^\circ = \frac{\Delta H^\circ - \Delta G^\circ}{T}$$

$$\Delta S^\circ = \frac{-44.2 - (-6.1)}{298 \text{ (temperature at standard conditions)}}$$

$\Delta S^\circ = -0.127852349 \text{ kJ K}^{-1} \text{ mol}^{-1}$

X1000

$\Delta S^\circ = -127.852349 \text{ J K}^{-1} \text{ mol}^{-1}$

*In this example ΔG° is expressed to <u>two significant figures</u> and ΔH° is expressed to <u>three significant figures</u>.
For expressing the final answer to the correct number of significant figures you must take the <u>lower value</u> given in the question, i.e. in this example we will concentrate on ΔG° as it has been expressed to two significant figures.

Therefore the possible answers for example 2 are in the range of 1 significant figure to 4 significant figures.

$\Delta S^\circ = -100 \text{ J K}^{-1} \text{ mol}^{-1}$ (1 significant figure)
$\Delta S^\circ = -130 \text{ J K}^{-1} \text{ mol}^{-1}$ (2 significant figures)
$\Delta S^\circ = -128 \text{ J K}^{-1} \text{ mol}^{-1}$ (3 significant figures)
$\Delta S^\circ = -127.9 \text{ J K}^{-1} \text{ mol}^{-1}$ (4 significant figures)

The following links are not mandatory but should only be used if you feel the need to refresh your knowledge on significant figures.

https://www.khanacademy.org/math/arithmetic-home/arith-review-decimals/arithmetic-significant-figures-tutorial/v/significant-figures

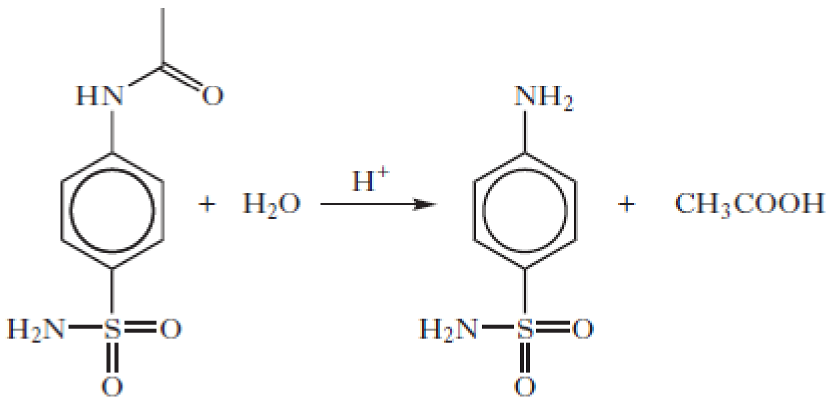
https://www.brightredbooks.net/subjects/calculators/sig?sortBy=0.56%2C2

TASK

→ Answer the questions from Sheet 4.14 and check the answers when you have completed them.

4.14 Significant Figures

1. Sulfanilamide is prepared in a six stage synthesis. The equation for the final step in the synthesis is shown.



$C_8H_{10}N_2SO_3$ $C_6H_8N_2SO_2$

4-acetamidobenzenesulfonamide sulfanilamide

Calculate the percentage yield of sulfanilamide if 4·282 g of 4-acetamidobenzenesulfonamide produced 2·237 g of sulfanilamide.
Express your answer using the highest acceptable number of significant figures.

2. When a high voltage is applied to a lamp filled with helium gas, a line of red light, wavelength 706 nm, is observed through a spectroscope.
Calculate the energy, in kJ mol^{-1}, associated with this wavelength using the lowest number of acceptable significant figures.

3. To determine the composition of an old coin containing silver, nickel and copper, a student dissolved the coin of mass 11·25 g in nitric acid. The resulting solution was diluted with deionised water to 1000 cm^3 in a standard flask.

   0·3 mol l^{-1} hydrochloric acid was added to 100 cm^3 of this solution until precipitation of the silver(I) chloride was complete. After filtration, the precipitate was washed and dried and found to have a mass of 0·740 g.

   Calculate the percentage, by mass, of silver in the coin expressing the answer in the highest number of acceptable significant figures.

4. The steel from a sword blade of mass 1252 g was found to have a vanadium concentration of 69 ppm.
Calculate the total mass of vanadium present in the sword blade.
Give all the acceptable answers taking the number of significant figures into consideration.

5. The equation for the reaction between oxalic acid solution and sodium hydroxide solution is

$H_2C_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4\ (aq) + 2H_2O(\ell)$

A student used a standard solution of 0·078 mol l^{-1} oxalic acid to standardise 25·0 cm^3 of approximately 0·1 mol l^{-1} sodium hydroxide solution.

The raw results for the titration are given in the table.

	1st attempt	*2nd attempt*	*3rd attempt*
final burette reading (cm^3)	17·2	33·8	16·6
initial burette reading (cm^3)	0·0	17·2	0·1
titre (cm^3)	17·2	16·6	16·5

Calculate the accurate concentration, in mol l^{-1} of the sodium hydroxide solution. Give all the acceptable answers taking the number of significant figures into consideration.

6. The concentration of ethanol in vodka can be determined by reacting the ethanol with excess acidified potassium dichromate solution.
20·0 cm^3 of vodka was transferred to a 1 litre volumetric flask and made up to the mark with deionised water. 5·0 cm^3 of the diluted vodka was pipetted into a conical flask. 25·0 cm^3 of 0·021 mol l^{-1} acidified potassium dichromate was added to the conical flask. The conical flask was then stoppered and warmed until the reaction was complete.

$3C_2H_5OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \rightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(\ell)$
It was found that $1{\cdot}96 \times 10^{-4}$ moles of dichromate ions were left unreacted.

Calculate the concentration of ethanol, in mol l^{-1}, in the undiluted vodka.
Give all the acceptable answers taking the number of significant figures into consideration.

7. When heated, phosphorus pentachloride dissociates to form phosphorus trichloride and chlorine.

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

In an experiment to determine the equilibrium constant, *K*, 0·200 mol of PCl_5 was placed in a sealed 1·00 litre flask and heated to 250 °C. At equilibrium 0·0630 mol of PCl_3 had been formed.

Calculate the equilibrium constant, *K*, for the reaction at 250 °C. Give all the acceptable answers taking the number of significant figures into consideration.