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SL HL Paper 3 Section A Experimental work (1) with worked answers

A student devised an experiment to determine the molar mass of an unknown gas **X**.

Firstly, he filled a glass gas syringe (accurate to ± 0.5 cm^3) with 100 cm^3 of air then placed a rubber seal over the nozzle and weighed the syringe.
He then emptied the gas syringe, refilled it with 100 cm^3 of the unknown gas **X**, replaced the rubber seal and reweighed the syringe.
Finally, he measured the temperature of the room.

He obtained the following data:

Mass of syringe + 100 cm^3 of air	186.293 ± 0.001 g
Mass of syringe + 100 cm^3 of unknown gas **X**	186.358 ± 0.001 g
Temperature	20.0 ± 0.5 °C

In order to calculate the mass of the unknown gas **X** the student made the following assumptions:

The atmospheric pressure = 100 kPa
Air contains 80% nitrogen and 20% oxygen by volume so has a 'molar mass' equivalent to 28.8 g mol^{-1}.

Due to Archimedes' Principle, a syringe containing 100 cm^3 of air appears to have the same mass as a syringe containing 0 cm^3 of air.

(a) Determine the mass of 100 cm^3 of air at 20 °C. ***[2]***

Either using $pV = nRT$
n = Mass/28.8 ***[1]***
Mass of 100 cm^3 of air = (28.8 x 1.00 x 10^5 x 100 x 10^{-6}) ÷ (8.31 x 293) = 0.118 g ***[1]***
or using 1 mole of any gas occupies 22.7 dm^3 at STP
1 mole occupies 22.7 x (293 ÷ 273) = 24.4 dm^3 at 293 K ***[1]***
Mass of 100 cm^3 of air = (28.8 x 100) ÷ (24.4 x 1000) = 0.118 g ***[1]***

(b) Determine the mass of 100 cm^3 of **X** at 20 °C. ***[1]***

Mass of **X** = increase in mass + mass of 100 cm^3 of air
= (186.358 - 186.293) + 0.118 = 0.183 g ***[1]***

(c) Show that the molar mass of **X** is equal to 44.7 g mol^{-1} ***[1]***

$M_{(x)}$ = (0.183 ÷ 0.118) x 28.8 = 44.7 g mol^{-1} ***[1]***
Award the mark for arriving at correct value if $pV = nRT$ or molar volume of a gas expression used.

(d) The accepted value for the molar mass of **X** is 44.0 g mol^{-1}. Calculate the percentage error in the student's result. ***[1]***

Experimental error = ((44.7 – 44.0) ÷ 44.0) x 100 = 1.6% ***[1]***

(e) Identify, with a reason, the piece of equipment used that had the largest percentage uncertainty associated with the result. ***[1]***

The balance.

The uncertainty of the temperature measured by the thermometer is (0.5 ÷ 20.0) x 100 = 2.5%
The uncertainty in the volume of the 100 cm^3 of gas measured twice is (1.00 ÷ 100) x 100 = 1.0 %
The uncertainty in the difference in mass between the two weighings of the syringe is (0.002 ÷ 0.065) x 100 = 3.1% ***[1]***