Calculating Avogadro's Number using the *Junior Basic* PEM Fuel Cell

Background

This experiment is useful for integrating several aspects of senior chemistry including:

- Stoichiometry
- The Gas Laws
- The mole concept
- Electrochemistry
- PEM fuel cell operation.

It is simple, safe and quick to carry out, and with careful measurement, it is possible to calculate Avogadro's Number to within 10% of its accepted value of 6.02×10^{23}.

Method

Prepare the Junior Basic fuel cell model by collecting at least 15mL of hydrogen gas in the storage tank. Attach an electrical load to the fuel cell that will result in a current of approximately 250mA. Close the circuit and record the current and the time taken to consume a known volume of hydrogen gas, say 10mL.

REDOX Reactions

$$H_2 \Rightarrow 2H^+ + 2e^- \qquad E_0 = 0.00V$$

$$½O_2 + 2H^+ + 2e^- \Rightarrow H_2O \qquad E_0 = 1.23V$$

Overall reaction:

$$H_2 + ½O_2 \Rightarrow H_2O \qquad E_0 = 1.23V$$

Comments & Tips

- For best results, purge the fuel cell thoroughly with fresh hydrogen and oxygen before starting the experiment.
- The measured volume of hydrogen that is consumed should be at least 10mL. Use the gauge on the storage tank to estimate the volume.
- You can use a stopwatch and ammeter to measure the current and the time taken for the hydrogen to react, or better still, a datalogger.

Calculations

Measure the average current and the time required to consume a known volume of hydrogen, V_{meas}. From the data, calculate the quantity of charge:

Quantity of charge = Current x Time

or

Q_{calc} (coulomb) = I_{meas} (ampere) x t_{meas} (second)

(If you have connected a datalogger to record current and time, use the datalogging software to calculate the quantity of charge as the area under the current vs time curve).

Now, the quantity of charge is proportional to the volume of gas consumed, so:

$$Q_{mol} / Q_{calc} = V_{mol} / V_{meas}$$

Where the volume of one mole of hydrogen gas, V_{mol}, is 22,400mL.

and thus $Q_{mol} = V_{mol} / V_{meas} \times Q_{calc}$

Each H_2 molecule gives rise to two electrons, so:

No. of H_2 molecules in one mole = Q_{mol} / 2e

Where e = the charge on each electron

= 1.6×10^{-19}C

Example

V_{meas} = 12mL

Q_{calc} = 97C

Therefore, the number of H_2 molecules in one mole = $22,400 \times 97 \;/\; 12 \times 2 \times 1.6 \times 10^{-19}$

= 5.7×10^{23}