I. Determination of e/k_B Through Electrolysis Process

Background Theory

The electrolysis of water is described by the reaction :

$$H_2O \rightarrow 2H^+ + O^{-2}$$

$$2H^+ + 2e^- \rightarrow H_2\,; \quad O^{-2} \rightarrow \frac{1}{2}\,O_2 + 2e^-$$

The reaction takes place when an electric current is supplied through a pair of electrodes immersed in the water. Assume that both gases produced in the reaction are ideal.

One of the gases produced by the reaction is kept in a test tube marked by arbitrary scale. By knowing the total charge transferred and the volume of the gas in the test tube the quantity $\boldsymbol{e/k_B}$ can be determined, where **e** is the charge of electron and $\boldsymbol{k_B}$ is the Boltzmann constant.

For the purpose mentioned above, this experiment is divided into two parts.

Part A: Calibration of the arbitrary scale on the test tube by using a dynamic method. This result will be used for part B

Part B: Determination of the physical quantity $\boldsymbol{e/k_B}$ by means of water electrolysis

You are not obliged to carry out the two experiments (part A and part B) in alphabetical order

The following physical quantities are assumed:

- Acceleration of gravity, $g = (9.78 \pm 0.01)\,ms^{-2}$
- Ratio of internal vs external diameters of the test tube, $\alpha = 0.82 \pm 0.01$

The local values of temperature T and pressure P will be provided by the organizer.

List of tools and apparatus given for experiment (part A & B):

- Insulated copper wires of three different diameters:
  1. Brown of larger diameter
  2. Brown of smaller diameter
  3. Blue
- A regulated voltage source (0-60 V, max.1A)
- A plastic container and a bottle of water.
- A block of brass with plastic clamp to keep the electrode in place without damaging the insulation of the wire.
- A digital stopwatch.
- A multimeter (beware of its proper procedure).
- A wooden test tube holder designed to hold the tube vertically.
- A multipurpose pipette
- A vertical stand.
- A bottle of white correction fluid for marking.
- A cutter

- A pair of scissors
- A roll of cellotape
- A steel ball
- A piece of stainless steel plate to be used as electrode.
- A test tube with scales.
- Graph papers.

Note that all scales marked on the graph papers and the apparatus for the experiments (e.g. the test tube) are of the same scale unit, but ***not calibrated*** in millimeter.

EXPERIMENT

Part A: Calibration of the arbitrary scale on the test tube

- Determine a dynamic method capable of translating the arbitrary length scale to a known scale available.
- Write down an expression that relates the measurable quantities from your experiment in terms of the scale printed on the test tube, and sketch the experiment set up.
- Collect and analyze the data from your experiment for the determination and calibration of the unknown length scale.

Part B: Determination of physical quantity e/k_B

- Set up the electrolysis experiment with a proper arrangement of the test tube in order to trap one of the gases produced during the reaction.
- Derive an equation relating the quantities: time t, current I, and water level difference Δh, measured in the experiment.
- Collect and analyze the data from your experiment. For simplicity, you may assume that the gas pressure inside the tube remains constant throughout the experiment.
- Determine the value of $\boldsymbol{e/k_B}$.

ANSWER FORM

PART A

1. State the method of your choice and sketch the experimental set up of the method: [***0.5 pts***]

2. Write down the expression relating the measurable quantities in your chosen method: [***0.5 pts***]**. State all the approximations used in obtaining this expression [1.0 pts].**

3. Collect and organize the data in the following orders : physical quantities, values, units [***1.0 pts***]

4. Indicate the quality of the calibration by showing the plot relating two independently measured quantities and mark the range of validity. [***0.5 pts***]

5. Determine the smallest unit of the arbitrary scale in term of mm and its estimated error induced in the measurements. [***1.5 pts***]

PART B

1. Sketch of the experimental set up. [***1.0 pts***]

2. Derive the following expression:

$$I\,\Delta t = \frac{\mathrm{e}}{\mathrm{k_B}}\,\frac{2P(\pi r^2)}{T}\,\Delta \mathrm{h}$$

[***1.5 pts***]

3. Collect and organize the data in the following format : physical quantities (value, units) [***1.0 pts***]

4. Determine the value of $\boldsymbol{e/k_B}$ and its estimated error [***1.5 pts***]