Laboratory Exercise: SI Unit Standards

In this short exercise we will use some crude physical measurements to estimate the number of moles of a particular entity, Carbon atoms in one case and electrons in another, which is present in a physical sample. For this exercise, we will be careful to report all of our measurements and estimates in terms of SI unit standards or those units derived therefrom:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter (m)</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram (kg)</td>
</tr>
<tr>
<td>Current</td>
<td>ampere (A)</td>
</tr>
<tr>
<td>Time</td>
<td>second (s)</td>
</tr>
<tr>
<td>Amount</td>
<td>mole (mol)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Derived Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>meter(^3) (m(^3))</td>
</tr>
<tr>
<td>Charge</td>
<td>coulomb = ampere \times second (C)</td>
</tr>
</tbody>
</table>

Specifically, we will measure the number of moles of Carbon atoms contained in a sample of Graphite and the number of moles of Electrons delivered to a household box fan while it operates over a period of time.

Recall, the mole is defined as:

The number of Carbon-12 atoms in a 12 g sample of Carbon-12 is exactly one mole.

This could easily be envisioned as paralleling a definition of the dozen:

The number of Eggs in a Carton of Eggs is exactly one dozen.

Notice that once each of these numbers is determined, it doesn't matter what we are counting, the number of entities being counted in the mole or the dozen are the same, regardless. Current measurements give:

1 dozen = 12 entities / dozen

1 mole = \(6.022 \times 10^{23}\) entities / mole

= \(N_A\) (Avogadro's Number)
Now, typically, we do not start picking off one atom at a time in a sample, if we are determining the number of atoms in the sample, and count them. Instead, we usually measure some other physical quantity, such as mass, and then divide this measurement by the value of that quantity per entity, mass per atom, to get the number of those entities contained in the sample. In the case of atoms, the atom is simply too small to be observed directly and the number of atoms in a sample is simply too large.

\[
\text{# entities} = \frac{\text{meas. Quantity for the Sample}}{\text{Quantity per entity}}
\]

Once the number of entities in a sample is known, it is relatively easy to determine the number of moles, or dozens, of them present.

**Moles of Carbon Atoms**

As just mentioned, in order to estimate the number of Carbon atoms in a given sample of Graphite, we can start by measuring the sample's mass. The known mass of the Carbon atom allows us to calculate the number of Carbon atoms in the sample. We will learn later how to measure the mass of a Carbon atom. (No, we do not simply put one on a scale.) For now, we will take it to be \(1.9945 \times 10^{-26}\) kg. (There is a bit of a sleight-of-hand here. We'll fix things up more properly later.) Now we can determine the number of Carbon atoms in this sample of Graphite; and hence, the number of moles of Carbon atoms.

As an added bonus, we can now determine how efficiently the Carbon atoms are packed into the sample. (See the "dead" space in the diagram above.) From the known diameter of the Carbon atom \((1.54 \times 10^{-10}\) m), we can determine its volume:

\[
V_{\text{sphere}} = \frac{4}{3} \pi \left( \frac{\text{dia}}{2} \right)^3
\]

(At this point it should be noted that Carbon atoms in different materials will have slightly different diameters. We are working with an estimate of the average diameter from a large number of materials composed of Carbon atoms.) If we know the volume of the sample, determined from its geometric measurements, we can determine the packing efficiency:

\[
\text{efficiency} = \frac{\text{(\# C atoms)}(\text{Vol. per C atom})}{\text{Vol. of Sample}}
\]
Moles Electrons

In order to estimate the number of moles of electrons delivered to an operating fan, we will measure the electric current \( I \) flowing through the fan's electric motor during a period of time when the fan is in operation using a *Kill A Watt EZ P4660* meter manufactured by P3 International. The meter is installed into a power outlet and the device whose power consumption is to be measured is plugged into the meter. The meter then monitors the current flow to the operating device from the power source.

By definition, the charge \( Q \) delivered by power source is then:

\[
Q = I \times \text{time}
\]

If the current is measured in *SI* units of amperes and the time is measured in seconds, then \( Q \) is reported in the *SI* unit coulomb.

Because the current flow is due to an opposite flow of electrons, the number of electrons delivered during the time the device is operating is simply the ratio of the charge delivered to the electric charge of an electron:

\[
\text{# electrons} = \frac{Q}{\text{Charge of Electron}}
\]

In a series of very elegant and tedious measurements that we will discuss later in the course, Robert Millikan was able to determine the charge of an electron. The currently accepted value for this quantity is \(-1.60217647 \times 10^{-19}\) coulombs. This determination will then allow for an estimation of the number of moles of electrons delivered during the fan's operation.
Procedure, Data & Data Analysis

Report all measurements and calculated results in terms of SI unit standards. Use appropriate abbreviations for all reported values.

The Mole

Moles of Carbon Atoms

1. Obtain a piece of geometrically regular Graphitic Carbon. **Handle this with gloves, otherwise you will smear Graphite everywhere.** Use a simple ruler to measure the dimensions of the object.

2. **Using a weigh boat on the analytical balance,** measure the mass of your Carbon sample.

Data

Dimensions  __________ x __________ x __________

Mass  __________

Data Analysis

Calculate the Number of Moles Carbon Atoms in Your Graphite Sample:

Calculate the Volume of Your Graphite Sample and the Volume of the Sample Occupied by Carbon Atoms:

Calculate the Packing Efficiency for the Carbon Atoms
Moles of Electrons

1. Proceed to a workstation set-up with a household box fan, a Kill A Watt meter and a stopwatch. Simply turn on the fan and note how fast the current increases to meet the fan's load. Allow the fan to operate for 100 seconds and note the current draw. Then, turn the fan off and again note how quickly the current draw drops to zero.

Data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Max. Current Draw</td>
<td>__________</td>
</tr>
<tr>
<td>Current Draw of Fan</td>
<td>__________</td>
</tr>
<tr>
<td>Time to Zero Current Draw</td>
<td>__________</td>
</tr>
</tbody>
</table>

Data Analysis

Calculate the Charge Delivered to the Fan while it was Operating:

Calculate the Number of Moles of Electrons Delivered to the Fan while it was Operating:

Larger question

What is the point of all of this?