

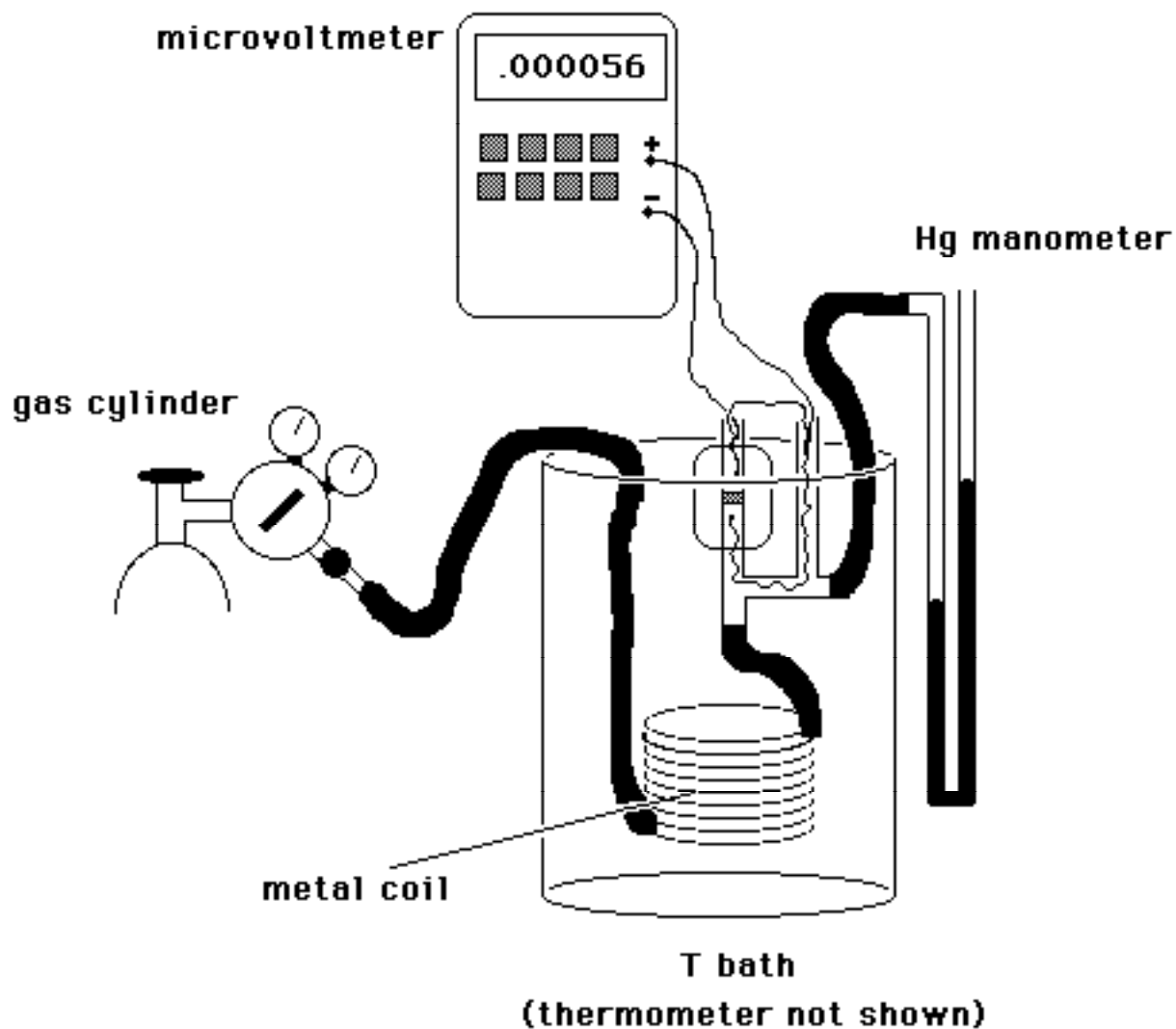
JOULE THOMSON EFFECT

References:

Shoemaker, Garland (and Nibbler) "Experiments in Physical Chemistry", various editions.

CRC "Handbook of Chemistry and Physics" will have tables for converting thermocouple voltages to temperature differences.

Figure 1. Joule-Thomson Equipment Setup



BE SURE TO CHECK WITH SOMEONE WHO HAS ALREADY DONE THIS !! IT IS QUITE POSSIBLE TO SET GAS FLOW WRONG AND GET THE GAS PRESSURE DANGEROUSLY HIGH.

Brief background:

What is the Joule-Thomson effect? When a non-ideal gas suddenly expands from a high pressure to a low pressure there is often a temperature change. Officially, the ratio of $\Delta T/\Delta P$ is known as the Joule-Thomson coefficient. Note that this is far from a reversible effect! It is however an adiabatic effect, and in many applications adiabaticity (yes, that is a real word!) results from the simple fact that the pressure change occurs too quickly for significant heat transfer to occur. For many gases at room temperature, the $\Delta T/\Delta P$ ratio is positive. Thus, a pressure drop is accompanied by a temperature drop. For example, if a tank of CO_2 is opened to the atmosphere, one can see a spray of fine dry ice particles emerging at about -78°C . Expansion of air from a very high pressure to atmospheric pressure can be used to cool the air to the point of liquification. Low-temperature distillation of the liquid thus produced is then used to make liquid nitrogen (nbp at 77 K), liquid oxygen (nbp = ?? K) and even liquid Ar (nbp = ??K). The latter, you may recall, constitutes about 1% of natural air. For a few gases, He and H_2 in particular, the JT coefficient is negative at room temperature. However, the sign switches to a positive value at lower temperatures, and so it is still possible to liquify these gases by JT expansion if they are first cooled, say by liquid nitrogen.

The even more official definition of the Joule-Thomson coefficient is given by the following equation, which is discussed fully in the Derivations manual discussion of this effect:

$$\mu_{JT} = \left(\frac{\partial T}{\partial P} \right)_H = \lim \left(\frac{\Delta T}{\Delta P} \right)_H \text{ as } \Delta P \rightarrow 0$$

Read the Shoemaker, et al. source for a more general background. The thermocouples are both copper-constantan, and you already have a calibration equation from lab 1 which can be used to convert voltage differences between the two junctions to temperature differences. The microvoltmeter is very sensitive to stray sources of voltage. Recommended gases are carbon dioxide and nitrogen. Hook up the carbon dioxide first (it shows the largest effect and is therefore easiest to work with at the star.) Make about 10 measurements between 50 and 200 kPa. For each pressure, set the pressure changes slowly, make sure that the magnetic stirrer is off, then step back and wait for the voltage to stabilize.

Analyzing the data: The Joule-Thomson coefficient is nearly constant over the limited range of the experiment. The μV values are proportional to ΔT , and therefore a plot of μV vs. kPa should be fairly linear. Before switching gases, make an Excel plot to see if the data is in fact reasonably linear. There may be a problem if there is significant curvature, and this should be ascertained before changing the gas.

For the final plots, use the “xyLsquare” Excel sheet on the lab computers. This is an interesting case where the “x” and “y” values are readings which both have significant uncertainties which you can estimate. The recommended spreadsheet allows both x and y uncertainties to be incorporated into a “weighted” linear fit which leads to much more realistic uncertainty estimates for the slope. The slope will, of course, be in units of μV per kPa.

Take the slope (and its uncertainty) and convert it to K per atm units which may be compared to literature values (see “Big Atkins” on reserve in the library for the accepted values for common gases.)

The report should include:

1. A derivation with discussion of the significant equations used in the Joule-Thomson analysis. There is information on this in the Derivations manual, and in Shoemaker et al.
2. Show how to get the result for the JT coefficient predicted by the Van der Waals equation – the derivation is outlined in the Shoemaker et al. resource.
3. Graphs and least-squares analysis of voltage changes versus pressure changes. Show how the results lead to your experimental JT values and their uncertainties.

4. Compare the experimental results with the accepted literature values and with values predicted by the Van der Waals-based theory (item 2 above).

5. References to literature sources, in accepted journal style.

The reports should be written individually.