

**Project #1**

**Background** In class, we have used the *ideal gas law* as an example. The context for the ideal gas law is having some amount of gas in a situation where we can control or measure various quantities such as

- number of gas particles  $n$  (typically in mols)
- pressure  $p$  (typically in pascals or atmospheres)
- volume  $V$  (typically in  $\text{m}^3$  or liters)
- temperature  $T$  (in Kelvin)

For a gas modeled as ideal, these are related by  $pV = nRT$  where  $R$  is the *universal gas constant* having value  $R = 8.314 \text{ J}/(\text{mol}\cdot\text{K}) = 0.082 \text{ L}\cdot\text{atm}/(\text{mol}\cdot\text{K})$ .

Not all gases are modeled well by the ideal gas law. The *van der Waals law* is a generalization of the ideal gas law that accounts for two factors:

- an attractive force between any pair of gas particles, and
- volume occupied by the gas particles themselves.

The van der Waals formula is

$$\left(p + \frac{n^2a}{V^2}\right)(V - nb) = nRT.$$

Note that the van der Waals law formula includes two parameters  $a$  and  $b$ . These are related to the two factors. Values for these parameters depend on the type of gas. As example, for carbon dioxide ( $\text{CO}_2$ ) we have  $a = 3.59 \text{ L}^2\cdot\text{atm}/\text{mol}^2$  and  $b = 0.043 \text{ L}/\text{mol}$ .

If we consider a situation in which the gas does not change (so  $a$  and  $b$  are constant) and the number of particles does not change (so  $n$  is constant), then we have three variables:  $p$ ,  $V$ , and  $T$ . We can think of one of these as a function of the other two. In particular, we will consider  $T$  as a function of  $p$  and  $V$ .

**Project** For this project, your task is to make a plot of  $T = T_0$  level curves in the  $Vp$ -plane and to then use this plot to give some insight on the nature of a van der Waals gas. Here are two approaches you can consider:

- Work with the parameters ( $a$ ,  $b$ ,  $n$ , and  $R$ ) unspecified.
- Use specific values for the parameters. For this, you could consider having 0.1 mol of carbon dioxide and use the values of  $a$  and  $b$  given above. (Use the value of  $R$  with the same system of units.)

The first of these approaches is more general and hence more powerful. The second approach might feel more comfortable since it will involve fewer symbols.

A draft of your report for this project is due on Friday, October 1. I will provide feedback on the draft and you will later submit a revised draft. The due date for the revised draft will be determined later.