**Worksheet: Adiabatic gas expansion between two tanks**

**Name(s)** ______________________________

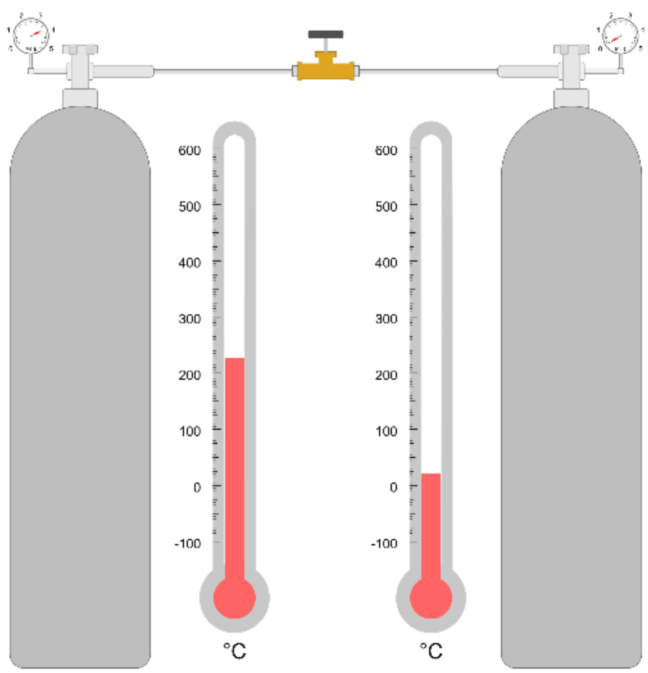
In this experiment, an ideal gas at high pressure in a tank expands adiabatically into a second tank that is under vacuum by opening a valve between the two tanks. The valve closes as soon as the pressure equalizes between the two tanks.

### Student learning objectives

1. Be able to apply the ideal gas law.
2. Be able to do energy balances on a closed system.
3. Be able to do energy balances on an open system.
4. Be able to do mass balances.

### Experimental Diagram

An insulated line that contains a valve connects the two tanks. Each tank has a pressure gauge and a temperature sensor.




### Assumptions

An insulated line contains a valve that connects the two tanks.

The volume of the valves and the line connecting the tanks is insignificant.

The expansion is fast so there is not time for significant heat transfer from the gas to the tanks, and thus the heat capacity of the tank material can be ignored.

The gas is ideal, and it has a constant heat capacity $C_P$ of 30. J / (mol K) and $C_V = C_P - R$.

**Questions to answer before beginning the experiment**

If the two tanks are the same volume and the initial temperature in the first tank is 400 K, is the final temperature in the first tank greater than, less than, or equal to 400 K? Explain.

If the two tanks are the same volume and the initial temperature in the first tank is 400 K, is the final temperature in the second tank greater than, less than, or equal to 400 K? Explain.

If the two tanks are the same volume and the initial pressure in the first tank is 20 bar, is the final pressure in the system greater than, less than, or equal to 20 bar? Explain.

If the two tanks are the same volume and the initial pressure in the first tank is 20 bar, and the initial temperature is 400 K, is the final average temperature of the two tanks greater than, less than, or equal to 400 K? Explain.

If the two tanks are the same volume, is the final number of moles larger in the first or second tank. Why?

**Start the experiment**

Set the initial conditions in the first tank and record the initial conditions (with units).

Temperature ___________

Pressure ______________

Volume _______________

Use the ideal gas law to calculate the number of moles in the first tank.

Moles ________________

Set the volume of the second tank, which is under vacuum, and record its volume.

Volume _______________

Open the valves on the two tanks, then open the valve connecting the tanks. When the tank pressure in the first tank stops decreasing and equals the pressure in the second tank, close the valve. Record the pressure.

Pressure ______________

Record the temperatures in the two tanks.

Temperature tank 1 ____________

Temperature tank 2 ____________

Use the ideal gas law to determine the number of moles in each tank.

Moles in tank 1 _________

Moles in tank 2 _________

Total number of moles _________

How close is the final total moles to the initial number of moles in the first tank?

Percent difference _____________

Calculate the final average temperature $T_{average}$ of the system from an internal energy balance.

$$( n_{1f} + n_2 ) C_V ( T_{average} - T_{ref} ) = n_{1f} C_V ( T_{1f} - T_{ref} ) + n_2 C_V ( T_{2f} - T_{ref} )$$

Note that since $( n_{1f} + n_2 ) = n_{i1}$

then $T_{average} = T_{1i}$

because an internal energy balance on the system is:

$$n_{1i} C_V ( T_{1i} - T_{ref} ) = n_{1f} C_V ( T_{1f} - T_{ref} ) + n_2 C_V ( T_{2f} - T_{ref} )$$

where

$n_{1i}$ = initial number of moles in first tank
$C_V$ = constant volume heat capacity of gas
$T_{1i}$ = initial temperature in tank 1
$T_{ref}$ = reference temperature (pick any convenient value)
$T_{1f}$ = final temperature in tank 1
$n_{1f}$ = final number of moles in tank 1
$n_2$ = final number of moles in tank 2
$T_{2f}$ = final temperature in tank 2

How close is the final average temperature to the initial temperature in tank 1?

Percent difference ______________

Why?

How close is the final pressure to the pressure expected if the expansion were conducted isothermally?

Percent difference ______________

Why?

Calculate the final temperature expected in the first tank if the final number of moles in the first tank had expanded adiabatically and reversibly using this equation:

$$\frac{T_{1f}}{T_{1i}} = \left(\frac{P_{1f}}{P_{1i}}\right)^{R/C_P}$$

where

$P_{1i}$ = initial pressure in tank 1

$P_{1f}$ = final pressure in tank 1

Temperature calculated for adiabatic reversible expansion _______________

How close is the final temperature in the first tank to that expected for reversible adiabatic expansion?

Percent difference _____________

Why?

**Questions to answer**

1. Why did the temperature in the first tank decrease?

2. Why did the temperature in the second tank increase above the initial temperature in the first tank?

3. What are sources of error in the measurements?

4. If this experiment were conducted in the laboratory, what might cause the measured pressure and temperatures to be different from the values calculated above?

5. What safety measures would you employ if making this measurement in the laboratory?