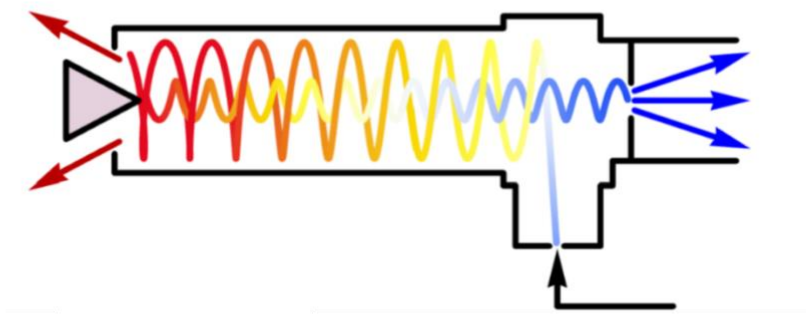
Name(s): ____

Higher-pressure, room-temperature air is fed to a Ranque-Hilsch vortex tube, which splits the air into hot and cold streams at lower pressure. The fraction of the air that goes to the cold side (or hot side) affects how cold the low temperature side (or high-temperature side) is. The Vortex tube allows cooling without electricity or moving parts.



Student Learning Objectives

1. Apply the first law of thermodynamics to a steady-state system.
2. Apply the second law of thermodynamics.
3. Distinguish between idealized and real system behavior by comparing a reversible, adiabatic model to an irreversible, non-adiabatic system.

Equipment

- Compressed air generator
- Compressed air flow valve
- Inlet rotameter
- Inlet pressure gauge
- Cold-side air outlet rotameter
- Cold-side air outlet pressure gauge
- Ranque-Hilsch Vortex Tube
- Hot-side temperature meter
- Cold-side temperature meter

Questions to answer before running the experiment:

1. Is it physically possible to split a room-temperature stream into a hot and cold stream?

2. Does the total entropy of the system increase, decrease, or not change? Explain why.

3. What are advantages and disadvantages of using a vortex tube over a typical refrigeration system?

4. If more air flows to the hot side of the tube, do you expect the high temperature to increase or decrease?

Running the experiment:

1. Open the valve to allow compressed air to flow to the Hilsch tube and adjust the flow rate leaving the hot side.
2. Record the required pressure, temperature, and flow rate values in the Table below.
3. Repeat these measurements for a range of feed pressures and for various openings of the valve on the high temperature outlet. Record values in the Table.

Experiment #	Feed temperature (°C)	Feed pressure (bar)	Feed flow rate (mL/s)	Cold-side temperature (°C)	Cold-side pressure (bar)	hot-side temperature (°C)	Hot-side pressure (bar)	hot-side flow rate (mL/s)
1								
2								
3								
4								
5								
6								
7								
8								

After the experiment:

For each experiment, record the results of these calculations in the Table below.

Calculate the molar flow rates for the hot and cold streams using the ideal gas law and material balances.

Calculate the two terms in the energy balance for the change in energy of the hot and cold streams.

Add the two terms together. Do they add to zero?

where T_f = feed temperature (K)

T_c = cold temperature (K)

T_h = hot temperature (K)

P_f = feed pressure (bar)

P_h = hot side pressure (bar)

P_c = cold side pressure (bar)

C_P = constant pressure heat capacity (J/(mol K))

Experiment #	$\dot{n}_h$ (mol/s)	$\dot{n}_c$ (mol/s)	$\dot{n}_h C_p (T_h - T_f)$ (J/s)	$\dot{n}_c C_p (T_c - T_f)$ (J/s)	Add 2 energy terms
1					
2					
3					
4					
5					
6					
7					
8					

Calculate the change in entropy for the hot and cold streams and enter in the table below.

Experiment #	$\dot{n}_h$ (mol/s)	$\dot{n}_c$ (mol/s)	$(\dot{n}_h C_p - R)\left[ln\left(\frac{T_h}{T_f}\right)\right]$ [J/(K s)]	$(\dot{n}_h C_p - R)\left[ln\left(\frac{T_c}{T_f}\right)\right]$ [J/(K s)]	Add 2 entropy terms
1					
2					
3					
4					
5					
6					
7					
8					

Is the total entropy change positive?

Questions to answer

1. What is the entropy change of the surroundings? Why?

2. What experimental aspect was ignored in applying the first law to this system?