First Law of Thermodynamics

New Topic
A gas cylinder and piston are covered with heavy insulation. The piston is pushed into the cylinder, compressing the gas. In this process, the gas temperature

1. doesn’t change.
2. decreases.
3. increases.
4. there’s not sufficient information to tell.

Work is done on the gas to compress it ... this increases the internal energy.

ConcepTest 17a.1 Work

A gas cylinder and piston are covered with heavy insulation. The piston is pushed into the cylinder, compressing the gas. In this process, the gas temperature

1. doesn’t change.
2. decreases.
3. increases.
4. there’s not sufficient information to tell.
The quantity of heat needed to change the temperature of \( n \) moles of gas by \( \Delta T \) is

\[ Q = nC_v \Delta T \]  (temperature change at constant volume)

where \( C_v \) is the molar specific heat at constant volume. **A couple of points that are important:**

1. \( C_v \) is an intensive variable, that is the amount per unit mass or mole.
2. Relating the above equation to the First Law:
   \[ dE = dQ - pdV \], if \( V \) is not changing, then all the heat goes to changing the internal energy.
3. In any process, where heat is input, then the amount that increases the internal energy is \( nC_v dT \).
4. Thus we can always use \( dE \) and \( nC_v dT \) interchangeably. How does this come from the definition of the internal energy of an ideal gas?
Example: Heat capacity and phase change

An insulated beaker with negligible mass contains liquid water with a mass of 0.215 kg and a temperature of 70.2°C. How much ice at a temperature of -11.6°C must be dropped into the water so that the final temperature of the system will be 29.0°C? Take the specific heat of liquid water to be 4190 J/kg K, the specific heat of ice to be 2100 J/kg K, and the heat of fusion for water to be 334 J/kg K.

Ponderable: Adiabatic change energy without heat

1. You need to raise the temperature of a gas by 10°C. To use the least amount of heat energy, should you heat the gas at constant pressure or at constant volume? Explain.
2. The figure shows an adiabatic process.
   1. Is the final temperature higher than, lower than, or equal to the initial temperature?
   2. Draw and label the $T_i$ and $T_f$ isotherms on the figure. Why is the isotherm, $T_i$, above or below the adiabat curve?
   3. Is the work done on the gas positive or negative? Explain.
   4. Show on the figure how you would determine the amount of work done.
   5. Is any heat energy added to or removed from the system in this process? Explain.
   6. Why does the gas temperature change? How is this change related to the heat capacity?
Ponderable: Isothermal expansion of a gas 2

1. How much work is done to expand the gas from $V_1$ to $V_2$?
2. By how much does the internal energy change?
3. How much heat is input?
4. By how much does the entropy change?
5. Does the entropy increase or decrease upon expanding? Does this make sense relative to the microscopic definition of entropy?
6. If the volume doubles, what is the change in entropy? Remember this result for later today

New Topic
**Entropy**

- Statistical definition of entropy:
  \[ S = k_B \ln W \]
  
  *W* is the multiplicity, that is the number of possible ways to achieve a given state.

- We also know that this is related to the heat input:
  \[ dQ = TdS \]
  
  Differences in entropy are important (because the tell you how much heat was input or released):

  \[ \Delta S = S_2 - S_1 = k_B \ln \left( \frac{W_2}{W_1} \right) \]

---

**Ponderable: Flipping Coins and Entropy -- Review**

- If you flip a coin one time, what is the total number of possible flips?
- Now if you flip a coin 4 times, what is the total number of possible flips?
- Now consider multiplicities for four coin flips
- How many unique scores are there (count +1 for heads, -1 for tails)?
- Which score has the highest multiplicity?
- Which score has the highest probability?
- Which score has the highest entropy?