PROPERTIES OF GAS

EXIT

The Nature of a Gas:

- have mass
- easy to compress
- have low densities
- fill containers completely
- diffuse quickly (move through each)
- exert pressure (depends on temperature)

Kinetic-Molecular Theory (KMT) describes the behavior of gases

- A gas consists of very small particles
- The distances between gas particles are relatively large.
- Gas particles are in constant, random motion.
- Collisions between gas particles are perfectly elastic.
- Average KE of particles depends only on the temperature of the gas.
- There is no attractive force between particles of a gas.

Variables That Effect Gases

- Moles (n) – the amount of gas.
- Volume (V) – the size of the container that holds the gas in liters (L).
- Temperature (T) – the speed or kinetic energy of the particles in kelvin (^oC +273)
- Pressure (P) – The outward push of gas particles on their container in atmospheres (atm) or millimeters of mercury (mm Hg) or pounds per square inch (psi)

  *Think of pressure as the number of collisions between gas particles and their container.

- if P increases, V decreases
- If P decreases, V increases

- If T increases, V increases
- if T decreases, V decreases

- If P increases, T increases
- if P decreases, T decreases

STP – Standard Temperature Pressure

- The behavior of a gas depends on its temperature and the pressure at which the gas is held.
- So far we have only dealt with gases at STP. Standard Temperature and Pressure.
    - 273 kelvins and 1 atm.

The Gas Laws

- Boyle's Law
- Charles's Law
- Gay-Lussac's Law
- The Combined Gas Law
- The Ideal Gas Law

Boyle's Law

- The Pressure-Volume Relationship
- The pressure and volume of a sample of gas at constant temperature are inversely proportional to each other.

  (As one goes up, the other goes down)
- $P_1V_1 = P_2V_2$
- If 3 of the variables are known, the fourth can be calculated.

Boyle's Law

- The gas in a 20.0mL container has a pressure of 2.77atm. When the gas is transferred to a 34.0mL container at the same temperature, what is the new pressure of the gas.

$P_1V_1 = P_2V_2$

$P \propto \frac{1}{V}$

$$P_2 = \frac{20.0mL(2.77atm)}{34.0mL}$$

$$P_2 = \frac{P_1V_1}{V_2}$$

$$P_2 = 1.63atm$$

Boyle's Law

- If a set amount of gas is transferred into a larger container, would the pressure go up or down?
- Would there be more collisions, or fewer collisions with the container holding the gas?
- More volume (space) means fewer collisions with the container, therefore pressure goes down. (From 2.77 atm to 1.63 atm)

Charles's Law

- The temperature-volume relationship
- At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature.
- $$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

If 3 of the variables are known, the fourth can be calculated.

Charles's Law

- What will be the volume of a gas sample at 355K if its volume at 273K is 8.57L?

$V \propto T$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{8.57L(355kelvin)}{273kelvin}$$

$$V_2 = \frac{V_1 T_2}{T_1}$$

$$V_2 = 11.1L$$

Charles's Law

- If the temperature of a given quantity of gas is increased, what will happen to the volume it occupies? (In an elastic container?)
- Gas particles moving faster would have more collisions with the container and exert more force to enlarge the volume of the elastic container.
- In this case, from 8.57L to 11.1L.

Gay-Lussac's Law

- The Temperature-Pressure Relationship
- If a volume of a sample of gas remains constant, the temperature of a fixed amount of gas is directly proportional to its pressure.
- $$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

- If you know 3 of the variables, you can calculate the 4th.

Gay-Lussac's Law

- The gas left in a used aerosol can is at a pressure of 2.03atm at 25°C. If this can is thrown onto a fire, what is the pressure of the gas when its temperature reaches 928°C?
- $$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad P_2 = \frac{2.03atm(1201K)}{298K}$$
- $$P_2 = \frac{P_1 T_2}{T_1} \qquad P_2 = 8.18atm$$

$P \propto T$

Gay-Lussac’s Law

- If the temperature of a fixed amount of gas goes up, the particles will have more collisions. More collisions means the pressure will increase.
- In this case, when the temp went up the pressure increased from 2.03atm to 8.18atm.

The Combined Gas Law

- If more than one variable changes, a different equation is needed to analyze the behavior of the gas.
- $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

  - 5 of the variables must be known to calculate the 6th.

The Combined Gas Law

- The volume of a gas-filled balloon is 30.0L at 40^{o}C and 1.75atm of pressure. What volume will the balloon have at standard temperature and pressure?

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$$

$$V_2=\frac{V_1P_1T_2}{P_2T_1}$$

$$V_2=\frac{30.0L(1.75atm)(273K)}{1.00atm(313K)}$$

$$V_2=45.8L$$

The Combined Gas Law

- You have a fixed volume of gas. The temperature decreases which would cause fewer collisions and the pressure decreases which causes fewer collisions as well. What can you do to volume to make the pressure decrease???
- Increase it. More space means fewer collisions.

The Ideal Gas Law

- Describes the physical behavior of an ideal gas in terms of the pressure, volume, temperature and the number of moles of gas.
- Ideal – a gas as it is described by the kinetic-molecular theory postulates.
- All gases are REAL gases… which behave like ideal gases only under most ordinary conditions.

The Ideal Gas Law

- Only at very low temperatures and very high pressures do real gases show significant non-ideal behavior.
- We will assume that gases are close to ideal and that the ideal gas equation applies.

Ideal Gas Equation

$$PV=nRT$$

- P-pressure
- V-volume
- n-number of moles of gas
- R-ideal gas constant (universal gas constant) 0.0821 atm·L/mol·K

  or 62.396 torr·L/mol·K
- T-temperature

Ideal Gas Equation

- What is the volume occupied by 9.45g of C_2H_2 at STP?

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

First, calculate amount of gas in moles.

$$n = 9.45gC_2H_2 \frac{1molC_2H_2}{26.03788gC_2H_2}$$

$$n = 0.3629328molC_2H_2$$

Ideal Gas Law

$$V = \frac{nRT}{P}$$

$$V = \frac{0.3629328mol(0.0821atm \cdot L / mol \cdot K)273k}{1.00atm}$$

$$V = 8.1345217L$$

$$V = 8.13L$$

Ideal Gas Law

- How many moles of a gas at 100^{o}C does it take to fill a 1.00L flask to a pressure of 1.5atm?

$$PV = nRT$$

$$n = \frac{1.5atm(1.00L)}{0.0821atm \cdot L / mol \cdot K(373k)}$$

$$n = \frac{PV}{RT}$$

$$n = 0.0490mol$$

INTERNAL ENERGY

- Internal energy is defined as
  the energy associated with the random, disordered motion of molecules.

RELATION BETWEEN Cp & Cv.

- $Cv = du/dT$......(1)
  $Cp = dh/dT$......(2)

  $h = u+Pv$
  $dh = d(u+Pv) = du+Pdv+ vdp$...(3)
  (3)-->(2)
  $Cp = du+Pdv+ vdp / dT = du / dT+Pdv / dT+ vdp / dT = Cv+(Pdv + vdp) / dT$....(4)
  For gas ideal, $Pv=RT$

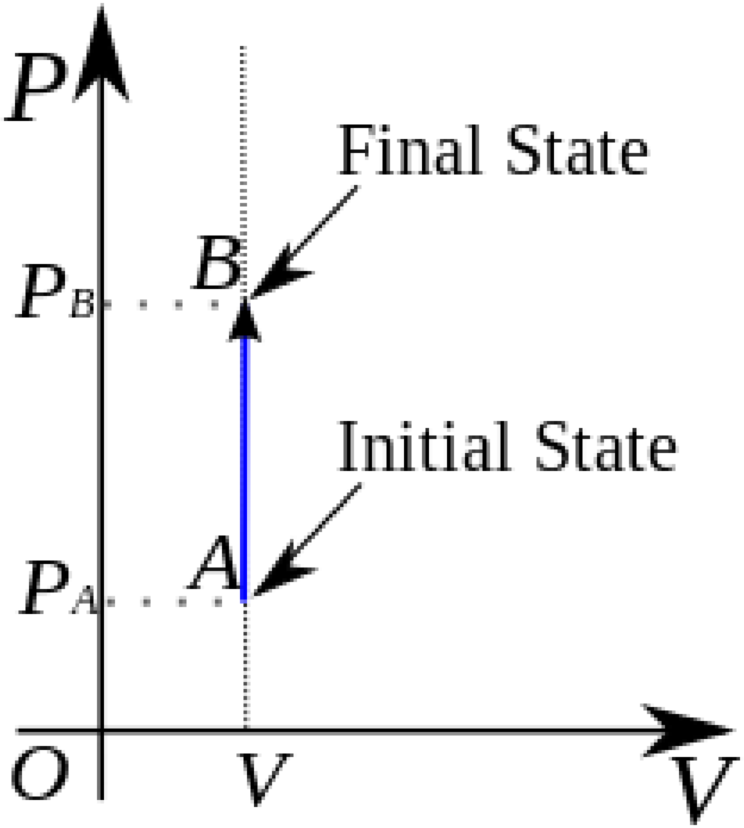
- $Pdv+vdp = RdT$...(5)
  (5)-->(4)
  $Cp = Cv + RdT/dT = Cv+R$
  $Cp-Cv = R$
  So, as temperature change, Cp-Cv will be the same as gas constant, R.

TYPES OF NON FLOW PROCESSES

- There are various types of non flow processes just like

1. Reversible constant volume process
2. Reversible constant pressure process
3. Isothermal process
4. Adiabatic process
5. Polytropic process

1. Reversible constant volume process



1. Reversible constant volume process

i) Work done:

$$W = \int_1^2 P.dV$$

$W = 0$ since dV is zero (no change in volume).

ii) Change in internal energy:

Since temperature changes from T_1 to T_2, there will be change in internal energy given by;

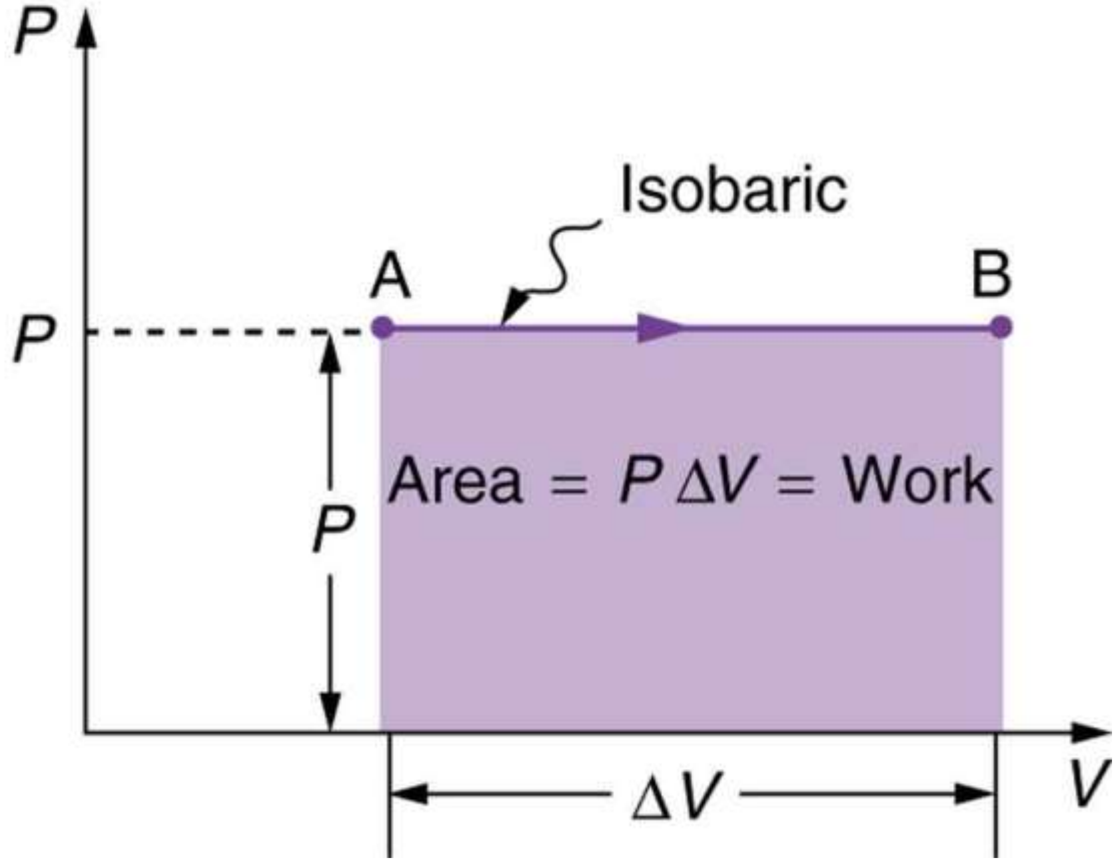
$$\Delta U = m\,C_v\,(T_2 - T_1)$$

iii) Heat transferred:

$$Q = W + \Delta U = 0 + \Delta U$$

i.e. $Q = \Delta U = m\,C_v\,(T_2 - T_1)$. That means, the whole of the heat supplied during the process is used to increase the internal energy of the system.

2. Reversible constant pressure process



2. Reversible constant pressure process

i) Work done:

$$W = \int_1^2 P.dV = P \int_1^2 dV$$

$$\dot{W} = P(V_2 - V_1) = mR(T_2 - T_1)$$

ii) Change in internal energy:

Change in internal energy is given by,

$$\Delta U = m\,C_v\,(T_2 - T_1)$$

iii) Heat transferred:

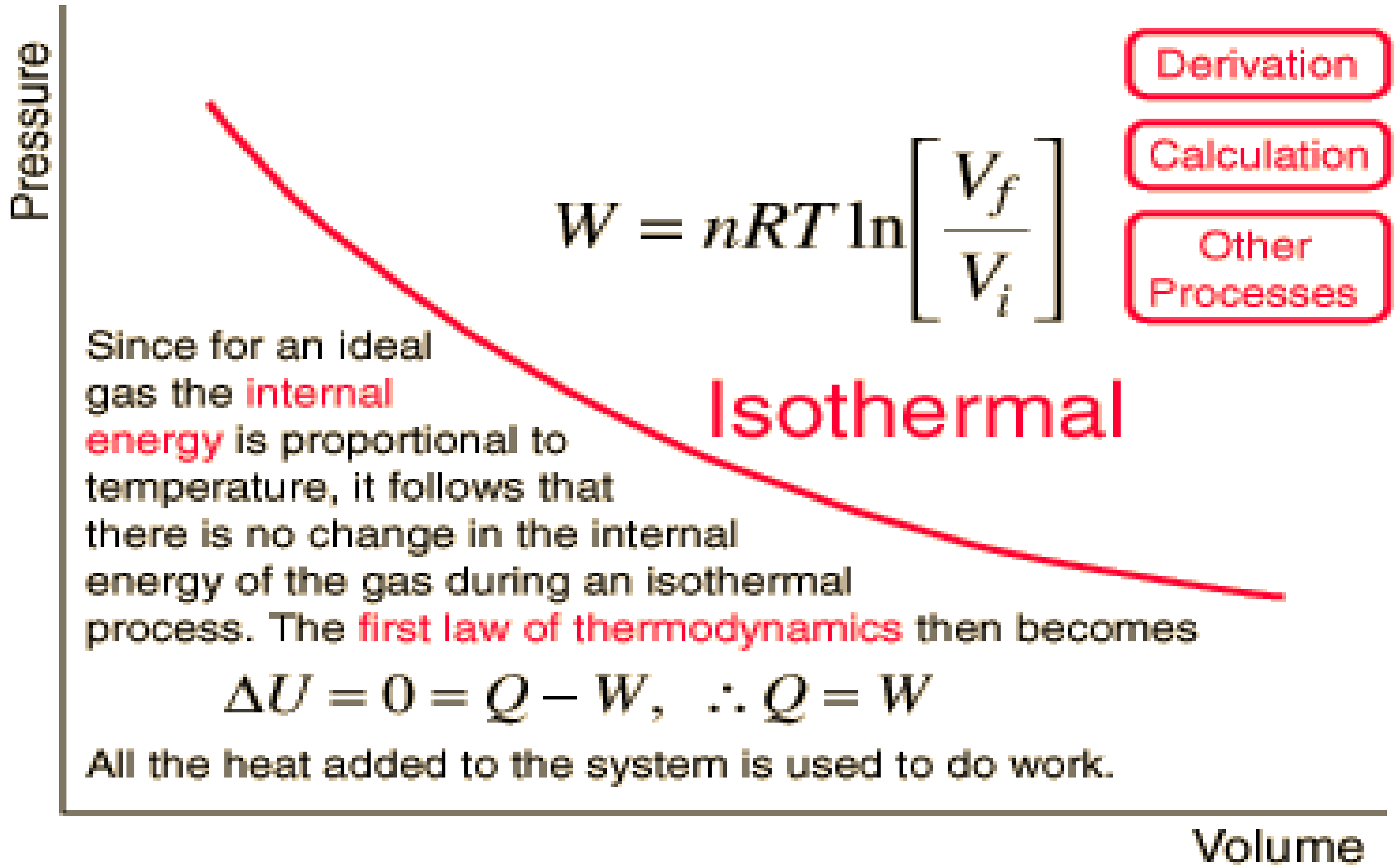
$$Q = W + \Delta U$$

$$Q = mR\,(T_2 - T_1) + m\,C_v\,(T_2 - T_1)$$

$$= m\,(T_2 - T_1)\,[R + C_v]$$

i.e. $Q = m\,C_p\,(T_2 - T_1)$ since $C_p - C_v = R$

3. Iso thermal process



3. Iso thermal process

P, V and T are the properties whose values are P_1, V_1 and T_1 respectively at the initial state 1, and P_2, V_2 and T_2 at the final state 2. The system considered is a gas which obeys perfect gas laws.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

But $T_1 = T_2$ since the process is isothermal.

Hence, $P_1V_1 = P_2V_2$ or, $PV = \text{constant}$

i) *Work done during an isothermal process is given by;*

$$W = \int_1^2 P.dV \qquad PV = P_1V_1 \text{, hence} \quad P = \frac{P_1V_1}{V}$$

$$W = \int_1^2 \frac{P_1V_1}{V} dV = P_1V_1 \int_1^2 \frac{1}{V} dV$$

$W = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$ or $W = mRT_1 \ln\left(\frac{V_2}{V_1}\right)$, if the working medium is considered as an ideal gas.

Also, $W = P_1V_1 \ln\left(\frac{P_1}{P_2}\right)$ since $\frac{V_2}{V_1} = \frac{P_1}{P_2}$ for isothermal process.

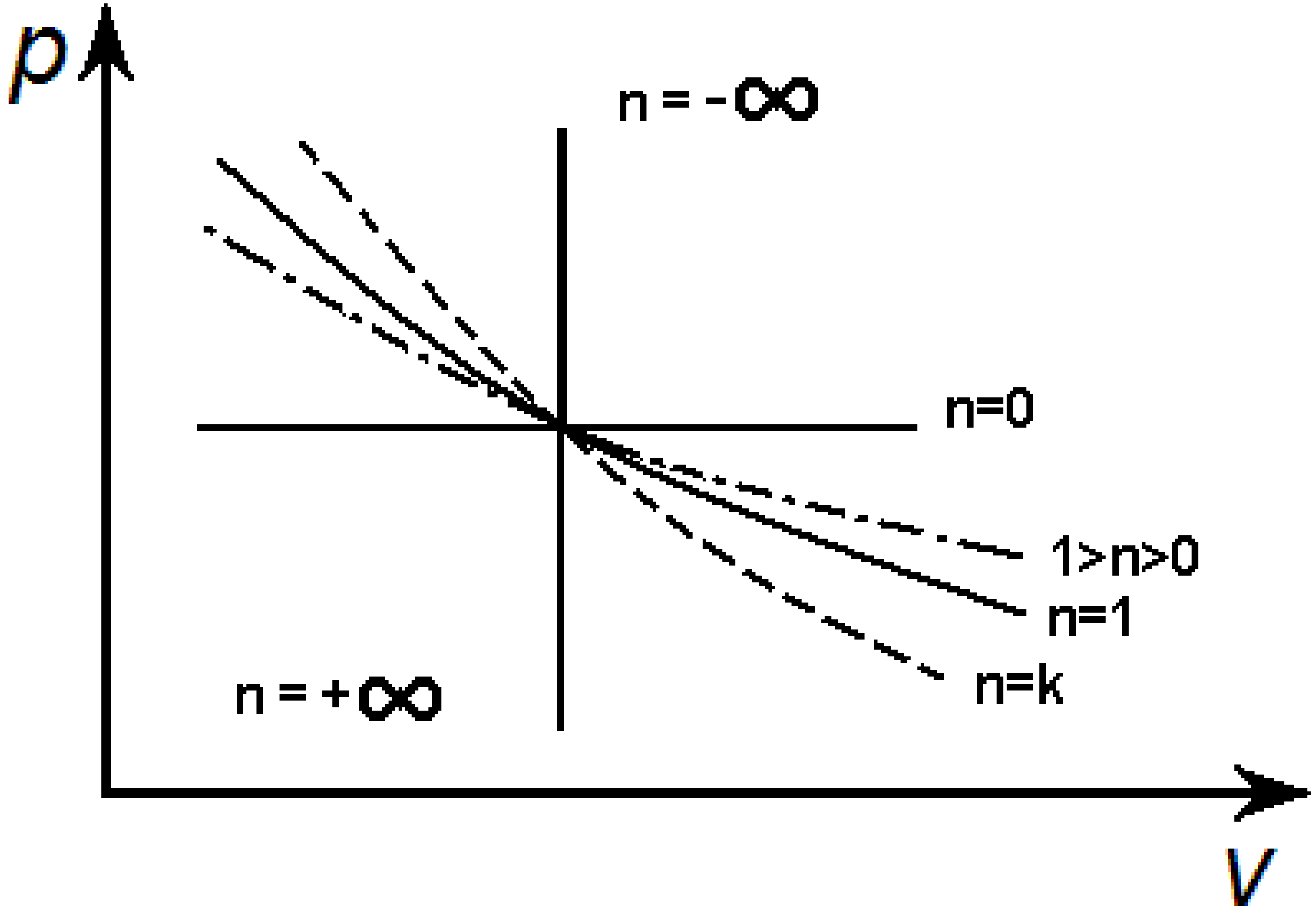
ii) *Change in internal energy (also change in enthalpy) is zero, since ΔT for this process is zero*

$$\Delta U = 0 \quad \text{and} \quad \Delta H = 0$$

iii) *Heat transferred,* $Q = W + \Delta U = W + 0 = W$

i.e. $Q = P_1V_1 \ln\left(\frac{V_2}{V_1}\right) = mRT_1 \ln\left(\frac{V_2}{V_1}\right)$

4. Poly-tropic process



4. Poly-tropic process

i) Work done:

$$W = \int_1^2 P.dV$$

$$W = \int_1^2 P_1V_1^n \frac{dV}{V^n}$$

$$= \frac{P_1V_1^n [(V_2)^{1-n} - (V_1)^{1-n}]}{1-n}$$

$$= \frac{P_2V_2^n [(V_2)^{1-n}] - P_1V_1^n [(V_1)^{1-n}]}{1-n}$$

$$= \frac{P_2V_2 - P_1V_1}{1-n}$$

i.e. $$W = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{mR(T_1 - T_2)}{n-1}$$

ii) Change in internal energy:

Since there occurs change in temperature, there will be change in internal energy.

$$\Delta U = m\,C_v\,(T_2 - T_1)$$

iii) Heat transferred:

$$Q = W + \Delta U = \frac{mR(T_1 - T_2)}{n-1} + m\,C_v\,(T_2 - T_1)$$

i.e. $$Q = m\,(T_2 - T_1)\,[C_v - \frac{R}{n-1}]$$