Lecture 1

Problem 22 : *A small electric immersion heater is used to heat 100 g of water for a cup of instant coffee. The heater is labeled "200 watts" (it converts electrical energy to thermal energy at this rate). Calculate the time required to bring all this water from 23° C to 100° C, ignoring any heat losses.*

Solution:

m = 0.100 kg

P = 200 W = 200 J/s

T_i = 23°C = 23+273 = 296 K

T_f = 100°C = 100 +273 K= 373 K

ΔT = Tf –Ti = 373 – 296 K=77 K   [ΔT = Tf –Ti = 100 – 23 =77 C°]

c = 4190 J/kg-K = 4190 J/kg-C°

P = W/t

P = Q/t   ***[Q = cm ΔT]***

$$t = \frac{Q}{P} = \frac{mc\Delta T}{P} = \frac{0.100(4190)(77)}{200} = 160 \text{ sec} \quad \textit{(Ans)}$$

Problem 24 : *A certain substance has a mass per mole of 50.0 g/mol. When 314 J is added as heat to a 30.0 g sample, the sample's temperature rises from 25.0℃ to 45.0℃. What are the (a) specific heat and (b) molar specific heat of this substance? (c) How many moles are in the sample?*

Solution :

Molar mass, M = 50 g =50 × 10^{-3} kg ; Q = 314 J ; mass of sample, m = M_{sam} = 30 g = 30 × 10^{-3} kg

T_i = 25°C; T_f = 45°C ; ΔT = (45 + 273)K – (25+273)K = (45 -25)K = 20 K

(a) Q = mcΔT

$$c = \frac{Q}{m\,\Delta T} = \frac{314}{30 \times 10^{-3} \times 20} = 523 \text{ J/kg-K}$$

(c)

M_{sam} = nM

$$n = \frac{Msam}{M} = \frac{30 \times 10^{-3}}{50 \times 10^{-3}} = 0.600 \text{ mol} \qquad [50 \text{ gm} = 1 \text{ mol}]$$

(b) Q = $nc_m\Delta T$

$$c_m = \frac{Q}{n\,\Delta T} = \frac{314}{0.600 \times 20} = 26.2 \text{ J/mol-K}$$

Lecture 2

Problem 27 : *Calculate the minimum amount of energy, in joules, required to completely melt 130 g of silver initially at 15.0° C.*

Solution:

m = 130 g = 0.130 kg

The melting point of silver is 1235 K

T_i=15.0°C = (273+15)K = 288 K

T_f= 1235 K

$\Delta T = (1235 - 288)K = 947$ K

c = 236 J/kg-K

$Q_1 = cm\Delta T$ = 236(0.130)947 = 2.91×10^4 J

$L_f = 105\times10^3$ J/kg

$Q_2 = mL_f$ = (0.130) (105×10^3) = 1.36×10^4 J

The total heat required, $Q = Q_1 + Q_2 = (2.91\times10^4 + 1.36\times10^4)$ J = 4.27×10^4 J

Problem 28 : *How much water remains unfrozen after 50.2 kJ is transferred as heat from 260 g of liquid water initially at its freezing point?*

Solution:

Q = 50.2 kJ = 50.2×10^3 J

Liquid water, m_1 *= 260 g = 0.260 kg*

L_f = 333 kJ/kg = 333×10^3 J/kg

Mass of frozen water (ice), m =?

Heat is lost by water, $Q = mL_f$

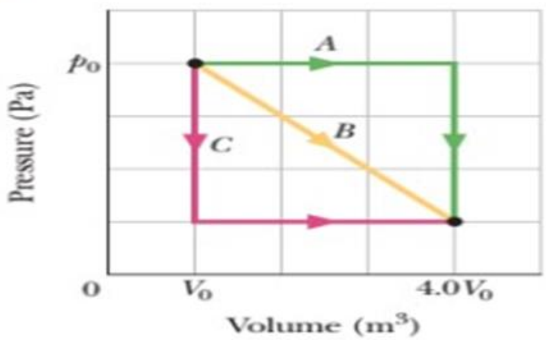
$$m = \frac{Q}{L_f} = \frac{50.2\times10^3}{333\times10^3} = 0.151 \text{ kg}$$

The amount of water that remains unfrozen (liquid water) = $m_1 - m$ = (0.260 – 0.151) kg = 0.109 kg = 109 g

Windows Ink Workspace

Lecture 3

43. In Fig., a gas sample expands from V_0 to $4.0V_0$ while its pressure decreases from p_0 to $p_0/4.0$. If $V_0 = 1.0\ m^3$ and $p_0 = 40$ Pa, how much work is done by the gas if its pressure changes with volume via (a) path A, (b) path B, and (c) path C?



Solution of 43

The volume increases through the three paths , so the work done by the gas is always positive.

W = $\int dW = \int_{Vi}^{Vf} pdV$ = Area under the curve of p-V

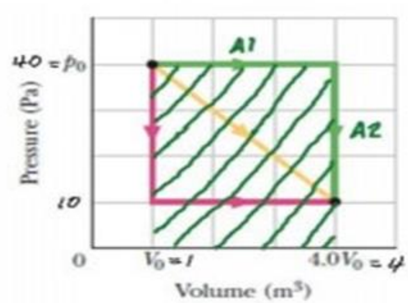
(a) $W_A = W_{A1} + W_{A2}$

W_{A1} = 40 (4-1) = +120 J

(constant pressure)

W_{A2} = 0 (constant volume)

W_A = 120 +0 = +120 J



or

[W = $p\Delta V = p(V_f - V_i)$= (40-0)(4-1)

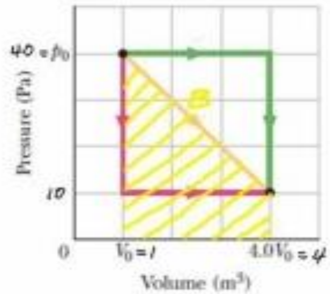
W=40(3) = +120 J]

(b) The work done by the gas is the area under the curve (yellow line)

$W_B = \frac{1}{2} \times (4 - 1)(40 - 10) + (4 - 1)(10 - 0)$

$= (45 + 30)$ J

$= +75$ J

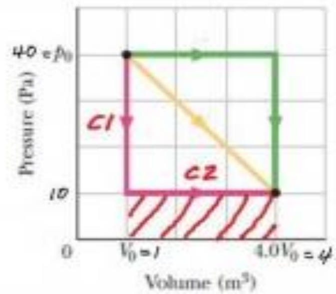


(c) $W_C = W_{C1} + W_{C2}$

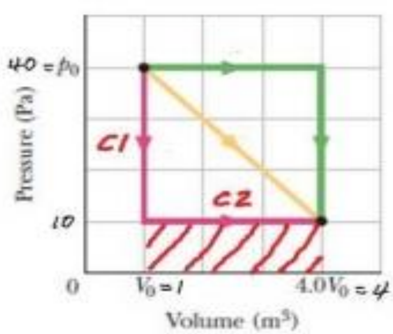
$W_{C1} = 0$ (constant volume)

$W_{C2} = (4-1)(10-0) = 30$ J

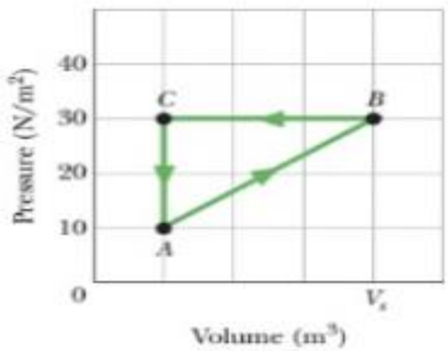
$W_C = 0 + 30 = +30$ J



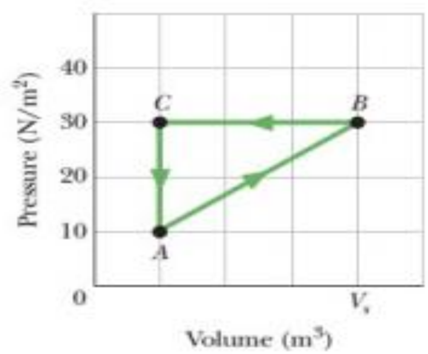
- (c) $W_C = W_{C1} + W_{C2}$
- $W_{C1} = 0$ (constant volume)
- $W_{C2} = (4-1)(10-0) = 30$ J
- $W_C = 0 + 30 = +30$ J



45. A gas within a closed chamber undergoes the cycle shown in the p-V diagram of Fig. The horizontal scale is set by $V_s = 4.0\ m^3$. Calculate the net energy added to the system as heat during one complete cycle.



Solution:
Since for a closed cycle, $\Delta E_{int} = E - E = 0$
1st law of thermodynamics, $\Delta E_{int} = Q - W$
$0 = Q - W$
$Q = W$



The work done in a complete cycle is given by the area inside the loop (triangle)
$W_{net} = ½ \times (4\text{-}1)(30\text{-}10) = 30$ J

Area under the curve B to C (compression) Is greater than the area under the curve A to B (expansion). So the net work done is negative.
$W_{net} = -30$ J

[or $W_{net} = ½ \times (V_f - V_i)(30\text{-}10) = ½ \times (1\text{-}4)(30\text{-}10) = -30$ J]

$Q = W = -30$ J
The gas (system) loses heat.

Lecture 4

46. Suppose 200 J of work is done on a system and 70.0 cal is extracted from the system as heat. In the sense of the first law of thermodynamics, what are the values (including algebraic signs) of (a) W, (b) Q, and (c) ΔE_{int}.

Solution:

(a) The work done is negative since work done on the system.

$$W = -200 \text{ J}$$

(b) Energy is extracted from the system,

$$Q = -70 \text{ cal} = -70(4.2) \text{ J} = -294 \text{ J} \qquad [1 \text{ cal} = 4.2 \text{ J}]$$

(c) Internal energy change,

$$\Delta E_{int} = Q - W = -294 - (-200) = -294 + 200 = -94 \text{ J}$$

48. As a gas is held within a closed chamber, it passes through the cycle shown in Fig. Determine the energy transferred by the system as heat during constant-pressure process CA if the energy added as heat Q_{AB} during constant-volume process AB is 20.0 J, no energy is transferred as heat during adiabatic process BC, and the net work done during the cycle is 15.0 J.

Solution: First law of thermodynamics,

$$\Delta E_{int} = Q - W$$

For a cyclical process,

$$\Delta E_{int} = E - E = 0$$

$$0 = Q - W$$

$$Q = W$$

$$Q_{AB} + Q_{BC} + Q_{CA} = W$$

$$+20 + 0 + Q_{CA} = +15$$

$$Q_{CA} = -5 \text{ J}$$

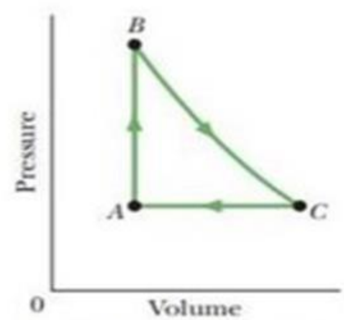


Figure 18-41 Problem 48.

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Lecture 5

4. A quantity of ideal gas at 10.0 °C and 100 kPa occupies a volume of 2.50 m³. (a) How many moles of the gas are present? (b) If the pressure is now raised to 300 kPa and the temperature is raised to 30.0 °C, how much volume does the gas occupy? Assume no leaks.

Solution:

(a) $p_iV_i = nRT_i$ ....(1)

$$n = \frac{p_i V_i}{RT_i} = \frac{1\times10^5 \times 2.50}{8.31 \times 283} = 106 \text{ mol}$$

(b) $p_fV_f = nRT_f$ ....(2)

(2) / (1)

$$V_f = \frac{V_i P_i T_f}{P_f T_i} = \frac{1 \times 10^5 \times 2.50 \times 303.15}{3 \times 10^5 \times 283} = 0.89\ m^3$$

OR

$p_fV_f = nRT_f$

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7. Suppose 1.80 mol of an ideal gas is taken from a volume of 3.00 m³ to a volume of 1.50 m³ via an isothermal compression at 30 °C. (a) How much energy is transferred as heat during the compression, and (b) is the transfer *to* or *from* the gas?

Solution:

(a) $\Delta E_{int} = Q - W$

$E_{int} = \frac{3}{2}nRT$

$\Delta E_{int} = \frac{3}{2}nR\Delta T$

$\Delta E_{int} = \frac{3}{2}nR(T-T)$ [Isothermal process, T= constant]

$\Delta E_{int} = \frac{3}{2}nR(0)$

$\Delta E_{int} = 0$

$0 = Q - W$

$Q = W$

$$W = nRT\ln\left(\frac{V_f}{V_i}\right) = 1.80 \times 8.314 \times 303 \ln\left(\frac{1.50}{3.00}\right) = -3140\ J$$

$Q = W$

$Q = -3140$ J

(b) The heat is transferred from the gas.

Lecture 6

Problem 18:

The temperature and pressure in the Sun's atmosphere are 2.00x10⁶ K and 0.0300 Pa. Calculate the rms speed of free electrons (mass 9.11x10⁻³¹ kg) there, assuming they are an ideal gas.

Solution:

$M = mN_A =$ **$9.11x10^{-31}$** $(6.023X10^{23}) = 5.49 \times 10^{-7}$ kg

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.31 \times 2.00 \times 10^{6}}{5.49 \times 10^{-7}}} = 9.53 \times 10^{6} \text{ m/s}$$

$$v_{rms} = 95,00000 \text{ m/s}$$

Problem 25

Determine the average value of the translational kinetic energy of the molecules of an ideal gas at temperatures (a) 0.00 °C and (b) 100 °C. What is the translational kinetic energy per mole of an ideal gas at (c) 0.00 °C and (d) 100 °C?

Solution:

(a) K_{avg} per molecule $= \left(\frac{3}{2}\right) kT = \frac{3}{2}\left(\frac{R}{N_A}\right) T = \frac{3}{2} \times \frac{8.314}{6.022 \times 10^{23}} (273.0) = 5.654 \times 10^{-21}$J

(b) K_{avg} per molecule $= \left(\frac{3}{2}\right) kT = \frac{3}{2}\left(\frac{R}{N_A}\right) T = \frac{3}{2} \times \frac{8.314}{6.022 \times 10^{23}} (373.0) = 7.724 \times 10^{-21}$J

The unit mole may be thought of as a (large) collection: 6.02 × 10^23 molecules of ideal gas, in this case. Each molecule has energy specified in part (a), so the large collection has a total kinetic energy equal to

(c) K_{avg} per mole $= K_{avg} N_A = 5.654 \times 10^{-21} \text{ x } 6.022 \times 10^{23} = 3405$ J

(d) K_{avg} per mole $= K_{avg} N_A = 7.724 \text{ J} \times 10^{-21} \text{ x } 6.022 \times 10^{23} = 4651$ J