Chap 20

Heat and First law of thermodynamic

20.1 Heat and Internal Energy

Internal Energy: All energy of a system that is associated with its microscopic components, Atoms and molecules, when viewed from a reference frame at rest with respect to the center of mass of the system.

Heat ≡ the transfer of energy across the boundary of a system due to a temperature difference between the system and its surroundings

Thermal Energy ≡ A collective of kinetic and potential energy associated with the random motion of atoms and moleules. The transferred energy is called "heat"

"+Q" absorb heat
"−Q" Emit heat

Calorie: the amount of heat that can raise 1 g of water from 14.5°C to 15.5°C

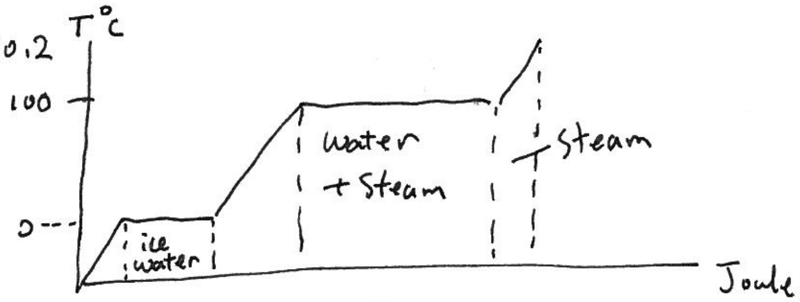
$$1\ \text{cal} \equiv 4.186\ \text{J} = 3.969 \times 10^{-3}\ \text{BTU}$$

$$\text{BTU} \equiv 63°\text{F} \to 64°\text{F}$$

$$Q = C(T_f - T_i) \qquad C \equiv \text{heat capacity} \quad [\text{energy}/\text{deg}]$$

$$= cm(T_f - T_i) \qquad c \equiv \text{Specific heat} \quad [\text{energy}/g°C]$$

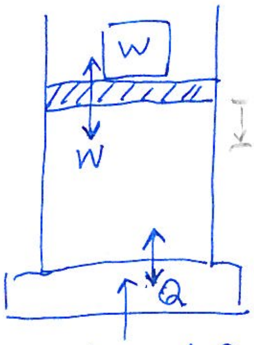
Figure 20.2



L ≡ Latent heat $\quad L \equiv \frac{Q}{m}$. Q heat for phase change

5, Heat and Work — path dependent quantities (W) (Q)

Consider a system of a piston



thermal reservoir

$$dW = F \cdot ds = pA \cdot ds = p\,dV$$

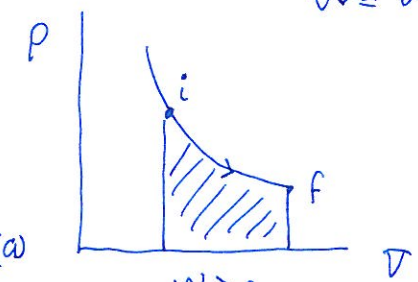
$$W = \int dW = \int_{V_i}^{V_f} p\,dV.$$

p may be a function of V

$p = p(V)$.

W = Work done by the gas

(a)

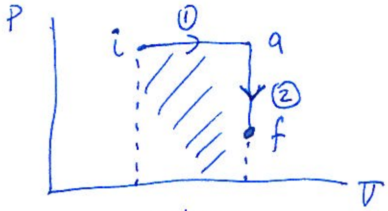


$W > 0$

$W > 0$, $P_f < P_i$

$V_f > V_i$

(b)

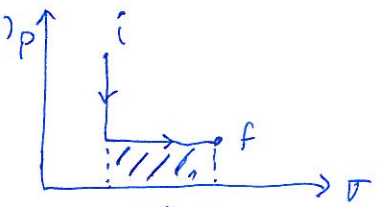


$W > 0$

① p = constant. V increase

② V = constant, P decrease.

(c)

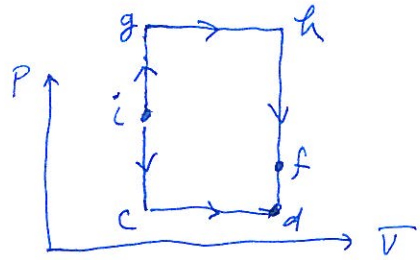


$W > 0$

① V constant. p decrease

② P = Con. V increase

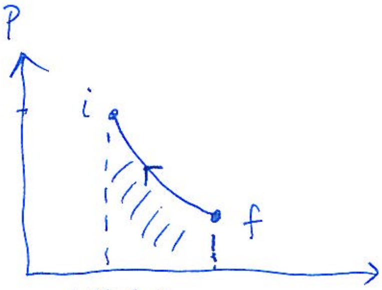
(d)



① path icdf W = min. Work

② path ighf W = max. Work

(e)



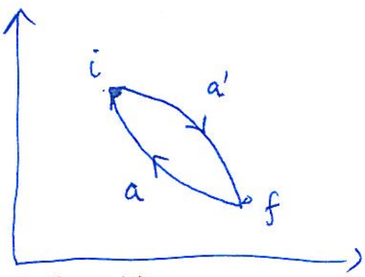
$W < 0$

gas is compressed

Work done by the gas

is negative

(f)



$$W = \underset{(+)}{W_{ia'f}} + \underset{(-)}{W_{iaf}} > 0$$

6 First law of thermodynamics

— The internal energy dE_{int} of a system tends to increase if energy is added to it via heat Q, and tends to decrease if energy is lost via work W done by the system.

— $dE_{int} = dQ - dW$

Work (W) and heat (Q) are very path dependent,

However, $Q-W$ is not path dependent for a system. it only depends on the initial and final states of the system; Therefore $Q-W$ is called the internal energy. it is the intrinsic property of a system.

$\rightarrow \Delta E_{int} = E_{int,f} - E_{int,i} = Q - W.$

$$\boxed{dE_{int} = dQ - dW}$$

— first law of thermodynamics.

— Assume $\Delta E_K = \Delta E_p = 0$ for the system

— dW is the work done by the system.

or

$$\boxed{dE_{int.} = dQ + dW_{on,sys}}$$

— $dW_{on.sys}$ is the work done on the system.

⟨1⟩ Adiabatic process — process in a well insulated system that no Heat transferred. process happens very rapidly.
絕熱
$Q=0$

$dE_{int.} = -dW$ — Adiabatic

(2) Constant-volume process — Volume held at constant.
— system can not do work $W=0$

$dE_{int.} = dQ$ — constant volume

(3) Cyclical process — After some process. the system is back to its original (initial) state

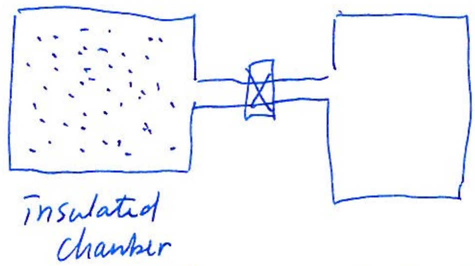
$\Delta E_{int} = 0$

$\rightarrow$ $dW = dQ$ — cyclical. work done in the process is exactly equal to the heat transferred

— form a close loop on a $p-V$ plot.

(4) Free Expansion — Adiabatic + $\Delta W = 0$, i.e. $\Delta W = \Delta Q = 0$

$\rightarrow$ $dE_{int.} = 0$



When gas freely expand to the evacuated chamber

① No heat transferred.

② No work is done on or by the gas, since it expand and meet no oppose pressure.

1st Law : $\Delta E_{int.} = Q - W$		
Adiabatic	$Q = 0$	$\Delta E_{int} = -W$
Constant Volume	$W = 0$	$\Delta E_{int} = Q$
Closed cycle	$\Delta E_{int.} = 0$	$Q = W$
Free expansion	$Q = W = 0$	$\Delta E_{int} = 0$

Note: W = Work done by the system or work done by the gas

$\boxed{19-8}$

① $W = \int_{V_i}^{V_f} p\,dV = (1.01 \times 10^5\ Pa) \int_{V_i}^{V_f} dV = 1.69 \times 10^5\ J$

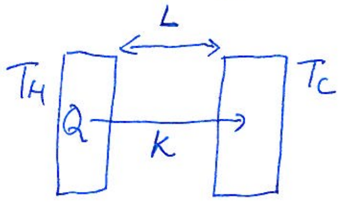
W is positive = Work done by the system

② $Q = L_v m$

③ $\Delta E_{int} = Q - W = 2260\ kJ - 169\ kJ$

7. Heat transfer Mechanism — Conduction
Convection
radiation

Conduction — Heat is transferred through the vibration of atoms in the materials. Heat Changes the vibrational amplitude, and hence the energy and then pass through atoms from one end to the other.



or $P = \frac{Q}{t}$

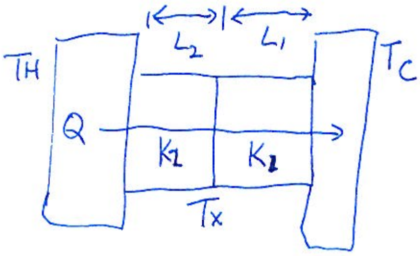
$$H = \frac{Q}{t} = kA\,\frac{T_H - T_C}{L}$$

K = thermal conductivity.

$P = H$ = conduction rate

$$R = \frac{L}{k}$$ R = thermal resistance

t = time



$$H = \frac{k_2 A (T_H - T_X)}{L_2} = \frac{K_1 A (T_X - T_C)}{L_1}$$

$$T_X = \frac{k_1 L_2 T_C + k_2 L_1 T_H}{k_1 L_2 + k_2 L_1}$$

for n slabs of thermal conductivities $k_1, k_2, \ldots, k_n$

$$H = \frac{A(T_H - T_C)}{\sum_n \left(\frac{L_n}{k_n}\right)} \qquad H = \frac{A(T_H - T_C)}{L_1/k_1 + L_2/k_2}$$

Convection — Heat transferred make hot gas less dense and rise up. Cooler gas will fill in.

— Convection is part of natural processes. Atmospheric convection plays fundamental roles in global climate patterns.

Radiation — thermal radiation transfered heat via electromagnetic waves.
— No media is required.

$$P_r = \sigma \varepsilon A T^4$$
(radiates)

$\sigma = 5.6703 \times 10^{-8} \frac{W}{m^2 \cdot K^4}$,
= Stefan-Boltzman Constant
ε = emissivity of the objects surface
$0 < \varepsilon \leq 1$, ideal Black body $\varepsilon = 1$
A = surface area
T = temperature in kelvin

$$P_a = \sigma \varepsilon A T_{env.}^4$$ — for absorption

$$P_{net} = \sigma \varepsilon A (T_{env}^4 - T^4)$$ — A body will emit and absorb heat at the same time

$e=1$ black body
ideal absorber
$e=0$ ideal reflector