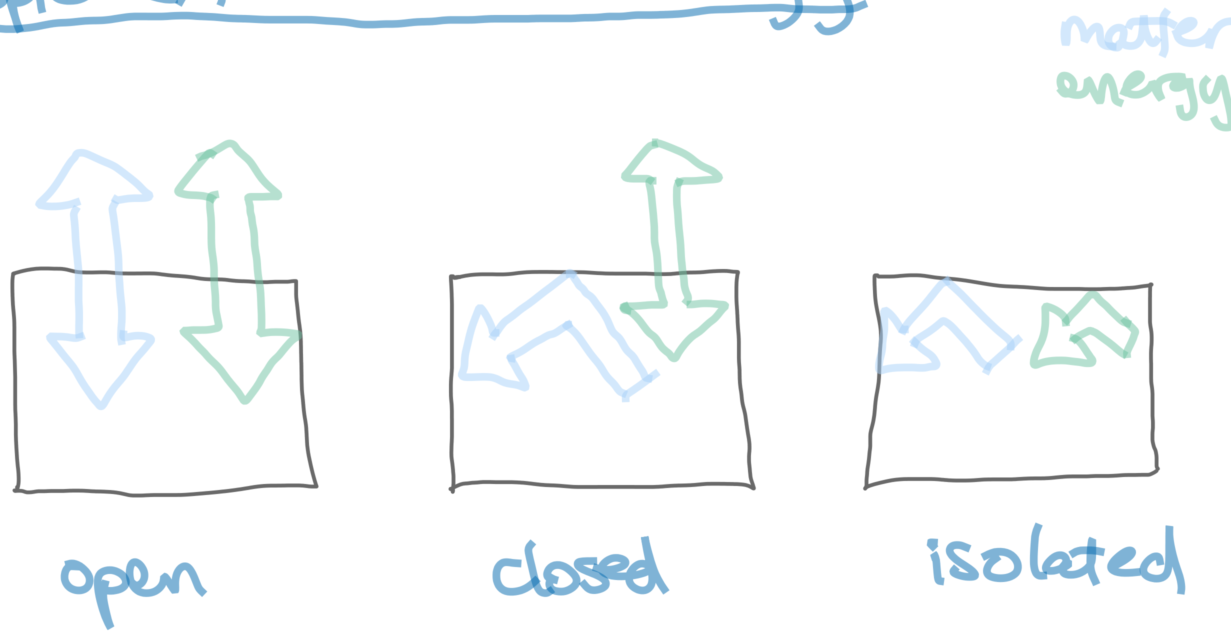
Lecture 4

Tuesday, September 17, 2024 09:58

Topic 2A : Internal Energy



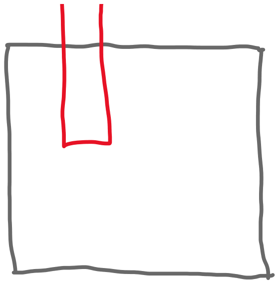
Energy: a system's capacity to do **work**

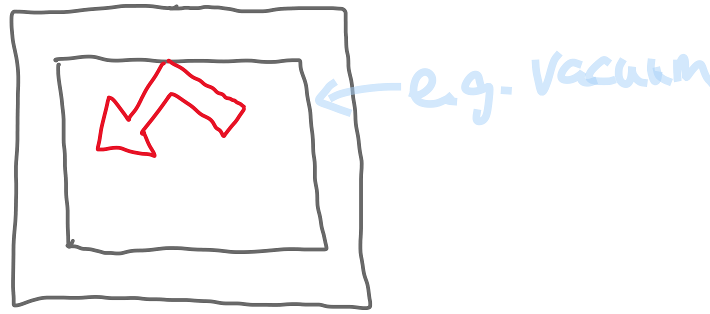
Work is done to achieve motion against an opposing force.

For example, compressing a sample of gas in a sealed syringe.

Heat can also be added to raise the energy of a system.

heat



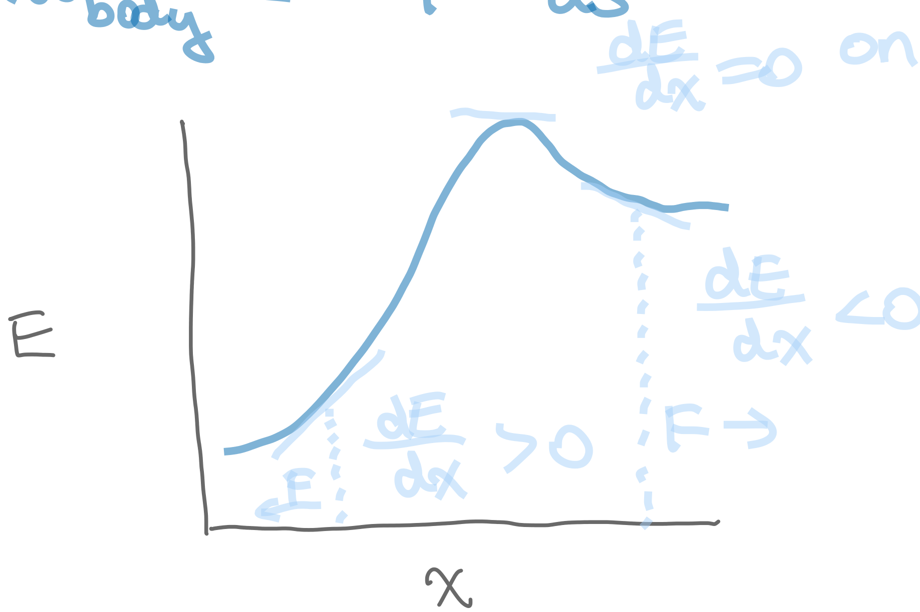


diathermic adiabatic

Mathematical definition of work

$$dw_{body} = -\vec{F} \cdot d\vec{s}$$

work done on body



$$\vec{F} \cdot d\vec{s} = F_x dx + F_y dy + F_z dz$$

$$1\,J = 1\,N \cdot m = 1\,kg\,m^2\,s^{-2}$$

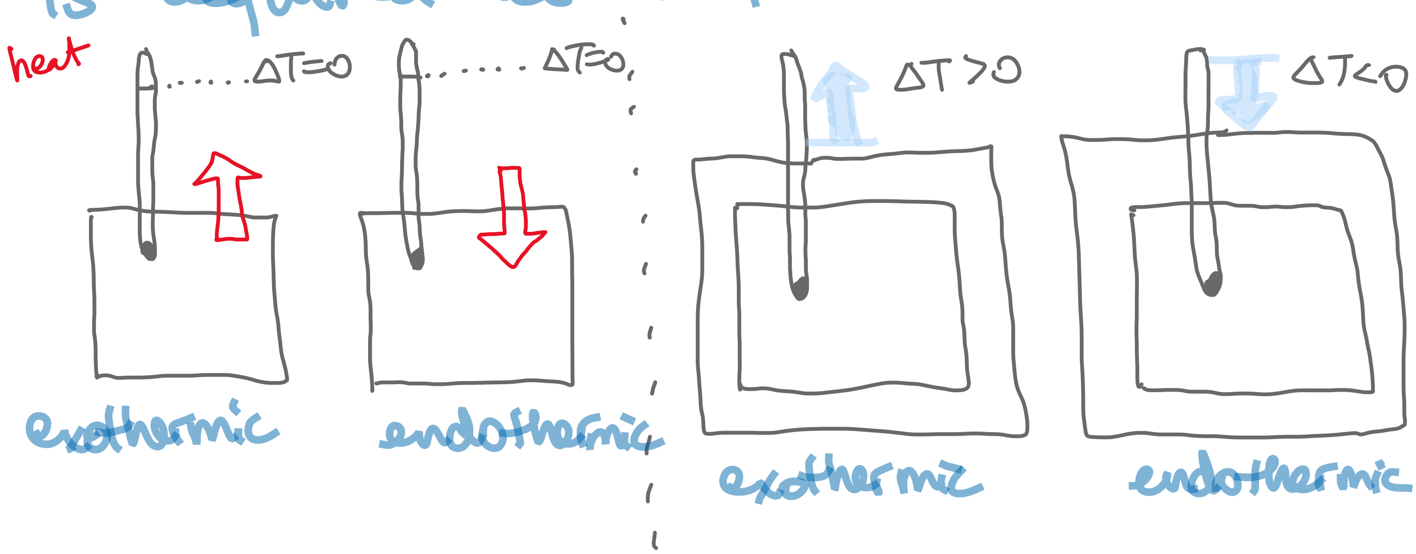
$$E = T + V$$

total energy — kinetic energy — potential energy

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

exothermic reaction ; releases energy as heat

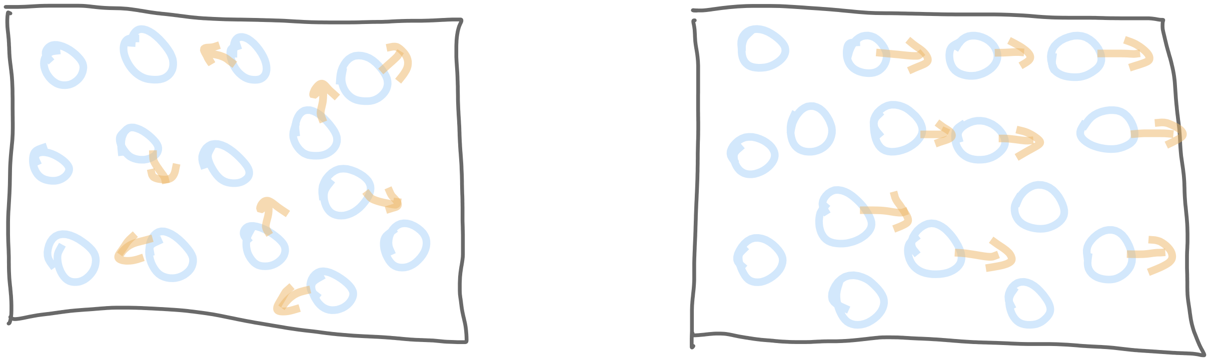
The reverse of this would be an endothermic reaction, where energy is acquired as heat



diathermic barrier

adiabatic

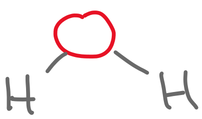
isothermal process



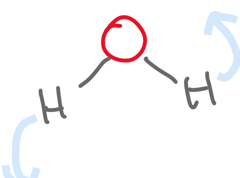
heat — disorderly motion

work — orderly motion

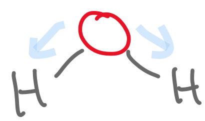
Internal energy : U



→ translation



rotation



vibration

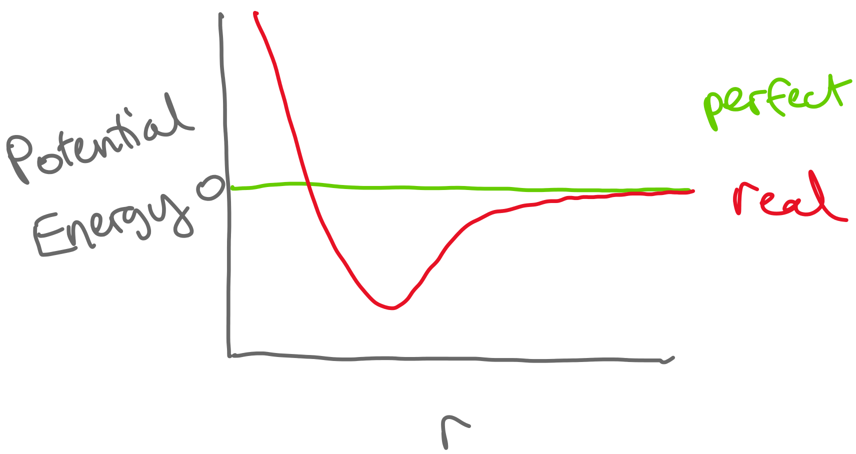
All these degrees of freedom contribute to the internal energy of a system.

U is a state function.

$$\Delta U = U_f - U_i$$

Molar internal energy: $U_m = \frac{U}{n}$

The internal energy of a perfect gas is <u>independent</u> of the volume it occupies.



The First Law of Thermodynamics

Heat and work are equivalent ways of changing the internal energy of a system.

The internal energy of an isolated system is constant.

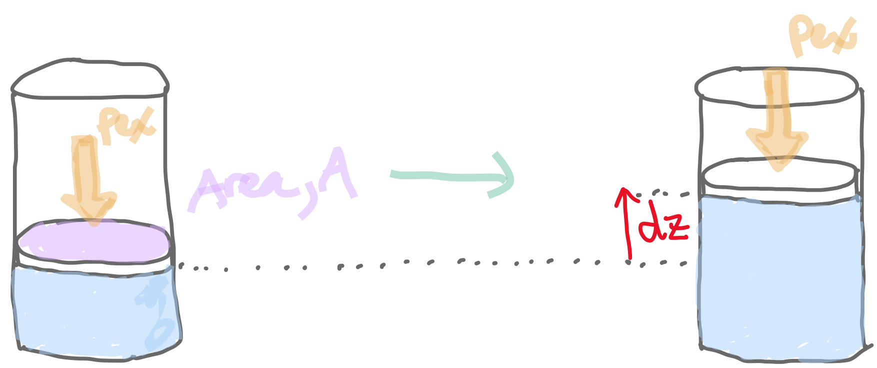
infinitesimal

$\Rightarrow dU = dq + dw$ infinitesimal changes

$\Delta U = q + w$ integrated form

Expansion Work

p_{ex} : external pressure



$dw = -|F|\,dz$

$dw = -p_{ex} \boxed{A\,dz}$ dV

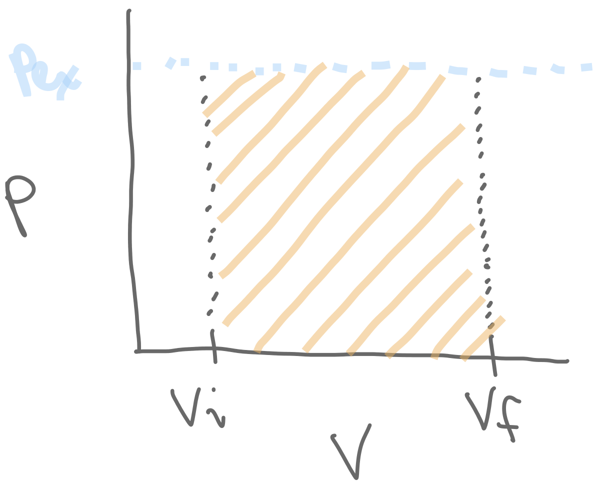
$dw = -p_{ex}\,dV$

$$\int_i^f dw = \int_{V_i}^{V_f} -p_{ex}\,dV$$

$$w = -p_{ex}\int_{V_i}^{V_f} dV$$

$$w = -p_{ex}(V_f - V_i)$$

$$\boxed{w = -p_{ex}\Delta V}$$

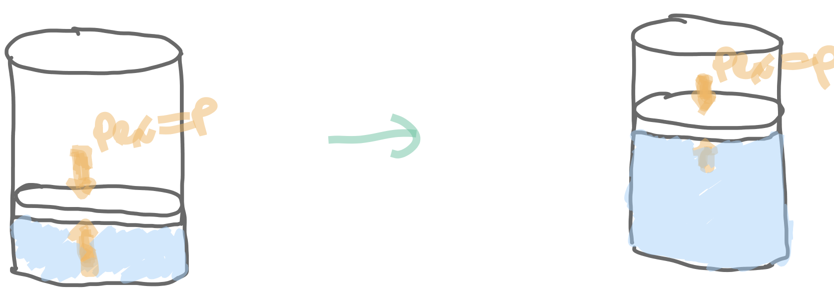


$$\text{area} = p_{ex}\Delta V$$

Free expansion : $w = 0$

(e.g. expansion into a vacuum)

Reversible Expansion



$$dw = -p_{ex}dV = -p\,dV$$

$$w = -\int^{V_f} \boxed{p}\, dV$$

perfect gas :

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

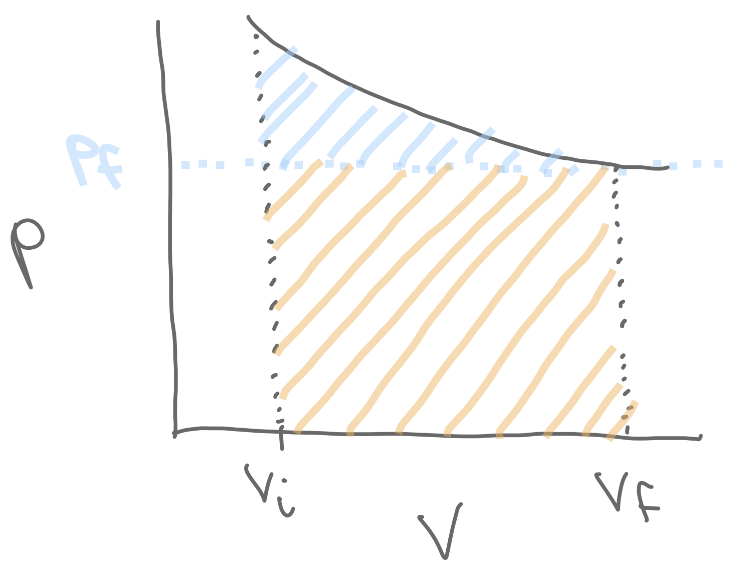
V_i

$$w = -nRT\int_{V_i}^{V_f} \frac{1}{V}\,dV$$

$$w = -nRT(\ln V_f - \ln V_i)$$

$$w = -nRT \ln\frac{V_f}{V_i}$$

work of isothermal reversible expansion of a perfect gas



Total work = /// + ///

Work done by reversible expansion is greater!