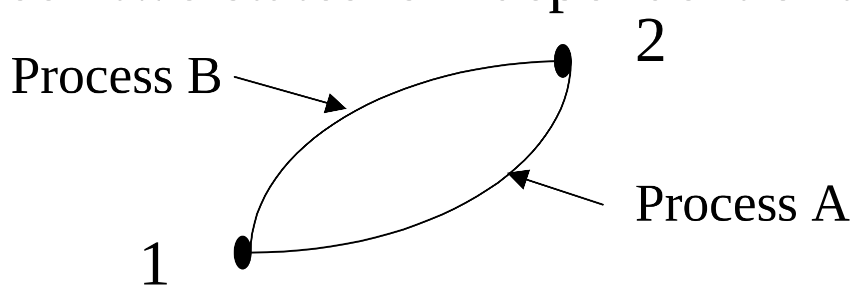
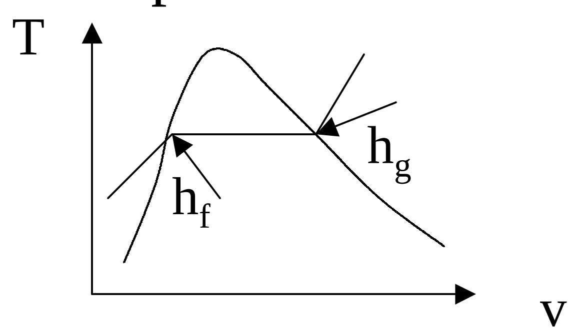
Internal Energy

- E=U(internal energy)+KE(kinetic energy)+PE(potential energy)
- Extensive property since it depends on the mass of the system, U=mu, where m is the mass of the system, u is the specific energy of the system (an intensive property like temperature and pressure)
- Unlike KE & PE, the internal energy is a form of energy measured on a molecular scale. It can consist of different modes: translational kinetic energy of individual molecules, rotational energy and vibrational energies associated with molecules, and intermolecular forces between molecules. The sum of all these molecular-level energies is called the **internal energy**.
- Internal energy is a property of the substance, thus, its change in value between two states is independent of the **process**.



Enthalpy

- $H=U+PV$, defined as total enthalpy
- $H=mh$, $h=u+Pv$, specific enthalpy will be an intensive property
- It is an important property in many situations, for example, the steady flow process, $h=u+P/\rho$ is a measure of the combined internal energy and the pressure work
- It is also useful when one considers phase transition: Example: when liquid water vaporizes into water vapor, its internal energy changes from u_f to u_g. At the same time, itsa specific volume also changes from v_f to v_g, going through an expansion process; and it does work. Therefore, the total combined change of the energy will be from $h_f=u_f+pv_f$ to h_g. Their difference $h_{fg}=h_g-h_f$ is called the latent heat of vaporization at the given temperature/pressure.



Latent heat$=h_g-h_f=h_{fg}$

Specific Heats

• The state of a pure, compressible substance can be determined by values of two thermodynamic properties. Ex: P=P(v, T)

• u=u(T,v): internal energy is a function of two variables T and v (or any other two independent properties such as P, h)

• The internal energy can be varied by altering these two properties:

$$du = (du)_v + (du)_T = \left(\frac{\partial u}{\partial T}\right)_v dT + \left(\frac{\partial u}{\partial v}\right)_T dv = c_v dT + \left(\frac{\partial u}{\partial v}\right)_T dv$$

• Define constant-volume specific heat c_v (can sometimes be considered as heat capacity, the ability of a substance to absorb or store energy.

• Similarly, the enthalpy can be described by:

$$dh = (dh)_p + (dh)_T = \left(\frac{\partial h}{\partial T}\right)_p dT + \left(\frac{\partial h}{\partial p}\right)_T dp = c_p dT + \left(\frac{\partial h}{\partial p}\right)_T dp$$

• Define constant-pressure specific heat c_p

Specific Heats (cont.)

- Both c_p and c_v can be considered as heat capacities but under different processes
- Their ratio k(specific heat ratio) $k=c_p/c_v$ is also a property of the substance.
- Special cases: incompressible fluid (density and v is a constant)

$$u = u(T,v) = u(T) \quad \text{since v is a constant}$$

$$c_v(T) = \frac{du}{dT} \quad \text{ordinary differential equation is used}$$

$$h(T,P)=u(T)+Pv$$

$$c_p = \left(\frac{\partial h}{\partial T}\right)_P = \frac{du}{dT} + P\left(\frac{\partial v}{\partial T}\right)_P = \frac{du}{dT}, \text{ since v=constant}$$

$$c_P = c_v, \text{ for an incompressible substance}$$

That is, for most of the compressed liquids and solids