Hukum termodinamika (1)

dan panas

Heat and Internal Energy

Energi dalam :

Energi dari suatu sistem yang berhubungan dengan komponen mikroskopik, seperti atom dan molekul, yang meliputi energi potensial dan kinetik.

Energi kinetik meliputi total energi kinetik dari seluruh partikel, serta energi potensial antar partikel.

Dalam hal ini tidak termasuk di dalamnya energi potensial antara partikel dengan lingkungannya.

Panas :

Didefinisikan sebagai transfer energi melewati batas sistem yang disebabkan oleh perbedaan temperatur antara sistem dengan lingkungan.

Panas dinyatakan sebagai suatu “fluida” yang disebut “caloric”

Satuan panas

Kalori :

Jumlah energi yang perlu dipindahkan untuk menaikkan suhu 1 g air dari 14.5°C menjadi 15.5°C.

Btu :

Jumlah energi yang perlu dipindahkan untuk menaikkan suhu 1 lb air dari 63°F menjadi 64°F.

Example 1

A student eats a dinner rated at 2 000 Calories. He wishes to do an equivalent amount of work in the gymnasium by lifting a 50.0-kg barbell. How many times must he raise the barbell to expend this much energy? Assume that he raises the barbell 2.00 m each time he lifts it and that he regains no energy when he lowers the barbell.

$$W = (2.00 \times 10^6 \text{ cal})(4.186 \text{ J/cal}) = 8.37 \times 10^6 \text{ J}$$

The work done in lifting the barbell a distance h is equal to mgh, and the work done in lifting it n times is $nmgh$. We equate this to the total work required:

$$W = nmgh = 8.37 \times 10^6 \text{ J}$$

$$n = \frac{W}{mgh} = \frac{8.37 \times 10^6 \text{ J}}{(50.0 \text{ kg})(9.80 \text{ m/s}^2)(2.00 \text{ m})}$$

$$= 8.54 \times 10^3 \text{ times}$$

Specific Heat and Calorimetry

Kapasitas panas (C) suatu bahan :

Jumlah energi yang dibutuhkan untuk menaikkan suhu suatu bahan sebesar 1°C.

Panas menghasilkan perubahan suhu suatu bahan sebesar ΔT :

$$Q = C.\ \Delta T$$

Kalor jenis (*specific heat,* c) suatu bahan :

Kapasitas panas tiap satuan massa bahan.

Sehingga, bila sejumlah energi Q diberikan pada suatu bahan seberat m dan mengalami perubahan suhu sebesar ΔT, maka kalor jenis bahan tersebut :

$$c = \frac{Q}{m\,\Delta T}$$

$$c = 1\ \text{cal/g}\cdot\text{C}^\circ = 1\ \text{Btu/lb}\cdot\text{F}^\circ = 4186.8\ \text{J/kg}\cdot\text{K}.$$

Kalor jenis merupakan perhitungan seberapa sensitif suatu bahan mengalami perubahan termal dengan penambahan energi.

Semakin besar nilai kalor jenis, semakin besar energi yang harus ditambahkan untuk menaikkan suhu yang sama bagi sejumlah tertentu massa bahan.

$$Q = mc\,\Delta T$$

Molar Specific Heat

Bila jumlah bahan dinyatakan dalam mol, maka kalor jenis juga dinyatakan dalam kalor jenis molar.

Table 18-3 Some Specific Heats and Molar Specific Heats at Room Temperature

Substance	Specific Heat $\frac{\text{cal}}{\text{g}\cdot\text{K}}$	Specific Heat $\frac{\text{J}}{\text{kg}\cdot\text{K}}$	Molar Specific Heat $\frac{\text{J}}{\text{mol}\cdot\text{K}}$
Elemental Solids			
Lead	0.0305	128	26.5
Tungsten	0.0321	134	24.8
Silver	0.0564	236	25.5
Copper	0.0923	386	24.5
Aluminum	0.215	900	24.4
Other Solids			
Brass	0.092	380	
Granite	0.19	790	
Glass	0.20	840	
Ice (−10°C)	0.530	2220	
Liquids			
Mercury	0.033	140	
Ethyl alcohol	0.58	2430	
Seawater	0.93	3900	
Water	1.00	4187	

Conservation of Energy: Calorimetry

Persamaan matematis untuk menyatakan konservasi energi :

$$Q_{\text{cold}} = -Q_{\text{hot}}$$

$$m_w c_w (T_f - T_w) = -m_x c_x (T_f - T_x)$$

$$c_x = \frac{m_w c_w (T_f - T_w)}{m_x (T_x - T_f)}$$

Example 2

A 0.050 0-kg ingot of metal is heated to 200.0°C and then dropped into a beaker containing 0.400 kg of water initially at 20.0°C. If the final equilibrium temperature of the mixed system is 22.4°C, find the specific heat of the metal.

$$m_w c_w (T_f - T_w) = -m_x c_x (T_f - T_x)$$

$$(0.400 \text{ kg})(4\,186 \text{ J/kg}\cdot{}^\circ\text{C})(22.4^\circ\text{C} - 20.0^\circ\text{C})$$

$$= -(0.050\,0 \text{ kg})(c_x)(22.4^\circ\text{C} - 200.0^\circ\text{C})$$

From this we find that

$$c_x = \boxed{453 \text{ J/kg}\cdot{}^\circ\text{C}}$$

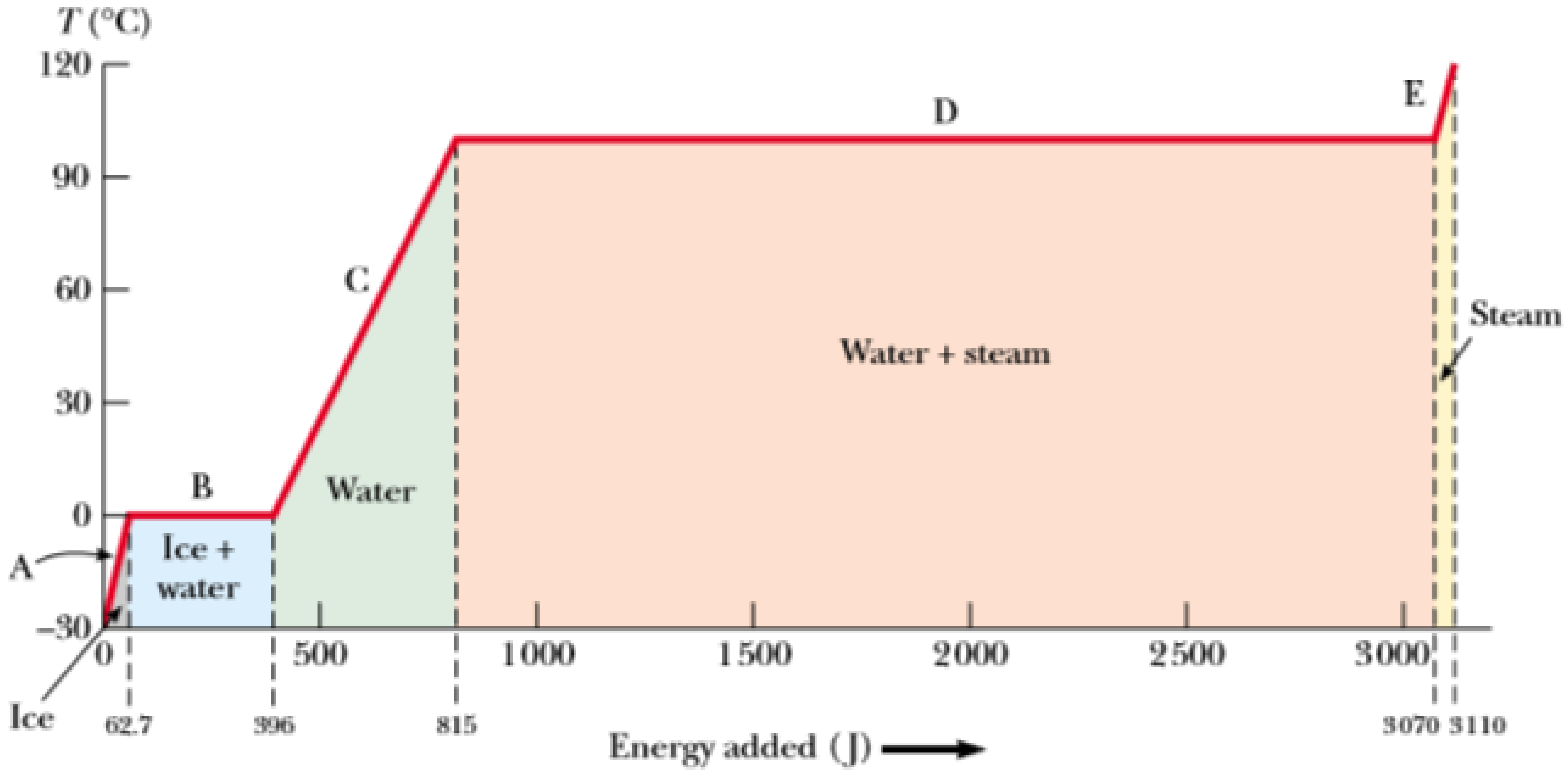
Latent heat

Bila sejumlah energi yang ditransfer (Q) dibutuhkan untuk mengubah fasa sejumlah m massa bahan, rasio L = Q/m merupakan suatu sifat termal bahan tersebut.

Penambahan atau penghilangan energi tidak menyebabkan perubahan temperatur, sehingga L disebut sebagai panas laten (*latent heat*).

$$Q = \pm mL$$

Untuk memahami pengertian panas laten pada perubahan fasa, bayangkanlah energi yang diperlukan untuk mengubah 1,00 g es batu bersuhu -30.0°C menjadi steam (uap air) bersuhu 120.0°C.



T (°C)
120
90
60
30
0
–30
A
B
C
D
E
Ice + water
Water
Water + steam
Steam
Ice
0
500
1000
1500
2000
2500
3000
62.7
396
815
3070
3110
Energy added (J)

Example 3

What mass of steam initially at 130°C is needed to warm 200 g of water in a 100-g glass container from 20.0°C to 50.0°C? Steam to be water at 50.0°C

Laten heat of water vaporization : 2,26. 10^6 J/kg

Spesific heat of steam : 2,01.10^3 J/kg.°C

Solution The steam loses energy in three stages. In the first stage, the steam is cooled to 100°C. The energy transfer in the process is

$$Q_1 = m_s c_s \Delta T = m_s(2.01 \times 10^3 \text{ J/kg}\cdot{}^\circ\text{C})(-30.0^\circ\text{C})$$
$$= -m_s(6.03 \times 10^4 \text{ J/kg})$$

where m_s is the unknown mass of the steam.

In the second stage, the steam is converted to water. To find the energy transfer during this phase change, we use $Q = -mL_v$, where the negative sign indicates that energy is leaving the steam:

$$Q_2 = -m_s(2.26 \times 10^6 \text{ J/kg})$$

In the third stage, the temperature of the water created from the steam is reduced to 50.0°C. This change requires an energy transfer of

$$Q_3 = m_s c_w \Delta T = m_s(4.19 \times 10^3\,\mathrm{J/kg\cdot °C})(-50.0°\mathrm{C})$$
$$= -m_s(2.09 \times 10^5\,\mathrm{J/kg})$$

Adding the energy transfers in these three stages, we obtain

$$Q_{\mathrm{hot}} = Q_1 + Q_2 + Q_3$$
$$= -m_s(6.03 \times 10^4\,\mathrm{J/kg} + 2.26 \times 10^6\,\mathrm{J/kg}$$
$$+ 2.09 \times 10^5\,\mathrm{J/kg})$$
$$= -m_s(2.53 \times 10^6\,\mathrm{J/kg})$$

Now, we turn our attention to the temperature increase of the water and the glass. Using Equation 20.4, we find that

$$\begin{aligned} Q_{\text{cold}} &= (0.200\ \text{kg})(4.19 \times 10^3\ \text{J/kg}\cdot{}^\circ\text{C})(30.0^\circ\text{C}) \\ &\quad + (0.100\ \text{kg})(837\ \text{J/kg}\cdot{}^\circ\text{C})(30.0^\circ\text{C}) \\ &= 2.77 \times 10^4\ \text{J} \end{aligned}$$

Using Equation 20.5, we can solve for the unknown mass:

$$\begin{aligned} Q_{\text{cold}} &= -Q_{\text{hot}} \\ 2.77 \times 10^4\ \text{J} &= -[-m_s(2.53 \times 10^6\ \text{J/kg})] \\ m_s &= \boxed{1.09 \times 10^{-2}\ \text{kg} = 10.9\ \text{g}} \end{aligned}$$

Example 4

A copper slug whose mass m_c is 75g is heated in a laboratory oven to a temperature T of 312°C. The slug is then dropped into a glass beaker containing a mass m_w 220g of water. The heat capacity C_b of the beaker is 45 cal/K. The initial temperature Ti of the water and the beaker is 12°C. Assuming that the slug, beaker, and water are an isolated system and the water does not vaporize, find the final temperature T_f of the system at thermal equilibrium.

(1) Because the system is isolated, the system's total energy cannot change and only internal transfers of thermal energy can occur. (2) Because nothing in the system undergoes a phase change, the thermal energy transfers can only change the temperatures.

Calculations: To relate the transfers to the temperature changes, we can use Eqs. 18-13 and 18-14 to write

$$\text{for the water:}\quad Q_w = c_w m_w (T_f - T_i); \tag{18-19}$$

$$\text{for the beaker:}\quad Q_b = C_b (T_f - T_i); \tag{18-20}$$

$$\text{for the copper:}\quad Q_c = c_c m_c (T_f - T). \tag{18-21}$$

Because the total energy of the system cannot change, the sum of these three energy transfers is zero:

$$Q_w + Q_b + Q_c = 0. \tag{18-22}$$

Substituting Eqs. 18-19 through 18-21 into Eq. 18-22 yields

$$c_w m_w (T_f - T_i) + C_b (T_f - T_i) + c_c m_c (T_f - T) = 0. \tag{18-23}$$

Temperatures are contained in Eq. 18-23 only as differences. Thus, because the differences on the Celsius and Kelvin scales are identical, we can use either of those scales in this equation. Solving it for T_f, we obtain

$$T_f = \frac{c_c m_c T + C_b T_i + c_w m_w T_i}{c_w m_w + C_b + c_c m_c}.$$

Using Celsius temperatures and taking values for c_c and c_w from Table 18-3, we find the numerator to be

$$(0.0923\ \text{cal/g}\cdot\text{K})(75\ \text{g})(312^\circ\text{C}) + (45\ \text{cal/K})(12^\circ\text{C}) + (1.00\ \text{cal/g}\cdot\text{K})(220\ \text{g})(12^\circ\text{C}) = 5339.8\ \text{cal},$$

and the denominator to be

$$(1.00\ \text{cal/g}\cdot\text{K})(220\ \text{g}) + 45\ \text{cal/K} + (0.0923\ \text{cal/g}\cdot\text{K})(75\ \text{g}) = 271.9\ \text{cal/C}^\circ.$$

We then have

$$T_f = \frac{5339.8\ \text{cal}}{271.9\ \text{cal/C}^\circ} = 19.6^\circ\text{C} \approx 20^\circ\text{C}. \qquad \text{(Answer)}$$

From the given data you can show that

$$Q_w \approx 1670\ \text{cal}, \qquad Q_b \approx 342\ \text{cal}, \qquad Q_c \approx -2020\ \text{cal}.$$