P2211K

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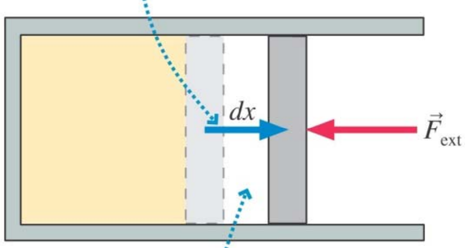
<u>Chapter 17: Work, heat, and energy.</u>

- Heat is a form of energy (re. the kinetic picture) & Thermal equilibrium (17.3)
  - Heat energy typically is symbolized by Q;
  - Units are Joules, but the units of calories also are used: 1 cal = 4.186 J, and is the amount of heat that will raise the temperature of 1 g of water by one degree C. (This introduces the idea of ***specific heat*** and ***heat capacity*** that we will consider later.)
  - The calorie we hear about for food actually is a kilocalorie and is abbreviated with a capital C: 1 food calorie = 1Cal = 1000 cal (or 1 kcal)



  - Heat energy can do mechanical work via expansions of gases ("working substances") as illustrated to the side.
  - Heat energy transfers from hot to cold in a system as long as there is a ***temperature difference***—i.e., until ***thermal equilibrium*** occurs with all parts at the same temperature.
- 1st law of thermodynamics (17.4)
  - $\Delta E_{th} = W + \Delta Q$. E_{th} typically is referred to as U, the internal energy
  - This extends the conservation of energy principle to include the effects of heat energy
- Vocabulary for processes: isochoric, isobaric, isothermal, adiabatic (17.4)
- Heat capacity, specific heat, and latent heats (of fusion and vaporization) (17.5)
  - Basic idea: It requires heat energy to raise the temperature of objects, but the amount depends on the type of material and the amount of its mass: $\Delta E_{th} = cM\Delta T$. In this relation, c represents the "specific heat" that is characteristic of the material.

Chapter 17: Work, heat, and energy, cont.

TABLE 17.2 Specific heats and molar specific heats of solids and liquids

Substance	c (J/kg K)	C (J/mol K)
Solids		
Aluminum	900	24.3
Copper	385	24.4
Iron	449	25.1
Gold	129	25.4
Lead	128	26.5
Ice	2090	37.6
Liquids		
Ethyl alcohol	2400	110.4
Mercury	140	28.1
Water	4190	75.4

- Calorimetry (17.6)
  - o When cold milk is poured into hot coffee, the result is a mixture at an intermediate temperature. The final temperature is a result of heat flow from the hot component to the cold component until all components are at the same temperature. However, the thermal energy of the whole system, milk + coffee, does not change
  - o This can be described as follows:

    $\Delta E_{th} = 0 = c_1M_1\Delta T_1 + c_2M_2\Delta T_2$, or

    $0 = c_1M_1(T_{1f} - T_{1i}) + c_2M_2(T_{2f} - T_{2i})$ where $T_{1f} = T_{2f} = T_f$

Example: 20 g of water at 5°C is added to 40 g of water at 90°C. What is the final temperature of the mixture? **61.7°C**

- Latent heats of fusion and vaporization:
  - o Basic idea: it takes energy to create a “phase” change—solid to liquid (melting), liquid to vapor (vaporization), etc., with ***no change in temperature.*** Similarly, the reverse processes(condensation and freezing) requires the extraction of thermal energy with no change in temperature. (The direct phase change from solid to vapor is “sublimation” and “dry ice”—solid CO_2 is a well-known example.)

Chapter 17: Work, heat, and energy, cont.

- Latent heats of fusion and vaporization, cont.:
  - That the change in phase (or “state”) occurs with no chnage in temperature means that solid & liquid, or liquid & gas, can coexist at the phase change temperature. For example, liquid water & ice can exist together with both at 0°C. As well, both liquid water & steam can coexist at 100°C.
  - Historically, these are called ***Latent Heats*** and symbolized by L_f and L_v. For example, to melt one kg of water requires 3.33 x 10^5 J of energy, which is enough to raise the temperature of one kg water by 79.4°C!

TABLE 17.3 Melting/boiling temperatures and heats of transformation

Substance	T_m (°C)	L_f (J/kg)	T_b (°C)	L_v (J/kg)
Nitrogen (N_2)	−210	0.26×10^5	−196	1.99×10^5
Ethyl alcohol	−114	1.09×10^5	78	8.79×10^5
Mercury	−39	0.11×10^5	357	2.96×10^5
Water	0	3.33×10^5	100	22.6×10^5
Lead	328	0.25×10^5	1750	8.58×10^5

  - How much steam (x) at 100°C is needed to melt 50g ice at 0°C and produce (50 + x) g liquid water at 50°C? ***10.98 g***

- Heat transfer: conduction, convection, and radiation (17.8): *temperature difference is the promoting factor with thermal energy flowing from hot to cold*.
- Vocabulary (p. 535)