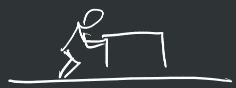
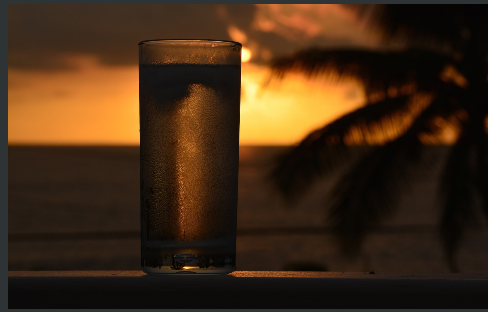
Chapter 14 – Heat

$\underline{W} = F \cdot \Delta x$

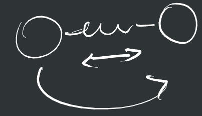




After this you can
- discuss the concept of heat and relate it to energy, work and temperature.
- differentiate the three types of heat flow

Heat - transfer of thermal energy
- always flows from objects of higher temperature to objects of lower temperature

- Kinetic energy
- vibrational energy
- rotational energy
- chemical energy



mechanisms of heat flow:

① Conduction

$$\frac{Q}{t} = \text{Power} \quad [\text{Watts}]$$

② Convection
heat transfer by moving material

③ Radiation ⤳ energy transfer through electromagnetic waves

After this you can

- discuss the various ways of calculating the heat needed to change the temperature of a substance
- determine the heat capacity of a substance and the various ways that can be expressed

Work

Heat $\rightarrow$ Q   [Joule] , [calorie]   vs. [Calorie]

$4.186\ J = 1\ cal$

$1\ Cal = 1\ kcal = 1000\ cal = 4186\ J$

Heat is proportional to temperature change (as long as no work is done, and the phase of substance does not change)

$\Delta T = T_f - T_i$

$$Q \propto \Delta T$$

$$\frac{Q}{\Delta T} = C$$

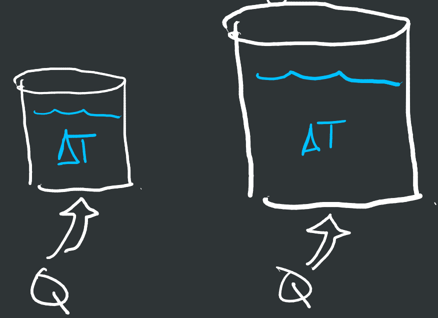
$\rightarrow$ heat capacity

$\hookrightarrow$ depends on the size/amount of subst.

$\rightarrow$ mass, number, volume

$$\boxed{Q = C \cdot \Delta T}$$

$\leftarrow$ big cee



Mass

Specific heat capacity

little cee $\rightarrow c = \dfrac{C}{m}$

$c \cdot m = C$

$\boxed{Q = c \cdot m \cdot \Delta T}$

most often used to study solids & liquids

Table 14.1 Specific Heats of Common Substances at 1 atm and 20°C

Substance	Specific Heat $\left(\frac{kJ}{kg \cdot K}\right)$
Gold	0.128
Lead	0.13
Mercury	0.139
Silver	0.235
Brass	0.384
Copper	0.385
Iron	0.44
Steel	0.45
Flint glass	0.50
Crown glass	0.67
Vycor	0.74
Pyrex glass	0.75
Granite	0.80
Marble	0.86
Aluminum	0.900
Air (50°C)	1.05
Wood (average)	1.68
Steam (110°C)	2.01
Ice (0°C)	2.1
Alcohol (ethyl)	2.4
Human tissue (average)	3.5
Water (15°C)	4.186

$\rightarrow \frac{J}{g \cdot K}$

number

$\dfrac{C}{n_m} \rightarrow$ molar heat capacity (molar specific heat)

most often used for gasses

$C_v \rightarrow$ molar heat capacity at constant volume

$C_p \rightarrow$ molar heat capacity at constant pressure constant volume

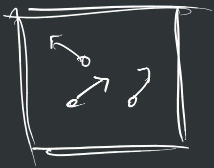
$$Q = n_m C_V \Delta T$$

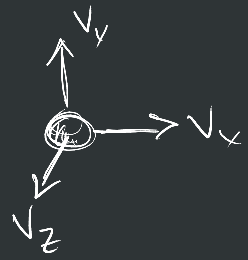
constant pressure

$$Q = n_m C_p \Delta T$$

$$C_p = C_V + R$$
(ideal gas)

$$\langle K \rangle = \frac{3}{2} k_B T$$





$$K_T = N \cdot \langle K \rangle$$

$$\boxed{K_T = \frac{3}{2} N k_B T}$$

$$\Delta K_T = \frac{3}{2} \underbrace{N k_B}_{n_m R} \Delta T$$

$$Q = \Delta U_{int}$$

for ideal gas

$$\Delta U_{int} = \Delta K$$

$$\Delta K_T = \frac{3}{2} n_m R \Delta T$$

$$\cancel{n_m} C_V \cancel{\Delta T} = \frac{3}{2} \cancel{n_m} R \cancel{\Delta T}$$

$$C_V = \frac{3}{2} R = 12.5 \text{ J/K mol}$$

(monoatomic ideal gas)

Table 14.2 Molar Specific Heats at Constant Volume of Gases at 25°C

	Gas	$C_V \left(\frac{\text{J/K}}{\text{mol}}\right)$
Monatomic	→ He	12.5
	→ Ne	12.7
	→ Ar	12.5
Diatomic	H_2	20.4
	N_2	20.8
	O_2	21.0
Polyatomic	CO_2	28.2
	N_2O	28.4

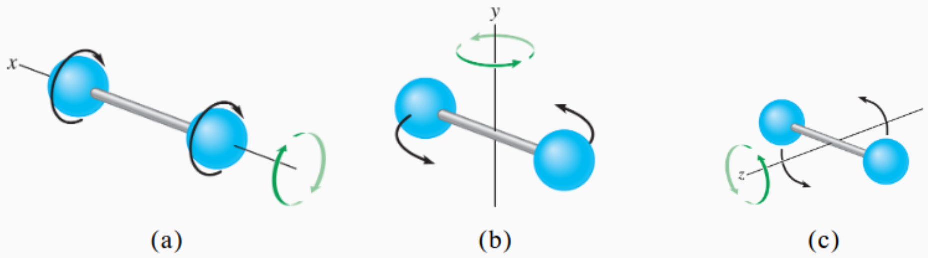


Figure 14.4 Rotation of a model diatomic molecule about three perpendicular axes. The rotational inertia about the x-axis (a) is negligible, so we can ignore rotation about this axis. The rotational inertias about the y- and z-axes (b) and (c) are much larger than for a single atom of the same mass because of the larger distance between the atoms and the axis of rotation.

diatomic ideal gas

$$C_v = \frac{5}{2}R = 20.8\ J/K\,mol$$

After this you can
- discuss the phases of matter
- discuss how much heat it takes to change the phase of matter

solid, liquid, gas, (plasma)

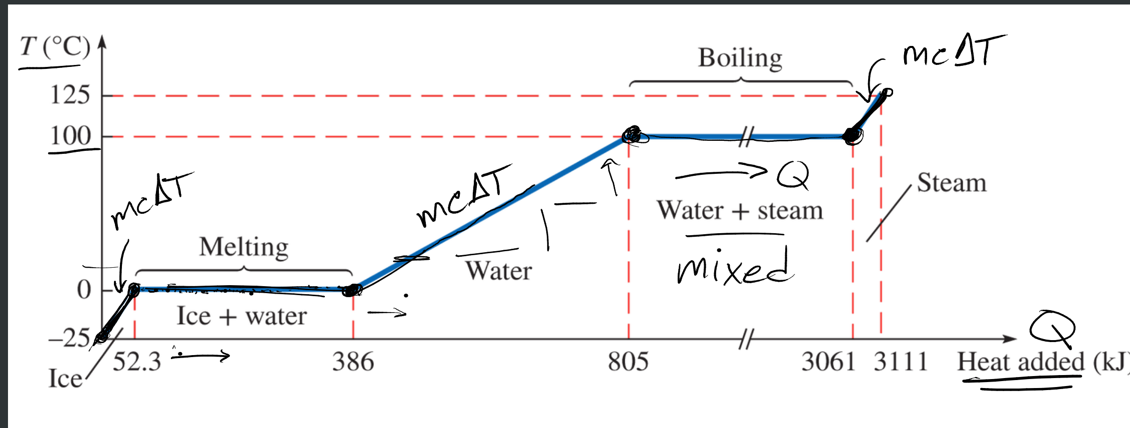
Q

$Q = mc\Delta T$

solid → liquid (melting)

Latent Heat of Fusion

$$Q = m \cdot L_f$$



liquid → gas (boiling)

Latent Heat of Vaporization

$$Q = mL_v$$

Table 14.4	Latent Heats of Some Common Substances			
Substance	**Melting Point (°C)**	**Heat of Fusion (kJ/kg)**	**Boiling Point (°C)**	**Heat of Vaporization (kJ/kg)**
Alcohol (ethyl)	−114	104	78	854
Aluminum	660	397	2450	11400
Copper	1083	205	2340	5070
Gold	1063	66.6	2660	1580
Lead	327	22.9	1620	871
Silver	960.8	88.3	1950	2340
Water	0.0	333.7	100	2256