Chpt 14 | A | Heat

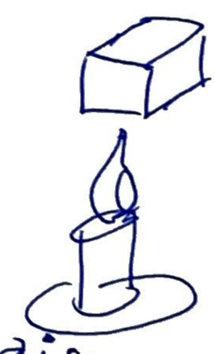
- Heat is energy - Infared Warming Lights generate heat. the SUN generates Heat.

Heat is thermal Radiation

- Heat is measured in Joules, N-m, but in USCS we also see Calorie and BTU
  [BTU = british thermal unit]

[BTW: 1 dietary Calorie = 1000 physics cals]

* Calorie (cal) is the heat needed to increase one gram of H_2O by 1 degree °C specifically
sugar cube
14.5°C to 15.5°C



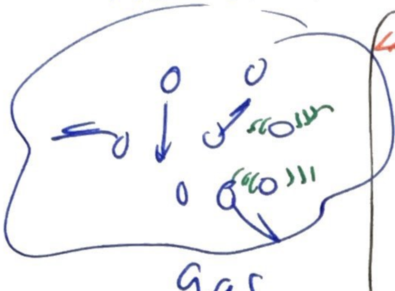
$\Delta T = 1°C$
Then one cal has been added

- 1 BTU is the heat needed to raise 1 lb of water by one deg. Farenheit.

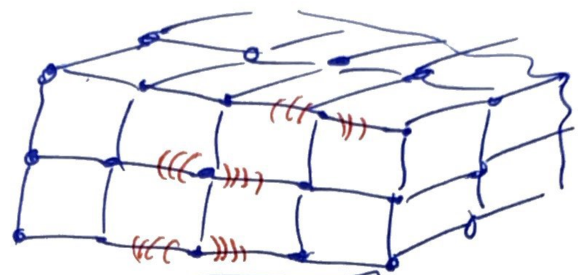
- $\boxed{4.186\ J = 1\ cal}$

⊛ Heat transfers from one object to another

- Internal Energies — sum of all energies in a substance:



- rotational $\frac{1}{2} I\omega^2$
- vibrational $\frac{1}{2} k x^2$
- translational $\frac{1}{2} m v^2$



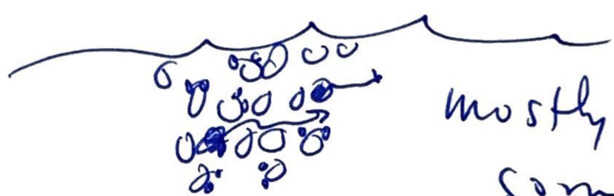
Solid

vibrational only

Total Int. Energy

$$= \sum \tfrac{1}{2} m v_i^2 + \sum \tfrac{1}{2} I \omega_i^2$$

Translat'n Rot'l'n

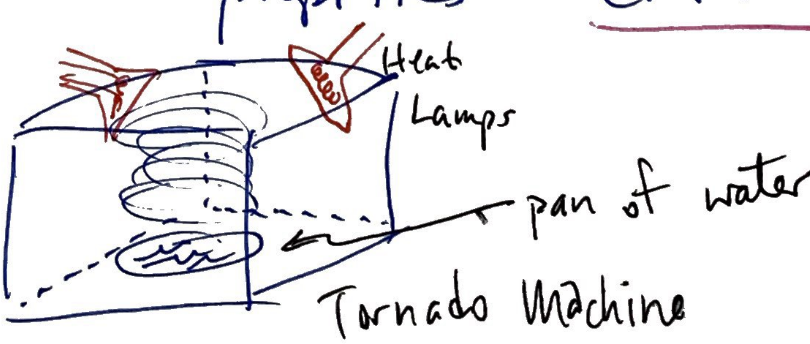


liquid

mostly wiggling with some transl'tnl {use Bernoulli's Eqn} if flowing motion

- Bottom Line

Int'l energy = sum of all energies in the substance. {not the gross flow properties — external energy Bernoulli's eqn}



For internal energy we use

$$U = \frac{1}{2} m\overline{v^2} \text{ for internal}$$

translational motion only.

If N atoms are present:

$$U = N\left(\frac{1}{2} m\overline{v^2}\right)$$

but we saw in Chpt 13: $\frac{1}{2} m\overline{v^2} = \frac{3}{2} kT$

{no molecular vibration or rotation}

then $\boxed{U = \frac{3}{2} nRT}$ Ideal monoatomic gas law

* specific heat: Different materials absorb heat internally at diffeent rates

Let Q = heat in an object.

ΔQ = change of heat in an object

$$\boxed{\Delta Q = m\, c\, \Delta T} \Leftarrow \Delta Q \propto \Delta T$$

The Specific heat of one kg of an substance is that heat needed to change the Temprature by 1 °C

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- Use the formula, but solve for "c", to determine a substances specific Heat:

$$\boxed{c \equiv \frac{\Delta Q}{m \Delta T}}$$

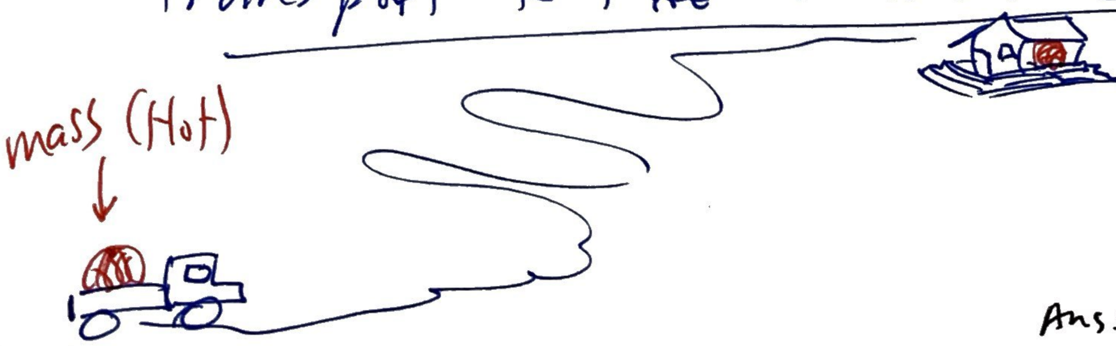
→ add heat (we control this)

→ measure Temperature.

Units $[c] = J/kg/°C$

Table	substance	$c\ (J/kg/°C)$	$c\ (kcal/kg/°C)$
	Al	900	0.22
	Cu	390	0.093
	water	4186 *	1.00
	Ice	2100	0.50

Quiz: You need to deliver "warmth" to your team at the top of a mountain. Your pick up truck can haul 1 ton. What substance should you choose to heat up, insulate, pack, and transport to the mountain cabin?



Ans: Water!

Ex How much heat is needed to warm a 20kg Vat of Iron Pot full of 15kg water from 10°C to 90°C ?

$$Q_{TOT} = Q_{Fe} + Q_{H_2O}$$

$$= m_{Fe} C_{Fe} \Delta T + m_{H_2O} C_{H_2O} \Delta T$$

$$= (m_{Fe} C_{Fe} + m_H C_H) \Delta T$$

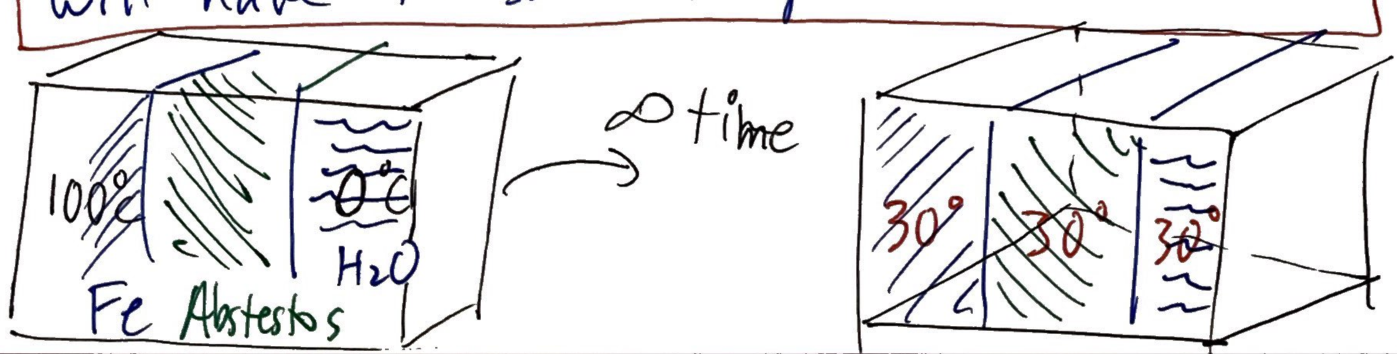
populate

$$Q_{TOT} = \left[(20kg)\left(0.11 \frac{kcal}{kg °C}\right) + (10kg)\left(1 \frac{kcal}{kg °C}\right)\right](90° - 10°)$$

Q_{TOT} = 976 kcal of heat needs to be added to the pot & water

* Calorimetry

0th Law of thermodynamics: After an ∞ amount of time, all materials in a closed syst. will have the same temperature.



A $200\,cm^3$ amount of Hot Tea @ 95° is poured into a 150g glass that was initially at 25°C. Q: What is the equilibrium temp?

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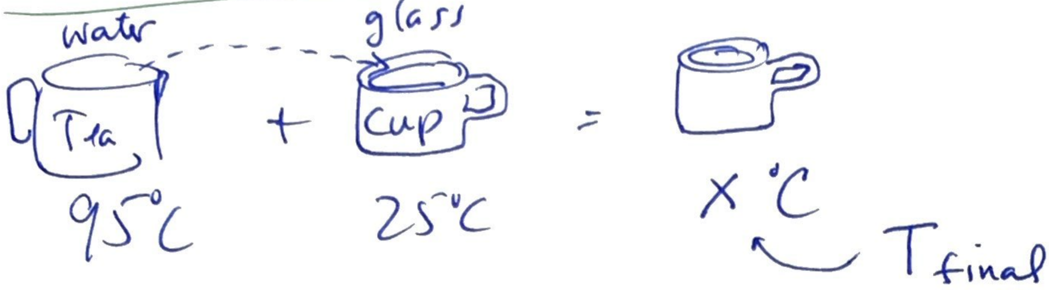
$\boxed{C_{glass} = 840 \frac{J}{kg\,°C}}$



Conservation of Energy:

Heat lost by the Tea = heat gained by the cup.

$$\Delta Q_T = \Delta Q_{cup}$$

$$m_T c_T \Delta T = m_{cup} C_{cup} \Delta T$$

$$(0.2\,kg)(4186\ J/kg\,°C)(95° - T_f) = (0.15\,kg)(840 \tfrac{J}{kg\,C})(T_f - 25°)$$

cooling heat why

$$\boxed{\Delta Q_{Tea} + \Delta Q_{cup} = 0} \rightarrow$$

Init−final

$$m_T c_T \Delta T + m c \Delta T = 0 \rightarrow m c_T (\Delta T) = -mc\Delta T$$

$$= mc(T_f - T_{init})$$

other side

Solve T_f: $(0.2)(4186)(95) - 0.2(4186)T_f$

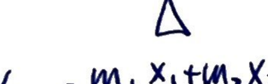
$$= (0.15)(840)(T_f) - (0.15)(840)(25)$$

$$\Rightarrow (0.2)(4186)(95) + (0.15)(840)(25) = (0.2)(4186)T_f + (0.15)(840)T_f$$

factor $(0.2)(4186)(95) + (0.15)(840)(25) = [(0.2)(4186) + (0.15)(840)]T_f$

$$\Rightarrow \boxed{T_f = \frac{(0.2)(4186)(95) + (0.15)(840)(25)}{(0.2)(4186) + (0.15)(840)}}$$

$\Rightarrow$

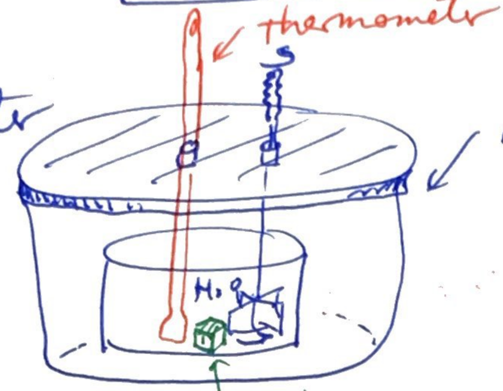


$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

⊗ Energy Conservation eqn becomes:

$$\boxed{\sum_i \Delta Q = 0}$$

• calorimeter



•• $\boxed{\text{"object" watch the thermometer until we see no change occuring} \rightarrow \text{@ equilibrium.}}$

Ideally we would use a dewar bottle

EX We want to find "C" for an unknow substance. If a 0.15kg sample @ 540°c is dropped into 0.4kg of water @ 10°C, and if the Internal vat is a 0.2kg Aluminium container @10°C What specific heat do we calculate if the eq. temp is 30.5°C

$$\sum \Delta Q = 0 : m_{sample}\, C_{sample}\,(T_f - T_i) + m_w C_w (T_f - T_i) + m_{al} C_{al} (T_f - T_i) = 0$$

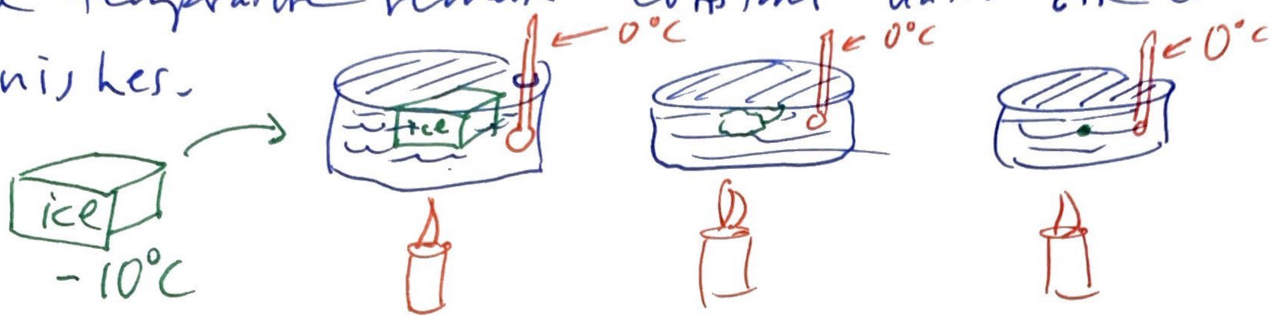
$$(0.15)C\,(30.5 - 540°C) + (0.4)(4186 \tfrac{J}{kg\,C°})(30.5 - 10°) + (0.2)(900 \tfrac{J}{kg\,°C})(30.5 - 10°) = 0$$

$$-C\,76.4 \quad + \quad 34\,300\ J \quad + \quad 3690\ J \quad = 0$$

$$C = \frac{-34300J - 3690J}{-76.4\ kg\,°C} = \boxed{497\ J/_{kg\,°C}}$$

⊛ Latent Heat of Fusion, L_f

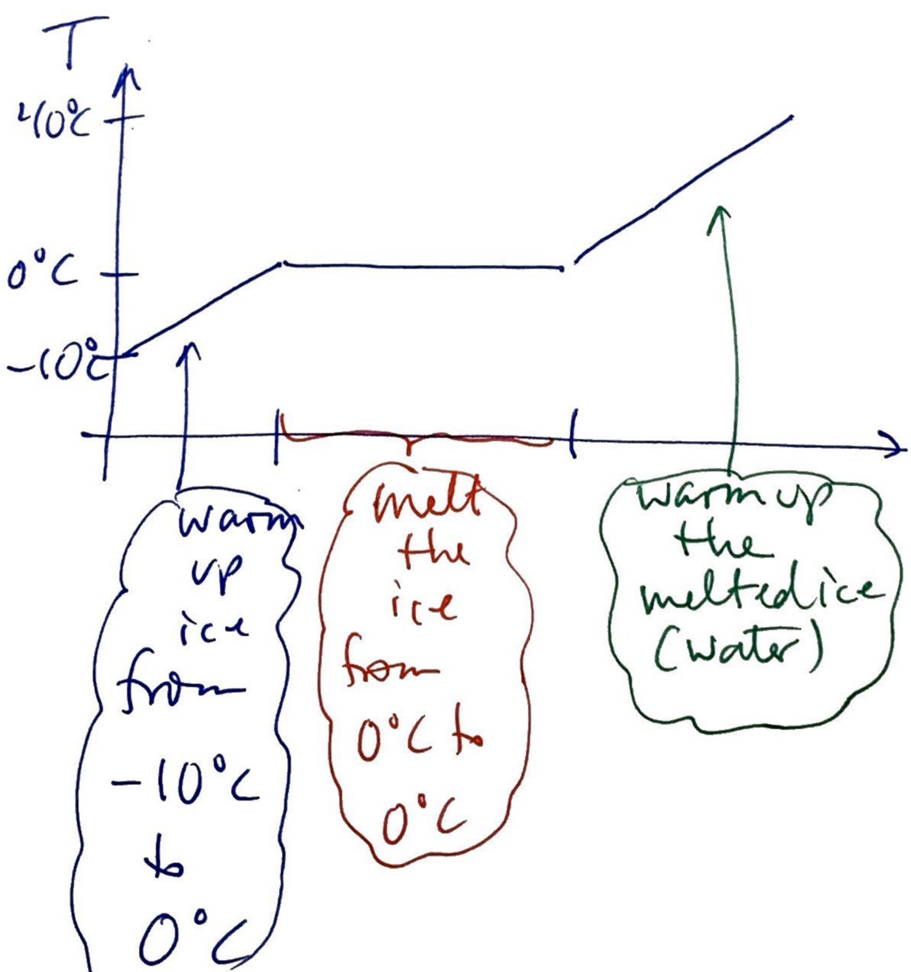
As we study an ice cube melting we will notice that the temperature remains constant until the cube vanishes.



The temp. remains the same. The added energy is needed to break the bonds of the ice as it melts.

This energy is called the $\boxed{\text{Latent Heat of Fusion}}$

This process is reversible: freezing



Q heat added

For water (ice)

$$L_f = 33 \, \text{kJ/kg}$$

OR

$$= 8.0 \, \frac{\text{kcal}}{\text{kg}}$$

EX How much heat is needed to melt 0.5 kg of silver if it is at 100°C. Silver melts at 961°C and it's latent heat is $L_{f_{Ag}} = 88{,}000\ J/kg$, $C_{Ag} = 230\ J/kg°C$

- Q_{heat} to warm Ag from 100°C to 961°C

$$= m_{Ag}\, C_{Ag}\, \Delta T$$

- Q heat to melt Ag $= m_{Ag} L_{f_{Ag}}$

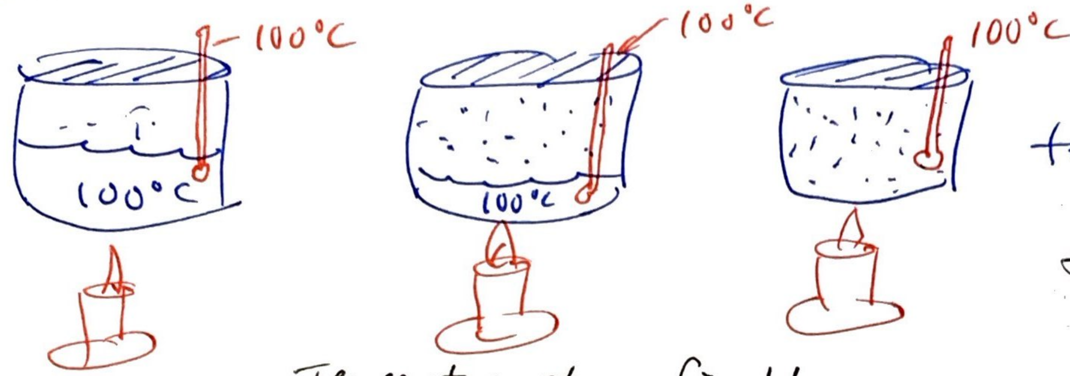
Total Heat

$$Q_{TOT} = (0.5kg)(230 \tfrac{J}{kg°C})(961-100°) + (0.5kg)(88{,}000 \tfrac{J}{kg})$$

$$= 99{,}015\ J \quad + \quad 44{,}000\ J$$

$$= \boxed{143{,}015\ J} \quad \text{or} \quad 143\ kJ$$

* Latent heat of Vaporization



Finally temp. will now increase once the liq. is gone.

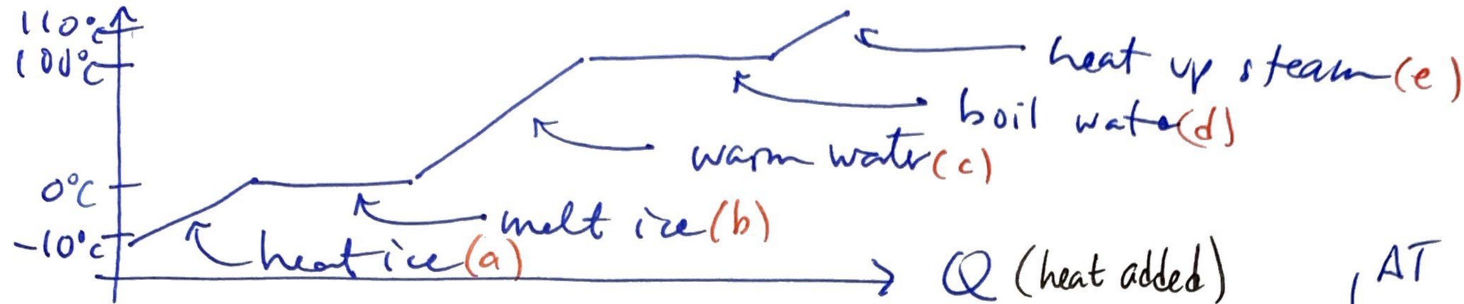
Temperature stays fixed!

the constant T, yet the added heat, tells us that energy is being used to convert the liquid to a gas

EX

$$\boxed{L_{V_{H_2O}} = 22,600 \text{ J/kg}}$$

Ex Lets heat a below frozen block of ice up until it becomes steam. Calculate the heat to take 7 kg of ice @ −10°C to 110°C steam



(a) warmup ice : $Q = m\,C_{ice}\,\Delta T = (7\,kg)(2100\,\frac{J}{kg\,°C})(10°C) = \underline{\underline{147\,kJ}}$ ← ΔT

(b) melt ice : $Q = m\,L_f = (7\,kg)(333{,}000\,\frac{J}{kg}) = \underline{\underline{2{,}331\,kJ}}$

0° → 100°

(c) warm water : $Q = m\,C_{H_2O}\,\Delta T = (7\,kg)(4186\,\frac{J}{kg\,°C})(100°C) = \underline{\underline{2{,}930\,kJ}}$

(d) boil water : $Q = m\,L_V = (7\,kg)(2{,}260{,}000\,\frac{J}{kg}) = \underline{\underline{15{,}820\,kJ}}$

110 → 110

(e) heat steam : $Q = m\,C_{steam}\,\Delta T = (7\,kg)(2010\,\frac{J}{kg\,°C})(10°C)$

$= \underline{\underline{141\,kJ}}$

sum up

Total Heat to do the Job...

$$\boxed{Q_{TOT} = 21{,}369\,kJ}$$