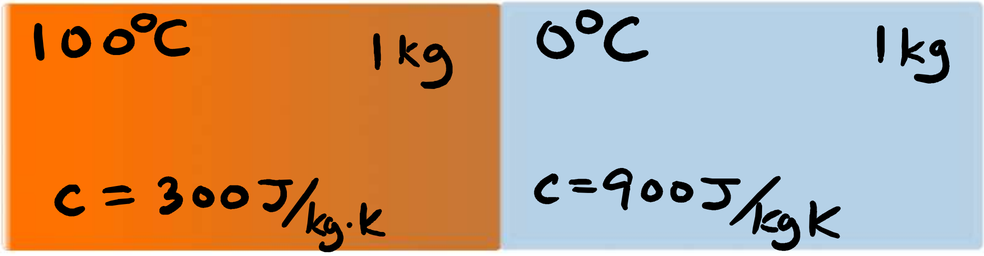
Office hours today: after class and 4-5pm
(Life 2nd floor) (Hennings 420)

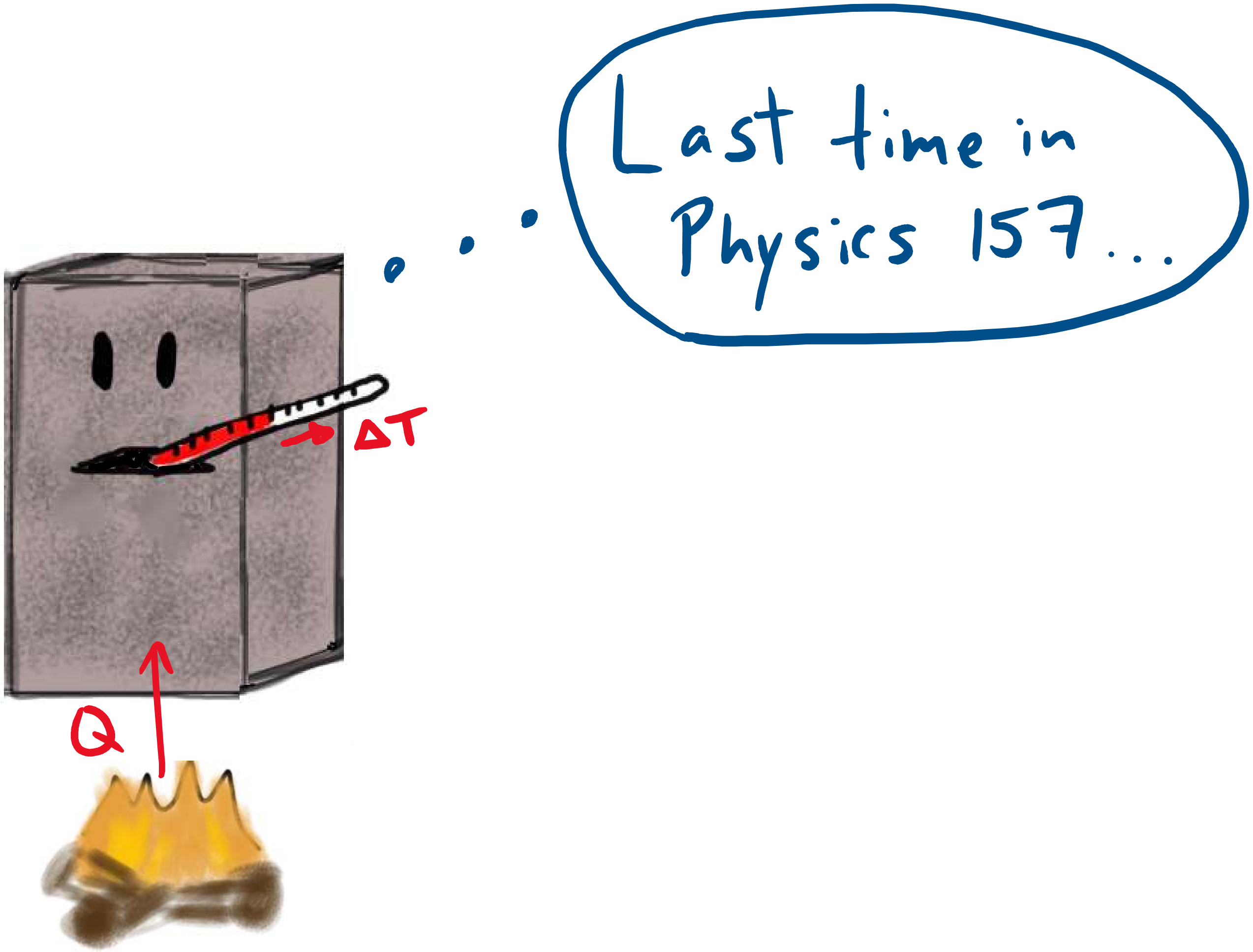
Homework sessions: 5-7pm Monday, Hennings 200
5-7pm Tuesday, Hennings 202

Food for thought:

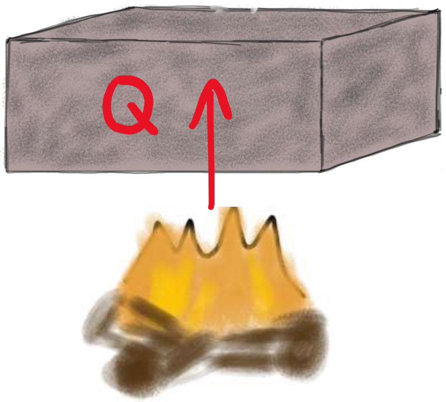


The final temperature will be

A) 50°C B) Greater than 50°C C) Less than 50°C


Last time in Physics 157...
ΔT
Q

Heat required to raise the temperature of a material determined by its SPECIFIC HEAT c:



$$\overset{\text{heat added}}{Q} = \overset{\text{mass}}{m}\,c\,\Delta T$$

OR:

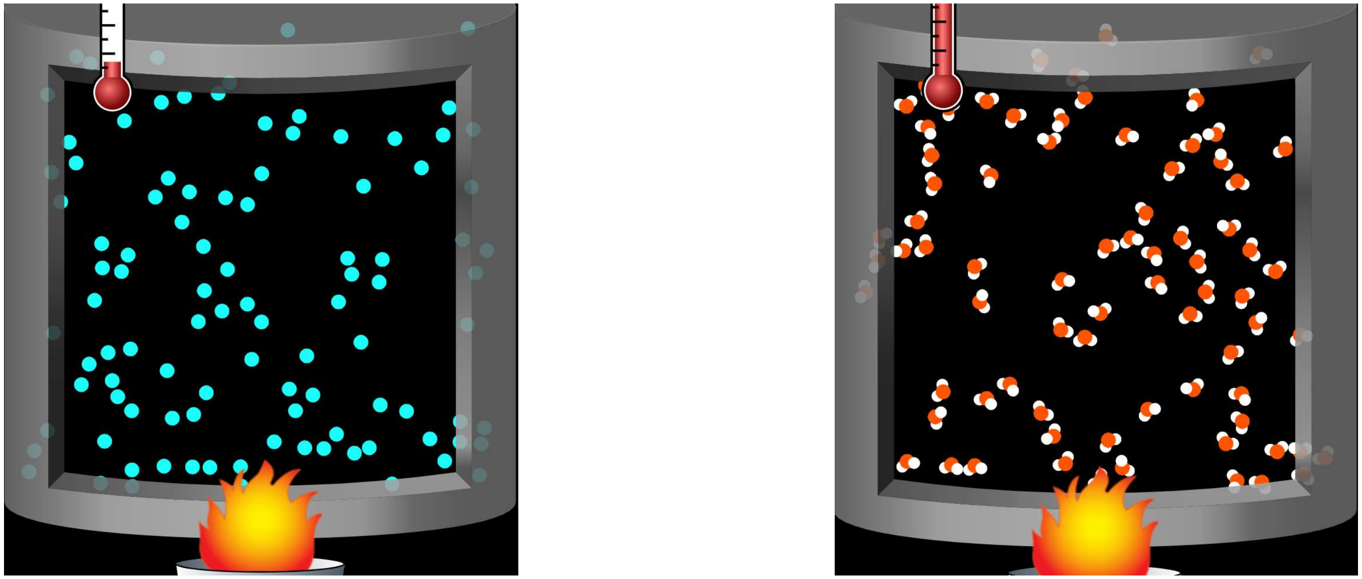
$$Q = \underset{\#\text{ moles}}{n}\,\underset{\text{MOLAR SPECIFIC HEAT = MOLAR HEAT CAPACITY}}{C}\,\Delta T$$

c in $\frac{J}{kg \cdot K}$: energy required to heat 1 kg of material by 1 K

C in $\frac{J}{mol \cdot K}$: energy required to heat 1 mole of material by 1 K

Why is heat capacity higher for some materials?

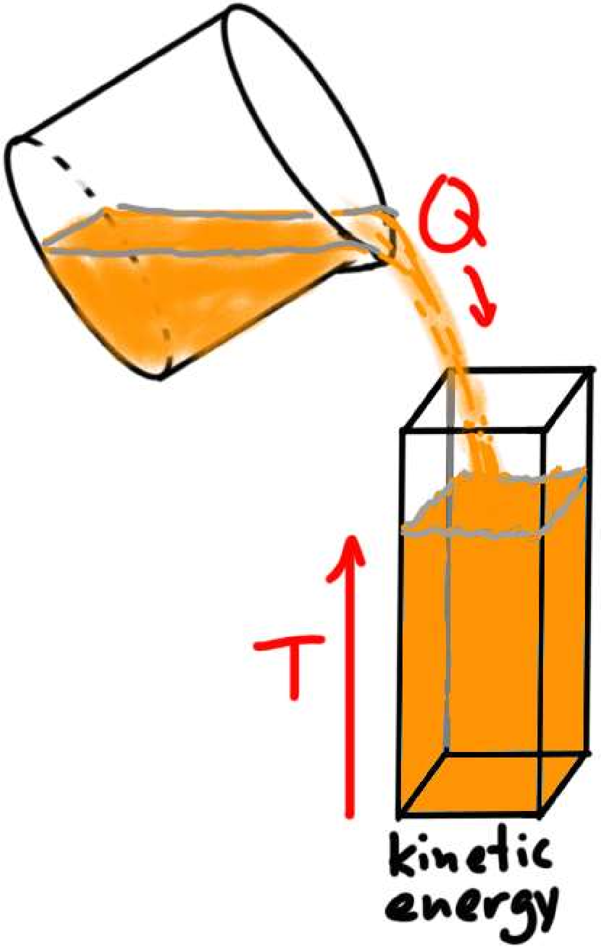
will see: temperature proportional to average kinetic energy of molecules



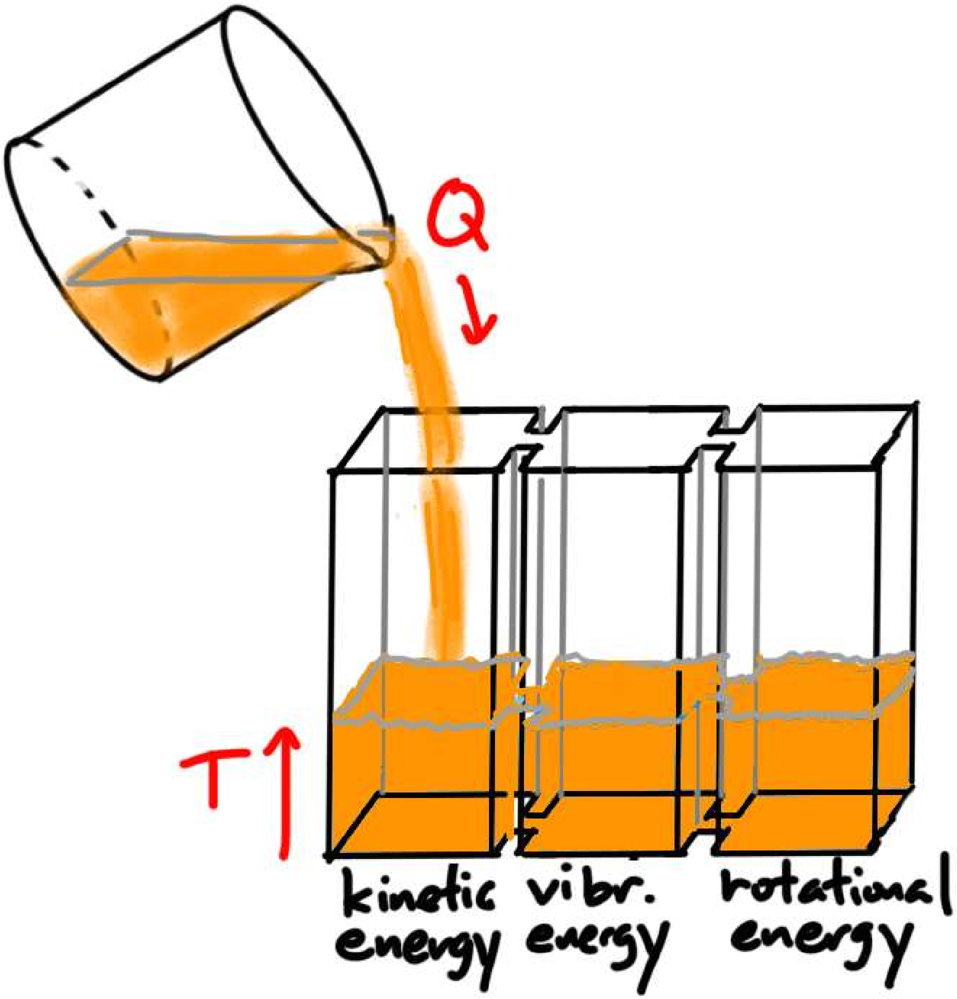
for more complicated materials, part of added energy added goes to rotations/vibrations etc..., so it takes more Q to increase the kinetic energy.

From PHET: states of matter simulation, https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html

An analogy:



lower heat capacity



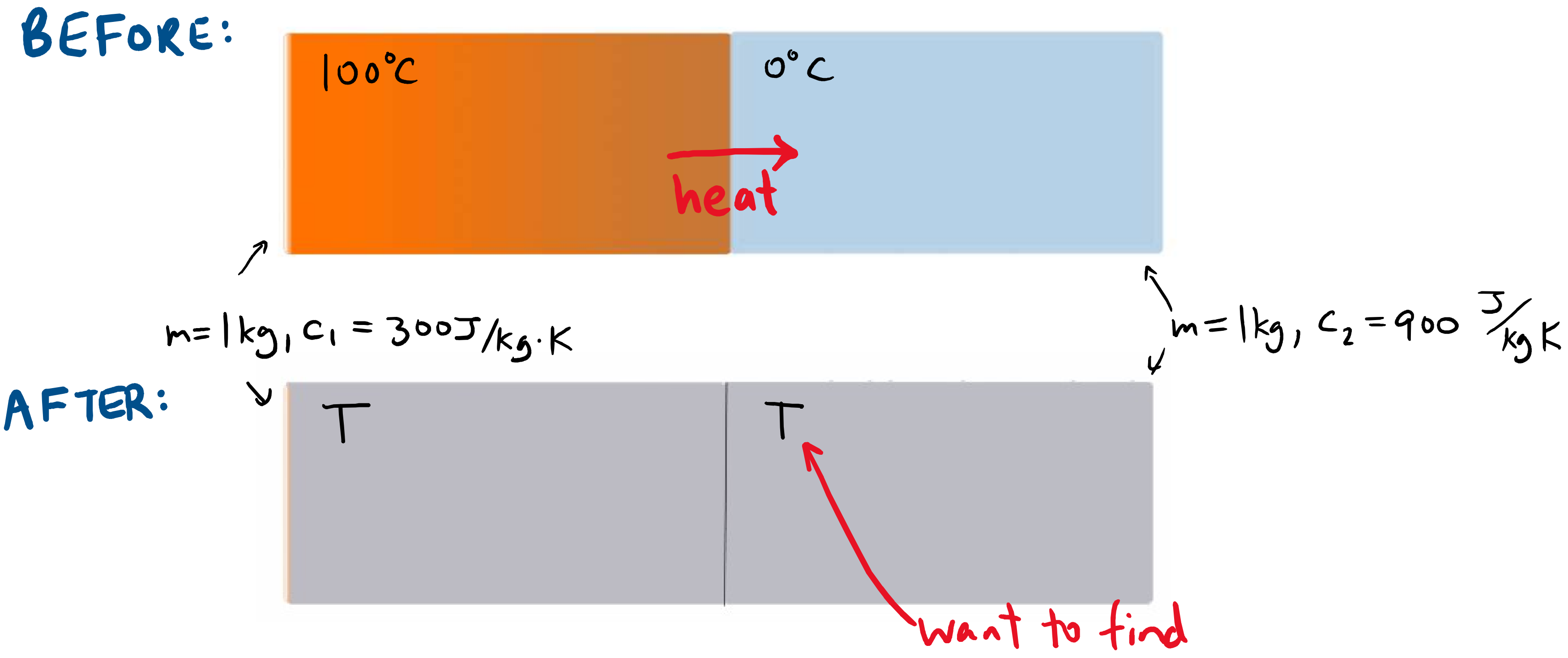
higher heat capacity

Exercise: two objects with mass 1kg are put in thermal contact but insulated from their environment. If the initial temperatures are $T_1 = 100^{o}C$ and $T_2 = 0^{o}C$, and the specific heats are $c_1 = 300$ J/kg·K and $c_2 = 900$ J/kg ·K, calculate the final equilibrium temperature.

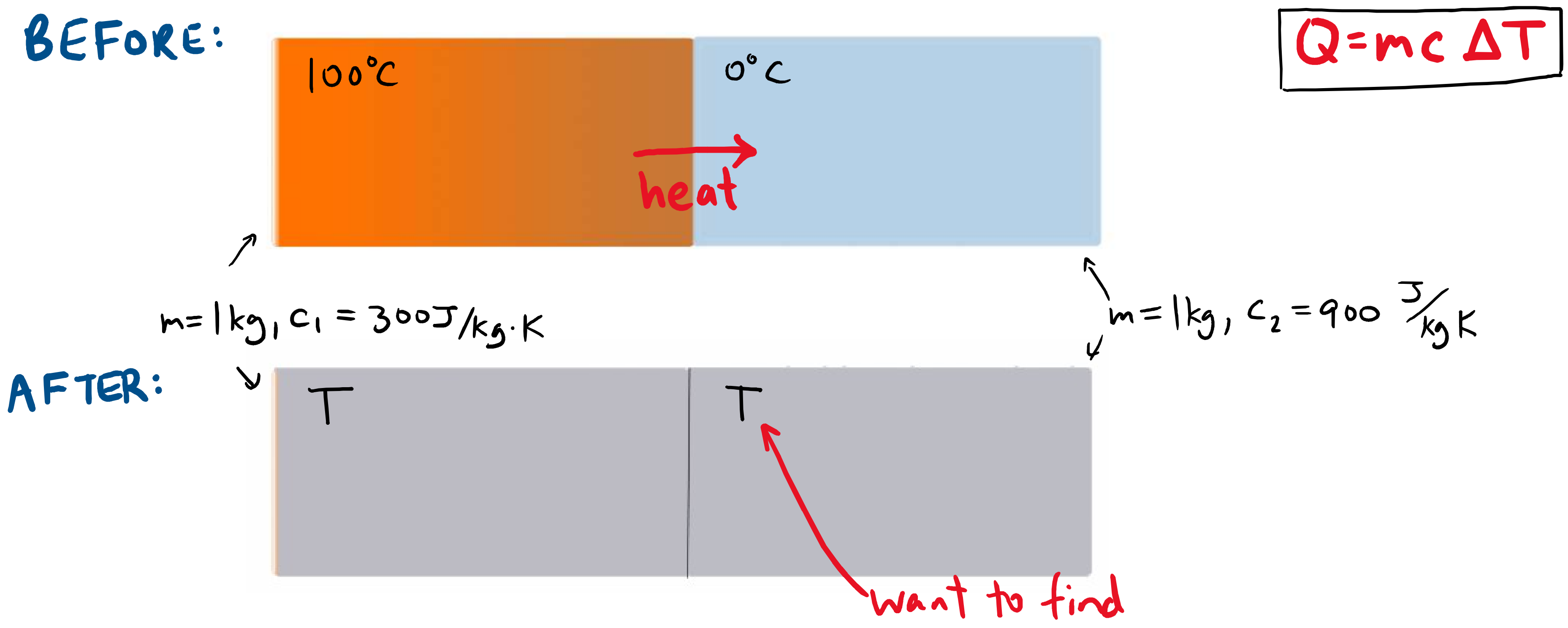
Exercise: two objects with mass 1kg are put in thermal contact but insulated from their environment. If the initial temperatures are $T_1 = 100^{o}C$ and $T_2 = 0^{o}C$, and the specific heats are $c_1 = 300$ J/kg·K and $c_2 = 900$ J/kg ·K, calculate the final equilibrium temperature.

Step 1: Draw before/after pictures, labeled with known + unknown quantities

Exercise: two objects with mass 1kg are put in thermal contact but insulated from their environment. If the initial temperatures are $T_1 = 100^oC$ and $T_2 = 0^oC$, and the specific heats are $c_1 = 300$ J/kg·K and $c_2 = 900$ J/kg ·K, calculate the final equilibrium temperature.



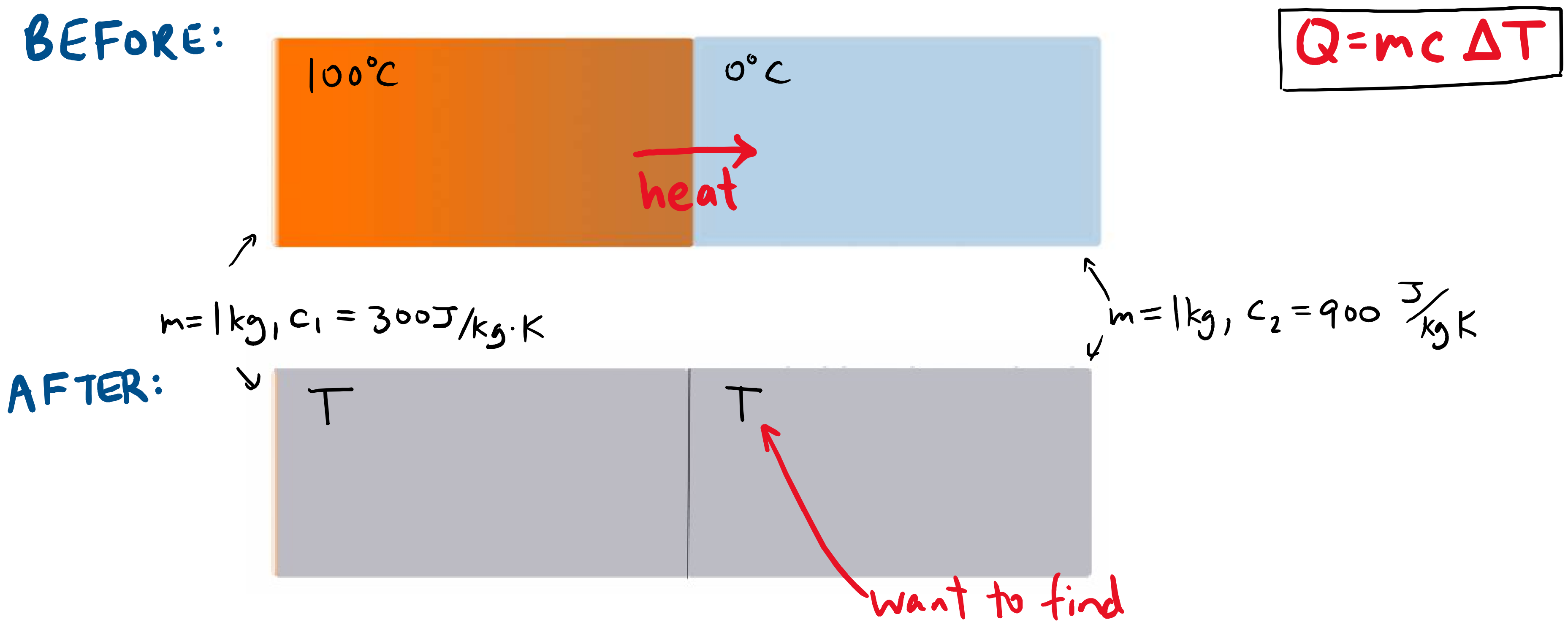
Next: for each part, determine how much heat was added



Clicker: For the object initially at 100°C, the amount of heat added is

A) $Q_1 = 300\ \text{J/K} \cdot T$
B) $Q_1 = 300\ \text{J/K} \cdot 100^{\circ}\text{C}$
C) $Q_1 = 300\ \text{J/K} \cdot (T - 100^{\circ}\text{C})$
D) $Q_1 = 300\ \text{J/K} \cdot (100^{\circ}\text{C} - T)$
E) $Q_1 = 300\ \text{J/K} \cdot (T + 100^{\circ}\text{C})$

EXTRA: what is Q_2? How are Q_1 and Q_2 related?



Clicker: For the object initially at 100°C, the amount of heat added is

$Q = m \cdot c \cdot \Delta T$ $m = 1\,kg$

$c_1 = 300\,J/kg\,K$

$\Delta T = T_{final} - T_{initial}$

$= (T - 100°C)$

A) $Q_1 = 300\,J/K \cdot T$

B) $Q_1 = 300\,J/K \cdot 100°C$

[✓ C) $Q_1 = 300\,J/K \cdot (T - 100°C)$]

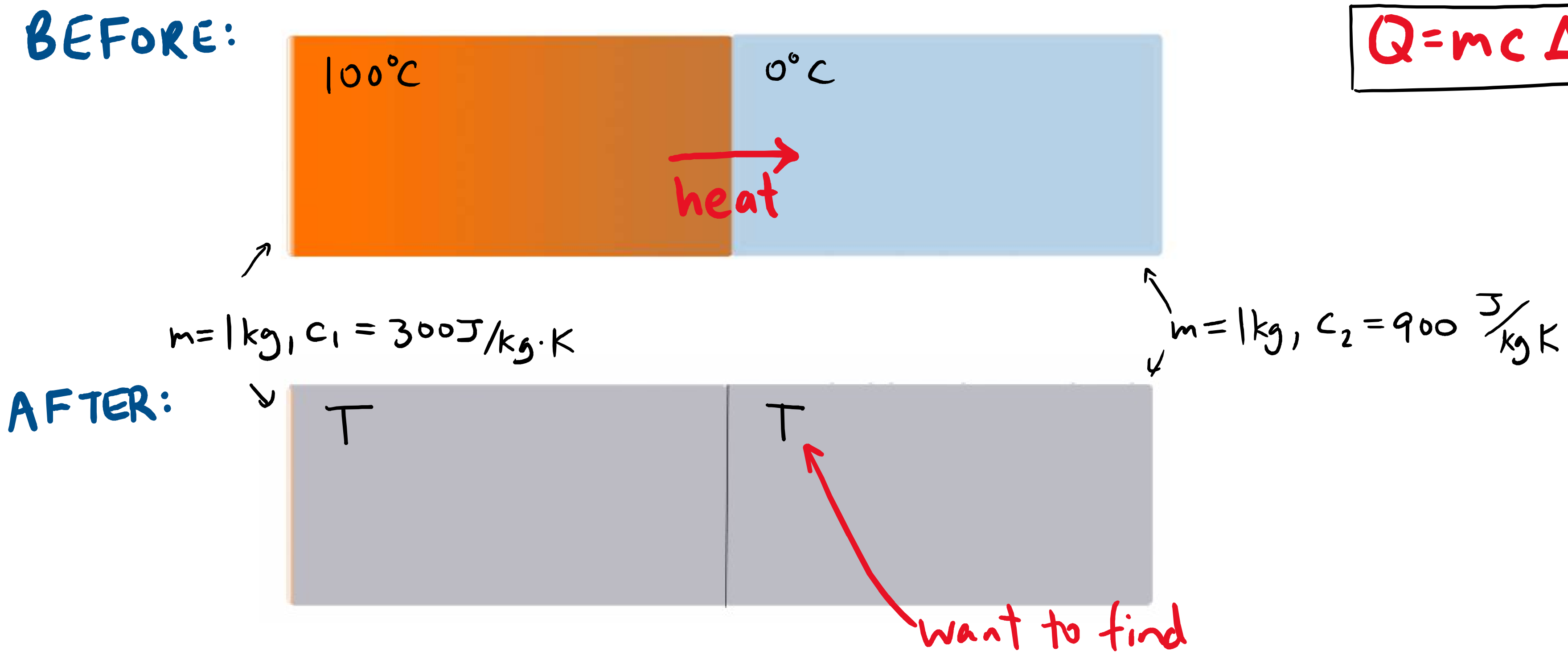
D) $Q_1 = 300\,J/K \cdot (100°C - T)$

E) $Q_1 = 300\,J/K \cdot (T + 100°C)$

this will be negative

EXTRA: what is Q_2? How are Q_1 and Q_2 related?

$$\boxed{Q = mc\,\Delta T}$$

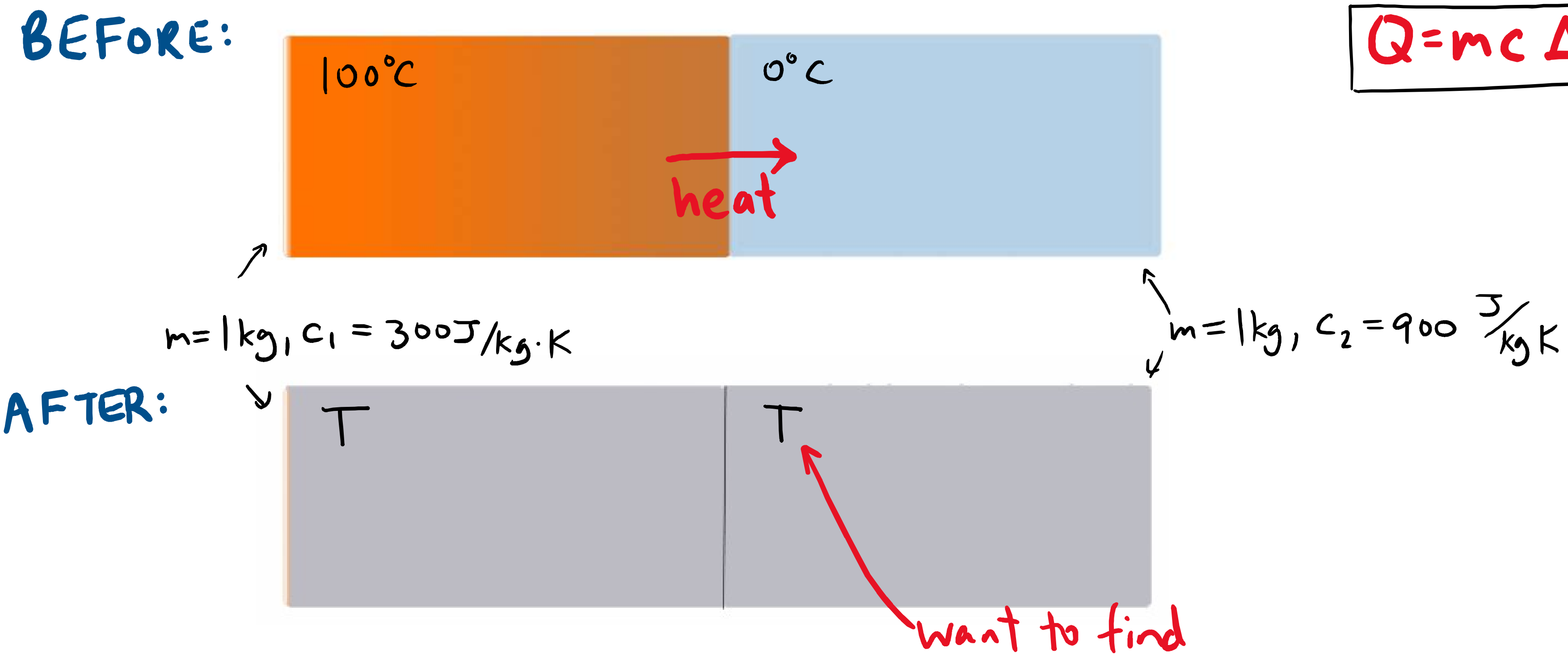


Have: $Q_1 = 300\,J/K \cdot (T - 100°C)$

$Q_2 = 900\,J/K \cdot (T - 0°C)$

How are Q_1 and Q_2 related? Why?

$$\boxed{Q = mc\,\Delta T}$$

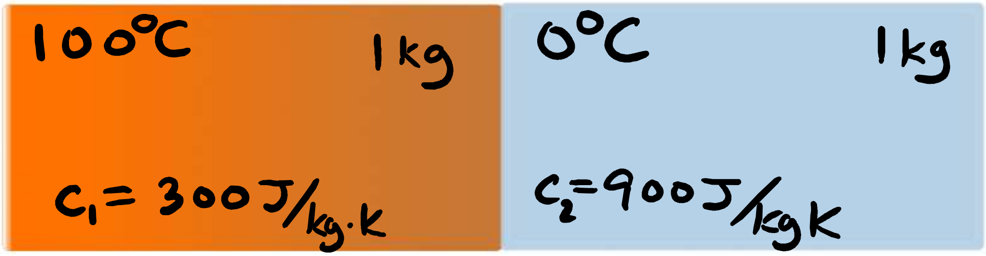


Have: $Q_1 = 300\,\mathrm{J/K} \cdot (T - 100^\circ\mathrm{C})$

$Q_2 = 900\,\mathrm{J/K} \cdot (T - 0^\circ\mathrm{C})$

Energy conservation: $Q_1 + Q_2 = 0$

$$1200\,\mathrm{J/K} \cdot T - 30000\,\mathrm{J} = 0 \Longrightarrow T = 25^\circ\mathrm{C}$$



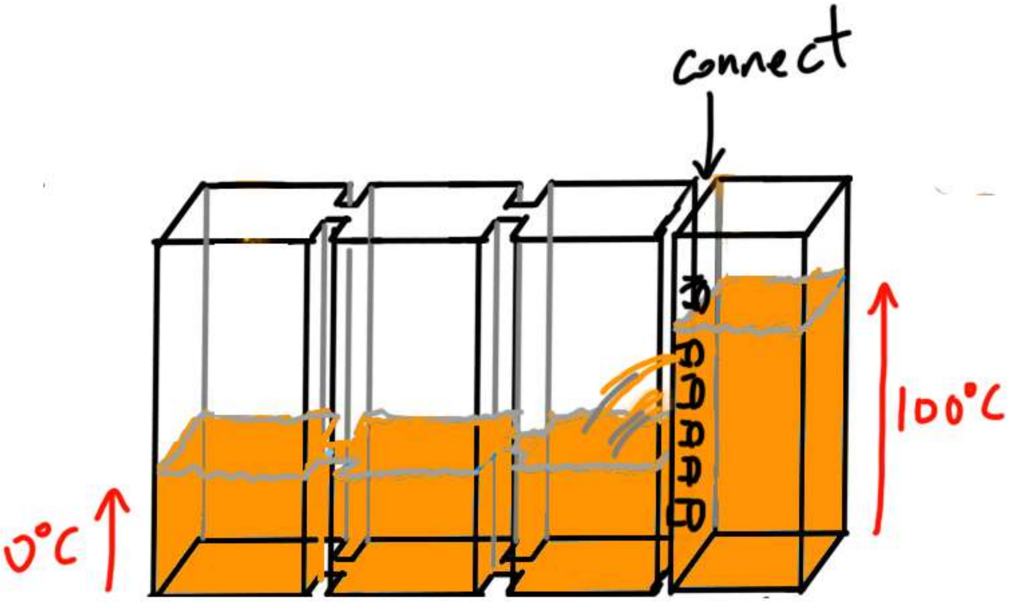
Intuitively: c_2 is $3 \times c_1$, so same magnitude of heat will cause $\frac{1}{3}$ the temperature change.

25° is $\frac{1}{3}$ of 75° and these add to 100°C

General answer: final temperature is:

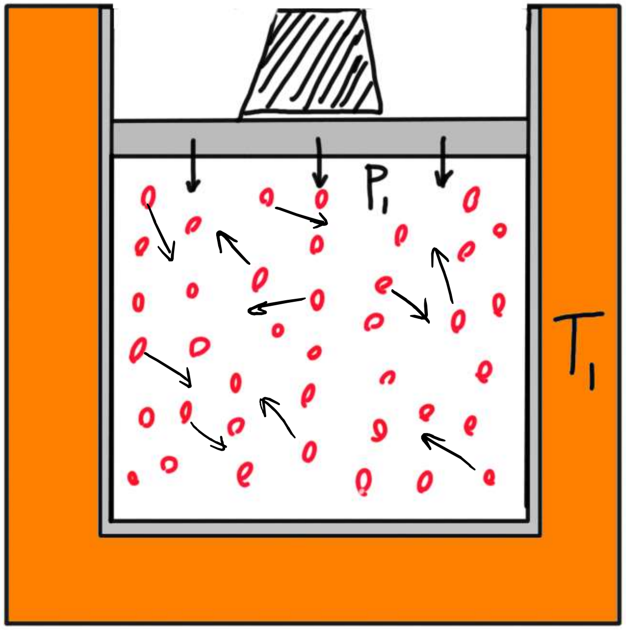
$$T = \left(\frac{m_1 c_1}{m_1 c_1 + m_2 c_2}\right) T_1 + \left(\frac{m_2 c_2}{m_1 c_1 + m_2 c_2}\right) T_2$$

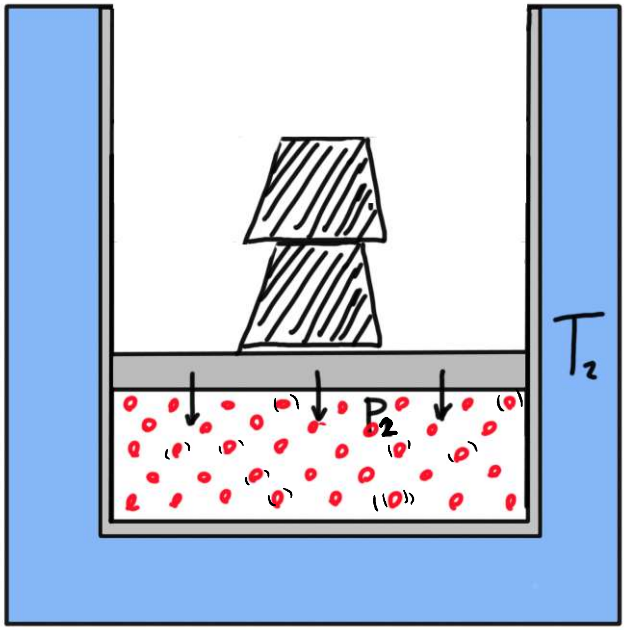
weighted average of T_1 and T_2


connect
0°C
100°C

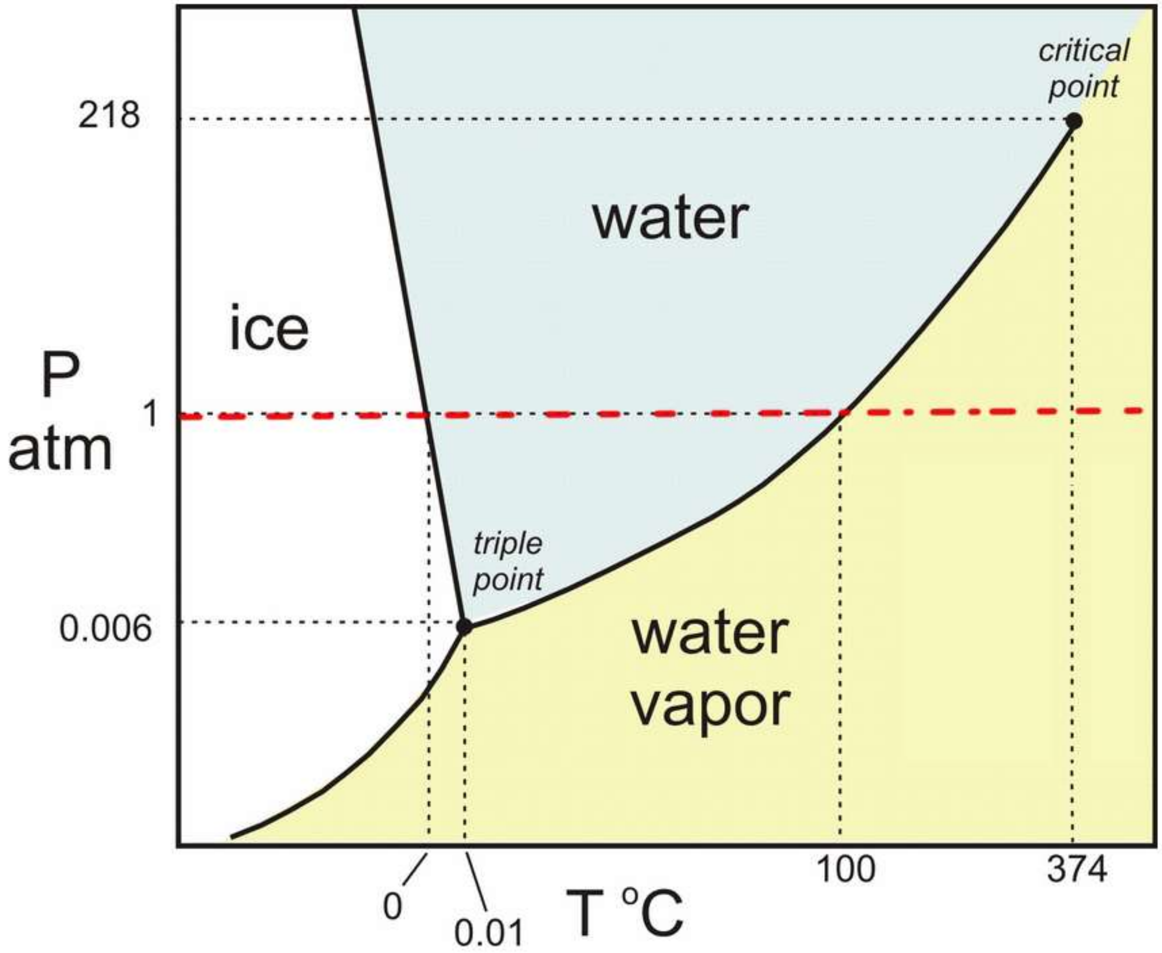
PHASES OF MATTER

- Take some molecules
- Put them in a container at some temperature & pressure
- Significant changes in configuration of molecules can occur as we vary T & P





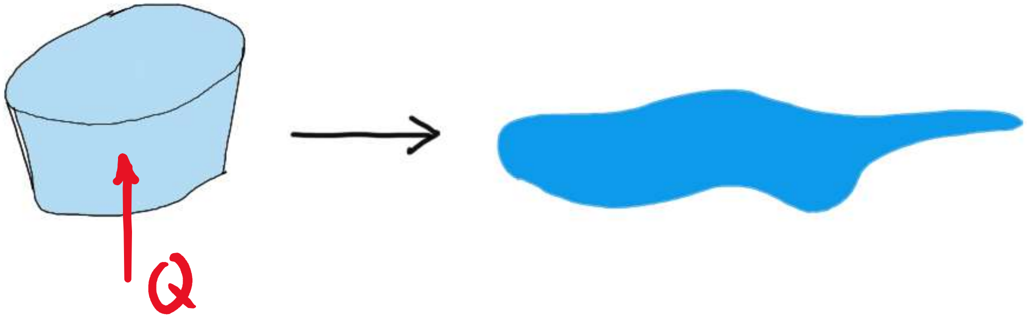
PHASE DIAGRAM: displays phases and phase transition curves as a function of T and P



normally here

PHASE CHANGES:

- macroscopic properties change dramatically across phase boundary



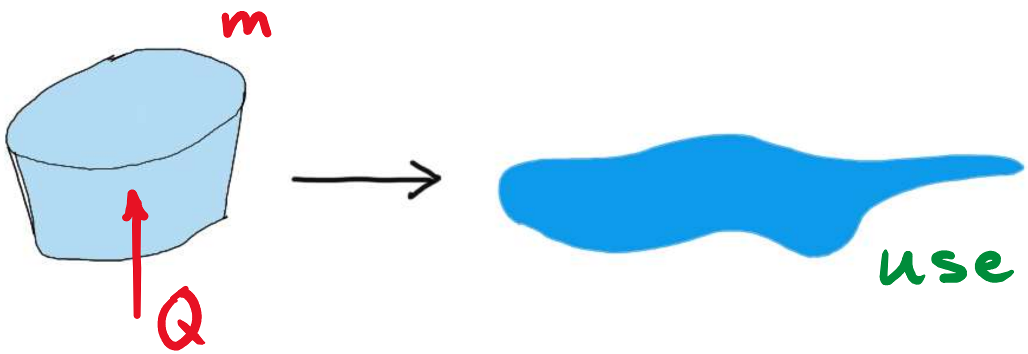
- At transition temperature, transition occurs due to heat added/removed no temp. change!
- Amount of heat required for transition per mass of material is **LATENT HEAT**

L_f: latent heat of fusion (freezing/melting)

L_v: latent heat of vaporization (boiling, condensing)

LATENT HEAT : Heat required to melt / boil a mass **m** of material (at melting / boiling point) is:

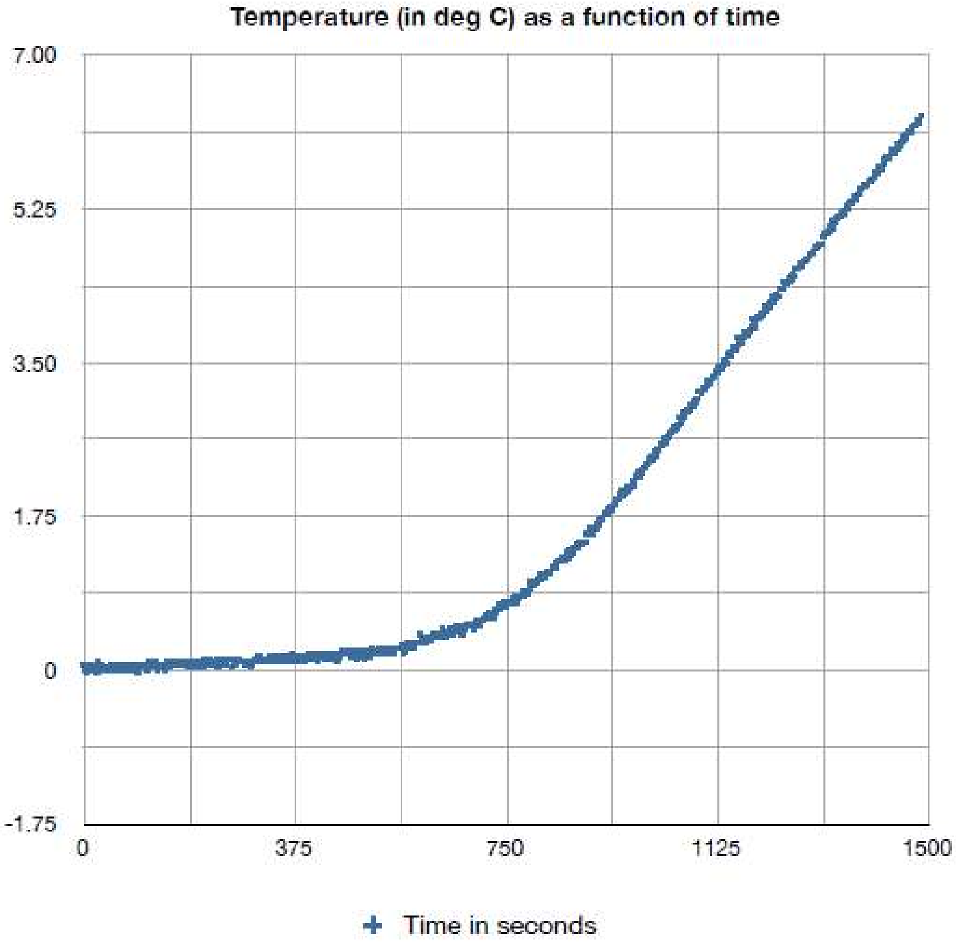
$$Q = \underset{\text{mass}}{m}\,\underset{\text{latent heat}}{L}$$



use L_f for melting/freezing

L_v for boiling/condensing

L in $\frac{J}{kg}$: energy required melt / vaporize 1 kg of material

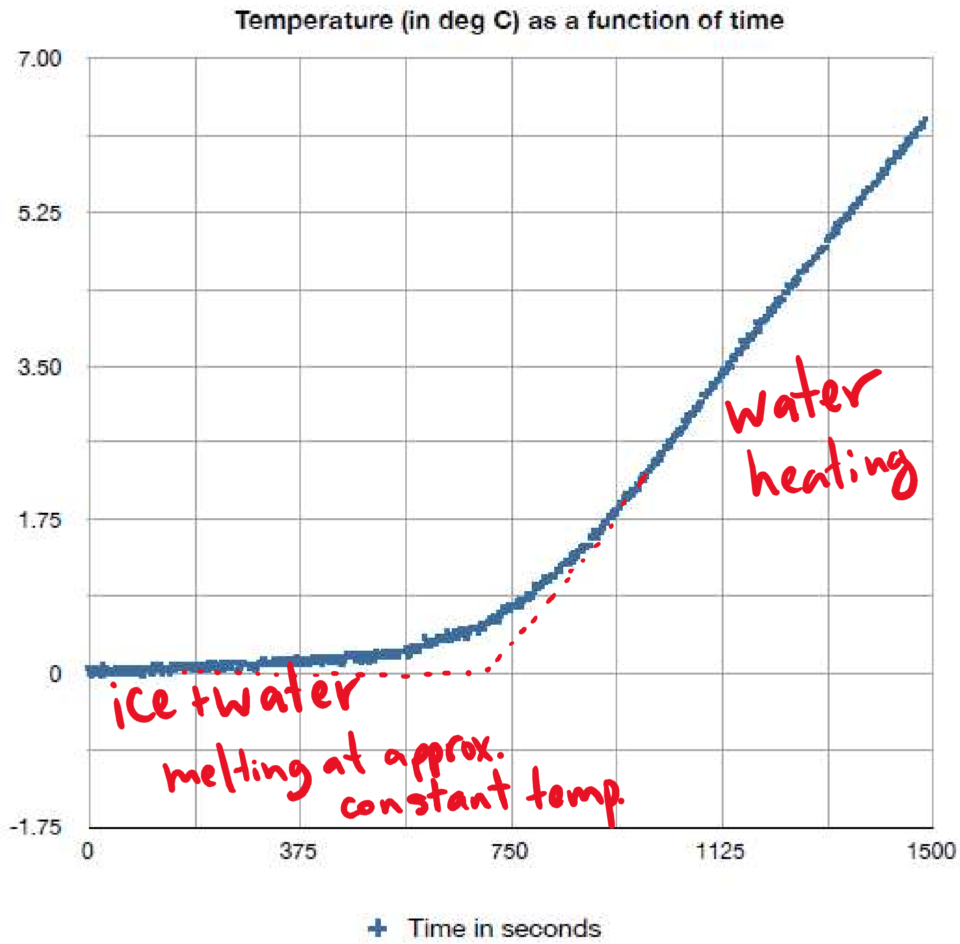


The graph shows the temperature vs time in an experiment where heat is supplied to ice water at a power of 240W.

(1 Watt = 1 Joule / second).

Why does the graph look like this?

NEXT: How much ice was present initially?

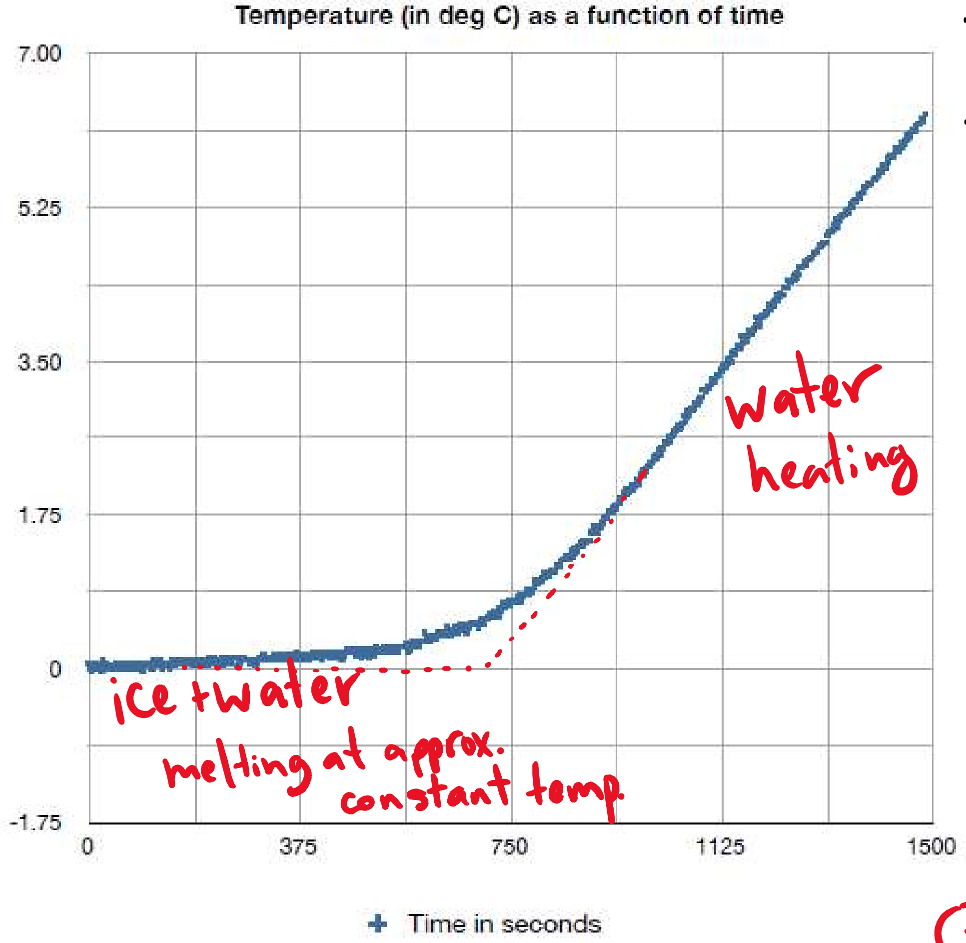


The graph shows the temperature vs time in an experiment where heat is supplied to ice water at a power of 240W. (1 Watt = 1 Joule / second).

Roughly how much ice was present initially? $L_f = 334 \times 10^3$ J/kg.

A) 0.05kg B) 0.5kg C) 5kg D) 50kg

EXTRA: why is the graph curved?



The graph shows the temperature vs time in an experiment where heat is supplied to ice water at a power of 240W.
(1 Watt = 1 Joule / second).

Roughly how much ice was present initially?
$L_f = 334 \times 10^3$ J/kg.

$Q = mL$ gives $m = \frac{Q}{L}$

$Q = 240\,J/s \times 700\,s$
$\approx 168{,}000\,J$

A) 0.05kg [✓ B) 0.5kg] C) 5kg D) 50kg

$L = 334{,}000\,J/kg$
$m = \frac{Q}{L} \approx 0.5\,kg$

EXTRA: why is the graph curved?

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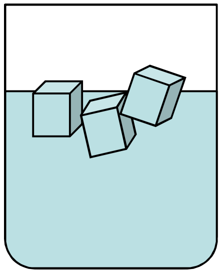
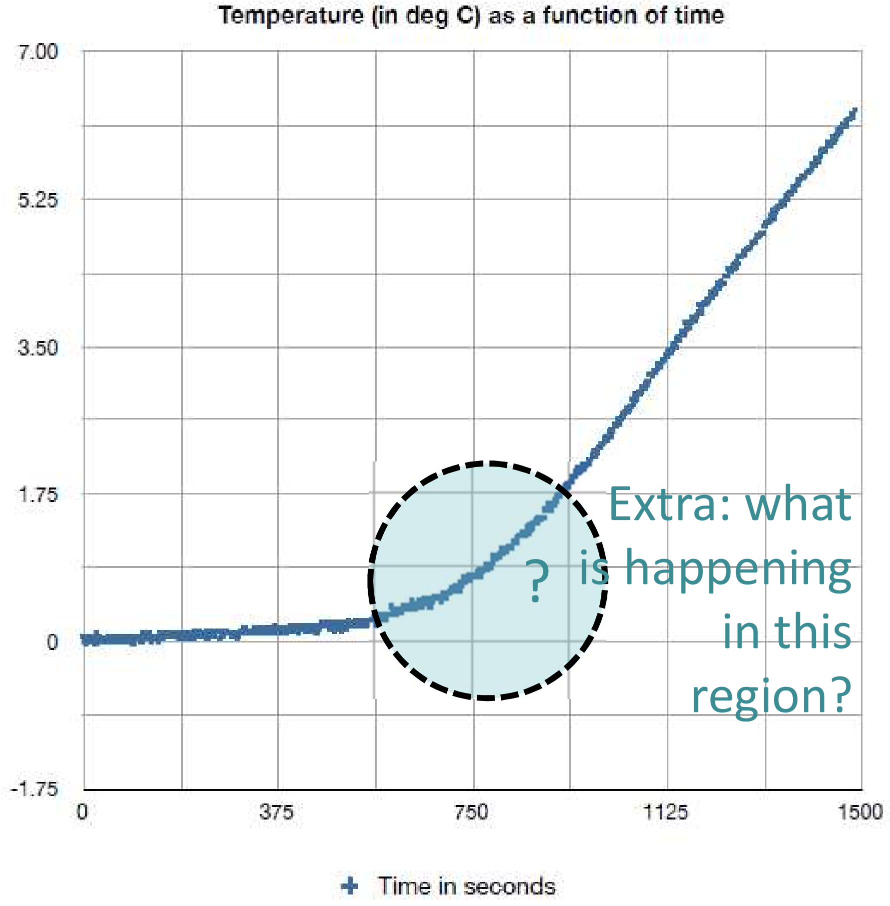
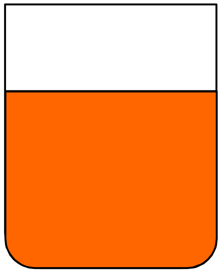
ice/water
0˚C



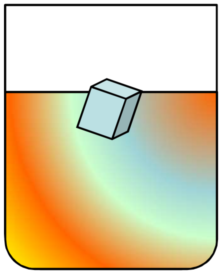


Extra: what is happening in this region?

all liquid water,
well mixed



poor mixing as ice melts, non-uniform temperature



T vs heat added (e.g. water at atmospheric pressure)