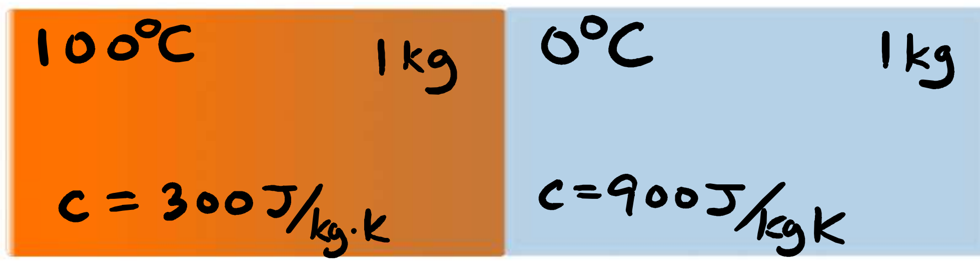
Office hours today: after class and 4-5pm
(Life 2nd floor) (Hennings 420)

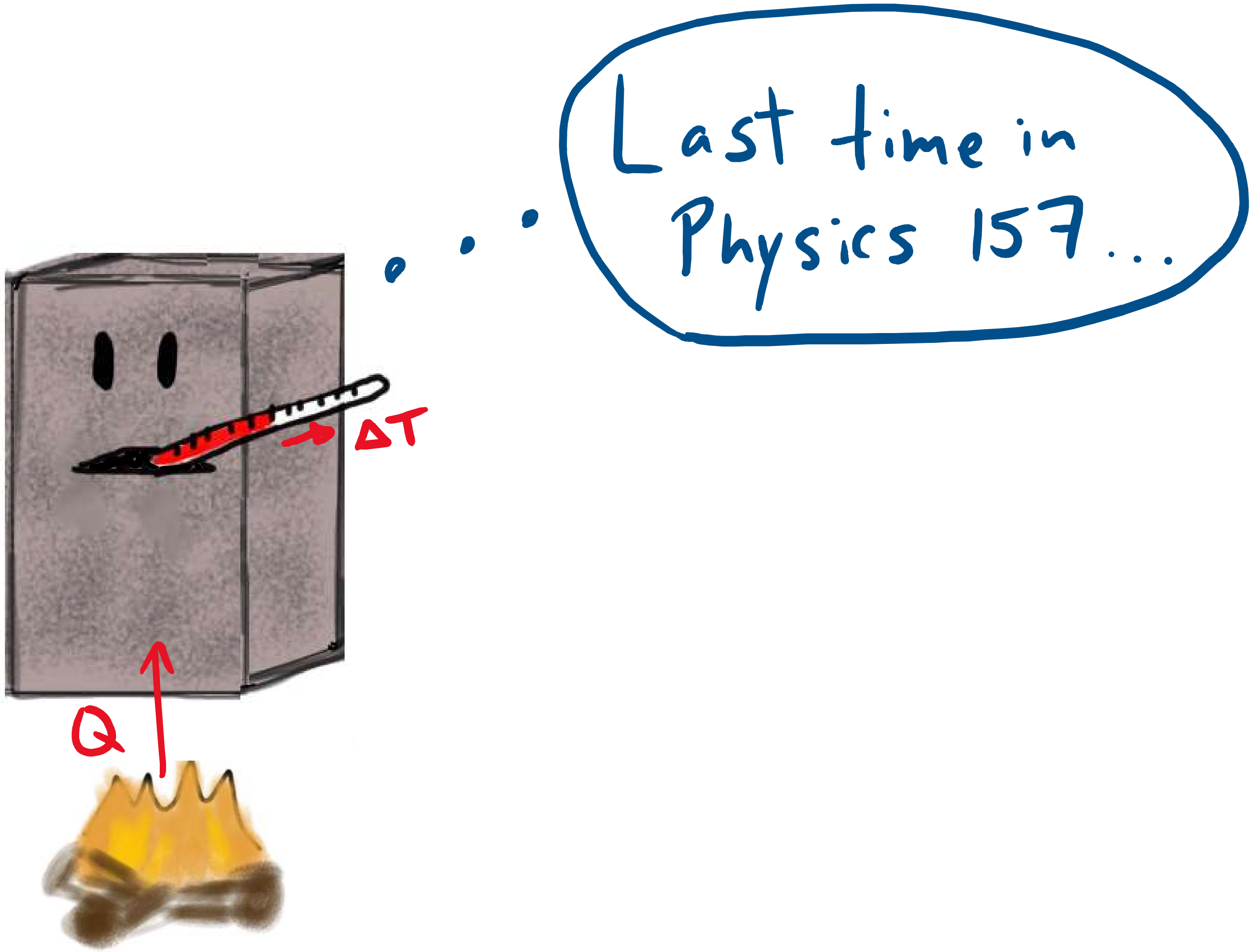
Homework sessions: 5-7pm Monday, Hennings 200
5-7pm Tuesday, Hennings 202

Food for thought:

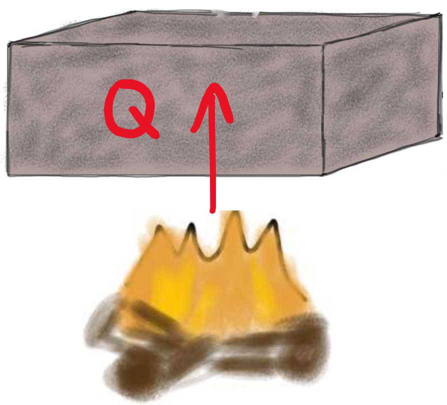


The final temperature will be

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:



heat added → Q, mass → m, specific heat → c

$$Q = mc\Delta T$$

OR:

$$Q = nC\Delta T$$

n ← # moles

C ← MOLAR SPECIFIC HEAT = MOLAR HEAT CAPACITY

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

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

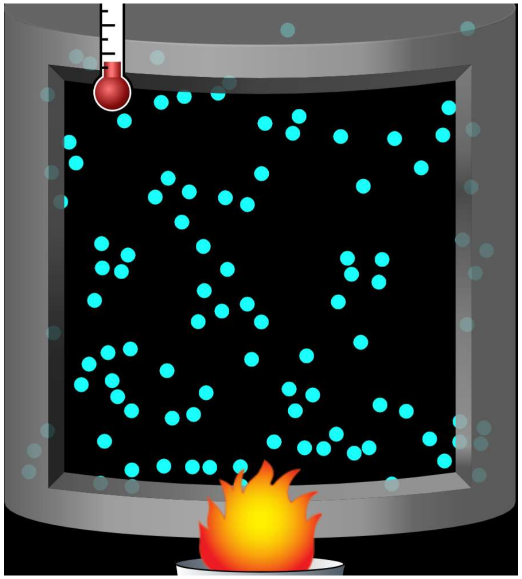
Specific heat values

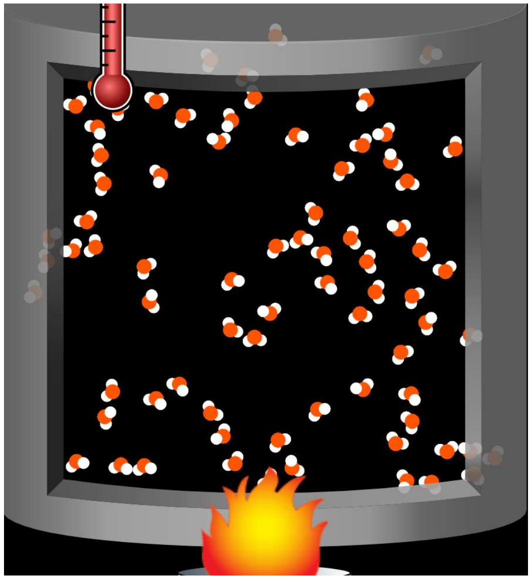
Table 17.3 Approximate Specific Heats and Molar Heat Capacities (Constant Pressure)

Substance	Specific Heat, c (J/kg · K)	Molar Mass, M (kg/mol)	Molar Heat Capacity, C (J/mol · K)
Aluminum	910	0.0270	24.6
Beryllium	1970	0.00901	17.7
Copper	390	0.0635	24.8
Ethanol	2428	0.0461	111.9
Ethylene glycol	2386	0.0620	148.0
Ice (near 0°C)	2100	0.0180	37.8
Iron	470	0.0559	26.3
Lead	130	0.207	26.9
Marble ($CaCO_3$)	879	0.100	87.9
Mercury	138	0.201	27.7
Salt (NaCl)	879	0.0585	51.4
Silver	234	0.108	25.3
Water (liquid)	4190	0.0180	75.4

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

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.

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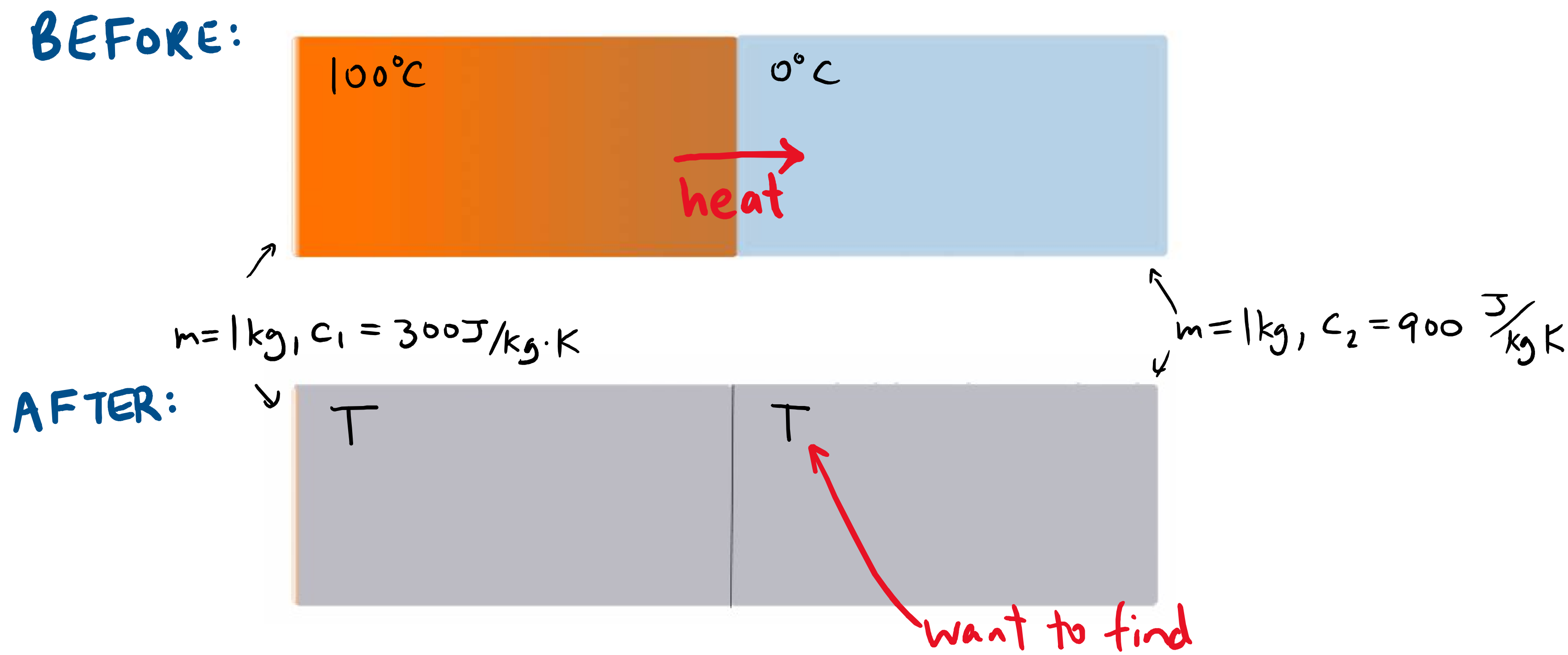
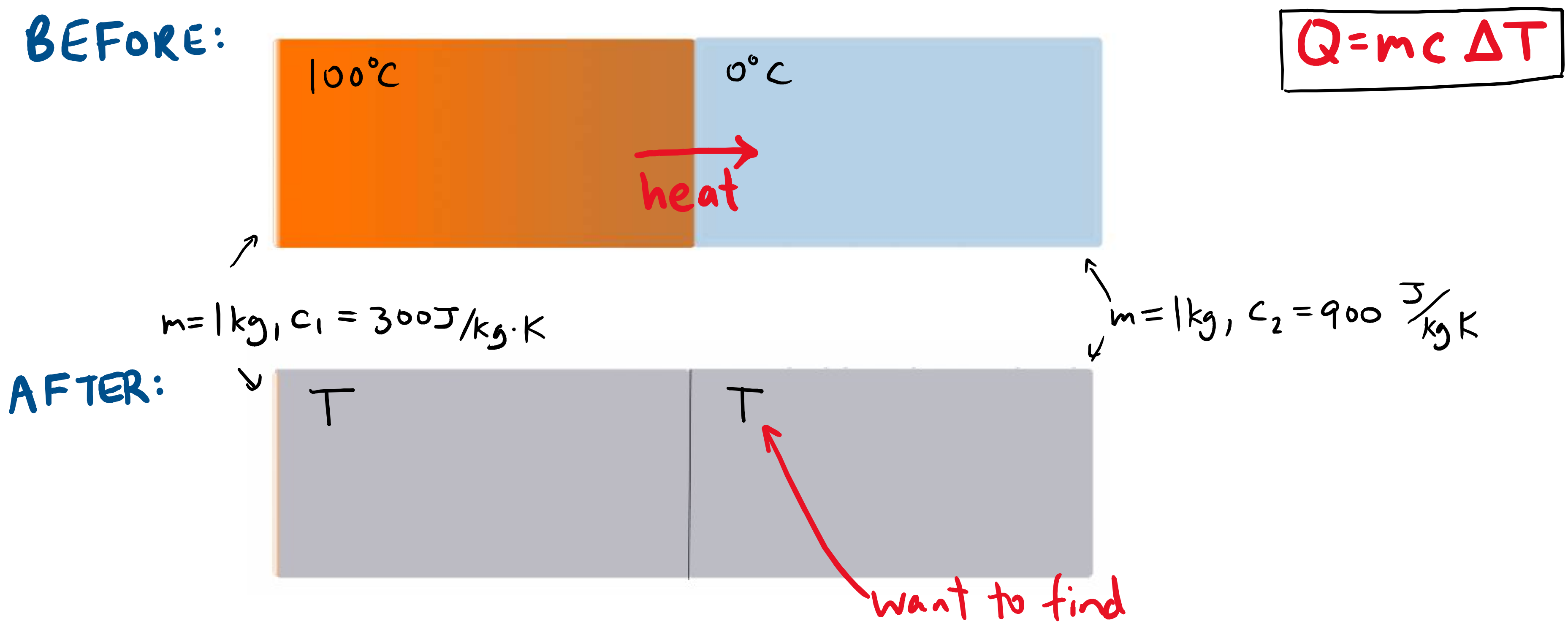
Step 1: Draw before/after pictures, labeled with known + unknown quantities

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



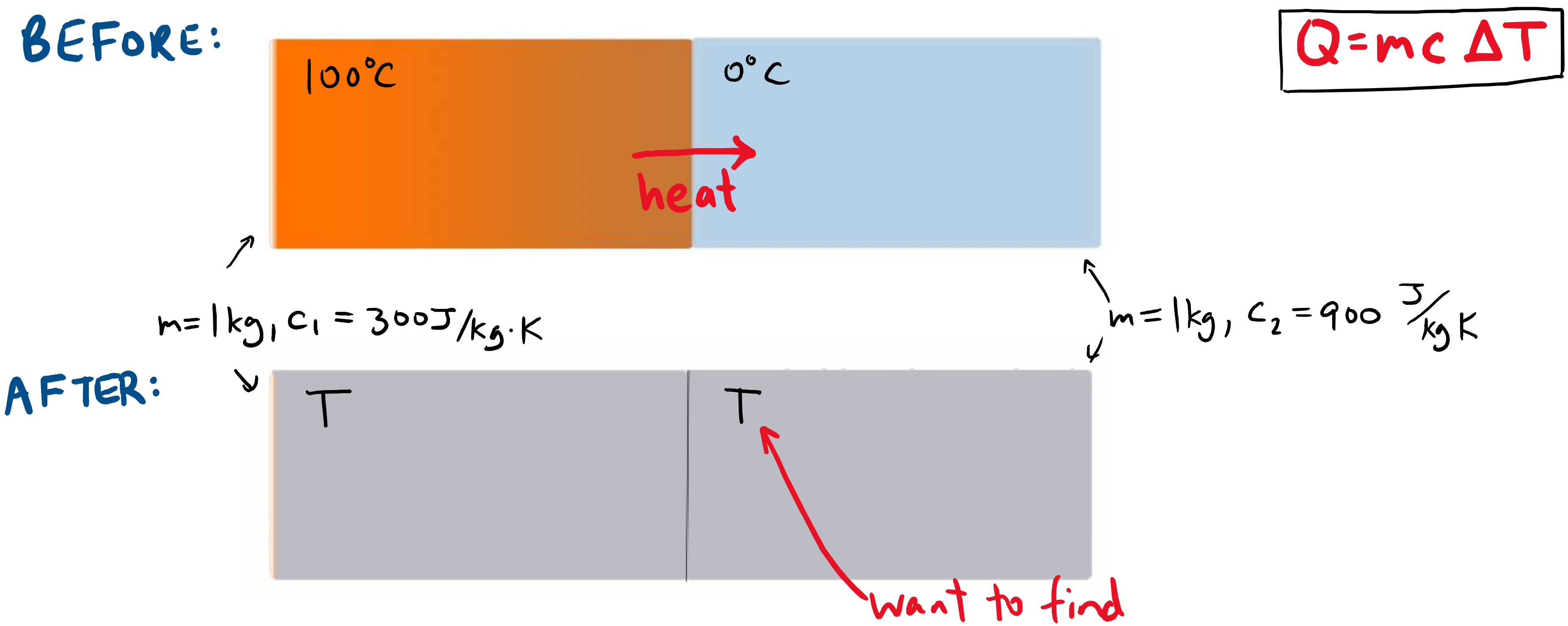
Next: for each part, determine how much heat was added



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

A) Q_1 = 300 J/K · T
B) Q_1 = 300 J/K · 100ºC
C) Q_1 = 300 J/K · (T - 100ºC)
D) Q_1 = 300 J/K · (100ºC - T)
E) Q_1 = 300 J/K · (T + 100ºC)

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) $Q_1 = 300\ J/K \cdot (T - 100°C)$

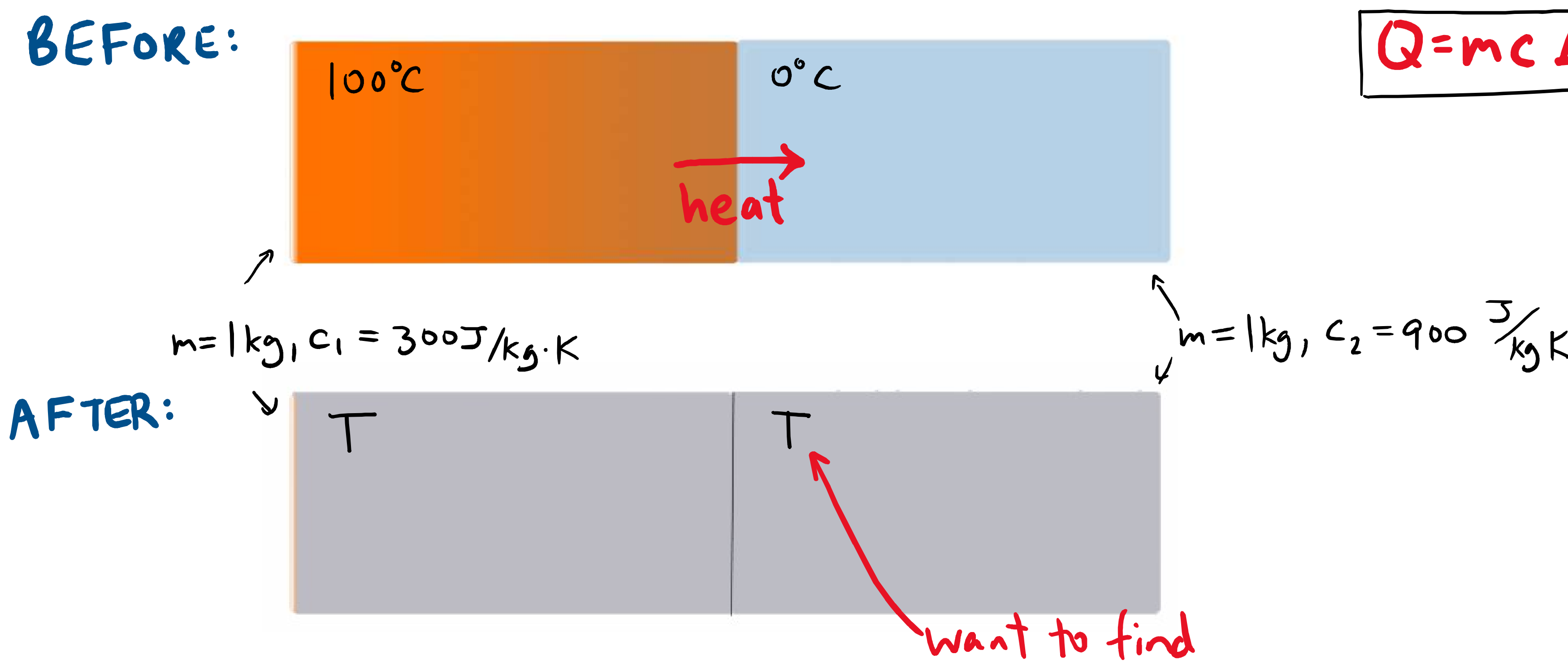
D) $Q_1 = 300\ J/K \cdot (100°C - T)$

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?

$Q = mc\,\Delta T$



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

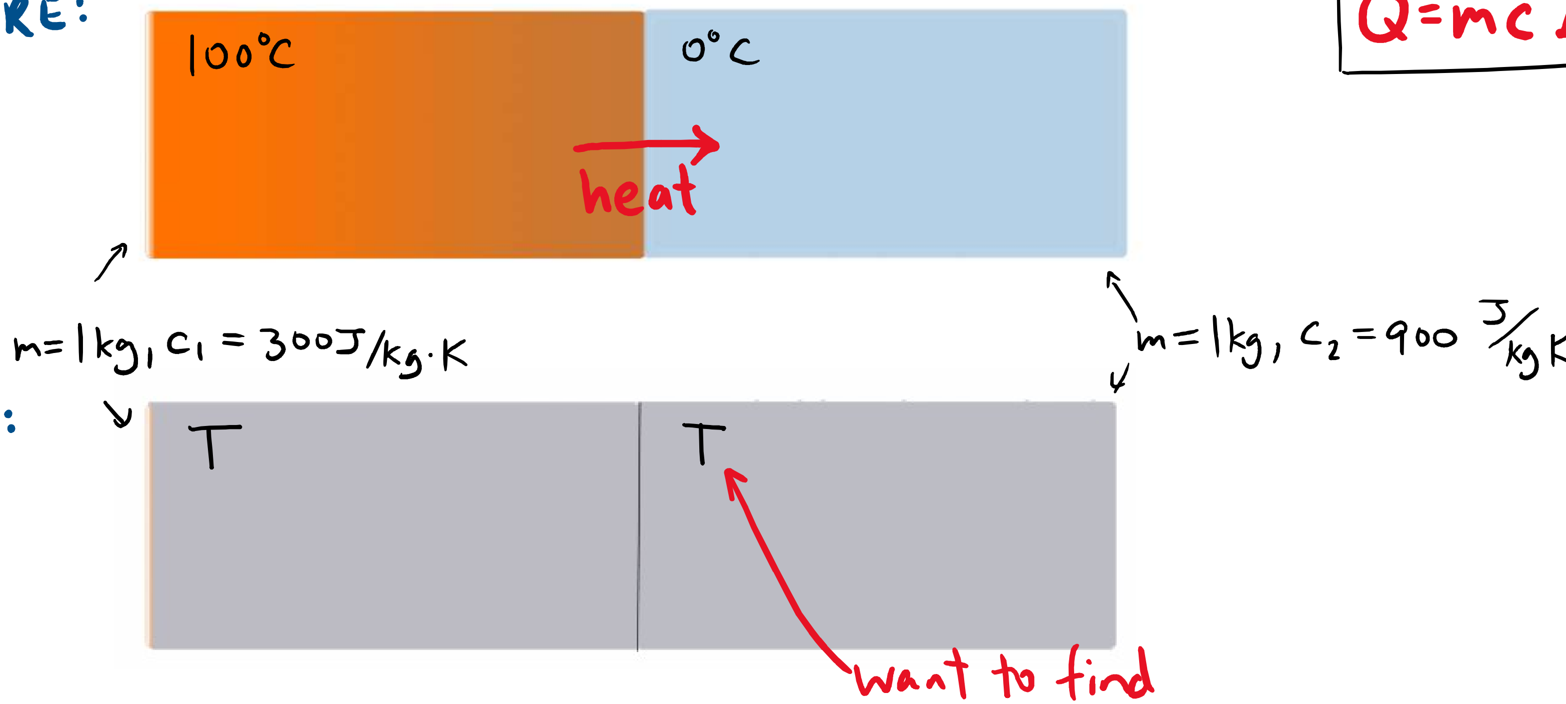
$Q_2 = 900\,J/K \cdot (T - 0°C)$

How are Q_1 and Q_2 related? Why?

$Q = mc\,\Delta T$

BEFORE:

AFTER:

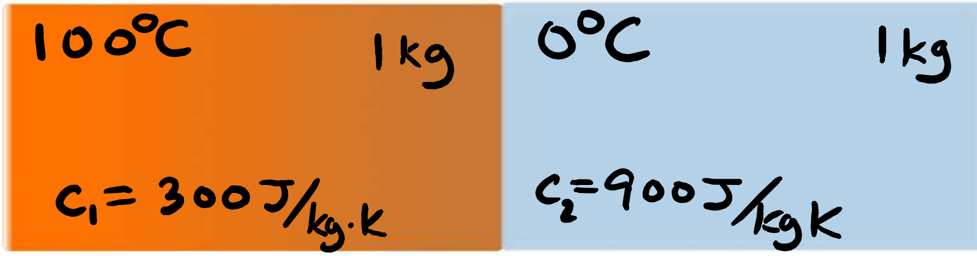


Have: $Q_1 = 300\,\mathrm{J/K} \cdot (T - 100°\mathrm{C})$

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

Energy conservation: $Q_1 + Q_2 = 0$

$1200\,\mathrm{J/K} \cdot T - 30000\,\mathrm{J} = 0 \Rightarrow T = 25°\mathrm{C}$



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

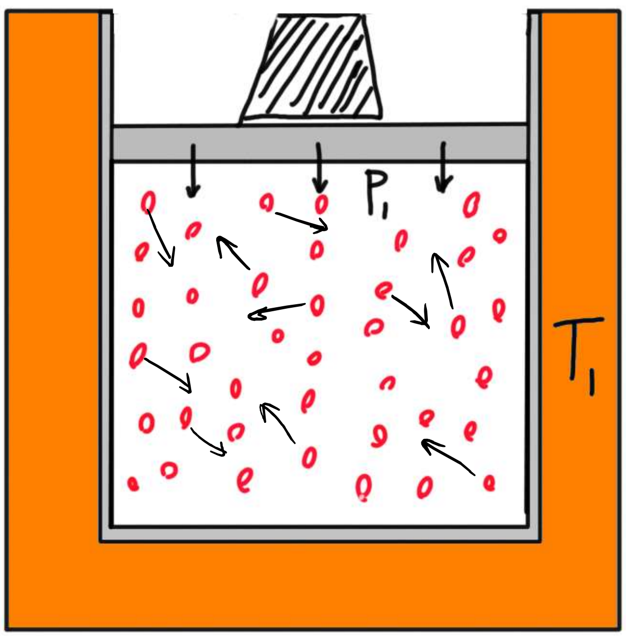
General answer: final temperature is:

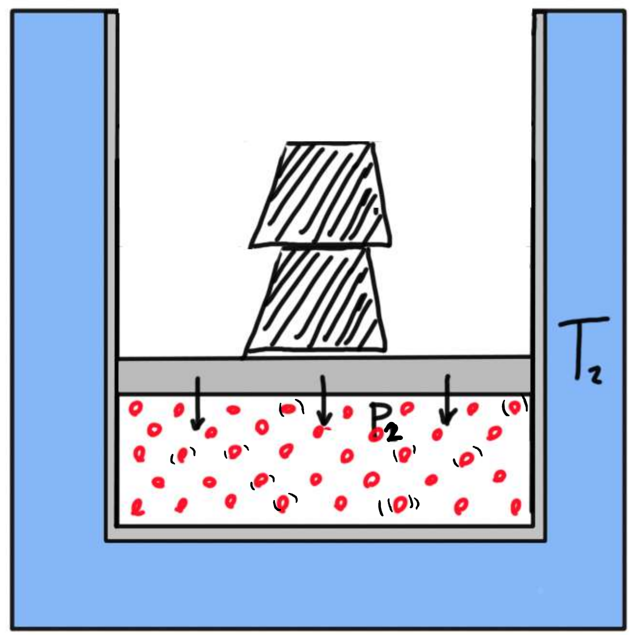
$$T = \left(\frac{m_1 c_1}{m_1 c_1 + m_2 c_2}\right) T_1 + \left(\frac{m_2 c_2}{m_1 c_1 + m_2 c_2}\right) T_2$$

weighted average of T_1 and T_2

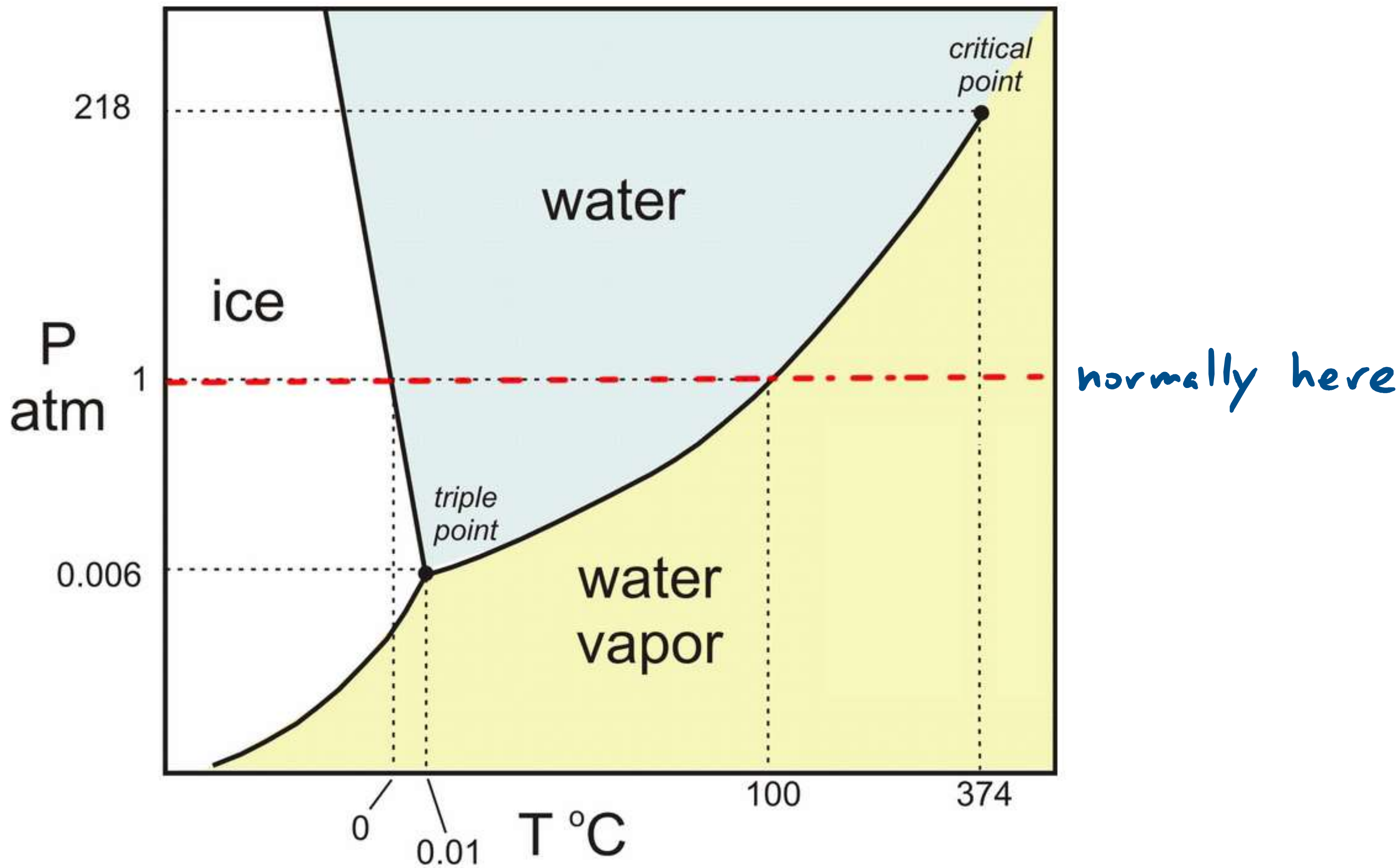
PHASES OF MATTER

- 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



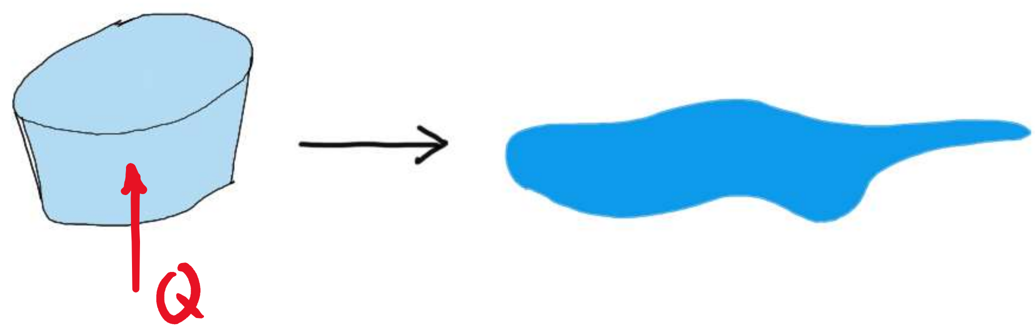


PHASE DIAGRAM: displays phases and phase transition curves as a function of T and P



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

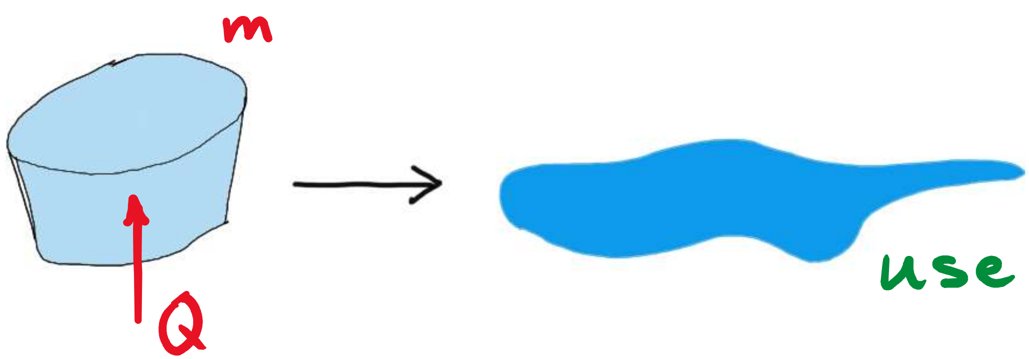
L_f: latent heat of fusion (freezing/melting)

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:

$$Q = mL$$

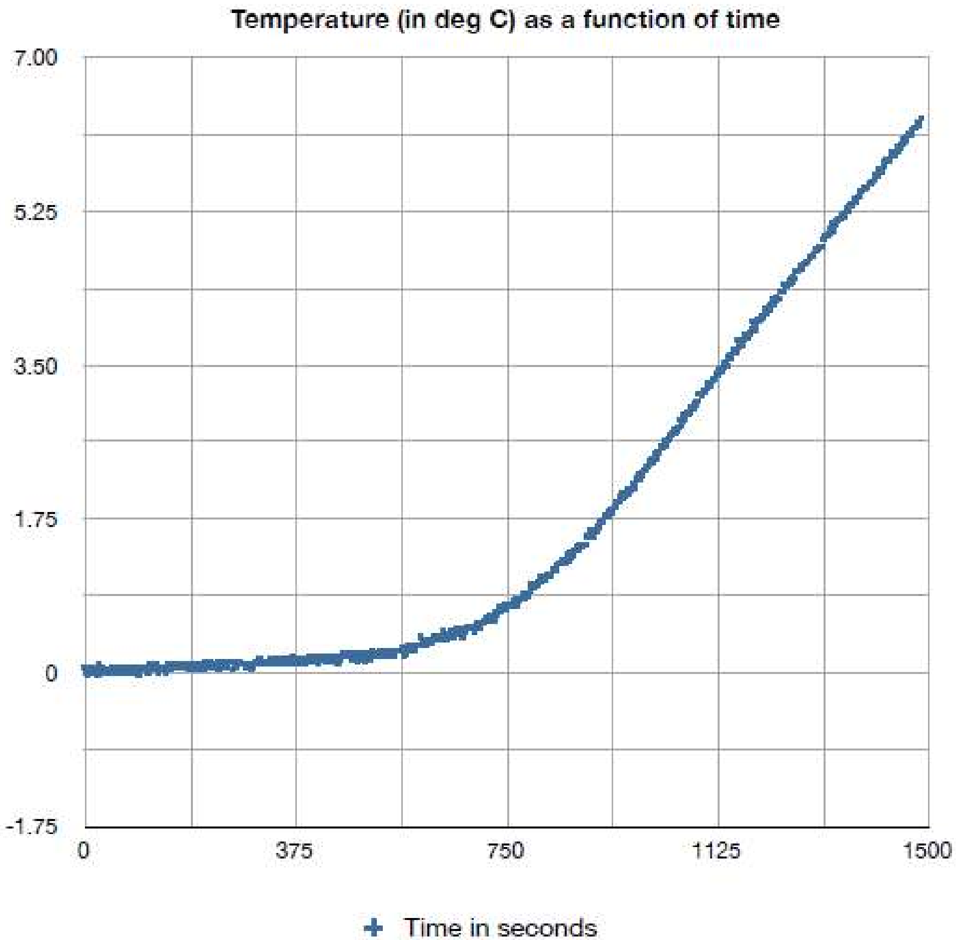
(m ← mass, L ← latent heat)



use L_f for melting / freezing

L_v for boiling / condensing

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

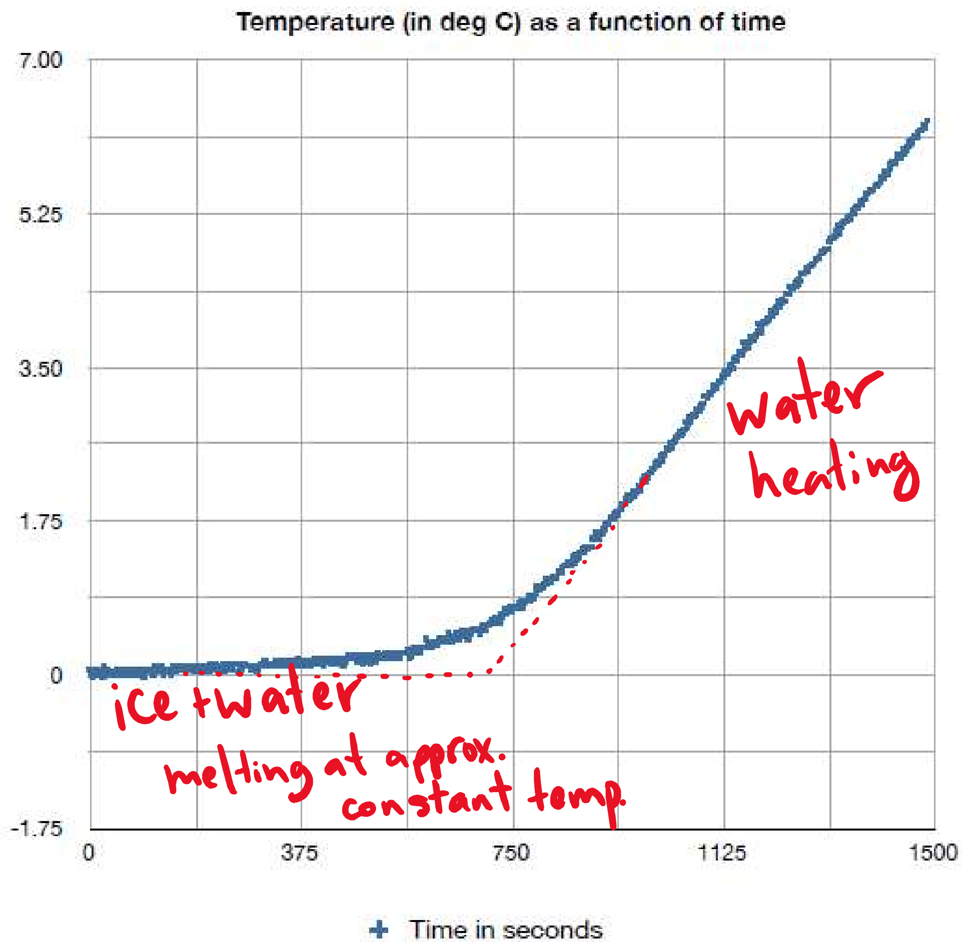


The graph shows the temperature vs time in an experiment where heat is supplied to ice water at a power of 240W.

(1 Watt = 1 Joule / second).

Why does the graph look like this?

NEXT: How much ice was present initially?

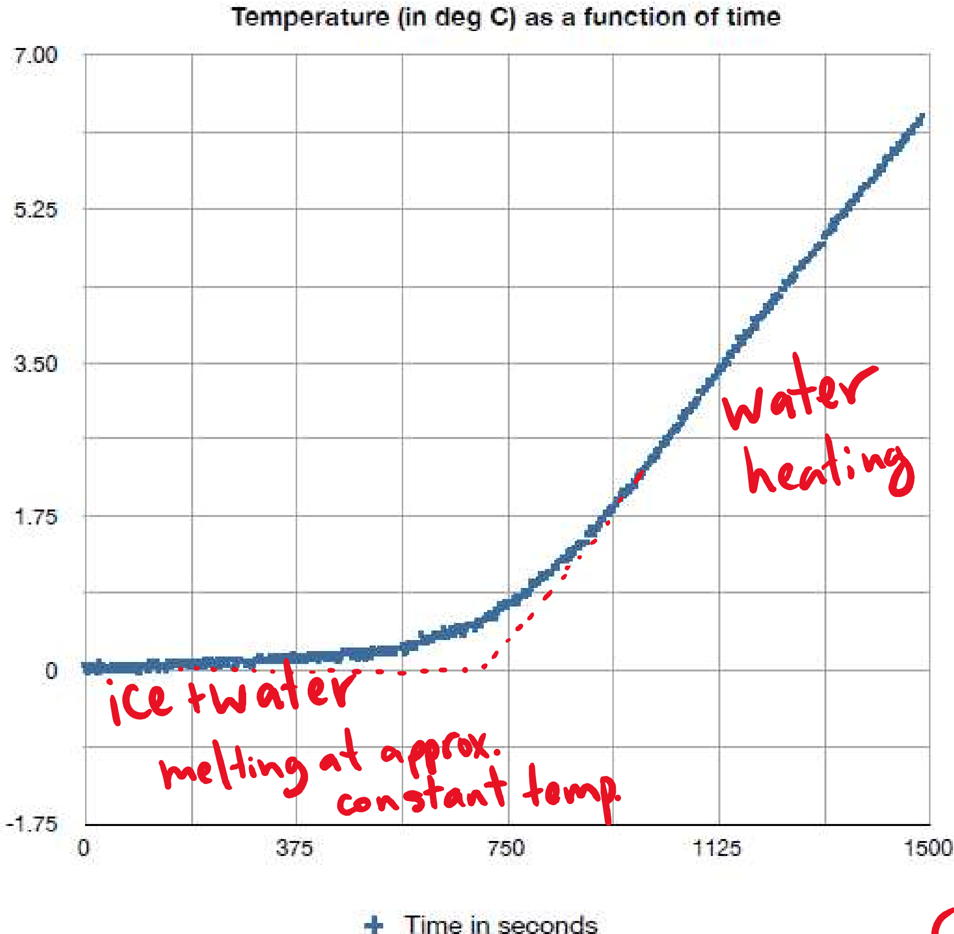


The graph shows the temperature vs time in an experiment where heat is supplied to ice water at a power of 240W.
(1 Watt = 1 Joule / second).

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?



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

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

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

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

$L = 334{,}000\ \text{J/kg}$

$m = \frac{Q}{L} \approx 0.5\ \text{kg}$

EXTRA: why is the graph curved?

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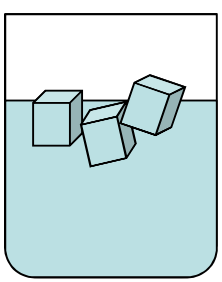
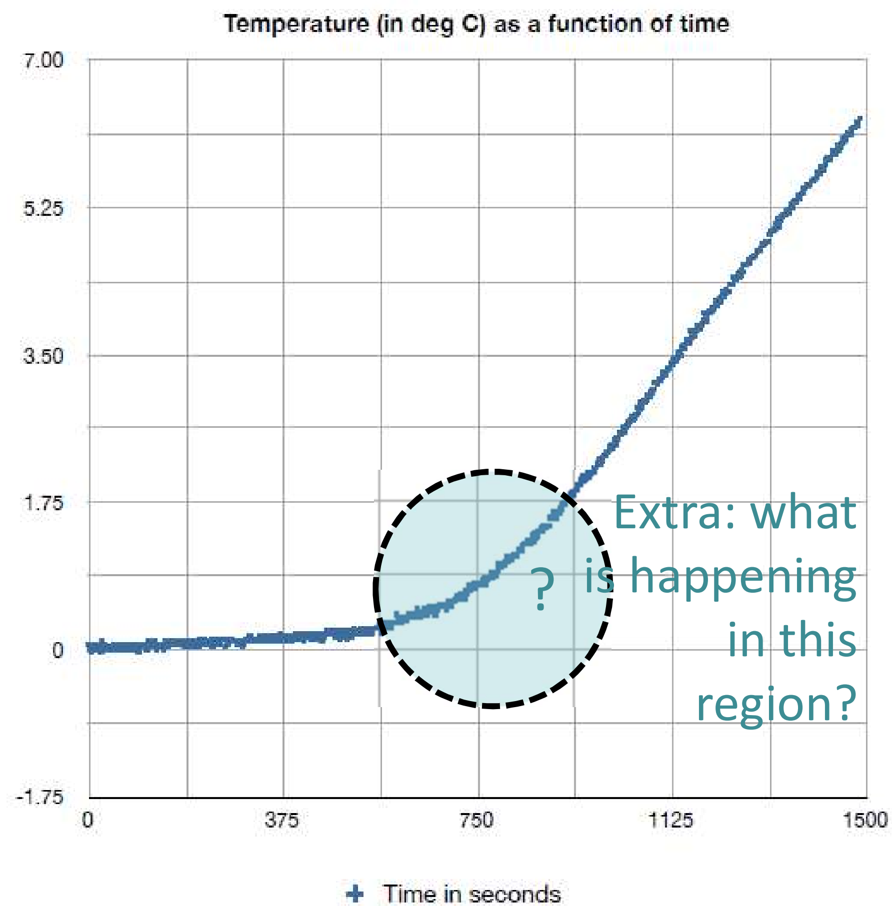
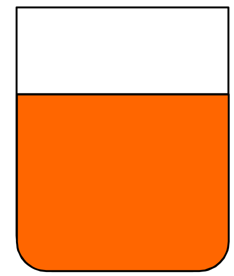
ice/water
0˚C

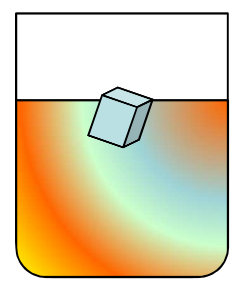




all liquid water,
well mixed



poor mixing as ice melts, non-uniform temperature



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