Announcements

1. Exam 4 not that far away…
   a. Starts 1 week from today!
   b. We'll have another evening TA review Thurs 7-9pm C215 ESC
2. "Boltzmann 3D" computer demo
3. Answer range error for HW 18-2 should be 0.1 - 0.3 mm (not 1-3 mm)
4. Extra credit papers are due the last day of class (midnight)
5. Dr Colton choir concert (Utah Baroque Ensemble) this Sunday, 7:30PM LDS church at 800E 600N, Orem. (sorry, no extra credit…)

From last time…

Worked Problem: In an engine piston, with air at 1 atm, the volume is decreased from 200 cm^3 to 40 cm^3, while the temperature increases from 300 K to 600 K. Find the final pressure.

Method 1: Find N (or n)

$$P_1 V_1 = n R T_1$$

$$n = \frac{P_1 V_1}{R T_1} = \frac{(1.01\cdot 10^5)(200 (\frac{1}{100})^3)}{8.31 (300)}$$

$$= \_\_\_\_\_\_$$

$$P_2 V_2 = n R T_2$$

$$P_2 (40 (\tfrac{1}{100})^3) = n (8.31)(600)$$

$$P_2 = 1.01\cdot 10^6 \text{ Pa}$$

Method 2: ratios

nR = constant

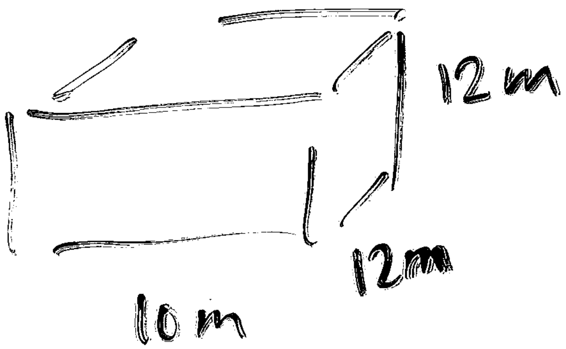
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(1 \text{ atm})(200 \text{ cm}^3)}{300 \text{ K}} = \frac{P_2 (40 \text{ cm}^3)}{600 \text{ K}}$$

$$P_2 = 10 \text{ atm}$$

Answer: 1.01×10^6 Pa, i.e. 10 atm

Worked Problem: What is the mass of all the air in this room? (Molar mass of nitrogen/oxygen combo ≈ 29.0 g)



$T = 300K$

$$PV = nRT$$

$$(1.01 \cdot 10^5)(10 \cdot 12 \cdot 12) = n(8.31)(300)$$

$$n = 58000 \text{ moles}$$

$$58000 \text{ moles} \times \frac{.029 \text{ kg}}{\text{mole}} = \boxed{1682 \text{ kg}}$$

Specific heat

How much does T rise when heat energy is added?

- temperature rise is proportional to heat added
- the more mass… the less the temperature rises
- material dependent

$$Q = mc\Delta T$$

c = "specific heat"
closely related to "heat capacity"

mc sometimes called "thermal mass"

Clicker quiz: If you add 5 J of heat to a mass of water, and 5 J of heat to the same mass of steel, which one increases the most in temperature?

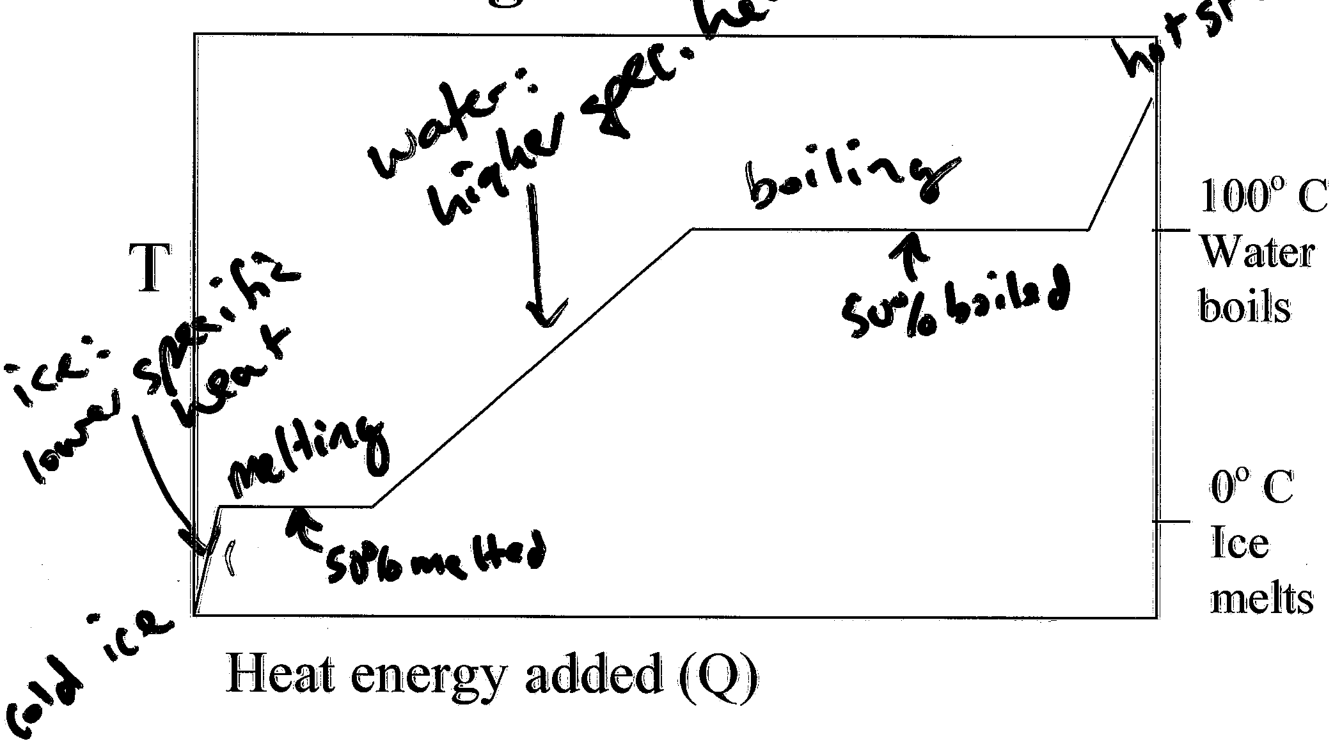
a. Water
b. Steel (iron)
c. Same

TABLE 11.1

Specific Heats of Some Materials at Atmospheric Pressure

Substance	J/kg · °C	cal/g · °C
Aluminum	900	0.215
Beryllium	1 820	0.436
Cadmium	230	0.055
Copper	387	0.0924
Germanium	322	0.077
Glass	837	0.200
Gold	129	0.0308
Ice	2 090	0.500
Iron	448	0.107
Lead	128	0.0305
Mercury	138	0.033
Silicon	703	0.168
Silver	234	0.056
Steam	2 010	0.480
Water	4 186	1.00

Phase Changes



During phase change, no T increase

→ but heat still needed to complete the phase change

→ both phases co-exist

$$\boxed{Q = mL}$$

L depends on

- Material
- Type of phase change (i.e. solid-liquid, liquid-gas, or other)

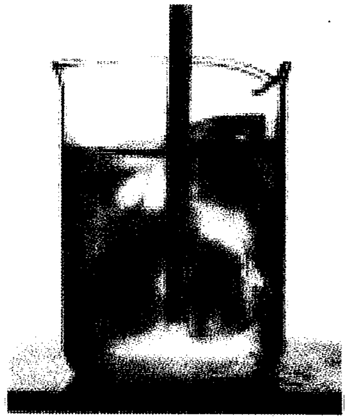
<u>Water:</u>

$L_{melting/freezing} = 3.33 \times 10^5$ J/kg

$L_{boiling/condensing} = 2.26 \times 10^6$ J/kg

Clicker quiz: If you want to melt ice at -40° C, which part takes the most energy?

a. Raising the temperature
b. Converting from solid to liquid phase
c. Same



$Q = mc\Delta T$

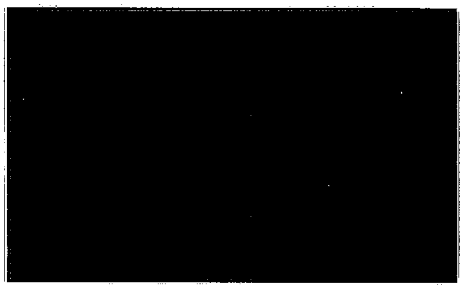
$= m(2090)(40)$

$= 80000\,m$

$Q = mL$

$= m(333{,}000)$

hot colder



Calorimetry

Conservation of energy:

$Q_{\text{gained by cold objects}} = Q_{\text{lost by hot objects}}$ (assuming no heat flow to outside)

New blueprint eqn

→ On both sides of equation use only *positive* quantities

→ May need to include melting and boiling: *mL* terms

Worked Problem: (a) 5 g of hot iron at 300° C is added to 100 g of water at 30° C. What is the final temperature? (b) Repeat, but with 500 g iron

Set up for both: $Q_{gained\ by\ water} = Q_{lost\ by\ iron}$

(a)

$$(mc\Delta T)_{water} = (mc\Delta T)_{iron}$$

$$(.1)(4186)(T_f - 30) = (.005)(448)(300 - T_f)$$

$$(.1)(4186)T_f - (.1)(4186)(30) = (.005)(448)(300) - (.005)(448)T_f$$

$$\boxed{T_f = 31.4°C}$$

(b)

$$(mc\Delta T)_{water} = (mc\Delta T)_{iron}$$

$$(.1)(4186)(T_f - 30) = (.5)(448)(300 - T_f)$$

$$T_f \simeq \underline{115°C} \quad ??$$

$$(mc\Delta T)_{water} + (mL)_{water\ boiling} = (mc\Delta T)_{iron}$$

$$(.1)(4186)(T_f - 30) + (.1)(2.26 \cdot 10^6) = (.5)(448)(300 - T_f)$$

$$T_f = \underline{-395°C} \quad ??$$

Answers: 31.44° C; -395.3° C (not real answer), 100° C

$\boxed{\text{At } 100°C}$

Worked Problem: 500 g iron at 300° C added to 100 g of water at 30° C. How much water boils away?

$Q_{\text{gained by water}} = Q_{\text{lost by iron}}$

$$(m_{tot} c \Delta T)_{water} + (mL)_{water} = (mc\Delta T)_{iron}$$

$$(.1)(4186)(100-30) + m(2.26\cdot 10^{6}) = (.5)(448)(300-100)$$

Solve for m

$$m = .00686 \text{ kg}$$

Answer: 6.86 g

Clicker quiz: A metal sphere is heated to 3000 K, and puts out 1000 W of radiation energy. If it is cooled to 1500 K, it will put out ______ W of radiation energy.

A. 160 B. 250 C. 500 D. 750 (E.) [redacted] None of the above

Hint: use ratios

$$\frac{P_2}{P_1} = \frac{\epsilon \sigma A T_2^4}{\epsilon \sigma A T_1^4} = \left(\frac{1500}{3000}\right)^4$$

$$= \left(\frac{1}{2}\right)^4$$

$$P_2 = \left(\frac{1}{16}\right)(1000\ \text{W})$$

Clicker quiz: You put the end of a rod in a fire and the other end in a tub of water. The rod that would heat the water fastest will be:

a. short and fat
b. long and fat
c. short and thin
d. long and thin

Why do things at **room temperature** feel cold or warm?

Recall: why could I pick up the liquid nitrogen marshmallow?

Worked Problem: Your house costs 200 cents/day to heat when you keep the temperature at 20° C and the average outside temperature is -10° C. How much will you save if you turn down the heat to 15° C?

R-value of house insulation:

R = L/k (written in British units)

$$\frac{\text{length}}{\text{conductivity}} = \text{how well it insulates}$$