Calorimetry

1. (p.40) 100 J of heat energy are transferred to 20 g of mercury initially at 20 C.
   a. By how much does the temperature increase?
   b. How much heat is needed to raise the temperature of 20 g of water by the same amount?

2. 200 g of hot water at 100 C is mixed with 150 g of cold water at 0 C. Find the equilibrium temperature, assuming the system is isolated.

3. 200 g of hot water at 100 C is mixed with 150 g of ice at -15 C. Find the equilibrium temperature, assuming the system is isolated.

4. (p.49) A 750 g aluminum pan is removed from the stove and plunged into a sink filled with 10.0 kg of water at 20.0 C. The water temperature quickly rises to 24.0 C. What was the initial temperature of the pan?

12 - 40 $Q = {}^{+}100\ J$

$0.020\ kg$ of Hg

a. $T_0 = 20°C$

$$Q = mc\Delta T$$

$$\Delta T = \frac{100\ J}{(0.020\ kg)(140\ J/kg\ K)}$$

$$\Delta T = 35.7\ K = 36\ K$$

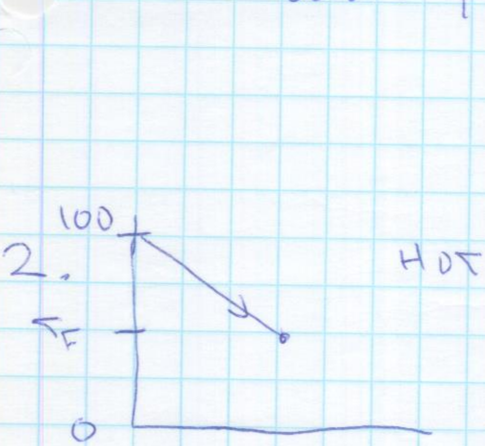
b. $Q = mc\Delta T$

$$Q = (0.020\ kg)(4190\ J/kg\ K)(35.7\ K)$$

$$Q = 2990\ J$$

So water takes significantly more, since c is so large.

2.



$$Q_{Hot} + Q_{cold} = 0$$

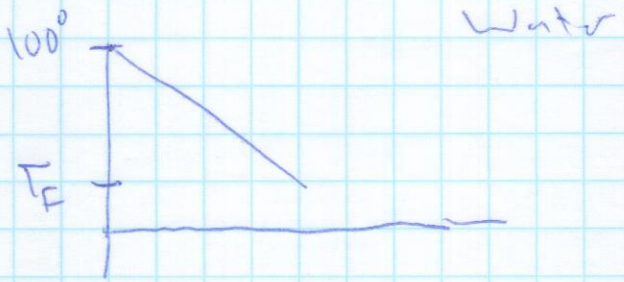
$$\underbrace{mc\Delta T}_{Hot} + \underbrace{mc\Delta T}_{cold} = 0$$

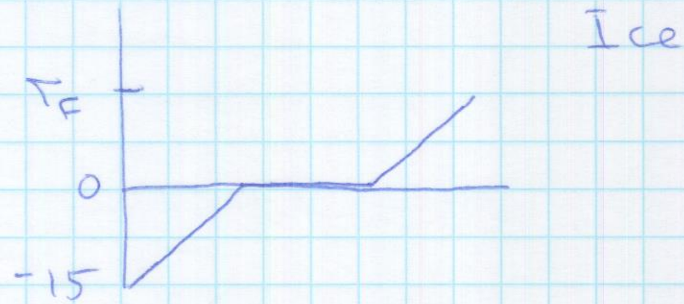
$$(0.20\ kg)(4190\ \tfrac{J}{kg\ K})(T_F - 100C) + (0.150)(4190)(T_F - 0) = 0$$

$$0.20\,T_F - 20 + 0.15\,T_F = 0$$

$$T_F = 57°\ C$$

3.





$$\underbrace{mc\Delta T}_{\text{Hot water cools to } T_F} + \underbrace{mc\Delta T}_{\text{Bring ice to } 0^\circ} + \underbrace{mL_f}_{\text{melt ice}} + \underbrace{mc\Delta T}_{\text{warm ice-water to } T_F} = 0$$

$$(0.20)(4190)(T_F - 100) + (0.15)(2090)(0 - {}^-15)$$

$$+ (0.15)(3.33 \times 10^5) + (0.15)(4190)(T_F - 0^\circ) = 0$$

$$838 T_F - 83800 + 4702.5 + 49950 + 628.5 T_F = 0$$

$$1466.5 T_F = 29147.5$$

$$T_F = 20^\circ C$$

12 - 49 $\quad Al: 0.750\ kg$ at T_0

$H_2O: 10.0\ kg$ at $20°C = 293\ K$

$H_2O: T_F = 24°C = 297\ K$

$Q_{Al} + Q_{H_2O} = 0 \qquad$ so $T_{F\,Al} = 297\ K$

$\underbrace{mc\Delta T}_{Al} + \underbrace{mc\Delta T}_{H_2O} = 0$

$\underset{kg}{(0.75)}\underset{J/kg\,K}{(900\ )}(\underset{K}{297} - \underset{K}{T_0}) + \underset{kg}{(10)}\underset{J/kg\,K}{(4190)}\underset{K}{(297 - 293)} = 0$

$200475 - 675T_0 + 167600 = 0$

$T_0 = 545\ K = 272°C$

Calorimetry group problems

For all problems, include Temperature vs. Q graphs for each material involved. Show relevant temperatures on your temperature axis.

1. Find the equilibrium temperature when 200 g of hot water at 100 C is mixed with 150 g of ice at 0 C.

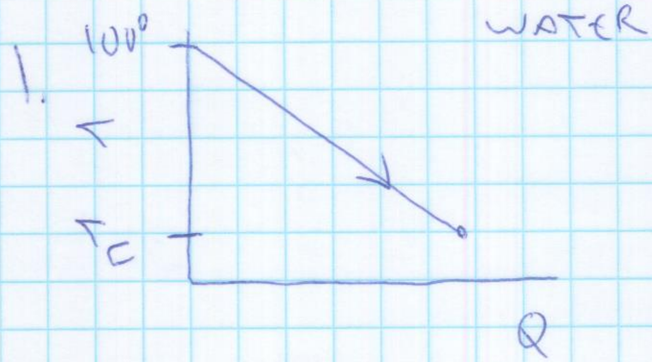
2. You have been given a cube of silvery metal with a mass of 75 g and have been asked to identify the material. You decide to do so by finding its specific heat capacity. You heat the cube to 350 K and drop it into an insulated container holding 250 g of water at 295 K. You find that the water comes to a final temperature of 296.73 K. Which element do you conclude your cube is?

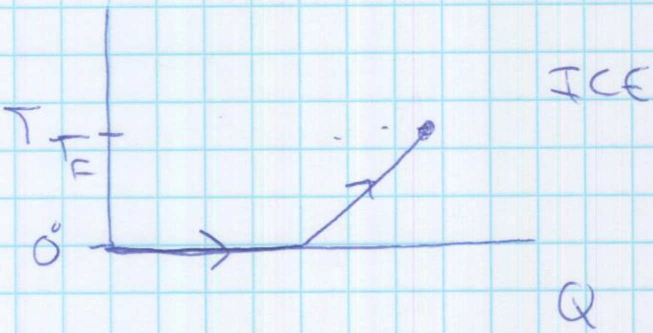
Element	c (J/kg K)
Magnesium	1017
Aluminum	900
Titanium	523
Iron	452
Silver	239
Lead	130

3. Find the equilibrium temperature when 100 g of steam at 100 C is mixed with 300 g of ice at -15 C. The system is thermally insulated.

4. A 0.35 kg coffee mug is made from a material that has a specific heat capacity of 920 J/kg K and contains 0.25 kg of water. The cup and water are at 15 C. To make a cup of coffee, you place the cup of water on a hot plate until you see that the water has reached its boiling point. Assume that the cup and water are brought to the same final temperature.
    a. How much heat energy was needed to bring both cup and water to this temperature?
    b. If it took 3 minutes to bring the water to this point, what power did the hot plate supply?

1.





$$Q_{net} = 0$$

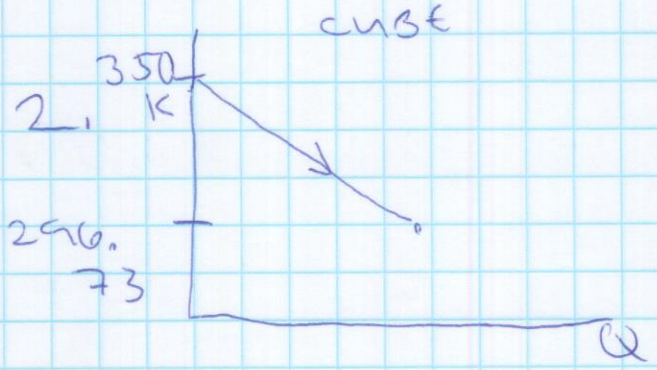
$$\underbrace{mc\Delta T}_{\text{Bring Hot to } T_F} + \underbrace{mL_f}_{\text{melt ice}} + \underbrace{mc\Delta T}_{\text{Bring ice-water to } T_F} = 0$$

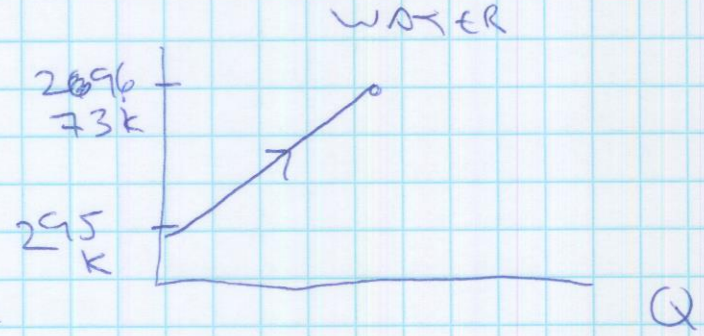
$$(0.20)(4190)(T_F - 100) + 0.15(3.33\times 10^5) + (0.15)(4190)(T_F - 0) = 0$$

$$838\,T_F - 83800 + 49950 + 628.5\,T_F = 0$$

$$T_F = 23^\circ C$$

2.





$Q_{net} = 0$

$mc\Delta T_{cube} + mc\Delta T_{water} = 0$

$(0.075\text{ kg})\,c\,(296.73 - 350)\text{ K} + (0.250\text{ kg})(4190\ \frac{J}{kg\,K})(296.73 - 295\text{ K})$

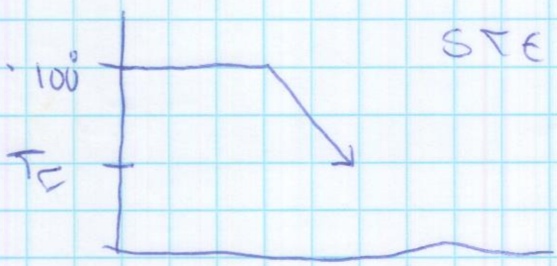
$3.995\,c = 1810.4$

$c = 453\ J/kg\,K$

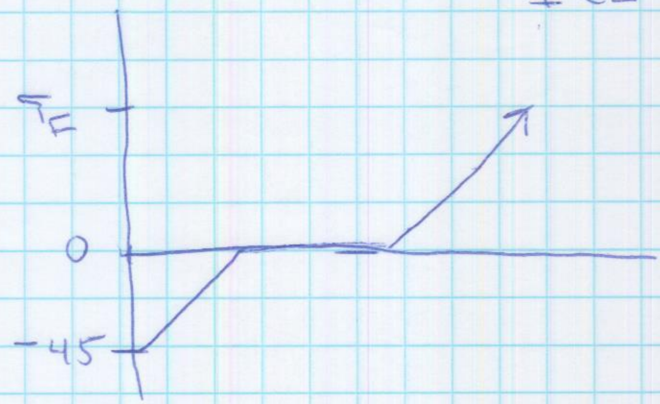
IRON

3

STEAM



ICE



$\underbrace{mL_v}_{\text{CONDENSE STEAM}} + \underbrace{mc\Delta T}_{\text{BRING STEAM-WATER TO } T_F} + \underbrace{mc\Delta T}_{\text{WARM ICE TO } 0°} + \underbrace{mL_f}_{\text{MELT ICE}} + \underbrace{mc\Delta T}_{\text{WARM ICE WAT. TO } T_F}$

$= 0$

$(0.1)(-22.6\times10^5) + (0.1)(4190)(T_F - 100) +$

$(0.3)(2090)(0 - {-15}) + (0.3)(3.33\times10^5) +$

$(0.3)(4190)(T_F - 0)$

$= 0$

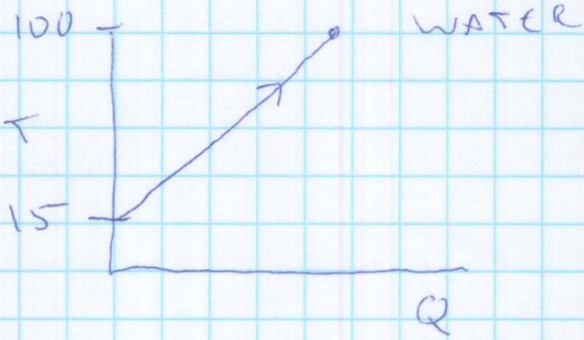
$-22.6\times10^4 + 419T_F - 41900 + 9405 +$

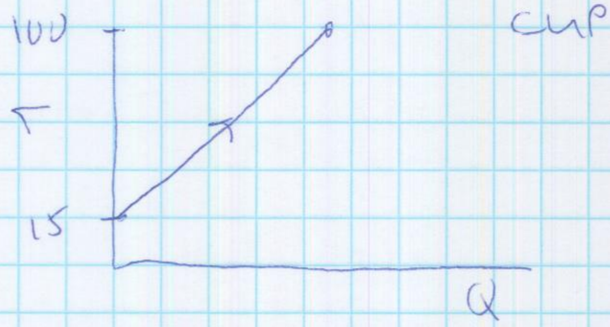
$9.99\times10^4 + 1257\,T_F = 0$

$1676\,T_F = 158595$

$T_F = 95°C$

4,





Q needed is $\underbrace{mc\Delta T}_{\text{WATER}} + \underbrace{mc\Delta T}_{\text{CUP}}$

$Q = (0.25)(4190)(100-15) + (0.35)(920)(100-15)$

$Q = 1.164 \times 10^5 \text{ J}$

This Q is delivered in 3 minutes

$P = \frac{E}{\Delta t} = \frac{Q}{\Delta t}$ Q is just energy. Heat energy.

$P = \frac{1.164 \times 10^5 \text{ J}}{180 \text{ s}}$

$P = 650 \text{ W}$