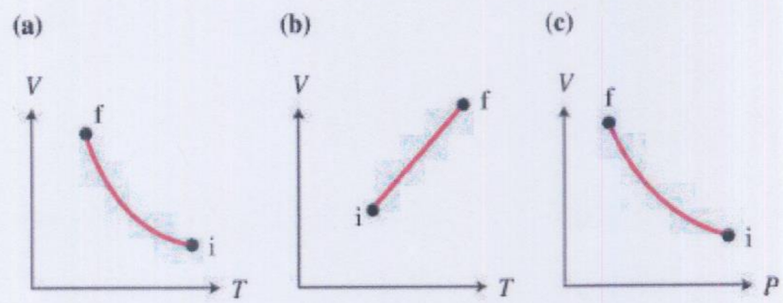
Review Problems Unit 4

1. When a solid melts at constant pressure, the volume of the resulting liquid does not differ much from the volume of the solid. Is the internal energy of the liquid greater, less than, or equal to the internal energy of the solid? Justify your answer with the first law of thermodynamics.

2. Make a schematic diagram of (A) a heat engine; (B) a heat pump; and (C) a refrigerator.
    a. For each, write an equation that shows the relationship between Q_H, Q_C, and W.
    b. Write the ratio of "what you get"/"what you paid" and the name of this quantity.

3. You have two cubes, each the same mass but two different materials. A has a larger specific heat than B. They are placed in contact with each other and well insulated from the outside world. If A is initially at 200 ^{0}C and B is initially at 0 ^{0}C, is the final temperature greater than, less than, or equal to 100 ^{0}C? Explain your reasoning.

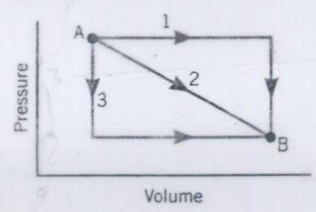
4. An ideal gas is in a sealed container with a heavy top that is free to move. Under constant pressure, the volume of the gas increases, causing the top to move up. Which of the graphs below could represent this process? Do not assume that only one is correct: assess each individually. Note that these are not PV graphs.



5. What is efficiency? Explain this concept in words. What is a typical human efficiency?

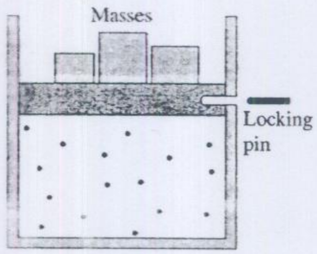
6. You have a certain quantity of mercury gas at 500 ^{0}C. You intend to cool the gas down until the entire quantity is in the state of a solid, at mercury's melting point. Draw a Temperature vs. Q graph for the changes which the mercury experiences. Label the temperature axis appropriately.

7. The PV graph below shows three paths in which a gas expands from an initial state A to a final state B. The change in thermal energy is the same for each path. Rank the paths according to the heat added to the gas, from largest to smallest.



8. The picture below shows a cylinder of an ideal gas with a moveable lid. You are able to

Lock the piston in place with a pin, or leave the piston free to move.
Add or remove masses from the top of the piston.
Place the entire cylinder in a hot bath or a cold bath.

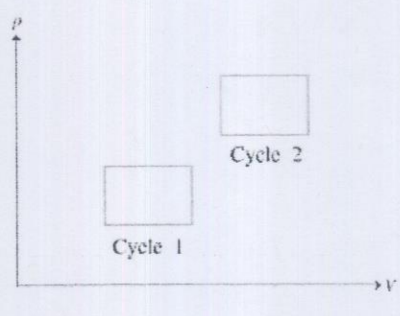


Describe what you would do to
a. decrease the pressure without changing the volume.
b. decrease the volume without changing the temperature.
c. cause the gas to do positive work in an adiabatic process.
d. cause the gas to do negative work in an isobaric process.

9. In the summer, you run two refrigerators: one in your kitchen, which is at room temperature, and one in your garage, where it gets quite warm in the summer. Which uses less electrical energy to run? Explain.

10. Explain how you could use calorimetry to identify an unknown liquid. Describe the process you would use.

11. The PV diagram shows two processes in which the same ideal gas sample is taken through a four-step process. Both processes run clockwise starting at the upper left corner.



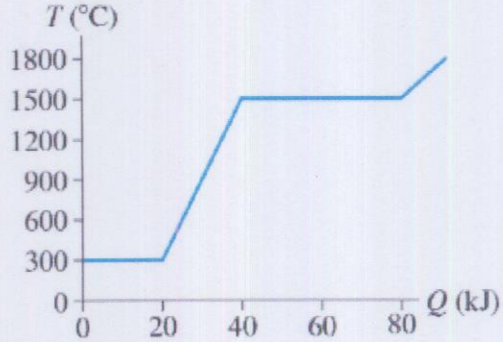
a. what is the total change in thermal energy over cycle 1?
b. is the net work done by the gas in cycle 1 positive, negative, or zero?
c. is the heat involved in cycle 2 positive, negative, or zero?
d. is the magnitude of the work done in cycle 1 greater, less, or equal to the magnitude of the work done in cycle 2?
e. which of your answers would be different if each cycle ran clockwise starting at its lower right corner? Explain.

12. A heat engine does 18500 J of work and rejects 6550 J of heat into a cold reservoir whose temperature is 12°C.

a. Make a schematic of this engine. Include all known values with their appropriate labels.

b. Calculate the smallest possible temperature of the hot reservoir.

13. An experiment measures the temperature of a 200 g substance while steadily supplying heat to it. The figure shows the results of the experiment. What are (a) the specific heat of the liquid phase and (b) the heat of vaporization?



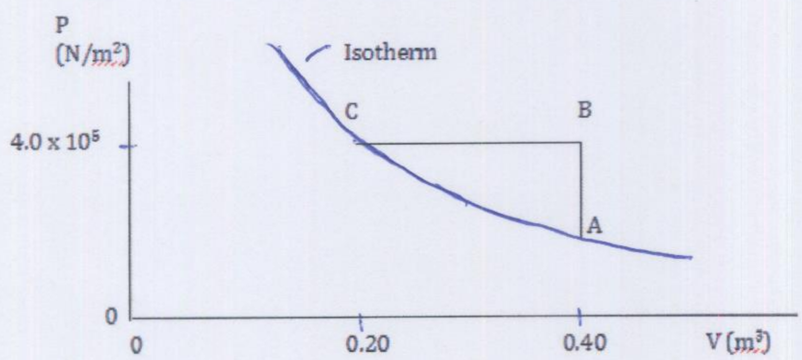
14. 0.70 moles of an ideal gas moves through a process from A to B to C, as shown. The curved line between A and C is an isotherm. Find

a. the temperature at points A, B, and C.

b. the work involved in each of the two steps. What is the net work for the whole process?

c. the change in thermal energy in each of the two steps. What is the net change in thermal energy?

d. the heat involved in each of the two steps. What is the net heat?



15. The box of a well-known breakfast cereal states that one ounce of the cereal contains 110 Calories. At a typical human efficiency, how many stairs could you climb while burning off these Calories, if each stair is 15 cm high?

↳ Mass = 62 kg

16. Two kilograms of liquid water at $0^{o}C$ is put into the freezer compartment of an ideal refrigerator. The temperature is $-15^{o}C$ inside, and the temperature of the kitchen is $27^{o}C$. You want to know how much electrical energy is needed to make 2.0 kg of ice at $0^{o}C$.

a. what amount of heat much be removed to freeze the water?

b. what electrical work input is needed to remove this heat?

Rev Problems Unit 4

1. $\Delta U = \Delta E_{TH} = Q - W$

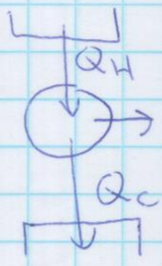
$\Delta V = 0$ so $W = 0$

Solid absorbed Q to melt,

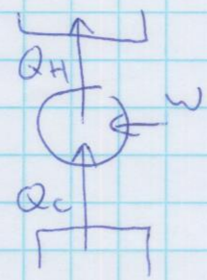
so Q +

$\therefore \Delta E_{TH}$ + Final E_{TH} greater than E_{TH_0}

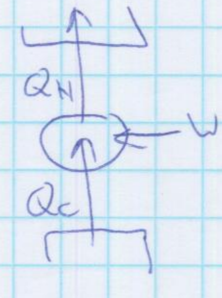
2. A



B



C



A: $Q_H = W + Q_C$, $e = W / Q_H$

B: $Q_H = W + Q_C$, $COP = Q_H / W$

C: $Q_H = W + Q_C$, $COP = Q_C / W$

3. $Q_A + Q_B = 0$

$m_A c_A \Delta T_A + m_B c_B \Delta T_B = 0$

$m_A c_A \Delta T_A = - m_B c_B \Delta T_B$

$m_A = m_B$.

$c_A \Delta T_A = - c_B \Delta T_B$

$c_A > c_B$, so $\Delta T_B > \Delta T_A$.

So T_F is closer to A's original T_0.

$T_F > 100°C$

4. $PV = nRT$

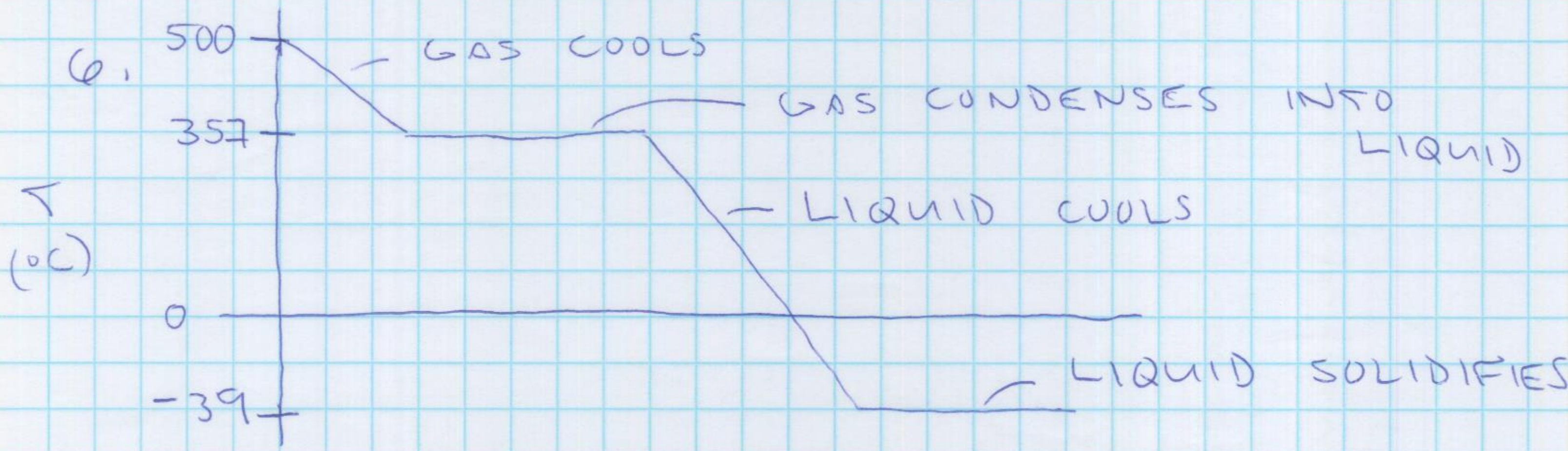
Told: P const; ΔV +.
So ΔT must be +.

(a) shows T decreasing, so NO
(b) shows V & T increasing, so yes, possible
(c) does not have constant P, NO

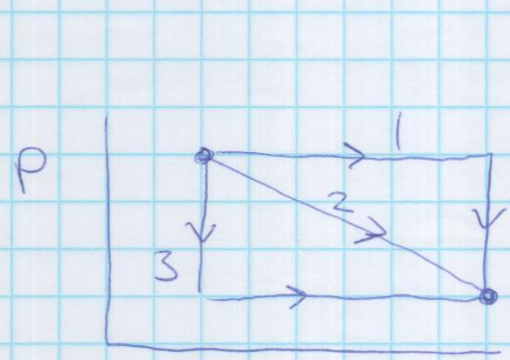
5. What you get as outcome of a process divided by what you paid, or used up, in doing it.

Human $e = 25\%$

6.



7. ΔE_{TH} = same for all
(All start & end at same points)



$\Delta E_{TH} = Q - W$

W = Area under graph. (+) for all.

$W_1 > W_2 > W_3$

so $Q = \Delta E_{TH} + W$: $Q_1 > Q_2 > Q_3$

8. $PV = nRT$

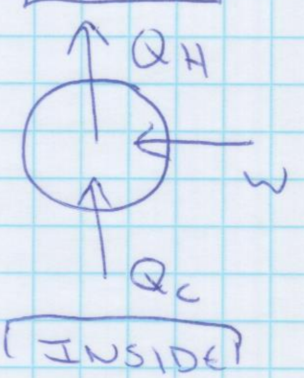
a. Put in cold bath to decrease T. Leave locking pin in.

b. Need to increase P. Add weights to lid + remove locking pin.

c. $Q = 0$, so no hot or cold bath. Leave pin out and remove weight from lid so gas can expand.

d. Want P constant, so do not add or remove weights. Keep pin out so volume can decrease and put in cold bath.

9. KITCHEN OR GARAGE. T_H.



INSIDE OF FRIDGE. T_C

$COP = \frac{Q_C}{W_{IN}}$. Best we can do is $COP_{MAX} = \frac{T_C}{T_H - T_C}$.

→ This number gets larger as $T_H - T_C$ gets smaller.

So as T_H goes up, COP goes down.

Fridge in kitchen uses less energy.

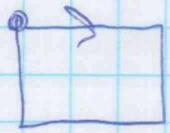
10. Take a known substance and heat it. Add it to a known mass of the liquid in insulated container.

If I get T of both mass and liquid just before I mix them, I can set up a Calorimetry Eq:

$$mc\Delta T)_{mass} = mc\Delta T)_{Liquid}$$

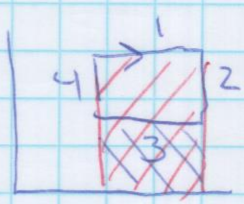
Since both have same T_F, only unknown is c_{Liquid}. Solve for it and look up in a table.

11.

a. 

Ends at same state it began.

$\Delta U = \Delta E_{TH} = 0$

b. 

W = 0 during 2, 4
+ during 1
− during 3.

More work done in 1 than 3.

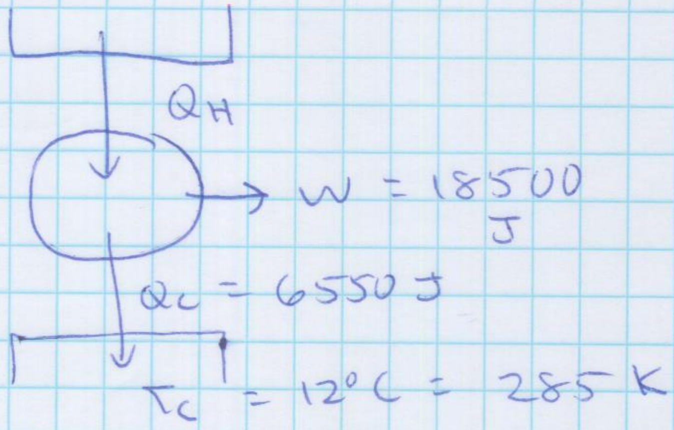
net Work +

c. Cycle 2: $\Delta E_{TH} = 0$. $W_{net} = +$.
$\Delta E_{TH} = Q - W$ so Q +

d. Same. Both are large rectangle bordered at top minus smaller rectangle bordered at bottom.

e. No answers would change. Try it.

17



$$e = \frac{W}{Q} = 1 - \frac{Q_C}{Q_H}$$

and $Q_H = W + Q_C$
$= 18500 + 6550$
$= 25,050$ J

$$e = 1 - \frac{6550}{25050} = 0.74$$

e cannot be above $e_{max} = 1 - \frac{T_C}{T_H}$

$$0.74 = 1 - \frac{285}{T_H}$$

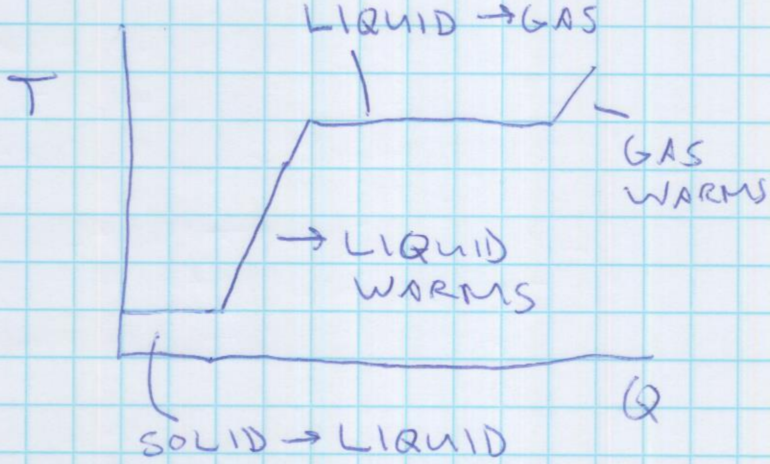
$T_H = 1100$ K

If $T_H < 1100$ K, actual e will decrease.
So this is smallest possible T_H.

13.

As liquid warms:

$Q = mc\Delta T$



from graph:

$Q = 40\text{ kJ} - 20\text{ kJ}$
$= 20{,}000$ during this phase.

$c = \frac{Q}{m\Delta T} = \frac{20{,}000\text{ J}}{(0.20\text{ kg})(1500 - 300\text{ C}^\circ)}$

$c = 83\text{ J/kg C}$
$= 83\text{ J/kg K}$

While vaporizing:

Q is $80\text{ kJ} - 40\text{ kJ}$
$= 40{,}000\text{ J}$

$L_v = \frac{Q}{m} = \frac{40{,}000\text{ J}}{(0.20\text{ kg})}$

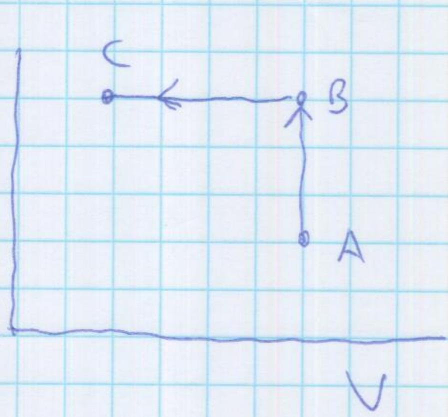
$L_v = 2.0 \times 10^5\text{ J/kg}$

~~17~~.
14.

a. $PV = nRT$

$$T_B = \frac{PV}{nR} = \frac{(4.0\times10^5)(0.4)}{(0.7)(8.31)}$$

$T_B = 27500$ K



$$T_C = \frac{(4.0\times10^5)(0.2)}{(0.7)(8.31)} = 13750 \text{ K}$$

A + C are on same isotherm, so
$T_A = 13750$ K

b. $W_{A\to B} = 0$. Constant volume.

$W_{B\to C} = P\Delta V$: Isobaric.
$= (4.0\times10^5)(0.20 - 0.40)$
$= -8.0\times10^4$ J

total $W = W_{AB} + W_{BC} = -8.0\times10^4$ J

c. $\Delta E_{TH} = \frac{3}{2}nR\Delta T$.

A → B: $\Delta E_{TH} = \frac{3}{2}(0.70)(8.31)(27500 - 13750)$
$= +1.2\times10^5$ J

B → C: $\Delta E_{TH} = \frac{3}{2}(0.70)(8.31)(13750 - 27500)$
$= -1.2\times10^5$ J

total $\Delta E_{TH} = 0$

$$Q = \Delta E_{th} + W$$

$A \to B$: $Q = +1.2 \times 10^5 + 0$

$= +1.2 \times 10^5$ J

$B \to C$: $Q = -1.2 \times 10^5 + -8.0 \times 10^4$

$= -2.0 \times 10^5$ J

total $Q = -8.0 \times 10^4$ J

15.

$$e = \frac{GET}{PAID}$$

GET — Δ Grav. Pot. Energy

PAID — my stored Energy from eating cereal.

e = 0.25 for humans.

$$0.25 = \frac{mg\Delta y}{\text{My E from cereal}}$$

110 Cal = x J

1 Cal = 4190 J

$x = 4.61 \times 10^5$ J

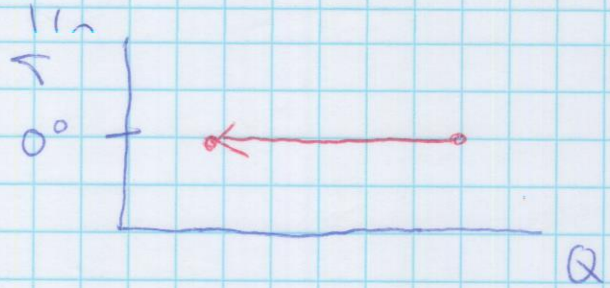
$$0.25 = \frac{(62\text{ kg})(9.8\text{ m/s}^2)(0.15\ \frac{\text{m}}{\text{step}})(N\text{ steps})}{4.61 \times 10^5\text{ J}}$$

N = 1264 steps

so reach height of

(1264 steps)(0.15 m/step)

= 190 m



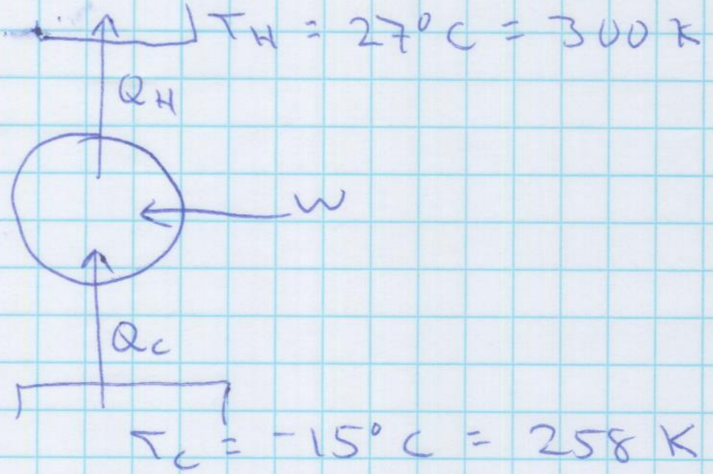
Phase change only.
Get ice at 0° C.

$$Q = mL_f$$
$$= (2.0\ kg)(3.33 \times 10^5\ J/kg)$$
$$= 6.66 \times 10^5\ J$$

This Q must be removed from ice to freeze it.

If this Q stays in freezer, freezer will warm up.

Need to remove this Q from freezer to keep freezer at constant T.



Ideal fridge:

$$COP = \frac{T_c}{T_H - T_c}$$

$$COP = \frac{258}{300 - 258}$$

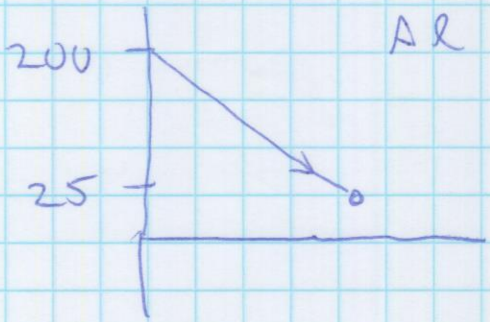
$$COP = 6.1$$

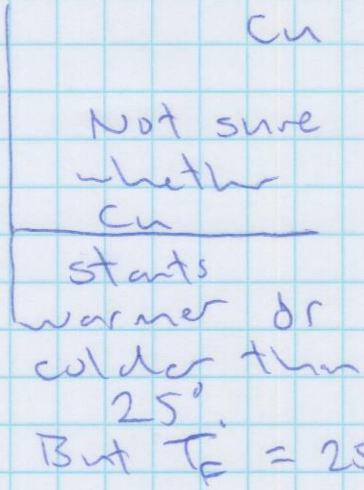
and $COP = \frac{Q_c}{W}$ always for fridge.

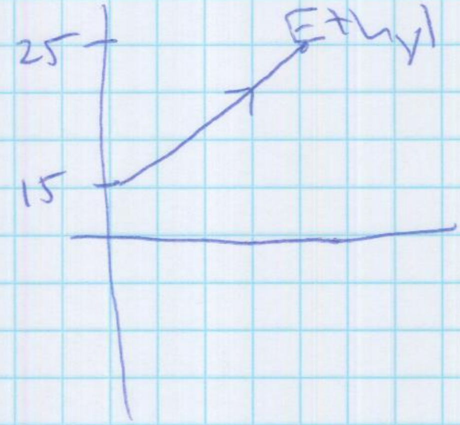
$$W = \frac{Q_c}{COP} = \frac{6.66 \times 10^5}{6.1}$$

$$W = 1.1 \times 10^5\ J$$

12-96







50 cm³ of Ethyl.

$$\text{mass} = \rho V = (790\ \text{kg/m}^3)(50\times10^{-6}\ \text{m}^3)$$
$$= 0.0395\ \text{kg}$$

$$Q_{net} = 0$$

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

$$(0.010)(900)(25-200) + (0.020)(385)(25-T_0)$$
$$+ (0.0395)(2400)(25-15) = 0$$

$$-1575 + 192.5 - 7.7T_0 + 948 = 0$$
$$-434.5 - 7.7T_0 = 0$$
$$T_0 = -56.4°C$$

So