Heat (Temperature) - Photon Absorption and Emission by Electrons
(OLD: Calorimetry, Fusion, Vaporization)

HEAT is the absorption and emission of photon by electrons in atoms and molecules

UNITS: One system of units is the easiest to solve problems. The primary system that will be used will be the SI system: $[\text{kilograms}(kg)\ \text{meters}(m)\ \text{seconds}(s)]$

The units most commonly used in measuring heat are:

- $\left[\xcancel{Joule}\ \ (kg)(m/s^2)(m)\ \ (M\vec{a}d)\right]$

  $\left[(kg)(m/s^2)(m)/(kg)(T)\right]$ is the SI derived unit of $\left(H_c^s\right)$. A material has the $\left(H_c^s\right)$ of $\left[1\ \ (kg)(m/s^2)(m)/(kg)(T)\right]$ if heat $(M\vec{a}d)$ of $\left[1\ (kg)(m/s^2)(m)\right]$ is required to raise the (T_A) of one kilogram of this material by one degree (T_A).
- $\left[calorie\ \ (g)(cm/s^2)(s)\right]$ is the metric derived unit of $\left(H_c^s\right)$. A material has the $\left(H_c^s\right)$ of (1 cal(IT)/g·°C) if heat $(M\vec{a}d)$ of one international calorie is required to raise the temperature of one gram of this material by one degree Celsius.

NOTE: A temperature rise of $(1^oC = 1^oT)$ is the same change in temperature.

- $\left[BTU\ \ (lb)(ft/s^2)(s)\right]$ is the derived international British thermal unit of $\left(H_c^s\right)$. A material has the $\left(H_c^s\right)$ of (1 Btu(IT)/lb·°F) if the heat $(M\vec{a}d)$ of (1 Btu(IT)/lb·°F) is required to raise the temperature of one pound of this material by one degree Fahrenheit.

SPECIFIC HEAT CAPACITY $\left(H_c^s\right)$ of a substance is the quantity of $(M\vec{a}d)$ required to raise the temperature of a substance by one degree.

If the quantity of $(M\vec{a}d)$ $(M_{ab}\vec{a}d_{in})$ required to produce a temperature increase of (ΔT) in a mass (M) or weight (W) of a substance, then the $\left(H_c^s\right)$ of that substance is:

$$\left[H_c^s = \frac{M_{ab}\vec{a}d_{in}}{M\Delta T}\right] \quad \text{or} \quad \left[H_c^s = \frac{M_{ab}\vec{a}d_{in}}{W\Delta T}\right]$$

HEAT CAPACITY $[H_C]$ of a body is the quantity of $(M\vec{a}d)$ required to raise the temperature of the whole body by one degree.

The $[H_C]$ of an object of mass (M) and $\left(H_c^s\right)$ is: $\left[(M)\left(H_c^s\right)\right]$

The $[H_C]$ of an object of weight (W) and $\left(H_c^s\right)$ is: $\left[(W)\left(H_c^s\right)\right]$

THE HEAT GAINED (OR LOST) by a body of mass (M) and specific heat $\left(H_c^s\right)$ is:

$\left[(M_{ab}\vec{a}d_{in})\,\&\,(M_{em}\vec{a}d_{out}) = \left(H_c^s\right)(M)(\Delta T)\right]$ when calories or $\left[(kg)(m/s^2)(m)\right]$ are used.

$\left[(M_{ab}\vec{a}d_{in})\,\&\,(M_{em}\vec{a}d_{out}) = \left(H_c^s\right)(W)(\Delta T)\right]$ when Btu's are used.

$\Big($*Heat* to change a solid to a liquid (H_L^S) ~~The Heat of Fusion H_F~~$\Big)$ The photon absorption needed to change a solid to a liquid $\left(H_L^S\right)$ is the quantity of $(M_{absorbed-hot}\vec{a}d_{in})$ required to melt a unit mass or weight of the solid at constant* temperature.

*NOTE: Constant temperature does not exist. Symmetry-Math and Kanarev's theory on heat and temperature show this to be incorrect. When photons are absorbed or emitted the temperature changes. It may not be measureable, but it changes. This applies to $\left[H_G^L\right]\&\left[H_G^S\right]$.

The $\left(H_L^S\right)$ of water is: $\left[\left(334944(kg)(m/s^2)(m)/kg\right) \quad (80\,cal/g) \quad (144\,Btu/lb)\right]$

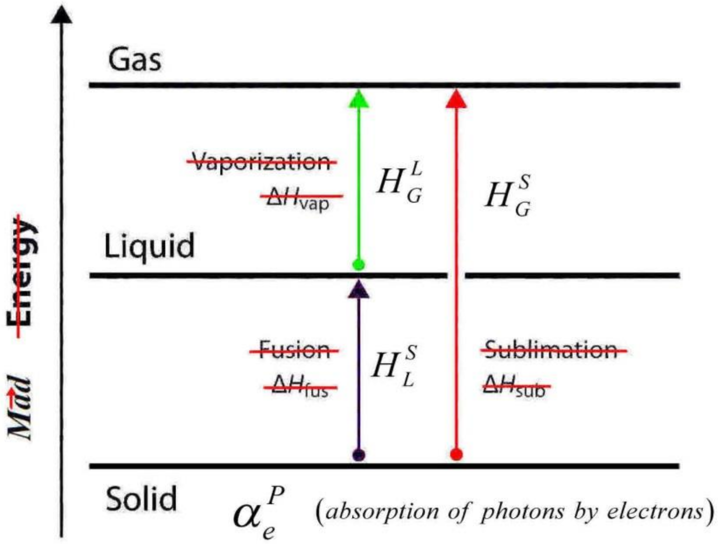
$\Big[$*Heat* to change a liquid to a gas (H_G^L) ~~**THE HEAT OF VAPORIZATION** H_V~~$\Big]$

The photon absorption needed to change a liquid to a gas $\left(H_G^L\right)$ is the quantity of $(M\vec{a}d)$ required to vaporize a unit of mass or weight of the liquid at constant temperature*. The $\left(H_G^L\right)$ of water at $(100^oC = 373^oT)$ is:

$$\left[\left(2259360(kg)(m/s^2)(m)/kg\right) \quad (540\,cal/g) \quad (970\,Btu/lb)\right]$$

$\Big[$*Heat* to change a solid to a gas (H_G^S)
~~**THE HEAT OF SUBLIMATION** H_{SUB}~~$\Big]$

The photon absorption needed to change a solid to a gas $\left[H_G^S\right]$ is the quantity of $(M\vec{a}d)$ required to convert a unit of mass or weight from a solid to the gaseous state at constant temperature* (*JK NOTE: No such process can exist; photons are being absorbed by the electrons of atoms and molecules).



SOLVING PROBLEMS: The conservation of $(M\vec{a}d)$ can be stated in the following equation:

$$\begin{bmatrix} (M_{emitted-hot}\vec{a}d_{out}) \text{ lost by the hot mass} = (M_{absorbed-cold}\vec{a}d_{in}) \text{ gained by the cold mass} \\ (M_{\varepsilon}\vec{a}d_{out})=(M_{\alpha}\vec{a}d_{in}) \end{bmatrix}$$

This assumes that no $(M\vec{a}d_{\text{initial-internal-}\varepsilon\alpha})$ is lost from the system.

ABSOLUTE HUMIDITY $[AH]$ is the mass of water vapor present per unit volume of gas (usually the atmosphere). Units are $\left[(kg/m^3) \;\; or \;\; (g/cm^3)\right]$.

RELATIVE HUMIDITY $[RH]$ is the ratio:

$$\left[(RH) = \frac{\text{mass of water vapor per unit volume present in the air}}{\text{mass of water vapor per unit volume present in saturated air at the same temperature}}\right]$$

When expressed in %, the answer is multiplied by 100.

DEW POINT (D_P): Cooler air at saturation contains less water than warmer air does at saturation. When air is cooled, it eventually reaches a temperature at which it is saturated. This temperature is labeled (D_P). At temperatures lower than this, water condenses out of the air.

PROBLEMS

1: How much $(M_\alpha \vec{a}d_{in})$ must be absorbed by $\left(250cm^3 = 0.00025m^3\right)$ of water to raise the temperature from $(20^oC = 293^oT)$ to $(35^oC = 308^oT)$?

- $\left(H_c^s\right)$ of water is $(1cal/g^oC = 4186.8(kg)(m/s^2)(m)/kg^o\,T)$
- $\left(250cm^3 = 0.00025m^3\right)$ of water has a mass of $(M = 250g = 0.25kg)$.

A: $\left[M_\alpha \vec{a}d_{in} = \left(H_c^s\right)(M)(\Delta T) = (1cal/g^oC)(250g)(15^oC) = 3750cal\right]$ IT units

$$\left[\begin{array}{l} M_\alpha \vec{a}d_{in} = \left(H_c^s\right)(M)(\Delta T) = (4186.8(kg)(m/s^2)(m)/kg^o\,T)(0.25kg)(15^oT) \\ = 15700.5(kg)(m/s^2)(m) \end{array}\right] \text{SI units}$$

How much $(M_\alpha \vec{a}d_{in})$ must be emitted for the water to cool back down to $(20^oC = 293^oT)$?

A: $\left[M_\varepsilon \vec{a}d_{out} = \left(H_c^s\right)(M)(\Delta T) = (1cal/g^oC)(250g)(15^oC) = 3750cal\right]$ IT units

$$\left[\begin{array}{l} M_\varepsilon \vec{a}d_{out} = \left(H_c^s\right)(M)(\Delta T) = (4186.8(kg)(m/s^2)(m)/kg^o\,T)(0.25kg)(15^oT) \\ = 15700.5(kg)(m/s^2)(m) \end{array}\right] \text{SI units}$$

NOTE: In Jack Kuykendall's Symmetry-Math, Physics and Chemistry, dashes and crosses are used ONLY as subtraction and addition operators. All dashes and crosses that define a process are removed. There is NO negative heat and there is NO positive heat. Heat is the absorption and emission of photons by electrons of atoms and molecules. The multiple uses of dashes and crosses in science make the understanding of fundamental principles extremely difficult.

2: How much $(M_{\varepsilon}\vec{a}d_{out})$ is emitted when $(25g = 0.025kg)$ of aluminum cools from $(100^{o}C = 373^{o}T)$ to $(20^{o}C = 293^{o}T)$?

- $\left(H_c^s\right)$ of aluminum is $(0.21cal/g^{o}C = 879.228(kg)(m/s^2)(m)/kg^{o}\,T)$

A: $\left[M_{\varepsilon}\vec{a}d_{out} = \left(H_c^s\right)(M)(\Delta T) = (0.21cal/g^{o}C)(25g)(80^{o}C) = 420cal\right]$ IT units

$$\left[\begin{aligned}&M_{\varepsilon}\vec{a}d_{out} = \left(H_c^s\right)(M)(\Delta T) = (879.228(kg)(m/s^2)(m)/kg^{o}\,T)(0.025kg)(80^{o}T)\\&= 1758.456(kg)(m/s^2)(m)\end{aligned}\right]$$ SI units

3: How much $(M_{\alpha}\vec{a}d_{in})$ must be absorbed to heat $(5lbs = 2.268kg)$ of aluminum from $(40^{o}F = 277.594^{o}T)$ to $(212^{o}F = 373.15^{o}T)$

- $\left(H_c^s\right)$ of aluminum is $(0.21cal/g^{o}C = 879.228(kg)(m/s^2)(m)/kg^{o}\,T)$

A: $$\left[\begin{aligned}&M_{\alpha}\vec{a}d_{in} = \left(H_c^s\right)(M)(\Delta T) = (879.228(kg)(m/s^2)(m)/kg^{o}\,T)(2.268kg)(95.556^{o}T)\\&= 190547.1784(kg)(m/s^2)(m)\end{aligned}\right]$$

4: A certain amount of $(M_{\alpha}\vec{a}d_{in})$ is added to a mass of aluminum and its temperature is raised $(57^{o}C = 57^{o}T)$The rise in temperature will be the same.

- $\left(H_c^s\right)$ of aluminum is $(0.21cal/g^{o}C = 879.228(kg)(m/s^2)(m)/kg^{o}\,T)$

If the same amount of $(M_{\alpha}\vec{a}d_{in})$ is added to same mass of copper, how much does the temperature of copper rise?

- $\left(H_c^s\right)$ of copper is $(0.093cal/g^{o}C = 389.372(kg)(m/s^2)(m)/kg^{o}\,T)$

A: From equation $\left[M_{\alpha}\vec{a}d_{in} = \left(H_c^s\right)(M)(\Delta T)\right]$, the temperature rise is inversely proportional to $\left(H_c^s\right)$.

$$\left[\Delta T_{copper} = \left(\frac{879.228}{389.372}\right)(57^{o}T) = 129^{o}T\right]$$

5: A thermos bottle contains $(250g = 0.25kg)$ of coffee at $(90^oC = 363^oT)$. To this is added $(20g = 0.02kg)$ milk at $(5^oC = 278^oT)$.

? After equilibrium is established, what is the temperature of the liquid?

- $(H_c^s = 1cal/g^oC = 4186.8(kg)(m/s^2)(m)/kg^oT)$ for water, coffee and milk.

A: $\begin{bmatrix} (M_\varepsilon \vec{a}d_{out})coffee = (M_\alpha \vec{a}d_{in})milk \\ (H_c^s)(M)(\Delta T_{out})coffee = (H_c^s)(M)(\Delta T_{in})milk \end{bmatrix}$ Since (H_c^s) is same for all the liquids,

$[(M)(\Delta T_{out})coffee = (M)(\Delta T_{in})milk]$ If the final temperature of the liquid is (T_f)

$[(\Delta T_{out})coffee = 363^oT - T_f]$ $[(\Delta T_{in})milk = T_f - 278^oT]$

Substituting into the above equation

$$\begin{bmatrix} (M)(\Delta T_{out})coffee = (M)(\Delta T_{in})milk \\ (0.25kg)(363^oT - T_f) = (0.02kg)(T_f - 278^oT) \\ 90.75 - 0.25T_f = 0.02T_f - 5.56 \\ 0.27T_f = 96.31 \\ T_f = 356.7^oT = 83.7^oC = 183^oF \end{bmatrix}$$

6: A thermos bottle contains $(150g = 0.15kg)$ of water at $(4^oC = 277^oT)$. $(90g = 0.09kg)$ of a metal at $(100^oC = 373^oT)$ is added to the thermos. After equilibrium is reached, the temperature of the water and metal is $(21^oC = 294^oT)$.

? What is the (H_c^s) of the metal? Assume $[(M_\alpha \vec{a}d_{in}) \& (M_\varepsilon \vec{a}d_{out}) = 0]$ for the thermos bottle.

- $(H_c^s = 1cal/g^oC = 4186.8(kg)(m/s^2)(m)/kg^oT)$ for water.

A: $$\begin{bmatrix} (M_\varepsilon \vec{a}d_{out})metal = (M_\alpha \vec{a}d_{in})water \\ (H_c^s)(M)(\Delta T_{out})metal = (H_c^s)(M)(\Delta T_{in})water \\ (H_c^s)(0.09kg)(373 - 294)metal = (4186.8)(0.15kg)(21 - 4)water \\ (H_c^s)_{metal} = \dfrac{(4186.8)(0.15kg)(21-4)water}{(0.09kg)(373-294)metal} = \dfrac{10676.34}{7.11} = 1501.59(kg)(m/s^2)(m)/kg^oT \end{bmatrix}$$

$[1501.59(kg)(m/s^2)(m)/kg^oT = 0.36cal/g^oC]$

7: A $(200g = 0.2kg)$ copper can contains $(150g = 0.15kg)$ of oil at a temperature of $(20^oC = 293^oT)$. $(80g = 0.08kg)$ of aluminum at $(300^oC = 573^oT)$ is added to the oil.

? What will be the temperature of the system when equilibrium is established?

- $\left(H_c^s\right)$ of aluminum is $(0.21 cal/g^oC = 879.228(kg)(m/s^2)(m)/kg^o\,T)$
- $\left(H_c^s\right)$ of copper is $(0.093 cal/g^oC = 389.372(kg)(m/s^2)(m)/kg^o\,T)$
- $\left(H_c^s\right)$ of the oil is $(0.37\, cal/g^oC = 1549.116(kg)(m/s^2)(m)/kg^o\,T)$

A:

$$\left[\begin{array}{l}
\left(M_\varepsilon \vec{a}d_{out}\right)_{\text{aluminum}} = \left(M_\alpha \vec{a}d_{in}\right)_{can} \,\&\, \left(M_\alpha \vec{a}d_{in}\right)_{oil} \\
\left(H_c^s\right)(M)(\Delta T_{out})_{\text{aluminum}} = \left(H_c^s\right)(M)(\Delta T_{in})_{can} \,\&\, \left(H_c^s\right)(M)(\Delta T_{in})_{oil} \\
(879.228)(0.08)(573^o - t) = (389.372)(0.2)(t - 293^o) + (1549.116)(0.15)(t - 293^o) \\
(40303.8) - 70.34t = (77.87t) - 22817.2 + 232.37t - 68083.665 \\
380.58t = 131204.665 \\
t = 345^oT = 72^oC
\end{array}\right]$$

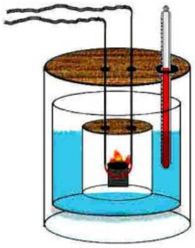
8: $(3g = 0.003kg)$ of carbon was burned to (CO_2) in a $(1500g = 1.5kg)$ copper calorimeter containing $(2000g = 2kg)$ of water. The initial temperature was $(20^oC = 293^oT)$ and the final temperature was $(31^oC = 304^oT)$.

? Calculate the $\left[\left(M_\varepsilon \vec{a}d_{out}/kg\right)_{CO_2}\right]$.

- $\left(H_c^s\right)$ of copper is $(0.093 cal/g^oC = 389.372(kg)(m/s^2)(m)/kg^o\,T)$

A:

$$\left[\begin{array}{l}
\left(M_\varepsilon \vec{a}d_{out}/kg\right)_{CO_2} = \left(M_\alpha \vec{a}d_{in}\right)_{can} \,\&\, \left(M_\alpha \vec{a}d_{in}\right)_{oil} \\
\left(H_c^s\right)(M)(\Delta T_{out})_{CO_2} = \left(H_c^s\right)(M)(\Delta T_{in})_{copper\ calorimeter} \,\&\, \left(H_c^s\right)(M)(\Delta T_{in})_{water} \\
\left(H_c^s\right)(M)(\Delta T_{out})_{CO_2} = (389.4)(1.5)(11^o) + (4186.8)(2)(11^o) \\
\left(H_c^s\right)(M)(\Delta T_{out})_{CO_2} = 6425.1 + 92109.6 = 98534.7(kg)(m/s^2)(m) \\
= 23550.3585 cal
\end{array}\right]$$



The $$\left[\begin{array}{l}
\left(M_\varepsilon \vec{a}d_{out}/kg\right)_{CO_2} = \dfrac{98534.7}{0.003} = 32844900(kg)(m/s^2)(m)/kg \\
= 7850\, cal/g
\end{array}\right]$$

9: Determine the final temperature when $(150g = 0.15kg)$ of ice at $(0^oC = 273^oT)$ is mixed with $(300g = 0.3kg)$ of water at $(50^oC = 323^oT)$.

- $\left(H_L^S = 80\,cal/g = 334960\,(kg)(m/s^2)(m)/kg\right)$
- $\left(1cal/g = 4187\,(kg)(m/s^2)(m)/kg\right)$

A:

$$\left[\begin{array}{l}
\left(M_\alpha \vec{a}d_{in}\right)_{ice} = \left(M_\varepsilon \vec{a}d_{out}\right)_{water} \\
(MH_L^S)_{ice} + \left(H_c^s\right)(M)(\Delta T_{in})_{ice\ water} = \left(H_c^s\right)(M)(\Delta T_{out})_{water} \\
(0.15)(334960) + (4187)(0.15)(t - 273^o) = (4187)(0.3)(323^o - t) \\
50244 + 628t - 171458 = (405720) - (1256t) \\
1884t = -50244 + 171458 + 405720 \\
1884t = 526934 \\
t = 279.7^oT = 6.7^oC
\end{array}\right]$$

10: How much $\left(M_\varepsilon \vec{a}d_{out}\right)$ is given of when $(20g = 0.02kg)$ of stream is condensed and cooled to $(20^oC = 293^oT)$?

- $H_L^G = (540\,cal/g = 2260980\,(kg)(m/s^2)(m)/kg)$
- $\left(1cal/g = 4187\,(kg)(m/s^2)(m)/kg\right)$
- $(1cal = 0.0041868 > 3(kg)(m/s^2)(m)$

A:

$$\left[\begin{array}{l}
\left(M_\varepsilon \vec{a}d_{out}\right) = \text{(condensation heat loss)+(heat lost by water during cooling)} \\
\left(M_\varepsilon \vec{a}d_{out}\right) = MH_L^G + \left(H_c^s\right)(M)(\Delta T_{out})_{water} \\
\left(M_\varepsilon \vec{a}d_{out}\right) = (0.02)(2260980) + (4187)(0.02)(373^o - 293^o) \\
\left(M_\varepsilon \vec{a}d_{out}\right) = 45220 + 6699 = 51919(kg)(m/s^2)(m) = 12400cal
\end{array}\right]$$

11: A $(20g = 0.02kg)$ piece of aluminum at $(90^oC = 363^oT)$ is dropped into a cavity in a large block of ice.

? How much ice does the aluminum melt?

- $\left(H_c^s\right)$ of aluminum is $(0.21cal/g^oC = 879.228(kg)(m/s^2)(m)/kg^o\,T)$
- $\left(H_L^S = 80cal/g = 334960(kg)(m/s^2)(m)/kg\right)$

A:

$$\left[\begin{array}{l}
\left(M_\varepsilon \vec{a}d_{out}\right)_{\text{Al as it cools to 273}^o\text{T}} = \left(M_\alpha \vec{a}d_{in}\right)_{ice\ melted} \\
\left(H_c^s\right)(M)(\Delta T_{out})_{Al} = (MH_L^S)_{ice} \\
(879)(0.02)(363^o - 273^o) = (334960)M \\
M = \dfrac{(879)(0.02)(90^o)}{334960} = \dfrac{1582.2}{334960} = 0.0047kg = 4.7g \qquad \text{ice melted}
\end{array}\right]$$

12: Convert $\left(H_L^S = 80cal/g = 334960(kg)(m/s^2)(m)/kg\right)$ to (Btu/lb) units.

$$\left(H_L^S = \left(80\frac{cal}{g}\right)\left(\frac{1Btu}{252cal}\right)\left(\frac{454g}{1lb}\right) = 144\frac{Btu}{lb}\right)$$

? How many Btu are absorbed by a refrigerator in changing $(5lb)$ of water at (60^oF) to ice at (32^oF)?

A:

$$\left[\begin{array}{l}
\left(M_\alpha \vec{a}d_{in}\right)_{refrigerator} = \left(M_\varepsilon \vec{a}d_{out}\right)_{to\ cool\ water} + \left(M_\varepsilon \vec{a}d_{out}\right)_{change\ water\ to\ ice} \\
\left(M_\alpha \vec{a}d_{in}\right)_{refrigerator} = \left(H_c^s\right)(W)(\Delta T_{out}) + (WH_L^S) \\
\left(M_\alpha \vec{a}d_{in}\right)_{refrigerator} = (1Btu/lb^oF)(5)(28^o) + (5)(144) = 860Btu
\end{array}\right]$$

Unfortunately, this cumbersome system of units still exists and is widely used. This is the reason I did not change this problem to the SI $(kg - m - s)$ system of units.

13: In a calorimeter can $(water\ equivalent = 40g = 0.04kg)$ are $(200g = 0.2kg)$ of water and $(50g = 0.05kg)$ of ice, all at $(0^oC = 273^oT)$. $(30g = 0.03kg)$ of water at $(90^oC = 363^oT)$ is poured into the calorimeter.

? What is the final condition of the system?

A: The maximum $(M_\varepsilon \vec{a}d_{out})$ of the (90^o) added water that can be emitted is $\left[\left(H_c^s\right)(M)(\Delta T_{out}) = (1)(30g)(90^oC) = 2700\,cal/g^oC\right]$. To melt $(50g)$ of ice would take $(MH_L^S = (50g)(80\,cal/g) = 4000cal)$. Since a maximum of $(2700cal)$ are available, all the ice cannot be melted. Since all the ice cannot be melted, the final temperature will remain at (0^oC). Eventually, any $(M_\alpha \vec{a}d_{in})$ absorbed by the Calorimeter or water will be reemitted into the water-ice solution into melting the ice.

$$\left[\left(H_c^s\right)(M)(\Delta T_{out})_{water} = (1cal/g^oC)(30g)(90^oC) = 2700cal\right]$$
$$\left[(M_\alpha)(H_L^S)_{ice} = (50g)(80\,cal/g) = 4000cal\right]$$

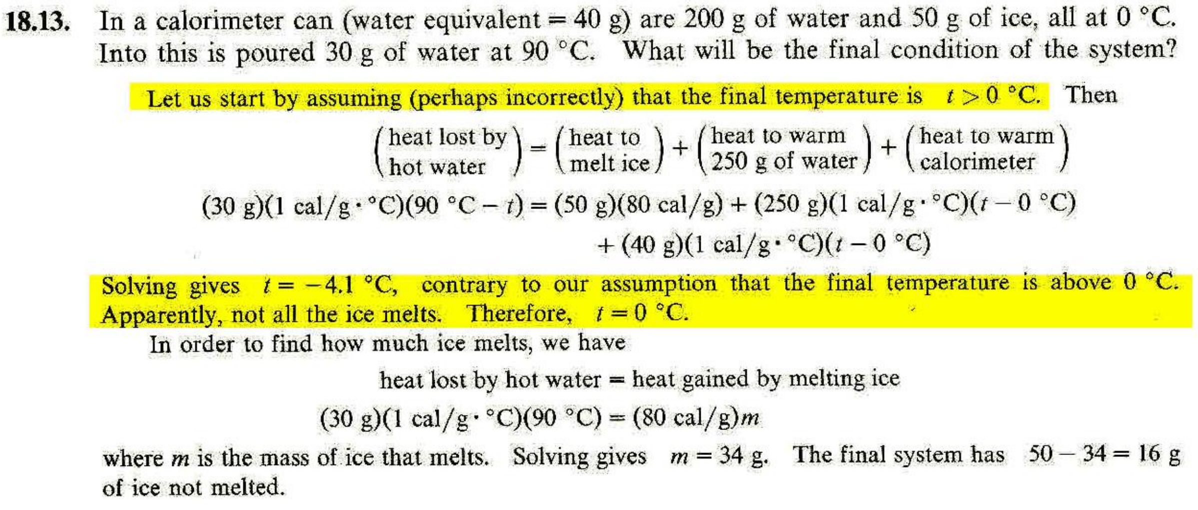
The percent of ice melted will be $\left(\dfrac{2700cal}{4000cal} = 0.675 = 67.5\%\right)$

$(67.5\%\ of\ \ 50g = 33.75g)$. $(50g - 33.75g = 16.25g)$ of remains as ice.

The final condition of the system is:

- Total amount of water and ice at (0^oC) is $(200 + 50 + 30 = 280g\ of\ \ water\ \&\ ice)$
- $(16.25g\ of\ \ ice)$ remain in the water-ice solution.

Comparing the above equations and answer to the Schaum's equations and answer is interesting. The Schaum's equation provides an incorrect answer for the temperature. The author did not like the answer and just makes a "therefore" statement that the answer is something different.



18.13. In a calorimeter can (water equivalent = 40 g) are 200 g of water and 50 g of ice, all at 0 °C. Into this is poured 30 g of water at 90 °C. What will be the final condition of the system?

Let us start by assuming (perhaps incorrectly) that the final temperature is $t > 0$ °C. Then

$$\begin{pmatrix}\text{heat lost by}\\ \text{hot water}\end{pmatrix} = \begin{pmatrix}\text{heat to}\\ \text{melt ice}\end{pmatrix} + \begin{pmatrix}\text{heat to warm}\\ \text{250 g of water}\end{pmatrix} + \begin{pmatrix}\text{heat to warm}\\ \text{calorimeter}\end{pmatrix}$$

$$(30\text{ g})(1\text{ cal/g}\cdot{}^\circ\text{C})(90\,{}^\circ\text{C} - t) = (50\text{ g})(80\text{ cal/g}) + (250\text{ g})(1\text{ cal/g}\cdot{}^\circ\text{C})(t - 0\,{}^\circ\text{C})$$
$$+ (40\text{ g})(1\text{ cal/g}\cdot{}^\circ\text{C})(t - 0\,{}^\circ\text{C})$$

Solving gives $t = -4.1$ °C, contrary to our assumption that the final temperature is above 0 °C. Apparently, not all the ice melts. Therefore, $t = 0$ °C.

In order to find how much ice melts, we have

$$\text{heat lost by hot water} = \text{heat gained by melting ice}$$
$$(30\text{ g})(1\text{ cal/g}\cdot{}^\circ\text{C})(90\,{}^\circ\text{C}) = (80\text{ cal/g})m$$

where m is the mass of ice that melts. Solving gives $m = 34$ g. The final system has $50 - 34 = 16$ g of ice not melted.

14: A thermomenter in a $(10m)x(8m)x(4m)$ room reads $(22^{o}C)$ and a humidistat reads the relative humidity to be (35%).

? What mass of water vapor is in the room?

- Saturated air at $(22^{o}C)$ contains $(19.33gH_2O/m^3)$

A:

$$\left[\begin{array}{l} (RH)=\left(\frac{\text{M of water}/m^3}{\text{M of water}/m^3\text{ of saturated air}}\right)(100) \\ 35\%=\left(\frac{\text{M}/m^3}{0.01933kg/m^3}\right)(100) \\ \text{M}/m^3=\frac{(35)(0.01933)}{100}=\frac{0.67655}{100}=6.77<3=0.00677kg/m^3 \end{array}\right]$$

The room has a volume of $\left[(10m)x(8m)x(4m)=320m^3\right]$.

The water in the room is: $\left[(320m^3)(6.77<3kg/m^3)=2.17kg\right]$

15: On a day when the temperature is $(28^{o}C)$, Dew forms on the outside of a glass of cold drink if the glass is at a temperature of $(16^{o}C)$ or lower.

? What is the (RH) on that day?

- Saturated air at $(28^{o}C)$ contains $(26.93g/m^3)$ of water.
- Saturated air at $(16^{o}C)$ contains $(13.50g/m^3)$ of water.

A:

$$(RH)=\frac{\text{M}/m^3}{\text{M}/m^3\text{ in saturated air}}=\frac{13.50}{26.93}=0.50=50\%$$

16: Outside air at $(5^o C)$ and (20%) relative humidity is introduced into a heating and air conditioning plant where it is heated to $(20^o C)$ and the relative humidity is increased to a comfortable (50%).

? How many grams of water must be evaported into a cubic meter of outside air to accomplish this?

- Saturated air at $(5^o C)$ contains $(6.8\, g/m^3)$ of water.
- Saturated air at $(20^o C)$ contains $(17.3\, g/m^3)$ of water.

A: (M/m^3) of water vapor in air at $(5^o C)$ is: $(M/m^3) = (20\%)(6.8\, g/m^3) = 1.36\, g/m^3$

(M/m^3) of water vapor in air at $(20^o C)$ is: $(M/m^3) = (20\%)(17.3\, g/m^3) = 8.65\, g/m^3$

One (m^3) of air at $(5^o C)$ expands to $\left[(293/278\, m^3) = 1.054 m^3\right]$ at $(20^o C)$

Mass of water vapor in $(1.054 m^3)$ at $(20^o C)$ is: $\left[M = (1.054 m^3)(8.65\, g/m^3) = 9.12 g\right]$

Mass of water vapor to be added to each (m^3) of air at $(5^o C)$ is:
$[M = 9.12 g - 1.36 g = 7.76 g]$