Phy 4C 1/11

Monday, January 11, 2016 12:00 PM

Goals for the Lecture:

1) Be able to do calorimetry problems, including phase changes that involve latent heat of fusion and vaporization
2) Understand the concept of "states of a system" and "state variables"
3) Understand Isobaric, Isovolumetric, Isothermal, and adiabatic processes

Calorimetry

Example: combine:
1) Ice (0.3 kg) at $-20^\circ C$
2) Water (0.5 kg) at $40^\circ C$
3) Aluminum (0.4 kg) at $200^\circ C$

$$\left.\begin{aligned} c_{ice} &= 2100 \\ c_{water} &= 4190 \\ c_{Al} &= 910 \end{aligned}\right\} \frac{J}{kg\,K}$$

water $L_f = 3.34 \times 10^5 \ \frac{J}{kg}$

To $0^\circ C$

$$Q_{(\text{warm ice to } 0^\circ C)} = M_{ice} C_{ice} \Delta T_{ice} = (0.3\ kg)(2100)(20) = 12{,}600\ J$$

$$Q_{(\text{melt all the ice})} = M_{ice} L_f = (0.3)(3.34 \times 10^5) = 100{,}200\ J$$

$$Q_{(\text{cool water to } 0^\circ C)} = M_{water} C_{water} \Delta T_{water} = (0.5)(4190)(-40) = -83{,}800\ J$$

$$Q_{(\text{cool Al to } 0^\circ C)} = (0.4\ kg)\left(910 \frac{J}{kg\,K}\right)(-200\ K) = -72{,}800\ J$$

$\Sigma Q < 0$ so, all ice melts and we will be above $0^\circ C$

$$\underbrace{Q_{\text{warm ice to } 0^\circ C} + Q_{\text{melt ice}} + Q_{\text{warm the melted ice}}}_{+} + \underbrace{Q_{\text{cool water}} + Q_{\text{cool Al}}}_{-} = 0$$

$$M_{ice} C_{ice}(0+20) + M_{ice} L_f + M_{ice} C_{water}(T_f - 0) + M_{water} C_{water}(T_f - 40) + M_{Al} C_{Al}(T_f - 200) = 0$$

$$12{,}600 + 100{,}200 + 1257\,T_f + 2095\,T_f - 83800 + 364\,T_f - 72800 = 0$$

$$T_f = 11.8^\circ C$$

No ice

0.8 kg water

0.4 kg Al

Example: Combine:

1) ice (0.5 kg) at $-20°C$ $\quad c_{ice} = 2100$
2) water (0.3 kg) at $40°C$ $\quad c_{water} = 4190$
3) Al (0.4 kg) at $200°C$ $\quad c_{Al} = 910$

$\left.\right\} \frac{J}{kg\,K}$

water: $L_f = 3.34\times10^5 \ \frac{J}{kg}$

To 0°C

$$Q_{(\text{warm ice to } 0°C)} = (0.5)(2100)(20) = 21{,}000 \text{ J}$$

$$Q_{(\text{melt ice})} = m L_f = (0.5)(3.34\times10^5) = 167{,}000 \text{ J}$$

$$Q_{(\text{cool water to } 0°C)} = (0.3)(4190)(-40) = -50{,}280 \text{ J}$$

$$Q_{(\text{cool Al to } 0°C)} = (0.4)(910)(-200) = -72{,}800 \text{ J}$$

$\Sigma Q > 0$ so, Not enough energy comes out of the water and Al to melt all the ice. $T_f = 0°C$ and some ice melts

$$Q_{\text{warm ice to } 0°C} + Q_{\text{melt some ice}} + Q_{\text{cool water to } 0°C} + Q_{\text{cool Al to } 0°C} = 0$$

$$21000 + m_{\text{melts}}(3.34\times10^5) - 50280 - 72800 = 0$$

$$m_{\text{melts}} = 0.306 \text{ kg}$$

$$T_f = 0°C$$

ice: 0.194 kg
water: 0.604 kg
Al : 0.4 kg

Calorimetry:

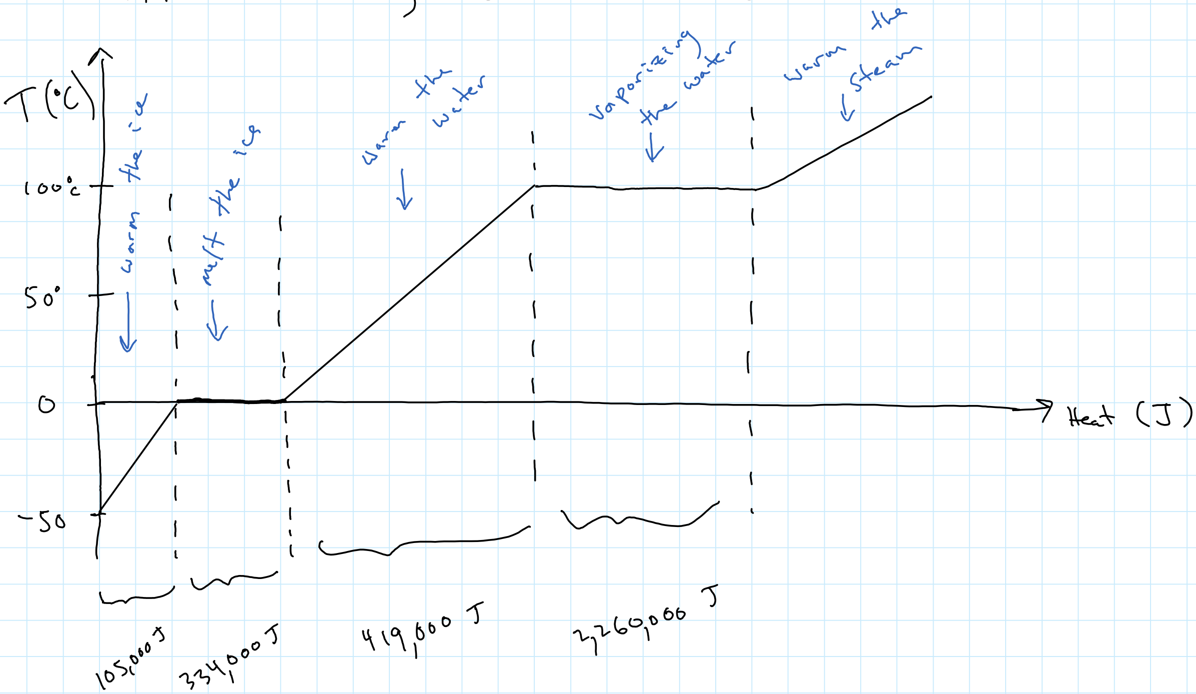
$c_{ice} = 2100 \ \frac{J}{kg\,K}$

$c_{water} = 4190 \ \frac{J}{kg\,K}$

$L_f = 3.34\times10^5 \ J/kg$

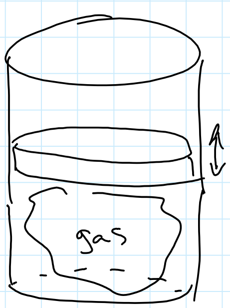
$L_v = 2.26\times10^6 \ \frac{J}{kg}$

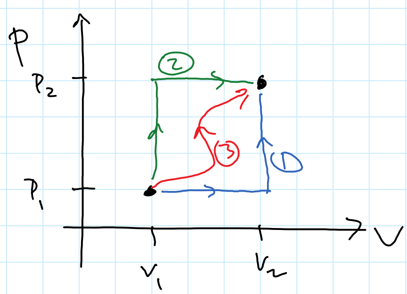
Start with 1 kg of ice at -50°C



States of a system & State Variables

$$PV = nRT$$



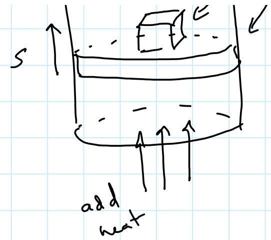


4 common thermal processes:

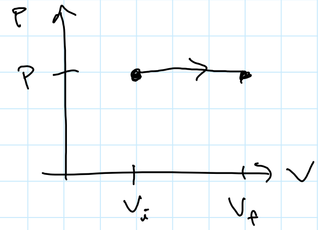
1) Isobaric : constant pressure
2) Isochoric : constant volume
3) Isothermal : constant temperature
4) Adiabatic : No heat transfer

1) Isobaric :

- add heat



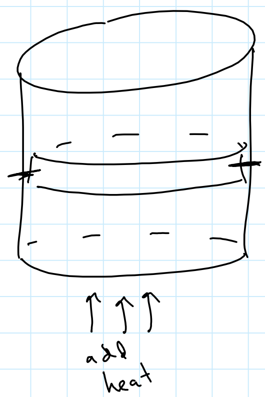
- add heat
- gas expands



$$\text{work} = F \times \text{distance}$$
$$= \underbrace{(PA)(s)}$$
$$= P\,\Delta V$$

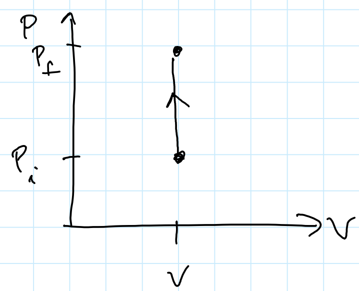
$As = \Delta V$ change in volume

2) Isochoric



Lock it in place

Volume is fixed

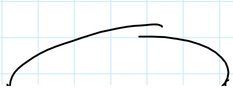


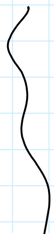
$W = 0$

Isothermal vs adiabatic

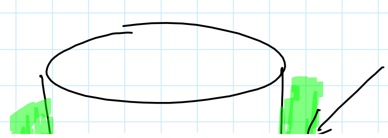
constant temp

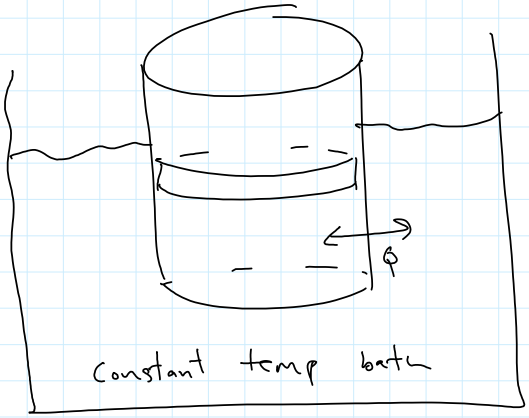
No heat transfer

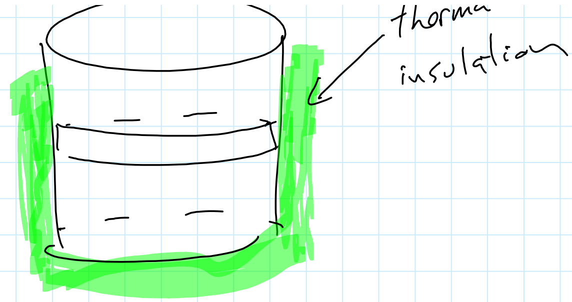




thermal insulation







$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$W = \frac{3}{2} nR(T_i - T_f)$$

monatomic ideal gas

Thermodynamics

Zeroth Law → we can take temp of objects

1st Law → conservation of energy

$$\Delta U = Q - W_{\text{By the gas}}$$

Q = heat $\begin{cases} >0 & \text{system gains heat} \\ <0 & \text{system loses heat} \end{cases}$

W = work $\begin{cases} >0 & \text{system does work} \\ <0 & \text{'' has work done on it} \end{cases}$

OR

$$\Delta U = Q + W_{\text{ON the gas}}$$

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examples of +/− work and heat:

① 1500 J of heat is added to system | 2200 J of work done by the system | change in internal energy of system (ΔU)

$Q = +1500$ J | $W = +2200$ J | $\Delta U = Q - W$

$= 1500 - 2200$

$= -700\ J$

(2)

1000 J
heat added
to system

$Q = +1000\ J$

800 J
work done
on the
system

$W = -800\ J$

ΔU

$\Delta U = 1000 - (-800)$
$= 1800\ J$

(3)

1200 J
heat removed
from system

$Q = -1200\ J$

1500 J
work done on
system

$W = -1500\ J$

ΔU

$\Delta U = -1200 - (-1500)$
$= +300\ J$

(4)

900 J
heat removed

$Q = -900\ J$

600 J
work done
by system

$W = +600\ J$

ΔU

$\Delta U = -900 - 600$
$= -1500\ J$