<u>Today</u>

I.    Days that we'll be taking a break: no class Wed Nov 25th, or Fri Nov 27th.

II.   Upcoming exam, a week from this Friday, on Nov 6th.

III.  Last Time

IV.   Heat

V.    Heat Capacity

VI.   Inexact Differentials and Path Dependence


I.    Yanpei Deng this week due to exam (will help in the lab. She's available M from 7-8pm in Brody lab).

This week: Antu Antu will be providing homework support. Hours are: Tu 8-9pm, Th 8-9pm.

III. We discussed the number of degrees of freedom of molecules

e.g. Diatomic molecule: 2 rotational degrees of freedom, 3 translational degrees of freedom, at higher temperatures we gain 2 more degrees of freedom, 1 motional and 1 potential.

We also introduced the notion of equipartition:

$$U = \frac{f}{2}NkT.$$

Started to distinguish heat and temperature: Temperature is a measure of the average motional energy, heat is a notion of energy in transit, in particular energy that is transferred because of a difference in temperature. We also had a notion of doing work on a system and putting them together…

III. We also had a notion of doing work on a system and putting them together we have a thermodynamical statement of the conservation of energy:

Both process dependent quantities.
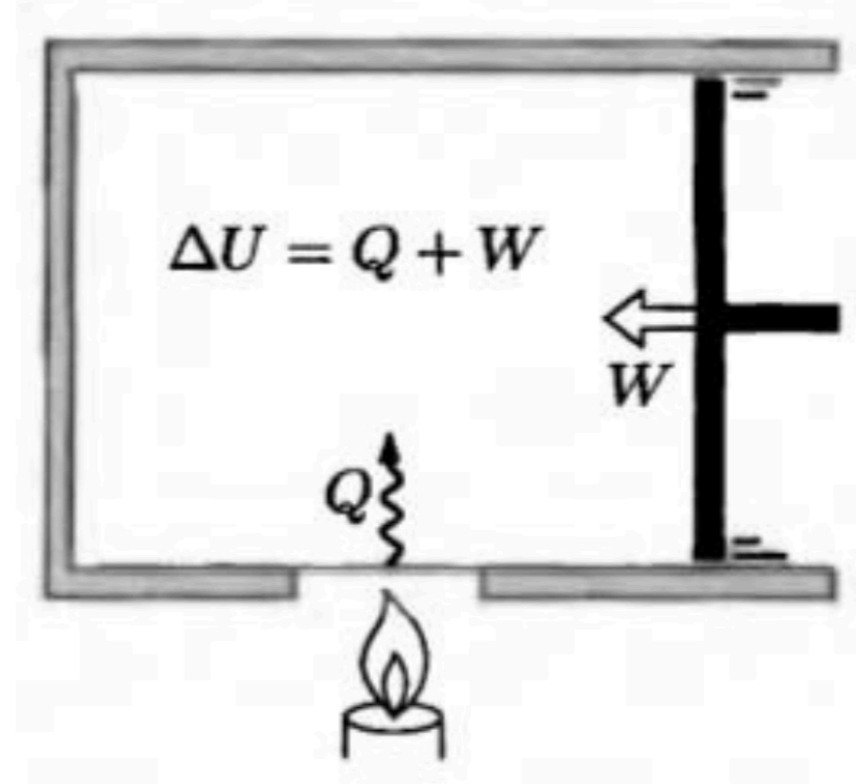
$$\Delta U = W + Q.$$

We adopt a set of conventions here $W > 0$ when it is being done on the gas, and $Q > 0$ when the energy is transferred into the system.

IV. Heat Capacity:

(1) How much heat ($Q$) does it take to raise the temperature of a sample by $\Delta T$?

$$\Delta U = Q + W$$

$Q = C\Delta T$, where $C =$ ``heat capacity'':

(i) how much stuff (ii) what stuff is it, (iii) how you did it (is work done?)

## IV. Heat Capacity:

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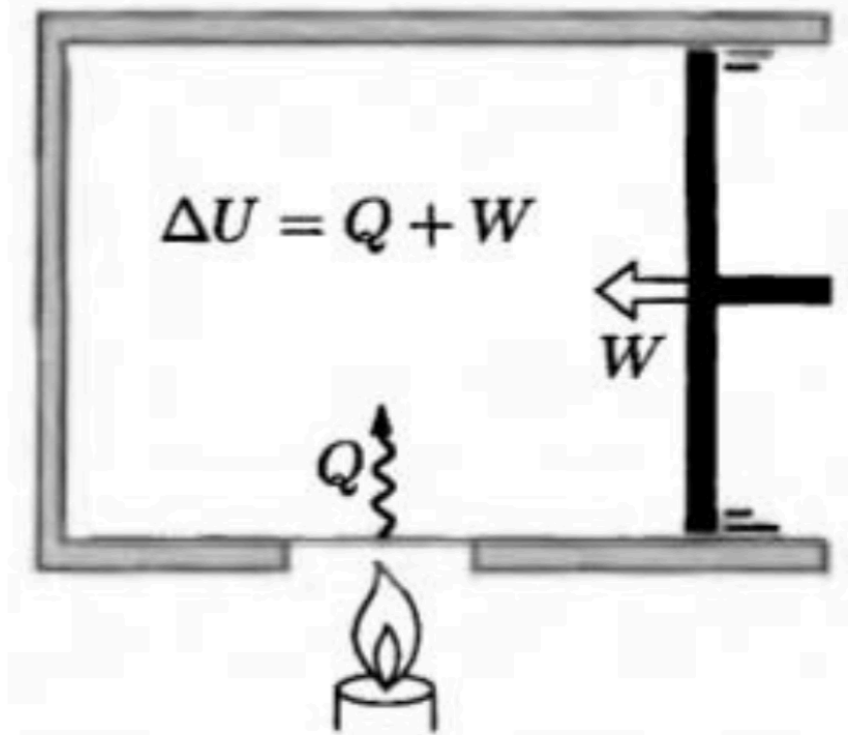(i) how much stuff (ii) what stuff is it, (iii) how you did it (is work done?)

We capture (i) with the "specific heat" c

$C = cm$,

here $m$ is the mass of your sample. Here and in other contexts "specific" means per unit mass.

$$\Delta U = Q + W$$

(3) Calorie: 1 calorie = amount of heat it takes to heat 1g of water by $1°C = 1$ K, i.e. $\quad C_{\text{water}} = 1\dfrac{\text{cal}}{\text{g°C}} \quad$ $\boxed{1 \text{ cal} = 4.184 \text{ J}}$

IV. <u>Heat Capacity</u>:

[Note: 1 food calorie, sometimes Cal, Cal=1,000 cal = 1kcal.]

In practice, we often also have to specify the conditions under which the heat was added, for example, the volume was held fixed while the heat was added

$C_V$ is the heat capacity at constant volume

$C_P$, the heat capacity at fixed pressure

V. Long aside on mathematics and notation. Let's teturn to our observation that the first law had a $\Delta$ on one side, but nothing on the other. What does this mean? What's going on?

$\Delta U = U_f - U_i$, but notice that we can never write something like $\Delta Q$! Why not? $\Delta Q = Q_f - Q_i$ Well, $Q$ by itself already represented a transfer; it's hard to say what you would mean by a change of that. There is no $Q$ at one moment, e.g. I or f.

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Let's setup an unfair footrace with Jade running once across the room and Antonio running thrice across the room. The distance that Jade ran is

**Fundamental Theorem of Integral Calculus (FTIC)**

$$d_{net} = \int_{x_i}^{x_f} dx = (x_f - x_i) \qquad d_{Antonio,net} = \int_{\text{the path } \gamma} |dx| = 3(x_f - x_i)$$

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inexact differential. Notice that this illustrates that the 1st law of thermodynamics is amazing(!): two process-dependent quantities add up to a process-independent quantity

$$dU = đQ + đW.$$

$$\text{E.g.} : \text{const } P \rightsquigarrow W = \int -PdV = -P\int_{V_i}^{V_f} dV = -P(V_f - V_i)$$

$$\text{const } T \rightsquigarrow W = \int -PdV = -\int \frac{NkT}{V}dV = -NkT\int_{V_i}^{V_f} \frac{1}{V}dV = -NkT \ln \frac{V_f}{V_i}$$