

Outline

- I Last time
- II Heat capacity of Gases
- III Inexact differentials and path dependence
- IV Return to heat capacity of gases
- V What is adiabatic?

- $\Delta Q = \Delta U + \Delta W$
- $\Delta Q = C \Delta T = c m \Delta T$

↳ Solids & liquids

(i) mass measures how much stuff
 (ii) how heated irrelevant because there is little expansion
 Hence heat exchange completely determined by $c = \text{specific heat}$

Modern
 Day 18

P/4
 I Expanding gas
 $dW = P dV$

• At temp. T each d.o.f gets $\frac{1}{2} kT$ of energy

- $U = N \frac{1}{2} kT = \frac{1}{2} nRT$

II Measure amount in terms of moles
 $C = \begin{cases} nC_v & (\text{constant volume}) \\ nC_p & (\text{constant pressure}) \end{cases}$
 with $C_v (C_p)$ "molar heat capacity at constant volume (pressure)"

III [Aside on notational lies:
 $\Delta U = U_f - U_i$
 but $\Delta Q \neq Q_f - Q_i$

What is going on? Let's have a footrace — two volunteers. Alice run from podium to wall, Bob you run from podium to wall back to podium and back to wall. Go!

Unfair race. Why?

Who travelled a greater net distance? Neither
 Who travelled a greater total distance? Bob.

$$d_{net} = \int_{x_i}^{x_f} dx = (x_f - x_i)$$

of Fundamental theorem of calculus

$$d_{tot} \neq \int_{x_i}^{x_f} dx \text{ instead}$$

$$d_{tot} = \int_{\text{path}} |dx|$$

This integral depends on the path that you take, e.g. on how we told Bob to run,

So, in some instances $\frac{P}{4}$ the path you take matters. If we want to know the distance from podium to wall it doesn't, but if we want ^{to travel} less total distance it does.

How does this show up in the mathematics?

and there is no way to calculate its value unless you know the details of the path.

In particular, you cannot use the fundamental thm. of calculus for such paths.

When we want to emphasize that a quantity is small

of the system. For $P \propto \frac{1}{V}$ example, in an ideal gas

$$U = \frac{3}{2} NkT$$

and we can calculate U directly from the current temperature without any knowledge of the history of how it got there.

Hence we write dU and say this is an exact differential.

$$dQ_p \equiv n C_p dT$$

Setting these two equal gives,

$$C_p = C_v + R$$

But, by equipartition we also

$$U = \frac{1}{2} nRT \Rightarrow dU = n C_v dT = \frac{1}{2} nR dT$$

$$\Rightarrow C_v = \frac{1}{2} R \quad \text{and} \quad C_p = \left(\frac{1}{2} + 1\right) R$$

but also that calculating sums of that quantity depends on the path you take we use the δ symbol, e.g.

δQ and δW and say that these are inexact differentials. Conversely, if you want to check if something is exact you ask whether you can compute it directly from knowing the current configuration

IV So we now know we should write

$$\delta Q = dU + \delta W = dU + P dV$$

Constant volume: $\delta Q_v = dU = n C_v dT$

Constant pressure: $\delta Q_p = dU + P dV$
 $\rightarrow n C_v dT + n R dT = n C_p dT + n R dT$
 always true since it only depends on state.

On the other hand we also have

Examples:

Monatomic: $d=3$, so $C_v = \frac{3}{2}R$, $C_p = \frac{5}{2}R$

Diatomic:
(rotational but no vibrational)
 $d=5$, $C_v = \frac{5}{2}R$, $C_p = \frac{7}{2}R$

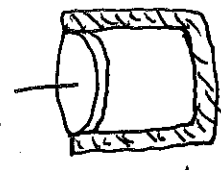
Polyatomic:
(no vibration)
 $d=6$, $C_v = 3R$, $C_p = 4R$

V We use a cooler to keep our drinks cold.

Adiabatic means: no heat in or out.

Question: How are P and

V related during an adiabatic expansion?



Thermal insulation