CHEM 6B WI24 F02-F06

Week 3: work and heat

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State function

- Definition: a property whose value doesn't depend on the path taken to reach that specific value.
  - Examples: energy E, volume V, temperature T, pressure P, number of particles n, entropy S
  - Counterexamples: work W, heat Q

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  - Examples: energy E, volume V, temperature T, pressure P, number of particles n, entropy S
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- Intuitively, imagine the following scenario: during weekdays, you will come to campus to take courses.
  - You can commute between two locations by car, bike, walk, and by different path.
  - **Location** is a state function, independent from path you take.
    9500 Gilman Dr, La Jolla, CA 92093.
  - **Way & path to commute** is not a state function.

Energy change of a system

- Energy change of a system equals to the work done on the system ΔW and heat ΔQ absorb by the system.

$$\Delta E = \Delta W + \Delta Q \tag{1}$$

- For an ideal gas system, one has $\Delta W = -P\Delta V$ and $\Delta Q = C\Delta T$, where C is the heat capacity at constant volume.

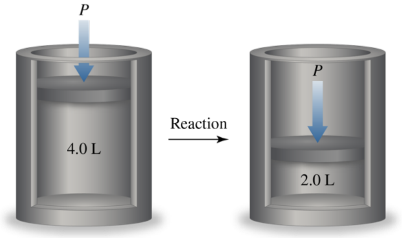
$$\Delta E = \underbrace{-P\Delta V}_{\Delta W} + \underbrace{C\Delta T}_{\Delta Q} \tag{2}$$

Sign of energy/work/heat change

- If $\Delta E/\Delta W/\Delta Q > 0$, the system gain energy/work/heat from the outside.
- If $\Delta E/\Delta W/\Delta Q < 0$, the system lose energy/work/heat to the outside.
- Recall $\Delta W = -P\Delta V$

Week 3, problem 4

4. A chemical process occurs at constant temperature and pressure within the cylinder.



a. The sign of the work based on the change in volume of the cylinder after the reaction is ____________________ (positive, negative).

b. Work is done ________ (on, by) the system.

Temperature change caused by heat transfer

Heat capacity

- Recall $\Delta Q = C\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{C}$.
- Exercise: let the heat capacity of a $10\,\mathrm{g}$ substance be $C = 10\,\mathrm{J}\cdot\mathrm{K}^{-1}$.
  - How would the temperature change if this substance gain $100\,\mathrm{J}$ heat?
  - How would the temperature change if this substance lose $100\,\mathrm{J}$ heat?

Temperature change caused by heat transfer

Specific heat capacity

- Now define specific heat capacity by $c = C/m \Leftrightarrow C = mc$, where m is the mass of the substance. The physical meaning is the heat absorbed per unit mass.
- From $\Delta Q = C\Delta T$ one can then derive

$$\Delta Q = C\Delta T \Rightarrow \Delta Q = mc\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{mc} \tag{3}$$

- Exercise: let the specific heat capacitiy of a substance be $c = 5\,\mathrm{J} \cdot \mathrm{g}^{-1} \cdot \mathrm{K}^{-1}$
  - How would the temperature change if 10 gram of such substance absorbs $1000\,\mathrm{J}$ heat?

Week 3, problem 5

5. The specific heat capacities for several substances are shown in the table.

Substance	Specific Heat (J/g·°C)
copper	0.39
methane	2.19
ethanol	2.44
glass	0.84

If equal masses of each substance absorb the same amount of heat, which substance undergoes the greatest temperature change? Why?

Week 3, problem 6

6. The gas inside a cylinder expands against a constant external pressure of 1.00 atm from a volume of 5.00 L to a volume of 13.00 L. In doing so, it turns a paddle immersed in 1.00 L of water. Calculate the temperature rise of the water, assuming no loss of heat to the surroundings or frictional losses in the mechanism. The density of water is 1.00 g mL^{-1} and its specific heat is 4.18 J K^{-1} g^{-1}.