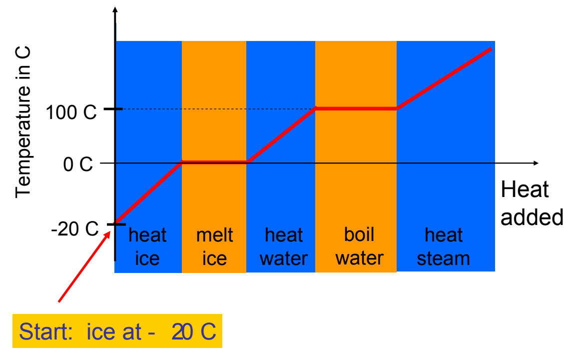
Thermodynamics [4]

- Change of phase (ice → water → steam)
- heat, work, and internal energy
- the 1st law of thermodynamics
- the 2nd law of thermodynamics
- order to disorder → entropy

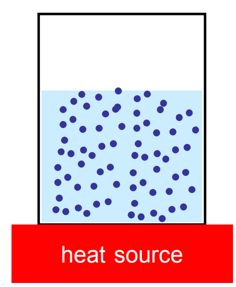
Change of Phase



Temperature is not the whole story!

- The temperature at which water boils is 212 F at **sea level**
- At higher altitudes where the pressure is lower, water boils at a lower temperature
  - at 5000 ft it boils at 203 F
  - at 7200 ft it boils at 199 F
- if we increase the pressure above atmospheric pressure, water is harder to boil
- some recipes have high altitude instructions

Boiling water

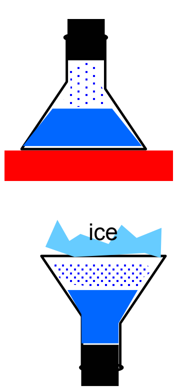


Energy is required to remove molecules from a liquid.

The buildup of pressure inhibits molecules from leaving the liquid.

A pressure cooker cooks food at a temp above the boiling point

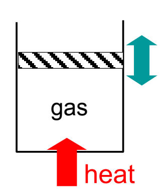
boiling water with ice!



- as the water boils, the pressure builds up
- by cooling the water vapor, the water can be made to boil
- you can freeze water by lowering the pressure above it→ freeze drying

Heat, work, and internal energy

- The gas has internal energy, as indicated by its temperature
- if heat is added its internal energy increases
- if the gas expands and does work on the atmosphere, its internal energy decreases
- the 1st law of thermodynamics keeps track of the balance between the heat, work and internal energy of the gas



the first law of thermodynamics

- the change in internal energy of the gas

  = the heat **absorbed** by the gas

  minus the work done **by** the gas

- this is a simple energy accounting principle

Analogy to your bank account

- the **change** in your bank account balance

  = deposits ($ in) - withdrawals ($ out)

- the same conservation principle applies to energy transfers➔ 1st Law of Thermo.

work done by or on a gas

- if a gas does work (expands) its internal energy goes down and so does its temp.
- if work is done on a gas (compressed) its internal energy goes up and so does its temperature
- the internal energy of a gas can be changed by adding or taking away heat or by having the gas do work or doing work on the gas

Change in internal energy	HEAT	WORK
increase	in	0
increase	0	on gas
decrease	out	0
decrease	0	by gas
increase	in	on gas
decrease	out	by gas

all quantities measured in Joules or Calories

EXAMPLE

- What is the change in the internal energy of a gas if 3000 J of heat are added while the gas does 1000 J of work?
- change in internal energy

  = Heat in - work done

  = 3000 J - 1000 J = 2000 J

Heat engines

- A heat engine is a device that uses heat (input, which you must pay for in some form) to do work (output which is useful).
- A central issue is how much of the heat taken in can be converted into work
- The outcome is first of all limited by the 1st law (you can't get more out than goes in)

The 2nd Law of Thermodynamics

- Not all of the heat can be converted into work.
- try to understand the difference between work energy and heat energy
- give the block a push– it will stop due to friction
- the kinetic energy is converted to HEAT
- but, I cannot make the block move by heating it!

Heat – disordered energy

- When an object is heated, the energy of all of its molecules is increased.
- however, the molecules do not all move in the same direction → they move about in all directions → this is what we mean by disordered energy
- on the other hand if we want to get the system to do some work, we want it to move in some particular direction

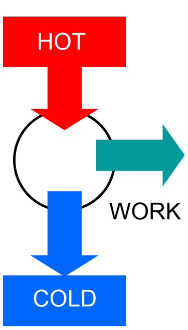
order to disorder

- All naturally occurring processes go in the direction from order to disorder
- for example: ice always melts
- ice, the solid state of H_2O is more ordered than water, the liquid state
- in a solid all the molecules are lined up in a regular (ordered) array
- There is far less order in the liquid state

Work is ordered energy, heat is not

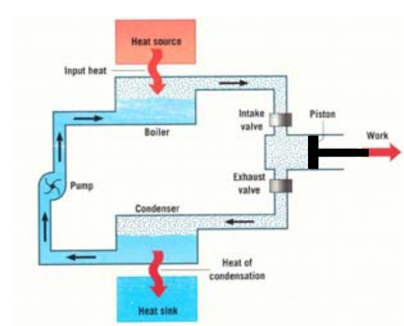
- It is possible to tap some of the random energy to do useful work
- when a gas is allowed to expand, some of its random thermal energy is converted into work
- **the 2nd law explicitly prohibits all of the heat from being converted into work**
- this is just a fact of nature- the way things work!

Heat Engines

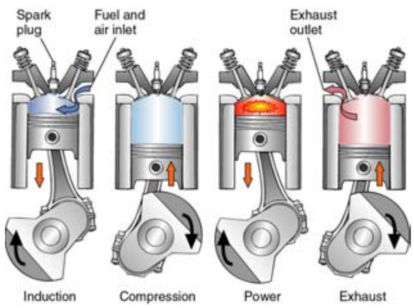


- an engine operates in a **cycle**
- fuel is burned to make heat
- some of the heat is converted into work
- the heat that is not converted to work is removed to bring the system back to the beginning state

heat engine



internal combustion engine



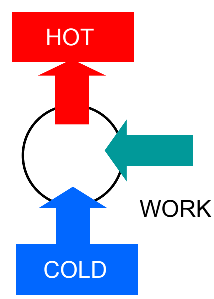
1st and 2nd Laws of Thermodynamics

- the 1st law requires that
  work out = heat in – heat out
- the 2nd law says that it is impossible to make the heat out = 0, not all the heat energy can be converted into work, some must be discarded – *thermal waste*
- engine efficiency = work out / heat in
- no engine can be 100% efficient

Order/disorder statement of the 2nd Law of Thermodynamics

- the total disorder of an object is quantified in a parameter called ENTROPY
- in terms of entropy the 2nd law states that the entropy of an isolated object never decreases – entropy either stays the same or increases

refrigerators and air conditioners



- Heat engines in reverse
- You can make heat flow backward (cold to hot) only if there is an input of work
- in an air conditioner or refrigerator, this work must be supplied by electricity.