P. Chem I　　　Lecture 6　　　2/6/23

Heat $\rightleftarrows$ Work
→ internal combustion engine
← A.C, refrigerator

Focus on

① Unlimited conversion (repeated)
② efficiency

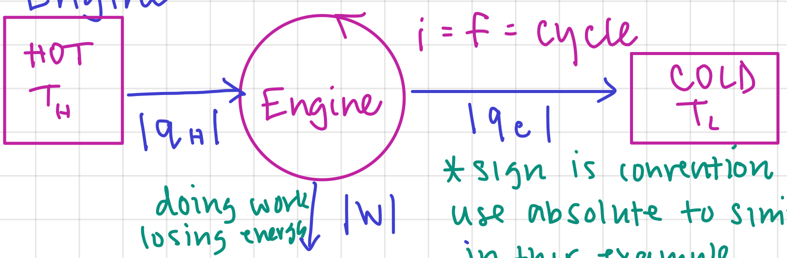
turning work into heat: work → heat ① ✓ ② 100% ✓ (both met)

heat → work　Isothermal expansion of gas
$q + w = 0 = \Delta U \Rightarrow w = -q$ (100% conversion)

system (gas) has changed because it expanded.

we really want unlimited conversion
sacrifice 100% efficiency

Heat Engine



* sign is convention
use absolute to simplify
in this example
arrows tell us direction
of energy flow

* assume T doesn't change
bc COLD & HOT is so big it
doesn't change
(like 2nd page of HW)

T_H, T_c don't change
temperature

1st Law: $\Delta U = 0$ (bc going in cycle)
implies in = out $\Rightarrow$ $|q_H| = |w| + |q_c|$　conservation of energy statement

Thermal Efficiency $\Rightarrow$ $\eta = \frac{|w|}{|q|}$

* you get most work out of reversible conditions (theoretical limit, bc not really possible) key point of ch 19

η_{max} = rev. conditions

Ch 20: Reversible: $\Delta S = \emptyset = \frac{|q_H|}{|T_H|} - \frac{|q_c|}{|T_c|}$
(because $S_i = S_f$)

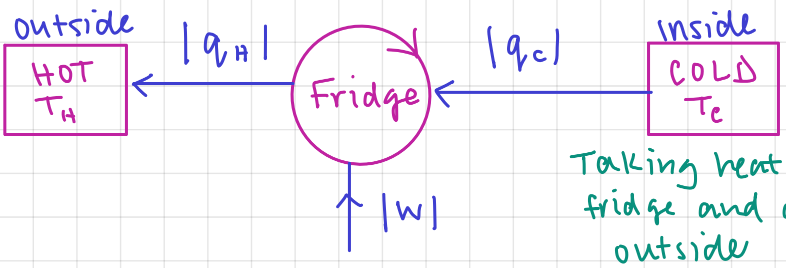
$\Rightarrow \frac{|q_H|}{T_H} = \frac{|q_c|}{T_c}$ $\quad \eta_{max} = \frac{|q_H| - |q_c|}{|q_H|} = 1 - \frac{|q_c|}{|q_H|} = 1 - \frac{|q_H|}{T_H} \cdot \frac{T_c}{|q_H|}$

$\eta_{max} = 1 - \frac{T_c}{T_H}$ Theoretical maximum
has nothing to do with actual engine, only T

When do you get max eff? T_H is big, T_c is small

Nuclear power: Turbines → steam → T_H is steam (hotter, more efficient)
T_c is enviornment

Refrigerator : Air Conditioning
(run heat engine backwards)



Taking heat out of fridge and dumping it outside

1st law: in = out $\quad |w| + |q_c| = |q_H|$
arrows going in $\quad$ arrows going out

COP = coefficient of performance

$COP = \frac{|q_c|}{|w|}$ want to extract most heat possible with minimum energy expenditure

Max efficiency : Reversible Conditions $\Delta S_{cycle} = \emptyset = \frac{|q_c|}{T_c} - \frac{|q_H|}{T_H} \Rightarrow \frac{|q_c|}{T_c} = \frac{|q_H|}{T_H}$

$$COP_{max} = \frac{|q_c|}{|q_H| - |q_c|} = \frac{|q_c|}{\frac{|q_c| \cdot T_H}{T_c} - |q_c|} = \frac{1}{\frac{T_H}{T_c} - 1} = \frac{1}{\frac{T_H}{T_c} - \frac{T_c}{T_c}} = \frac{1}{\frac{T_H - T_c}{T_c}} = \frac{T_c}{T_H - T_c}$$

$T_H = 113^\circ F$
$T_c = 68^\circ F$ $\Rightarrow COP_{max} = \frac{293}{23} = 11.7$ actual a/c typically ~2.5
so not actually efficient

* keep in mind this is unitless

Least amount of work to get max efficiency