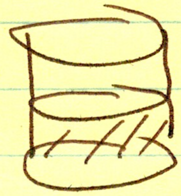
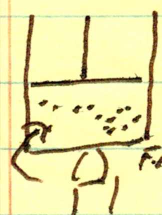
B.2 Introduction to Thermodynamics Concepts

Ideal Gas in a Piston



① Can use $PV = nRT$
② All Energy coming from Random KE of the molecules

Add heat Energy to Gas



Gas
Flame Q (Heat Energy)

① Gas Atoms speed up
- ↑ Temp ΔT
- ↑ in Internal Energy (ΔU)

② Piston can Rise (W)
- Gas does work to raise piston

(Q, W, & ΔU are All Energy)

First Law of Thermodynamics

$Q = \Delta U + W$

Add Heat Energy to System = Change in Internal Energy + Work

This is just a conservation of Energy

- All Terms can be positive or negative

$Q+$: Gas absorbs Energy — $Q-$: Gas Releases Energy
$U+$: Inc. temp of Gas — $U-$: Dec. temp of Gas
$W+$: Gas expands & does Work — $W-$: Gas Contracts Environ. does work on gas

$Q = \Delta U + W$ Rewrite $\Delta U = Q - W$

Internal Energy of an Ideal Gas

- Think Temperature in K (Kelvin)

$U = \Sigma KE + PE$

Internal Energy — Ideal Gass - $PE = 0$ (No Bonding)

- So Temp is the measure of Avg KE per molecule

For an ideal gas: $U \propto T$

Internal Energy will Vary to Temp (K)

Applies to monotomic or noble gases

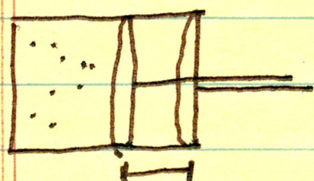
IB Eqn $U = \frac{3}{2} nRT$

so.

$\Delta U = \frac{3}{2} nR(T_f - T_I)$

U - Internal Energy
n - number of moles in a gas
R - Universal gas constant 8.31 J/mol K
T - Temp in Kelvin

Work done by a gas @ Constant Pressure



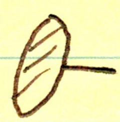
Δx

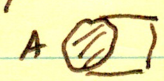
(1) Need to know Pressure = $\frac{Force}{Area}$ or $F = PA$

(2) since $W = F \times d$
$P(A \Delta x)$

(3) $W = P\Delta V$

Area is Front of cylinder





A $\cdot \Delta x$ = Volume

Heat Added

$Q = mc\Delta T$ (Temp Change)

$Q = mL$ (Phase Change)

(Heat of Fusion or Heat of Vaporization)

4 Processes with Gases & Cylinders

① **Adiabatic** No Heat Flow $Q = 0$

① Use an Insulated Container & Piston
System is thermally isolated

② Move piston fast
Heat takes time to flow

$\Delta U = \cancel{Q}^{0} - W$ so $\Delta U = -W$

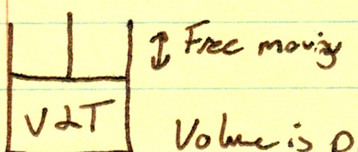
If we compress the gas $(-W)$ then ↑ Temp $(+U)$

② **Isochoric** Hold constant Volume / Not move piston
If you do not move the piston $W = 0$

$\Delta U = Q - \cancel{W}$ $\Delta U = Q$

If you add heat to gas $(Q+)$ → ↑ Temp $(+U)$

③ **Isobaric** Constant Pressure
Use a Free moving piston $\Delta U = Q - P\Delta V$



Volume is proportional to Temp. in Kelvin (2x Vol → 2x Temp)

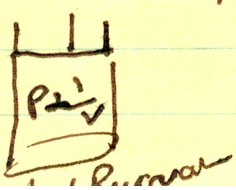
④ **Isothermic** (Constant Temperature) $\Delta U = 0$
Move piston slowly $\cancel{\Delta U}^{0} = Q - W$

$\boxed{Q = W}$

~~As the gas expands & does work (W+) → Gas absorbs Energy~~ (+Q)

Work done = Heat Added

Temp Constant



Pressure will vary with $\frac{1}{\text{volume}}$ 2x Press → $\frac{1}{2}$ Vol.

Q1: An ideal gas expands isothermally, doing 2500 J of external work in the process. The thermal energy absorbed by the gas is:

Time 15:21

a) zero
b) < 2500 J
c) = 2500 J
d) > 2500 J

Isothermal Constant Temp → $\Delta U = 0$

So $Q = W$ (Work = Heat Added)

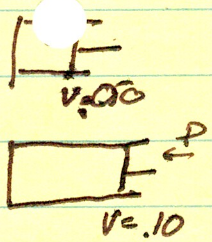
$Q = 2500\ J$ Choice C

Q2. An ideal Gas is held in a Container by a moveable piston and thermal energy is supplied to the gas such that it expands at a constant pressure of 1.2×10^5 PA.

Time 15:47

The initial Volume of the container is $0.050\ m^3$ and after expansion $0.10\ m^3$. Total energy supplied by the gas is 8.0×10^3 J

$Q = 8000\ J$



$\Delta V = 0.050\ m^3$
$p = 1.2 \times 10^5$ PA

1) State if process is isothermal or ~~iso~~ adiabatic

Temp Const. $Q = W$ or No Heat Flow $Q = 0$, $\Delta U = -W$

Const. Pressure

No $PV = nRT$ — No Q is not 0 ($Q = 8000$)

So $V \propto T$ (Temp not Const in Example)

2) Determine the Work done by the gas

$W = P \Delta V$

$(1.2 \times 10^5\ PA)(0.050\ m^3) = 6000\ J$

3) Find the change in internal Energy (ΔU)

$\Delta U = Q - W$

$8000\ J - 6000\ J = 2000\ J$ inc in internal Energy

Tue 17:53

Q3. Suggest how the state of an ideal gas may be changed such that each of the conditions is met separately

$\Delta U = 0$: No change in internal Energy → No change in Temp
Constant Temp : Heat Reservoir, slow motion of piston

$W = 0$: No Compression of Gas → Constant Volume
Fixed Container

$Q = 0$: Adiabatic - No Heat flow into/out of system
Insulated Container or rapid motion of container

Tue 18:50

Q4 Work done by an ideal gas as it expands isothermally from V_1 to V_2 is W.

Tough Problem

The work done by the gas as it expands adiabatically from the same initial state to a state of Volume V_2 is

1. 0
(2) Between 0 and W
C W
D. Greater than W