10.2 Thermodynamics

Ideal Gas - Between collisions there is no force acting on the molecules

↳ No work done to change the position of the molecules

↳ Molecules have no PE

Internal Energy of a gas (U) - Total KE of all molecules

$R = 8.31 \frac{J}{mol\,K}$ $\boxed{U = \frac{3}{2} n R T}$ $\text{Avg } KE = \frac{3}{2} kRT \times n_{(moles)} = U$

- When heat is transferred to a fixed volume of gas, internal energy and temp will increase $Q = \Delta U$

Example: 500 J of heat is transferred to 2g of He kept at a constant volume. Calculate the temperature rise of the gas

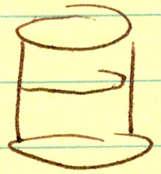
^4_2He Molar Mass of He is 4g so $n = .5$

$U = \frac{3}{2} n R T$

$500J = (3/2)(.5)(8.31)T$ $T = 12.5K$

Work done by/on a gas

$Work = P \Delta V$ U depends on Temperature

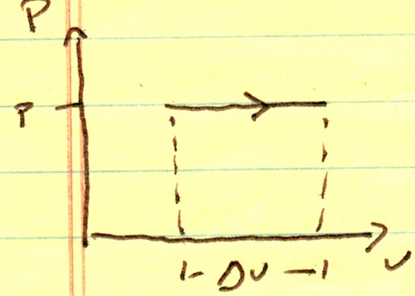


- When work is done <u>on</u> a gas, something must be pushing down on a piston & <u>compressing</u> it

~~The would generate~~

- When work is done <u>by</u> a gas, expanding the cylinder,

~~This would cause it~~



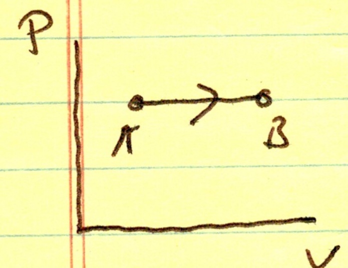
Work is given by the area under the PΔV graph

First Law of Thermodynamics

$Q = \Delta U + W$

Q - Amount of heat (Energy)
W - Work done by the gas
ΔU - Increase in internal Energy

PV Diagrams to represent states of a Gas



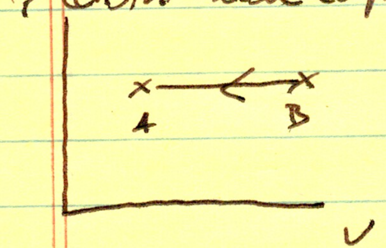
1) Volume is increasing, gas is doing work W+
2) Since T is increasing, int. Energy is inc. ΔU+

$\frac{\bar{P} V\uparrow}{T\uparrow} = \text{constant}$

3) $Q = \Delta U + W = +$ (ΔU +, W +)

Q is positive, so heat must have been added.

Constant Pressure compression (Isobaric)



1) Volume is dec., work is done on the gas W-
2) T is dec, internal energy is negative ΔU-

$\frac{\bar{P} V\downarrow}{T\downarrow} = \text{const}$

3) $Q = \Delta U + W$
$- \quad + \quad - = -$

Q is negative → heat is lost

↑V W+ ↓V W-

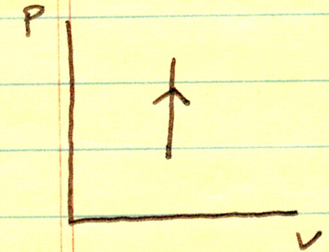
ΔVolume - Work is done by gas or on the gas

ΔTemp - Internal Energy goes up or down

↑T U+ ↓T U-

Δ pressure - Not interesting

Constant Volume, Increase Temp (isochoric)



1) Volume not changing - No Work done
2) Temp must inc. $\Delta U = +$

$\frac{PV}{T} = \text{Const.}$

First Law of Thermo.

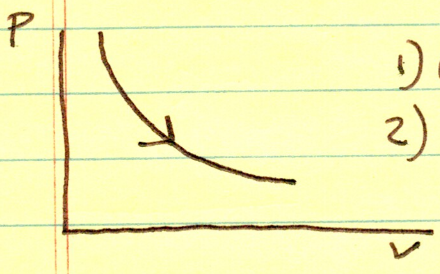
$Q = \Delta U + W$

$+ \quad + 0 = +$

Q is positive, heat has been added

Isothermal Expansion

$PV = nRT$ so if T is Const $PV = \text{Constant}$ so $P = \frac{\text{Const}}{V}$



1) Volume ↑ - Work done by gas W+ $y = \frac{k}{x}$
2) Temp doesn't Change $\Delta U = 0$

$Q = \Delta U + W$

$0 + + = +$

$Q = W$

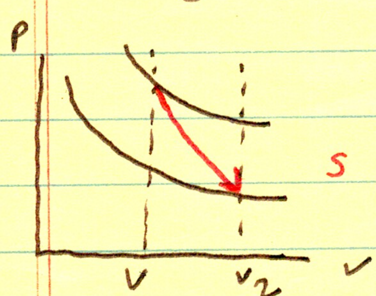
Heat ~~must have been~~ added to enable gas to do work

Adiabatic Expansion

- No Exchange of heat between system & surroundings

Isothermal - Work done by gas, internal Energy constant - heat must be added

To do the same amount of work w/out adding heat, internal Energy must go down (↓T)



1) Volume ↑ - Work done by gas W+
2) Temp ↓ - ΔU -

So

$Q = \Delta U + W$

$0 = \Delta U + W$

$W = \Delta U$

Energy required for gas to do work came from internal Energy

Adiabatic Transformation $PV^{5/3} = \text{Constant}$

Shape of curve $y = \frac{1}{x^{5/3}}$

Examples A cylinder contains 1.203×10^{-3} moles of gas

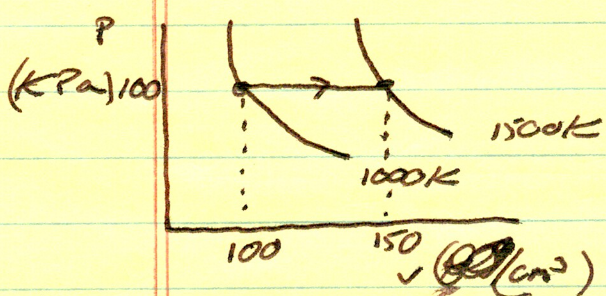
$nR = .01\ JK^{-1}$ so $\frac{PV}{T} = 10{,}000\ Pa\ cm^3 K^{-1}$

1 Joule = Pa × Volume³ in meters — or

$1m^3 = 100\ cm \times 100\ cm \times 100\ cm^3 = 1 \times 10^6$ — $10\ kPa\ cm^3 K^{-1}$

kPa

1) Isobaric Expansion - Constant Pressure



Find work done, ΔU, and Q

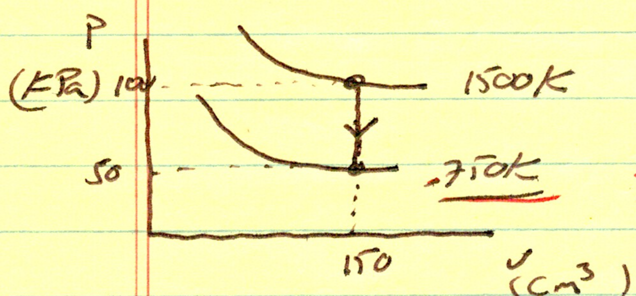
① $W = P\Delta V$ (↑V → W+)
$100{,}000\ Pa\ (50)\ (10^{-6}) = {}^{+}5\ J$
cm³ → m³

② ΔU (↑T → U+)

$\Delta U = \frac{3}{2} nR\Delta T = 1.5(.01)(500) = {}^{+}7.5\ J$

③ $Q = \Delta U + W = 7.5\ J + 5\ J = 12.5\ J$

2) Isochoric Fall



ΔT
1500K
-750K
750K

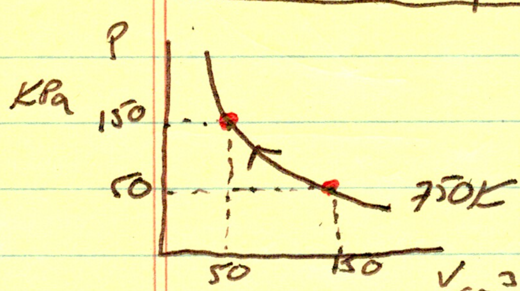
Find W, ΔU, Q

① W V No Change → W = 0

② $\Delta U = \frac{3}{2} nR\Delta T$ ↓T → U−
$1.5(.01)(750K) = -11.25$

③ Q = loss of heat 11.25 J

3) Isothermal Compression



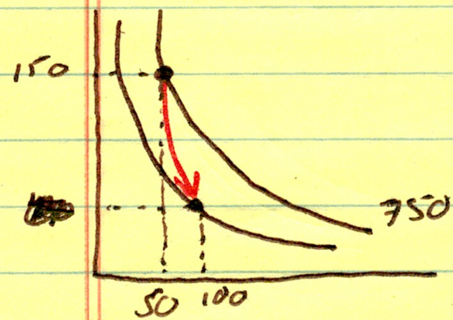
Gas is compressed 150cm³ to 50cm³

Volume ↓ 1/3 so ↑P 3x T-Const.

ΔU = 0 T-Const

W = Q = Area under curve

integral calculus



The gas pressure 150 kPa and 50 cm³ expands adiabatically until the volume is 100 cm³. Find the final temp & Pressure

Pressure

① $\frac{P_1 V_1^{5/3}}{V_2^{5/3}} = \frac{P_2 V_2^{5/3}}{V_2^{5/3}}$

$P_2 = P_1 \left(\frac{V_2}{V_1}\right)^{5/3}$

$P_2 = 150 \left(\frac{50}{100}\right)^{5/3} = 47$ kPA

Final Temp

$PV = nRT$

$47{,}000\ Pa \left(100 cm^3 \times \frac{1 m^3}{(100 cm)^3}\right) = .015 K^{-1}\ T$

(10^{-6})

$T = 470 K$

Bottom Curve is 470K