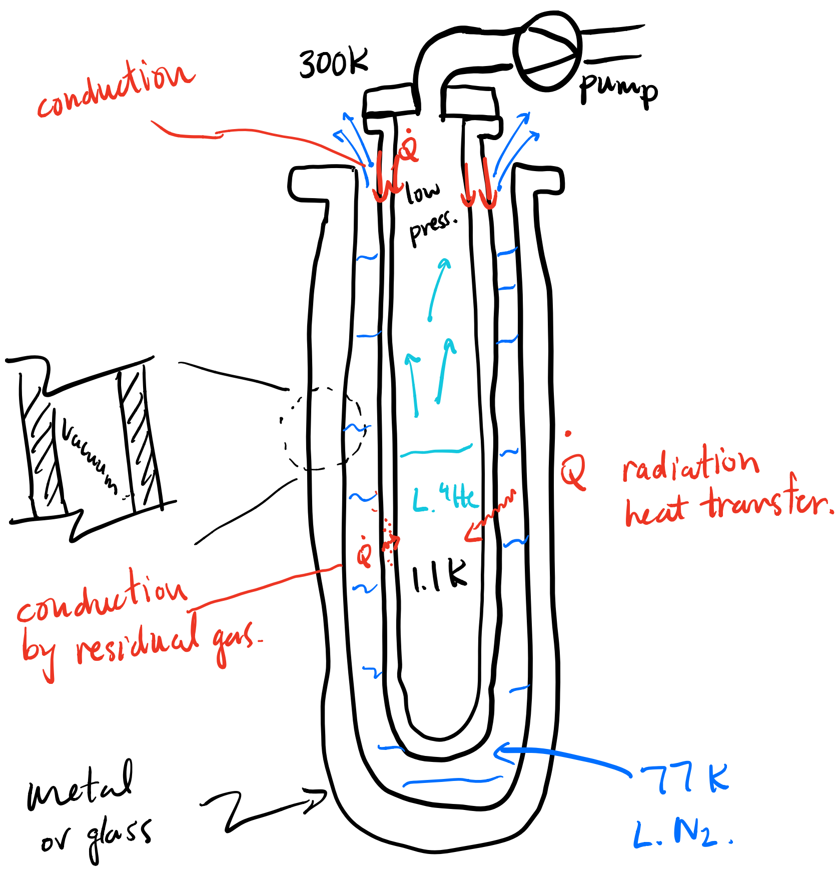
PHYS 425 - w2l3

Experimental Setup to Reach 1K using a bath of L. ^4He

$$P = Be^{-L/Nk_BT}$$



Heat load on low-temp bath:

1. Conduction through solid structor
2. Conduction by residual gas
3. Radiative heat transfer.

Cooling Power of Pumped L. ^4He Bath

heat removed per unit time $\quad \frac{dQ}{dt} = \frac{dN}{dt}\,\frac{\Delta Q}{N}$ ← heat of vaporization per particle

rate that particles converted from liquid vapour

Recall $dQ = dH$ for a const. pressure process.

$\hookrightarrow \Delta Q = \Delta H = L$

$$\dot{Q} = \frac{dQ}{dt} = \frac{dN}{dt}\,\frac{L}{N} = \frac{d}{dt}\underbrace{\left(\frac{N}{N_A}\right)}_{\equiv n \text{ no. of moles}} \frac{L}{N/N_A} = \dot{n}\,\underbrace{L_m}_{\text{molar latent heat}}$$

Usually pumps remove gas at a constant volume rate.

Eg. Pumping speed of typical mechanical pump might be 10 cfm $\simeq 300 \frac{L}{min}$

↑ cubic feet per minute

Pumping speed is usually approx const over a wide range of pressures.

For low-press. gas

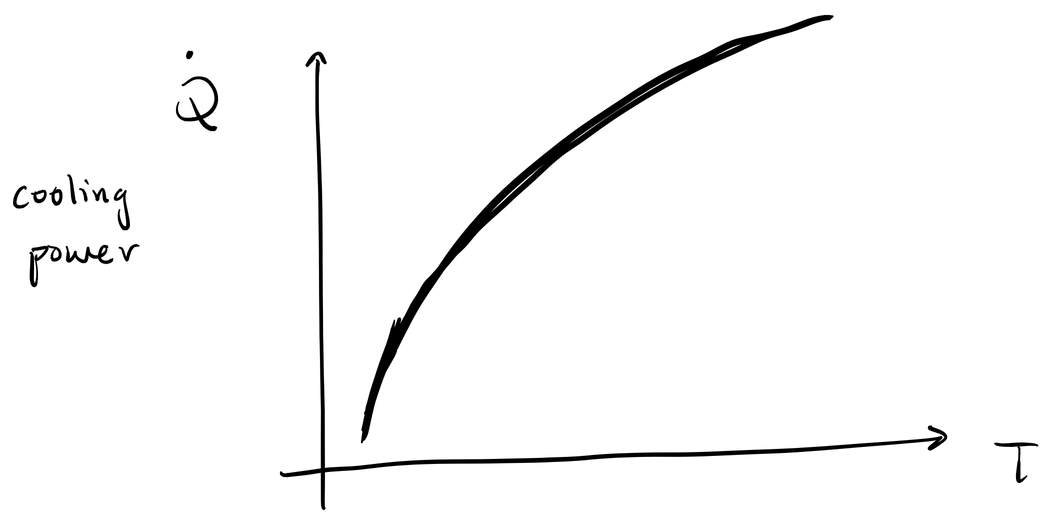
$$PV = Nk_BT$$

$$V = \frac{Nk_BT}{P} = \frac{nRT}{P}$$

If reached equil., then T & $P \approx$ const.

$$\dot{V} = \dot{n}\frac{RT}{P} \Rightarrow \dot{n} \propto P$$

$$\dot{Q} \propto PL_m \propto e^{-\frac{1}{T}}$$



Cooling power of pumped ^{4}He bath decrease rapidly as you go to lower & lower temps.

Eventually power that can be extracted from bath by evaporation is insufficient to offset heat load. $\Rightarrow$ Equil. temp is reached.

Experimental Setup to Reach ~300 mK using a bath of L. ^{3}He.

<u>Properties</u>

^{3}He	0.000137 %	^{4}He : ^{3}He
^{4}He	99.999863 %	$\simeq 7.3\times10^5 : 1$

Cost: 1 cm^3 of liquid ^{3}He $\simeq$ \$ 150

$\Rightarrow$ 1 L of liquid ^{3}He \$ 150 k

compare to 1 L of liquid ^{4}He \$ 13

^3He used in low-temp experiment comes as a result of byproduct in tritium production in nuclear reactors.

6 p+n → 3p →
$$^{6}_{3}Li + ^{1}_{0}n \Rightarrow ^{3}_{1}T + ^{4}_{2}He$$

$$^{3}_{1}T \xRightarrow{12.3y} ^{3}_{2}He + ^{0}_{-1}e + \bar{\nu}_e$$

- At one pt. amount of ^3He possessed by US government was classified info b/c it revealed how active nuclear reactors were.

- Crater seas of the moon known to be a repository of high concentrations of ^3He.

Now a "space race" to retreive ^3He from moon.

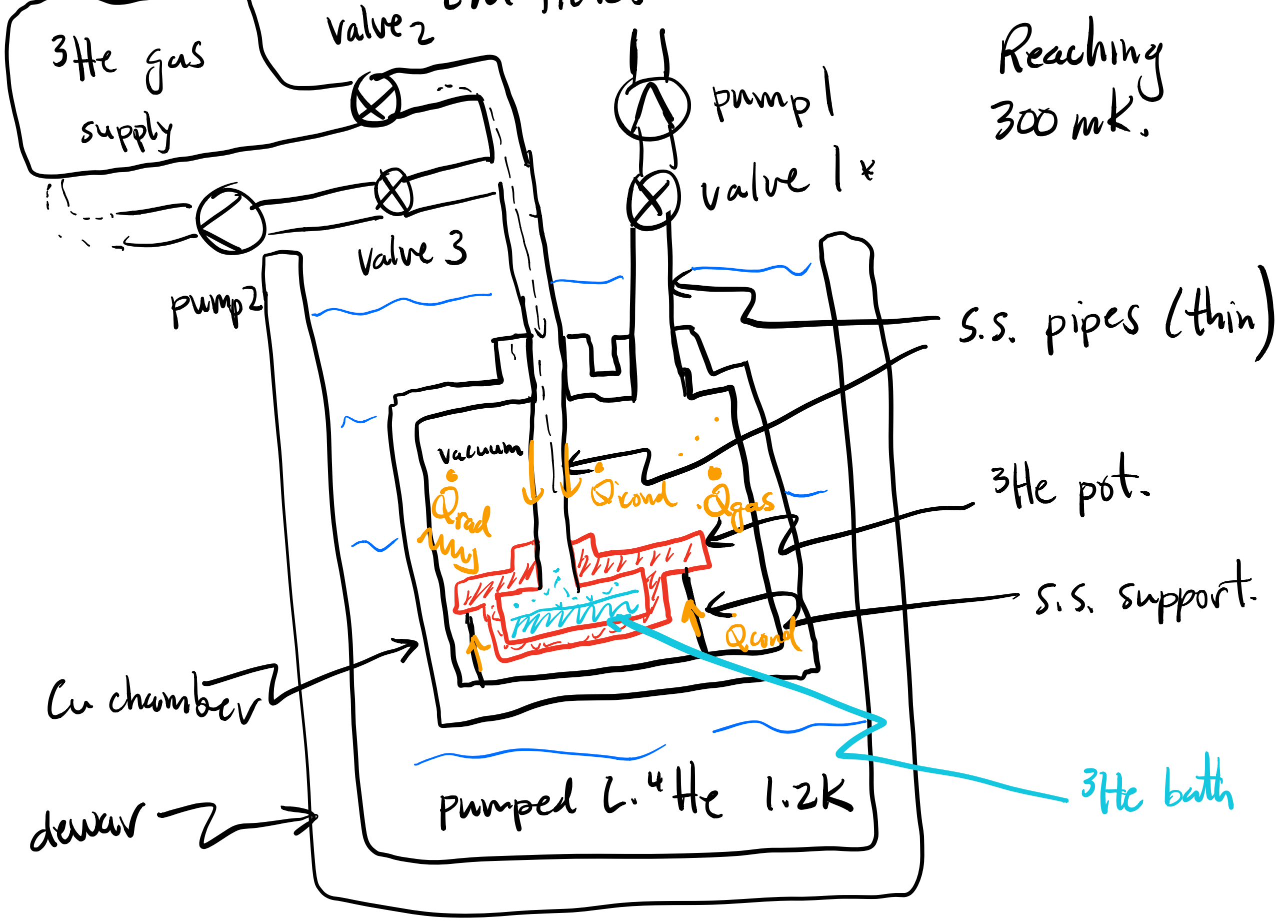
Want to use ^3He as an energy source in fusion

$$^2D + {}^3He \rightarrow {}^4He + {}^1p + \underset{\sim}{18.3\ MeV}$$

$$^3He + {}^3He \rightarrow {}^4He + 2p^1 + \underset{\sim}{12.86\ MeV}$$

Advantegous: no radioactive products
can control high-energy protons w/ EM fields

Reaching 300 mK.



① w/ valve 1 open, use pump 1 to evacuate space between 3He pot & Cu chamber

(2) Cool Cu chamber to 1.2 K using pumped L. ^4He bath.

(3) Wait for ^3He pot to cool to 1.2 K via conduction through s.s. support. Time that it takes to cool depends on heat capacity of ^3He pot & thermal resistance of s.s. support.

(4) Open valve 2 to let ^3He gas into pot. It cools to 1.2K & liquifie.

(5) Close valve 2 & open valve 3 to pump on vapour pressure above ^3He liquid. Can reach $\approx$ 300mK typically

Heat Load on ^3He pot:

(i) radiation from surrounding Cu chamber @ 1.2 K. $\dot{Q}_{rad}$

(ii) Conduction by residual gas inside Cu chamber. $\dot{Q}_{gas}$

(iii) Conduction along s.s. support & pipe $\dot{Q}_{cond.}$

Improved 300mK setup diagram