

# Topic Outline

## 2b. Vacuum Production

### Terminology

#### Pumps

Types

Summary

#### Plumbing

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Metal Gaskets

Welds

### Sample Systems

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Sample 2

Sample 3

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### Operation

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Bake Out

Steady State

Maintenance

### Materials

# Terminology

Pumping Speed (S)	L/s
Pumping Rate (Q)	mbar L/s
Leak Rate ( $Q_L$ )	mbar L/s
Outgassing Rate ( $Q_O$ )	mbar L/s

$P \dot{V} = \dot{n} R T$  therefore  $\dot{n}$  is proportional to  $P \dot{V}$

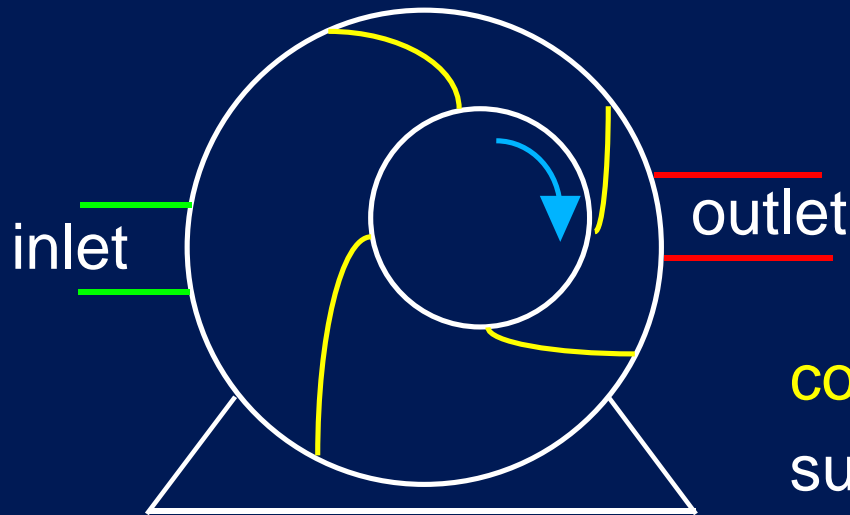
# Types

The following are the major pump types for vacuum applications.

Type	Mechanical	non-Mechanical
gas transfer	rotary turbomolecular	sorption diffusion
entrapment	cryo	ion sublimation

Gas transfer pumps remove gas permanently from the chamber, entrapment do not.

# Rotary



## pros

low maintenance

high Q

## cons

subject to wear

not UHV compatible

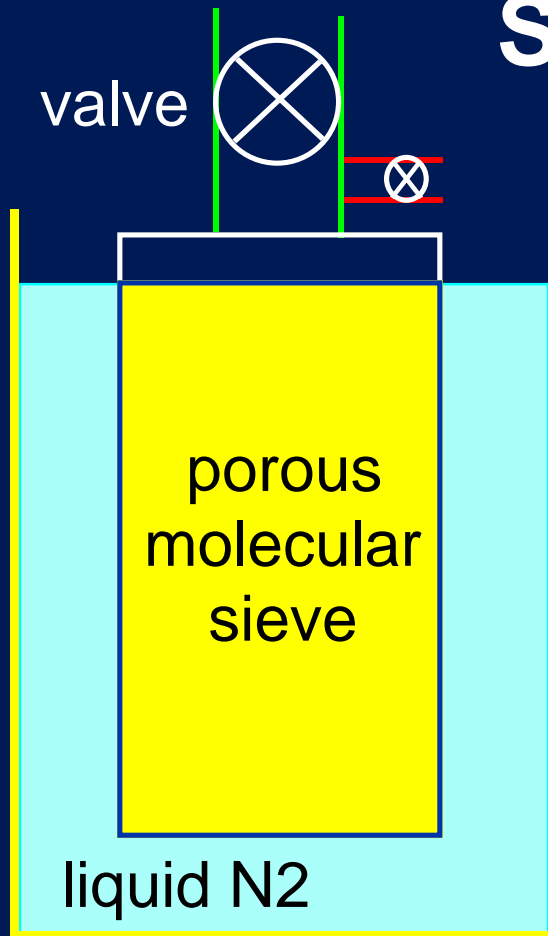
do not pump condensable  
gases well

cause vibrations

operation

$$P_i V_i = P_f V_f$$

# Sorption



## pros

- very low maintenance
- no vibrations
- clean

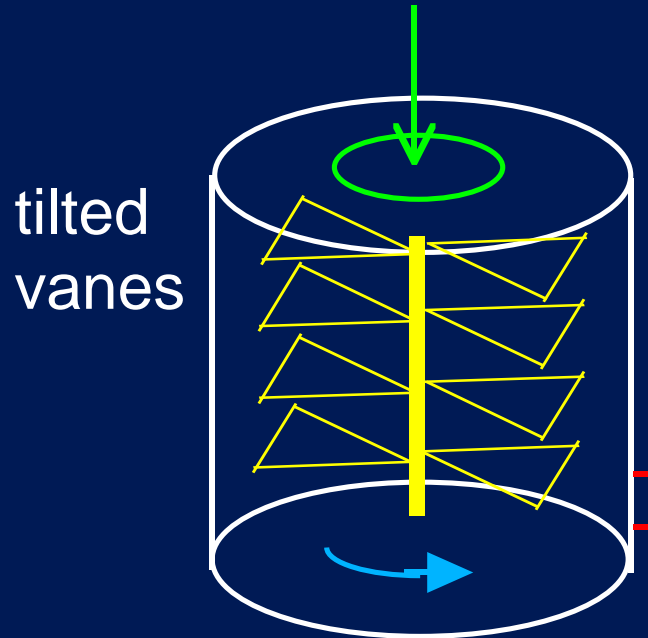
## cons

- Q depends strongly on P
- must be recharged each time
- not capable of reaching UHV

operation

molecular adsorption on large surface area (100s of  $m^2$ )

# Turbomolecular



tilted  
vanes

very high rotation rate

operation

vanes change the direction of travel of gas molecules

## pros

wide range of P

wide range of Q

S nearly constant with P

(nearly) 100% UHV compatible

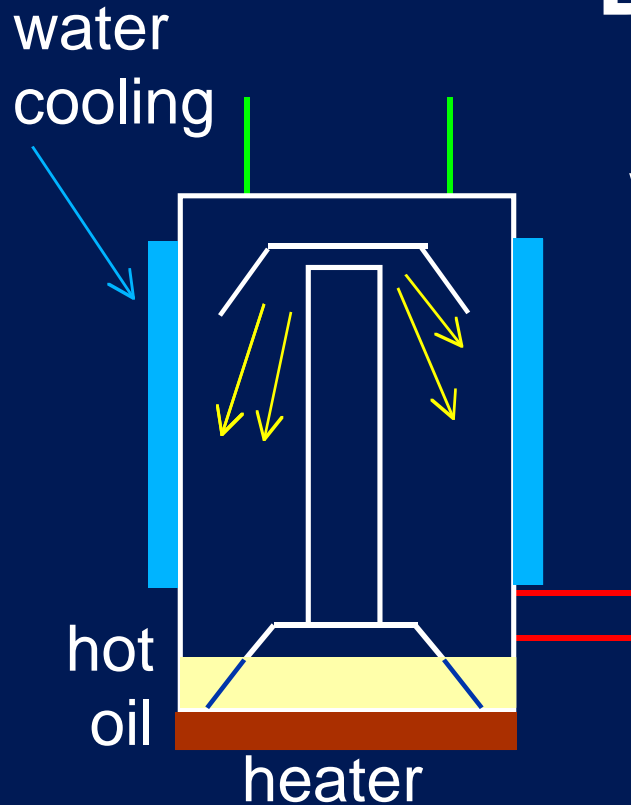
## cons

pump light gases poorly

requires additional stage

causes vibrations

# Diffusion



## pros

- wide range of  $Q$
- $S$  nearly constant with  $P$
- no vibrations
- pump light gases well

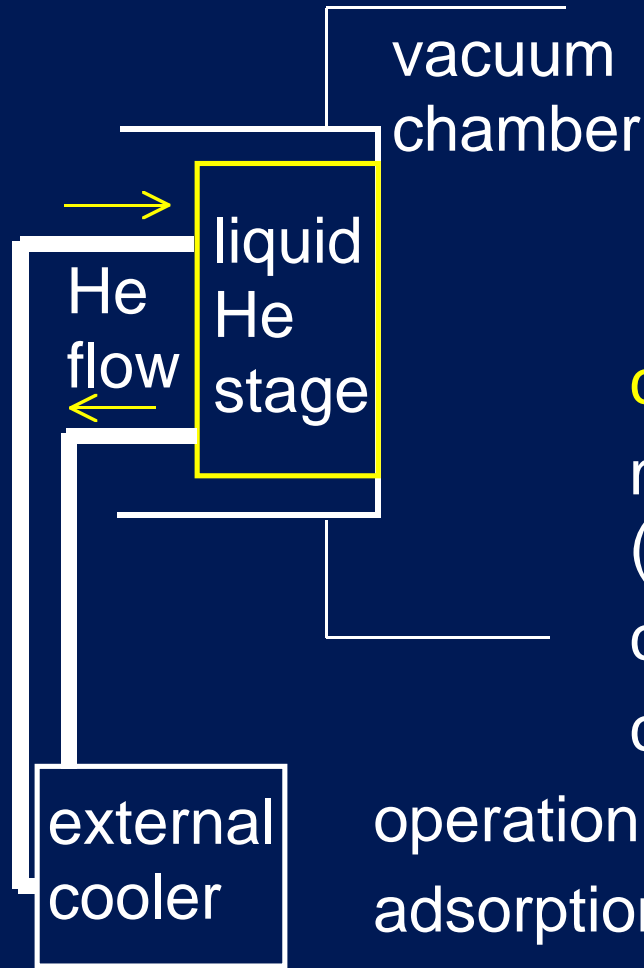
## cons

- must use liquid  $N_2$  trap to reach UHV
- requires additional stage
- high operational costs

operation

oil spray changes the momentum of gas molecules

# Cryopump



## pros

high Q

(nearly) 100 % UHV compatible

## cons

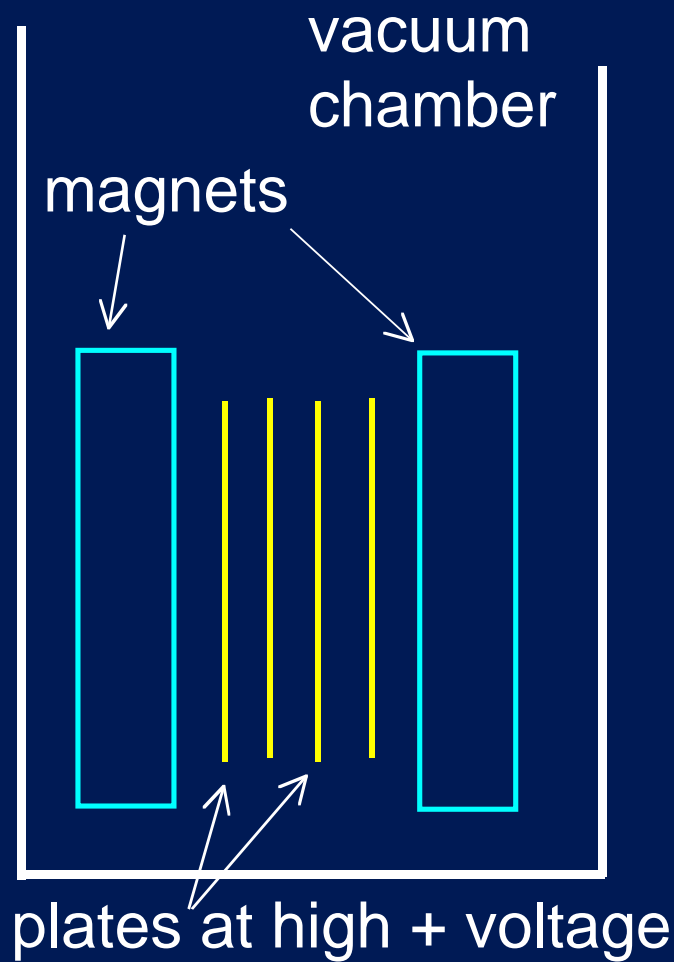
must recharge occasionally (other pumps needed)

causes vibrations

can be high maintenance

operation

adsorption of gases on the cold pump wall



# Ion

operation

B field causes gas ions to spiral into walls and imbed themselves

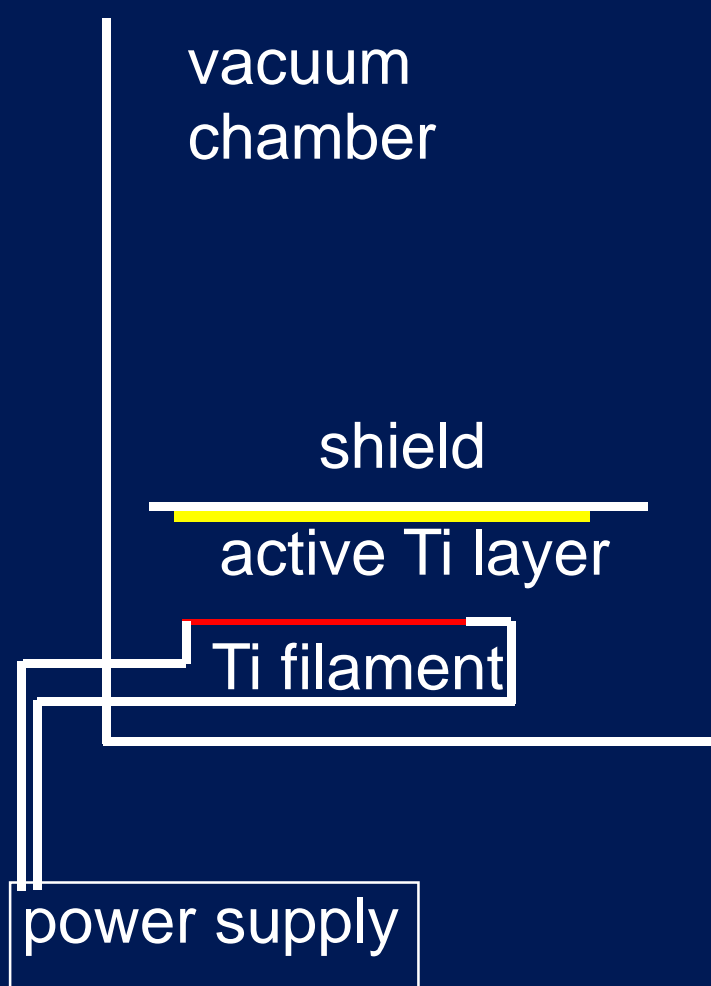
pros

wide range of Q  
wide range of P  
no vibrations

cons

magnetic field  
high voltage

# Sublimation



operation

freshly evaporated Ti  
layer actively retains  
adsorbing gas molecules

pros

no vibrations

100 % UHV compatible

cons

not continuous

low Q

narrow range of P

# Summary

Type	P range (mbar)	S (L/s)
rotary	1000 - 0.001	
sorption	1000 - $10^{-5}$	
turbo	(1000) - UHV	
diffusion	$10^{-5}$ - UHV	
ion	(1000) - UHV	
cryo	$10^{-5}$ - UHV	
sublimation	$10^{-7}$ - UHV	

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# Dimensions

These are some of the considerations we face in designing a vacuum system.

## Vacuum Chamber

provide sufficient room for the operation of the analytical techniques

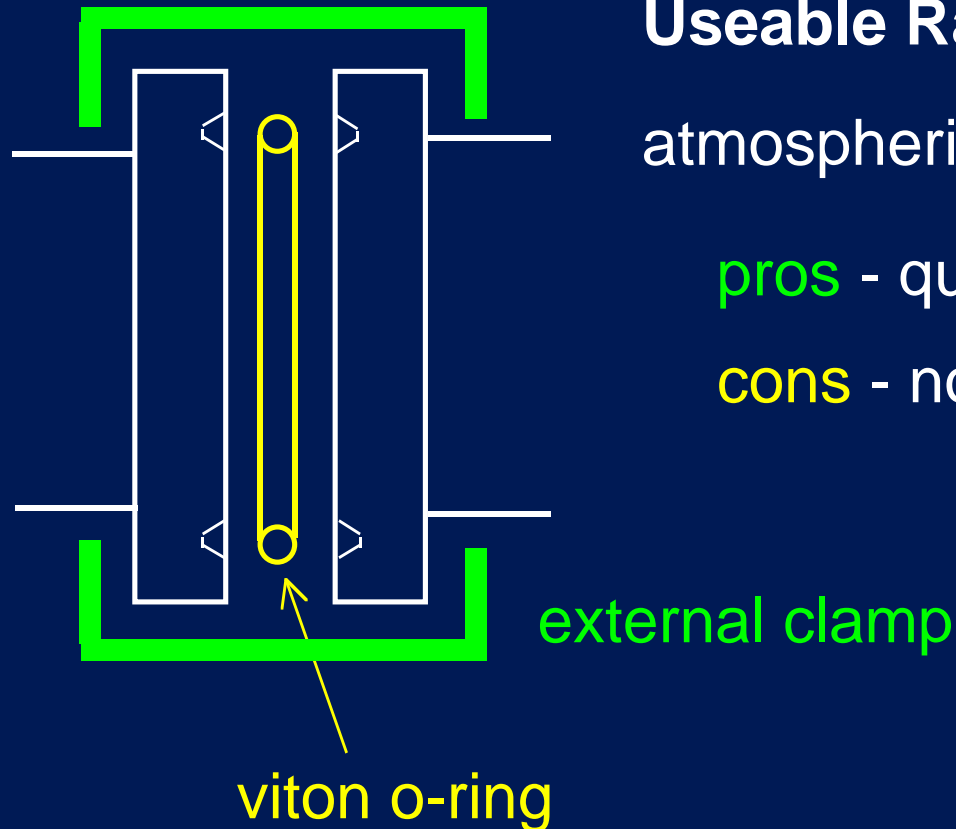
large diameters increase the conductance

## Connections

the smaller the diameter of the tube, the lower will be its conductance

large diameter metal tubing is expensive and unwieldy

# O-ring Seals



## Useable Range

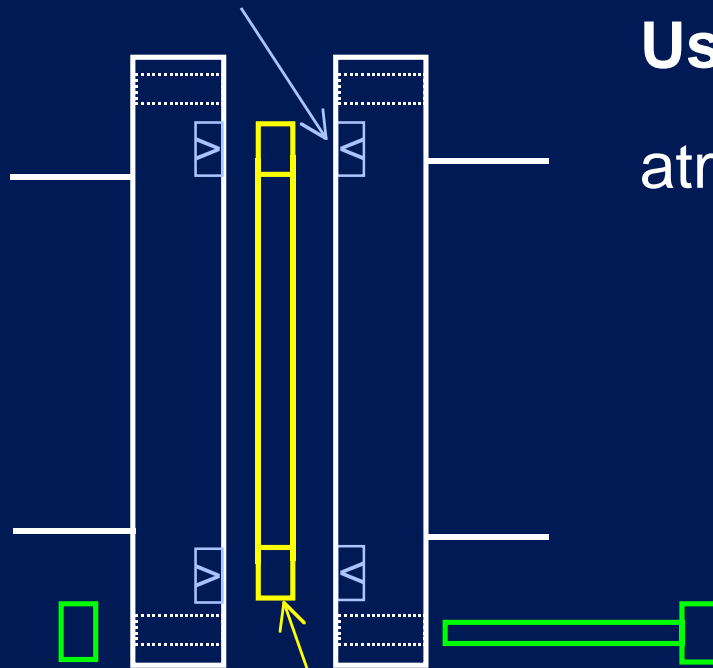
atmospheric to  $10^{-5}$  mbar

**pros** - quick connection

**cons** - not good to UHV

# Metal Gaskets

knife edge



metal gasket

## Useable Range

atmospheric to  $10^{-11}$  mbar

**pros** - good to UHV

**cons** - must use a new gasket each time

bolts

The metal gasket is typically Cu, In, or Au.

# Welds

weld for  
stability



UHV compatible  
weld

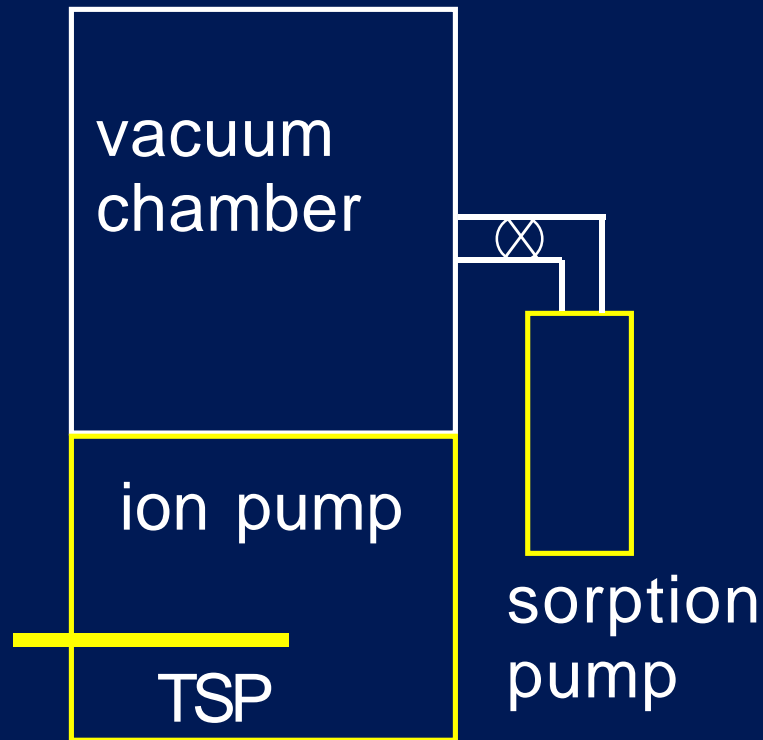
## Useable Range

atmospheric to  $10^{-11}$  mbar

**pros** - good to UHV

**cons** - must use UHV  
welding techniques

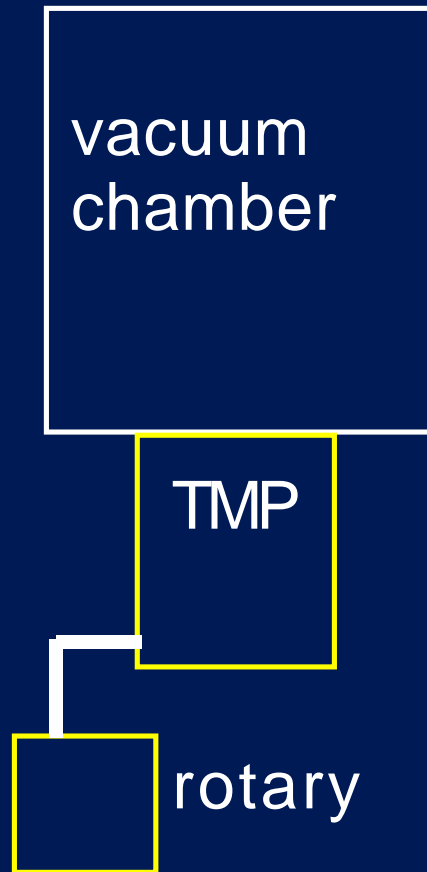
# Sample 1



**pros**  
clean  
vibration free

**cons**  
magnetic fields

# Sample 2



## pros

rapid turn around after venting to air

handles continuous gas flow to chamber

## cons

vibrations (and noise)

with DP for TMP

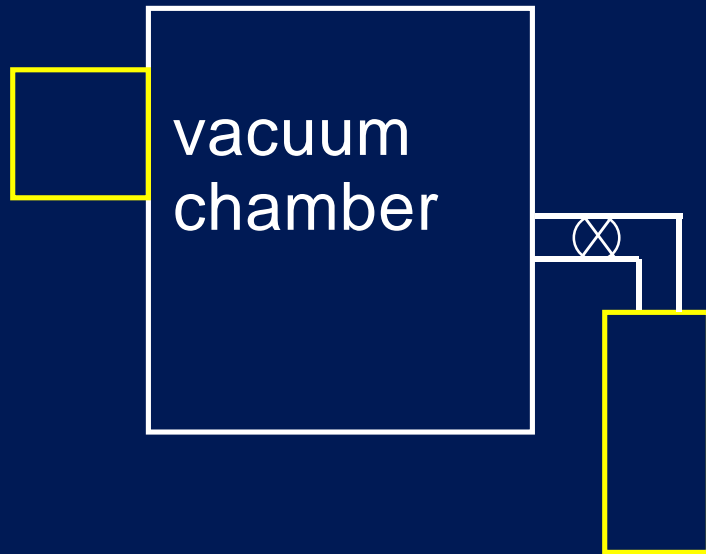
## pros

pumps light gases better  
no vibrations

cons - high maintenance costs

# Sample 3

cryopump



pros

clean

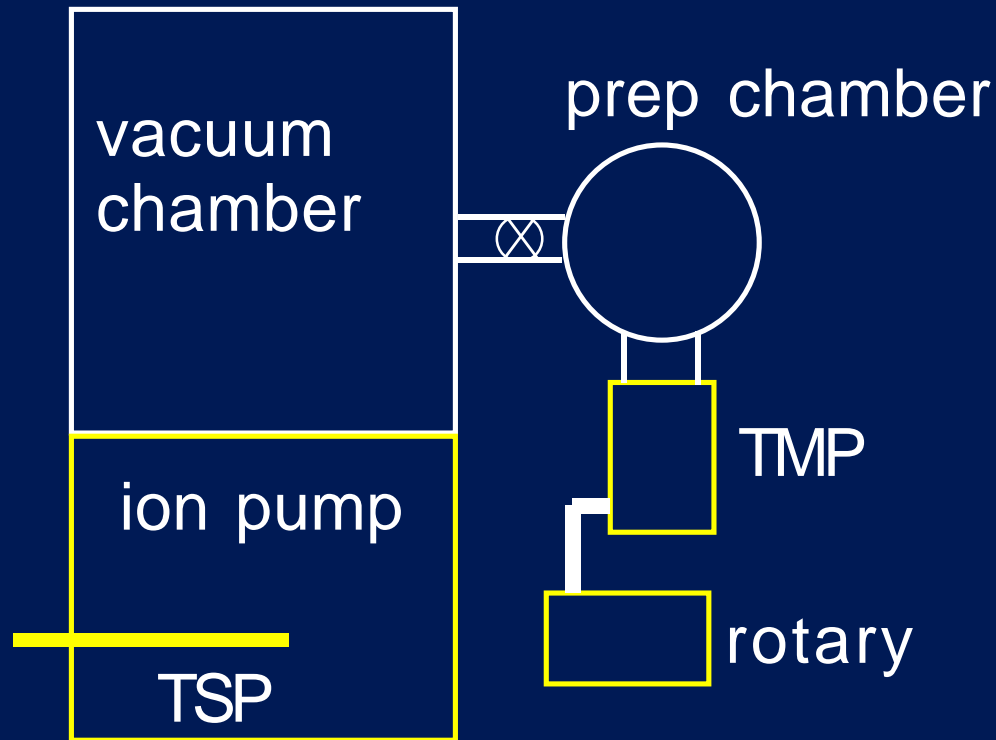
can handle some gas  
flow situations  
(with high Q cryro)

cons

vibrations

sorption  
pump  
(or turbo  
+ rotary)

# Sample 4



## pros

provides place  
to treat  
samples

reasonable turn  
around from  
venting to air

# Pump Down

typically follows a well-defined sequence according to the types of pumps on the vacuum system

for UHV systems, typically requires a few hours to reach a medium vacuum after a vent to air

for low vacuum systems, typically requires within an hour to reach operating conditions after a vent to air

# Bake Out

heats the chamber to temperatures between 100 °C to 200 °C for an extended period of time (1 - 2 days)

rapidly removes adsorbed gases from the chamber walls at high temperatures in order to lower the outgassing rates at room temperature

# Steady State

This determines the chamber pressure.

leak rates

{ flanges  
virtual leaks

The lowest P possible is called the base pressure.

these are typically independent of P +

outgassing rates

{ materials  
samples  
contaminants

||

pumping rates

typically depends on P

# Maintenance

We must take care to keep a good vacuum.

use materials and samples with low outgassing rates (low vapor pressures)

maintain pumps at operation conditions

change gaskets or o-rings on sliding seals according to requirements

avoid contamination from “finger grease” in chamber and on samples

# Materials

## Considerations

1. outgassing rates
2. integrity against “virtual” leaks
3. mechanical stability
4. weldability
5. chemical inertness
6. temperature stability
7. conductivity

## Typical Materials

### chambers

316 SS, 304 SS, (Al)

### components

#### metals

316 SS, 304 SS

OHF Cu

#### ceramics

quartz, mica (!)

glass, alumina

#### polymers

PTFE, PE