Turbopump preselection of analytes based on molecular weight

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Scientific Basis

- The compression ratio of a turbomolecular pump increases rapidly with the mass of the molecules being pumped.
- It should be possible to harness this effect to preconcentrate analyte molecules based on their mass for improved measurement sensitivity.

Applications

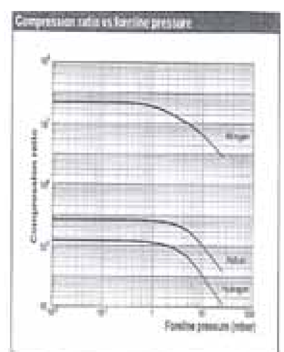
Molecules lighter than air

- He, H_2, HT, T_2

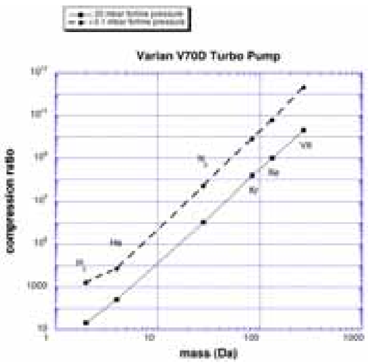
Molecules heavier than air

- CW agents
- Explosives
- Drugs
- Unexploded ordinance
- Chlorinated VOCs
- Toxic gases, trace VOCs
- Tracer molecules

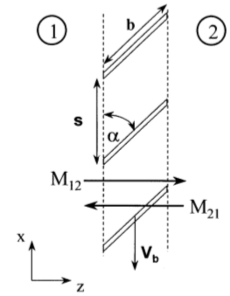
Compression ratio for different molecules for a V-70D turbopump from the Varian catalog



Inverted compression ratio vs mass, extrapolated to 267 amu (VX nerve agent)



Model of a single turbopump stage



compression ratio

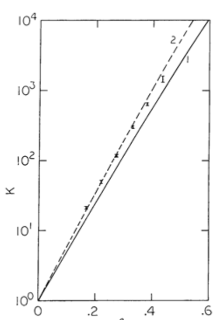
$$K_{\max} = \frac{M_{12}}{M_{21}} = \exp\left(\frac{3\pi^{1/2}}{8}\frac{\beta}{\sin\alpha}\right)$$

$$\beta = \frac{v_b}{v_g} = v_b\sqrt{\frac{m}{2kT}}$$

where v_b is the speed of the blades and v_g is the speed of the gas molecules

T. N. Schneider et al., *J. Vac. Sci. Technol.* **A 16**, 175-180 (1998).

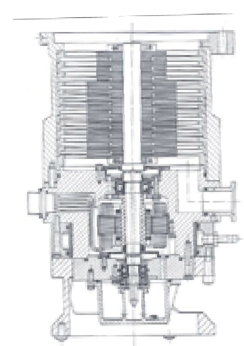
Experimental results for 9-stage turbopump compression ratio vs blade speed



- gas was dry air
- v_g was constant
- v_b was varied, $\beta = v_b/v_g$
- solid curves are from theory

J. G. Chu and Z. Y. Hua, *J. Vac. Sci. Technol.* **20**, 1101 (1982)

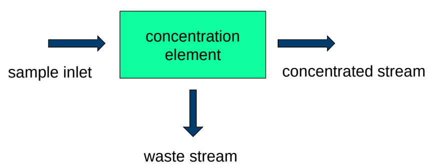
Cross section of a typical turbopump



A practical pump has many stages connected to a single rotating shaft.

M. H. Hablanian, High-Vacuum Technology, Marcel Dekker, 1990

Steady-state concentrator requires 3 streams – these units can be ganged



Scheme for molecules lighter than air

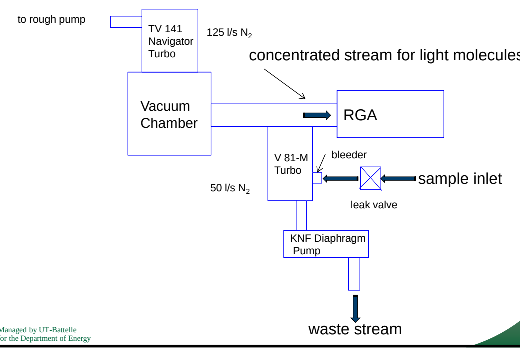
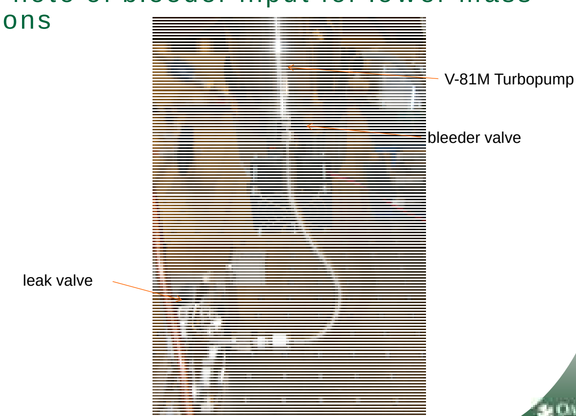
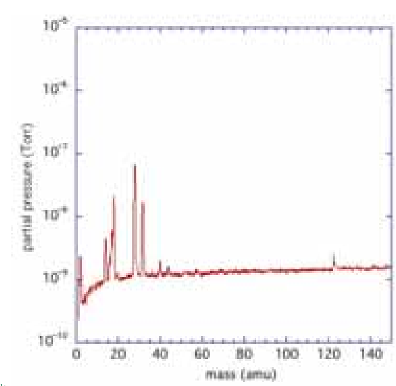


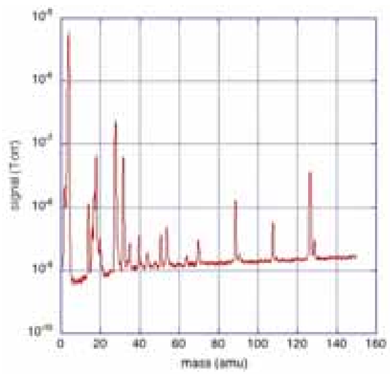
Photo of bleeder input for lower mass ions



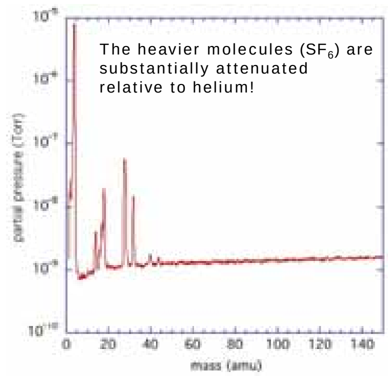
Background mass spectrum for light molecules



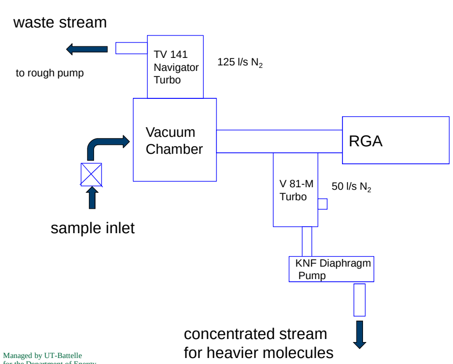
RGA with 1% SF_6 in He into vacuum chamber



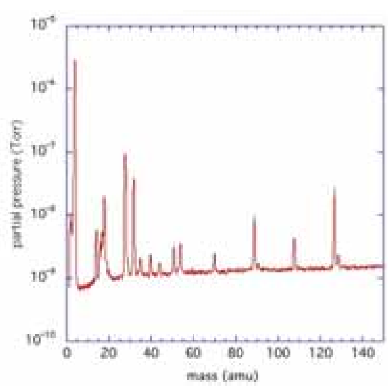
RGA with 1% SF_6 in He into bleeder valve



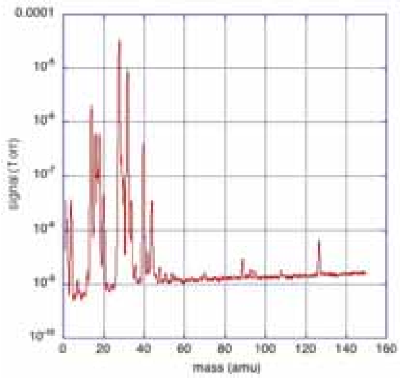
Scheme for molecules heavier than air



RGA with input of 1% SF_6 in He into vacuum chamber



RGA of exhaust from diaphragm pump transferred to chamber with some extra air



Preliminary Results

Light Molecules

$(He/SF_5)_{bleeder}$ = 5.5 E+3

$(He/SF_5)_{chamber}$ = 1.1 E+2

Change in He relative to SF_5 = 50

Heavy Molecules

$(SF_5/He)_{exhaust}$ = 1.8 E-1 (neglecting additional air)

$(SF_5/He)_{chamber}$ = 6.1 E-3

Change in SF_5 relative to He = 30

These results are only approximate because there was no background correction and SF_5 peak in the light molecule measurement was below the background.

Small Turbo Pumps

Conclusions

- We have shown that the mass dependence of compression ratio for a turbomolecular pump can be used to preconcentrate either molecules lighter than air or heavier than air depending on the experimental arrangement.
- Further enhancement should be possible with multiple stages.
- Very small turbopumps are now commercially available making targeted applications in portable instrumentation attractive.