

Outgassing - the villain in the vacuum

Dr Austin Chambers

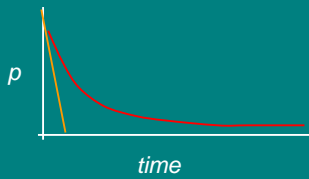
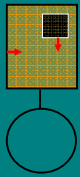
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Outgassing

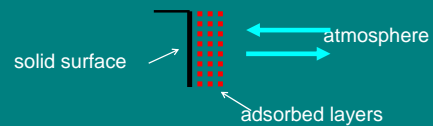
- What it is and why it's important
- Why it happens
- Analysis / Measures
- Counter-measures

Continuous and unceasing release of gas into the vacuum from the surfaces of the vacuum wall and internal fixtures.

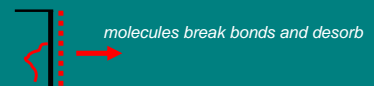


Why it happensthe picture at a molecular level

- at atmospheric pressure, equilibrium....



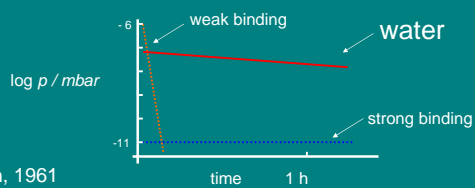
- when atmosphere removed outgassing



Factors involved:-

- Strength of binding - specified by bond energy, E
- Temperature, T
- Supply

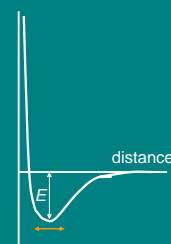
.... thermal agitation (T) versus bonding (E)



Hobson, 1961

E vs. T and stay-time τ

- E/kT appears as $\exp \{E/kT\}$



for H_2O / metal ($E \sim 90 \text{ kJ/mol}$):

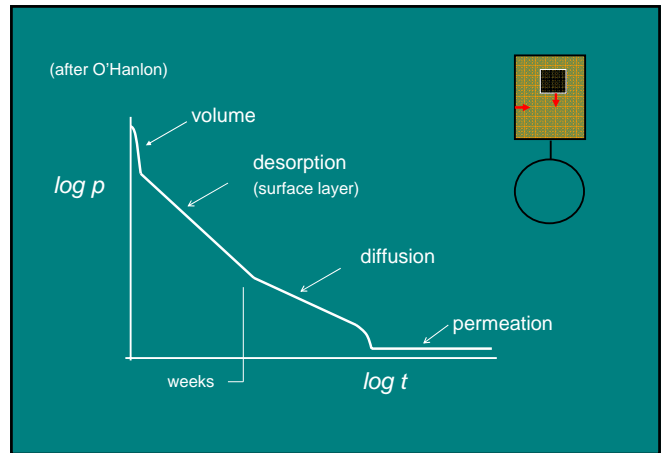
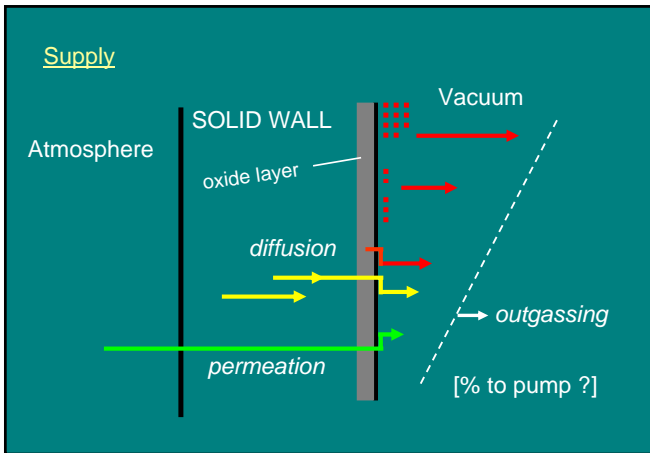
$T = 77 \text{ K}$ τ is forever

$T = 295 \text{ K}$... $\tau = 15$ minutes

$T = 523 \text{ K}$... $\tau = 0.1$ millisecond

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Measures

The quantity of a given amount of gas (at fixed temperature) may be specified as the product of its pressure and its volume

$$p \times V \text{ mbar litre}$$

- flowing quantity : mbar litre per second
- surface outgassing rate : mbar litre per second / cm²

$$q \text{ mbar l s}^{-1} / \text{cm}^2$$

(SI units : Pa m³ s⁻¹ / m² = Pa m s⁻¹)

How does outgassing vary with time?

- decreases, but slowly ...
- frequently

$$q = q_1 / t^\alpha \quad t \text{ in hours, } \alpha \sim 1$$

q

1 5 10 hours

Values

Range widely ...

materials / manufacture / atmospheric exposure / vacuum usage / temperature /

Stainless steel, $q_1 = 1.2 \times 10^{-7} \text{ mbar l s}^{-1} / \text{cm}^2$
 $q_{10} = 2.7 \times 10^{-8} \text{ mbar l s}^{-1} / \text{cm}^2$

Example

Q

volume 30 litre, 0.03 m³
area 5000 cm², 0.5 m²

pump, speed S = 100 l/s

after 1 hour, gas load, $Q = \text{area} \times q_1$
 $= 5000 \times 1.2 \times 10^{-7}$
 $= 6 \times 10^{-4} \text{ mbar litre}$

pressure $p = Q/S = 6 \times 10^{-6} \text{ mbar}$

after 10 hour, $p = 1.3 \times 10^{-6} \text{ mbar}$

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Counter-measures

- careful selection of materials
- good pre-cleaning / drying procedures
- hygienic handling
- minimising exposure to atmosphere
- venting to warmed walls, dry nitrogen

- pre-process glow discharge cleaning / ion bombardment
- baking ... q 's down by factors 10^3 - 10^4
... bakeout temperature / duration
- ex-situ preliminary vacuum firing (if feasible)
- photon-stimulated desorption

Resources

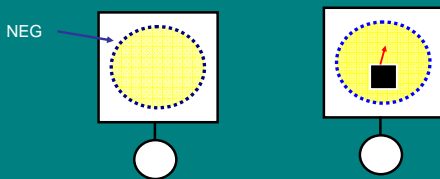
- Elsey Vacuum, 25, 1975
- O'Hanlon User's guide to vacuum technology
3rd edition, 2003, Wiley
- Berman Vacuum, 47, 1996
- Hurley Outgassing tutorial, www.vacuumtunes.co.uk
- Dobrozemsky JVST A23, 2007
- HDBK VS&T Academic Press, 1994

Foregoing was traditional

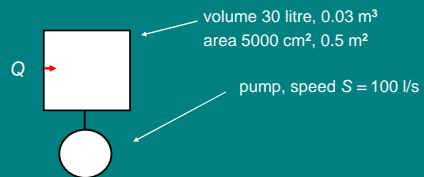


- New approaches ...

non-evaporable getter pumping



Example – after bakeout



$$\begin{aligned} \text{gas load, } Q &= \text{area} \times q_i \\ &= 5000 \times 10^{-10} \\ &= 5 \times 10^{-7} \text{ mbar litre} \end{aligned}$$

$$\text{pressure now is } p = Q/S = \underline{5 \times 10^{-9} \text{ mbar}}$$

END