



Gas Solubility & Diffusion

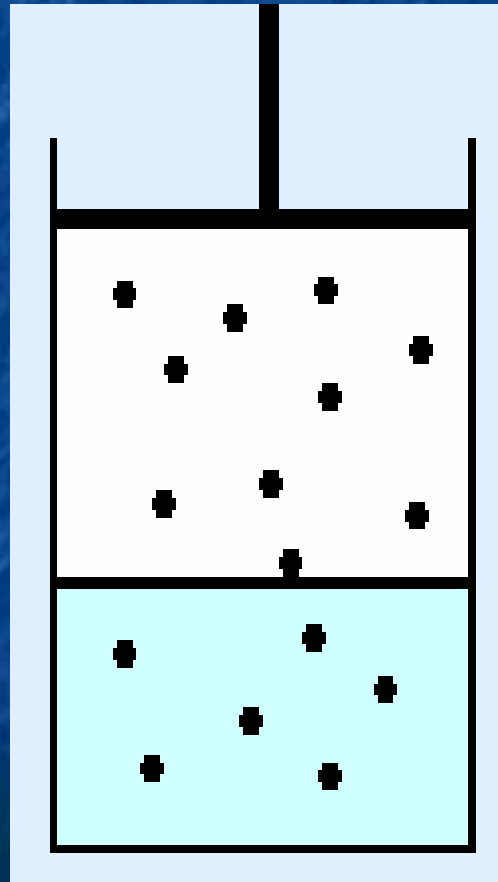
By

Ahmed Ibrahim ; M.D.

Prof.of Anesthesia,Intensive care &Pain
management

Ain Shams University

solubility of gases in liquids



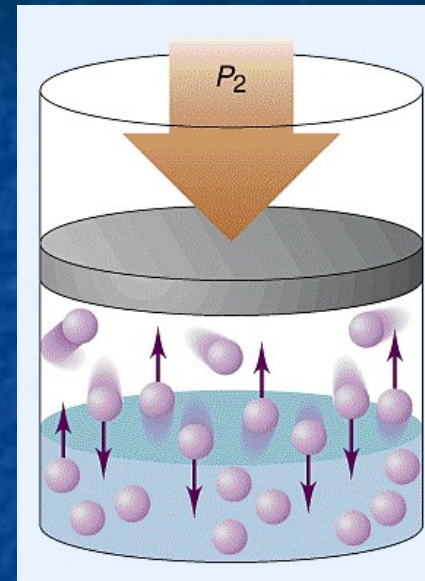
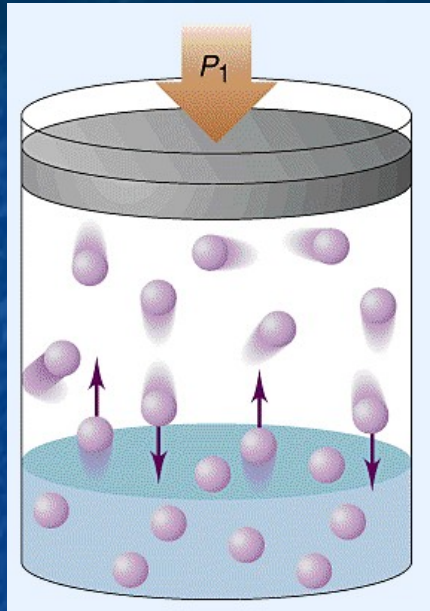
Amount of a gas dissolved in a liquid depends on:

★ Gas nature

★ Liquid nature

★ Liquid temperature $\propto 1 / \text{Solubility}$

★ Gas pressure above liquid



Solubility $\propto$ Pressure

“ at constant **temperature** , AMOUNT of a **given gas** dissolved in a **given liquid** $\propto$ **partial pressure** of the gas in equilibrium with that liquid “

Henry's Law

volume of **Gas** dissolved in unit volume of
Liquid (at certain temperature & pressure)

**Solubility
Coefficient** $\underline{v}$

$\underline{V}$

- ❖ Gas volume is stated at certain temperature

$$\frac{V_T}{V}$$

- ❖ Pressure independent
- ❖ Ostwald (λ)

- ❖ Gas volume is *corrected* to STP

$$\frac{V_0}{V}$$

- ❖ Bunsen (α)

$$\text{Ostwald} = \text{Bunsen} + \left\{ \frac{\text{Bunsen}}{\text{temp}} \right\}$$

how a gas divides itself between
two phases?



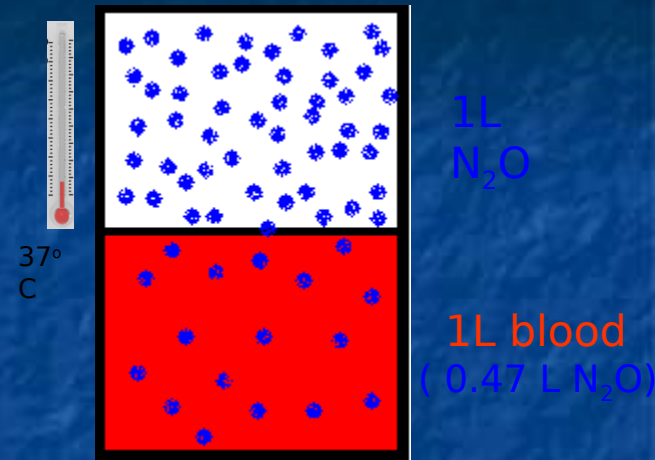
Partition Coefficient

||

ratio between the amount of gas in one phase ,
compared with other at:

- Equal volumes
- Equilibrium in both phases
- Certain temperature
- Phases in order

$$\begin{aligned}\text{Blood / Gas} &= 0.47 \\ \text{Gas / Blood} &= 1 / 0.47 = 2.1\end{aligned}$$



Partition coefficient

Temperature
dependant

||

Solubility coefficient

Pressure
independent

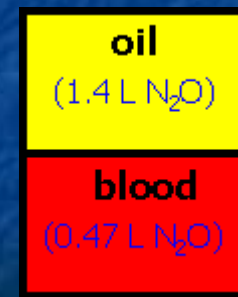
differences

2

**order of phases should
be stated**

(always liquid /gas in Ostwald)

**Partition coefficient can
be
applied to 2 liquids**



N₂O Blood/Oil = 0.47/1.4=
0.33

**For anaesthetic agent , the more it is soluble in blood (higher B/G coefficient)*

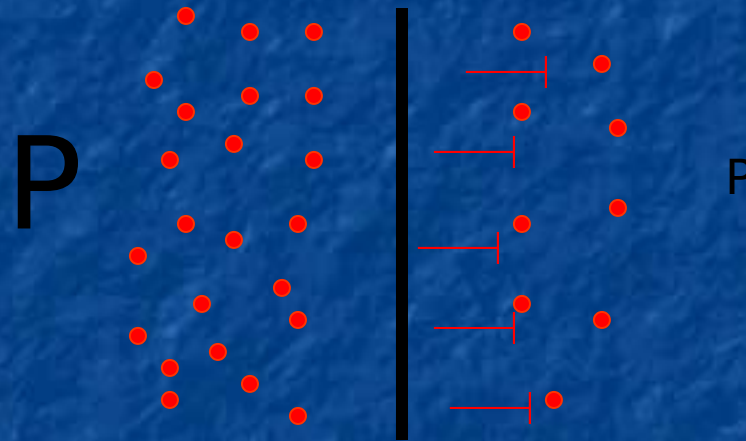
————→ *slow equilibrium with blood* —————→ *slower induction (vice versa)*

	Blood:Gas Solubility Co-efficient
Desflurane	0.42
Nitrous Oxide	0.47
Sevoflurane	0.6
Isoflurane	1.4
Enflurane	1.9
Halothane	2.3
Diethyl Ether	12.1

**Oil/Gas* ——— *reflects potency (MAC) of inhalation anaesthetic*

The more oil/gas *more potency (less MAC)*

Gas diffusion through porous membranes



**Gas transfer in
lungs**

**Diffusion
oxygenation**

Membrane

Rate of diffusion $\propto$ pressure difference (Ficks' law)
 solubility
 surface area
 $1/\sqrt{\text{molecular weight}}$ (Graham's law)
 $1/\text{membrane thickness}$

$$\text{Diffusion Rate } \frac{V}{T} \propto \frac{P. \text{ diff} \times \text{Solubility} \times \text{surface area}}{\sqrt{\text{molecular weight}} \times \text{thickness}}$$

Diffusion Rate = constant x pressure diff.

$$\text{Constant} = \frac{\text{Diffusion Rate}}{\text{pressure diff.}} = \textbf{Diffusion Capacity}$$

Diffusion capacity : rate of gas transfer in ml/min/mmHg

$$\text{Diffusion capacity for lung for O}_2 = \frac{\text{O}_2 \text{ uptake}}{P_{A-P} \text{ O}_2}$$

= 21 ml/min/mmHg (adult at rest)

For CO₂

	O₂	CO₂
Mol wt	32	44
P_{A-P} gradient	~60 mmHg	~6 mmHg
B/G coeff.	0.023	0.49

Diffusion capacity of lungs for CO₂ is 20 times that for O₂ (alveolo-capillary membrane is a wet membrane)

O₂ B/G partition coefficient = 0.023 (37°C)

1 liter blood contains 0.023 Liter = 23 ml O₂

100 ml blood contains 2.3 ml O₂ (at 760 mmHg)

For each mmHg , every 100 ml blood contains $\frac{23}{10 \times 760} = 0.003$ ml O₂

If at equilibrium between blood and alveolar air (breathing air) ,

PaO₂ = 100 mmHg

At tension of 100 mmHg , 100 ml blood contain 0.3 ml O₂
dissolved

O₂ content of arterial blood = (Hb% x sat x1.34) +

on breathing air , $P_AO_2 \sim 100$ mmHg

$$P_AO_2 = P_IO_2 - \frac{P_ACO_2}{RQ}$$

$$P_AO_2 = \{ F_IO_2 \times (P_B - P_{H_2O}) \} - \frac{P_ACO_2}{RQ}$$

- P_{H_2O} : SVP of H_2O at body temp.
- RQ : Respiratory Quotient

B/G coeff (37°C):

N ₂	0.015
O ₂	0.023
N ₂ O	0.47
CO ₂	0.49

- Diffusion oxygenation
- Diffusion hypoxia
- 2nd gas effect
- Body air spaces

Body air spaces: N_2O diffuses in and out of air spaces faster than N_2 . Air filled spaces expand in the presence of N_2O e.g. bowel, pneumothorax

Diffusion hypoxia: when one turns off N_2O at the end of anaesthesia, its concentration in the alveoli becomes lower than in the blood. Consequently N_2O floods in from the blood, diluting the alveolar gases and the patient breathes in a hypoxic mixture. To overcome this, one should administer 100% O_2 to the patient until the N_2O washes out.

2nd gas effect (concentration effect) : occurs when N_2O is the second gas used for anaesthesia. Even though N_2O is highly insoluble in blood - as an anaesthetic agent- it is much more soluble than O_2 and N_2 . Its rapid absorption from the alveoli causes a sharp rise in the concentration of the other inhalational agent.

Thank You