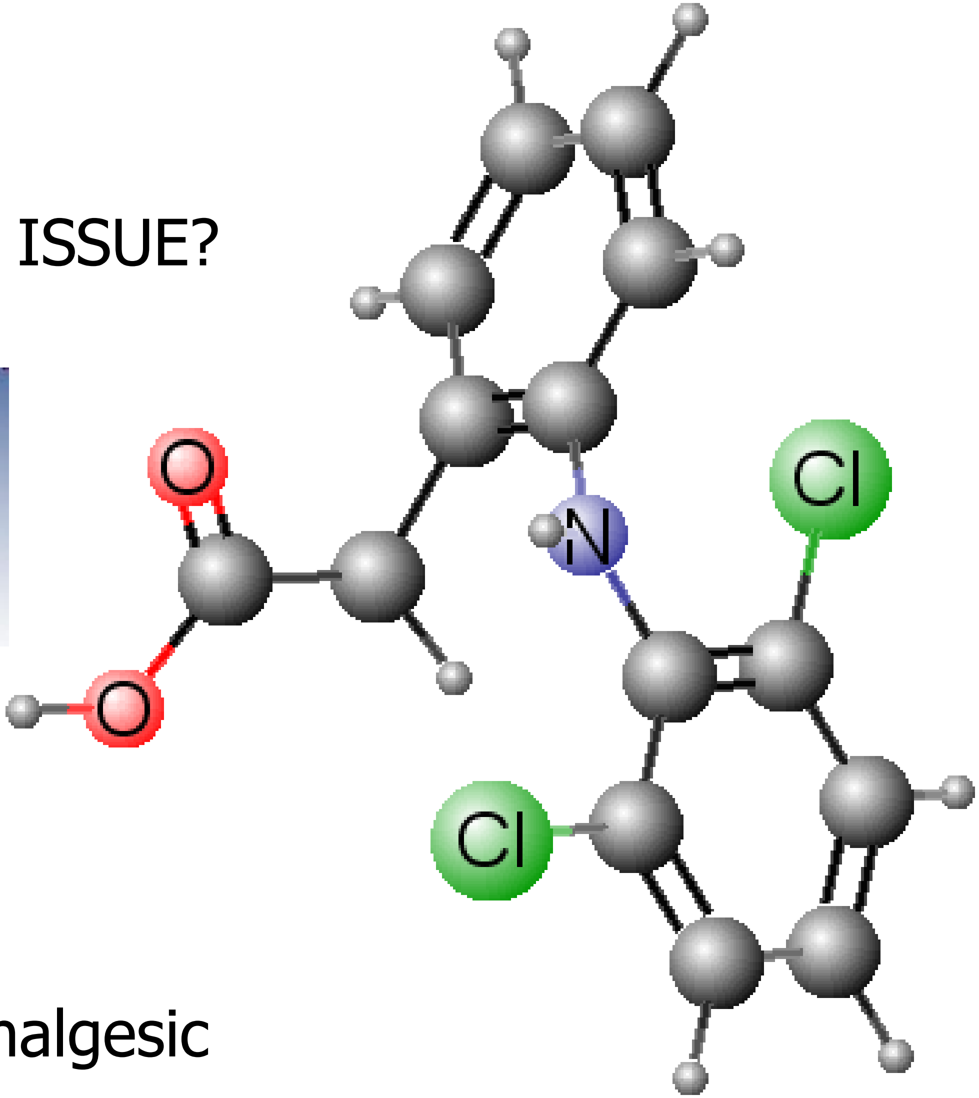
Interesting molecule of the day

- Diclofenac

ENVIRONMENTAL ISSUE?

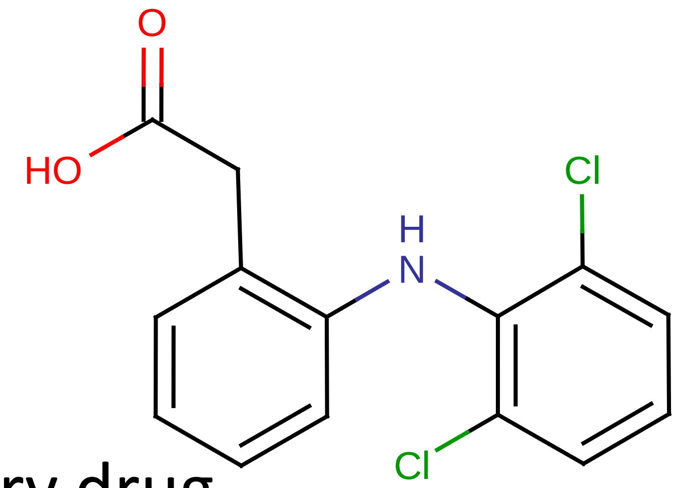


Cataflam NSAID analgesic

Interesting molecule of the day

- Diclofenac
  - pK_a: 4.15
    K_{ow}: $10^{4.51}$
    C_w^{sat}: 2.4 mg L^{-1}
    K_H: 4.8×10^{-9} bar L mol^{-1}
  - non-steroidal anti-imflammatory drug
    - arthritis, acute injury
    - 30 years of human use
  - contaminant in India
    - used on cattle
    - vultures eat dead cattle; kidney failure
    - use was phased out

2-((2,6-dichlorophenyl)amino)benzeneacetic acid



Interesting molecule of the day

Gyps Species	NSAID	Phase	Dose (mg kg^{-1})	Route	*N* Dosed	*N* Died	% Mortality	*N* Control	Status and Source of Birds
G. bengalensis	Diclofenac	—	0.007 to 0.940	Fed treated tissue	20	13	65	—	Captive birds (Pakistan)[a]
G. bengalensis	Diclofenac	—	0.25 and 2.5	Gavage	4	3	75	2	Captive birds (Pakistan)[a]
G. africanus	Diclofenac	—	0.8	Gavage	2	2	100	2	Captive birds (South Africa)[b]
G. africanus	Meloxicam	I	0.5	Gavage	5	0	0	3	Captive birds (South Africa)
G. africanus	Meloxicam	II	1.0	Gavage	5	0	0	3	Captive birds (South Africa)
G. africanus	Meloxicam	III	2.0	Gavage	5	0	0	3	Captive birds (South Africa)
G. africanus	Meloxicam	IV.1	2.0	Gavage	14[c]	0	0	—	Captive birds (South Africa)
G. africanus	Meloxicam	IV.2	2.0	Gavage	21	0	0	4	Wild-caught birds (Namibia)
G. africanus	Meloxicam	V	0.03 to 1.98	Fed treated tissue	6[d]	0	0	—	Captive birds (South Africa)
G. africanus	Meloxicam	V	1.18 to 2.45	Gavage	6[d]	0	0	—	Captive birds (South Africa)
G. bengalensis	Meloxicam	VI	0.5	Gavage	3	0	0	1	Captive birds (India)
G. bengalensis	Meloxicam	VI	2.0	Gavage	3	0	0	1	Captive birds (India)
G. indicus	Meloxicam	VI	0.5	Gavage	2	0	0	2	Captive birds (India)
G. indicus	Meloxicam	VI	2.0	Gavage	2	0	0	1	Captive birds (India)

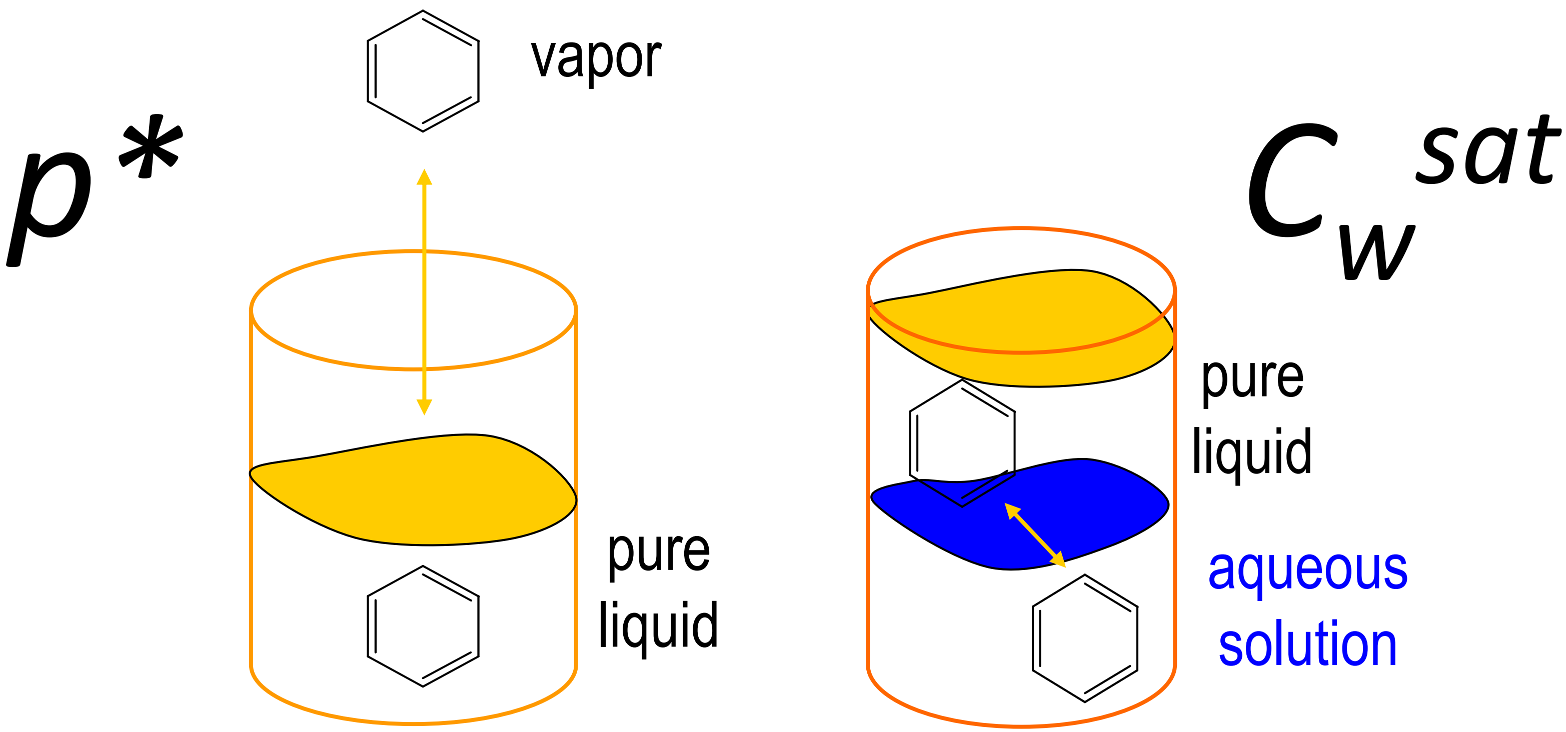
There was no mortality in any of the control birds.
[a]Experimental results from reference [1].
[b]Experimental results from reference [7].
[c]Experimental and control birds from phases I to III (including three control birds not previously dosed with meloxicam).
[d]Five of the six birds were experimental birds from Phase III and IV.1. The same birds were used for feeding tissue and oral gavage, with a 2-wk washout period between treatments (see Materials and Methods).
DOI: 10.1371/journal.pbio.0040066.t001

Swan et al., 2006, PLoS Biol. 4(3):e66

Vultures in India

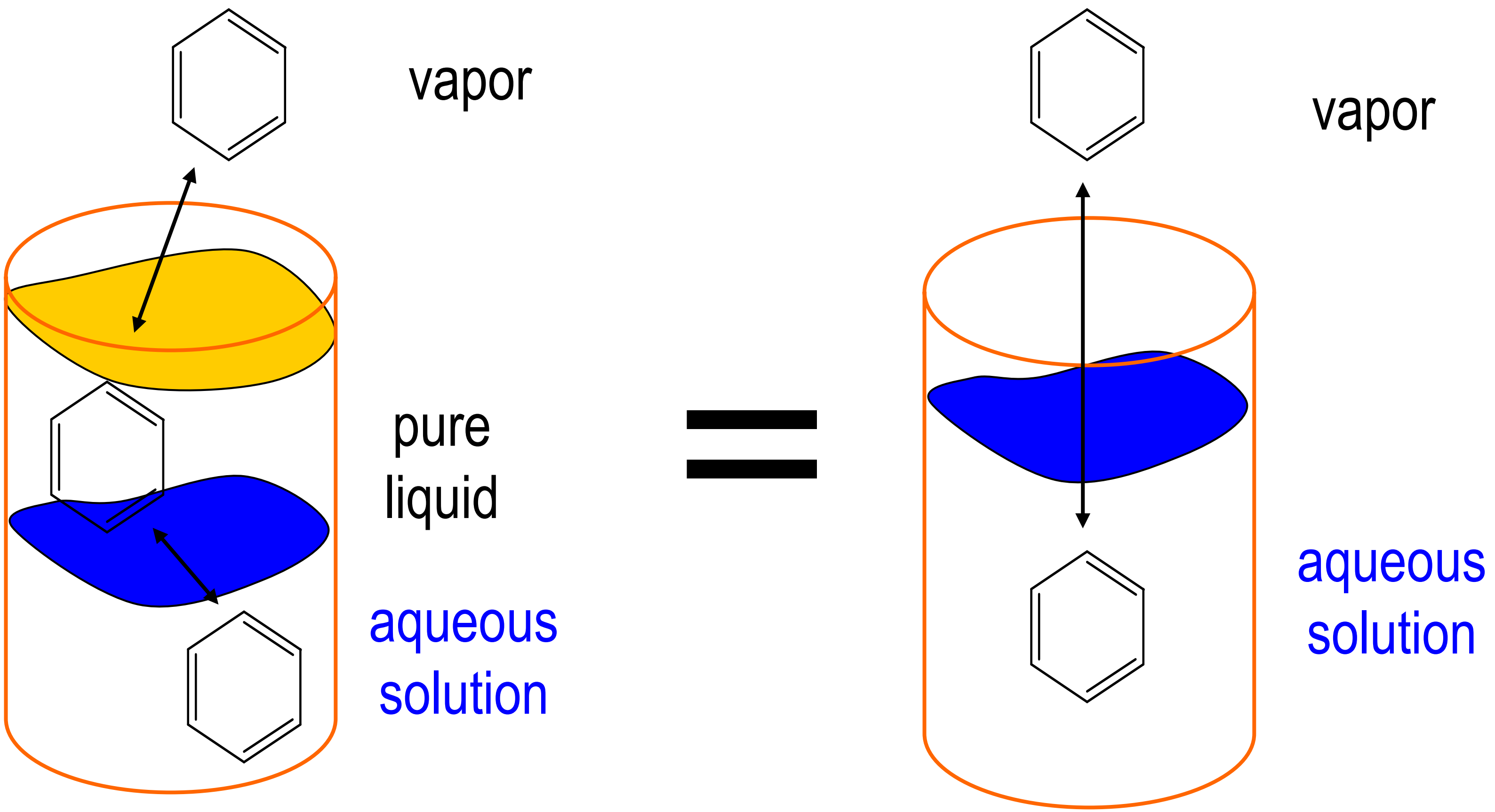
Air-Water Exchange

- Phase transfers
  - vaporization/sublimation
  - aqueous solution



Air-Water Exchange

- Another phase exchange
  - air-water exchange



Air-Water Exchange

$$e^{p} = e^{kc}$$

- Phase exchange

$$A_{water} \leftrightarrow A_{air}$$

$$p = kc$$

- Henry's Law constants

$$K_{H} = \frac{p_{A}}{[A_{water}]}$$ (bar L mol^{-1})

$$K_{aw} = \frac{[A_{air}]}{[A_{water}]}$$ dimensionless (mol L_a^{-1} mol^{-1} L_w)

Air-Water Exchange

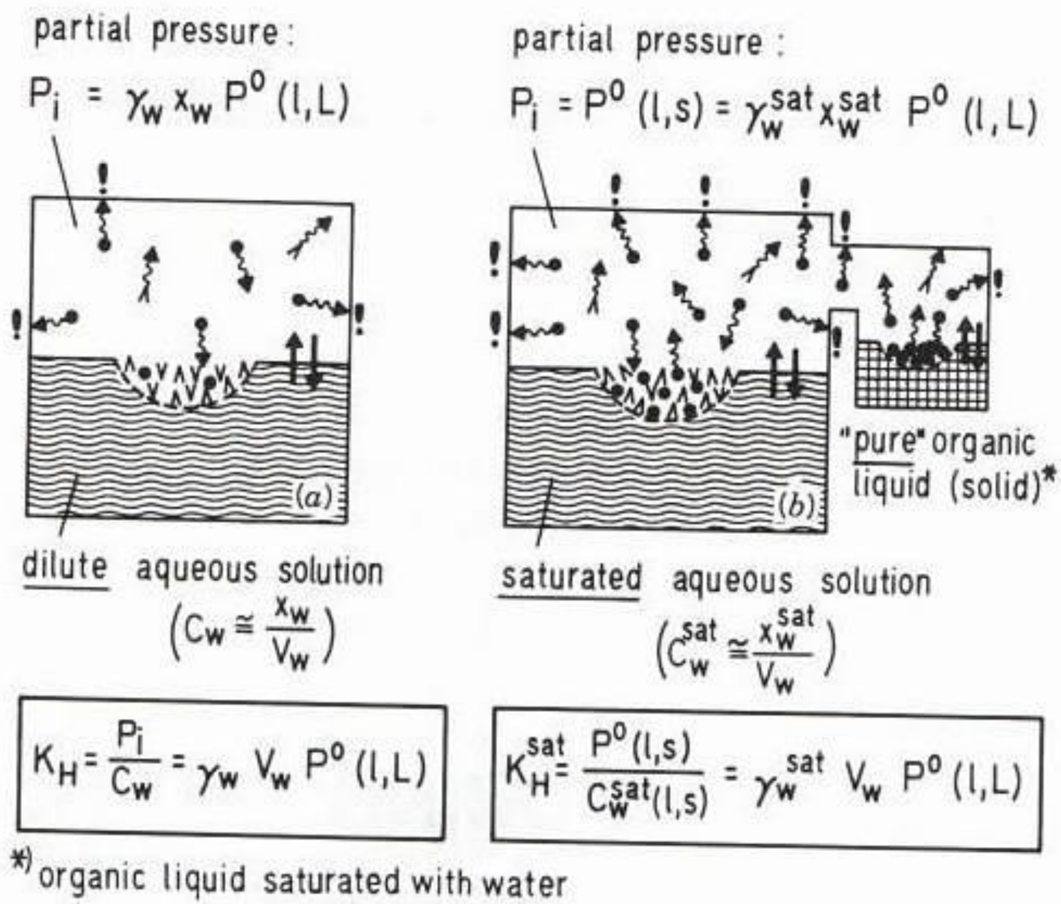
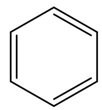
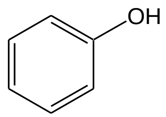
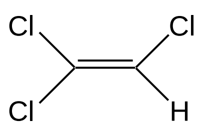
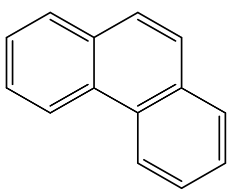
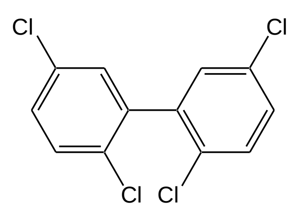


Figure 6.1 Equilibrium partitioning of a compound between a gas phase (air) and water. (*a*) System at dilute concentrations. (*b*) System at saturated concentrations.

Air-Water Exchange

compound		Henry’s Law constant K_{aw} (dimensionless)
benzene		$10^{-0.65}$
phenol		$10^{-4.59}$
trichloroethene		$10^{-0.31}$
phenanthrene		$10^{-2.85}$
2,2’,5,5’-tetrachlorobiphenyl		$10^{-1.70}$

Air-Water Exchange

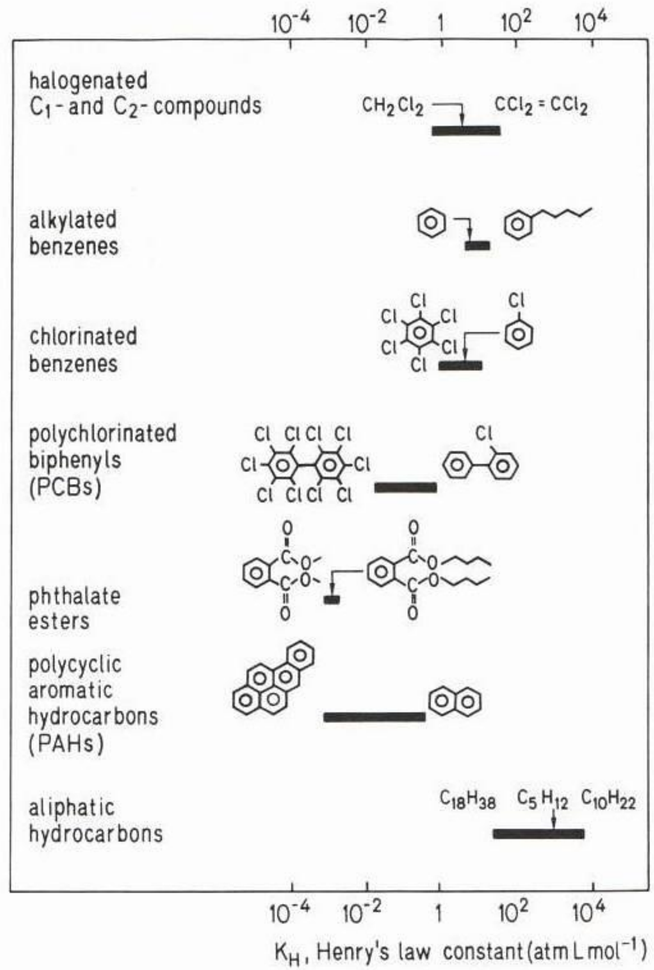


Figure 6.2 Ranges in Henry's Law constants (K_H) for some important classes of organic compounds.

High P^0

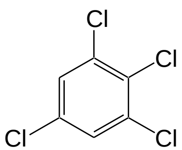
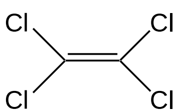
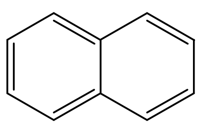
High C_w^{sat}

$$K_H = \frac{Pi}{Cw}$$

$$K_H^{sat} = \frac{P^0}{C_w^{sat}}$$

Air-Water Exchange

- Rank the following three compounds by Henry's Law constant from highest to lowest:

	compound	vapor pressure (bar)	solubility (M)
	1,2,3,5-tetrachlorobenzene	$10^{-4.00}$	$10^{-4.79}$
	tetrachloroethene	$10^{-1.60}$	$10^{-3.07}$
	naphthalene	$10^{-3.95}$	$10^{-3.60}$

A. 1,2,3,5-tetrachlorobenzene > tetrachloroethene > naphthalene
B. tetrachloroethene > 1,2,3,5-tetrachlorobenzene > naphthalene
C. naphthalene > tetrachloroethene > 1,2,3,5-tetrachlorobenzene

b) K_H: $10^{1.47}$ $10^{0.79}$ $10^{-0.35}$ bar L mol^{-1}

Air-Water Exchange

- Temperature dependence
  - enthalpy of liquid-air phase change, $\Delta_{al}H$

$$\ln K_H = -\frac{\Delta_{al}H}{R}\frac{1}{T} + c$$

  - Two components of $\Delta_{al}H = \Delta_{vap}H - \Delta_w H^E$
    - enthalpy to vaporize, $\Delta_{vap}H$, related to p_L^*
      - has to be paid
    - (excess) enthalpy to solubilize, $\Delta_w H^E$, related to C_w^{sat}
      - get this back
    - for solids and gases, melting and condensation enthalpies cancel out

Air-Water Exchange

- Liquid: $$D_{al}H_i = D_{vap}H_i - D_w H^E$$

(getting to gas phase) (getting out of water phase)

- Solid: $$D_{al}H_i = D_{sub}H_i - D_w H^E$$

$$= \left(D_{fus}H_i + D_{vap}H\right) - \left(D_{fus}H_i + D_w H^E\right)$$

$$= D_{vap}H_i - D_w H^E$$

gas already in gas phase

- Gas: $$D_{al}H_i = (0) - D_w H$$

$$= \left(0\right) - \left(- D_{vap}H_i + D_w H^E\right)$$

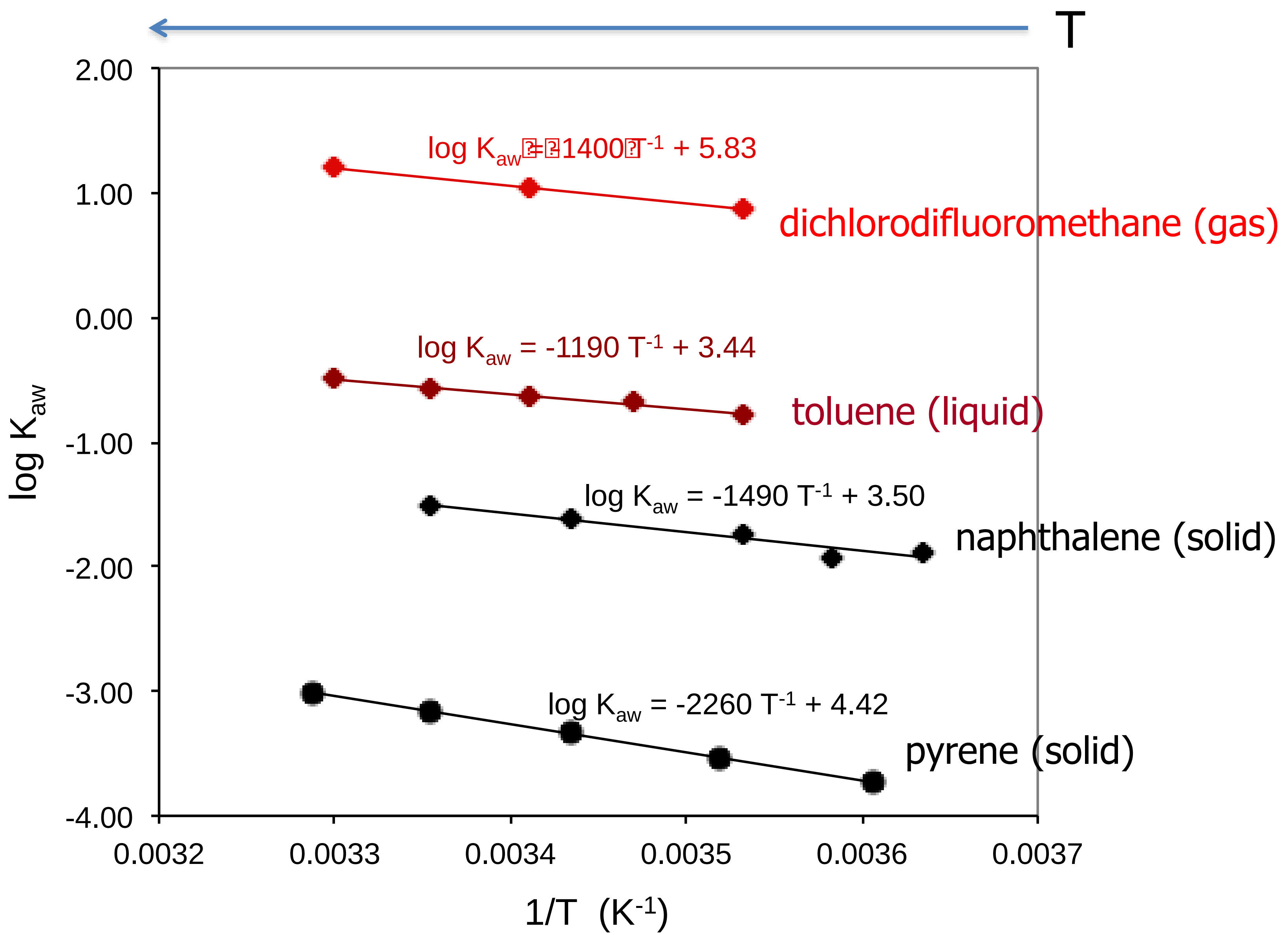
$$= D_{vap}H_i - D_w H^E$$

Air-Water Exchange

- How does temperature affect the Henry's Law constant?

A. an increase in T causes an increase in K_H
B. an increase in T causes a decrease in K_H
C. depends on whether we are talking about a solid, liquid, or gas

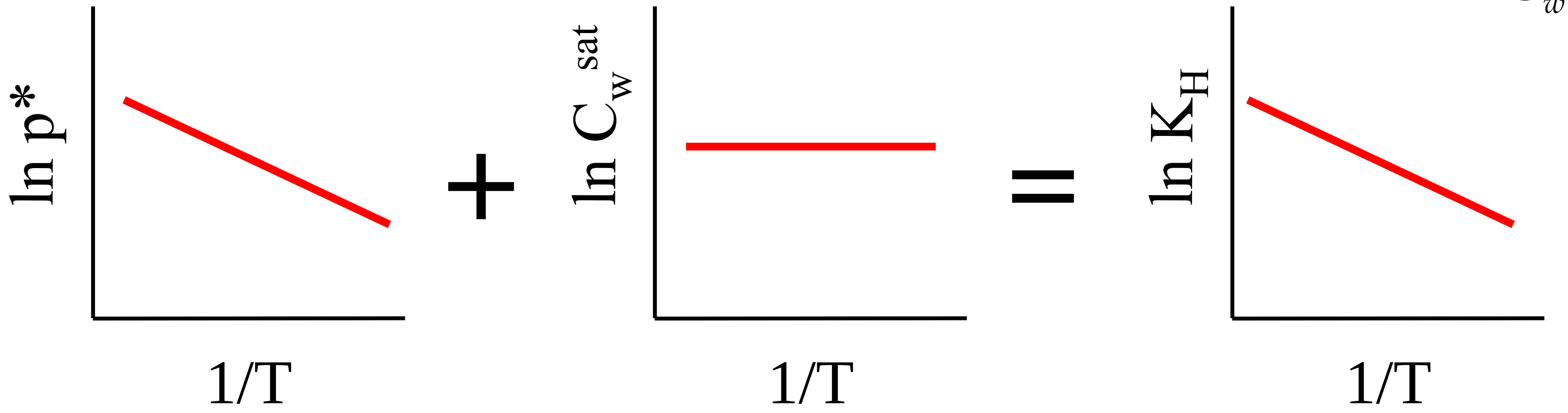
Air-Water Exchange



Air-Water Exchange

- Temperature dependence
  - liquids
    (e.g., benzene, tetrachloroethylene)

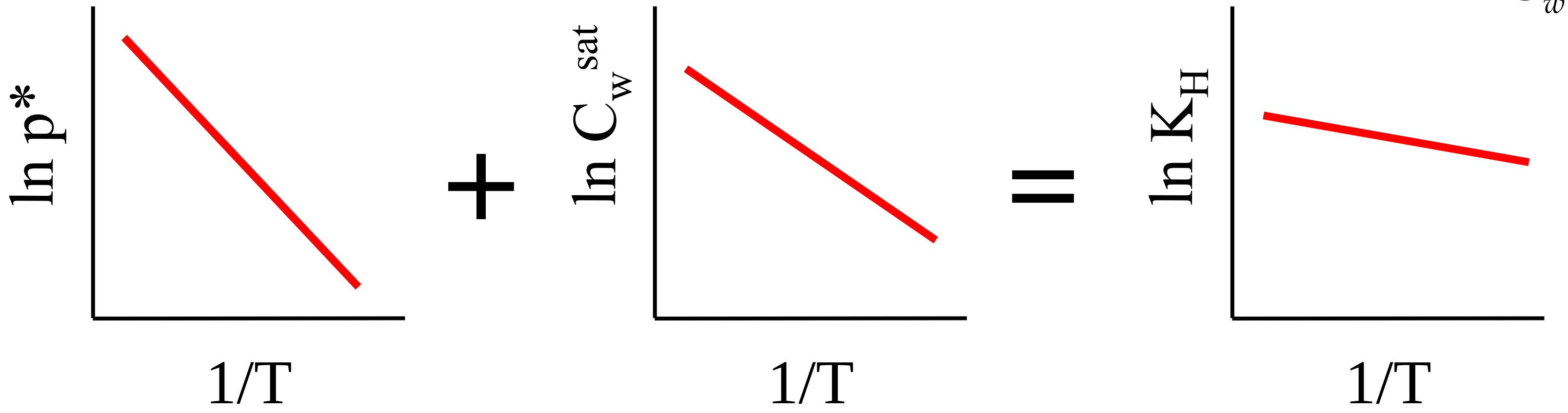
$$K_H = \frac{p_L^*}{C_w^{sat}}$$



Air-Water Exchange

- Temperature dependence
  - solids
    (e.g., naphthalene, 1,4-dichlorobenzene)

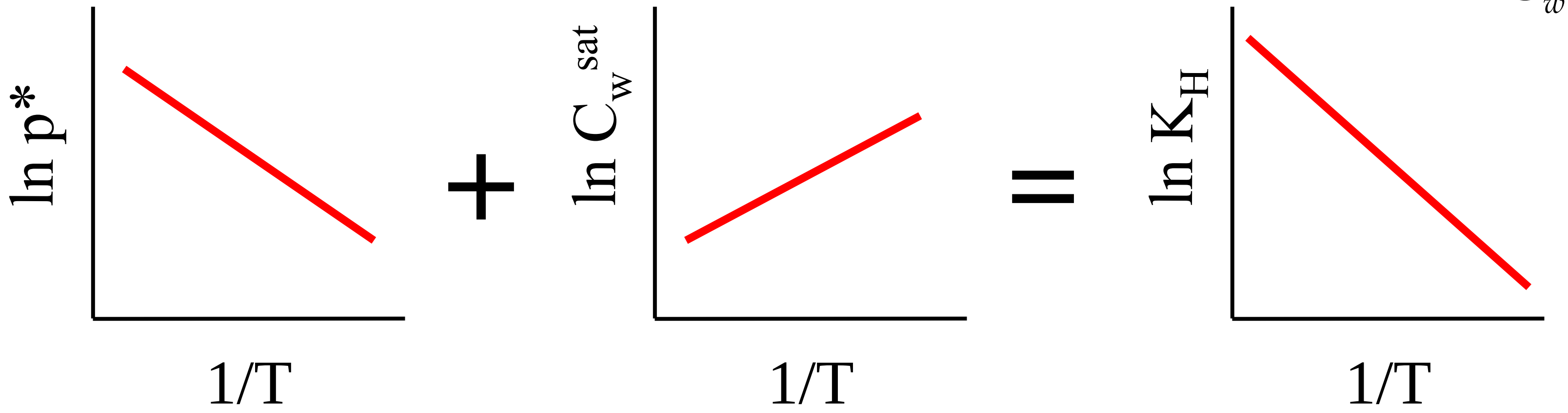
$$K_H = \frac{p_L^*}{C_w^{sat}}$$



Air-Water Exchange

- Temperature dependence
  - gases
    (e.g., vinyl chloride, chloromethane)

$$K_H = \frac{p_L^*}{C_w^{sat}}$$



Air-Water Exchange

- How does salinity affect the Henry's Law constant?

A. an increase in salinity causes an increase in K_H
B. an increase in salinity causes a decrease in K_H
C. depends on whether we are talking about the Atlantic, Pacific, or Indian Ocean

Air-Water Exchange

- Effect of salt
  - Salting out decreases solubility; increases K_{aw}

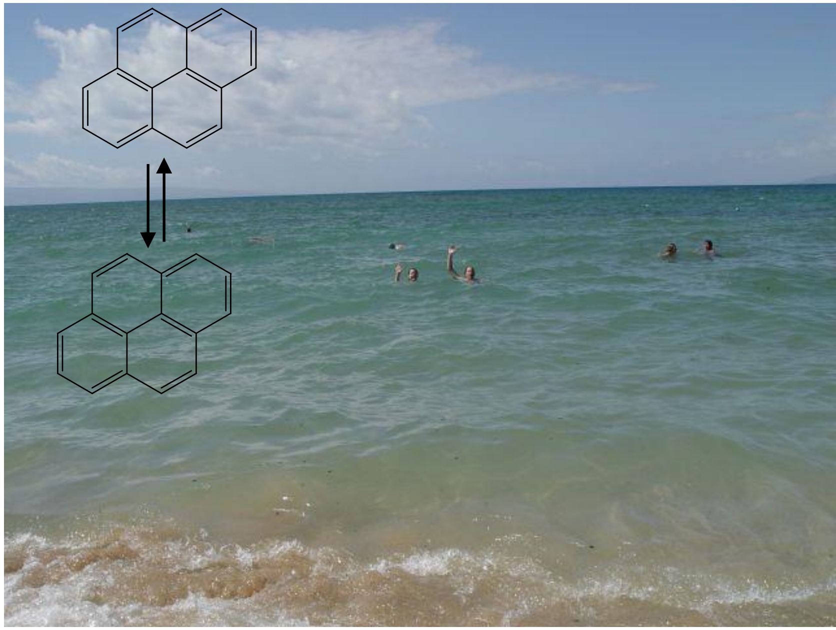
$$K_{aw,salt} = \frac{C_a}{C_{w,salt}^{sat}}$$

$$K_{aw,salt} = \frac{C_a}{C_w^{sat}} \frac{C_w^{sat}}{C_{w,salt}^{sat}} = K_{aw} \frac{C_w^{sat}}{C_{w,salt}^{sat}}$$

$$K_{aw,salt} = K_{aw} \times 10^{K^S [salt]_{tot}}$$

Air-Water Exchange

- Effect of salt
  - pyrene, $K_{aw} = 10^{-3.32}$
  - seawater
    - $[salt]_{tot} = 0.5$ M
    - $K^S = 0.30$



$$K_{aw,salt} = \left(10^{-3.32}\right)10^{K^S[salt]_{tot}}$$

$$K_{aw,salt} = \left(10^{-3.32}\right)10^{(0.30)(0.5)} = \left(10^{-3.32}\right)(1.4)$$

$$K_{aw,salt} = 10^{-3.17}$$

Air-Water Exchange

- How does a co-solvent affect the Henry's Law constant?

A. an increase in co-solvent concentration causes an increase in K_H
B. an increase in co-solvent concentration causes a decrease in K_H
C. depends on the co-solvent
D. depends on the contaminant compound

Air-Water Exchange

- Effect of co-solvents
  - Co-solvents increase solubility; decrease K_H

$$K_{aw,mix} = \frac{C_a}{C_{w,mix}^{sat}}$$

$$K_{aw,mix} = \frac{C_a}{C_w^{sat}} \frac{C_w^{sat}}{C_{w,mix}^{sat}} = K_{aw} \frac{C_w^{sat}}{C_{w,mix}^{sat}}$$

$$K_{aw,mix} = K_{aw} \frac{\gamma_{w,mix}^{sat}}{\gamma_w^{sat}} = K_{aw} \times 10^{-\sigma^c f_v}$$

Air-Water Exchange

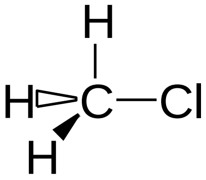
- Effect of co-solvents
  - naphthalene, $K_{aw} = 10^{-1.74}$
  - 20% acetone solution
    - $f_v = 0.2$
    - $\sigma^c = 6.5$

$$K_{aw,mix} = 10^{-\sigma^c f_v} K_{aw} = 10^{-(6.5)(0.2)}(10^{-1.74})$$

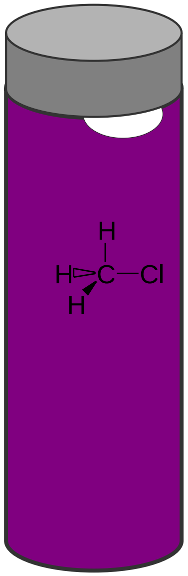
$$K_{aw,mix} = 10^{-3.04}$$

Air-Water Exchange

- Partition between air and water
  - importance of keeping bubbles out of water samples for VOCs
  - 40 mL vial
  - 39 mL water, 1 mL bubble
  - VOC is chloromethane
    - $K_{aw} = 10^{0.16}$



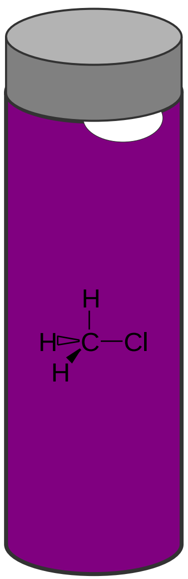
  - what fraction of the chloromethane is in the bubble?



Air-Water Exchange

- Partition between air and water

$$f_a = \frac{\text{moles in air}}{\text{moles in air} + \text{moles in water}} = \frac{C_a V_a}{C_a V_a + C_w V_w}$$



$$f_a = \frac{V_a}{V_a + \frac{V_w}{K_{aw}}}$$

$$f_a = \frac{1}{1 + \frac{39}{10^{0.16}}} = \frac{1}{28.0} = 0.036 = 3.6\% \, \textit{in the air}$$