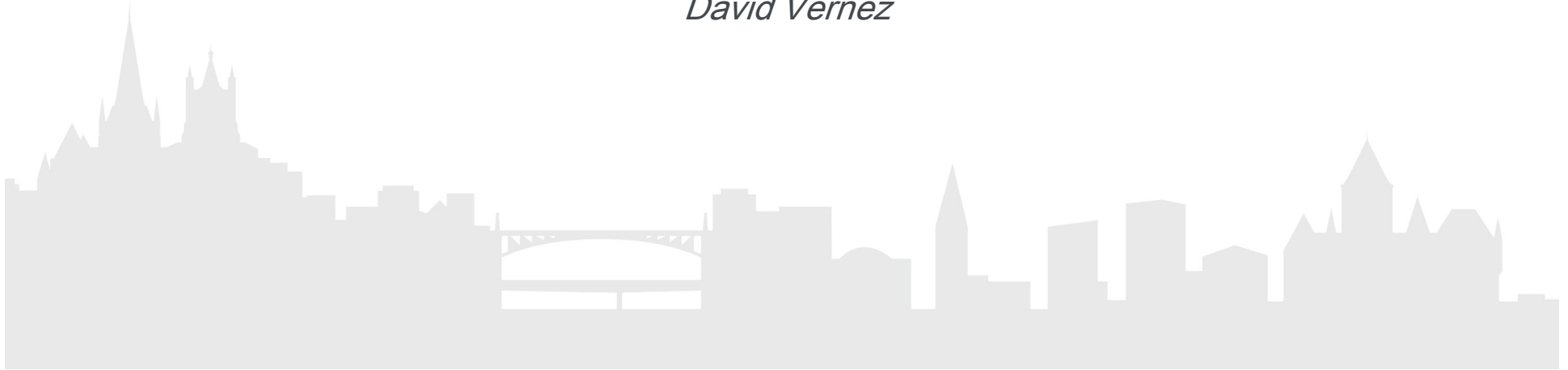


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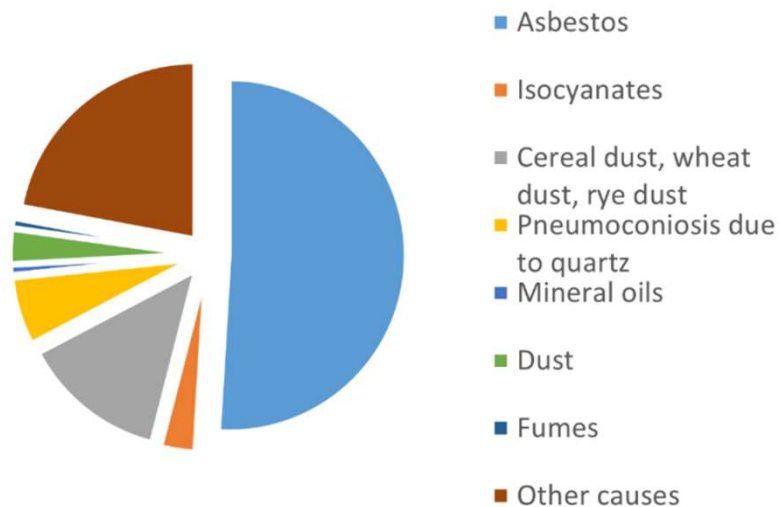
# Chemical pollutants properties

*David Vernez*



# Occupational diseases and chemicals

## Recognized respiratory diseases (2019), per source



### Recognized diseases:

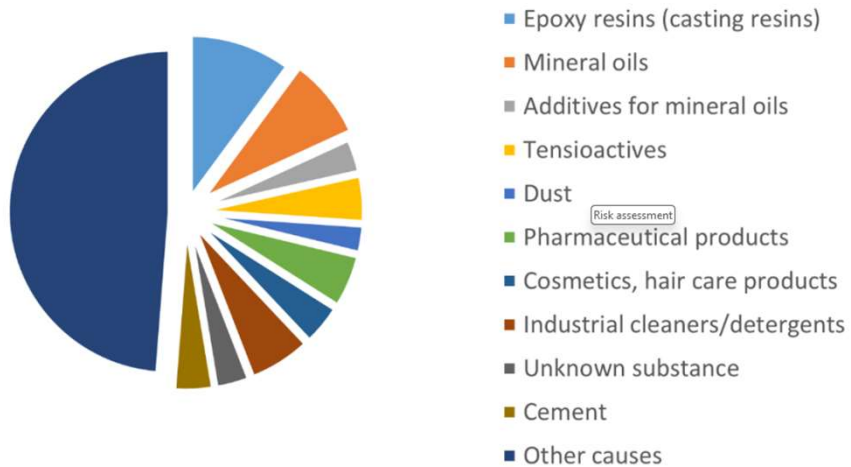
- Total number (in 2019): 2490
- Numb. of respiratory diseases: 314

### Exposure (declarative)

- 22% of EU workers declare being exposed to vapors fumes and dust > 25% of their time

# Occupational diseases and chemicals

## Recognized skin diseases (2019), per source



## Recognized diseases:

- Total number (in 2019): 2490
- Numb. of skin diseases: 393
- Mostly irritative and sensitive substances

# Case study

## Restoration workshop

In a restoration workshop, a restorer is busy removing the varnish from old wooden furniture. This work is long and tedious and can take several hours.

To remove the varnish, he rubs the furniture with a cloth soaked in thinner, then sands it to remove any remaining traces of paint.

- After a few hours of work, he suffers from eye irritation and nausea.

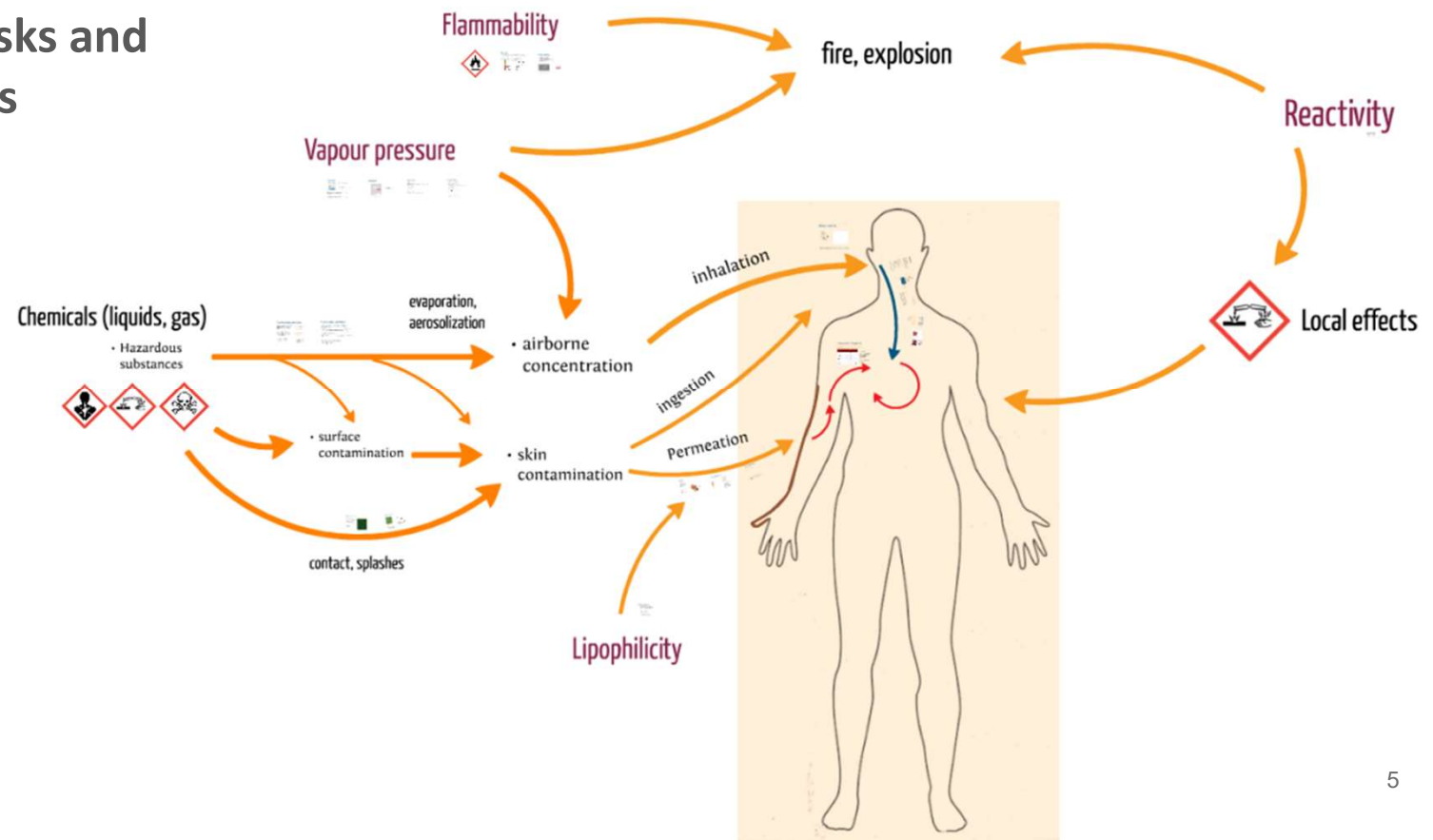
### Question (2.1.a)

What could have happened?



# Exposure to chemicals

## Chemical risks and entry routes



# Airborne exposure

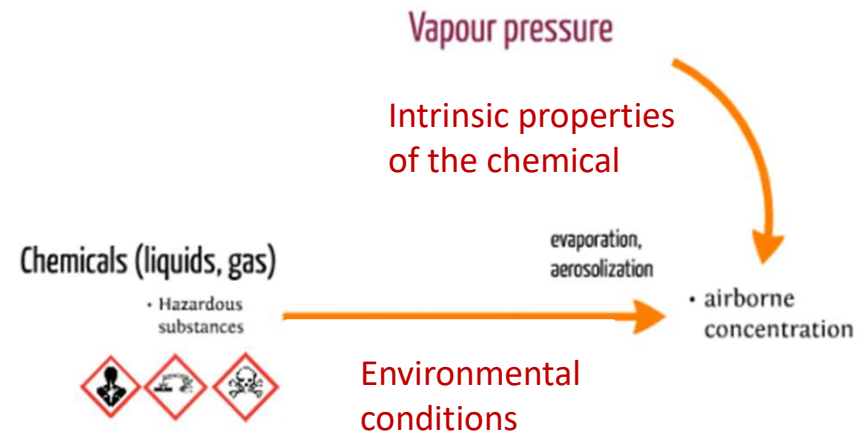
## Determinants of airborne concentration

- Environmental conditions  
*Temperature, Pressure, air movement, quantity, physical state...*
- Intrinsic properties  
*vapor pressure, vaporization enthalpy ...*

**Risk = hazard x exposure**

Toxicity

Airborne exposure,  
intake, uptake



# Gas and vapors

## Equation of state

$P = f(T, V, n)$  *There is a relationship between the volume of a give quantity of material and the values of pressure and temperature*

Equation of state

$P \cdot V = n \cdot R \cdot T$  *The case of gases is particular since they have almost all the same equation*

Ideal gas law

$$V = \frac{M \cdot R \cdot T}{M_w \cdot P} \rightarrow V = \frac{M \cdot 24.05}{M_w}$$

*Molar volume at 20°C and 1 atm is 24.05 liters*

R constant [J mol<sup>-1</sup> K<sup>-1</sup>]  
T temperature abs. [K]  
P pressure [Pa]  
V volume [m<sup>3</sup>]  
n numb. of moles

# Case study

## Restoration workshop (cont.)

### Question (2.1.b)

The occupational Exposure Limit (OEL) for isopropanol is  $500 \text{ mg/m}^3$ .

What is the OEL expressed in ppm ?

- $1 \text{ ppm} = 1 \text{ cm}^3 \text{ per m}^3 \text{ of air}$
- Volumetric ratio
- $\text{MW}_{\text{isopropanol}} = 60.1 \text{ g/mol}$
- $\text{Temp.} = 20^\circ\text{C}$
- $P = 98 \text{ kPa}$



# Gas and vapors

## Some properties of perfect gases

$$P + \rho \frac{v^2}{2} + \rho g z = \text{constant}$$

*The energy balance of a moving gas is expressed by the Bernoulli equation*

$$\sum P_i = P_{\text{tot}}$$

*The partial pressure (Dalton)*

$$\ln P = \frac{\Delta H_{\text{vap}}}{RT} + \text{const}$$

*Vaporization energy  
(Clausius-Clapeyron)*

P : pressure

j : volumic mass

v : speed

z : height

g : acceleration of gravity

P<sub>i</sub> : partial pressure of the components (1,2,...,i)

P<sub>tot</sub> : total pressure

# Vapors

## Vapor pressure

- Liquid-vapor equilibrium is reached when the evaporation and condensation rates are equal

$$P_A = X_A \cdot P_A^0$$

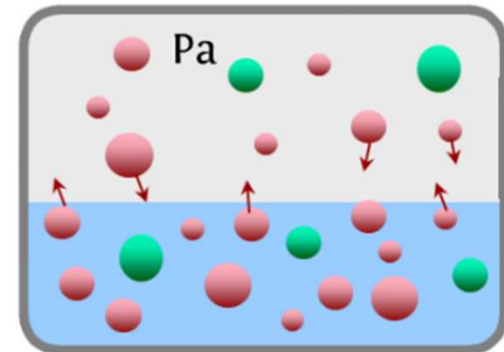
Raoult's Law

*The vapor pressure of an ideal solution depends on the partial pressure of each component and their respective fractions*

$$P_A = X_A \cdot K_H$$

Henry's Law

*The quantity of gas dissolved in a liquid is proportional to the partial pressure that this gas exerts on the liquid*

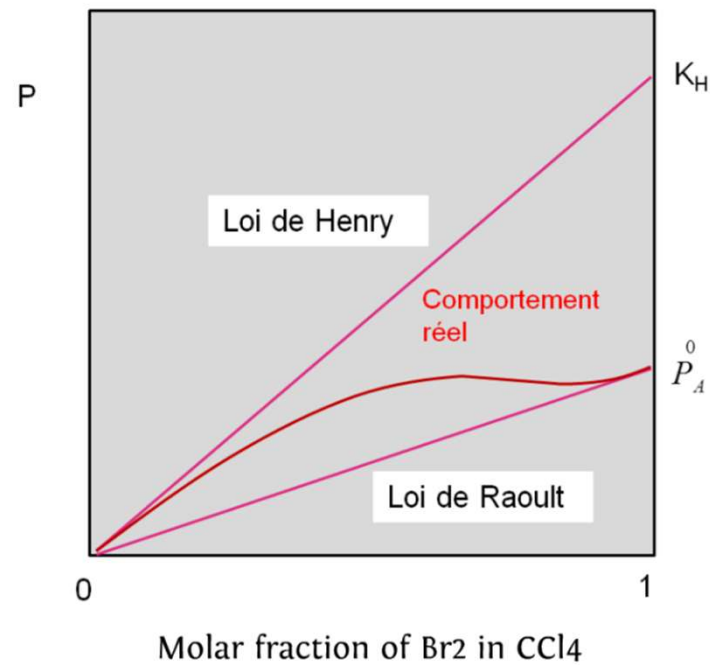


Pa :partial pressure of A  
Xa :molar fraction of A  
PO :saturation vapour pressure (pure substance)  
Kh: Henry's ratio

# Vapor pressure

## Relation with liquid concentration

- The real behavior is between the two model
- Raoult law is more adequate in [ ] solutions
- Henri's constant not always available



# Airborne exposure

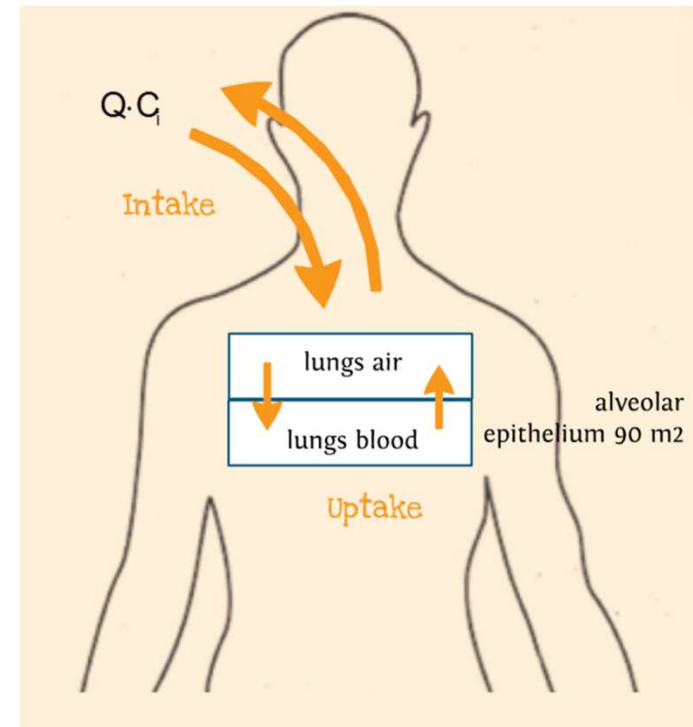
## Intake

- Inhaled dose is proportional to the pulmonary ventilation and the concentration of the pollutant (vapor pressure)

## Ventilation flow, Q

- Adult male
  - At rest: 7.5 l/min.
  - Light activity 20 l/min.
- Adult female
  - At rest: 6.0 l/min.
  - Light activity 19 l/min.

Approx. **10 m<sup>3</sup>** air inhaled per working day



# Airborne exposure

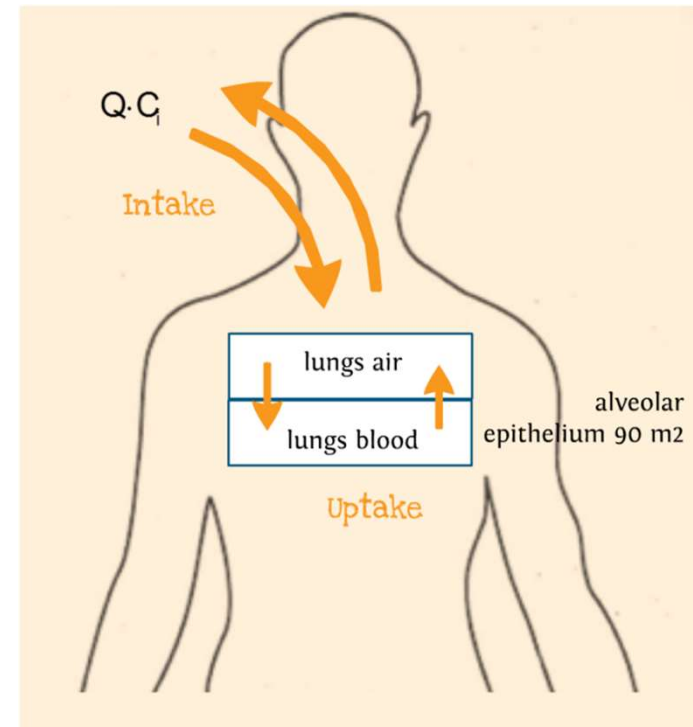
## Intake dose

$$D_{\text{pot}} = \int_{t_1}^{t_2} C_i(t) \cdot Q \cdot dt$$

Dpot: potential dose (mg)  
Ci: concentration (mg/m<sup>3</sup>)  
Q pulm. ventilation (m<sup>3</sup>/min)

## Uptake ?

- Variable deposition/absorption in the respiratory system
  - Hydrophilic gases and vapors reach the systemic circulation via the alveoli.
  - Hydrophilic gases and vapors dissolve in the respiratory tract

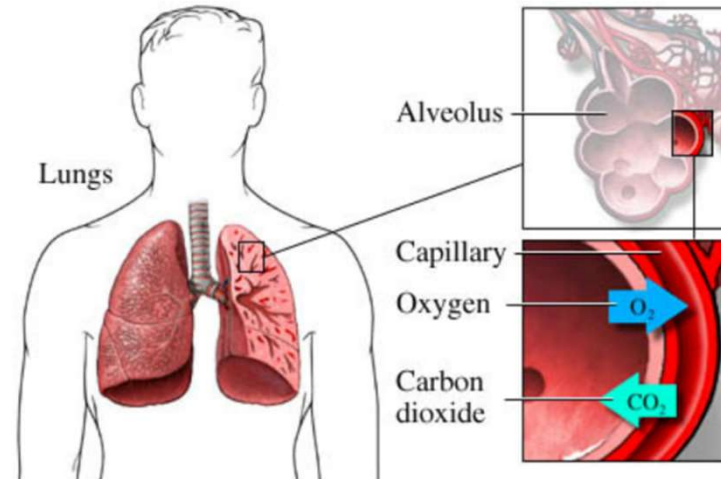


# Systemic absorption

## Gas exchange at the alveoli level

- Fast blood-air equilibrium
- Usual gas composition at the alveolar level
  - $P_{O_2}$ : 13.2%
  - $P_{CO_2}$ : 5.3%
  - $P_{CO_2}$ : 6.2 %
- Examples of blood/air partition coefficient

Sustance	blood/air partition coefficient
Methy alcohol	1700
Acetone	330
Diethyl Ketone	157
Ethyl ether	15
Benzene	6.6



# Case study

## Airborne exposure to isopropanol ?

### Question (2.1.c)

What would be the maximal isopropanol concentration in the air, knowing the properties of the thinner solution ?

The room Temperature is 20°C

Thinner solution:

70% (volume)  
Isopropanol

Isopropanol:  
 $\rho_{20^\circ\text{C}} = 0.785 \text{ kg/l}$   
 $P^\circ_{\text{isopropanol}}(20^\circ \text{C}) = 4.3 \text{ kPa}$ ,  
MW = 60.1 g/mol

30% (volume)  
Perchloroethylene

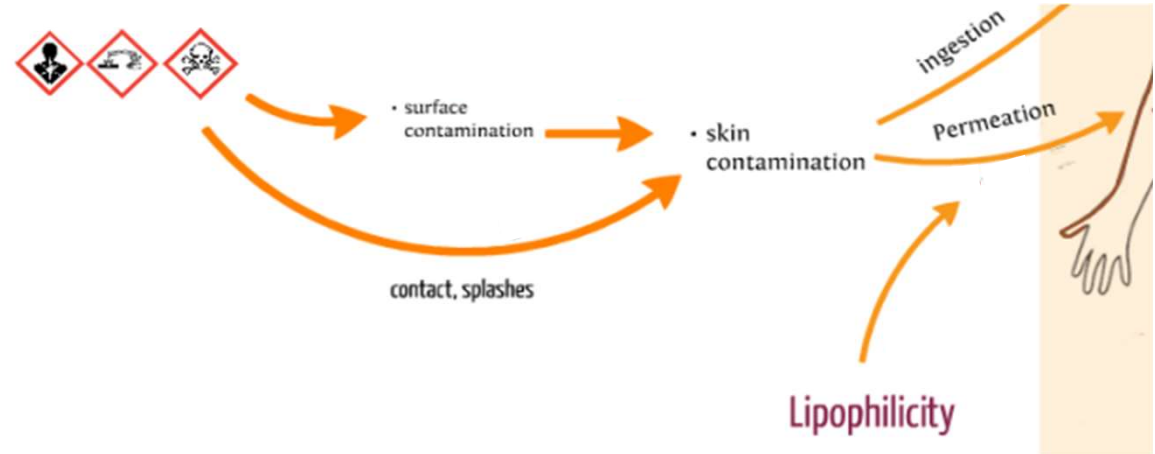
Perchloroethylene  
 $\rho_{20^\circ\text{C}} = 1.62 \text{ kg/l}$   
 $P^\circ_{\text{perchlo}}(20^\circ\text{C}) = 0.25 \text{ kPa}$   
MW = 165.83 g/mol



# Skin exposure

## Determinants of skin exposure and uptake

- Environmental conditions  
*Temperature, surface, quantity...*
- Skin condition
- Intrinsic properties  
*partition coefficient, co-formulants*

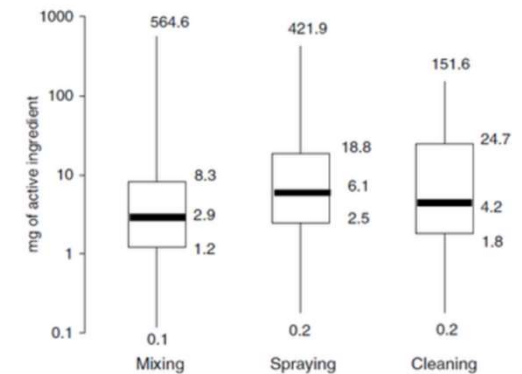


- Historical focus on inhalation, which was considered as predominant
- And yet... possible transcutaneous passage (damaged skin) or percutaneous passage (permeation)
- **Examples**  
**Scrotal cancers, glycols ethers, pesticides**

# Skin exposure

## Exposure to pesticides

- High surface contamination (skin, clothing, tools...)
- Resilience of the active substances (several weeks)
- **Example in vineyards (Pestexpo study)**
  - Dermal and inhalation exposure to Dithiocarbamates**
  - Internal exposure explained by**
    - Inhalation 1%
    - Hands permeation 40-50%



Contamination of the winegrowers' skin (Baldi 2006)

# Skin permeation

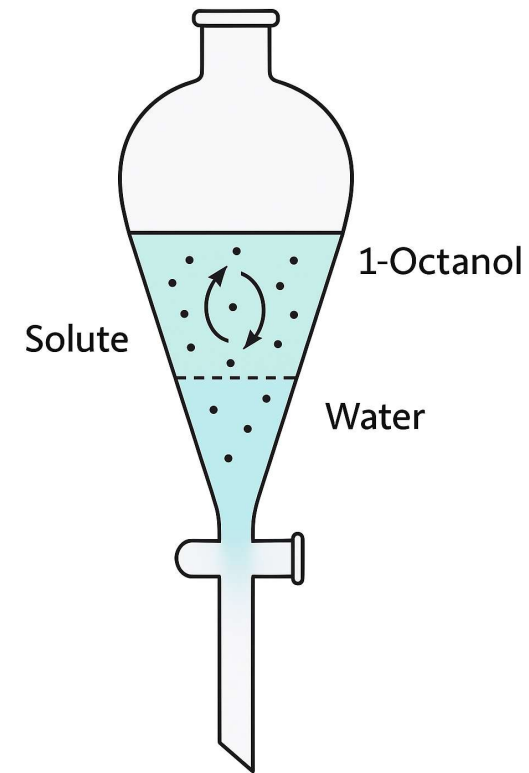
## Partition coefficient

- Octanol-water coefficient  
Differential solubility in two solvents (hydrophilic or lipophilic)

$$\text{Log}K_{ow} = \text{Log}\left(\frac{C_{\text{oct}}}{C_{\text{water}}}\right)$$

- Typical partition coefficients

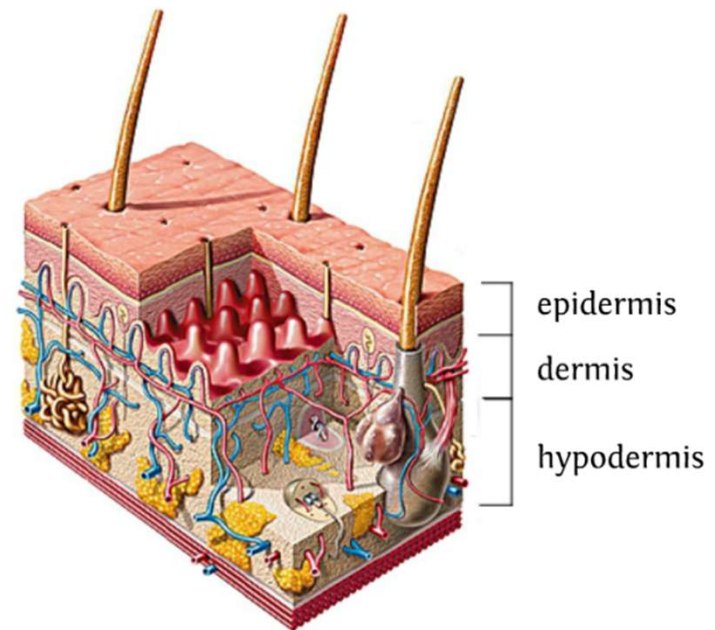
Ethanol	-0.28
Ethyl acetate	0.69
Benzene	2.14
Biphenyl	3.96



# Skin permeation

## The skin barrier

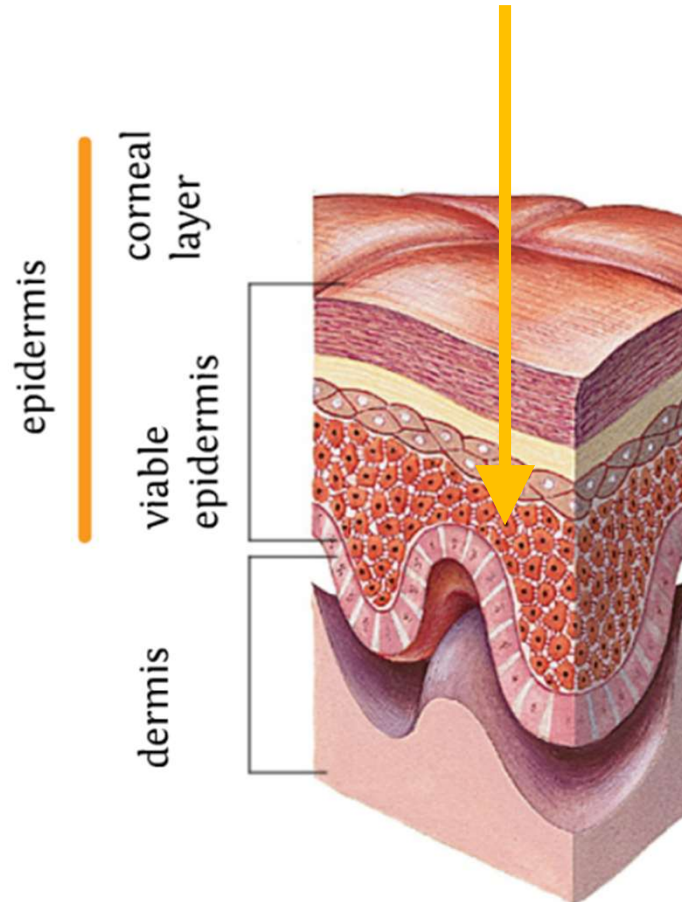
- Functions
  - Aesthetic, social
  - Tactile, thermoregulation
  - Barrier against physical, biological and chemical aggressions
- The first organ of the body
  - Weight 4-6 kg
  - Surface 1.2-2 m<sup>2</sup> in adults



# Skin permeation

## The skin permeation process

- Corneal layer
  - **Lipophilic** (dead cells)
  - 8-10  $\mu\text{m}$
  - Main barrier
- Viable epidermis
  - Hydrophilic (living cells)



- Percutaneous passage
  - Multiple layers
  - Favoring moderately lipophilic molecules
  - $1 < \log K_{ow} < 3$
  - Limited size  $< 500$  Da
  - **Molecular diffusion** process

# Skin permeation

## The skin permeation process

- QSAR model based on molecular diffusion
- Predicts the permeation flux  $F$  [ $\text{mg}\cdot\text{cm}^{-2}\cdot\text{h}^{-1}$ ]

$$F = \frac{C_{\text{sat}}}{15} (0.038 + 0.153 P_{\text{ow}}) e^{-0.016\text{MW}}$$

F: Flux in  $\text{mg}/\text{cm}^2\cdot\text{h}$   
C<sub>sat</sub>: Concentration of the saturated substance in water ( $\text{mg}/\text{mL}$ )  
P<sub>ow</sub>: Octanol-water partition coefficient  
MW: Molecular Weight

- Numerous factors of influence: the best practice is to use experimental data obtained with human viable skin

# Risk assessment

Possible uptake from skin permeation ?

## Question (2.1.d)

What could be the maximal absorption of isopropanol through the skin when using a soaked cloth for one hour (both hands)

Isopropanol (70%):

$P^{\circ}_{\text{isopropanol}}(20^{\circ}\text{C}) = 4.3\text{ kPa}$ ,

MW = 60.1 g/mol

Solubility in water: soluble

Partition coefficient oct/water = 0.05 ( $P_{ow}$ )

Perchloroethylene (30%):

$P^{\circ}_{\text{perchlo}}(20^{\circ}\text{C}) = 0.25\text{ kPa}$

MW = 165.83 g/mol

Solubility in water = 0,15 g/l

Partition coefficient oct/water = 2.53 log  $P_{ow}$



# Cutaneous vs. pulmonary

## Uptake dose estimate

- Hypothesis, inhalation\*  
alveolar ventilation: 16 l/min,  
alveolar absorption 100%  
8h exposure
- Hypothesis, permeation\*  
hand contact: 450 cm<sup>2</sup>,  
15 min. exposure

<i>Substance</i>	<i>Flux mg/cm<sup>2</sup>/h</i>	<i>Poumons* mg</i>	<i>Peau** mg</i>
Aniline	0.6405	58.4	72
Biphenyl	0.0759	9.98	8.5
o-Crésol	4.5338	169	510
Dieldrine	0.0013	1.92	0.15
DMF	1.0347	230	116
2-Ethoxéthanol	1.2054	138	136
Lindane	0.0087	3.84	0.98
Dichlorométhane	0.14	1337	16

# Other properties of interest

## Odor thresholds

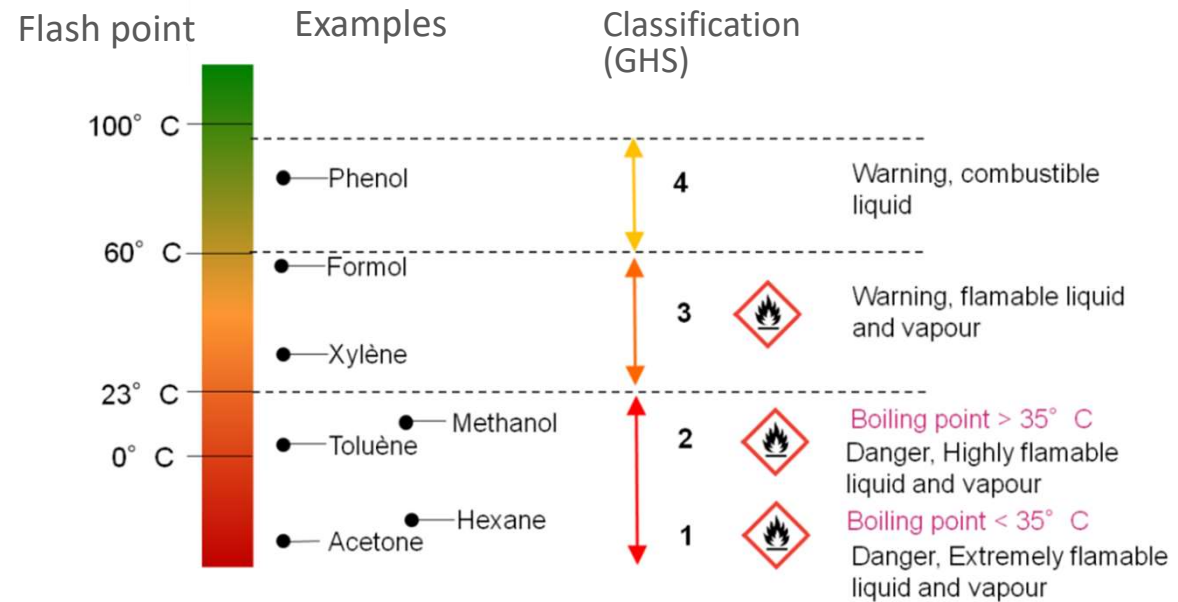
- The nose as measuring instrument
  - High selectivity
  - Calibration difficult
  - Uncertain detection limit
  - Interferences
  - Intoxication

Substance	Odor threshold	Odor	OEL [ppm]
Acetaldehyde	0.21	apple, sweet	50
Acetic acid	1.0	bitter	10
Dimethylformamide	100	fish	5
methanol	100	sweet	200
Hydrogen sulfide	0.0005	rotten egg	5
Nitrobenzene	0.005	almond	1
Nitrogen	n.d.		-
Mercury	n.d.		0.005
Carbon monoxide	n.d.		30

# Other properties of interest

## Flash point

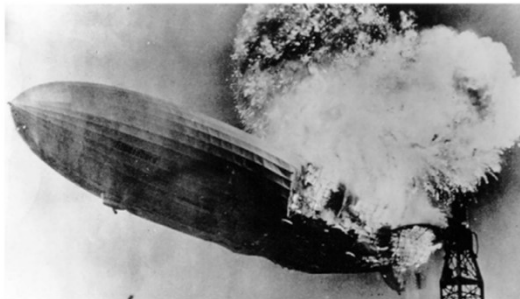
- The lowest temperature at which a sample gives off enough vapor to form a flammable mixture with the surrounding air
- Fire is a gaseous phenomenon !



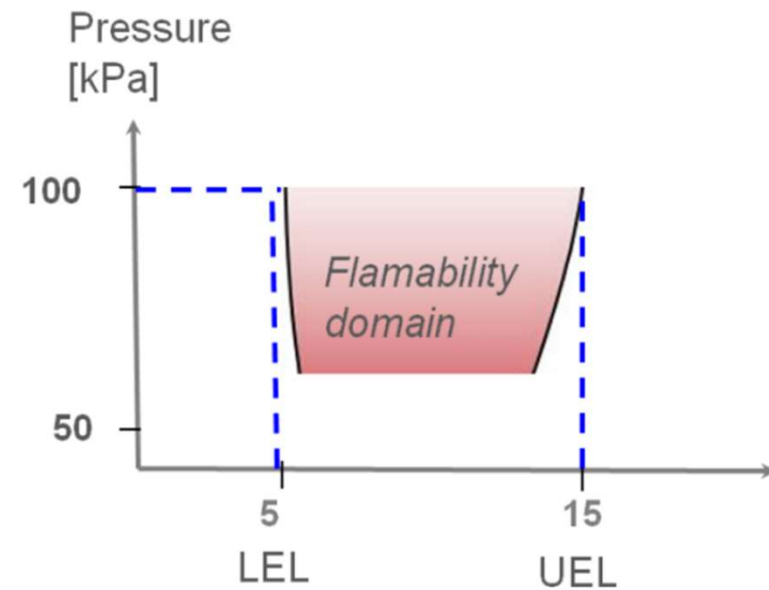
# Other properties of interest

## Flammability limits

- LEL: Lower explosibility limit
- UEL: Upper explosibility limit
- % of volume of combustible gas in the air
- Between LEL and UEL, the gas, vapor or dust concentration in the air forms a **flammable** mixture



*Hydrogen has a flammability domain of 4% – 75%*



# Case study

Is it safe to store in a fridge ?

## Question (2.1.e)

Is there a risk of fire/explosion if he stores the thinner solution in a fridge (4°C), where there is a source of ignition (such as an electrical spark from the thermostat)?

### Isopropanol (70%)

Boiling Temp.: 82.5 °C

LEL : 2,5 % vol,

UEL : 12,0 % vol

Vapor pressure (25°C): 4,4 kPa

Vapor pressure (2°C): 1.3 kPa



# Other properties of interest

## Safety data sheet (SDS)

- Properties of interest for health and safety for a given chemical can be found in the SDS
- Regulatory document (16 chapters)
- Mandatory for marketing, can be obtained from any product manufacturer or suppliers

- |  |                                     |
|--|-------------------------------------|
| 1. Identification of the substance/product | 9. Physical and chemical properties |
| 2. Information on ingredients              | 10. Stability and reactivity        |
| 3. Hazard identification                   | 11. Toxicological information       |
| 4. First aid measures                      | 12. Ecological information          |
| 5. Fire fighting measures                  | 13. Disposal considerations         |
| 6. Accidental release measures             | 14. Transport information           |
| 7. Handling and storage                    | 15. Regulatory information          |
| 8. Exposure control/personal protection    | 16. Other information               |

# Other properties of interest

## CLP labelling

- Main hazard properties
- Standardized tests



Hazard Statement <sup>1</sup>	Risk Phrase <sup>2</sup>
H300 Fatal if swallowed	R28
H301 Toxic if swallowed	R25
H304 May be fatal if swallowed and enters airways	R65
H310 Fatal in contact with skin	R27
H311 Toxic in contact with skin	R24
H330 Fatal if inhaled	R23; R26
H331 Toxic if inhaled	R23
H340 May cause genetic defects	R46
H341 Suspected of causing genetic defects	R68
H350 May cause cancer	R45
H350i May cause cancer by inhalation	R49