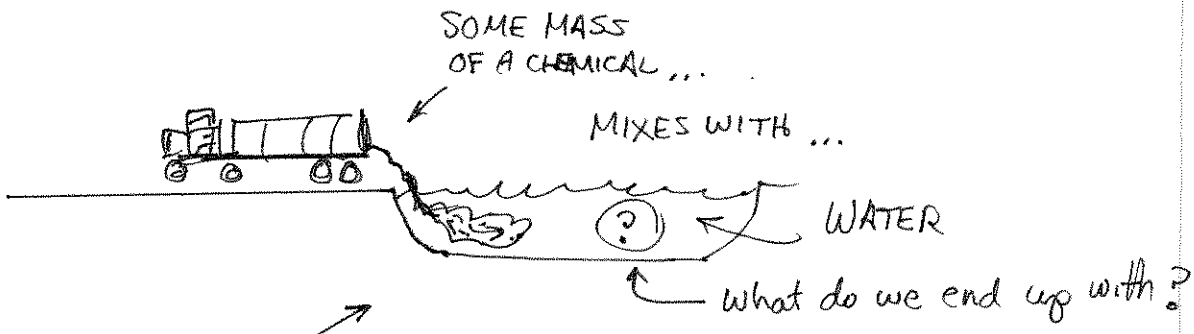
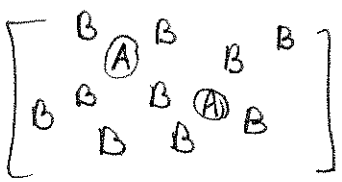
BASIC CONCEPTS ABOUT MASS MIXED WITH A FLUID



"BINARY FLUID"

Molecules of "A" are dissolved in fluid "B"



Eg.) A = C_2H_5OH = ethanol = EtOH

B = H_2O = water

A in B: VODKA ← BINARY FLUID

MASS Abbrev - M SI unit g or kg

10^{-18}	10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{0}	10^{3}	10^{6}	10^{9}	10^{12}
ag	fg	pg	ng	μg	mg	g	kg	Mg	Gg	Tg

RANGE WE'LL USE MOST

↑ Used in global scale processes "Tg of CO_2/year"

LENGTH Abbrev - L SI unit m

We're most interested in:

10^{-9}	10^{-6}	10^{-3}	10^{0}	10^{3}
nm	μm	mm	m	km
wavelength of light	size of suspended particles	grains of coarse sand	scale of eddies, water depth	Length of lakes, rivers

EXAMPLES:

AREA Abbrev - A

$A = L \times L = L^2$ Units: m^2 OR HECTARE = $100m \times 100m$ (~2.5 acres) = $10^4 m^2$

VOLUME Abbrev - V

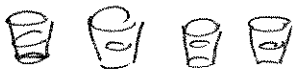
$V = L \times L \times L = L^3$ Units: m^3 OR dm^3 = LITER (L) OR cm^3 = mL (10^{-3} L)

NEXT: EXTENSIVE PROPERTIES VS. INTENSIVE PROPERTIES

EXTENSIVE For given system: SUM UP THE VALUE OF THE PROPERTY IN EVERY PART OF THE SYSTEM

EX: MASS:

↳ POUR OUT SHOTS & WEIGH...



50g 50g 50g ... Σ 1000 g

(x 20)

WE SAY THE TOTAL MASS is 1 kg

EXTENSIVE PROPERTY

VOLUME Determine Volume of each shot & sum

50 mL x 20 → Σ 1000 mL = 1 L

Volume is EXTENSIVE PROPERTY

TOTAL NUMBER OF MOLES OR MOLECULES Same process: Moles, number of molecules (N) EXTENSIVE

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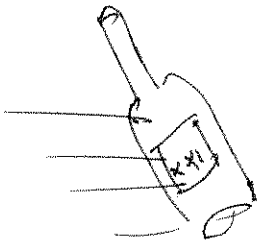
① IN GENERAL: EXTENSIVE PROPERTIES ARE PROPORTIONAL TO THE MASS OF THE SYSTEM (check each above to convince yourself of that) (Characteristic of "whole system")

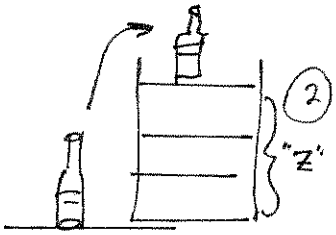
Some other examples: ① If we hurl the bottle...



Bottle gains KINETIC ENERGY

Definition of K.E.?

Is K.E. EXTENSIVE?



② Put bottle up on top shelf some height "z"

P.E. = Force x Distance = $Fz = maz$

$= mgz$

Is P.E. EXTENSIVE?

INTENSIVE PROPERTIES are NOT obtained by summing all parts of system

Instead an Intensive Prop. is MEASURED AT A POINT in system

INTENSIVE PROPERTY VALUE is INDEPENDENT OF TOTAL MASS

Ex: MASS - Extensive

VOLUME - Extensive

But what if we pour up one (random) shot and measure the MASS OF THAT VOLUME

$V = 50\,mL = 0.05\,L$

$M = 45\,g = 0.045\,kg$

$$\frac{M}{V} = \frac{0.045\,kg}{0.05\,L} = 0.90\,\frac{kg}{L} \equiv \text{DENSITY } (\rho)$$

Density of Vodka is same for any shot, of any size $V = 25\,mL$, $M = 22.5\,g$ $\Rightarrow \rho = 0.90$ (RHO)

DENSITY (ρ) IS INTENSIVE PROPERTY (DOES NOT DEPEND ON TOTAL MASS IN SYSTEM)

In fact: Take 2 bottles, both exactly 1 kg

① FREEZER ($T = -10°C$)
② SHELF ($T = 20°C$)

SAME MASS (YES) → SAME DENSITY? (?)

OTHER INTENSIVE PROPERTIES...

Name some important common things we measure in a fluid that don't depend on total mass.

Let's combine some of these to describe binary fluids

CONCENTRATION (Intensive Property) Abbrev – C

↑

"Amount of "A" dissolved in "B"

↑

[MASS OR VOLUME] of A – IN → [MASS OR VOLUME] of B

$\frac{VOL}{MASS}$ = specific volume = $\hat{V}$ NOT A "CONC." But used in Thermodynamics a lot

	MASS of A / VOLUME of B	MASS of A / MASS of B	VOL. of A / VOL of B
DIMENSIONS	$\frac{M}{L^3}$	$\frac{M}{M}$	$\frac{L^3}{L^3}$
SAMPLE UNITS	g/L mg/L $\mu g/cm^3$ kg/m^3 mol/L	mg/kg $\mu g/g$	mL/m^3
	Most common for water pollutants (dissolved) NOTICE that this C depends on fluid density (L^3 varies)	Common for pollutants attached to soil or sediment SOLIDS ALSO: Used a lot in OCEAN WATER for dissolved chemicals (seawater = variable density)	Mostly used in AIR QUALITY standards because the density of air is so easily changed by temp or altitude (V/V changes in proportion; $\hat{V}$ constant)

THE PART-PER-MILLION (ppm) OR PART-PER-BILLION, etc

$1\ \mu g/g = 10^{-6}\ g/g$ = "10^{-6}" = 1 ppm [exactly]

$1\ mL/m^3 = 10^{-6}\ m^3/m^3$ = 1 ppm [exactly]

$1\ mg/L \approx 1\ mg/kg$ OF DILUTE, FRESHWATER near 25°C = 1 ppm (close, but still approx.)

CONC. EXAMPLE

Make Vodka: $\underset{\text{RECIPE}}{\text{Rx}}$: 0.40 kg EtOH ("A")
0.60 kg H_2O ("B")

M_T = 1.00 kg VODKA (A+B)

$$C_A = \frac{0.40\ kg}{1.00\ kg} = 0.40\ \frac{kg}{kg} = 0.40 \equiv \boxed{40\%}$$ PARTS PER HUNDRED (PER CENT)

$C_B = 0.60 = 60\%$

↑ We say "40% EtOH by weight (mass)" [(w/w) BASIS]

OR) $C_A = \frac{g}{L} \; ? \; \left(\frac{M}{V}\right)$ Check volume

V_{EtOH} = 510 mL = 0.51 L
V_{H_2O} = 600 mL = 0.60 L
V_T = 1,100 mL = 1.10 L

$$C_A = \frac{0.40\ kg}{1.10\ L} = 0.36\ \frac{kg}{L} = 360\ \frac{g}{L} = \boxed{36\%}$$

"BY WEIGHT / VOLUME" (W/V BASIS)

OR) $$C_A = \frac{0.51\ L}{1.10\ L} = 0.46\ \frac{L}{L} = \boxed{46\%}$$

"BY VOLUME (V/V)" BASIS

↖ Legal Definition for Booze (I think)

NOTICE that if you put your vodka in the freezer the conc. (w/v) changes (gets higher) but w/w stays same and v/v changes very slightly

Combine some more concepts

Intensive Properties: Don't depend on mass or volume so perfect for doing experiments or computations

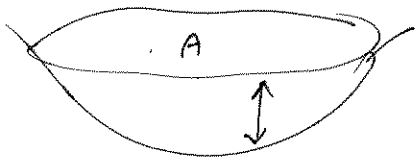
E.g. Conc. in a small volume is same as conc. in huge volume.

But may need to convert

INTENSIVE back to EXTENSIVE

Ex: 1

POND



Surf Area = 2.0 HA

= 20,000 m^3

Mean Depth = 2 m

V_T = 2m × 20,000 m^2 = 40,000 m^3 = (40 mill. L)

Water Polluted WITH BUTANOL (C_4H_9OH, BuOH) (As in Ex 1-1 IN TEXT)

$C_{BuOH} = 10^{-4}$ kg/m^3 ($= 10^{-4}$ g/L = 0.1 mg/L) [INTENSIVE]

WHAT IS TOTAL MASS [EXTENSIVE] OF BuOH IN LAKE

$C = \frac{M}{V} \Rightarrow M = CV = \left(10^{-4}\ \frac{kg}{m^3}\right) \times \left(4 \times 10^4\ m^3\right)$

= 4 kg TOTAL BUTANOL (ANS)

Ex: 2

Oil well discharges BRINE to a holding pond of 1000 m^3 (mostly NaCl)

Brine conc is 5% NaCl w/w } Intensive

Brine density is 1.3 kg/L }

$M_T = C \cdot V = \left(0.05\ \frac{kg\text{-}NaCl}{kg\text{-}H_2O}\right)\left(1.3\ \frac{kg}{L}\right)\left(\frac{1000\ L}{m^3}\right)\left(1000\ m^3\right)$

(1.3 kg/L: DENSITY CORR'N)

M_T = 65,000 kg NaCl

What about MOVEMENT OF EXTENSIVE PROPERTIES ?

⇒ FLOW of MASS or VOLUME

FLOW ≡ $\frac{\text{QUANTITY MOVED}}{\text{UNIT TIME}}$

EXPRESSION	$\frac{\text{mass}}{\text{time}}$ $\left[\frac{M}{T}\right]$	$\frac{\text{volume}}{\text{Time}}$ $\left[\frac{L^3}{T}\right]$
NAME	MASS FLOW	VOLUMETRIC FLOW
EXAMPLES	kg/s lb/d	m^3/s L/h (Lph) gal/d (gpd) million gal/d (mgd)
ABBREV	$\dot{m}$	Q

FOR A BINARY FLUID A in B

$$\boxed{\dot{m}_A = C_A Q_{tot}}$$ ← SIMPLE, SO MEMORIZE

Ex (from 1-1 in text) A = BuOH

$C_A^{LAKE} = 10^{-4}$ kg/m^3

$Q_T^{OUT} = 3 \times 10^4$ m^3/d

$\dot{m}_{BuOH} = (3\times10^4 \text{ m}^3/\text{d})(10^{-4} \text{ kg/m}^3) = \underline{3 \text{ kg/d}}$ LEAVING LAKE VIA STREAM

Another VERY USEFUL RELATIONSHIP (MEMORIZE!!)

$$\boxed{Q = v A_{x.s.}}$$

v = mean VELOCITY OF RIVER/STREAM

$A_{x.s.}$ = cross-sectional area of RIVER/STREAM

Hence: $\dot{m}_A = C_A v A_{xs}$