29 MAR 2021 HANDNOTES F. MORRISON CM3120 1

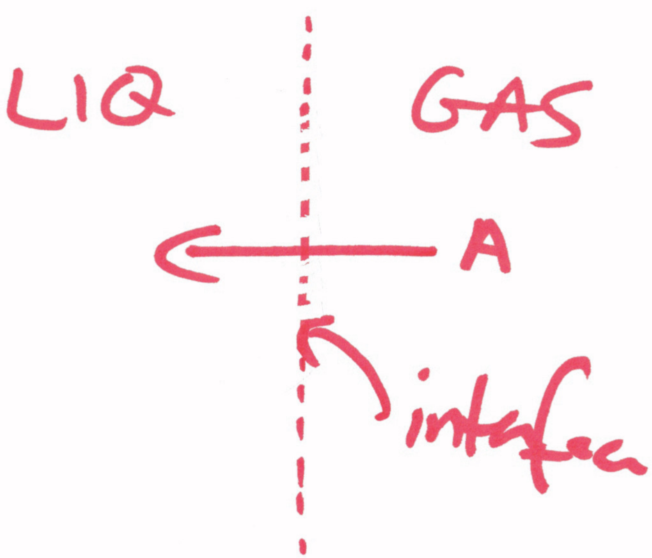


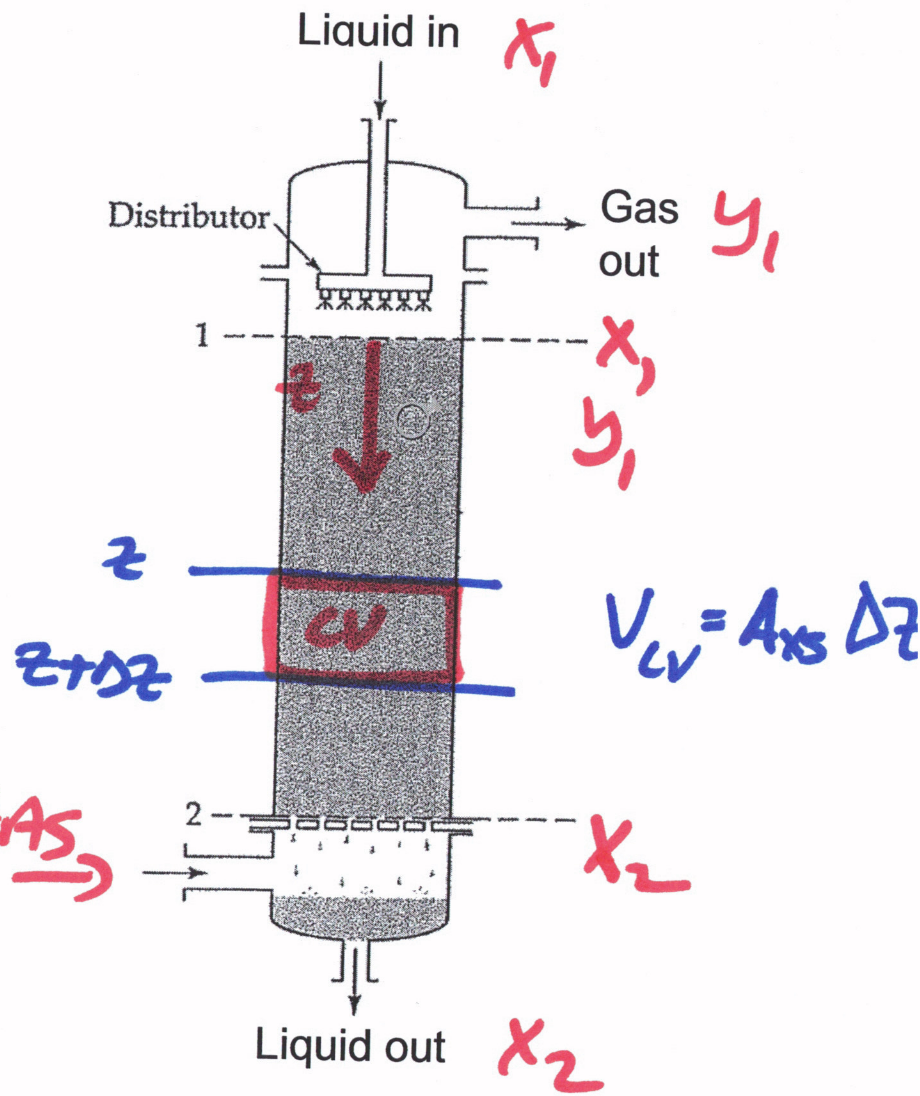
**Example 6**

# What is our model for the entire column??

(our assumptions) ?

1. Control volume =
2.



1½

**Example 6:** Height of a packed bed absorber

How can we use mass transfer to design a packed bed gas absorber to achieve a desired separation?

**Example 6** is presented as a series of **linked examples** that navigate around apparent "dead ends" in modeling mass-transfer units

→ TODAY

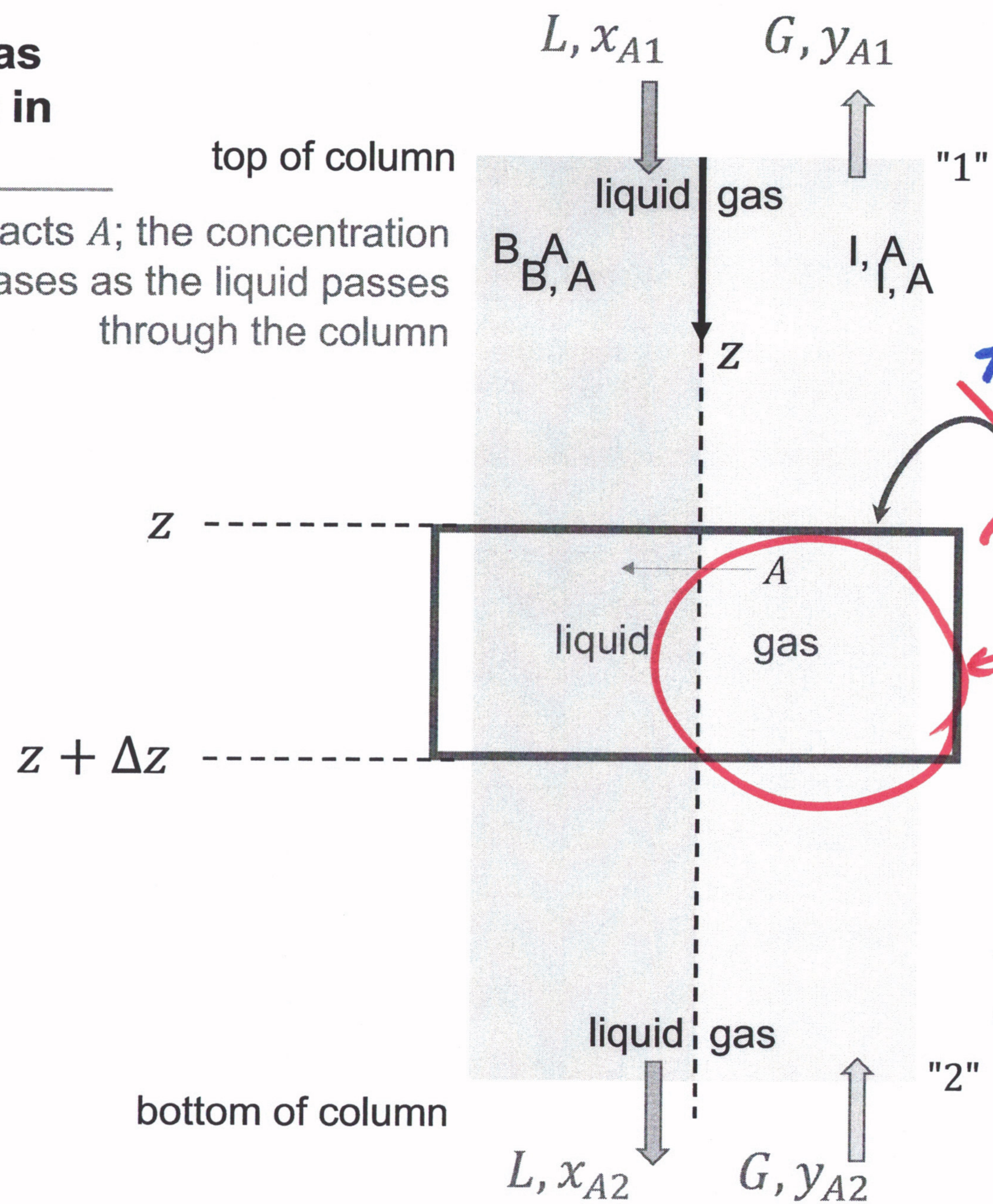
| Identify a question | Invent something | Try to use it |
| --- | --- | --- |
| 1. How can we model a large, practical device dependent on mass transfer? | 1. Apply the species A mass balance to a macroscopic C.V. | 1. Lack a system to account for A going between phases ☹ |
| 2. How an we account for A going between phases? | 2. Invent $k_x$ through linear driving force (LDF) model | 2. Gets A *to* the boundary, but not *across* |
| 3. How can we improve LDF model to cross the boundary (bulk-to-bulk transfer)? | 3. Write LDF in both phases and combine to create overall effect of multiple resistances | 3. Working, but can we devise a convenient shorthand? |
| 4. Can we model a large, practical device, incorporating $K_L, K_G$ to account for mass xfer between phases? | 4. Yes | |

2

## Model of Gas Absorption in a Column

Liquid $B$ attracts $A$; the concentration of $A$ increases as the liquid passes through the column

$$0 \leq z \leq L$$

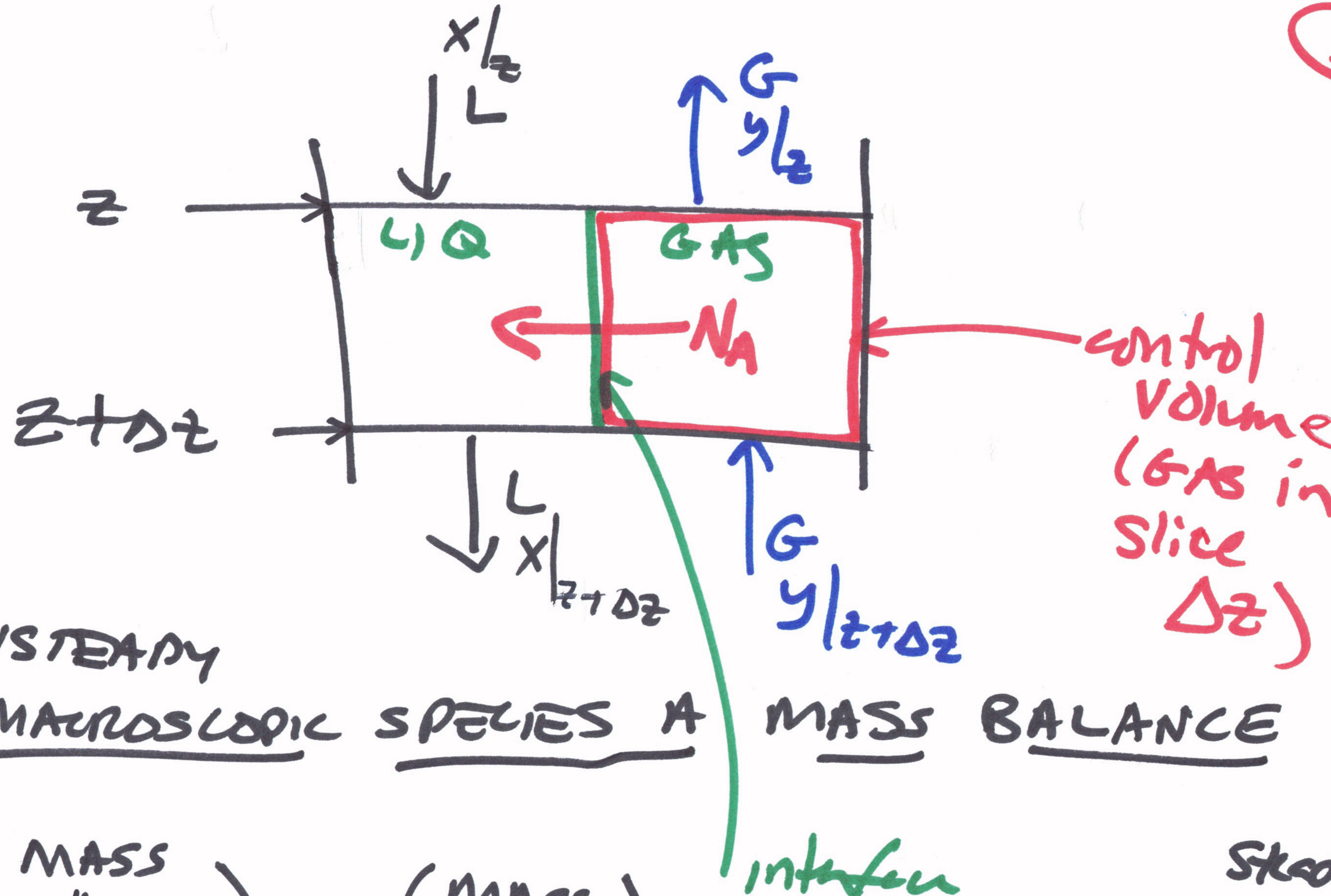



We want to capture mass xfer

~~C.V.~~

choose gas only as control volume

Gas contains $A$, which depletes as the gas passes through the column




UNSTEADY
MACROSCOPIC SPECIES A MASS BALANCE

$$\begin{pmatrix}\text{MASS}\\ \text{A}\\ \text{into c.v.}\end{pmatrix} - \begin{pmatrix}\text{MASS}\\ \text{A}\\ \text{out of}\\ \text{CV}\end{pmatrix} - \begin{pmatrix}\text{MASS}\\ \text{A}\\ \text{crossing}\\ \text{interface}\end{pmatrix} = \frac{dm}{dt}$$

Steady

9

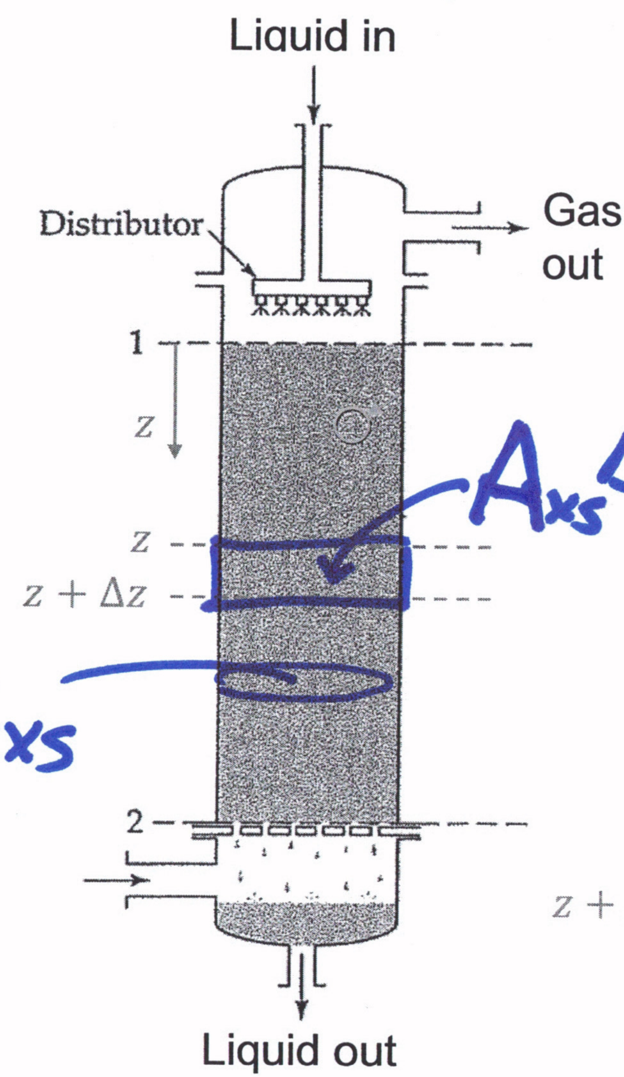
## Unsteady Macroscopic Species $A$ Mass Balance—Gas Absorption

**Example 6**

$$a \equiv \frac{\text{interfacial area}}{\text{volume}}$$

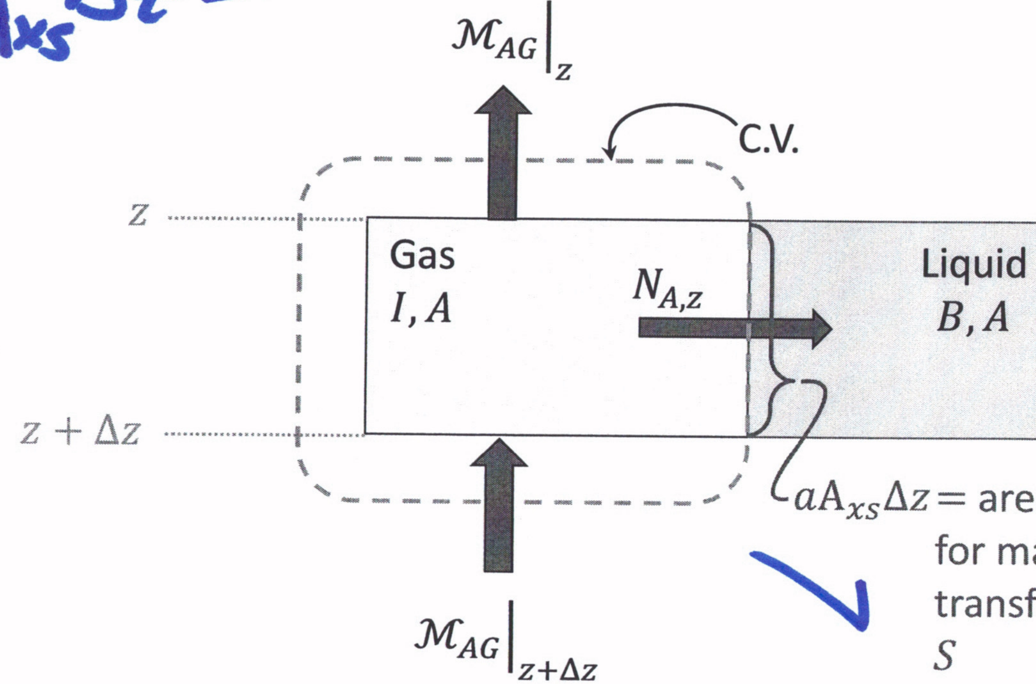
A property of the column and packing, in operation

Mass flux of species $A$ **from gas to liquid** $\equiv N_{A,z} = \frac{\text{moles } A}{\text{area} \cdot \text{time}}$




$A_{xs}\Delta z$ = volume

$A_{xs}$




$aA_{xs}\Delta z =$ area for mass transfer, $S$

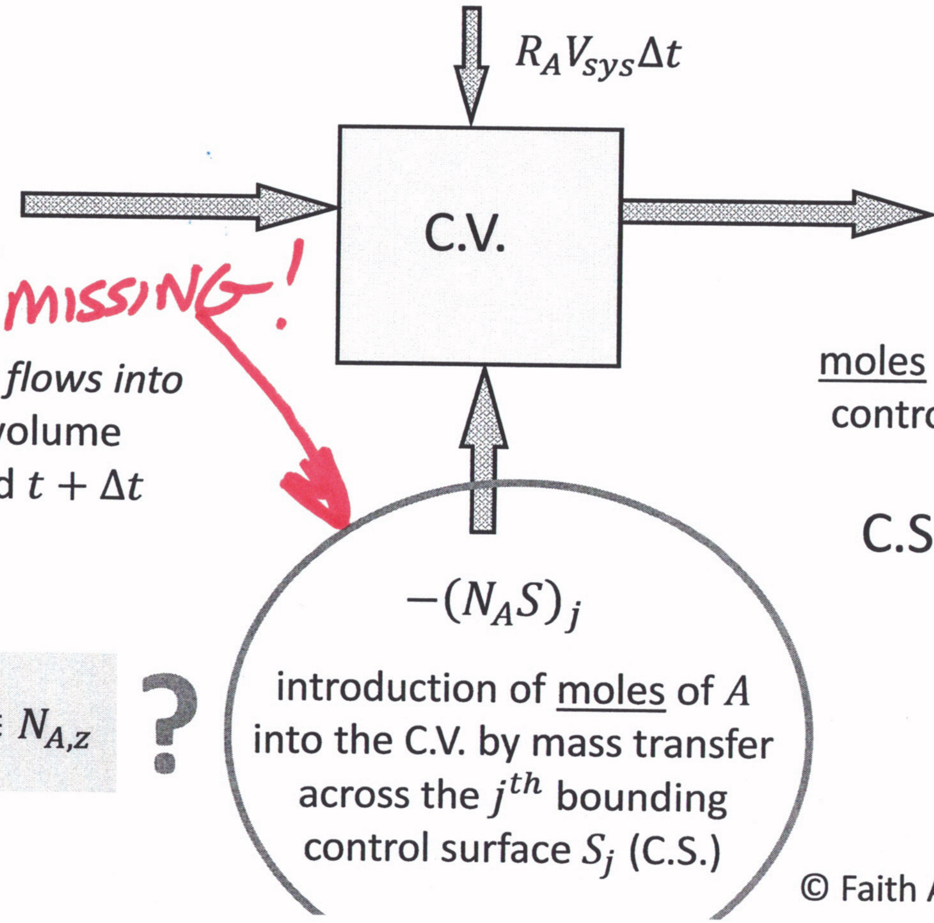
MOLES

## Unsteady, Macroscopic, Species A Mass Balance

balance over time interval $\Delta t$

Macroscopic control volume, C.V.

$R_A$ = net rate of production of moles of $A$ in the C.V. by reaction, per unit volume




$\underbrace{\dot{\mathcal{M}}_A \, \Delta t}$

moles of $A$ that *flows into* the control volume between $t$ and $t + \Delta t$

$\underbrace{\dot{\mathcal{M}}_A \, \Delta t}$

moles of $A$ that *flows out of* the control volume between $t$ and $t + \Delta t$

C.S.

$$S_{sys} = \sum_j S_j$$

C.S. = control surface
C.V. = control volume

Mass flux of species $A$ **from gas to liquid** $\equiv N_{A,z}$ ?

BSL2, p727

Recall Energy:

$$\left|\frac{q_x}{A}\right| = h\left|\overbrace{(T_L - T_W)}^{\text{heat xfer (temp) driving force at an interface}}\right|$$

$\textcircled{SL}$ 2

now MASS SPECIES A:

$$N_A = K \underbrace{\Delta C_{\text{driving force}}}_{\text{at interface}}$$

## Unsteady Macroscopic Species $A$ Mass Balance—Intro

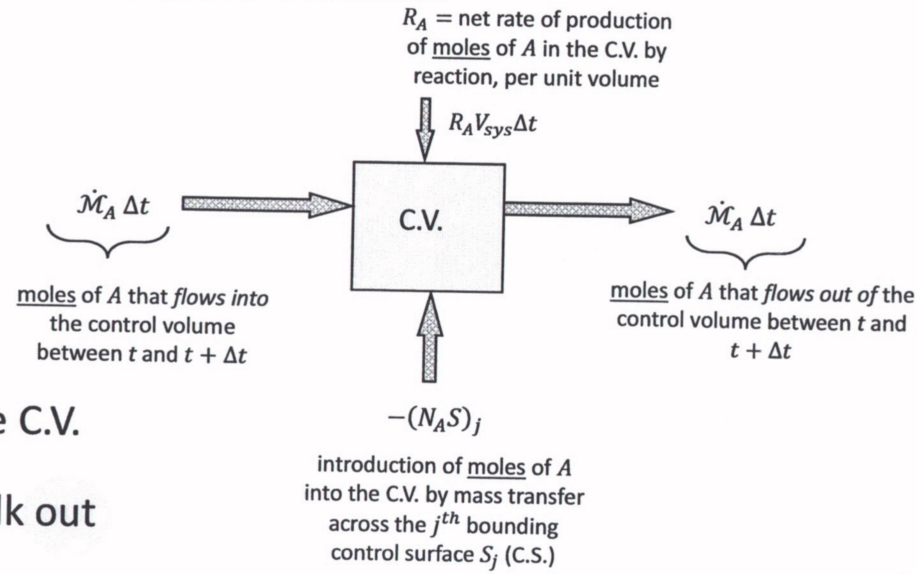
**MOLES**

*accumulation = net flow in + production + introduction*

$$\boxed{\frac{d}{dt}\left(\mathcal{M}_{A,sys}\right) = -\Delta\dot{\mathcal{M}}_A + R_A V_{sys} - \sum_j (N_A S)_j}$$

WE NEED

$N_A = K\Delta c_{df}$




$\mathcal{M}_{A,sys} = c_A V_{sys}$ = total moles of $A$ in the C.V.

$\Delta\dot{\mathcal{M}}_A = \sum_{j,outs}\dot{\mathcal{M}}_{A,j} - \sum_{j,ins}\dot{\mathcal{M}}_{A,j}$ = bulk out

$R_A$ = net rate of production of moles of $A$ in the C.V. by reaction, per unit volume

$V_{sys}$ = system volume

$N_{A_j} = K\Delta c_{df}$ =molar flux of $A$ out through the $j^{th}$ C.S.

mass transfer between two phases

$S_{sys} = \sum_j S_j$

$\Delta$ is "out"- "in"

C.S. = control surface

C.V. = control volume