

3. MACROSCOPIC MATERIAL BALANCES

A. INTRODUCTION

SYSTEM - A DEFINABLE VOLUME
A CONTROL VOLUME

SPECIES - A DISTINGUISHABLE "COMPONENT" OF
A MIXTURE ... CONTEXTUAL

AIR O_2, N_2, Ar, CO_2, H_2O

SOIL SAND, CLAY, WATER

SOIL C, N, S, P, K, Fe

BLOOD WHITE BLOOD CELLS, RED BLOOD CELLS, etc.

LAW OF CONSERVATION OF MASS

MASS CANNOT BE CREATED NOR DESTROYED

i. MASS BALANCES

THIS LAW RESULTS IN THE FOLLOWING EQUATION
REPRESENTING AN "OVERALL BALANCE"

$$\begin{array}{ccccc} \text{ACCUMULATION} & & \text{MASS} & & \text{MASS} \\ \text{OF MASS IN} & = & \text{INTO} & - & \text{OUT OF} \\ \text{SYSTEM} & & \text{SYSTEM} & & \text{SYSTEM} \end{array}$$

AN OVERALL BALANCE MEANS WE ARE CONSIDERING
ALL MATERIALS.

EXAMPLE 1

SYSTEM: A BUCKET

PUT 5 POUNDS OF SAND INTO BUCKET

REMOVE 3 POUNDS OF SAND FROM BUCKET

HOW MUCH SAND HAS ACCUMULATED IN SYSTEM?

$$ACC = IN - OUT$$

$$IN = 5$$

$$OUT = 3$$

$$ACC = 5 - 3 = \underline{2 \text{ POUNDS}}$$

"ACC" MEANS
CHANGE
(FINAL STATE -
INITIAL STATE)

- MASS OF SAND IN SYSTEM HAS INCREASED BY 2 POUNDS
 - WE CANNOT TELL HOW MUCH SAND IS NOW IN BUCKET BECAUSE WE DO NOT KNOW HOW MUCH SAND WAS INITIALLY PRESENT.
-

TOTAL MASS OF MATERIAL DOES NOT CHANGE. HOWEVER, INDIVIDUAL SPECIES CAN BE CONVERTED INTO OTHER SPECIES. A SPECIES BALANCE (OR "COMPONENT BALANCE") HAS AN TERM TO ACCOUNT FOR ANY REACTION.

ACCUMULATION
OF MASS OF
SPECIES

=

MASS OF
SPECIES INTO
SYSTEM

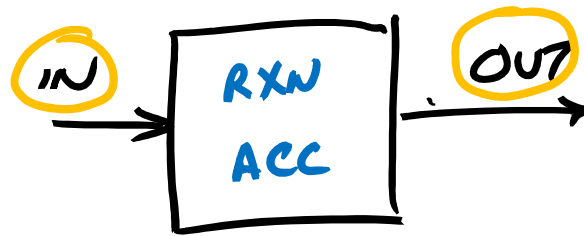
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MASS OF
SPECIES OUT
OF SYSTEM

+

MASS
GENERATED
IN SYSTEM

NOTE: "ACCUMULATION" $\neq$ "GENERATION" TERMS REFER TO WHAT'S OCCURRING INSIDE SYSTEM
"INTO" $\neq$ "OUT OF" TERMS REFER TO STREAMS WHICH ENTER OR EXIT SYSTEM.



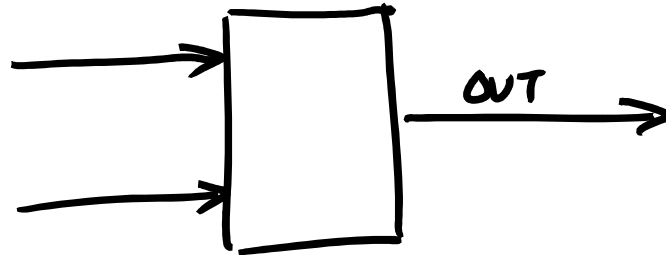
- SYSTEMS IN WHICH A REACTION OCCURS ARE GENERALLY HANDLED USING MOLE BALANCES. (LATER)
- SYSTEM CAN EITHER BE BATCH (LIKE THE BUCKET EXAMPLE) IN WHICH THERE IS NO SENSE OF TIME OR CONTINUOUS. THERE IS NOT CHANGE IN THE FORM OF THESE EQUATIONS.

EXAMPLE 2

60 g/min OF 70% (BY MASS) ETHANOL IN
WATER IS MIXED WITH 90 g/min OF 40% ETHANOL.
WHAT IS THE RESULTING MIXTURE'S MASS FLOWRATE
AND COMPOSITION?

60 g/min
 $w_E = 0.70$

90 g/min
 $w_E = 0.40$



$\dot{m}^{OUT} = ?$
 $w_E^{OUT} = ?$

SUBSCRIPT:
SPECIES
SUPERSCRIPT:
STREAM
NAME

NOTE: NO REACTION.

OVERALL BALANCE

$$ACC = IN - OUT$$

$$0 = 60 \text{ g/min} + 90 \text{ g/min} - \dot{m}^{OUT}$$

$$\dot{m}^{OUT} = 150 \text{ g/min}$$

SPECIES BALANCE - ETHANOL

$$ACC = IN - OUT + GEN$$

$$0 = (0.70)(60 \text{ g/min}) + (0.40)(90 \text{ g/min}) - w_E^{OUT}(150 \text{ g/min}) + 0$$

$$w_E^{OUT} = 0.52$$