Reactors

WAT-E2120 Physical and Chemical Treatment of Water and Waste

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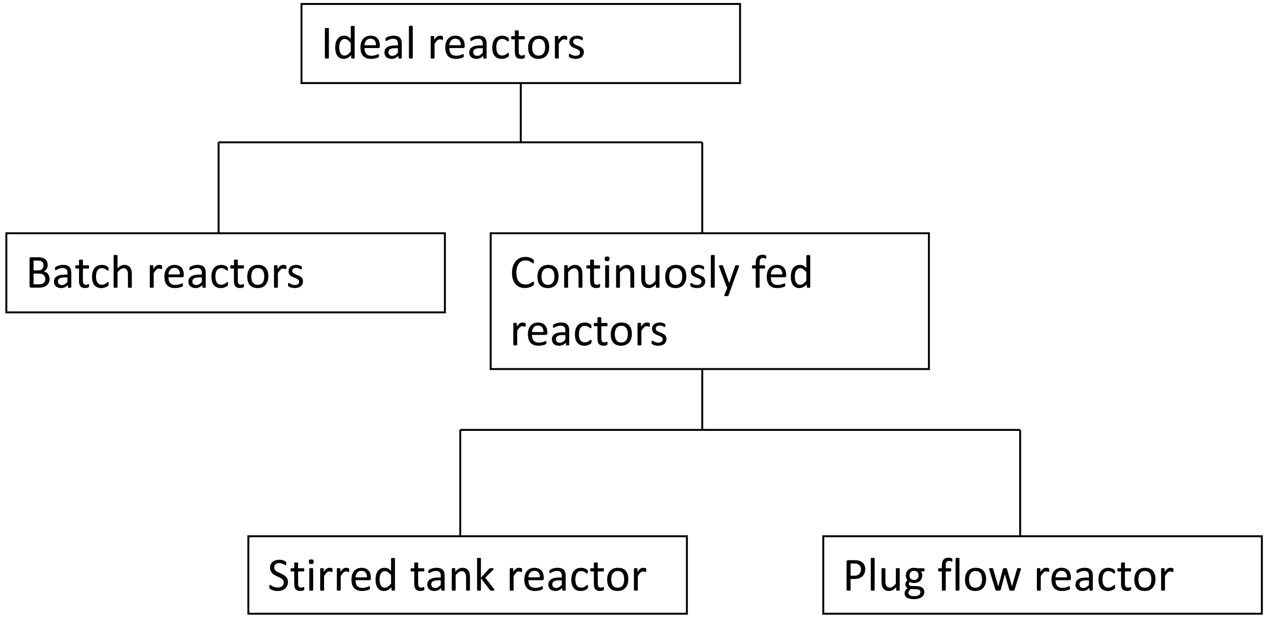
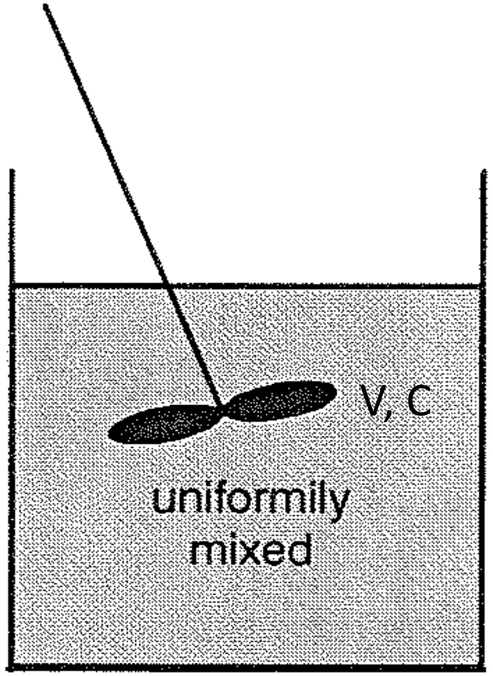
Designing reactors



Batch reactor



- The reaction is let run until the desired yield is reached
- No flow in or out
- => The end products are available only after the reaction time is finished
- For a constant volume V:

$$V\frac{dC}{dt} = Vr_c$$

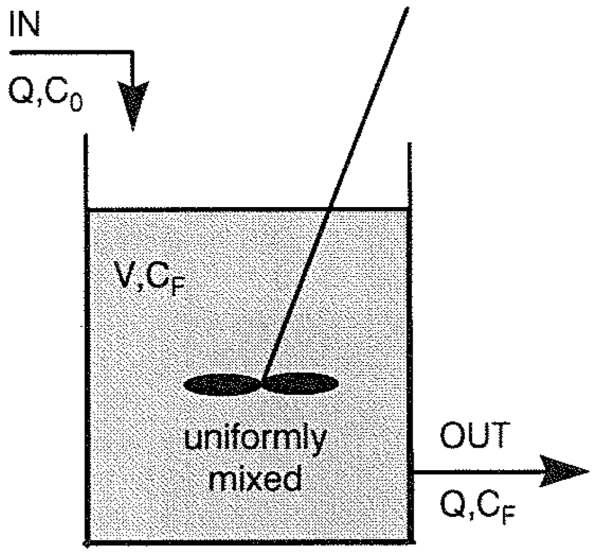
$$\frac{dC}{dt} = r_c$$

for a first-order reaction where C is consumed from an initial concentration of C_O:

$$r_C = -kC$$

Integrated form with solved concentration by time: $C = C_O\exp(-kt)$

Continuous flow stirred tank reactor (CFSTR, CSTR)



- Flow in and out = Q
- Tank volume = V
- Influent concentration = C_0
- Effluent concentration = C_F
- Completely mixed
- The concentration of the end products in the reactor = concentration in the outflow
  - The yield is limited because the influent is mixed to the whole tank volume

Steady-flow of water conditions: $Q_{in} = Q_{out} = Q$ and $\frac{dV}{dt} = 0$

Mass Inflow + Mass generated = Mass outflow + Mass accumulated

$$QC_O + Vr_C = QC + V\frac{dC}{dt}$$

$$C_O - C + \frac{V}{Q}r_C = \frac{V}{Q}\frac{dC}{dt}$$

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CFSTR cont'd

From previous page

$$C_O - C + \frac{V}{Q} r_C = \frac{V}{Q} \frac{dC}{dt}$$

Definition: Retention time = hydraulic residence time = the time required for a reaction

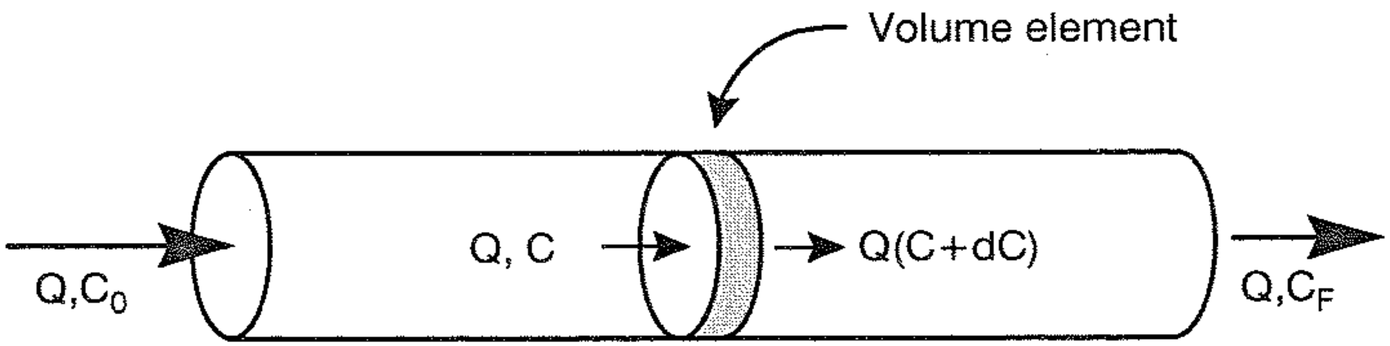
$$\theta = \frac{V}{Q}$$

In stationary state dC/dt =0

$\Rightarrow$ C_o- C + θ r_c =0

(Exercise 3 b)

Plug flow reactor (PFR)



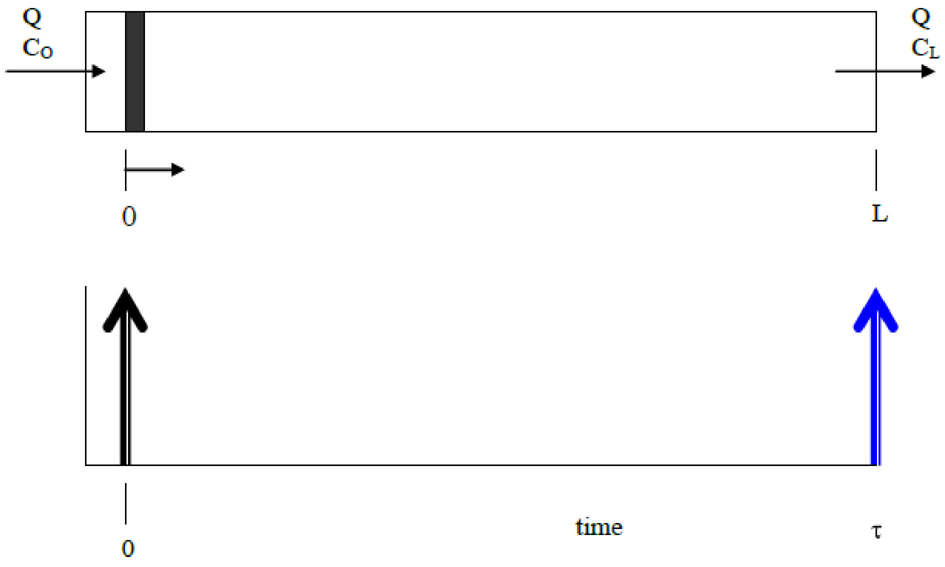
- Continuous flow reactor
- Influent fed to one end of the reactor
- Effluent drawn from the other end
- No mixing
- Reaction advances along the length of the reactor
- Concentrations different in the influent and effluent
- Hydraulic retention time is the same as for CFSTR

$$\theta = \frac{V}{Q}$$

Plug flow reactor

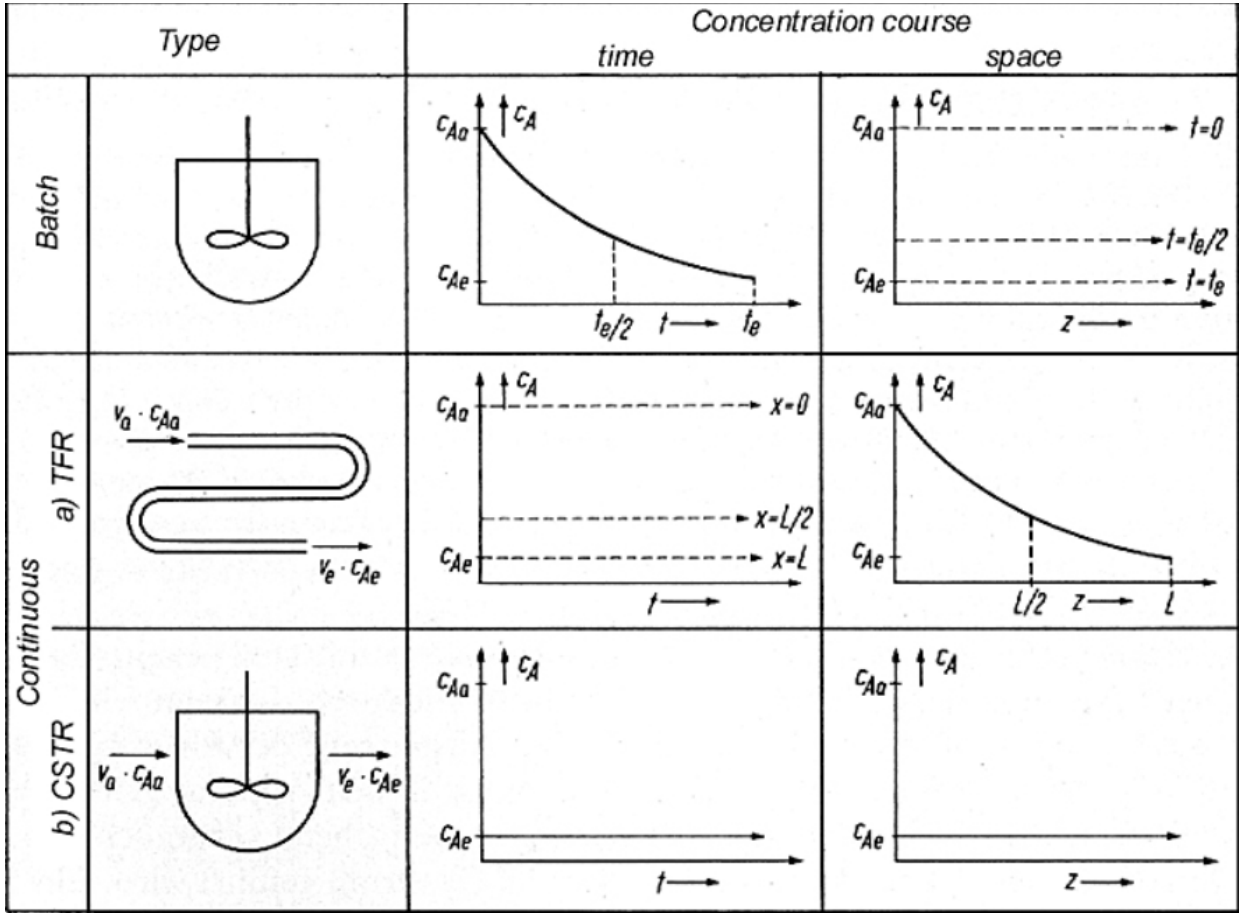
Characteristics of ideal plug flow

- PERFECT MIXING IN THE RADIAL DIMENSION (UNIFORM CROSS SECTION CONCENTRATION)
- NO MIXING IN THE AXIAL DIRECTION, OR NO AXIAL DISPERSION (SEGREGATED FLOW)



TRACER PULSE INPUT AT t = 0 TRANSLATED TO EQUAL PULSE

Ideal reactors

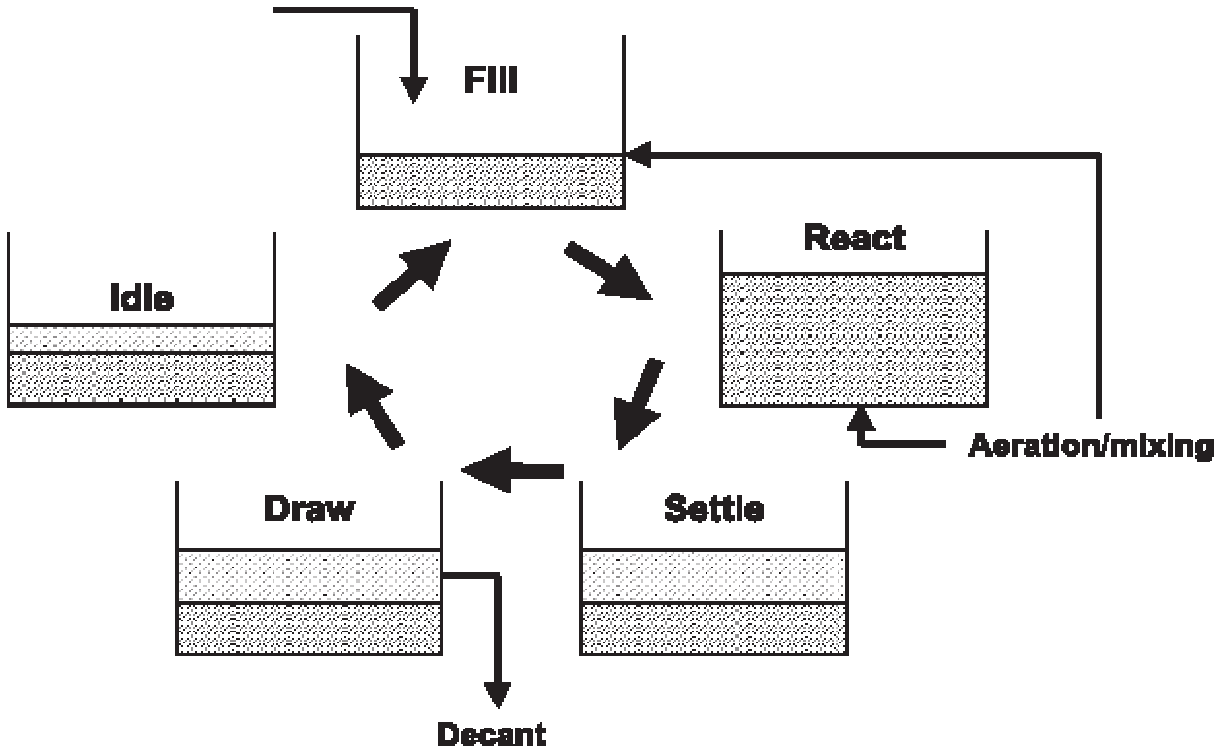


<u>the batch stirred tank reactor:</u> concentration is constant in the whole tank, but it is dropping down with the time. The reactor is **<u>not</u> stationary in (both) space <u>and</u> time.**

<u>the continuous plug (tubular) flow reactor:</u> concentration is constant over the time at different length positions along the tube. The concentration drops down along the reactor length. The reactor is **<u>not</u> stationary in (both) space <u>and</u> time.**

<u>the continuous stirred tank reactor:</u> concentration is stationary in space and time. The reactor is **stationary in space <u>and</u> time**. (not in the start-up- , shutdown- or disturbed operation phase)

Semicontinuous batch reactor SBR – especially in wastewater treatment



All phases happen in the same tank sequentially

Reactors in series

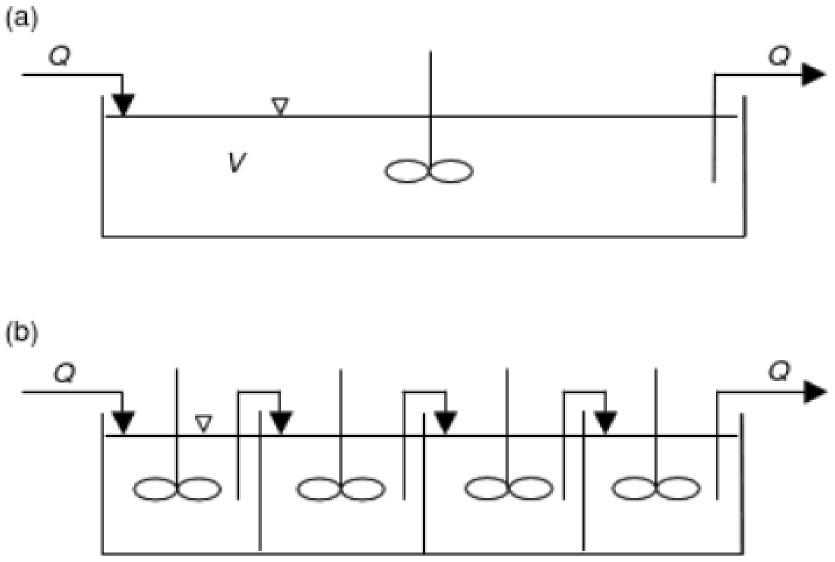


FIGURE 2-18. (a) A single CFSTR with volume V, and (b) the same tank divided into four equal-sized ($V/4$) CFSTRs in series.

- CFSTRs are sometimes used in series.
- Increases the yield, without adding volume
- The more CFSTRs in series the more it approaches PFR