

GATE 2023 CH-58

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Question: A fresh catalyst is loaded into a reactor before the start of the following catalytic reaction:



The catalyst gets deactivated over time. The instantaneous activity $a(t)$, at time t , is defined as the ratio of the rate of reaction $-r_A(t)$ ($\text{mol.}(g_{\text{cat}})^{-1}\text{hr}^{-1}$) to the rate of reaction with fresh catalyst. Controlled experimental measurements led to an empirical correlation:

$$-r_A(t)' = -0.5t + 10$$

where t is in hours. The activity of the catalyst at $t = 10$ hours is given by (rounded off to one decimal place):

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Solution:

Values	Parameters	Description
$-r_A(t)$	$-0.25t^2 + 10t + C$	Rate of reaction at time t
$-r_A(0)$	10	Rate of fresh catalyst
$a(t)$	$\frac{-r_A(t)}{-r_A(0)}$	Activity of a catalyst at time t

TABLE 0
GIVEN PARAMETERS

$$-r_A(t)' = -0.5t + 10 \quad (1)$$

Integrating the rate expression with respect to time:

$$-r_A(t)' dt = (-0.5t + 10)dt \quad (2)$$

$$-r_A(t) = -0.25t^2 + 10t + C \quad (3)$$

Using the initial condition $t = 0$, where $-r_A(0) = 10$

$$-r_A(0) = -0.25(0)^2 + 10(0) + C \quad (4)$$

$$\Rightarrow C = 10 \quad (5)$$

$$= -0.25t^2 + 10t + 10 \quad (6)$$

The activity $a(t)$ is calculated by dividing the rate at any time ' t ' by the rate with fresh catalyst:

$$a(t) = \frac{-r_A(t)}{-r_A(0)} \quad (7)$$

$$= \frac{-0.25t^2 + 10t + 10}{-0.25(0)^2 + 10(0) + 10} \quad (8)$$

$$= \frac{-0.25t^2 + 10t + 10}{10} \quad (9)$$

Now, we calculate the activity at $t = 10$ hours:

$$a(10) = \frac{-0.25(10)^2 + 10(10) + 10}{10} \quad (10)$$

$$= \frac{-25 + 100 + 10}{10} \quad (11)$$

$$= \frac{85}{10} \quad (12)$$

$$= 8.5 \quad (13)$$

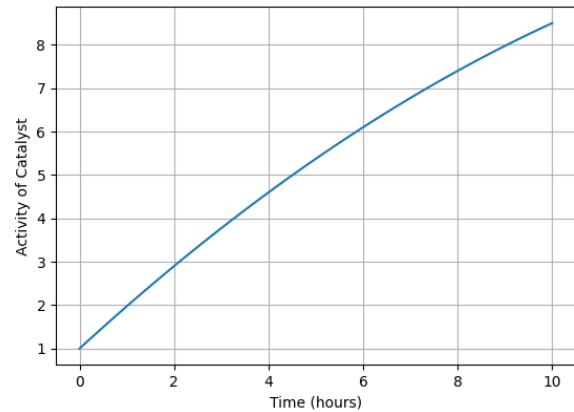


Fig. 0. Activity of catalyst