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:

$$A \rightarrow \text{Products}$$

The catalyst gets deactivated over time. The instantaneous activity $a(t)$, at time t, is defined as the ratio of the rate of reaction $-r_A(t)$ (mol.$(g_{cat})^{-1}$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:

$$-r_A(t)' = -0.5t + 10 \tag{1}$$

Integrating the rate expression with respect to time:

$$\int -r_A(t)'dt = \int (-0.5t + 10)dt \tag{2}$$

$$-r_A(t) = -0.25t^2 + 10t + C \tag{3}$$

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

$$-r_A(0) = -0.25(0)^2 + 10(0) + C = C = 10 \tag{4}$$

$$-r_A(t) = -0.25t^2 + 10t + 10 \tag{5}$$

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

$$a(t) = \frac{-r_A(t)}{-r_A(0)} \tag{6}$$

$$a(t) = \frac{-0.25t^2 + 10t + 10}{-0.25(0)^2 + 10(0) + 10} \tag{7}$$

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

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

$$a(10) = \frac{-0.25(10)^2 + 10(10) + 10}{10} \tag{9}$$

$$a(10) = \frac{-25 + 100 + 10}{10} \tag{10}$$

$$a(10) = \frac{85}{10} \tag{11}$$

$$a(10) = 8.5 \tag{12}$$