Thermal deactivation of bacteria is viewed as a simple first order reaction. If N(t) is the number of viable microorganisms per unit volume at time t and N0 is the initial number of viable microorganisms per unit volume, one can write

$$\frac{dN}{dt} = -k(T)N \quad (1)$$

$$N = N_0 \exp\{-k(T)t\} \quad (2)$$

k(T) is the first order rate constant at temperature T. Now,

$$k(T) = k_0 e^{-E/RT} \quad (3)$$

Eq. (2) can be written as

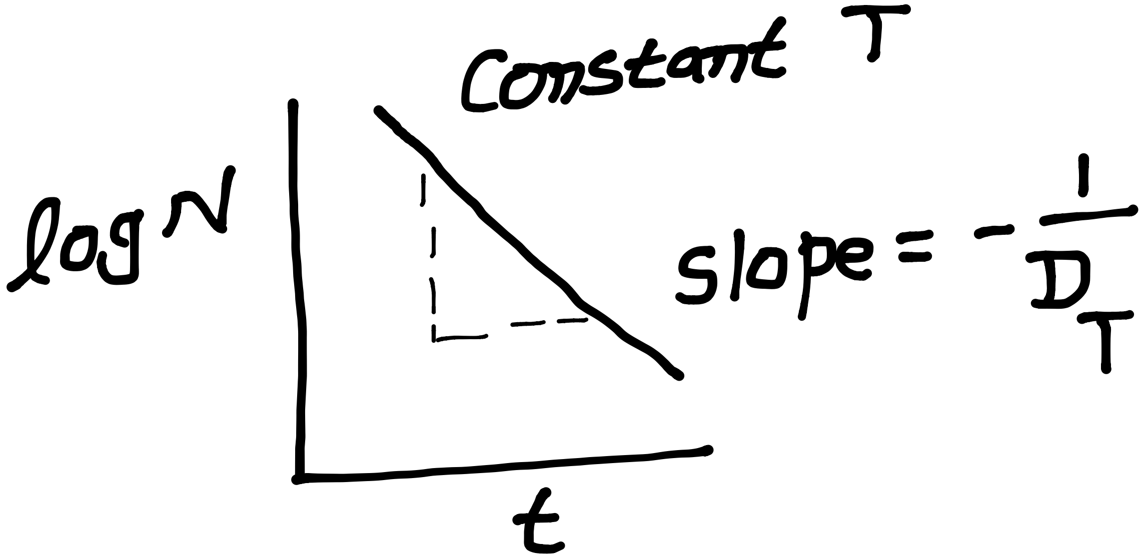
$$k(T)t = \ln\left(\frac{N_0}{N}\right) = \frac{1}{2.303} \log\left(\frac{N_0}{N}\right) \quad (2a)$$

Decimal reduction time $D_T$ is defined as the time it takes to reduce the number of viable microorganism by a factor of 10, i.e.

$$k(T)D_T = \frac{1}{2.303} \log(10) = \frac{1}{2.303}$$

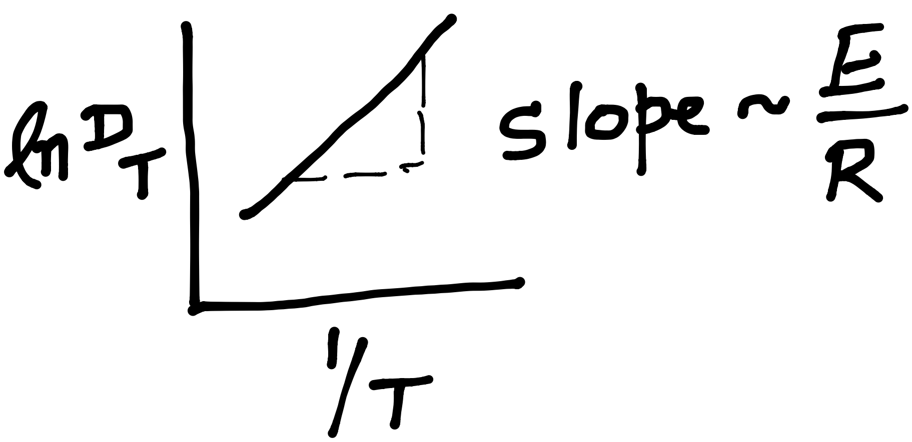
$$D_T = \frac{1}{2.303\, k(T)} \quad (4)$$

$$\therefore \; t = D_T \log\left(\frac{N_0}{N}\right) \quad (5)$$




As you would expect, the rate of deactivation increases with temperature, i.e. k(T) increases with temperature. Therefore, $D_T$ decreases with temperature.

$$D_T \propto \frac{1}{k(T)} \sim e^{E/RT}$$




Over a narrow range of temperatures encountered in thermal processing, $\log D_T \propto T$


The slope is usually referred to as z value which is found to be around 10 C. Each increment in temperature by z results in a 10 fold decrease in decimal reduction time. Of course, it varies from organism to organism. Clostedium botulinum is usually taken as reference microorganism for low acid (pH>4.6) foods.

$$\log\left(\frac{D_T}{D_{T_0}}\right) = -\frac{(T-T_0)}{z}$$

$$D_T = D_{T_0}\, 10^{-\frac{(T-T_0)}{z}} \qquad (6)$$

$$t = D_T \log\frac{N_0}{N} = D_{T_0} \log\frac{N_0}{N}\, 10^{-(T-T_0)/z}$$

$$\text{or} \quad D_{T_0} \log\frac{N_0}{N} = \text{Lethality} = t\, 10^{(T-T_0)/z} \qquad (7)$$

Lethality refers to equivalent processing time at reference temperature T0 for specified reduction in viable microorganism. Reference temperature T0 is usually taken as 250 F or 121.1 C. For example, for a 10^-12 reduction in viable microorganism, we have,

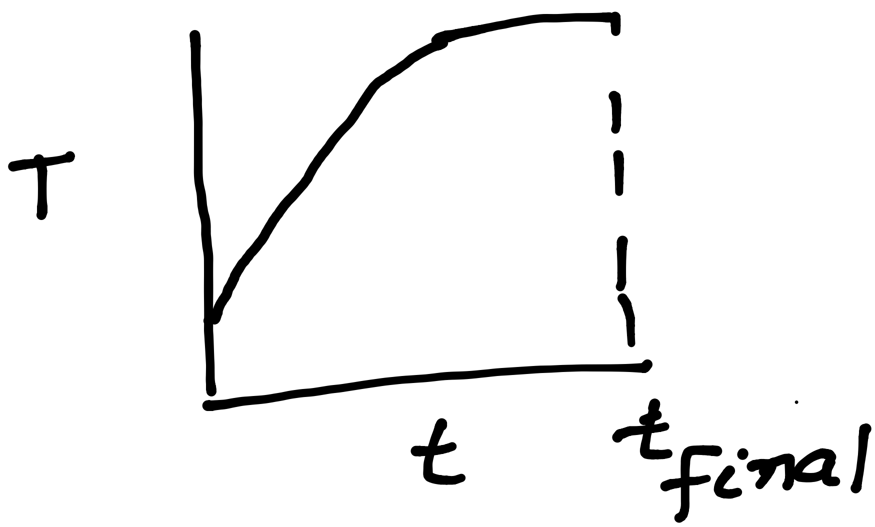
$$\frac{N}{N_0} = 10^{-12}$$

Lethality $F_0 = D_{T_0} \log \frac{N_0}{N} = 12 D_{T_0}$

$\therefore t = 12 D_{T_0} \, 10^{-(T-T_0)/z}$

As $T > T_0$ $t < 12 D_{T_0}$

As $T < T_0$ $t > 12 D_{T_0}$




$$F_0 = D_{T_0} \log \frac{N_0}{N} = \int_0^{t_{final}} 10^{\frac{T(t)-T_0}{z}} \, dt$$