For the purpose of ensuring a medication formulation's quality, efficacy, and safety, stability testing of pharmaceutical goods is a complex series of processes requiring significant expense, time commitment, and scientific skill. The capacity of a specific formulation in a specific container/closure system to maintain its physical, chemical, microbiological, toxicological, protective, and informational characteristics is referred to as a pharmaceutical product's stability. Thus, stability testing assesses how the environment affects a drug substance's or a formed product's quality in order to estimate its shelf life, identify the best conditions for storage, and recommend labeling guidelines.

Due to the inclusion of numerous elements that can affect a pharmaceutical product's stability, stability testing is considered to be a difficult operation. These variables include the stability of the active ingredient(s), interactions between active ingredients and excipients, manufacturing procedures used, dosage form type, packaging container/closure system, and environmental conditions for light, heat, and moisture during transportation, storage, and handling. Additionally, the stability of a pharmaceutical product can be greatly impacted by degradation reactions like oxidation, reduction, hydrolysis, or racemization. These reactions depend on a variety of factors, including the raw materials used, the time between production and use of the product, as well as environmental factors like reactant concentration, pH, radiation, and catalysts.

The stability of a pharmaceutical product can be affected by changes in its appearance, consistency, content uniformity, clarity (solution), moisture content, particle size and shape, pH, and package integrity. These physical alterations could be the result of collision, vibration, abrasion, temperature changes like freezing, thawing, or shearing, etc. Chemical reactions in pharmaceutical products like solvolysis, oxidation, reduction, racemization, etc. can result in degradation products, loss of active pharmaceutical ingredient (API) potency, and loss of excipient activity like antimicrobial preservative action and antioxidants, etc. (Carstensen et al., 2000). Microbiological alterations can also have an impact on a pharmaceutical product's stability, such as the expansion of bacteria in non-sterile products and modifications to preservative effectiveness (Matthews et al., 1999).

**IMPORTANCE OF STABILITY TESTING**

The well-being of the patient suffering from the ailment for which the medicine is intended is the main driver behind stability testing. A therapeutic failure that results in mortality, such as the use of nitroglycerine tablets for angina and cardiac arrest, may occur when an unstable product loses up to 85% of the advertised level of activity. This is in addition to the unstable product degrading into deadly decomposition products. Due to this worry, it is now a mandated by law that before a new product is approved, regulatory bodies must receive data from specific types of stability studies.

The second major priority is to safeguard the manufacturer's reputation by guaranteeing that the product will continue to be fit for use with regard to all functionally relevant features throughout the duration of their time on the market. The development of a database that may be useful in choosing appropriate formulations, excipients, and container closure systems, determining shelf life and storage conditions, preparing a registration dossier, substantiating the claimed shelf life for the registration dossier, and ensuring that no changes have been made are additional benefits of stability studies at the developmental stage or of the marketed products. (Singh *et al.,* 2000; Carstensen *et al.,* 2000).

Stability testing has been classified into 4 different types based on the procedure used. They are as shown in figure-

**Real-Time stability testing**

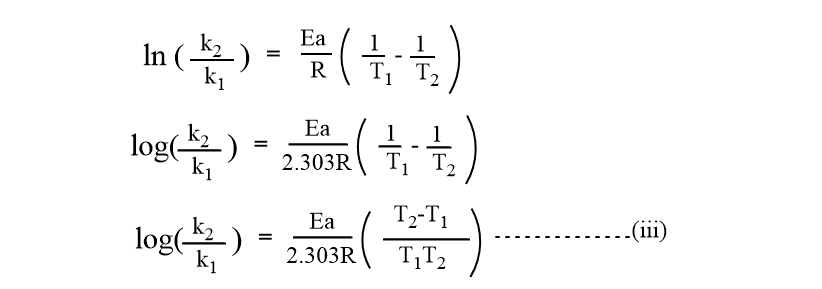
In order to account for significant product degradation under advised storage settings, real-time stability testing is typically conducted over a longer test period. The test's duration is determined by the product's stability, which should be lengthy enough to clearly show that no detectable deterioration exists. It must also allow one to differentiate between deterioration and inter-assay variation. Data is gathered throughout testing at a frequency that allows a trend analysis to distinguish between daily ambiguity and instability. (Anderson et al., 1991).

**Accelerated stability testing**

In accelerated stability testing, a product is subjected to stress at a number of high temperatures (warmer than ambient), and the amount of heat input needed to trigger product failure is calculated. By doing this, a situation is created for the product that speeds up degradation. Following that, the expected shelf life or the relative stability of different formulations are compared using this information. The development schedule is typically shortened because this usually gives a head start on the product shelf life. During accelerated stability testing, stress factors such as moisture, light, agitation, gravity, pH, and package are also used in addition to temperature (Kommanaboyina et al., 1999). In an accelerated stability test, samples are stressed, then immediately afterward, they are chilled, and they are simultaneously tested. In comparison to real-time stability testing, the likelihood of measuring system instability is lower due to the short analysis length. The stressed sample recovery is given as a percentage of the unstressed sample recovery in accelerated stability testing, which also compares the unstressed product with the stressed material inside the same assay.

The concept of accelerated stability testing is based upon the Arrhenius equation and modified Arrhenius equation

(Anderson *et al.,* 1991), (Connors *et al.,* 1973) :



where *K* = degradation rate/s, *A* = frequency factor/s, *Ea* = activation energy (kJ/mol), R = universal gas constant (0.00831kJ/mol), *T*=absolute temperature (K), *k*1 and *k*2 are rate constants at temperatures *T*1 and *T*2 expressed in degree kelvins;

**Retained sample stability testing**

Every marketed product that needs stability data follows this standard procedure. Stability samples for storage for at least one batch per year are chosen for this study. Stability samples from two batches should be obtained if there are more than 50 batches being marketed. When the product is first introduced to the market, stability samples of each batch may be taken; afterwards, this number may be reduced to merely 2% to 5% of marketed batches. For example, if a product has a shelf life of five years, it is customary to test samples at three, six, nine, twelve, eighteen, twenty-four, thirty-six, and sixty months.

According to Kommanaboyina et al. (1999) and Carstensen et al. (1993), the constant interval method is the traditional approach for gathering stability data on samples kept in storage. Using a modified approach, stability testing by market sample evaluation involves taking samples that are already available on the market and assessing stability qualities. Since the product is put to the test in both the real market and the idealized conditions for storing retained samples, this method of testing is intrinsically more realistic (Kommanaboyina et al., 1999).

**Cyclic temperature stress testing**

This is not a typical testing procedure for marketed items. In this procedure, cyclic temperature stress tests are created based on product knowledge to imitate actual market storage circumstances. Because of the diurnal rhythm on earth, which the commercially available medications are most likely to undergo during storage, the cycle period is typically 24 hours. It is advised that the minimum and maximum temperatures for the cyclic stress testing be chosen product-by-product and taking into account things like the recommended storage temperatures for the product and particular chemical and physical degradation properties of the items. Additionally, it is advised that the test should typically consist of 20 cycles (Kommanaboyina et al., 1999; Carstensen et al., 2000).

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