REFERENCES

1. Saisorn, B. , Laungchonlatan, S. , Pummangura, S. , Saisorn, S. , Pothisiri, A. , Rujirawatana, S. , and Learnsuwan, W. "Stability of Vitamin C in Oral Liquid Preparations ". In Research report of Bioavailibility of Patent Drugs. Faculty of Pharmaceutical Sciences, Chulalongkorn University (1978-1979).

2. Tingstad, J.E. , Mac Donald, L.H. , and Meister, P.D. "Stability of Ascorbic Acid in a Liquid Multivitamin Emulsion containing Sodium Fluoride". Journal of Pharmaceutical Sciences 52 (April 1963) : 343.

3. The United States Pharmacopeia. 19 th rev. Rockville, Md. : United States Pharmacopeial Convention, Inc. 1975.

4. Bibart, C.H. "Stability Testing for Expiration Dating". Drug Development and Industrial Pharmacy 5 (April 1979) : 349-363.

5. Tingstad, J.E. "Physical Stability Testing of Pharmacy". Journal of Pharmaceutical Sciences 53 (August 1979) : 955.

6. Martin, A.N. , Swarbrick, J. , and Cammarata, A. Physical Pharmacy. Philadelphia : Lea and Febiger, 1969.

7. Riggs, T.H. "Practical Relationships of Stability Data to Expiration Date". Bulletin of the Parenteral Drug Association 25 (May-June 1971) 3 : 116.

8. Remington's Pharmaceutical Sciences. 15th ed. , Easton, Pennsylvania: Mack Publishing Co. 1975.

9. DeRitter, E. , and Johnson, J.B. "Stability of Vitamin C (Ascorbic Acid) in Tablets". Journal of Pharmaceutical Sciences 65 (July 1976) : 963.

10. Grochmalicka, J. "Stability of L-Ascorbic Acid in water Solutions". Zeszyty Probl. Postepow Nauk Rolniczych 53 (1965) : 57-63 (Pol), through Chemical Abstracts; vol. 64 (1966) : 5813 f.

11. Connors, K.A. , Amidon, G.L. , and Kennon, L. Chemical Stability of Pharmaceuticals : A Handbook For Pharmacists. New York: Wiley-Interscience Publication, 1979.

12. Blaug, S.M. , and Hajratwala, B. "Kinetics of Aerobic Oxidation of Ascorbic Acid". Journal of Pharmaceutical Sciences 61 (April 1972) : 556.

13. Finholt, P. , Paulssen, R. , Alsos, I. , and Higuchi, T. "Rate Studies on the Anaerobic Degradation of Ascorbic Acid II". ibid 54 (January 1963) : 124.

14. Finholt, P. , Paulssen, R.B. , and Higuchi, T. "Rate of Anaerobic Degradation of Ascorbic Acid in Aqueous Solution". ibid 52 (October 1963) : 948.

15. Taylor, E.W. , et al. "Investigation of the Properties of Cellulose Oxidized by Nitrogen Dioxide II. The Evolution of Carbon Dioxide from Uronic Acids and Polyuronides". Journal of the American Chemical Society 69 (Febuary 1947) : 342.

16. Yamamoto, R. , and Yamamoto, E. "Anaerobic Decomposition of Ascorbic Acid in Aqueous Solution I. Formation of Carbondioxide". Yakuzaigaku 24 (April 1964) : 309 (Japan) through Chemical Abstracts vol.63 (1965) : 1663e.

17. Otami, S. "Protection Against Color Changes of Pharmaceutical Preparations II. On the Color Formation of Ascorbic Acid in Aqueous Solution". Yakuzaigaku 24 (April 1964): 293 (Japan) through Chemical Abstracts vol.63 (1965) : 1663f.

18. Sudeb, D. , Dutta, B.K. , and Dutta, B.N. "Stability of Ascorbic Acid in Oral Liquid Formulation II. Effect of pH and Metallic Ions". J. Proc. Inst. Chemists 36 (May 1964) : 252-255. through Chemical Abstracts vol. 63 (1965) : 1663a.

19. Steinberger, R. , and Westheimer, F.H. "Metal Ion-catalyzed Decarboxylation : A model for an Enzyme System". Journal of the American Chemical Society 73 (January 1951) : 429.

20. Prue, J.E. "The Kinetics of the Metal-ion catalysed. Decarboxylation of Acetonedicarboxylic Acid". Journal of the Chemical Society (June 1952) : 2331.

21. Poust, I.R. "Copper-Catalyzed Oxidation of Ascorbic Acid in Gels and Aqueous Solution of Polysorbate 80". Journal of Pharmaceutical Sciences 57 (December 1968) : 2119.

22. Finholt, P. , Kristiansen, H. , Krowczyński, L. , and Higuchi, T. "Rate Studies on the Anaerobic Degradation of Ascorbic Acid IV". ibid 55 (December 1966) : 1435.

23. Bandelin, F.J. , and Tuschhoff, J.V. "The Stability of Ascorbic Acid in Various Liquid Media". Journal of the American Pharmaceutical Association (Scientific Edition) 44 (April, 1955) : 241.

24. Bandelin, F.J. , and Tuschhoff, J.V. "Ascorbic Acid Syrup". Journal of the American Pharmaceutical Association (Practical Pharmacy Edition) 15 (December 1954) : 761.

25. Bartilucci, A. , and Foss, N.E. "Cyanocobalamine (Vitamin B_{12}), I. A Study of the Stability of Cyanocobalamine and Ascofbic Acid in Liquid Formulations". Journal of the American Pharmaceutical Association (Scientific Edition) 43 (March, 1954) : 159.

26. Giral, F. "On the Stability of Vitamin C in Aqueous Solution and in Pharmaceutical Preparations". ibid 36 (1947) : 82.

27. Sudeb, D. , Dutta, B.K. , and Dutta, B.N. "Stability of Ascorbic Acid in Oral Liquid Formulations I. Effect of Base". J. Proc. Inst. Chemists (India) 36 (May 1964) : 245. "III. Effect of Vitamins". ibid 36 (May 1964) : 256, "IV. Influence of Amino Acid". ibid 36 (July 1964) : 296 "V. Effect of Stabilizers". ibid 36 (July 1964) : 299. through Chemical Abstracts vol 63 (1965) : 1662f.

28. Uprety, M.C. , Revis, B. , and Jafar, S.M. "Ascorbic Acid Stability in Certain Aqueous and Fruit Juice vehicles Subjected to Elevated temperature". Journal of Pharmaceutical Sciences. 52 (October 1963) : 1001.

29. Uprety, M.C. , and Revis, B. "Elevated Temperature Studies on Stability of Ascorbic Acid in Certaine Fruit Juice and Aqueous Vehicles". ibid 53 (October 1964): 1248.

30. Gupta, B.K. "Effect of Metallic ion on the oxidation of Ascorbic Acid". Pharmastudent 17 (1973) : 28 through Chemical Abstracts vol 82 (1975) : 21756f.

31. Nixon, J.R. , and Chawla, B.P.S. "Viscosity and Stability relations of the System Ascorbic : water : Polysorbate 20". Journal of Pharmacy and Pharmacology 17 (1965): 558 - 565.

32. Kassem, M.A. , Kassem, A.A. , and Ammar, H.O. "Studies on the Stability of Injectable L-Ascorbic acid and Solution". Pharmaceutica Acta Helvetica 44 (1969) : 611.

33. Kassem, M.A. , Kassem, A.A. , and Ammar, H.O. "Studies on the Stability of Injectable L-Ascorbic acid and Solution 3. Effect of Metal Complexing agent". ibid 47 (1972) : 89.

34. Gladkikh, S.P. , et al. "Unithiol as a Stabilizer of Ascorbic Acid Injection Solutions". Farmatsiya (Moscow) 23 (May 1974) : 65 through Chemical Abstracts vol 82 (1975) : 64428w.

35. Blaug, S.M. , and Hajratwala, B. "Kinetics of Aerobic Oxidation of Ascorbic Acid in the Presence of Nonionic Surfactants". Journal of Pharmaceutical Sciences. 63 (August 1974) : 1240.

36. Trivedi, B.M. , and Patal, N.J. "Stability Studies on Ascorbic Acid in the Presence of Flavors". Idian Journal of Pharmacy 33 (1971) : 15, through Chemical Abstracts vol 75 (1971) : 40333r.

37. Fox, S.H. , and Opferman, L.P. "Stable Ascorbic Acid - Nicotinamide Vitamin Preparations". US. Patent 2,433,688 (Dec. 1947) : 30 through Chemical Abstracts vol 48. (1947) : 1710a.

38. Ismaiel, S.A. , and Ismaiel, E.A. "Syrups Containing Ascorbic Acid and B-Complex Vitamins". Pharmazie 30 (1975) : 59, through Chemical Abstracts vol 82 (1975) : 144917v.

39. Zoni, G. , and Lazzeretti, V. "Stabilization of a Solution Containing High Concentrations of B-Vitamins and L-lysine". Bull. Chim. Farm. 106 (1967) : 872, through Chemical Abstracts vol. 68 (1968) : 72236h.

40. Higuchi, T. , Havinga, A. , and Busse, L.W. "The Kinetics of the Hydrolysis of Procaine". Journal of the American Pharmaceutical Association (Scientific Edition) 39 (1950) : 405.

41. Higuchi, T. , and Busse, L.W. "Heat Sterilization of Thermally Labile Solutions". ibid 39 (1950) : 411

42. Garrett, E.R. "Prediction of Stability of Drugs and Pharmaceutical Preparations". Journal of Pharmaceutical Sciences. 51 (September 1962) : 811.

43. Garrett, E.R. "Kinetics and Mechanisms in Stability of Drugs". In Advances in Pharmaceutical Sciences vol. 2 Edition by H.S. Bean, A.H. , Beckett and J.E. Carless, New York : Acaclemic Press. 1967.

44. Garrett, E.R. , and Carper, R.F. "Prediction of Stability in Pharmaceutical Preparations I. Color Stability in a Liquid Multisulfa Preparation". Journal of the American Pharmaceutical Association (Scientific Edition) 44 (August 1955) : 515.

45. Kennon, L. "Use of Models in Determining Chemical Pharmaceutical Stability". Journal of Pharmaceutical Sciences 53 (July 1964) : 815.

46. Garrett, E.R. "Prediction of Stability in Pharmaceutical Preparations III. Comparison of Vitamin Stabilities in Different Multivitamin Preparations". Journal of the American Pharmaceutical Association (Scientific Edition) 45 (July 1956) : 470.

47. Taqui, M.M. , and Martel, A.E. "Metal Ion and Metal Chelate Catalyzed Oxidation of Ascorbic Acid by Molecular Oxygen I. Cupric and Ferric Ion Catalyzed Oxidation". Journal of the American Chemical Society 89 (August 1967) : 4176.

48. Hashmi, M.H. Assay of Vitamins in Pharmaceutical Preparations, London : John-Wiley and Son, 1973.

49. Higuchi, T. and Brochmann-Honssen E. Pharmaceutical Analysis, New York : Interscience, 1961.

50. Laidler, K.J. Chemical Kinetics. , 2 d. Ed. , New York : McGraw Hill, 1961.

51. Lachman, L. , Lieberman, H.A. and Kanic, J.L. The Theory and Practical of Industrial Pharmacy. 2 d. Ed. Philadelphia: Lea and Febiger 1976.

52. Carstensen, J.T. , and Su, K.S.E. "Statistical, Aspects of Arrhenius Plotting". Bulletin of the Parenteral Drug Association 25 (Nov.- Dec. 1971): 287.

53. Neter, J. , and Wasserman, W. Applied Linear Statistical Models, Illinois : Irwin Inc. (1974).

54. Draper, N.R. , and Smith, H. Applied Regression Analysis. New York : John Wiley and Son Inc. 1966.

55. Garrett, E.R. "Prediction of Stability in Pharmaceutical Preparation II. Vitamin Stability in Liquid Multivitamin Preparations". Journal of the American Pharmaceutical Association (Scientific Edition) 45 (1956) : 171-178.

56. Lintner, C.J. "Pharmaceutical Product Stability". In Quality Control in the Pharmaceutical Industry. vol. 2 Edited by Murry S. Cooper , New York : Academic Press, Inc. 1973.

57. Carstensen, J.T. Theory of Pharmaceutical Systems. vol. 1 New York : Academic Press 1972.

APPENDIX

Correlation coefficient

The best fitted straight line is determined by the least squares method (53, 54). The correlation coefficient (r) of concentration (Y) and the corresponding time (X) can be calculated

$$r = \frac{n \sum(XY) - \sum X . \sum Y}{\left(n\left[\sum(X)^2 - (\sum X)^2\right]\left[n \sum(Y)^2 - (\sum Y)^2\right]\right)^{\frac{1}{2}}}$$

Specific rate constant

The slope of the straight line is a specific rate constant that can be calculated from

$$k = \frac{n \sum(XY) - \sum X . \sum Y}{n \sum(X)^2 - (\sum X)^2}$$

The 95 % confidence limit of slope is obtained from

$$k \pm t_{.05} Sk = k \pm t_{.05} S_{y.x} \left(\frac{1}{n} + \frac{(\bar{x})^2}{\sum(x - \bar{x})^2} \right)^{\frac{1}{2}}$$

The significant difference of the specific rate constant (k) is determined by t - test

$$t = \frac{k_1 - k_2}{\sqrt{S_p^2 \left[\left(\frac{1}{\sum(x - \bar{x})^2} \right)_1 + \left(\frac{1}{\sum(x - \bar{x})^2} \right)_2 \right]}}$$

$$t = \frac{k_1 - k_2}{\sqrt{\left[\left(\frac{\text{Res. S.S.}}{n_1+n_2-4}\right)_1 + \left(\frac{\text{Res. S.S.}}{n_1+n_2-4}\right)_2\right]\left[\left(\frac{1}{\sum x^2 - \frac{(\sum x)^2}{n}}\right)_1 + \left(\frac{1}{\sum x^2 - \frac{(\sum x)^2}{n}}\right)_2\right]}}$$

The predicted rate

The predicted rate at room temperature (30°C) and at 20°C are obtained by extrapolated the Arrhenius plot and the 95 % condidence limits of prediction are calculated (15, 52)

$$\hat{y} \pm t_{.05} S_{\hat{y}} = y \pm t_{.05} S_{y.x} \left(\frac{1}{n} + \frac{(x_o - \bar{x})^2}{\sum x^2 - \frac{(\sum x)^2}{n}}\right)^{\frac{1}{2}}$$

Where x_o is the extrapolated temperature (30°C, 20°C)

$\bar{x}$ is the average of temperature studies in Arrhenius plot

n is the number of temperature studies

VITA

Name : Miss SUWANNA LAUNGCHONLATAN

Education : Bachelor of Science in Pharmacy (Honors) in 1973.
Chulalongkorn University. Bangkok 5, Thailand.

Site of the Employer's office :

Department of Pharmaceutical Chemistry
Faculty of Pharmaceutical Sciences
Chulalongkorn University. Bangkok, Thailand.