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Analytical Method Development and Validation of RP-HPLC Method for the Quantitative Determination of Ketorolac Tromethamine in Bulk & Pharmaceutical Formulations

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Abstract

A simple, precise, accurate, sensitive, and robust reversed-phase high-performance liquid chromatography (RP-HPLC) method was developed and validated for the quantitative determination of Ketorolac Tromethamine in bulk drug and pharmaceutical dosage forms. The chromatographic separation was achieved using a C18 column (250 mm × 4.6 mm, 5 µm) with a mobile phase consisting of 0.01 M Ammonium Dihydrogen Orthophosphate Buffer and Acetonitrile (60:40 v/v). The mobile phase was pumped at a flow rate of 1.0 mL/min, and detection was carried out at 313 nm. Under the optimized chromatographic conditions, Ketorolac Tromethamine exhibited a retention time of approximately 7.6 min. The developed method was validated according to ICH guidelines for specificity, precision, intermediate precision, accuracy, linearity, solution stability, robustness, limit of detection (LOD), and limit of quantification (LOQ). The method showed excellent specificity with no interference from blank or excipients at the retention time of Ketorolac Tromethamine. Precision studies demonstrated satisfactory repeatability with %RSD values less than 2.0%. The accuracy of the method was confirmed by recovery studies at 80%, 100%, and 120% concentration levels, yielding mean recoveries of approximately 100.39%. Linearity was established over the concentration range of 16–24 ppm, with a correlation coefficient (R^2) of 0.9978, indicating excellent linear relationship between concentration and peak area. The LOD and LOQ values were found to be 0.6 ppm and 1.7 ppm, respectively, demonstrating adequate sensitivity of the method. Robustness studies showed that small deliberate variations in chromatographic conditions did not significantly affect the assay results. Solution stability studies confirmed that the sample solutions remained stable for up to 24 hours under room temperature conditions. The validated RP-HPLC method was found to be simple, reliable, reproducible, and suitable for routine quality control analysis and assay determination of Ketorolac Tromethamine in bulk drug substances and pharmaceutical formulations.

Keywords
Ketorolac Tromethamine, RP-HPLC, Method Development, Method Validation, Assay, ICH Guidelines, Pharmaceutical Analysis, Quality Control.

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INTRODUCTION:

Analytical method validation is the process of establishing documented evidence that an analytical procedure is suitable for its intended purpose. Validation confirms that the developed method consistently produces accurate, precise, and reliable results within specified limits.

Method validation is an essential regulatory requirement in pharmaceutical industries and is performed according to International Council for Harmonisation (ICH) guideline Q2(R1): "Validation of Analytical Procedures: Text and Methodology."

Validation provides confidence that the analytical method is capable of producing scientifically sound results during routine quality control testing.

MATERIALS AND METHODS:

Ketorolac Tromethamine working standard was obtained from the Quality Control Department and used as reference standard throughout the study.

Table No 1: Materials Used.

Parameter	Description
Drug Name	Ketorolac Tromethamine
Category	NSAID
Dosage Form	Tablet
Label Claim	10 mg
Working Standard	Ketorolac Tromethamine Reference Standard

Table No 2: Chemicals and Reagents Used.

Sr. No.	Chemical/Reagent
1	Ketorolac Tromethamine Working Standard
2	Acetonitrile (HPLC Grade)
3	Methanol (HPLC Grade)
4	Water (HPLC Grade)
5	Ammonium Dihydrogen Phosphate
6	Orthophosphoric Acid

METHOD DEVELOPMENT:

Selection of Analytical Technique

Several analytical techniques are available for quantitative determination of pharmaceutical compounds including UV Spectroscopy, HPTLC, HPLC, and LC-MS. Based on literature review and physicochemical characteristics of Ketorolac Tromethamine, RP-HPLC was selected because of its superior sensitivity, precision, and reproducibility

Selection of Detection Wavelength

The UV spectrum of Ketorolac Tromethamine was recorded using a UV-Visible spectrophotometer. The wavelength corresponding to maximum absorbance was selected for chromatographic detection.

Table 3: UV Spectral Characteristics

Parameter	Observation
λ_{max}	313 nm
Solvent	Methanol
Detection Mode	UV Detection

Selection of Chromatographic Column

Different chromatographic columns were evaluated to obtain acceptable retention time, peak symmetry, and resolution.

Table 4: Column Optimization Study

Column	Observation
C8 Column	Broad Peak
Phenyl Column	Peak Tailing
Cyano Column	Poor Resolution
C18 Column	Good Peak Shape

The C18 column was selected because it produced satisfactory chromatographic performance.

Mobile Phase Optimization

Several mobile phase compositions were evaluated during method development.

Table 5 Mobile Phase Optimization Trials

Trial	Mobile Phase	Observation
1	Methanol: Water	Broad Peak
2	Acetonitrile: Water	Peak Tailing
3	Buffer: ACN (50:50)	Acceptable
4	Buffer: ACN (60:40)	Optimized

Flow Rate Optimization

Different flow rates were evaluated to obtain optimum chromatographic performance.

Table 6 Flow Rate Optimization

Flow Rate (mL/min)	Observation
0.8	Longer Retention Time
1.0	Optimum
1.2	Peak Distortion

The optimized flow rate selected was **1.0 mL/min**.

Final Optimized Chromatographic Conditions

Table 7 Optimized Chromatographic Conditions

Parameter	Condition
Column	C18 Column
Mobile Phase	Buffer: ACN (60:40)
Flow Rate	1.0 mL/min
Detection Wavelength	313 nm
Injection Volume	20 µL
Run Time	10 Minutes
Temperature	Ambient

Preparation of Solutions:

Preparation of Buffer

Accurately weigh the required quantity of Ammonium Dihydrogen Phosphate and transfer into a 1000 mL volumetric flask containing approximately 800 mL of HPLC grade water. Dissolve completely with continuous stirring. Adjust the pH using Orthophosphoric Acid and make up the volume with HPLC grade water. The prepared buffer solution was filtered through a 0.45 µm membrane filter and degassed by sonication before use.

Table 8: Buffer Preparation

Parameter	Description
Buffer Used	Ammonium Dihydrogen Phosphate Buffer
Solvent	HPLC Grade Water
pH Adjuster	Orthophosphoric Acid
Filtration	0.45 µm Membrane Filter
Degassing	Sonication

Preparation of Mobile Phase

The mobile phase was prepared by mixing Ammonium Dihydrogen Phosphate Buffer and Acetonitrile in the ratio of 60:40 v/v. The mixture was filtered through a 0.45 µm membrane filter and degassed by sonication for 15 minutes prior to chromatographic analysis.

Table 9: Mobile Phase Composition

Component	Ratio
Buffer	60
Acetonitrile	40

Preparation of Diluent

The diluent used for preparation of standard and sample solutions consisted of mobile phase. Fresh diluent was prepared daily and filtered before use.

Table 10: Diluent Composition

Component	Composition
Buffer	60%
Acetonitrile	40%

Preparation of Standard Solution

Accurately weigh an appropriate quantity of Ketorolac Tromethamine working standard and transfer into a volumetric flask. Add diluent and sonicate to dissolve completely. Make up the volume with diluent to obtain the required concentration. Further dilution was carried out to obtain the working standard concentration suitable for chromatographic analysis.

Table 11: Standard Solution Preparation

Parameter	Description
Standard Used	Ketorolac Tromethamine Working Standard
Solvent	Diluent
Dilution	As Required
Final Concentration	Working Standard Solution

Preparation of Sample Solution

Twenty tablets were accurately weighed and powdered. A quantity of powder equivalent to the required amount of Ketorolac Tromethamine was transferred into a volumetric flask.

Diluent was added and the mixture was sonicated for complete extraction of the drug. The volume was adjusted with diluent and filtered through a 0.45 µm membrane filter. Appropriate dilutions were made to obtain the final sample concentration for chromatographic analysis.

Method Validation

The developed RP-HPLC method was validated according to ICH Q2(R1) guidelines for analytical procedure validation. Validation parameters evaluated included specificity, precision, accuracy, linearity, range, robustness, ruggedness and solution stability.

Specificity

Principle

Specificity is the ability of an analytical method to measure the analyte response in the presence of components such as impurities, degradation products and excipients.

Procedure

Blank solution, placebo solution, standard solution and sample solution were prepared and injected into the HPLC system under optimized chromatographic conditions.

Chromatograms obtained from blank, placebo, standard and sample solutions were compared for any interference at the retention time of Ketorolac Tromethamine.

Acceptance Criteria

- No interference should be observed at the retention time of Ketorolac Tromethamine.
- Peak purity should comply with acceptance criteria.

Table 12: Specificity Acceptance Criteria Precision

Parameter	Acceptance Criteria
Blank Interference	No Interference
Placebo Interference	No Interference
Peak Purity	Pass

Principle

Precision expresses the closeness of agreement among a series of measurements obtained from multiple sampling of the same homogeneous sample under prescribed conditions.

Precision was evaluated as:

- System Precision
- Method Precision

System Precision

Procedure

Six replicate injections of standard solution were injected into the chromatographic system.

Peak areas were recorded and percentage relative standard deviation (%RSD) was calculated.

Acceptance Criteria

The %RSD for peak area should not exceed 2.0%.

Table 13: System Precision Acceptance Criteria

Parameter	Acceptance Criteria
%RSD	NMT 2.0%

Method Precision

Procedure

Six individual sample preparations were prepared and analysed according to the developed method.

The assay results were calculated and %RSD was determined.

Acceptance Criteria

The %RSD of assay results should not exceed 2.0%.

Table 14: Method Precision Acceptance Criteria

Parameter	Acceptance Criteria
%RSD	NMT 2.0%

Accuracy

Principle

Accuracy expresses the closeness of agreement between the value found and the value accepted as a conventional true value.

Recovery studies were performed using the standard addition method.

Procedure

Accuracy was evaluated at three concentration levels:

- 50%
- 100%
- 150%

Known quantities of Ketorolac Tromethamine standard were added to pre-analyzed sample solution and analyzed using the developed method

.

Table 15: Accuracy Levels

Level	Concentration
Level I	50%
Level II	100%
Level III	150%

Acceptance Criteria

Mean recovery should be between 98.0% and 102.0%.

Table 16: Acceptance Criteria

Parameter	Acceptance Criteria
Mean Recovery	98–102%

Linearity

Principle

Linearity is the ability of the analytical method to obtain test results directly proportional to analyte concentration within a given range.

Procedure

Standard solutions were prepared at different concentration levels.

The solutions were injected into the chromatographic system and corresponding peak areas were recorded.

Calibration curve was constructed by plotting concentration versus peak area.

Table 17: Linearity Concentration Levels

Level	Concentration (%)
Level 1	50
Level 2	75
Level 3	100
Level 4	125
Level 5	150

Acceptance Criteria

Correlation coefficient (r^2) should not be less than 0.999.

Principle

Range is the interval between upper and lower concentration levels of analyte that have been

demonstrated to be determined with suitable precision, accuracy and linearity.
The range was established from linearity and accuracy studies.

Acceptance Criteria

The developed method should demonstrate acceptable accuracy, precision and linearity across the selected concentration range.

Robustness

Principle

Robustness is a measure of the capacity of the analytical procedure to remain unaffected by small deliberate variations in method parameters.

Procedure

The following variations were introduced:

- Flow Rate ±0.2 mL/min
- Wavelength ±2 nm
- Mobile Phase Composition ±2%

Table 18: Robustness Parameters

Parameter	Variation
Flow Rate	±0.2 mL/min
Wavelength	±2 nm
Mobile Phase	±2%

Acceptance Criteria

System suitability parameters should comply with predefined acceptance criteria.

Ruggedness

Principle

Ruggedness evaluates reproducibility of the test results under normal operating conditions.

Procedure

The analysis was performed by:

- Different analysts
- Different days
- Different instruments (if applicable)

The assay results were compared and %RSD was calculated.

Acceptance Criteria

%RSD should not exceed 2.0%.

Solution Stability

Principle

Solution stability studies were performed to evaluate the stability of standard and sample solutions over a specified period.

Procedure

Standard and sample solutions were stored at room temperature and analyzed at different time intervals. Chromatographic responses were compared with freshly prepared solutions.

Table 19: Solution Stability Study

Time Interval	Observation
Initial	Recorded
12 Hours	Recorded
24 Hours	Recorded

Acceptance Criteria

Difference in assay value should not exceed 2.0%.

Statistical Analysis

The data obtained during validation studies were subjected to statistical evaluation. Mean, standard deviation and percentage relative standard deviation (%RSD) were calculated wherever applicable.

Formula for %RSD

$$\%RSD = \frac{Standard\ Deviation}{Mean} \times 100$$

Summary of Validation Parameters

Table 20: Validation Parameters Evaluated

Sr. No.	Parameter
1	Specificity
2	Precision
3	Accuracy
4	Linearity

5	Range
6	Robustness
7	Ruggedness
8	Solution Stability

RESULT AND DISCUSSION:

Standard Solution:

Weigh accurately 10 mg of Keterolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solution:

Weigh accurately 10 tablets and determine average weight. Crush the tablets to fine powder. Weigh accurately powder weight equal to average weight (Tablet weight) in 50 ml volumetric flask. Add 30ml of Water and Sonicate for 10 minutes and make up volume with water.Filter the above solution through whatmann filter paper 41.Collect the filterate. Further dilute 5ml of above solution to 50ml and dilute with water.

Acceptance criteria:

The relative standard deviation for Keterolac Tromethamine should not be more than 2.0There is no interference of blank with the principal peaks i.e. Keterolac Tromethamine.

Observation Table:

System Suitability observed during Specificity

Specificity

Table 21: System Suitability observed during Specificity

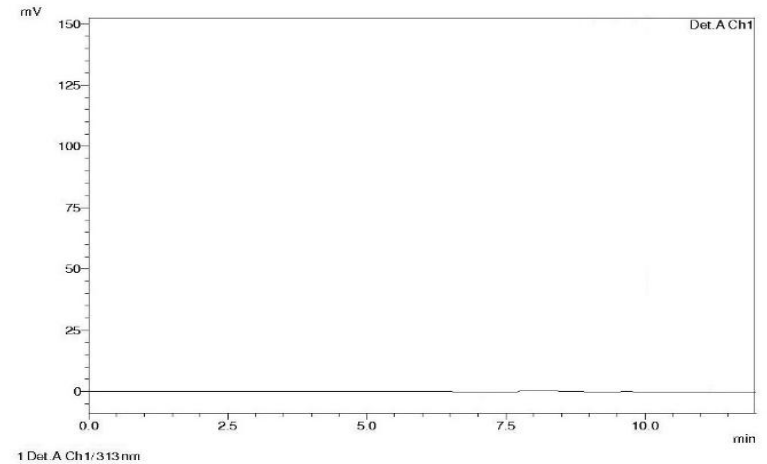
	R.T.
Sample	**Keterolac Tromethamine**
Blank	0
Standard Solution	7.662
Sample Solution	7.640

Conclusion: There was no interference observed in Standard & Sample due to Blank.

===== HPLC DATA =====

Acquired by : Admin
Sample Name : Keterolac Tromethamine
Sample ID : Specificity Blank
Tray# : 1
Vail# : 1
Injection Volume : 20 uL
Data Filename : Specificity Blank.lcd
Method Filename : Keterolac Tromethamine.lcm

<Chromatogram>

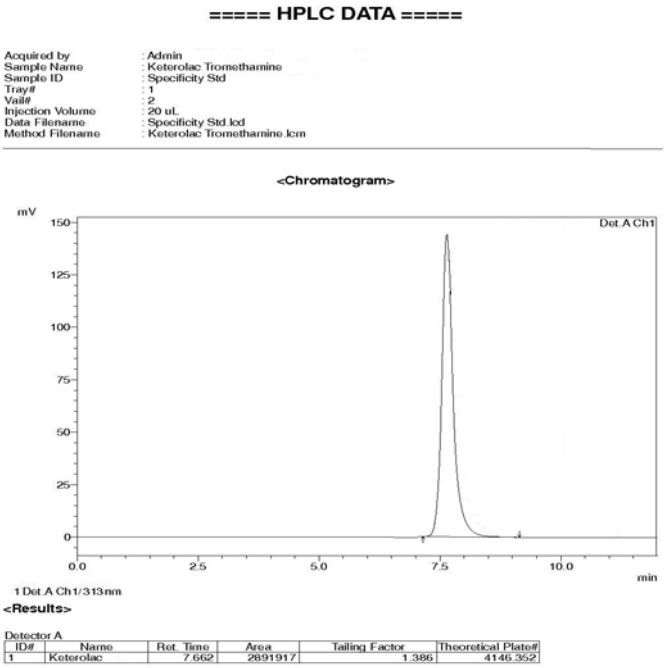


1 Det.A Ch1/313nm

<Results>

Detector A

ID#	Name	Ret. Time	Area	Tailing Factor	Theoretical Plate#
1	Keterolac	0.000	0	0.000	0.000



Precision: Precision is a measurement of degree of Reproducibility of analytical method and it will be expressed in terms of % relative standard for the area and retention time of Solution prepared. The precision of an analytical procedure expresses the closeness of agreement (degree of scatter) between a series of measurements obtained from multiple sampling of the same homogeneous sample under the prescribed conditions.

Preparation of Solutions:

Standard Solution: Weigh accurately 10 mg of Ketorolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solution: Weigh accurately 10 tablets and determine average weight. Crush the tablets to fine powder. Weigh accurately powder weight equal to average weight (Tablet weight) in 50 ml volumetric flask. Add 30ml of Water and Sonicate for 10 minutes and make up volume with water. Filter the above solution through Whatman filter paper 41. Collect the filtrate. Further dilute 5ml of above solution to 50ml and dilute with water.

Acceptance criteria:

The relative standard deviation for Keterolac Tromethamine should not be more than 2.0%

Observation Table:

Table 1.22 System Suitability observed during Precision

Standard Solution	
	Area
No. Of Inj.	**Keterolac Tromethamine**
1	2599668
2	2591301
3	2600340
Average	**2597103**
STDEV	5035.901
RSD	**0.19**

Acceptance criteria:

% Assay of Keterolac Tromethamine is NLT 90.0% And NMT 110.0%.

Conclusion:

The assay values of three preparation of Keterolac Tromethamine 10gm is having % Assay is NLT 90.0% and NMT 110.0% so the method for assay of Keterolac Tromethamine 10gm Tablet is precise.

Intermediate Precision:

Precision under analysis repeatability conditions i.e. conditions where independent test results were obtained with the same method on identical test

items in the same laboratory by the same operator using the same equipment within short intervals of time.

Preparation of Solutions:

Standard Solution: Weigh accurately 10 mg of Keterolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solution: Weigh accurately 10 tablets and determine average weight. Crush the tablets to fine powder. Weigh accurately powder weight equal to average weight (Tablet weight) in 50 ml volumetric flask. Add 30ml of Water and Sonicate for 10 minutes and make up volume with water. Filter the above solution through Whatman filter paper 41. Collect the filtrate. Further dilute 5ml of above solution to 50ml and dilute with water.

Table 23: Sample Solution

Standard Solution	
	Area
No. of Inj.	**Keterolac Tromethamine**
1	2864071
2	2846354
3	2847835
Average	2852753
STDEV	9829.320
RSD	0.34

(Difference = Intermediate Precision % Assay –Precision %Assay)

Acceptance criteria:

% Assay of Secnidaole is NLT 90.0% And NMT 110.0%

Conclusion: The assay values of three preparation of Keterolac Tromethamine is having % Assay is NLT 90.0% and NMT 110.0% so the method for assay of Keterolac Tromethamine and Tablet is precise.

Accuracy: The accuracy of an analytical method is defined as the closeness between the observed values with actual or true value for a specific concentration. Accuracy - closeness to the true value, measured by % recovery

80 % of the standard concentration.

100 % of the standard concentration.

120 % of the standard concentration.

Calculate % Recovery for every solution at each level.

Preparation of Solutions:

Standard Solution:

Standard Solution: Weigh accurately 10 mg of Keterolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solutions for Accuracy:

1) 80% Solution: -Weigh accurately 10 mg of Keterolac Tromethamine in 50 ml volumetric flask add 30 ml of Water and sonicate for 5 minutes and make up the volume. Further dilute 4 ml of above solution to 50 ml with Water.

2)100% Solution: Weigh accurately 10 mg of Keterolac Tromethamine in 50 ml volumetric flask add 30 ml of Water and sonicate for 5 minutes and make up the volume. Further dilute 5ml of above solution to 50 ml with Water.

3)120% Solution: Weigh accurately 10 mg of Keterolac Tromethamine in 50 ml volumetric flask add 30 ml of Water and sonicate for 5 minutes and make up the volume. Further dilute 6 ml of above solution to 50 ml with Water.

Acceptance Criteria: The % recovery of the Keterolac Tromethamine for each injection of each concentration must be between 98 % and 102%.

Table 23: Accuracy of Keterolac Tromethamine:

Test Solutions					
Level	**Sr.No.**	**mg of drug spiked**	**Keterolac Tromethamine Area**	**mg of drug Recovered**	**% Recovery**
80%	1	0.016000	2291479	0.016090	100.56

100%	1	0.020000	2862476	0.020099	100.49
120%	1	0.024000	3422392	0.024030	100.13
				Average	**100.39**
				Std.dev	0.23
				%RSD	0.23

Conclusion:
The % recovery of the Keterolac Tromethamine for each injection of each concentration is 99.96%, 99.31%99.81% and mean recovery is 99.69%, which is within the acceptance criteria, hence the method for % assay determination of Keterolac Tromethamine is accurate.

Linearity & range:

Linearity Sample Stock Solution:
Weigh 10 mg of Keterolac Tromethamine in 50 ml of volumetric flask sonicate and dissolve anddilute to volume with Water.Further dilute 5.0ml of standard to 50 ml with Water.

Linearity Solutions:

Linearity Solution (80%):
Take 4.0 mL sample stock solution in 50 mL volumetric flask and make up to the volume with Water.

Linearity Solution (90%): Take 4.5 mL sample stock solution in 50 mL volumetric flask and make up to the volume with Water.

Linearity Solution (100%): Take 5.0 mL sample stock solution in 50 mL volumetric flask and make up to the volume with Water.

Linearity Solution (110%): Take 5.5 mL sample stock solution in 50 mL volumetric flask and make up to the volume with Water.

Linearity Solution (120%): Take 6 mL sample stock solution in 50 mL volumetric flask and make up to the volume with Water.

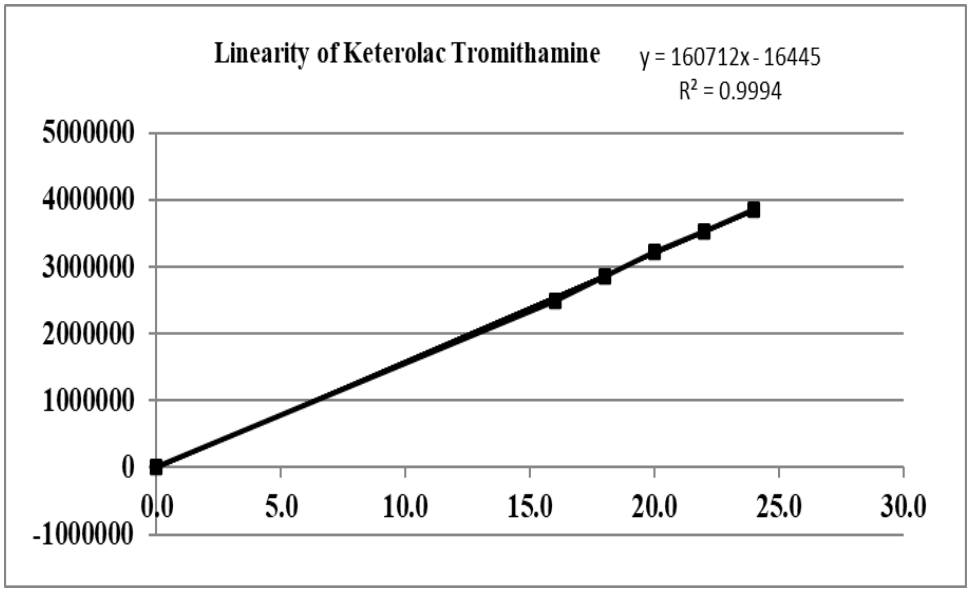
Acceptance Criteria: The limit for coefficient of correlation for the standard curve must not be less than 0.99

Observation Table:

Table 24: Linearity of Keterolac Tromethamine

Diluted to	Area	Conc in ppm	Conc. of Solution
0	0	0.0	**0**
50	2496938	16.0	80
50	2858681	18.0	90
50	3233480	20.0	100
50	3535616	22.0	110
50	3847813	24.0	120

Keterolac Tromethamine	
Y intercept	**-184179.4000**
Slope	**168934.2500**
Corelation Coefficient	**0.9978**



Conclusion: The obtained results are within the range and coefficient of correlation for the standard curve is 0.9999which is within acceptance criteria of 0.9900, hence the method is linear within given range.

Limit of Detection:

The detection limit of an individual analytical procedure is the lowest amount of analyte in a sample which can be detected but not necessarily quantitated as an exact value.

Calculated by following formula

$$= \frac{3.3 \times Std.Deviation}{Slope} \qquad = \frac{3.3 \times 28944.5}{168934.2500}$$

LOD = 0.6 ppm

Limit of Quantitation: The quantitation limit of an individual analytical procedure is the lowest amount of analyte in a sample which can be quantitatively determined with suitable precision.

Calculated by following formula

$$= \frac{10 \times Std.Deviation}{Slope} \qquad = \frac{10 \times 28944.5}{168934.2500}$$

LOQ = 1.7 ppm

Stability of Solution: The solution stability of Keterolac Tromethamine in the assay method was carried out by leaving the working standard in tightly capped volumetric flasks at room temperature for 32 hrs. The assay sample is also prepared and kept for stability up to 24 hours.

Preparation of Solutions:

Standard Solution: Weigh accurately 10 mg of Keterolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solution: Weigh accurately 10 tablets and determine average weight. Crush the tablets to fine powder. Weigh accurately powder weight equal to average weight (Tablet weight) in 50 ml volumetric flask. Add 30ml of Water and Sonicate for 10 minutes and make up volume with water. Filter the above solution through Whatman filter paper 41. Collect the filtrate. Further dilute 5ml of above solution to 50ml and dilute with water.

Acceptance Criteria:

Stability of solution: % Difference between Initial solution & different Interval is NMT 2.0 %.

Table 24: Solution Stability of Keterolac Tromethamine

Standard Solution	
No. Of Inj.	**Area Keterolac Tromethamine**
1	6560149
2	6428624
3	6399922
Average	6462898
STDEV	85435.475
RSD	1.32

Conclusion: The sample solutions of Keterolac Tromethamine are stable up to 8 hours at room temperature.

Robustness: The robustness of an analytical procedure is the characteristic of its stability with respect to small variations of the system parameters possible under real conditions. This stability is usually evaluated in terms of RSD of the results of analyses compared to analogous data obtained using strictly observed conditions according to the validation analytical procedure.

Preparation of solution:

Standard Solution: Weigh accurately 10 mg of Keterolac Tromethamine standard in 50ml volumetric flask add 30ml of water and sonicate for 5 minutes and make up volume with water further dilute 5ml to 50 ml with water.

Sample Solution: Weigh accurately 10 tablets and determine average weight. Crush the tablets to fine powder. Weigh accurately powder weight equal to average weight (Tablet weight) in 50 ml volumetric flask. Add 30ml of Water and Sonicate for 10 minutes and make up volume with water. Filter the above solution through Whatman filter paper 41. Collect the filtrate. Further dilute 5ml of above solution to 50ml and dilute with water.

Variability in wavelength: Changed in wavelength (± 5nm) & performed the analysis by using the same chromatographic conditions.

Prepared the standard solution and injected into the chromatographic conditions.

Acceptance Criteria:

% RSD of Peak Area of Standard solution: Not more than 2.0 %

% RSD of % Assay: Not more than 2.0 %

Difference between normal Assay results and wavelength change: NMT 2.0

Variability in mobile phase flow rate:

Changed in mobile phase flow rate (± 10%) & performed the analysis by using the same chromatographic conditions. Prepared the standard solution and injected into the chromatographic conditions.

Acceptance Criteria:

Table 25: % RSD of Peak Area of Standard

S.No	Composition		Flow rate	
	Composition 1	**Composition 2**	**1.1 ml/min**	**0.9 ml/min**
1	2769229	2996631	2623014	2617030
2	2800240	2986547	2696848	2612572
3	2786736	2976186	2687635	2607914
Mean	2785402	2986455	2669166	2612505
STDEV	15548.500	10222.813	40233.097	4558.366
RSD	0.56	0.34	1.51	0.17

Table 1.27 Robustness for Standard Solution Peak Area Keterolactum

Sr. No	Composition		Flow rate	
	Composition 1	**Composition 2**	**1.1 ml/min**	**0.9 ml/min**
Average	100.05	99.94	100.07	100.21

Conclusion: The percentage relative standard deviation of peak area of Standard Solution is less than 2.0% and % assay difference of sample during Robustness is less than 2.0% which is within the acceptance criteria, hence the method is robust.
Solution: Not more than 2.0 %
% RSD of % Assay: Not more than 2.0 %
Difference between normal Assay results and mobile phase flow rate change: NMT 2.0

Conclusion: A simple, precise, accurate, and economical RP-HPLC method was successfully developed for the estimation of Ketorolac Tromethamine in pharmaceutical dosage form.

The developed method showed satisfactory chromatographic performance with acceptable system suitability parameters. Validation studies confirmed that the method complied with ICH Q2(R1) guidelines with respect to specificity, precision, accuracy, linearity, robustness, and solution stability.

The results indicated that the developed RP-HPLC method is suitable for routine quality control analysis and assay determination of Ketorolac Tromethamine in pharmaceutical formulations. Therefore, the method can be effectively employed in pharmaceutical industries and quality control laboratories for the regular analysis of Ketorolac Tromethamine tablets.

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