UV-VIS and FTIR Instrumentation: Qualification Guidelines

UV-VIS

FTIR

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  - ✓ UV-Visible spectrophotometer
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Introduction

- **Validation:** Establishing documented evidence that provides a high degree of assurance that a process, system, equipment or assay will consistently produce the desired results according to predetermined specifications and quality attributes.
- It is a requirement for Good Manufacturing Practices and other regulatory requirements.

Calibration

Calibration is a necessary component to ensure of the authenticity of Qualification and Validation.

- Calibration is a process that demonstrates a particular instrument or device produces results within specified limits, as compared to those produced by a definite standard over an appropriate range of measurements.

Qualification

- Action of proving and documenting that any equipment, utilities, and systems actually and consistently leads to the expected results.
- Qualification should be completed before process validation is performed.
- **Qualification Phases:**
  - The Qualification phases consist of mainly 5 phases.
  - Its start with **User Requirement Specification** (URS).
  - URS is a document which states the laboratory requirement and technical with operational requirements that should be met.

- The other phases consist of
  - Design qualification(DQ)
  - Installation qualification(IQ)
  - Operational qualification(OQ)
  - Performance qualification(PQ)

Design Qualification:
Documented evidence which shows that the plant **design** agrees with the design specifications of the customer.

Operational qualification:
Documented evidence which shows that all parts of the plant and equipment **work** within their specifications and parameters

Performance Qualification: Provides documented evidence that all parts of a plant and other processes produce products of specified quality under conditions of normal production for a longer period of time.

Qualification

Installation Qualification:
Written evidence is given that all parts of equipment are **installed** according to the equipment supplier's and purchase specifications.

Design Qualification	Installation Qualification		Operational Qualification		Performance Qualification
Timing and Applicability					
Prior to purchase of a new model of instrument	**At installation** of each instrument (new, old, or existing unqualified)		**After installation** or major repair of each instrument		**Periodically** at specified intervals for each instrument
Activities					
Assurance of manufacturer's DQ	Description	⇆	Fixed parameters		Preventive maintenance and repairs
Assurance of adequate support availability from manufacturer	Instrument delivery				Establish practices to address operation, calibration, maintenance, and change control
Instrument's fitness for use in laboratory	Utilities/facility	⇆	Environment		
	Assembly and installation				
	Network and data storage	⇆	Secure data storage, backup, and archive		
	Installation verification	⇆	Instrument function tests	⇆	Performance checks

Table:- **Timing, Applicability, and Activities for Each Phase of Analytical Instrument Qualification**: Activities under each phase are usually performed as indicated in the table. In some cases, it may be more appropriate to combine a given activity or perform with another phase. Such activities are shown linked (↔). It is more important that the activity is performed, but not so important under which phase it is performed.

- Instruments can generally be classified as belonging to groups A, B, or C. It should be noted that the same type of instrument can fit into one or more categories, depending on its intended use.

Class	Type of class	instrument or equipment	Process of qualification
A	Simple	Magnetic stirrer	No qualification
B	Moderate	pH meter/oven	Partial qualification routine calibration, performance check maintenance
C	Complex	FT-IR/HPLC/GC	Full qualification-all elements of qualification including software validation

Qualification of UV-Visible spectrophotometer

Design Qualification(DQ)

- Supplier must provide documented evidence that the product has been designed, developed and manufactured in a quality environment e.g. ISO 9001:2000 certification.
- Design Qualification Should be performed before the purchase of new model of UV Spectrophotometer.
- The documents of design qualification should explain:
- **What the user want the instrument to do?**
- Examples of functional and operational specifications are:
  - Optics: Double beam/ Single beam
  - Measurable range: e.g 190-1100 nm
  - Wavelength Accuracy: e.g. ±0.5 nm or better

Design Qualification(DQ)

- Criteria for selection of the vendor
- Warranty and maintenance support
- Discount
- Cost of Annual Maintenance Contract (AMC) after expiry of standard warranty.

Installation Qualification(IQ)

- IQ is the documented collection of activities necessary to establish that an instrument is delivered as designed and specified, and is properly installed in the selected environment, and that this environment is suitable for the instrument.
- According to USP, the IQ requirements provide evidence that the hardware and software are properly installed in the desired location.
- The instrument has been checked and verified as undamaged.
- The appropriate documentation has been supplied and it is of correct issue and uniquely identified by part number, version number and date.

Operational Qualification(OQ)

- OQ is the documented collection of activities necessary to demonstrate that an instrument will function according to its operational specification in the selected environment.
- Following are the test performed during Operational . Qualification for UV Spectrophotometer

Wavelength Accuracy	Limit of Stray Light
Control of Absorbance	Noise
Resolution	Stability

Parameter	Test	Acceptance criteria
Wavelength accuracy	• Perform to understand deviation of the wavelength reading from the known wavelength of the band • Usually, **Holmium oxide solution** (4% holmium oxide in 10% perchloric acid) is used • Holmium oxide solution gives characteristic peaks at 241.1. 249.9, 278.1, 287.2. 333.5, 345.4 etc.	• ±1 nm in UV region (200-400 nm). ± 2 nm (400-700 nm) • Three repeated scans of same peak standard deviation of the mean must not exceed 0.5 nm
Stray light	• This may be due to poor design or faulty monochromator or may be because of operator, usually not problem in new instrument but increases with age of optics and its degradation. • Higher absorbance ranges (above 1) are more susceptible. • For the range of 300-350 nm, aqueous **sodium nitrite** (50 g/L) is scanned	The transmittance of the solution in a 1cm cell should be less than 0.01 or the absorbance value should be greater than 2

Parameter	Test	Acceptance criteria
Resolution power	• Insufficient resolution in any spectrophotometer may loose some features of fine spectrum or unable to show difference of absorbance values between two close wavelengths. • Measure the ratio of the absorbance of a 0.020% (v/v) solution of **toluene in hexane** (UV grade) at the maximum and minimum at about 269 and 266 nm. respectively, using hexane as the reference.	• The ratio of the absorbance at 269 nm and absorbance at 266 nm should be greater than 1.5
Noise	• Noise originating from light source and electronic systems in UV spectrophotometer and effects the measurement of absorbance in both lower and higher wavelengths. • To estimate the noise of spectrophotometer air is scanned (no sample) for 10 min in absorption mode and Root Mean Square (RMS) is calculated and recorded at 500 nm.	• The RMS noise should be less than 0.001 AU

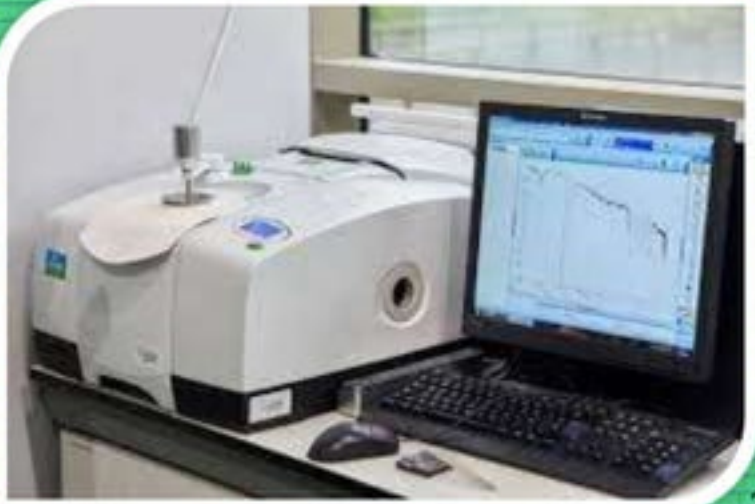
Parameter	Test	Acceptance criteria
Baseline flatness	• Baseline is used to nullify the effect of environment in measurement by removing background noise to get true absorption profile of analyte. • In double beam UV spectrophotometer baseline correction is usually performed by keeping solvent in one cuvette and test solution in other. This will automatically correct the baseline and subtract the background noise by solvent. • This test is performed by scanning air in the absorbance mode in UV region and highest and lowest deflections in the absorbance unit are recorded.	• The measurement is typically less than 0.01 A U
Stability	• The changes in the components and age are major factors making instability of response by UV Spectrophotometer resulting error in readings • The error caused by this factor may be positive or negative (Positive: more than actual observed, Negative: less than actual response observed) • For checking stability air is for 60 mins in absorbance mode particular wavelength at (generally 340 nm) and deflections in the absorbance are recorded.	• The deflection is less than 0.002 AU/ hr

Parameter	Test	Acceptance criteria
Photometric accuracy	• Photometric accuracy is determined by comparing the difference between the measured absorbance of the reference material and the established value.	• Six replicate measurements of the 0.006% w/v of the potassium dichromate solution at 235 257, 313 and 350 nm should be less than 0.5% RSD.
Linearity	• Ideally, the absorbance should increase with increase in the concentration of analyte in solution • For this various dilutions of **Potassium Dichromate** are prepared ranging from 20, 40, 60, 80, and 100 mg/L in 0.005 M sulfuric acid and scanned by keeping 0.005 M sulphuric acid in reference cuvette. • The calibration curve is prepared by measuring absorbance of each solution and correlation coefficient is calculated.	• Correlation coefficient r > 0.999

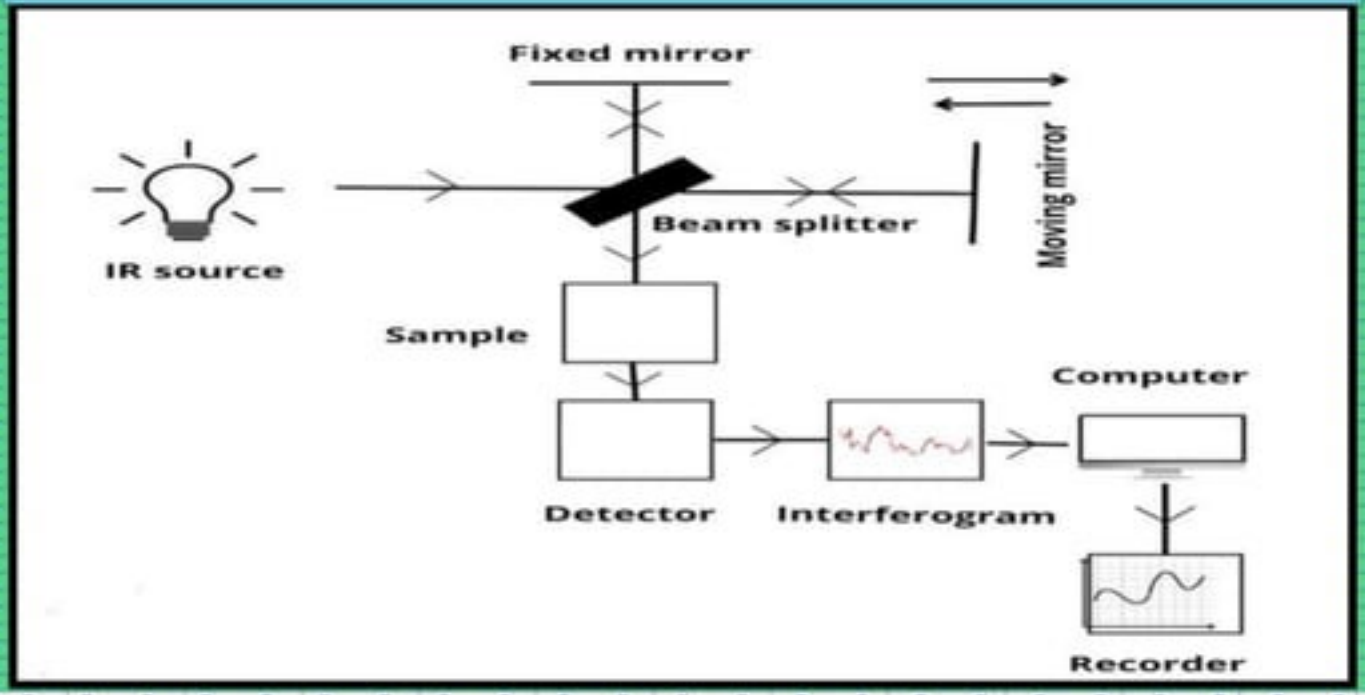
Performance Qualification(PQ)

- Performance of instrument may change gradually over time because of normal wear of parts, failure or change of its components.
- The purpose of the PQ is to provide evidence that instrument is fit for its routine use.
- Generally, performance of spectrophotometer measurements are performed under identical condition for the test specimen and the reference substance.

Qualification of FTIR



Instrumentation of FTIR



Design Qualification(DQ)

- Supplier must provide documented evidence that the product has been designed, developed and manufactured in a quality environment e.g. ISO 9001:2000 certification.
- Supplier must provide phone and on-site support in case of defects.
- Supplier must provide Information through the internet on availability of new firmware upgrades.

The below is a sample of technical attributes that may be considered in design qualification of an FT-IR spectrometer and may be adapted if necessary.

Attribute	Specifications
Detector range	The optical bench shall include a DTGS(Deuterated triglycine sulfate) detector with a 7400-350cm^{-1}.
Compressed air interferometer	-
Air cooled standard infrared source	-
Spectral resolution	The instrument shall have a spectral resolution not exceeding than 1.07400-350cm^{-1}.

Installation Qualification(IQ)

- Equipment is compared as received with purchase order, including software, accessories, spare parts and consumables.
- Documentation checked for completeness of operating, maintenance instructions, standard operating procedures for testing and safety, validation certificates and health and safety instruments.
- Equipment is checked for any damage.
- The supplier's instruction for installation is read.

- The instruments are switched on and ensured that all modules power up and an electronic self test is performed. Any deviations are recorded.
- Software is installed on computer by following the manufacturer's recommendation.
- Correct software installation is verified.
- A backup copy of software is made.
- Peripherals (e.g. printers and equipment) modules are configured.
- A list with a description of all hardware are identified an made including drawings where appropriate.

- A list with a description of all software installed on the computer is made.
- Equipment's manuals and SOPs are listed.
- An installation report is prepared.

Operational Qualification

List of parameters which should be checked:-

- Wavelength accuracy
- Wavelength resolution
- Wave number scale
- Detector Energy Ratio
- Signal/noise Ratio
- Zero Test
- Contamination Test

Wavelength accuracy

Test procedure	Acceptance limits	Test frequency	Remarks
Measurement of polystyrene spectrum at 1144, 1680, 2167 and 2307 nm. The results are compared with reference values.	±2 nm	Daily	Standard should be traceable to national standard.

Wavelength resolution

Test procedure	Acceptance limits	Test frequency
Resolution of polystyrene at 2870/2851 and at 1589/1583 nm.	➢ T(band 2870 cm^{-1} - band 2851 cm^{-1})18 ➢ T(band 1589 cm^{-1} - band 1583 cm^{-1})12	Daily

Wave number Scale

Test procedure	Transmission minima(cm^{-1})	Acceptable tolerance(cm^{-1})
Recording the spectrum of a polystyrene film which has transmission minima(absorption maxima) at the wave numbers given in the next column.	3060.0	±1.0
	2849.5	±1.0
	1942.9	±1.0
	1601.2	±1.0
	1583.0	±1.0
	1154.5	±1.0
	1028.3	±1.0

Detector Energy Ratio

Test procedure	Acceptance limits
The minimum energy ratio value for at least one of the following is measured and it is compared to the vendor's specifications: ○ Energy at 3990 cm^{-1} /energy at 2000 cm^{-1} ○ Energy at 3400 cm^{-1} /energy at 1300 cm^{-1}	Energy ratio test specifications vary for each spectrometer configuration and must be referred to the manufacturer's specifications.

Signal/noise Ratio

Test procedure	Peak to peak noise between	RMS(root mean square) noise between	Limits(%T)
The maximum noise level is recorded for each of the regions given in the next two columns.	• 4050 cm^{-1} and 3950 cm^{-1} • 2050 cm^{-1} and 1950 cm^{-1} • 050 cm^{-1} and 950 cm^{-1} • 550 cm^{-1} and 450 cm^{-1}	• 4050 cm^{-1} and 3950 cm^{-1} • 2050 cm^{-1} and 1950 cm^{-1} • 1050 cm^{-1} and 950 cm^{-1} • 550 cm^{-1} and 450 cm^{-1}	Noise level test specifications vary for each spectrometer configuration and must be referred to the manufacturer's specifications.

Zero Test

Test procedure	Limits(%T)
➢ When using a polystyrene film of approximately 35µm in thickness as standard at the wavelength of 2925 cm^{-1} and 700 cm^{-1}, almost complete absorption of the irradiated energy can be observed. ➢ With this test, the remaining transmission is measured. ➢ As the maximum absorption can be observed at 700 cm^{-1} negative values may be observed. ➢ The objective of the test is to evaluate if despite the fact that there is almost complete absorption, energy is still detectable. ➢ Non-valid results are an indication of a non-linear behavior of the detector and the electronic system.	Results vary for each spectrometer configuration and must be referred to the manufacturer's specifications.

Contamination Test

Test procedure	Wave number(cm^{-1})	Upper limit(A)
➢ The automated function of the instrument is used to perform this test (If automation is not available then a background spectrum is recorded). ➢ This test checks the presence of peaks that signal a contamination problem.	3100 -2800	0.1
	1800 -1600	0.1
	1400 -1100	0.2

Performance Qualification(PQ)

- Wavenumber Accuracy
- Wavenumber reproducibility
- Transmittance reproducibility

Wavenumber accuracy

- The wave number scale is usually calibrated by the use of several characteristics.
- Wave numbers of a polystyrene film:
  - 3060.0 (±1.5)cm^{-1}
  - 2849.5 (±1.5)cm^{-1}
  - 1942.9 (±1.5)cm^{-1}
  - 1601.2 (±1.0)cm^{-1}
  - 1583.0 (±1.0)cm^{-1}
  - 1154.5 (±1.0)cm^{-1}
  - 1028.3(±1.0)cm^{-1}
- The software then judges whether the values are within the allowable range and the program labels the results 'PASS' if all the peak numbers are within the range.

Wavenumber reproducibility

- This program specifies three points to measure the peak wave numbers.
- Then it obtains the actual peak wave numbers at each point by measuring the polystyrene film twice.
- It should satisfy 5 cm^{-1} around 3000 cm^{-1} of polystyrene absorption wave number, 1 cm^{-1} around 1000 cm^{-1} .
- The software determines whether the difference between each of two measurements are within the allowable range and it labels the results 'PASS' if they are within the range.

Transmittance reproducibility

- This program specifies peak wave numbers at three points and the transmittance at each point is measured twice.
- The transmittance reproducibility should satisfy 0.5 %T when the several points of polystyrene absorption from 3000 cm^{-1} to 1000 cm^{-1} are measured twice.
- Then it is determined whether the differences between the two data are within the range.
- The FT-IR abnormalities or large changes over short term and long term are assessed by these tests.

The two parameters checked by this program are:

Energy spectrum test:-power spectra obtained in the inspection are compared with reference data and the spectra are checked for changes over long periods. 100%T line spectra are calculated for power spectra and are measured continuously in inspection and the spectra are checked for changes over short periods.

A.Polystyrene test:- evaluation is performed using differences between spectra obtained for polystyrene film in inspection and the stored reference data. When the differences are within the standard, it passes the first.

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Thank
You!