Designation: D2621 − 87 (Reapproved 2016)

Standard Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints[1]

This standard is issued under the fixed designation D2621; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the qualitative characterization or identification of separated paint vehicle solids by infrared spectroscopy within the limitations of infrared spectroscopy.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1467 Guide for Testing Fatty Acids Used in Protective Coatings (Withdrawn 2003)[3]

D1962 Test Method for Saponification Value of Drying Oils, Fatty Acids, and Polymerized Fatty Acids (Withdrawn 2004)[3]

D2372 Practice for Separation of Vehicle From Solvent-Reducible Paints

E131 Terminology Relating to Molecular Spectroscopy

E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms and symbols, refer to Terminology E131.

4. Summary of Test Method

4.1 Infrared spectra are prepared from dried films of isolated paint vehicles. Vehicle types are identified by comparing the spectra to a collection of reference infrared spectra.

5. Significance and Use

5.1 The ability to qualitatively identify paint vehicles is useful for characterizing unknown or competitive coatings, for complaint investigations, and for in-process control.

6. Apparatus

6.1 *Spectrophotometer*—A recording double-beam infrared spectrophotometer with a wavelength range from at least 2.5 to 15 µ m and a spectral resolution of at least 0.04 µm over that range. See Practice E275.

6.2 *Demountable Cell Mount,* with NaCl window.

6.3 *Vacuum Drying Oven* thermostatically controlled to operate at 60 ± 2°C. A water aspirator vacuum source is satisfactory.

6.4 *Oven, Gravity or Forced Draft,* capable of maintaining temperature from 105 to 110°C.

7. Procedure

7.1 Place the vehicle, separated from the paint in accordance with Practice D2372, on a NaCl window and spread to form a uniform film. Make sure that the thickness of the film is such that when the infrared spectrum is recorded, the transmittance of the strongest band falls between 5 and 15 % (Note). Dry the film in an oven at 105 to 110°C for 15 min and cool in a desiccator. Inspect the film visually for defects such as bubbles, wrinkles, contamination, etc. If defects are present, cast another film. If easily oxidizable substances are present such as tung, oiticica, or linseed oils, make sure that the film is dried at 60 ± 2°C in a vacuum oven for 1 h. If solvents of low volatility such as cyclohexanone or isophorone are present, the film may need to be dried for several hours in a 60°C vacuum oven.

NOTE 1—Numerous procedures and variations may be used to obtain a film on which to prepare a suitable spectrum. These include liquid mounting between two NaCl plates, transmission through free films, and reflectance from highly polished surfaces.

7.2 Immediately record the infrared spectrum from 2.5 to 15 µm so that a spectral resolution of 0.04 µm is maintained throughout that range (methods for achieving this resolution will vary according to the directions of the manufacturer of the instrument used).

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[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.21 on Chemical Analysis of Paints and Paint Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 1 Correlation of Absorption Bands in Alkyd Spectra

Wavelength, µm	Wavenumbers, cm^{-1}	Group Vibration
2.9	3448	O–H stretch
3.4 to 3.5	2941 to 2857	alkane C–H stretch
5.8	1724	ester, C=O stretch
6.2, 6.3, 6.6, 6.7	1613, 1587, 1515, 1493	skeletal in-plane aromatic C=C
6.9, 7.3	1449, 1369	aliphatic C–H bending
7.5 to 9.4	1333 to 1063	ester, C–O–C stretch (*o*-phthalate ester)
8.6	1163	ester, C–O–C stretch (fatty acid ester)
9.6, 13.5, 14.3	1042, 741, 699	out-of-plane aromatic C–H bending denoting *o*-disubstituted benzene ring.

7.3 Compare the spectrum obtained with reference spectra prepared from nonvolatile vehicles of known composition (see Annex A1) or consult other published spectra available in the literature (Annex A3). Interpret the spectrum on the basis of available information, recognizing certain limitations of infrared spectroscopy, and qualifying the interpretation accordingly (Annex A2).

8. Keywords

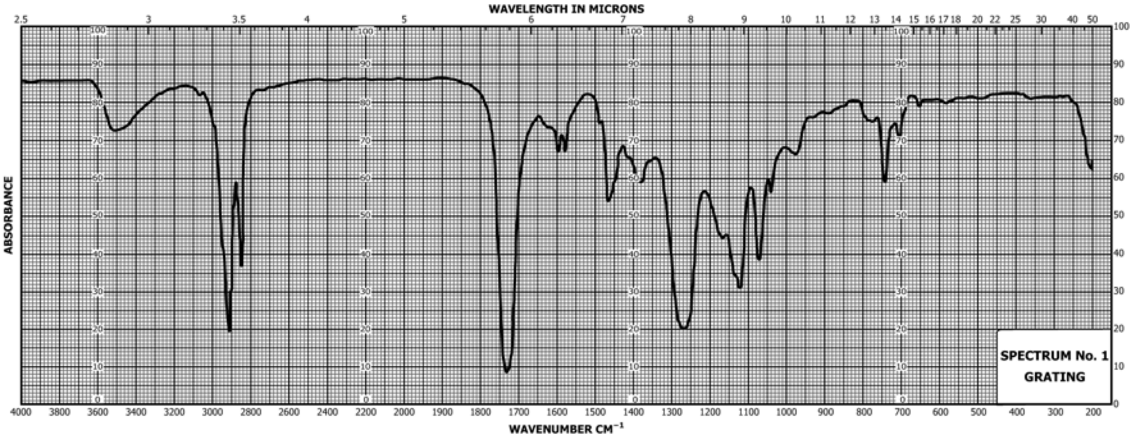
8.1 infrared spectra; paint binders; solvent reducible paint

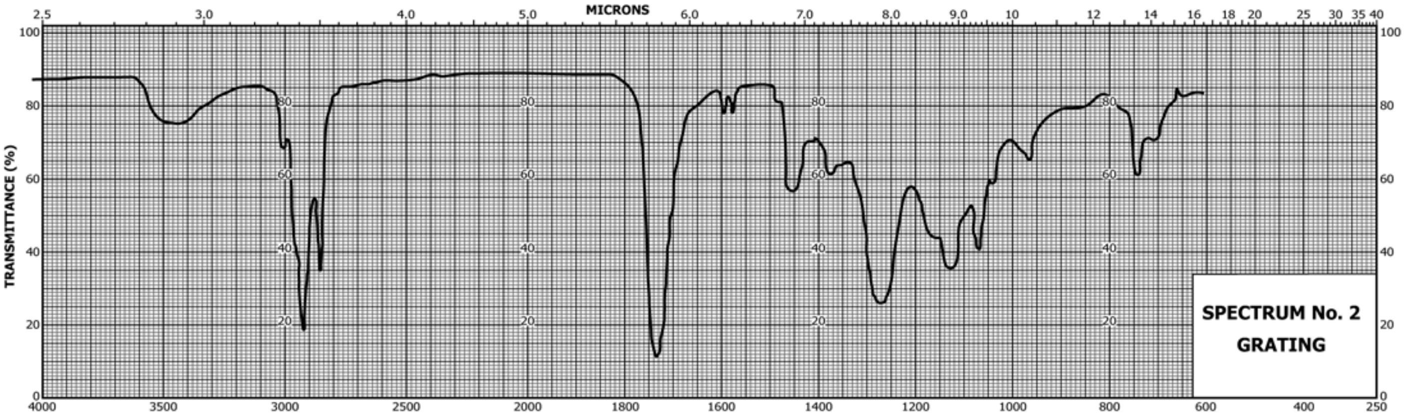
ANNEXES

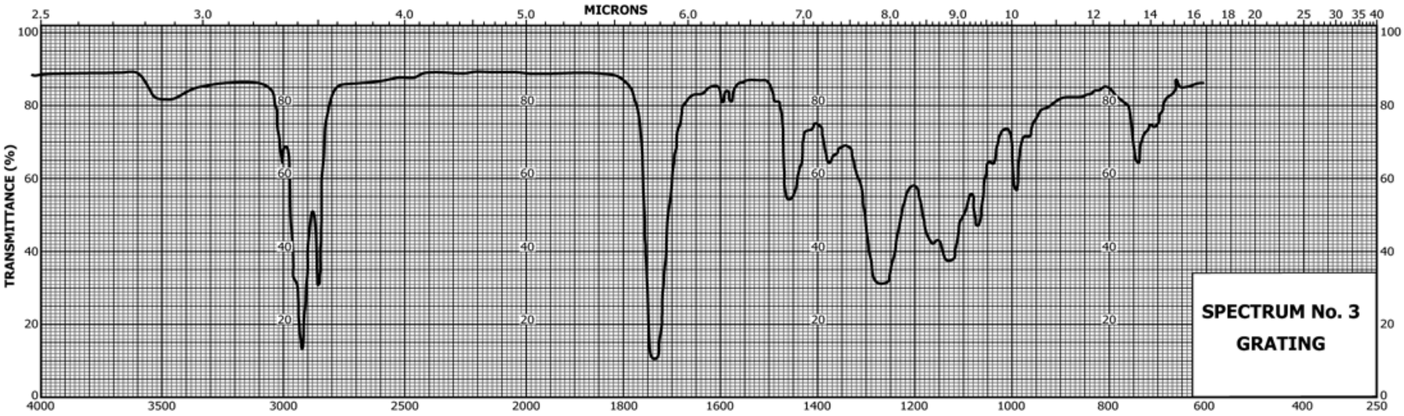
(Mandatory Information)

A1. INFRARED SPECTRA OF NONVOLATILE VEHICLES OF KNOWN COMPOSITION

A1.1 A set of reference infrared spectra on grating and prism is reproduced on the following pages.




MICRONS
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10
12
14
16
18
20
25
30
35
40
TRANSMITTANCE (%)
100
80
60
40
20
0
4000
3500
3000
2500
2000
1800
1600
1400
1200
1000
800
600
400
250
SPECTRUM No. 2
GRATING


MICRONS
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10
12
14
16
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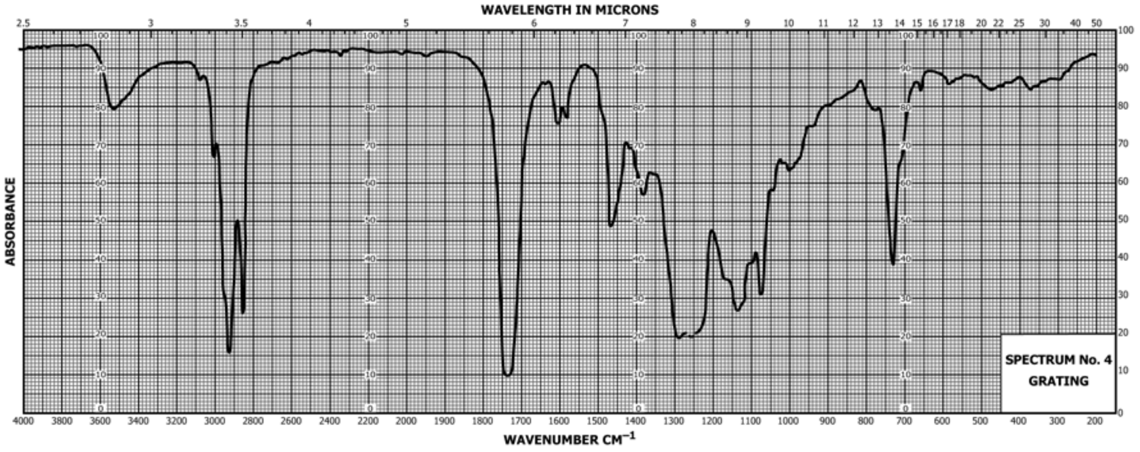
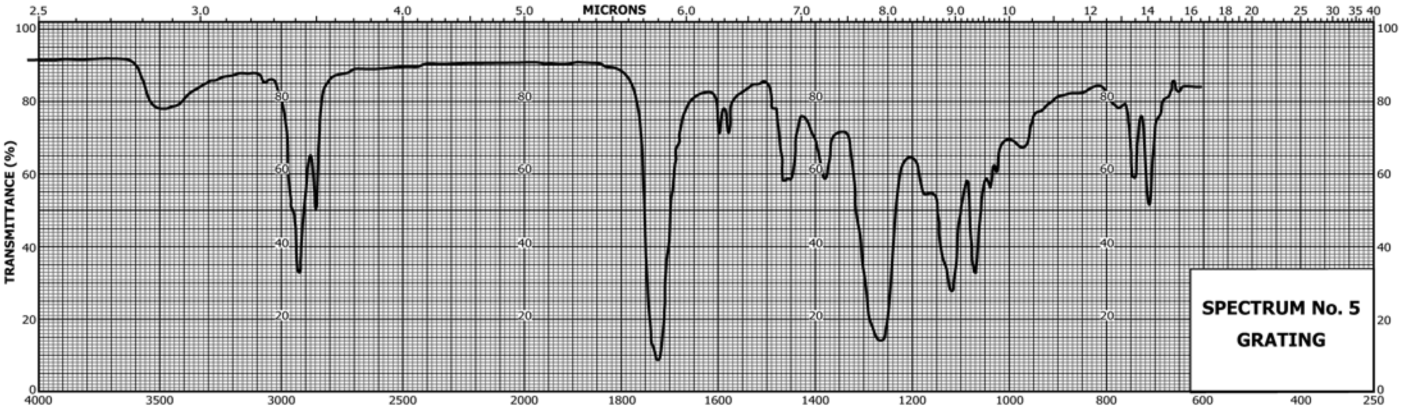
20
25
30
35
40
TRANSMITTANCE (%)
100
80
60
40
20
0
4000
3500
3000
2500
2000
1800
1600
1400
1200
1000
800
600
400
250
SPECTRUM No. 3
GRATING


WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
22
25
30
40
50
ABSORBANCE
100
90
80
70
60
50
40
30
20
10
0
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}
SPECTRUM No. 4
GRATING


MICRONS
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4.0
5.0
6.0
7.0
8.0
9.0
10
12
14
16
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20
25
30
35
40
TRANSMITTANCE (%)
100
80
60
40
20
0
4000
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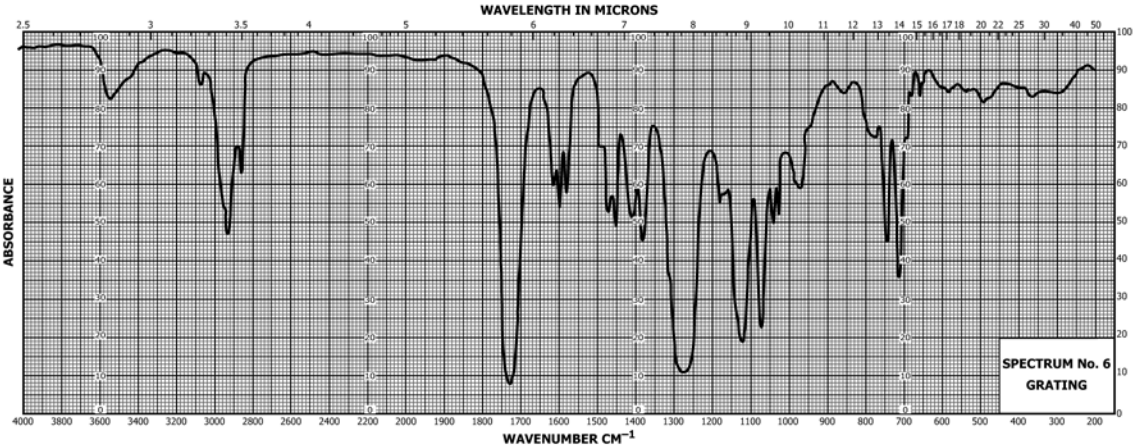
3000
2500
2000
1800
1600
1400
1200
1000
800
600
400
250
SPECTRUM No. 5
GRATING


WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
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16
17
18
20
22
25
30
40
50
ABSORBANCE
100
90
80
70
60
50
40
30
20
10
0
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
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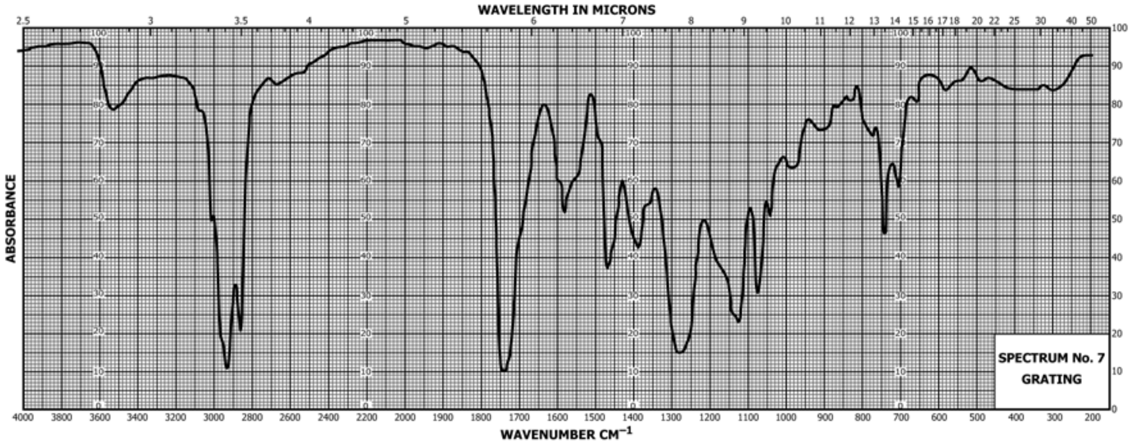
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}
SPECTRUM No. 6
GRATING


WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
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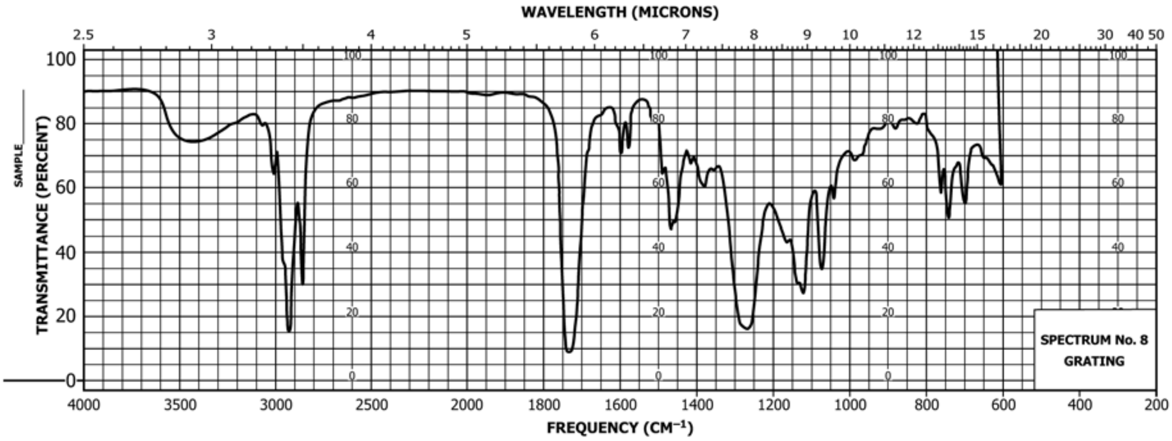
16
17
18
20
22
25
30
40
50
ABSORBANCE
100
90
80
70
60
50
40
30
20
10
0
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}
SPECTRUM No. 7
GRATING



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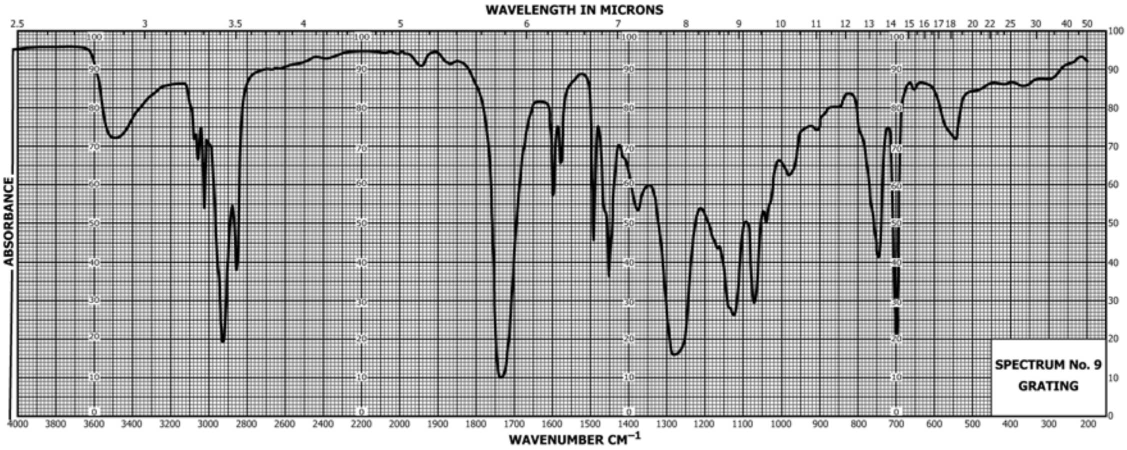

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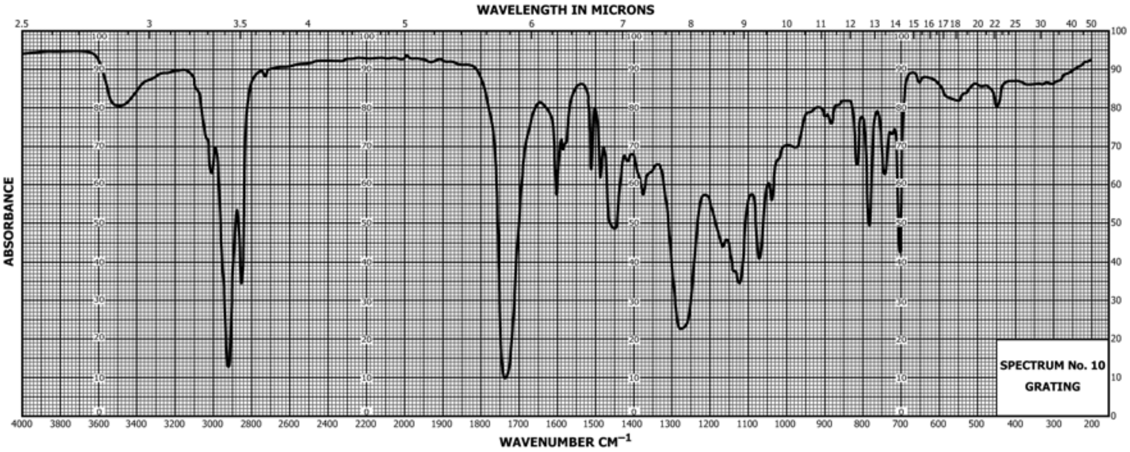

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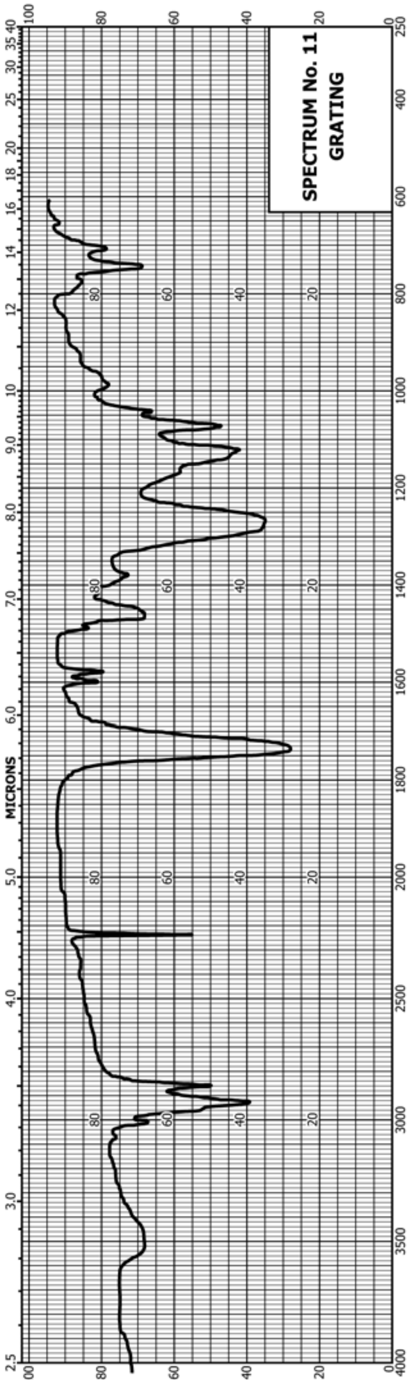
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GRATING
MICRONS
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4.0
5.0
6.0
7.0
8.0
9.0
10
12
14
16
18
20
25
30
35
40
4000
3500
3000
2500
2000
1800
1600
1400
1200
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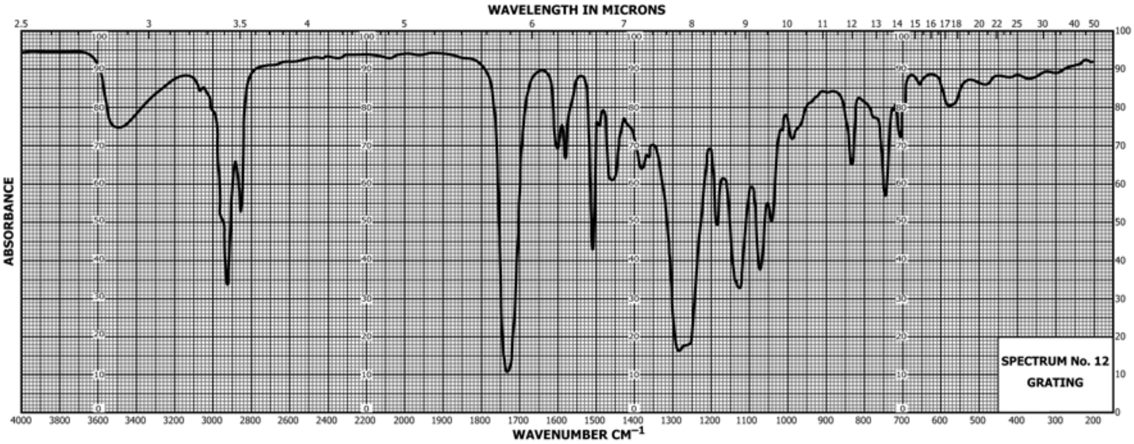
800
600
400
250
TRANSMITTANCE (%)
100
80
60
40
20
0


WAVELENGTH IN MICRONS
2.5
3
3.5
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7
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9
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11
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13
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15
16
17
18
20
22
25
30
40
50
ABSORBANCE
100
90
80
70
60
50
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30
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10
0
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
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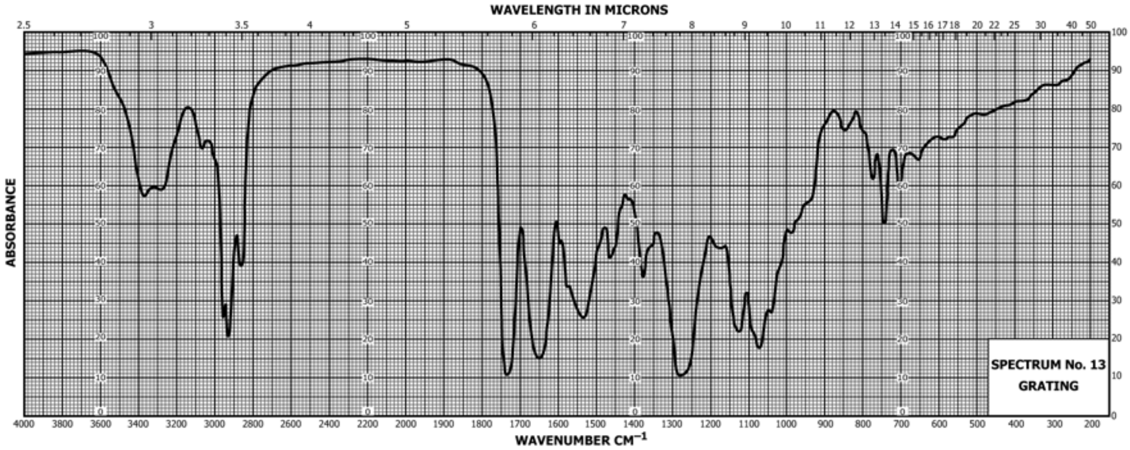
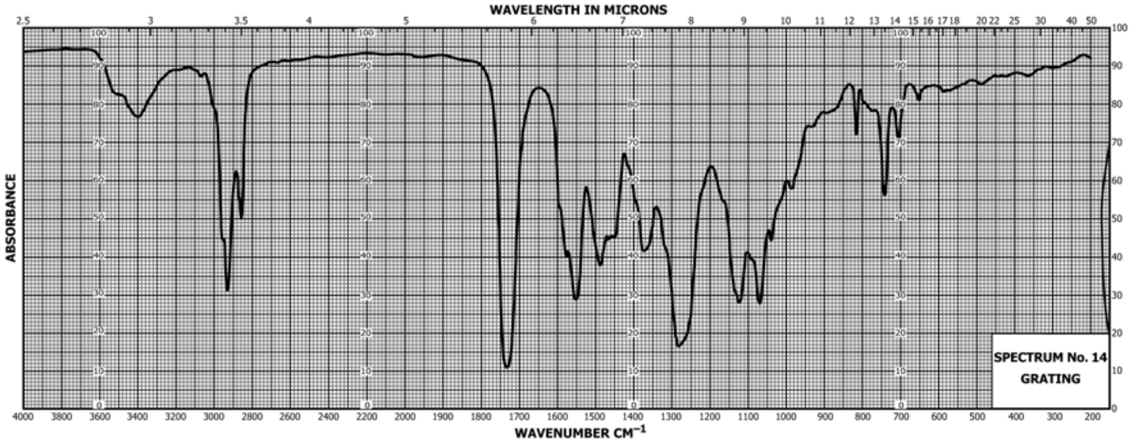
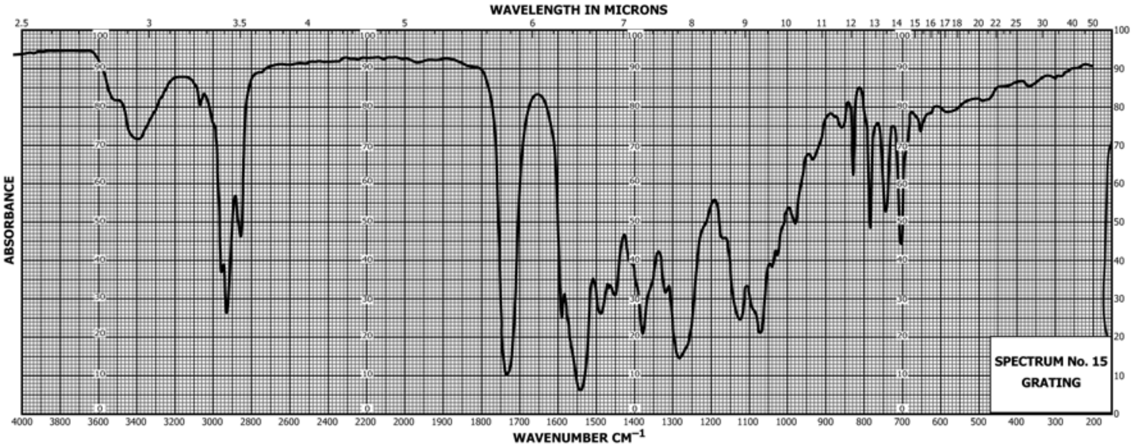
900
800
700
600
500
400
300
200
WAVENUMBER CM⁻¹
SPECTRUM No. 12
GRATING


WAVELENGTH IN MICRONS
ABSORBANCE
WAVENUMBER CM⁻¹
SPECTRUM No. 13
GRATING


WAVELENGTH IN MICRONS
ABSORBANCE
WAVENUMBER CM⁻¹
SPECTRUM No. 14
GRATING



SPECTRUM No. 15
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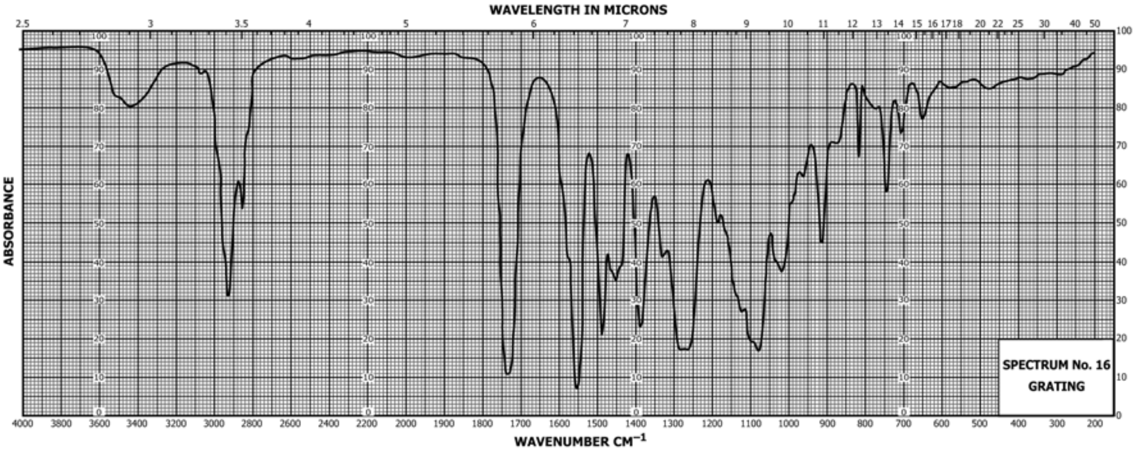

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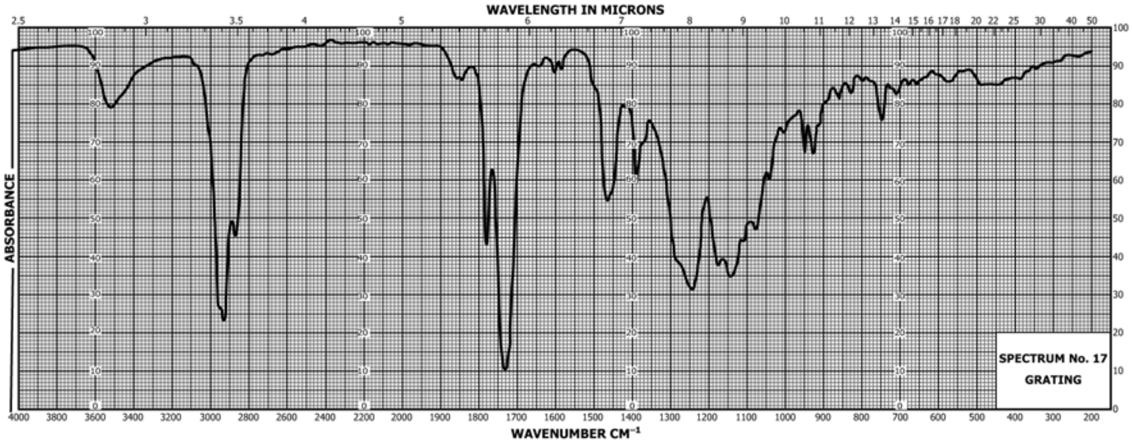

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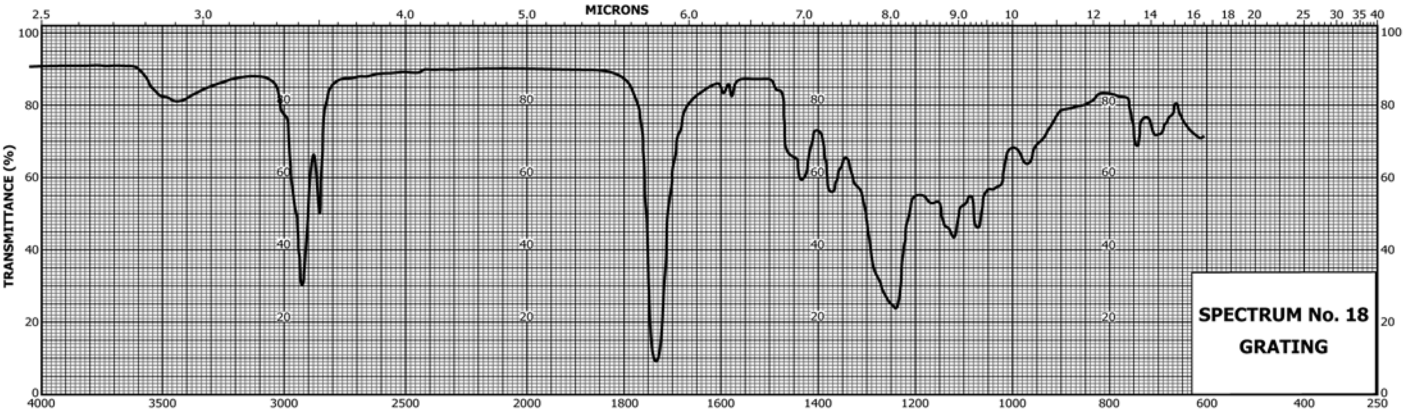
MICRONS
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
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14
16
18
20
25
30
35
40
TRANSMITTANCE (%)
100
80
60
40
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0
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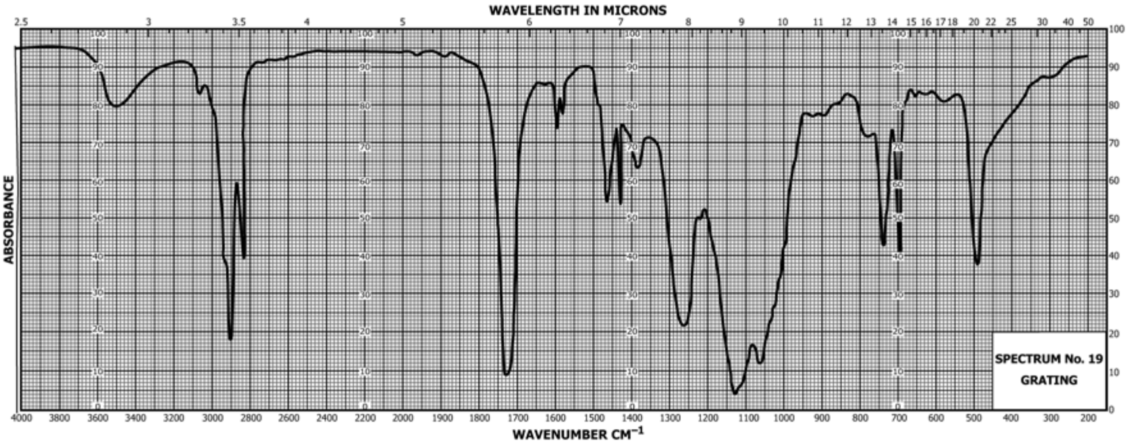
SPECTRUM No. 18
GRATING


WAVELENGTH IN MICRONS
2.5
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3.5
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17
18
20
22
25
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40
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ABSORBANCE
100
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80
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60
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3800
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3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
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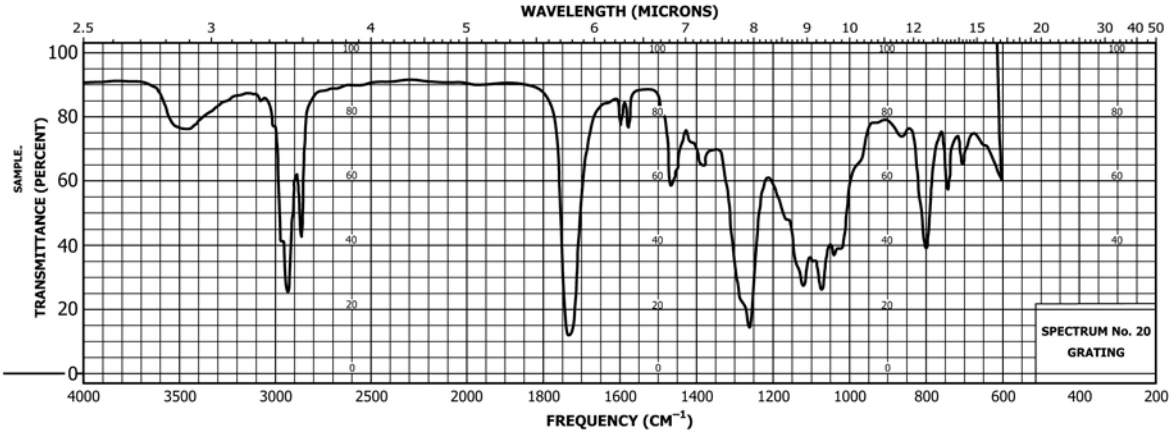
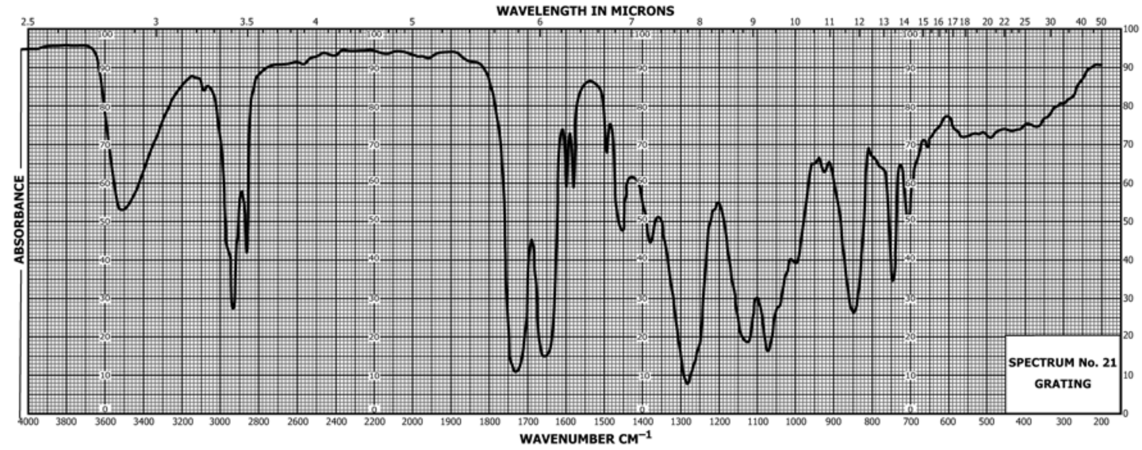
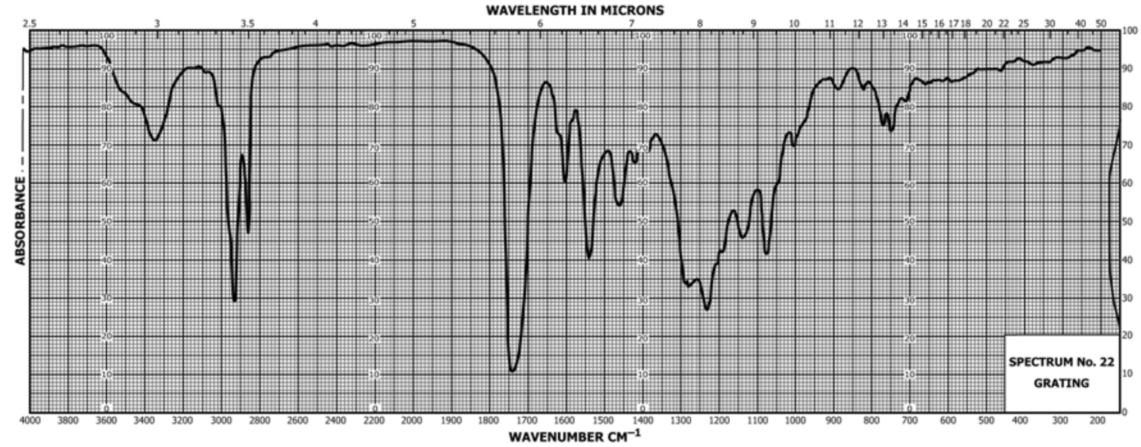
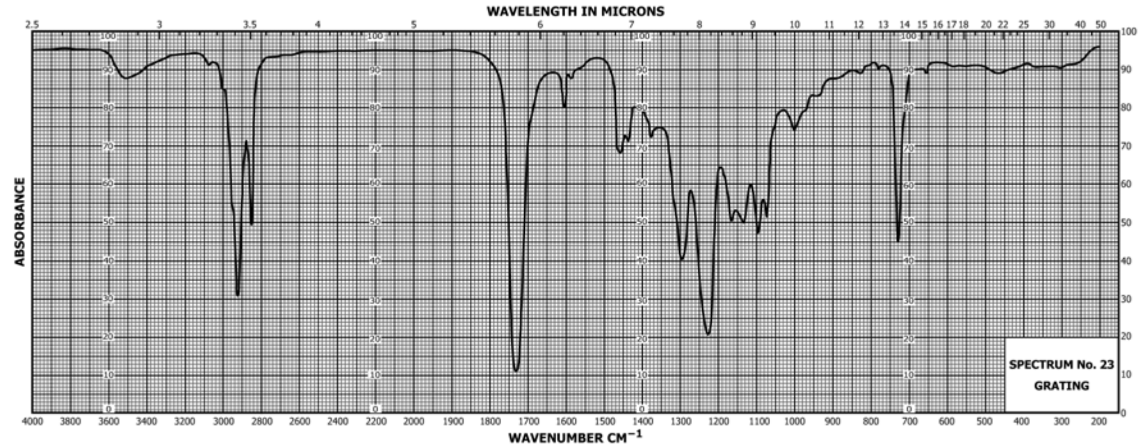
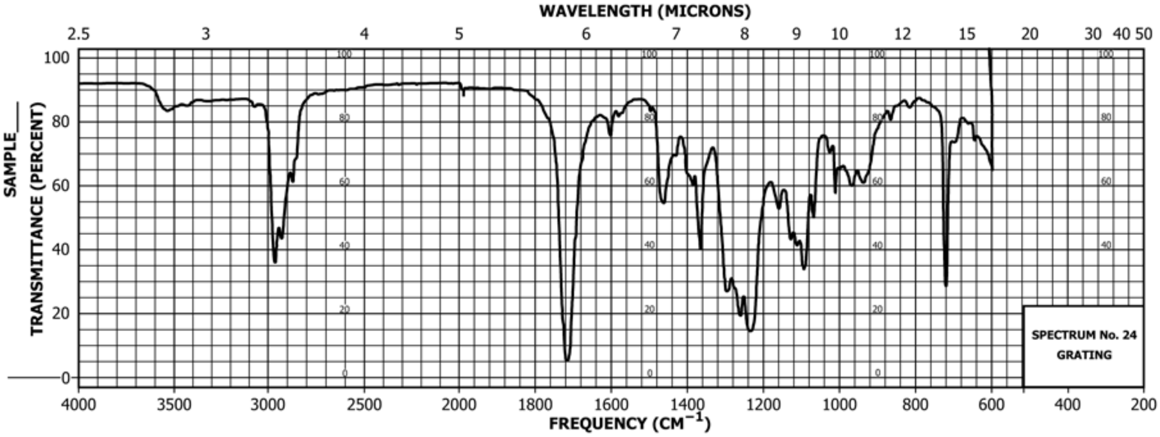
400
300
200
WAVENUMBER CM^{-1}
SPECTRUM No. 19
GRATING

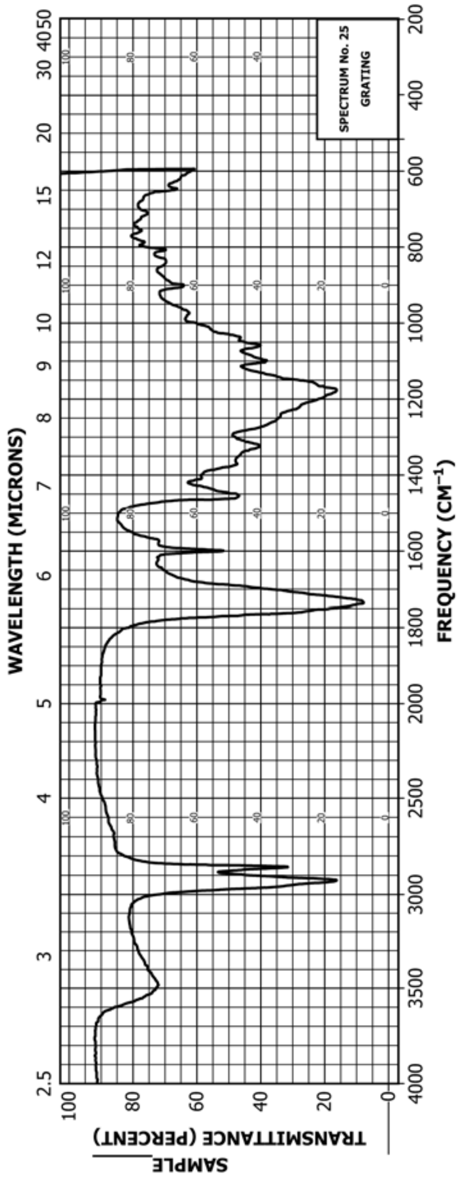

WAVELENGTH (MICRONS)
2.5
3
4
5
6
7
8
9
10
12
15
20
30
40
50
SAMPLE.
TRANSMITTANCE (PERCENT)
100
80
60
40
20
0
4000
3500
3000
2500
2000
1800
1600
1400
1200
1000
800
600
400
200
FREQUENCY (CM^{-1})
SPECTRUM No. 20
GRATING

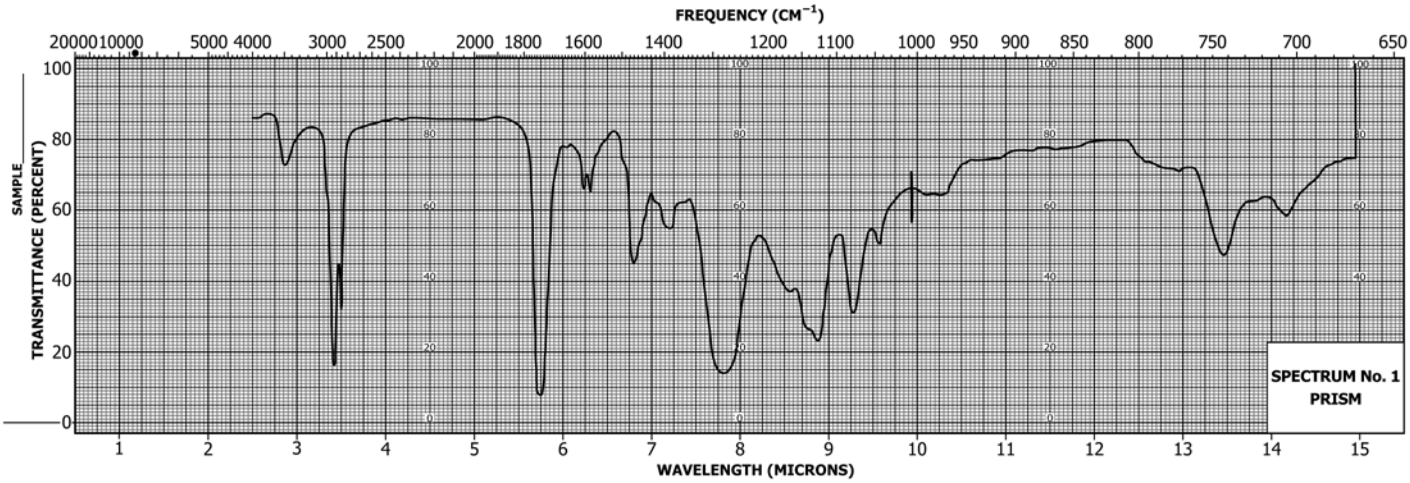

WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
22
25
30
40
50
ABSORBANCE
0
10
20
30
40
50
60
70
80
90
100
SPECTRUM No. 21
GRATING
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}

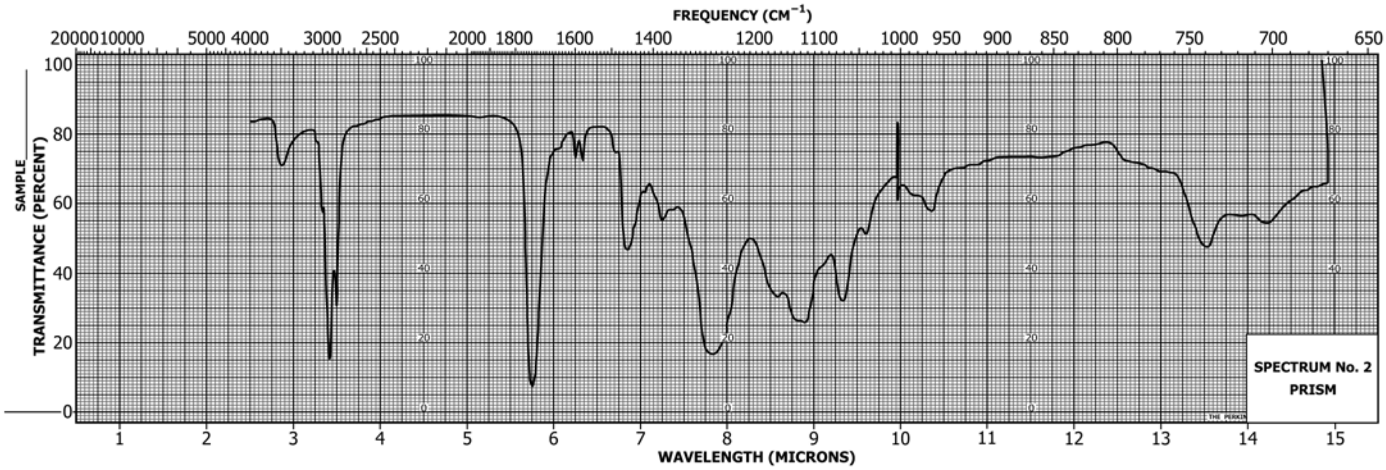

WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
22
25
30
40
50
ABSORBANCE
0
10
20
30
40
50
60
70
80
90
100
SPECTRUM No. 22
GRATING
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}

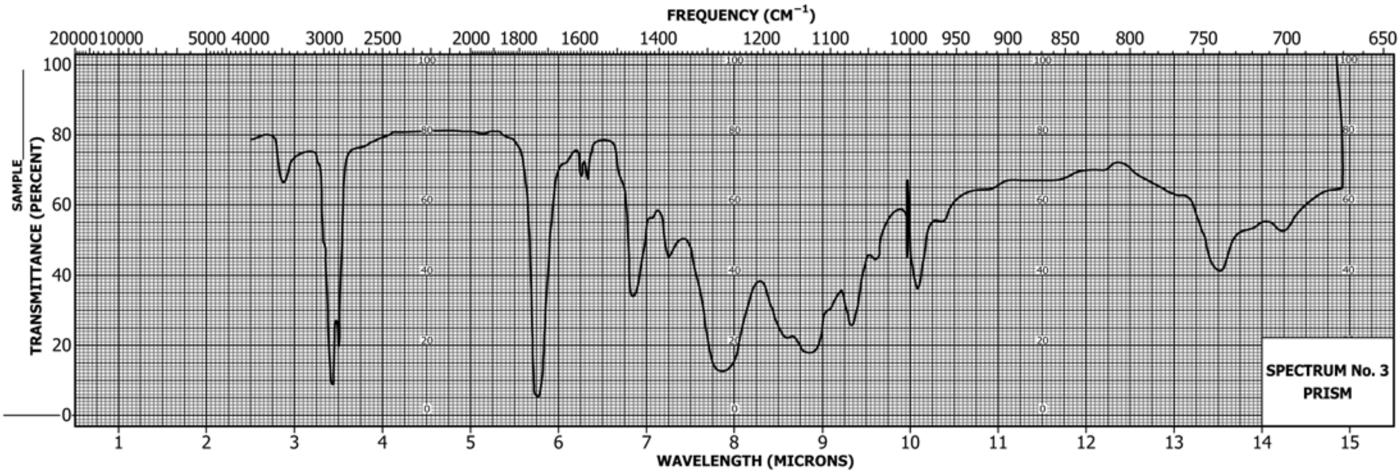

WAVELENGTH IN MICRONS
2.5
3
3.5
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
22
25
30
40
50
ABSORBANCE
0
10
20
30
40
50
60
70
80
90
100
SPECTRUM No. 23
GRATING
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
WAVENUMBER CM^{-1}

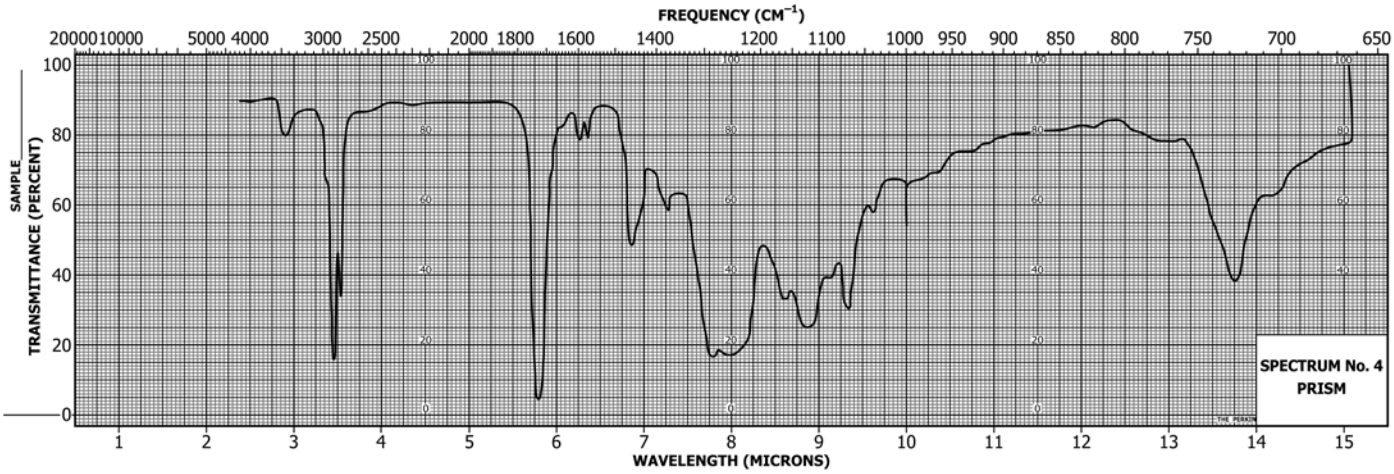

WAVELENGTH (MICRONS)
2.5 3 4 5 6 7 8 9 10 12 15 20 30 40 50
SAMPLE___
TRANSMITTANCE (PERCENT)
100 80 60 40 20 0
SPECTRUM No. 24
GRATING
4000 3500 3000 2500 2000 1800 1600 1400 1200 1000 800 600 400 200
FREQUENCY (CM^{-1})


WAVELENGTH (MICRONS)
2.5 3 4 5 6 7 8 9 10 12 15 20 30 40 50
SPECTRUM No. 25
GRATING
FREQUENCY (CM^{-1})
4000 3500 3000 2500 2000 1800 1600 1400 1200 1000 800 600 400 200
100 80 60 40 20 0
TRANSMITTANCE (PERCENT)
SAMPLE___


FREQUENCY (CM⁻¹)
20000 10000 5000 4000 3000 2500 2000 1800 1600 1400 1200 1100 1000 950 900 850 800 750 700 650
SAMPLE
TRANSMITTANCE (PERCENT)
0 20 40 60 80 100
WAVELENGTH (MICRONS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SPECTRUM No. 1
PRISM


FREQUENCY (CM⁻¹)
20000 10000 5000 4000 3000 2500 2000 1800 1600 1400 1200 1100 1000 950 900 850 800 750 700 650
SAMPLE
TRANSMITTANCE (PERCENT)
0 20 40 60 80 100
WAVELENGTH (MICRONS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SPECTRUM No. 2
PRISM


FREQUENCY (CM⁻¹)
20000 10000 5000 4000 3000 2500 2000 1800 1600 1400 1200 1100 1000 950 900 850 800 750 700 650
SAMPLE
TRANSMITTANCE (PERCENT)
0 20 40 60 80 100
WAVELENGTH (MICRONS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SPECTRUM No. 3
PRISM


FREQUENCY (CM^{-1})
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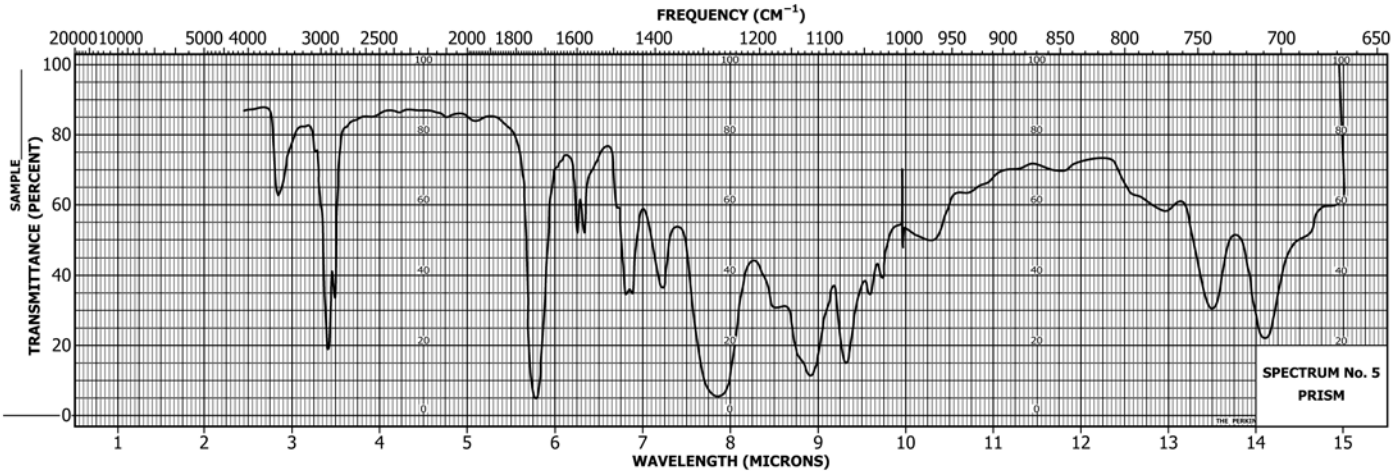
SPECTRUM No. 4
PRISM
THE PERKIN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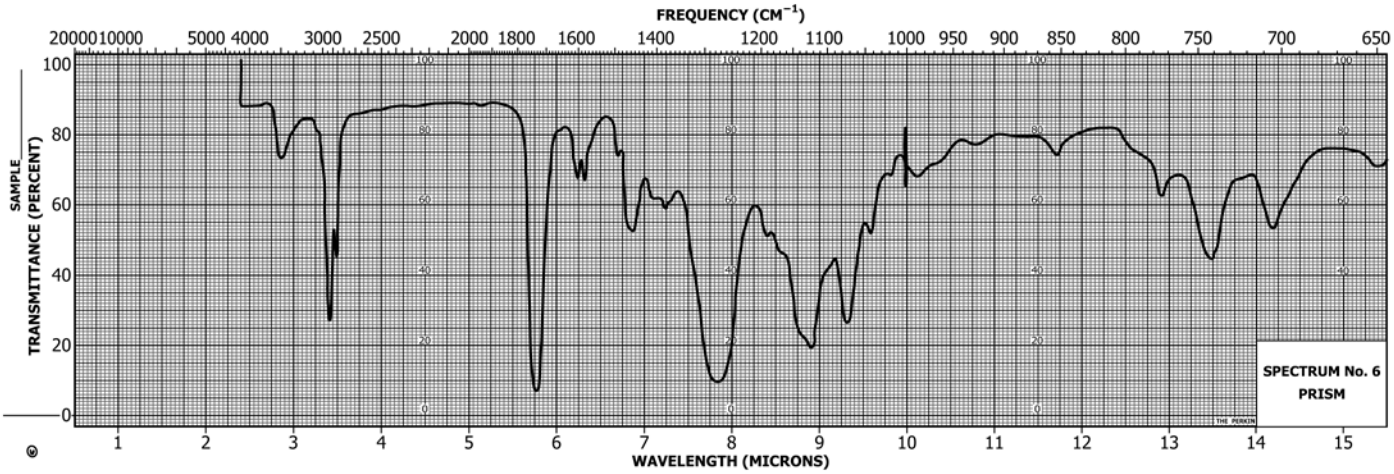
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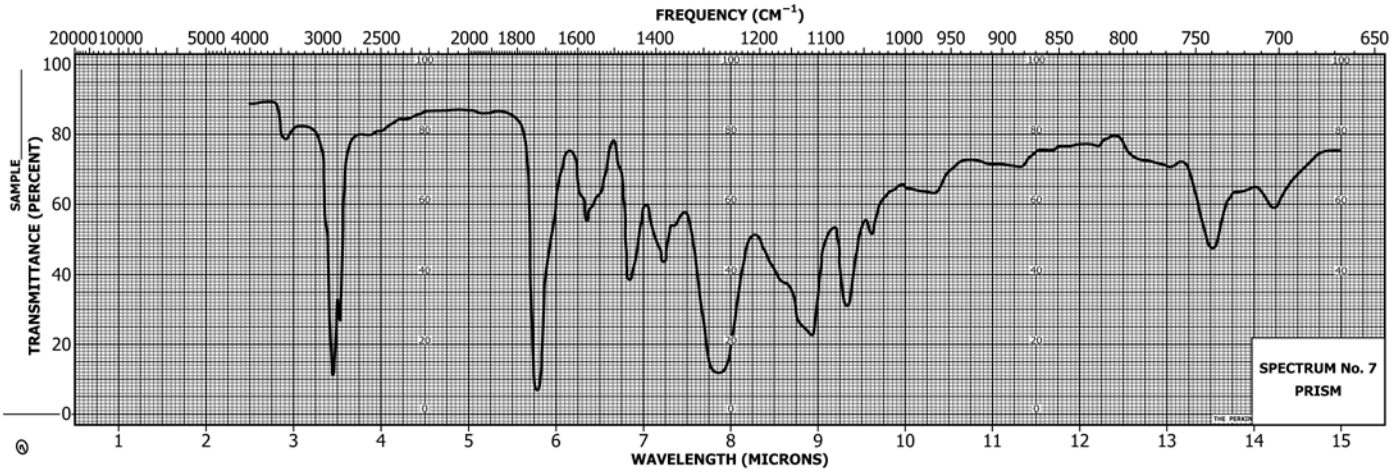
PRISM
THE PERKIN
©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WAVELENGTH (MICRONS)
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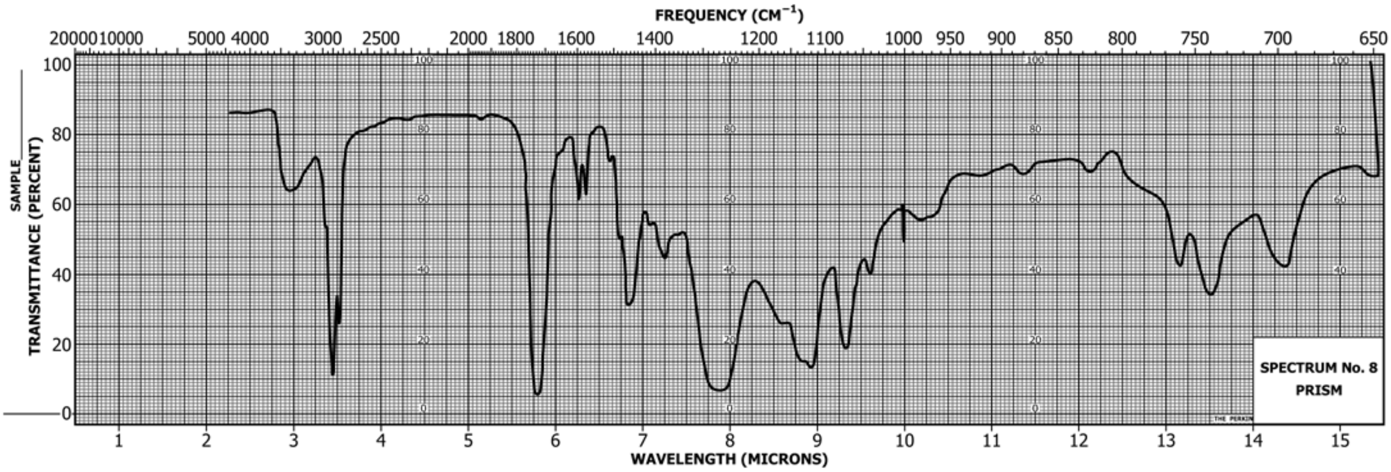
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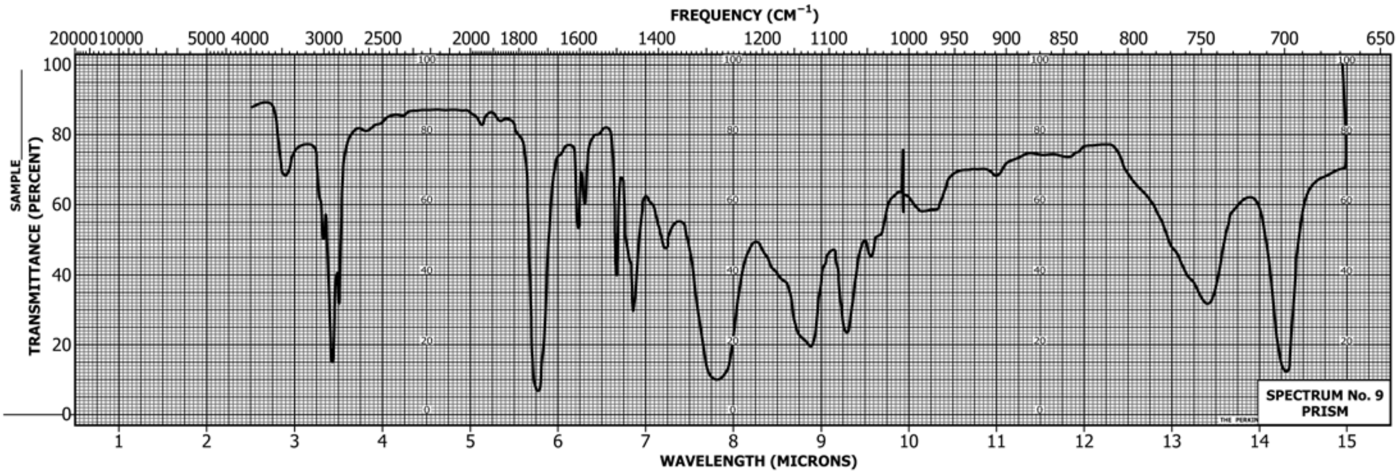
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WAVELENGTH (MICRONS)
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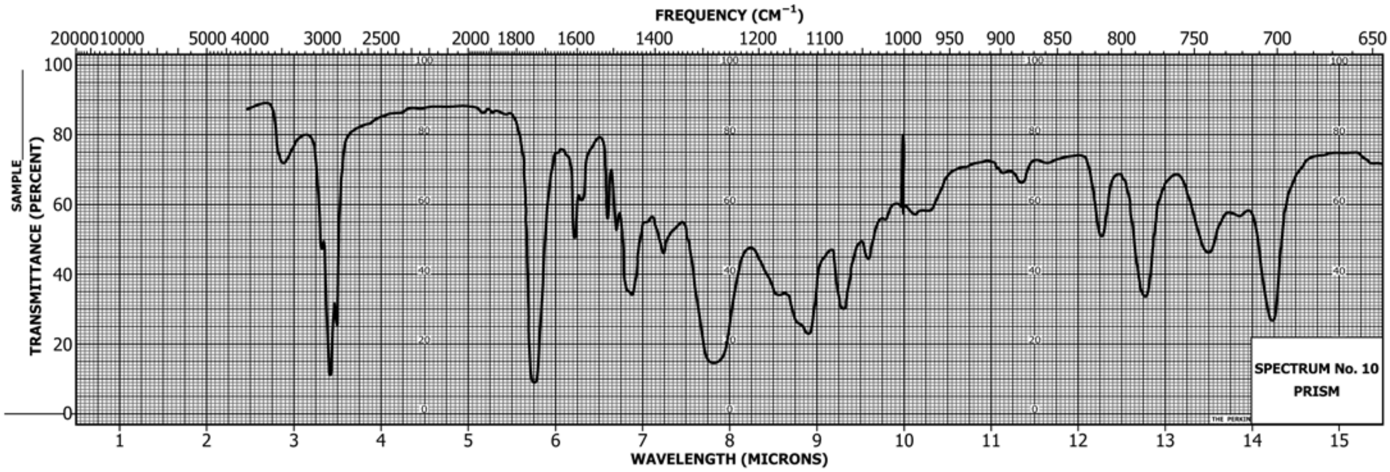
PRISM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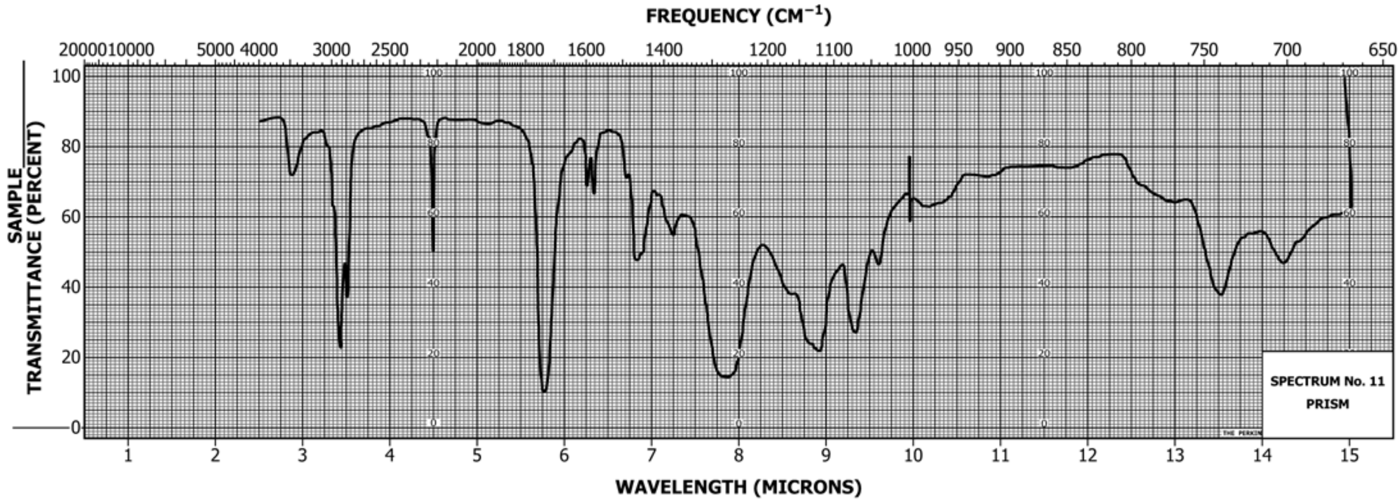
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WAVELENGTH (MICRONS)
SPECTRUM No. 11
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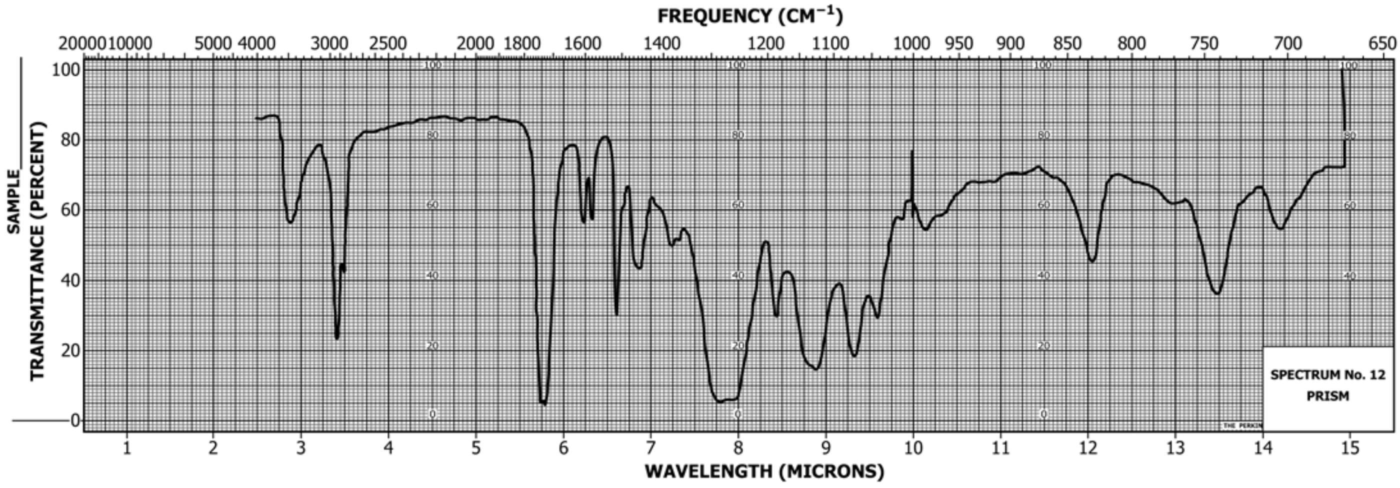
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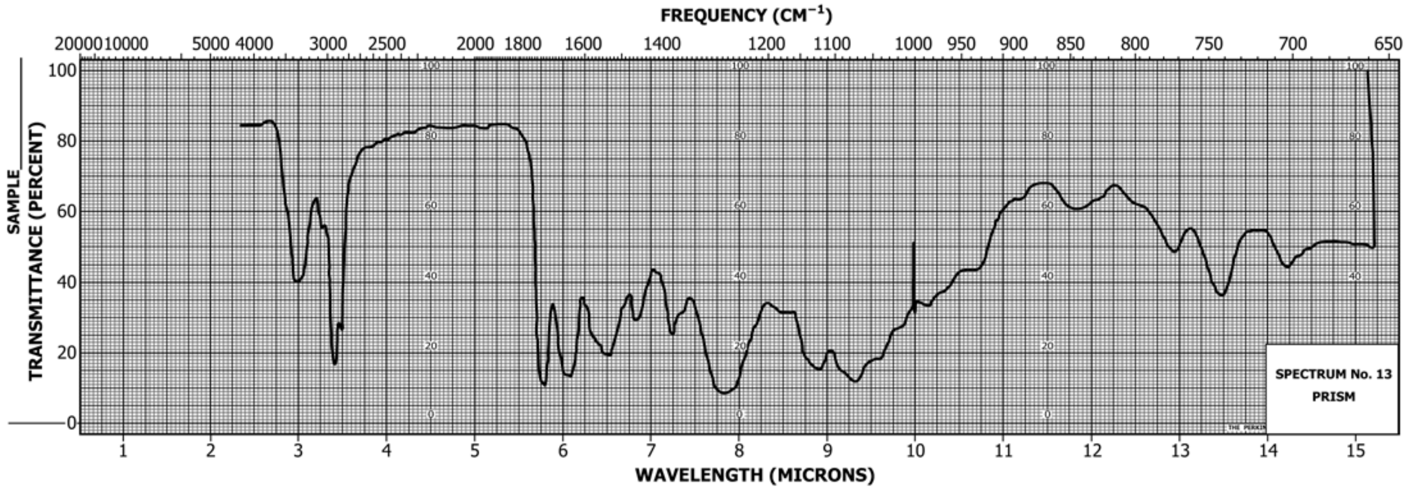
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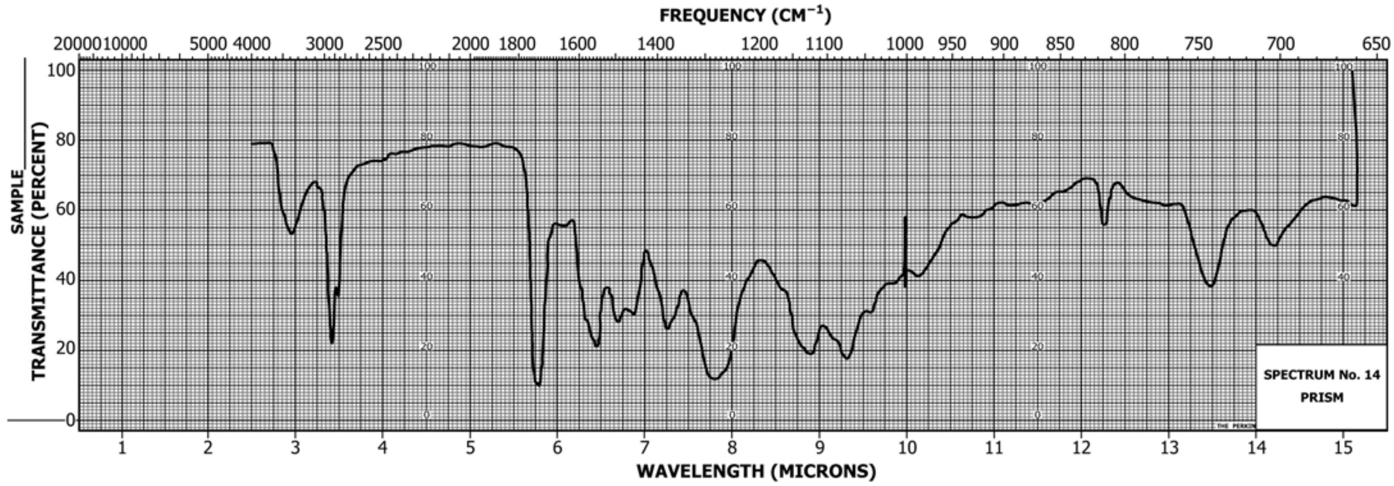
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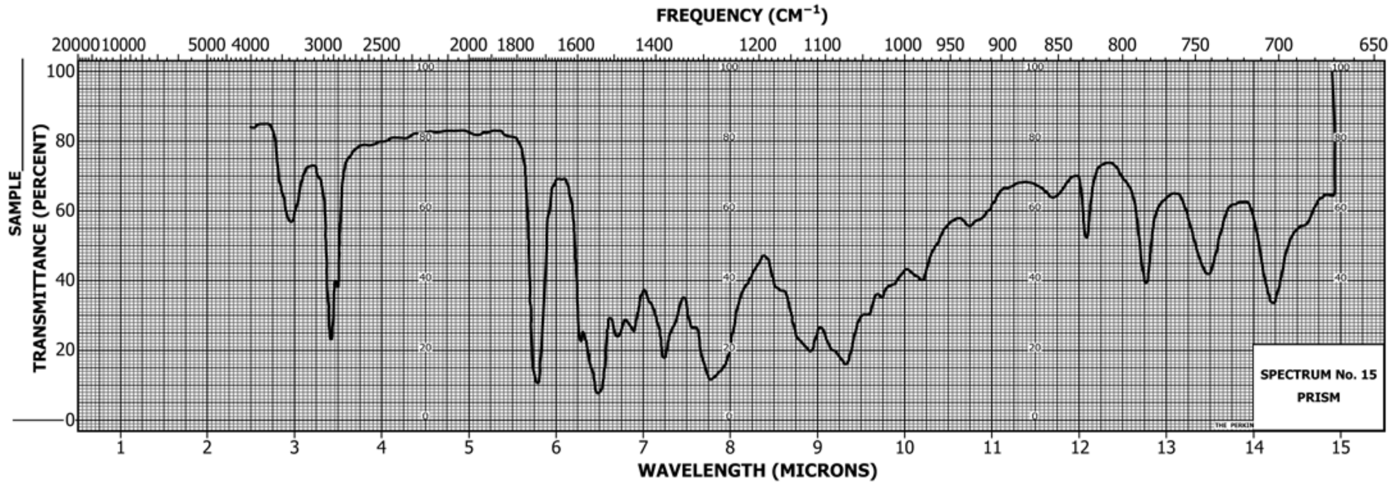
WAVELENGTH (MICRONS)
SPECTRUM No. 14
PRISM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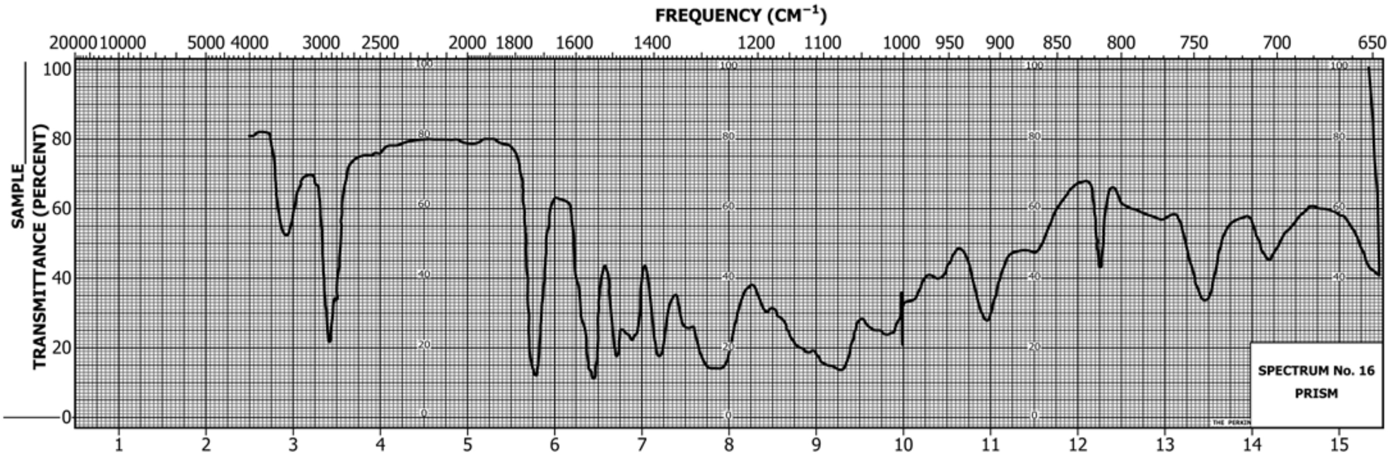
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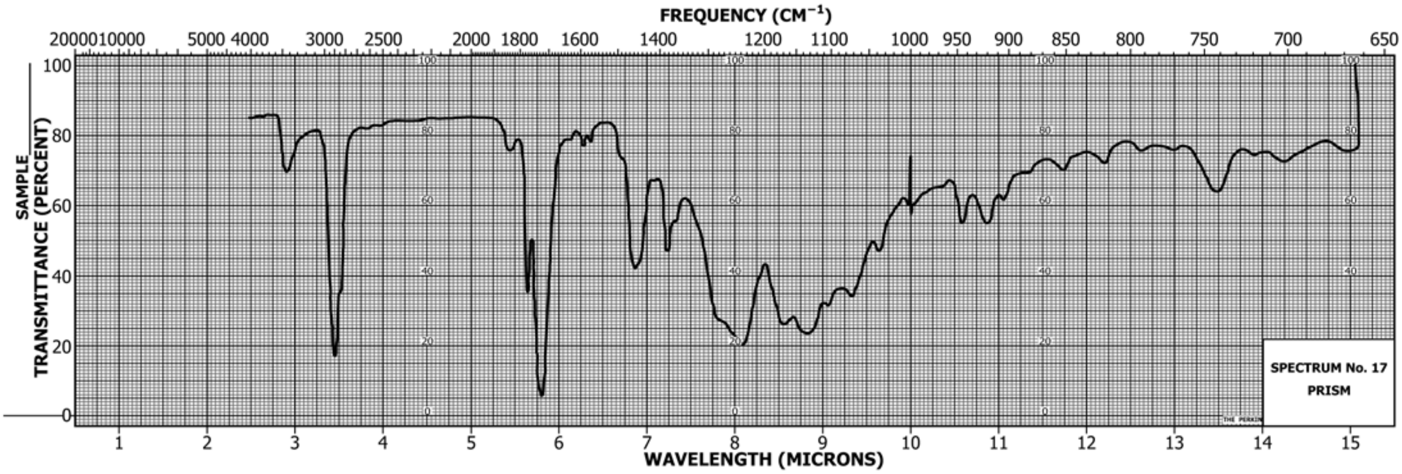
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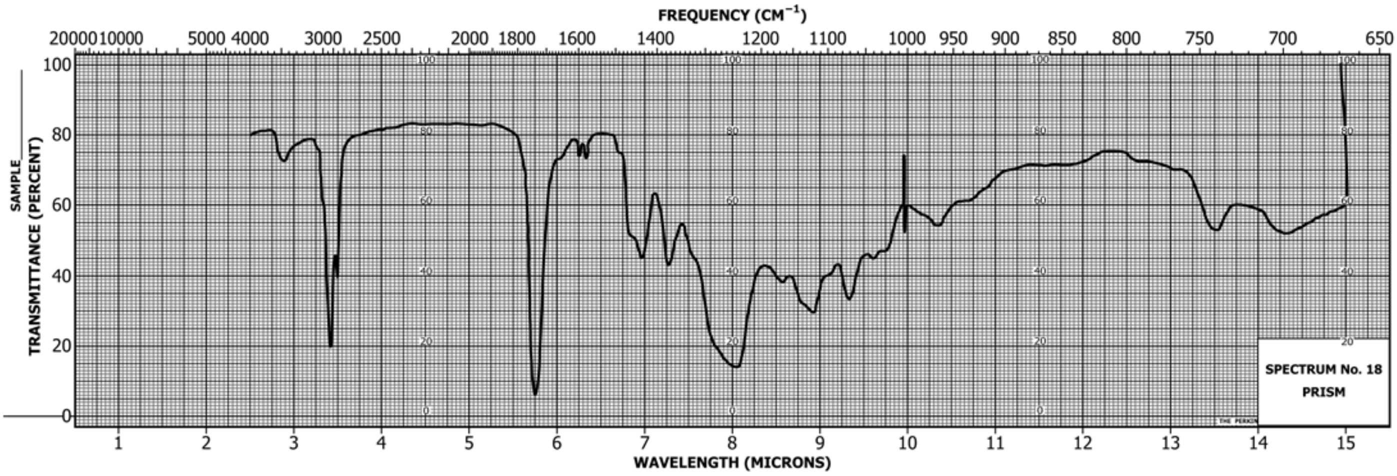
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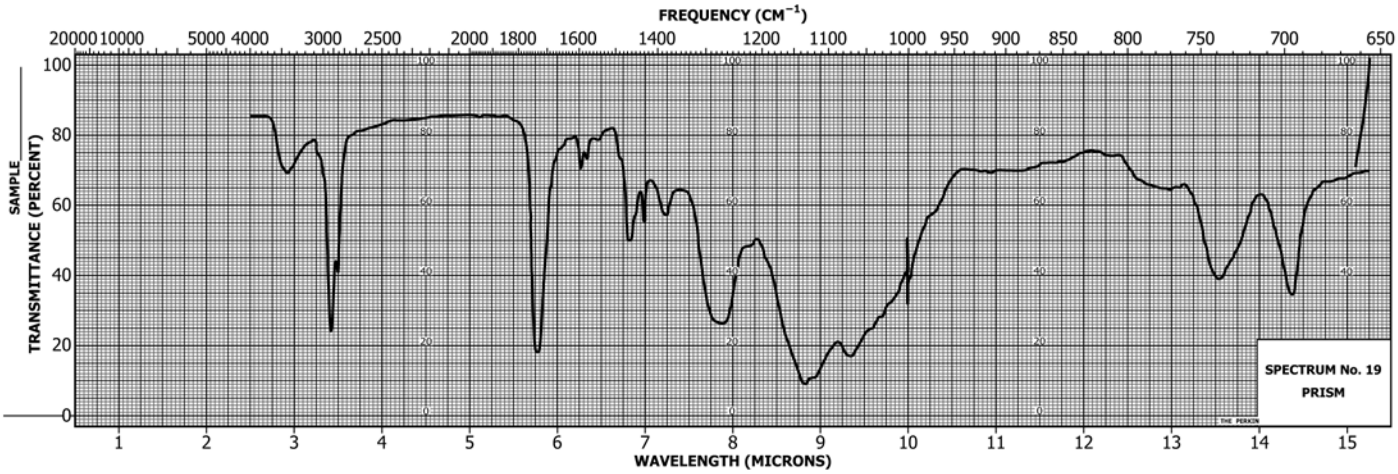
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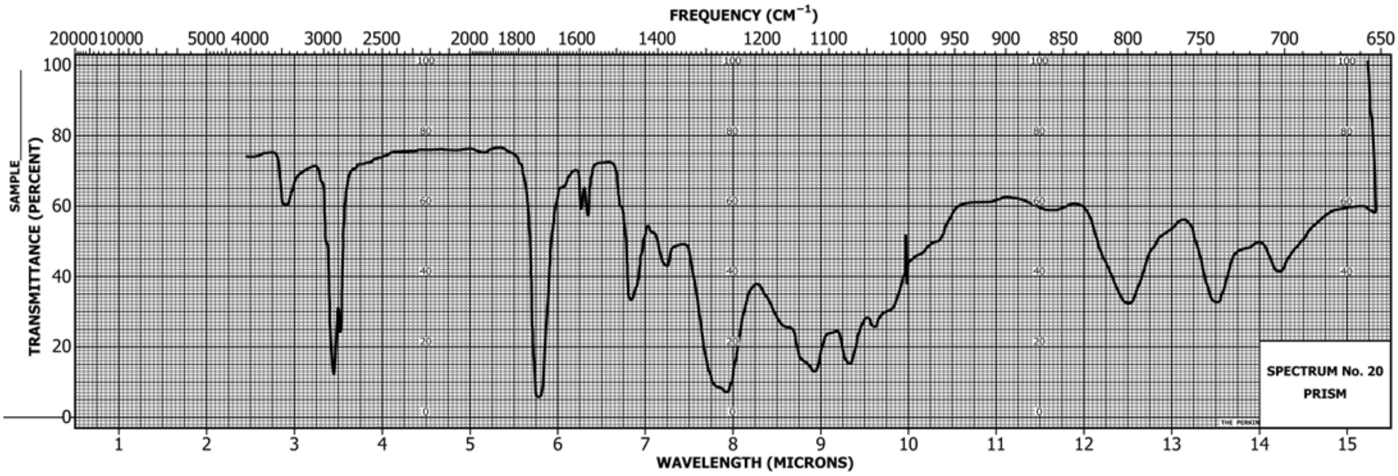
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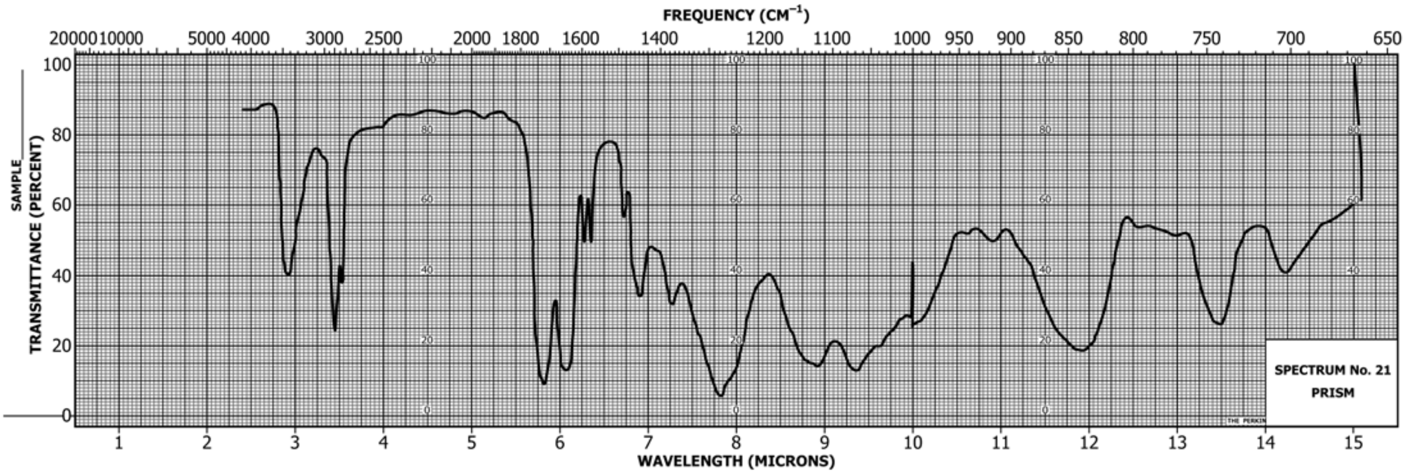
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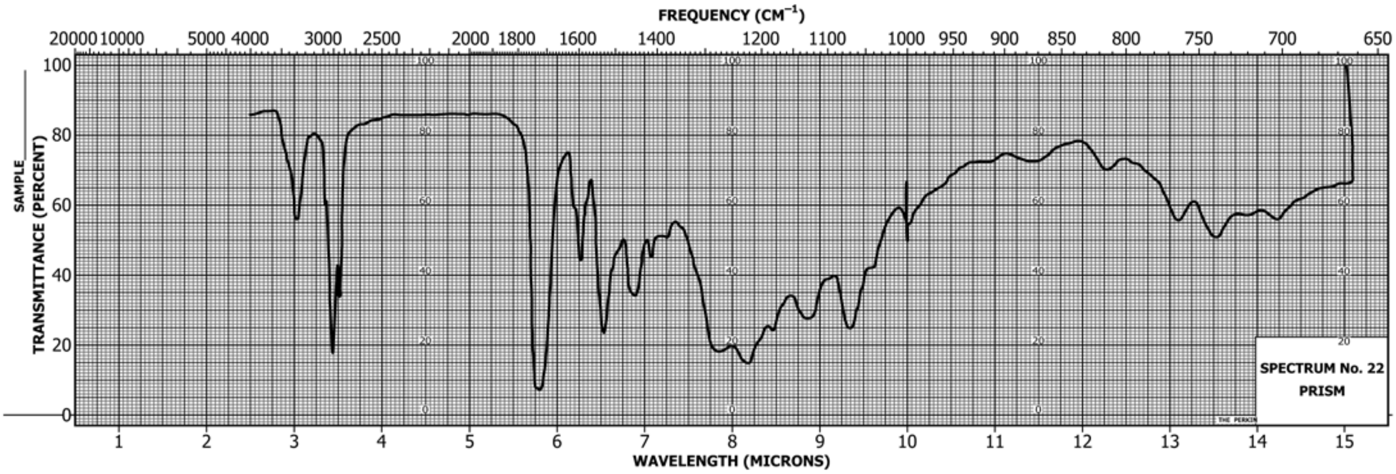

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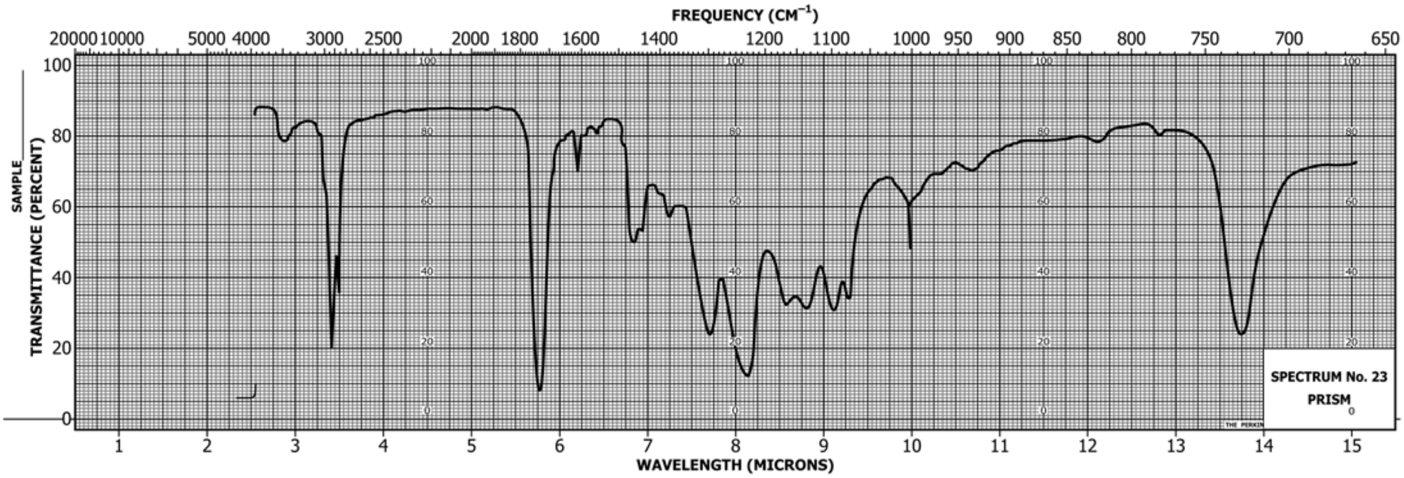

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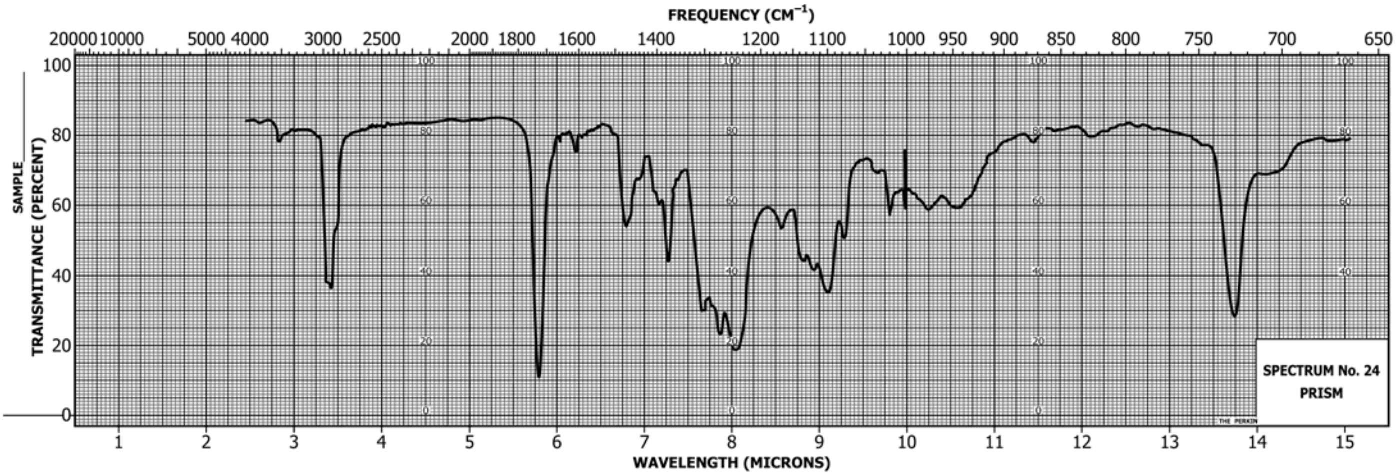

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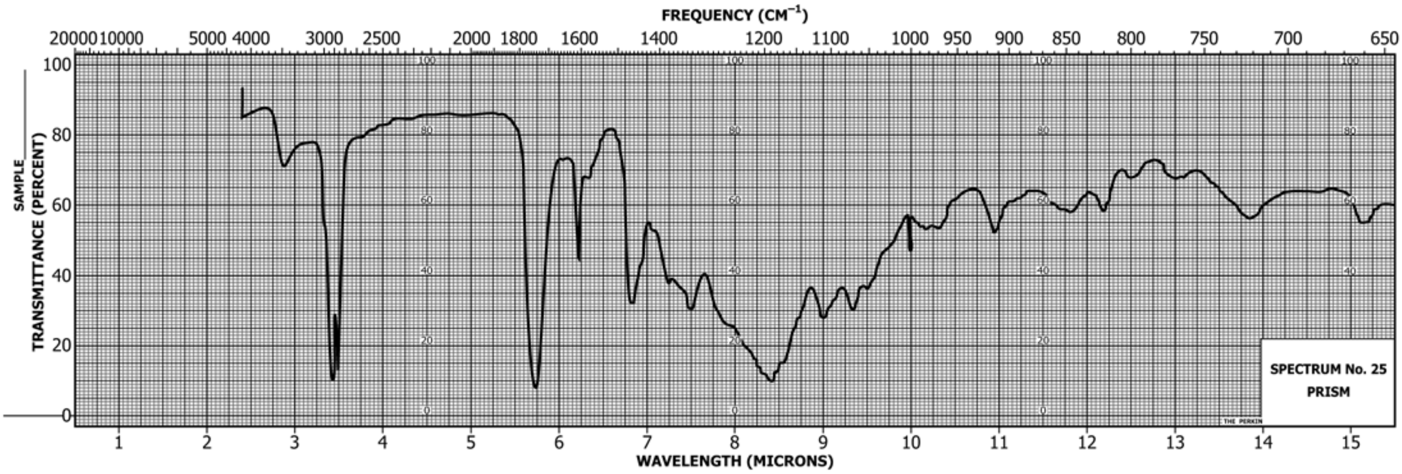


A2. CONSIDERATIONS IN THE INTERPRETATION OF INFRARED SPECTRA OF NONVOLATILE VEHICLES SEPARATED FROM SOLVENT-TYPE PAINTS

INTRODUCTION

The infrared spectra of vehicles recovered from whole paint are presented in Annex A1. The aim of this compilation is to aid those using this test method in the practical interpretation of the spectra they obtain.

The spectra are compiled with one representative spectrum of each vehicle presented in both a prism and a grating format. In the discussion of the spectra, the general assignment refers to the first spectrum. The subsequent spectra discussion will include only those bands which aid in the identification of the particular modifications being illustrated. In addition, some practical information is provided where it is believed to be helpful to the analyst. In general, previously noted band assignments are not repeated.

The data compiled here were obtained from spectra prepared on very carefully calibrated instruments. In comparing them to spectra prepared in any given laboratory, it is expected that the wavelength values of absorption bands may differ slightly depending upon the calibration of the instrument used.

GROUP I-ALKYDS

A2.1 Spectrum 1: Ortho-Phthalic Alkyd, Medium Oil Length

A2.1.1 *2.9-µm Region (3448 cm^{-1})*—The 2.9-µm band in alkyds is due to the O—H stretching vibration. This is usually attributed to the unesterified hydroxyl OH on the polyhydric alcohol used in manufacturing the alkyd. This absorption is known to increase on drying of unsaturated oil modified alkyds due to oxidation of the double bonds. This absorption band can be used to determine the hydroxyl number of alkyds.

A2.1.2 *3.3 to 3.6-µm Region (3030 to 2778 cm^{-1})*—The bands in this area are all due to aromatic and aliphatic C–H stretching vibrations.

A2.1.3 *5 to 6-µm Region (2000 to 1667 cm^{-1})*—The 5.8-µm band in alkyds is due to the combined C=O stretch of the phthalate and fatty acid esters. Unreacted phthalic anhydride, if present, may be detected by the appearance of a sharp absorption band at approximately 5.6 µm (1786 cm^{-1}). Free carboxyl groups (due to unreacted fatty acid or incompletely reacted phthalic acid) may often be detected by the appearance of a shoulder on the high wavelength (low frequency) side of the ester carbonyl band.

A2.1.4 *6.2 to 6.4-µm Region (1613 to 1563 cm^{-1})*—The doublet appearing in this region of the spectrum is due to vibrations associated with the double bonds in an aromatic ring. The band shape and position of this doublet is characteristic of non-oil modified, *o*-phthalic alkyds.

A2.1.5 *6.8 to 6.9-µm Region (1470 to 1449 cm^{-1})*—This absorption is produced by C–H bending vibrations of methylene (scissoring deformation) and methyl (asymmetrical deformation) groups in the alkyd. The intensity of this absorption band will vary with oil length.

A2.1.6 *7.2 to 7.3-µm Region (1389 to 1370 cm^{-1})*—This absorption band is due to the C—CH$_3$ symmetrical deformation vibration, and is produced by the methyl groups on the fatty acid chains.

A2.1.7 *7.5 to 10.0-µm Region (1333 to 1000 cm^{-1})*—The absorption bands in this region are due to the C—O—C stretching vibrations of the phthalate ester. These absorptions are most strongly influenced by the acid portion of the ester rather than the alcoholic portion.

A2.1.8 *13.5 and 14.2-µm Regions (741 and 704 cm^{-1})*—These two bands are due to out-of-plane bending vibrations of ring hydrogens of aromatic compounds having four adjacent hydrogens (orthodisubstitution).

A2.1.9 *Comments:*

A2.1.9.1 Note that in oil-modified alkyds, the intensity of the absorption at 8.6 µm (1163 cm^{-1}) is indicative of the amount of oil modification or oil length of the alkyd. In unmodified alkyds, this band may be little more than a side shoulder on the 8.9-µm (1124-cm^{-1}) C—O—C absorption. The correlation to oil length is only a very general one in that within a given group of alkyds one may say a sample is a "short," "medium," or "long" oil type.

A2.1.9.2 Alkyd spectra generally reveal little or no information concerning the type of combined oil or polyol present.

A2.1.9.3 Identification of polyol and unsaponifiables may usually be accomplished by infrared examination of saponification fractions. Identification of the oil acids used usually requires gas chromatographic analysis of the methylated fatty acids recovered by saponification. (For saponification procedures see Guide D1467 and Test Method D1962.)

A2.2 Spectrum 2: Ortho-Phthalic Alkyd, Long Oil Length

A2.2.1 8.6 µm (1163 cm^{-1}); fatty acid ester C—O—C

A2.2.2 *Comments*—Note the difference in the 8.6-µm (1163-cm^{-1}) peak compared to Spectrum 1, due to increased oil length.

A2.3 Spectrum 3: Ortho-Phthalic Alkyd, Tung Oil Modified

A2.3.1 10.12 µm (988 cm^{-1}); –C=C–C=C–C=C– Conjugated triene unsaturation

A2.3.2 *Comments*—Note the difference in band shapes in the 10 to 10.4-µm region (1000 to 962 cm^{-1}) compared to Spectra 1 and 2. Absorption due to conjugated unsaturation (in such oil types as tung, oiticica, dehydrated castor, and conjugated safflower) occurs here. Oil types used for alkyds 1 and 2 contain only isolated double bonds.

A2.4 Spectrum 4: Ortho-Isophthalic Alkyd

A2.4.1 7.8 µm (1282 cm^{-1}) isophthalate ester C—O—C

A2.4.2 8.2 µm (1220 cm^{-1}) isophthalate ester C—O—C

A2.4.3 8.9 µm (1124 cm^{-1}) isophthalate ester C—O—C

A2.4.4 13.7 µm (730 cm^{-1}) meta-disubstituted benzene ring

A2.4.5 *Comments*—The spectrum of this alkyd is typical of an isophthalic alkyd. The major band that identifies this as an isophthalate is the 13.7-µm (730-cm^{-1}) band. The presence of orthophthalic alkyd can be suspected by comparison to a straight isophthalic alkyd spectrum (see following) and noting the influence of the ortho-phthalate at 7.9 µm (1266 cm^{-1}), 9.0 µm (1111 cm^{-1}), 9.4 µm (1064 cm^{-1}), and at 14.2 µm (704 cm^{-1}).

A2.5 Spectrum 5: Ortho-Phthalic Alkyd, Benzoic Acid Modified

A2.5.1 14.0 to 14.1 µm (714 to 709 cm^{-1}); aromatic ring vibration where ring contains five adjacent hydrogens. Position is characteristic of benzoate esters.

A2.5.2 *Comments*—The band at approximately 14.0 µm (714 cm^{-1}) is the identifying peak for this modification. Because of the *o*-disubstitution peak at 14.3µ m (699 cm^{-1}) present in *o*-phthalates, it is difficult to observe this band when the benzoic acid modification drops below 3 %.

A2.6 Spectrum 6: Ortho-Phthalic Alkyd, Para-Tertiary Butyl Benzoic Acid Modified

A2.6.1 8.4 µm (1190 cm^{-1}) C—O—C *p*-tert. butyl benzoate

A2.6.2 9.6 µm (1042 cm^{-1}) C—O—C *p*-tert. butyl benzoate

A2.6.3 9.8 µm (1020 cm^{-1}) C—O—C *p*-tert. butyl benzoate

A2.6.4 11.7 µm (855 cm^{-1}) aromatic ring substitution patterns

A2.6.5 12.9 µm (775 cm^{-1}) aromatic ring substitution patterns

A2.6.6 *Comments*—The characteristic bands for the identification of the paratertiary butyl benzoic acid modification are the 11.7-µm (855-cm^{-1}) and the 12.9-µm (775-cm^{-1}) bands. The other absorption bands, although sharp and distinctive, can tend to be lost in the background of the spectrum when the modification drops below 2 to 3 %

A2.7 Spectrum 7: Ortho-Phthalic Alkyd, Tall Oil, Rosin Modified

A2.7.1 12.3 µm (813 cm^{-1}) abietic acid ring vibration

A2.7.2 *Comments*—The curve shows only a very slight depression at 12.3 µm (183 cm^{-1}). In general, the band is never very intense and, if suspected, the presence of rosin is readily confirmed by a Lieberman-Storch spot test. Note also the obscured nature of the 6.3 to 6.5-µm (1587 to 1538-cm^{-1}) region. This is most likely due to the salt or "soap" formation with the acids present in the system and the pigment used.

A2.8 Spectrum 8: Ortho-Phthalic Alkyd, *p*-Phenyl Phenol Modified

A2.8.1 11.4 µm (877 cm^{-1}) associated with substituted aromatic rings

A2.8.2 12.1 µm (826 cm^{-1}) associated with substituted aromatic rings

A2.8.3 13.1 µm (763 cm^{-1}) associated with substituted aromatic rings

A2.8.4 14.4 µm (694 cm^{-1}) associated with substituted aromatic rings

A2.8.5 *Comments*—The main identifying band is the 13.1-µm (763-cm^{-1}) band. The other bands are less distinctive, especially the 14.4-µm (694-cm^{-1}) area. It is always best to consider the positions of the 3 or 4 absorptions in the far end of the curve as a group in assigning the modifying structure.

A2.9 Spectrum 9: Ortho-Phthalic Alkyd, Styrene Modified

A2.9.1 6.7 µm (1493 cm^{-1}) aromatic ring vibration

A2.9.2 13.2 µm (758 cm^{-1}) monosubstituted aromatic (5 adjacent ring hydrogens)

A2.9.3 14.3 µm (699 cm^{-1}) monosubstituted aromatic (5 adjacent ring hydrogens)

A2.9.4 *Comments*—The very general forebroadening in the 13 to 13.3-µm (769 to 758-cm $^{-1}$) area of the ortho substitution band is characteristic of styrene modification. The 14.3-µm (699-cm^{-1}) absorption that obscures the normally present small 14.3-µm (699-cm $^{-1}$) band is the primary styrene absorption. Note also the sharp 6.7-µm (1493-cm^{-1}) peak which is associated with the presence of an aromatic.

A2.10 Spectrum 10: Ortho-Phthalic Alkyd, Vinyl Toluene Modified

A2.10.1 6.6 µm (1515 cm^{-1}) aromatic ring vibrations

A2.10.2 6.7 µm (1492 cm^{-1}) aromatic ring vibrations

A2.10.3 11.4 µm (877 cm^{-1}) meta-disubstituted aromatic

A2.10.4 12.3 µm (813 cm^{-1}) para-disubstituted aromatic

A2.10.5 12.8 µm (781 cm^{-1}) meta-disubstituted aromatic

A2.10.6 14.2 µm (704 cm^{-1}) meta-disubstituted aromatic

A2.10.7 *Comments*—The general pattern of peaks at the end of the spectrum is characteristic for vinyl-toluene modification. They arise from the meta-para mixed isomers.

A2.11 Spectrum 11: Ortho-Phthalic Alkyd, Acrylonitrile Modified

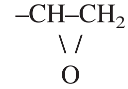
A2.11.1 4.5 µm (2222 cm^{-1}) C≡N nitrile stretching vibration

A2.11.2 *Comment*—The 4.5-µm (2222-cm^{-1}) band is the outstanding feature characteristic of an acrylonitrile modification.

A2.12 Spectrum 12: Ortho-Phthalic Alkyd, Bis-Phenol Epoxy Modified

A2.12.1 8.4 µm (1190 cm^{-1}) aromatic C—O—C

A2.12.2 10.9 µm (917 cm^{-1}) terminal epoxy grouping



$$\begin{array}{c} -CH-CH_2 \\ \backslash\ / \\ O \end{array}$$

A2.12.3 12.1 µm (826 cm^{-1}) para-disubstituted aromatic.

A2.12.4 *Comments*—The band at 10.9 µm (917 cm^{-1}) is due to the weakly absorbing terminal epoxy group. The 12.1-µm (826-cm^{-1}) absorption is due to the bis-phenol backbone of the epoxy polymer. The band at 8.4 µm (1190 cm^{-1}) is also always present in conjunction with the 12.1-µm (826-cm^{-1}) band.

A2.13 Spectrum 13: Ortho-Phthalic Alkyd, Urea-Formaldehyde Modified

A2.13.1 3.1 µm (3226 cm^{-1}) N—H stretching vibration.

A2.13.2 6.1 µm (1639 cm^{-1}) amide linkage band

A2.13.3 6.6 µm (1515 cm^{-1}) amide linkage band

A2.13.4 9.3 µm (1075 cm^{-1}) —C—O—C ether

A2.13.5 13.0 µm (769 cm^{-1}) unknown (but present in all urea-formaldehyde resins).

A2.13.6 *Comments*—The presence of urea-formaldehyde in an *o*-phthalic alkyd can always be observed in the spectrum by its influence at the wavelengths listed above. The general curve shape is somewhat depressed throughout. The 3.1-µm (3226-cm^{-1}) absorption appears as a shoulder on the O–H stretch at 3.0 µm (3333 cm^{-1}).

A2.14 Spectrum 14: Ortho-Phthalic Alkyd, Melamine-Formaldehyde Modified

A2.14.1 6.5 µm (1538 cm^{-1}) C=N

A2.14.2 12.3 µm (813 cm^{-1}) triazine ring vibration

A2.14.3 *Comments*—A melamine modification is always distinguishable from the urea-formaldehyde modification in that it lacks the 6.1-µm (1639-cm^{-1}) absorption and contains the 12.3-µm (813-cm^{-1}) triazine ring vibration.

A2.15 Spectrum 15: Ortho-Phthalic Alkyd, Benzoguanamine-Formaldehyde Modification

A2.15.1 6.3 µm (1587 cm^{-1}) aromatic ring vibration

A2.15.2 6.5 µm (1538 cm^{-1}) C=N

A2.15.3 12.1 µm (826 cm^{-1}) characteristic band for benzoguanamine derived modification

A2.15.4 12.8 µm (781 cm^{-1}) characteristic band for benzoguanamine derived modification

A2.15.5 14.2 µm (704 cm^{-1}) characteristic band for benzoguanamine derived modification

A2.15.6 *Comments*—The C=N band occurs at a slightly lower wavelength than in the melamine resins. The band at 12.1 µm (826 cm^{-1}) rather than at 12.3 µm (813 cm^{-1}) also helps to distinguish between the two types of triazine based resins.

A2.16 Spectrum 16: Ortho-Phthalic Alkyd, Hexa-Methoxymethylmelamine Modified

A2.16.1 9.3 µm (1075 cm^{-1}) C–O–C ether

A2.16.2 *Comments*—The presence of hexamethoxymethylmelamine can be observed in the spectrum of an ortho-phthalic-alkyd by its influence at 6.5 µm (1538 cm^{-1}); 6.7 µm (1493 cm^{-1}); 9.3 µm (1075 cm^{-1}); 9.9 µm (1010 cm^{-1}); 10.9 µm (917 cm^{-1}); 11.5 µm (870 cm^{-1}); and 12.3 µ m (813 cm^{-1}).

A2.17 Spectrum 17: Ortho-Phthalic Alkyd, Rosin-Maleic Adduct Modified

A2.17.1 5.4 µm (1852 cm^{-1}) —C=O stretching vibrations associated with anhydrides

A2.17.2 5.6 µm (1786 cm^{-1})—C=O stretching vibrations associated with anhydrides

A2.17.3 *Comments*—The most characteristic absorptions are the ones listed above which cause multiple bands in the carbonyl area. The presence of the rosin-maleic adduct can also be seen at 10.6 µm (943 cm^{-1}); 10.9 µm (917 cm^{-1}); 11.7 µm (855 cm^{-1}); and 12.2 µm (820 cm^{-1}). These bands are generally found in all rosin-maleic adducts even if slightly changed in intensities.

A2.18 Spectrum 18: Ortho-Phthalic Alkyd, Vinyl Chloride-Acetate Modified

A2.18.1 7.0 µm (1428 cm^{-1})—CH_2—

A2.18.2 8.0 µm (1250 cm^{-1})—CH in—CHC—

A2.18.3 14.5 µm (690 cm^{-1}) C—Cl

A2.18.4 *Comments*—The most characteristic features of this spectrum are the 8 to 8.1-µm (1250 to 1234-cm^{-1}) absorption and the very broad band peaking at approximately 14.5 µm (690 cm^{-1}). A general depression of the entire curve is noted between 7.0 µm (1428 cm^{-1}) and 10.0 µm (1000 cm^{-1}).

A2.19 Spectrum 19: Ortho-Phthalic Alkyd, Phenyl Siloxane Modified

A2.19.1 7.0 µm (1429 cm^{-1}) aromatic silicon bond

A2.19.2 8.8 µm (1136 cm^{-1}) Si—O—Si

A2.19.3 10.0 µm (1000 cm^{-1}) aromatic silicon bond

A2.19.4 14.4 µm (694 cm^{-1}) mono-substituted aromatic

A2.19.5 *Comments*—The general influence of the presence of silicone is seen in the depressed area from 8.8 µm (1136 cm^{-1}) to 10.0 µm (1000 cm^{-1}).

A2.20 Spectrum 20: Ortho-Phthalic Alkyd, Methyl Siloxane Modified

A2.20.1 7.9 µm (1266 cm^{-1}) —Si—CH_3

A2.20.2 12.5 µm (800 cm^{-1}) —$(CH_3)_2$—Si

A2.21 Spectrum 21: Ortho-Phthalic Alkyd, Nitrocellulose Modified

A2.21.1 6.1 µm (1639 cm^{-1}) R—O—NO_2 stretching vibration

A2.21.2 7.8 µm (1282 cm^{-1}) R—O—NO_2 stretching vibration

A2.21.3 9.5 µm (1053 cm^{-1}) general C—O—C ether from the cellulose ring

A2.21.4 11.9 µm (840 cm^{-1}) low-frequency vibrations associated with R—O—NO_2

A2.21.5 *Comments*—The most prominent absorptions are the 6.1-µm (1639-cm^{-1}) band and the very broad 11.9-µm (840-cm^{-1}) peak. An additional reliable feature of nitrocellulose is the ether linkage which causes a general depression in the mid-section of the spectrum.

A2.22 Spectrum 22: Ortho-Phthalic Alkyd, Urethane Modified

A2.22.1 5.8 µm (1724 cm^{-1}) R—NH—CO—OR amide I band

A2.22.2 6.3 µm (1587 cm^{-1}) aromatic vibration (in aromatic di-isocyanate systems)

A2.22.3 6.5 µm (1538 cm^{-1}) amide II band, C—N

A2.22.4 12.3 µm (813 cm^{-1}) 1,2,4 tri-substitution (in systems with toluene di-isocyanate)

A2.23 Spectrum 23: Isophthalic Alkyd, Medium Oil Length

A2.23.1 6.2 µm (1613 cm^{-1}) ring unsaturation

A2.23.2 13.8 µm (725 cm^{-1}) meta-disubstitution band

A2.23.3 *Comments*—Note the change from a doublet in the 6.2-µm (1613-cm^{-1}) region to the singlet. The 13.8-µm (725-cm^{-1}) band is characteristic for isophthalic alkyds.

A2.24 Spectrum 24: Tere-Phthalic Alkyd, Medium Oil Length

A2.24.1 8.6 µm (1163 cm^{-1}) C—O—C

A2.24.2 9.8 µm (1020 cm^{-1}) C—O—C

A2.24.3 *Comments*—The tere-phthalate spectrum is identified mainly by the 8.6-µm (1163 cm^{-1}) and 9.8-µm (1020 cm^{-1}) peaks combination in conjunction with a 13.8-µm (725 cm^{-1}) peak position.

A2.25 Spectrum 25: Ortho-Phthalic Alkyd, Chlorendic Acid Modified

A2.25.1 *Comments*—The overall appearance of the absorption band pattern in this spectrum is characteristic of this modification.

A3. SOURCES OF INFRARED SPECTRA OF KNOWN MATERIALS

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