

1,3-Dimethyl-imidazolium dimethyl phosphate ([MMIM]⁺[DMP]⁻) analyzed by XPS and HAXPES ^{EP}

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 Xenia Knigge and  Jörg Radnik

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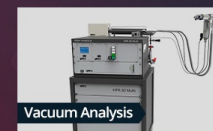
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1,3-Dimethyl-imidazolium dimethyl phosphate ([MMIM]⁺[DMP]⁻) analyzed by XPS and HAXPES



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Note: This paper is part of the 2023 Special Topic Collection on Higher Energy X-ray Photoelectron Spectroscopy.

ABSTRACT

The ionic liquid 1,3-dimethyl-imidazolium-dimethylphosphate ([MMIM]⁺[DMP]⁻) was analyzed using (hard) x-ray photoelectron spectroscopy. Here, XPS and HAXPES spectra are shown in comparison. For the acquisition of the XPS spectra, monochromatic Al K_{α} radiation at 1486.6 eV was used, while for the acquisition of the HAXPES spectra, monochromatic Cr K_{α} radiation at 5414.8 eV was applied. Here, survey scans and high-resolution spectra of P 2*p*, P 2*s*, C 1*s*, O 1*s*, and N 1*s* for both methods and P 1*s*, P $KL_{2,3}L_{2,3}$, and P $KL_1L_{2,3}$ for HAXPES are shown.

Key words: C₇H₁₅N₂O₄P, [MMIM]⁺[DMP]⁻, ionic liquid, hard x-ray photoelectron spectroscopy, HAXPES, Cr K_{α}

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Accession#: 01809, 01810, 01811, and 01812

Technique: XPS and XAES

Host Material: C₇H₁₅N₂O₄P ionic liquid

Instrument: ULVAC-PHI Quantes

Major Elements in Spectra: C, O, N, and P

Minor Elements in Spectra: None

Published Spectra: 21

Spectral Category: Comparison

INTRODUCTION

Ionic liquids (ILs) are organic salts that are liquid below temperatures of 100 °C. Due to their unique properties, they attract a lot of attention in different fields like catalysis (Ref. 1), electrochemistry (Ref. 2), solar cells (Ref. 3), pharmaceuticals, and medicine (Ref. 4).

Furthermore, they exhibit a high degree of lateral and depth homogeneity and have a well-defined stoichiometry, an extremely low vapor pressure, and high surface tension, which make them optimally suited as reference materials for the XPS analysis (Ref. 5).

Recently, spectra of the ionic liquid [PMIM]⁺[NTf₂]⁻ were published (Refs. 6 and 7) showing the suitability as reference of this material. In this work, the ionic liquid 1,3-dimethyl-imidazolium dimethyl phosphate ([MMIM]⁺[DMP]⁻) was analyzed, which is a vacuum ionic liquid with high thermal and hydrolytic stabilities (Ref. 8) consisting of C, O, N, and P. A lab-based ULVAC-PHI Quantes system equipped with a monochromatic Al K_{α}

(at 1486.6 eV) and a Cr K_{α} x-ray source (at 5414.8 eV) was used for the measurements. This instrument allows a comparison of XPS and HAXPES data. The use of XPS detects photoemission from about 10 nm depths of the sample, while the detection depth of HAXPES is about three times as deep. This leads to a minimization of surface contamination effects. It is also possible to detect peaks at higher binding energy with HAXPES, here, e.g., the P 1*s* and the Auger peaks, due to the higher energy of the Cr K_{α} source compared to Al K_{α} .

Survey and high-resolution spectra are shown in this work. The spectra were obtained using monochromatic Al K_{α} and Cr K_{α} x-ray sources at 1486.6 and 5414.8 eV. High-resolution spectra of C 1*s*, O 1*s*, N 1*s*, P 2*p*, P 1*s*, P 2*s*, P $KL_{2,3}L_{2,3}$, and P $KL_1L_{2,3}$ are shown.

XPS and HAXPES results agree broadly. The element composition measured in this study is in close agreement with the expected stoichiometric ratio of [MMIM]⁺[DMP]⁻ with an average

relative deviation of 3.6%, indicating that the sample is homogeneous in the information depth of HAXPES (Refs. 9 and 10).

SPECIMEN DESCRIPTION (ACCESSION # 01809)

Host Material: C₇H₁₅N₂O₄P ionic liquid

CAS Registry #: 654058-04-5

Host Material Characteristics: Homogeneous; liquid; unknown crystallinity; unknown conductivity; organic compound; other

Chemical Name: 1,3-Dimethyl-imidazolium dimethyl phosphate ([MMIM]⁺[DMP]⁻)

Source: Merck KGaA, Darmstadt, Germany

Host Composition: C₇H₁₅N₂O₄P

Form: Ionic liquid

Structure: Ionic liquid

History and Significance: [MMIM]⁺[DMP]⁻ is commercially available from Merck.

As Received Condition: In a bottle

Analyzed Region: Same as the host material

Ex Situ Preparation/Mounting: In a sample holder, which was mounted on a platen using an insulating double-sided tape, a drop of approx. 5 μ l of the ionic liquid was filled in. This sample was stored in the intro chamber of the spectrometer at $\sim 10^{-5}$ Pa for 7 days to remove vapors before the measurement started.

In Situ Preparation: None

Charge Control: Low-energy electrons (1 eV, filament 1.1 A) and low-energy ions (10 eV, 5 mA emission)

Temp. During Analysis: 300 K

Pressure During Analysis: $<10^{-6}$ Pa

Pre-analysis Beam Exposure: 0 s

SPECIMEN DESCRIPTION (ACCESSION # 01810)

Host Material: Au

CAS Registry #: 7440-57-5

Host Material Characteristics: Homogeneous; solid; polycrystalline; conductor; metal; other

Chemical Name: Au

Source: Alfa Aesar

Host Composition: Au

Form: Solid foil

Structure: Face centered cubic

History and Significance: The calibration sample was mounted and provided by the manufacturer of the spectrometer (ULVAC PHI).

As Received Condition: Mounted foil

Analyzed Region: Same as the host material

Ex Situ Preparation/Mounting: The foil was mounted on a sample holder on a platen by the manufacturer. This platen did not leave the vacuum chamber of the spectrometer for several months.

In Situ Preparation: The Au foil was sputtered with 4 kV with an Argon ion gun over a 2×2 mm² area for 5 min before the measurement to remove surface contamination.

Charge Control: Low-energy electrons (1 eV, filament 1.1 A) and low-energy ions (10 eV, 5 mA emission)

Temp. During Analysis: 300 K

Pressure During Analysis: $<10^{-6}$ Pa

Pre-analysis Beam Exposure: 0 s

SPECIMEN DESCRIPTION (ACCESSION # 01811)

Host Material: Ag

CAS Registry #: 7440-22-4

Host Material Characteristics: Homogeneous; solid; polycrystalline; conductor; metal; other

Chemical Name: Ag

Source: Alfa Aesar

Host Composition: Ag

Form: Solid foil

Structure: Face centered cubic

History and Significance: The calibration sample was mounted and provided by the manufacturer of the spectrometer, ULVAC PHI.

As Received Condition: Mounted foil

Analyzed Region: Same as the host material

Ex Situ Preparation/Mounting: The foil was mounted on a sample holder on a platen by the manufacturer. This platen did not leave the vacuum chamber of the spectrometer for several months.

In Situ Preparation: The Ag foil was sputtered with 4 kV with an Argon ion gun over a 2×2 mm² area for 5 min before the measurement to remove surface contamination.

Charge Control: Low-energy electrons (1 eV, filament 1.1 A) and low-energy ions (10 eV, 5 mA emission)

Temp. During Analysis: 300 K

Pressure During Analysis: $<10^{-6}$ Pa

Pre-analysis Beam Exposure: 0 s

SPECIMEN DESCRIPTION (ACCESSION # 01812)

Host Material: Cu0

CAS Registry #: 7440-50-8

Host Material Characteristics: Homogeneous; solid; polycrystalline; conductor; metal; other

Chemical Name: Cu

Source: Alfa Aesar

Host Composition: Cu

Form: Solid foil

Structure: Face centered cubic

History and Significance: The calibration sample was mounted and provided by the manufacturer of the spectrometer, ULVAC PHI.

As Received Condition: Mounted foil

Analyzed Region: Same as the host material

Ex Situ Preparation/Mounting: The foil was mounted on a sample holder on a platen by the manufacturer. This platen did not leave the vacuum chamber of the spectrometer for several months.

In Situ Preparation: The Cu foil was sputtered with 4 kV with an Argon ion gun over a 2×2 mm² area for 5 min before the measurement to remove surface contamination.

Charge Control: Low-energy electrons (1 eV, filament 1.1 A) and low-energy ions (10 eV, 5 mA emission)

Temp. During Analysis: 300 K

Pressure During Analysis: $<10^{-6}$ Pa

Pre-analysis Beam Exposure: 0 s

INSTRUMENT DESCRIPTION

Manufacturer and Model: ULVAC-PHI Quantes

Analyzer Type: Spherical sector

Detector: Multichannel resistive plate

Number of Detector Elements: 32

INSTRUMENT PARAMETERS COMMON TO ALL SPECTRA

Spectrometer

Analyzer Mode: Constant pass energy

Throughput ($T = E^N$): The energy dependence can be modeled

using the following equation: $\frac{A}{E_p} = \left(\frac{a^2}{a^2 + R^2}\right)^b$, where a and b are constants, E_p is the pass energy, A is the peak area, and R is the retard ratio equal to E/E_p , where E is the kinetic energy. Three spectral regions are recorded on a sputter cleaned sample at different pass energies. The values of a and b are then determined by a linear least square fit of the data applying the equation described above.

Excitation Source Window: Al

Excitation Source: Al K_{α} and Cr K_{α} monochromatic

Source Energy: 1486.6 and 5414.8 eV

Source Strength: 24.0 and 51.4 W

Source Beam Size: $100 \times 100 \mu\text{m}^2$

Signal Mode: Multichannel direct

Geometry

Incident Angle: Al: 0° , Cr: 22°

Source-to-Analyzer Angle: Al: 45° , Cr: 49°

Emission Angle: 45°

Specimen Azimuthal Angle: 0°

Acceptance Angle from Analyzer Axis: 0°

Analyzer Angular Acceptance Width: $20^\circ \times 20^\circ$

Ion Gun

Manufacturer and Model: ULVAC-PHI Quantes

Energy: 10 eV

Current: 5 mA

Current Measurement Method: Biased stage

Sputtering Species: Ar

Spot Size (unrastered): $100 \mu\text{m}$

Raster Size: N/A

Incident Angle: 45°

Polar Angle: 45°

Azimuthal Angle: 45°

Comment: The E-Gun was used for charge neutralization.

DATA ANALYSIS METHOD

Energy Scale Correction: The energy scale shift was calculated by setting the C 1s binding energy to 284.80 eV. The XPS and

HAXPES high-resolution spectra of the C 1s peak give a position of 283.97 and 284.22 eV; therefore, the correction shift is 0.83 eV for XPS and 0.58 eV for HAXPES.

Recommended Energy Scale Shift: XPS: 0.83 eV; HAXPES: 0.58 eV for binding energy (photoelectron spectra) and -0.58 eV for kinetic energy (Auger electron spectra)

Peak Shape and Background Method: The inbuilt Gaussian-Lorentzian peak shapes routine of MultiPak and a Shirley background method were used.

Quantitation Method: For Quantification, the PHI MultiPak software version 9.9.2 was used applying a nonlinear least square routine (Ref. 11) with relative empirical sensitivity factors that were provided by the manufacturer.

ACKNOWLEDGMENTS

The authors thank B. P. Reed and A. G. Shard for discussion. This research is part of the project “NanoSolveIT,” which has received funding from European Union Horizon 2020 Programme (H2020) under Grant Agreement No. 814572.

AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

Author Contributions

X. Knigge: Formal analysis (equal); Writing – original draft (equal). **J. Radnik:** Formal analysis (equal); Writing – original draft (equal).

DATA AVAILABILITY

The data that support the findings of this study are available within the article and its [supplementary material](#).

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SPECTRAL FEATURES TABLE

Spectrum ID #	Element/Transition	Peak Energy (eV)	Peak Width FWHM (eV)	Peak Area (eV × cts/s)	Sensitivity Factor	Concentration (at. %)	Peak Assignment
01809-02	C 1s	284.80	1.47	7073	0.314	49.7	C ₇ H ₁₅ N ₂ O ₄ P
01809-03	O 1s	528.79	1.29	4381	0.733	29.3	C ₇ H ₁₅ N ₂ O ₄ P
01809-03	O 1s	531.03	1.29	4711	0.733	...	C ₇ H ₁₅ N ₂ O ₄ P
01809-04	N 1s	400.17	1.15	3144	0.499	14.0	C ₇ H ₁₅ N ₂ O ₄ P
01809-05	P 2p	131.76	1.41	1231	0.525	7.0	C ₇ H ₁₅ N ₂ O ₄ P
01809-06	P 2s	188.82	2.19	1299	0.380	...	C ₇ H ₁₅ N ₂ O ₄ P
01809-08	C 1s	284.80	1.47	148	0.199	48.6	C ₇ H ₁₅ N ₂ O ₄ P
01809-09	O 1s	528.75	1.45	139	0.589	28.8	C ₇ H ₁₅ N ₂ O ₄ P
01809-09	O 1s	530.98	1.45	148	0.589	...	C ₇ H ₁₅ N ₂ O ₄ P
01809-10	N 1s	400.15	1.36	85	0.331	15.4	C ₇ H ₁₅ N ₂ O ₄ P
01809-11	P 2p	131.15	1.34	20	0.156	...	C ₇ H ₁₅ N ₂ O ₄ P
01809-12	P 2s	188.67	2.15	55	0.450	...	C ₇ H ₁₅ N ₂ O ₄ P
01809-13	P 1s	2145.66	1.56	874	5.136	7.1	C ₇ H ₁₅ N ₂ O ₄ P
01809-14 ^a	P KL _{2,3} L _{2,3}	1852.05	1.41	345	C ₇ H ₁₅ N ₂ O ₄ P
01809-15 ^a	P KL ₁ L _{2,3}	1787.35	3.02	82	C ₇ H ₁₅ N ₂ O ₄ P

^aThe P KL_{2,3}L_{2,3} and the P KL₁L_{2,3} peak energies are listed as kinetic energy.

ANALYZER CALIBRATION TABLE

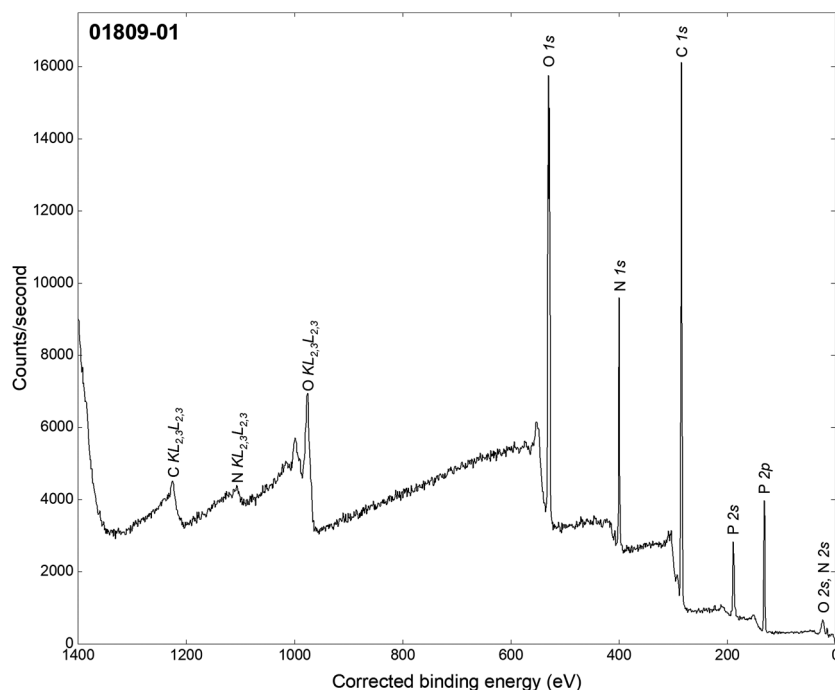
Spectrum ID #	Element/Transition	Peak Energy (eV)	Peak Width FWHM (eV)	Peak Area (eV × cts/s)	Sensitivity Factor	Concentration (at. %)	Peak Assignment
01810-01	Au 4f _{7/2}	84.1	2.17	392 520	3.849	...	XPS Au
01811-01	Ag 3d _{5/2}	368.4	1.70	470 847	3.742	...	XPS Ag
01812-01	Cu 2p _{3/2}	932.7	2.00	396 795	2.626	...	XPS Cu
01810-02	Au 4f _{7/2}	83.9	2.17	7 293	1.103	...	HAXPES Au
01811-02	Ag 3d _{5/2}	368.0	1.97	10 340	1.996	...	HAXPES Ag
01812-02	Cu 2p _{3/2}	932.5	2.15	24 495	3.829	...	HAXPES Cu

GUIDE TO FIGURES

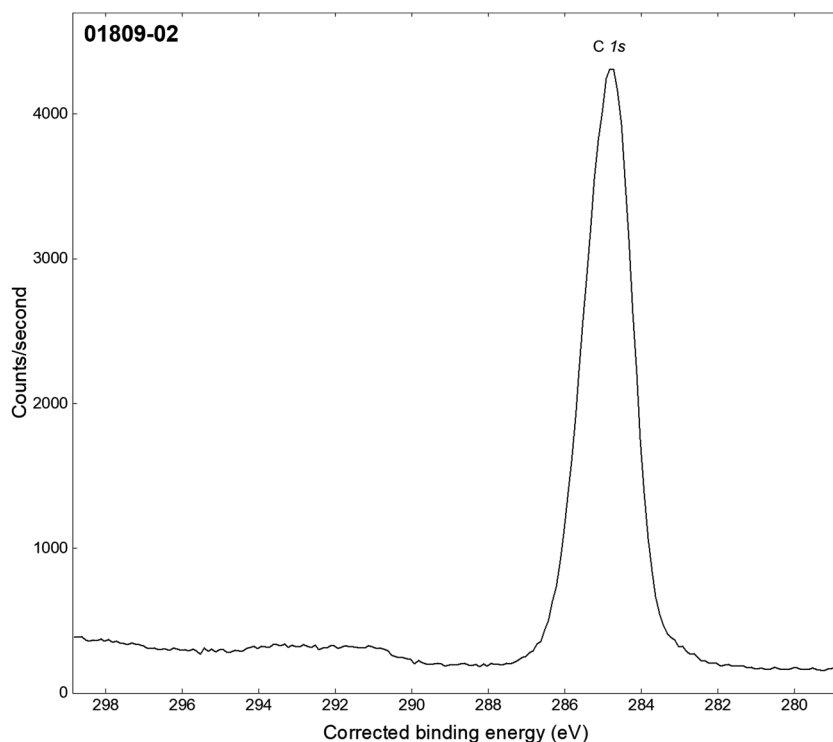
Spectrum (Accession) #	Spectral Region	Voltage Shift ^a	Multiplier	Baseline	Comment #
01809-01	Survey	−0.83	1	0	1
01809-02	C 1s	−0.83	1	0	1
01809-03	O 1s	−0.83	1	0	1
01809-04	N 1s	−0.83	1	0	1
01809-05	P 2p	−0.83	1	0	1
01809-06	P 2s	−0.83	1	0	1
01809-07	Survey	−0.58	1	0	2
01809-08	C 1s	−0.58	1	0	2
01809-09	O 1s	−0.58	1	0	2
01809-10	N 1s	−0.58	1	0	2
01809-11	P 2p	−0.58	1	0	2
01809-12	P 2s	−0.58	1	0	2
01809-13	P 1s	−0.58	1	0	2
01809-14	P $KL_{2,3}L_{2,3}$	+0.58	1	0	2
01809-15	P $KL_1L_{2,3}$	+0.58	1	0	2
01810-01	Survey (Au)	...	1	0	3
01811-01	Survey (Ag)	...	1	0	3
01812-01	Survey (Cu)	...	1	0	3
01810-02	Survey (Au)	...	1	0	4
01811-02	Survey (Ag)	...	1	0	4
01812-02	Survey (Cu)	...	1	0	4

^aVoltage shift of the archived (as-measured) spectrum relative to the printed figure. The figure reflects the recommended energy scale correction due to calibration correction, sample charging, flood gun, or other phenomenon.

1. C₇H₁₅N₂O₄C ionic liquid XPS
2. C₇H₁₅N₂O₄C ionic liquid HAXPES
3. Calibration XPS
4. Calibration HAXPES

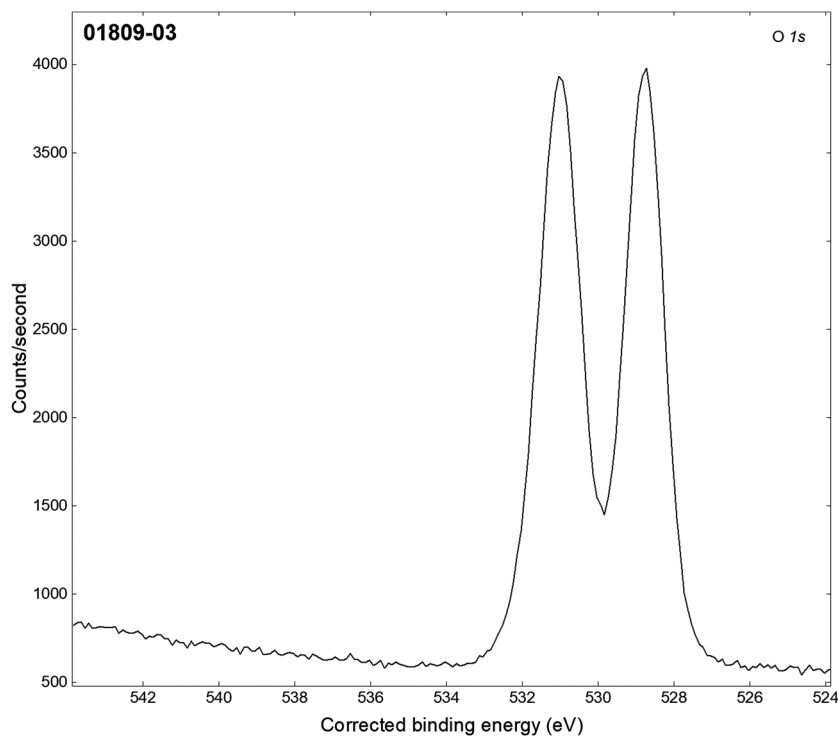


Accession #:	01809-01
Host Material:	C ₇ H ₁₅ N ₂ O ₄ P ionic liquid
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Al K _α monochromatic
Source Energy:	1486.6 eV
Source Strength:	24.0 W
Source Size:	0.1 × 0.1 mm ²
Analyzer Type:	Spherical sector analyzer
Incident Angle:	0°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	1434 s
Total Elapsed Time:	1572 s
Number of Scans:	3
Effective Detector Width:	31 eV



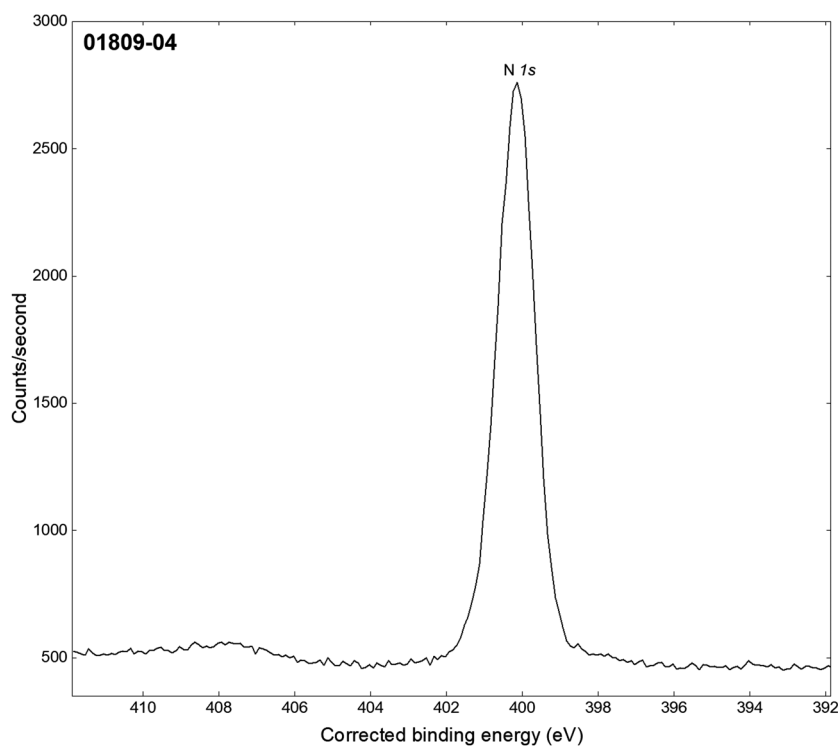
■ **Accession #:** 01809-02
 ■ **Host Material:** C₇H₁₅N₂O₄P ionic liquid
 ■ **Technique:** XPS
 ■ **Spectral Region:** C 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Al K_α monochromatic
 Source Energy: 1486.6 eV
 Source Strength: 24.0 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 0°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 1182 s
 Total Elapsed Time: 1302 s
 Number of Scans: 15
 Effective Detector Width: 6.2 eV



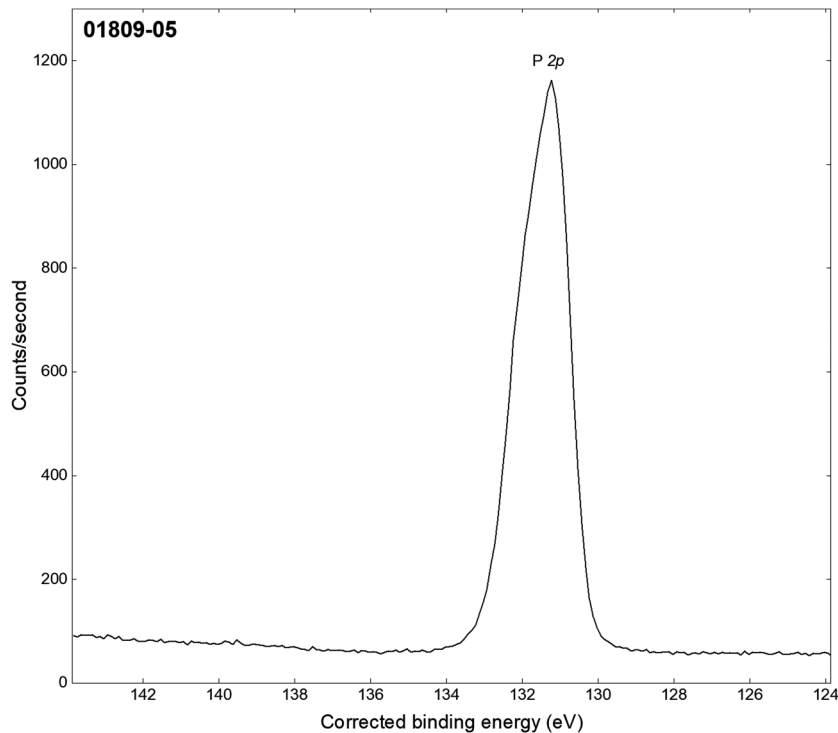
■ **Accession #:** 01809-03
 ■ **Host Material:** C₇H₁₅N₂O₄P ionic liquid
 ■ **Technique:** XPS
 ■ **Spectral Region:** O 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Al K_α monochromatic
 Source Energy: 1486.6 eV
 Source Strength: 24.0 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 0°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 1182 s
 Total Elapsed Time: 1302 s
 Number of Scans: 15
 Effective Detector Width: 6.2 eV



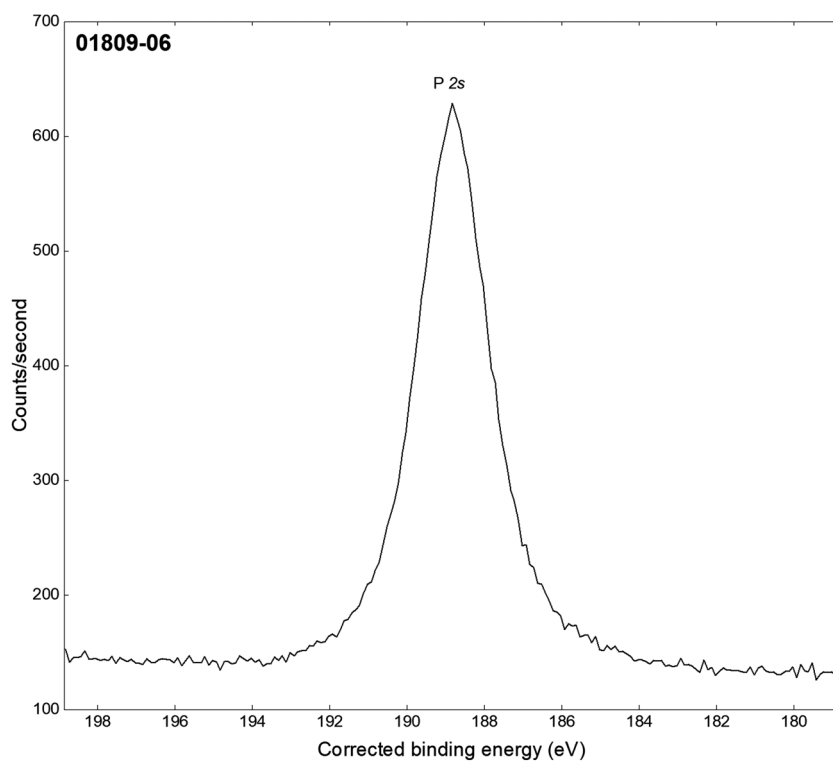
- Accession #: [01809-04](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: N 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Al K_α monochromatic
 Source Energy: 1486.6 eV
 Source Strength: 24.0 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 0°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 2358 s
 Total Elapsed Time: 2604 s
 Number of Scans: 30
 Effective Detector Width: 6.2 eV



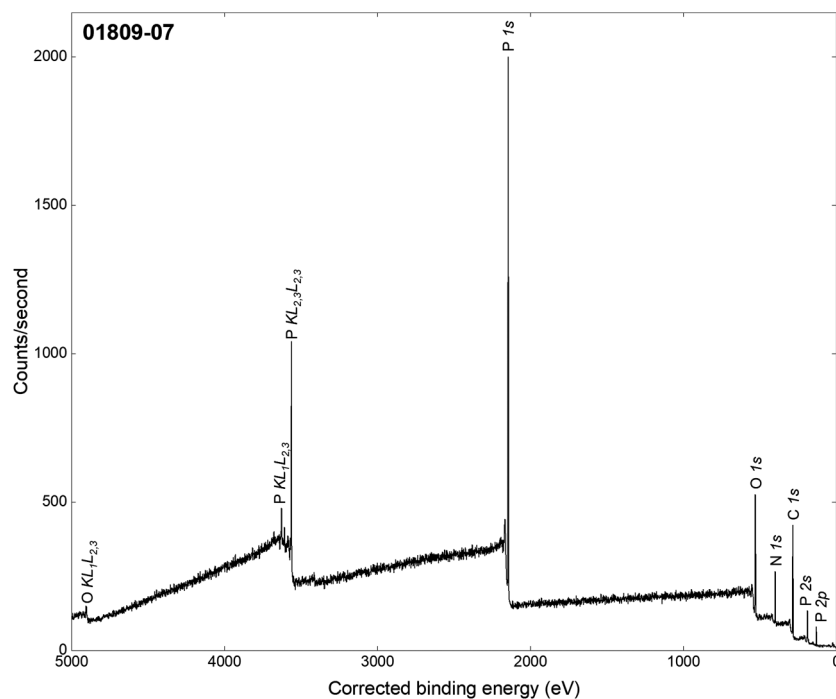
- Accession #: [01809-05](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: P 2p

Instrument: ULVAC-PHI Quantes
 Excitation Source: Al K_α monochromatic
 Source Energy: 1486.6 eV
 Source Strength: 24.0 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 0°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 4716 s
 Total Elapsed Time: 5208 s
 Number of Scans: 60
 Effective Detector Width: 6.2 eV



■ Accession #: [01809-06](#)
 ■ Host Material: C₇H₁₅N₂O₄P ionic liquid
 ■ Technique: XPS
 ■ Spectral Region: C 1s

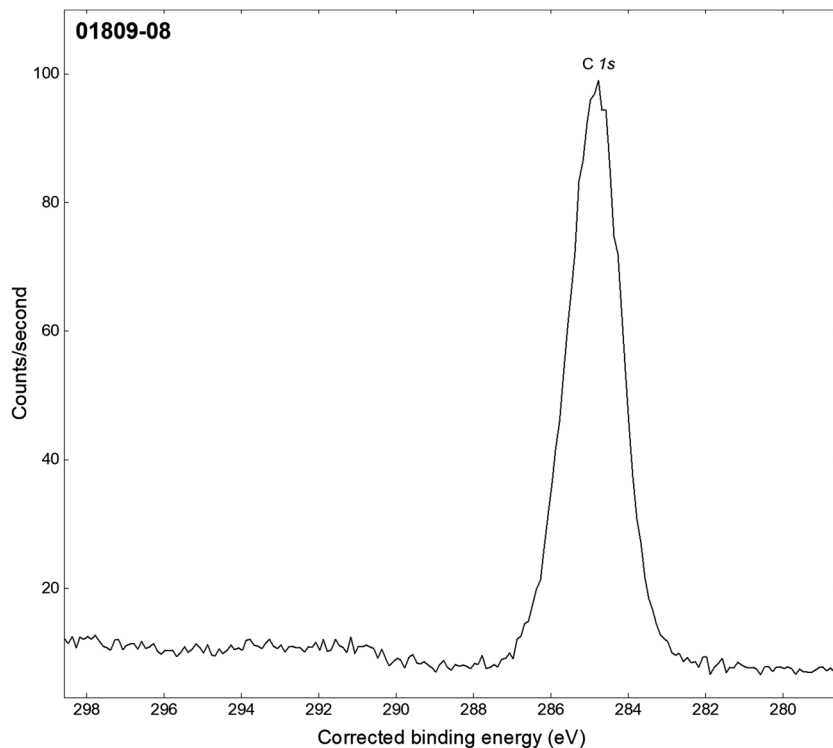
Instrument: ULVAC-PHI Quantes
 Excitation Source: Al K_α monochromatic
 Source Energy: 1486.6 eV
 Source Strength: 24.0 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 0°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 5898 s
 Total Elapsed Time: 6510 s
 Number of Scans: 75
 Effective Detector Width: 6.2 eV



Accession #:

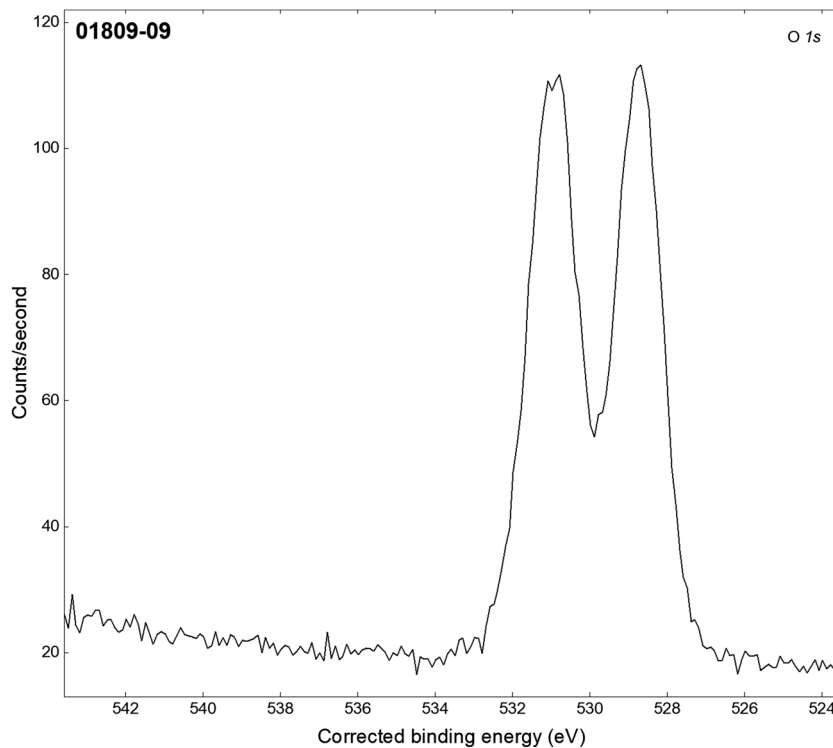
01809-07

Host Material:	C ₇ H ₁₅ N ₂ O ₄ P ionic liquid
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Cr K _α monochromatic
Source Energy:	5414.8 eV
Source Strength:	51.4 W
Source Size:	0.1 × 0.1 mm ²
Analyzer Type:	Spherical sector analyzer
Incident Angle:	22°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	25 158 s
Total Elapsed Time:	27 672 s
Number of Scans:	5
Effective Detector Width:	31 eV



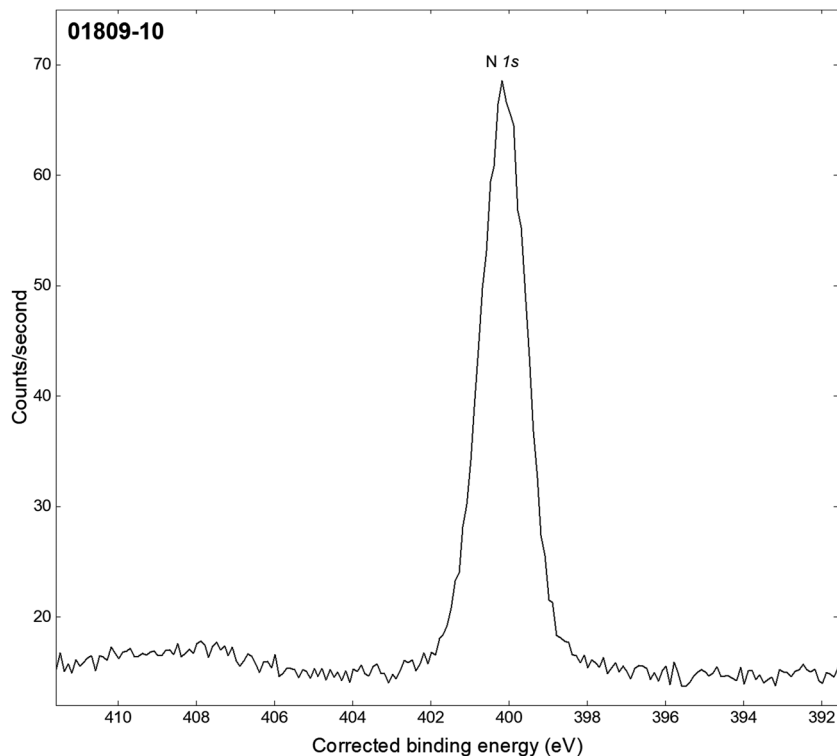
■ **Accession #:** 01809-08
 ■ **Host Material:** C₇H₁₅N₂O₄P ionic liquid
 ■ **Technique:** XPS
 ■ **Spectral Region:** C 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 7074 s
 Total Elapsed Time: 7806 s
 Number of Scans: 90
 Effective Detector Width: 6.2 eV



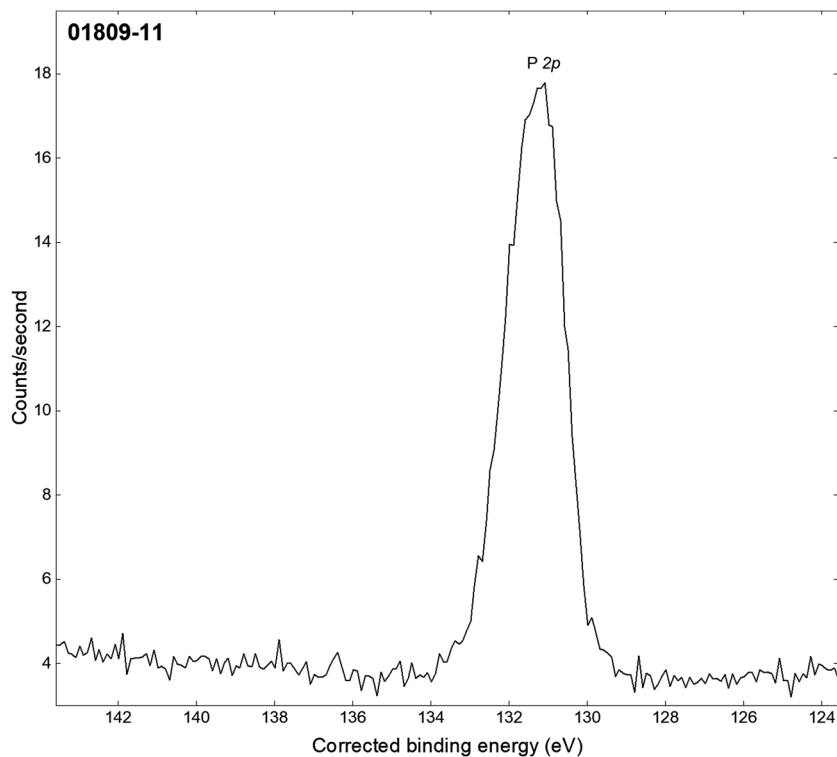
■ **Accession #:** 01809-09
 ■ **Host Material:** C₇H₁₅N₂O₄P ionic liquid
 ■ **Technique:** XPS
 ■ **Spectral Region:** O 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 7074 s
 Total Elapsed Time: 7806 s
 Number of Scans: 90
 Effective Detector Width: 6.2 eV



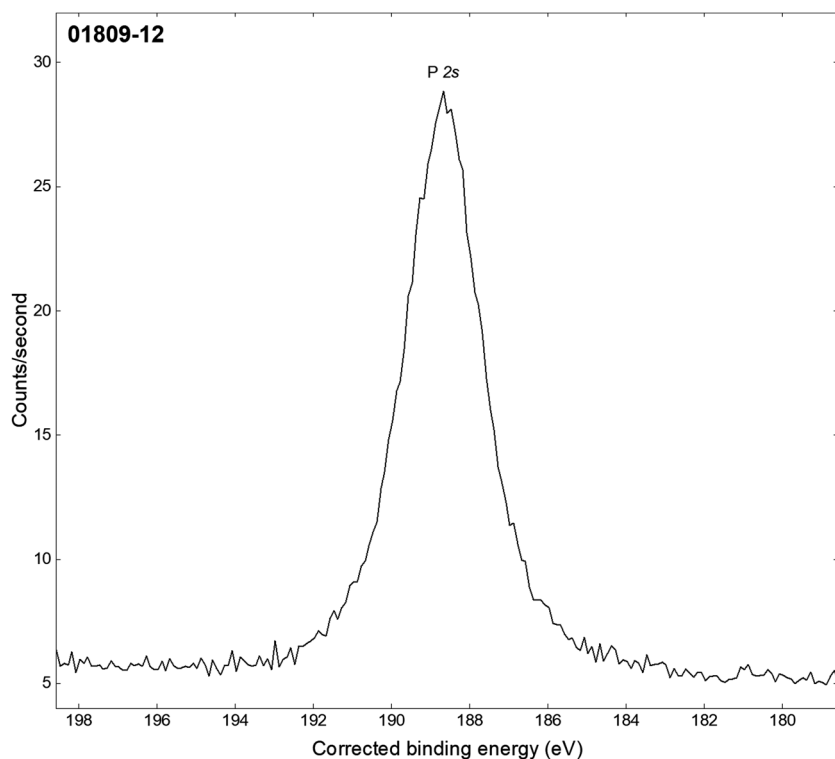
- Accession #: [01809-10](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: N 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 15 330 s
 Total Elapsed Time: 16 920 s
 Number of Scans: 195
 Effective Detector Width: 6.2 eV



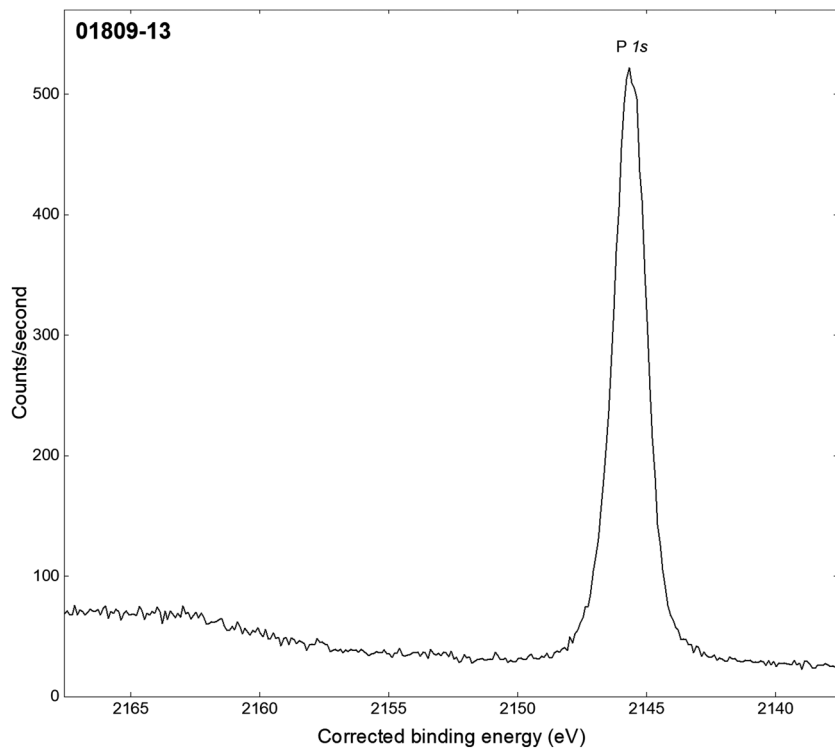
- Accession #: [01809-11](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: P 2p

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 35 370 s
 Total Elapsed Time: 39 042 s
 Number of Scans: 450
 Effective Detector Width: 6.2 eV



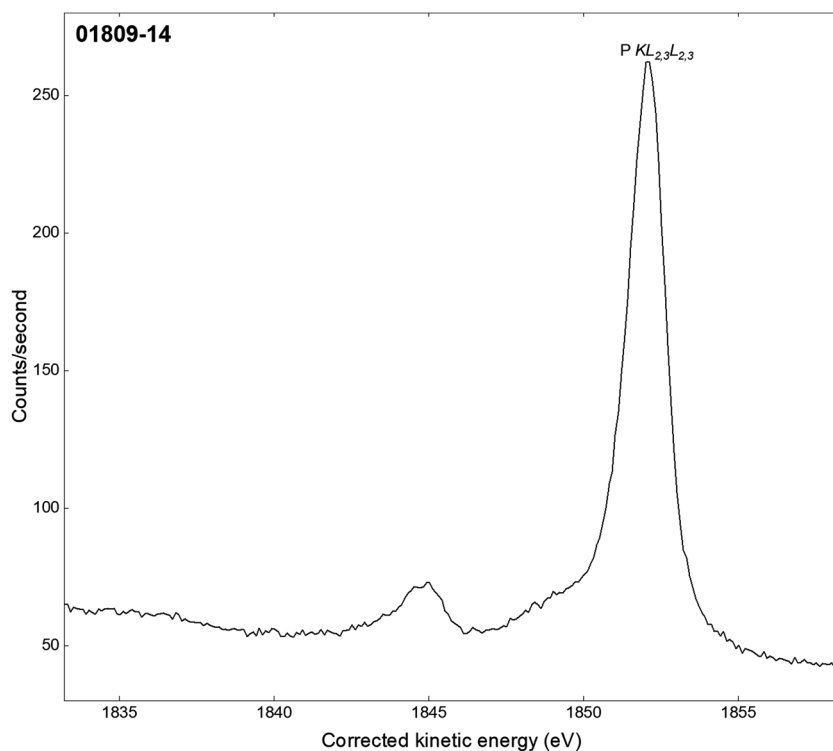
- Accession #: [01809-12](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: P 2s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 35 370 s
 Total Elapsed Time: 39 042 s
 Number of Scans: 450
 Effective Detector Width: 6.2 eV



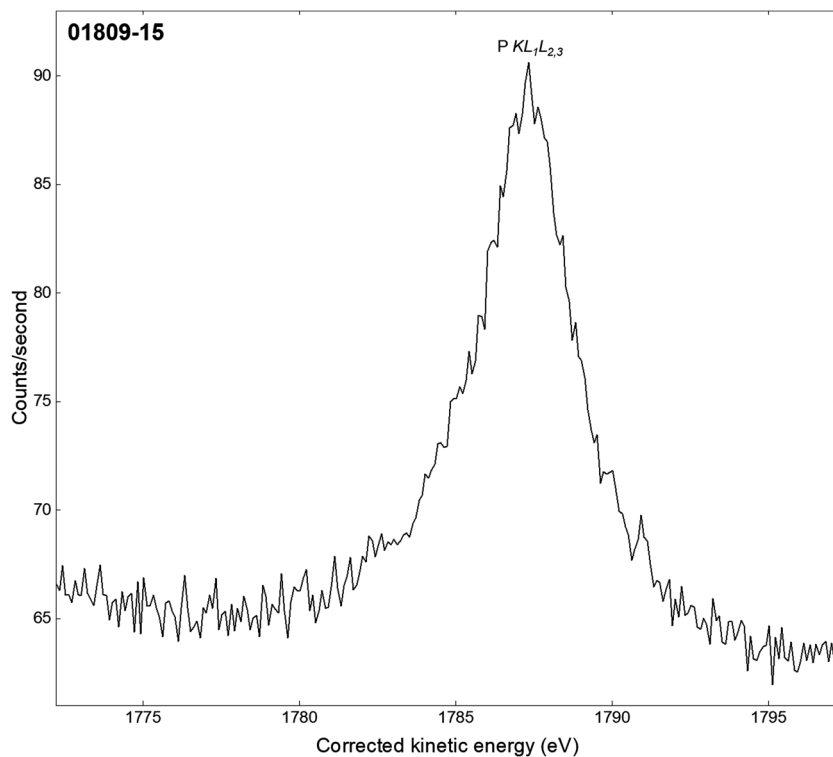
- Accession #: [01809-13](#)
- Host Material: C₇H₁₅N₂O₄P ionic liquid
- Technique: XPS
- Spectral Region: P 1s

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_α monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: 0.1 × 0.1 mm²
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 3258 s
 Total Elapsed Time: 3594 s
 Number of Scans: 30
 Effective Detector Width: 6.2 eV



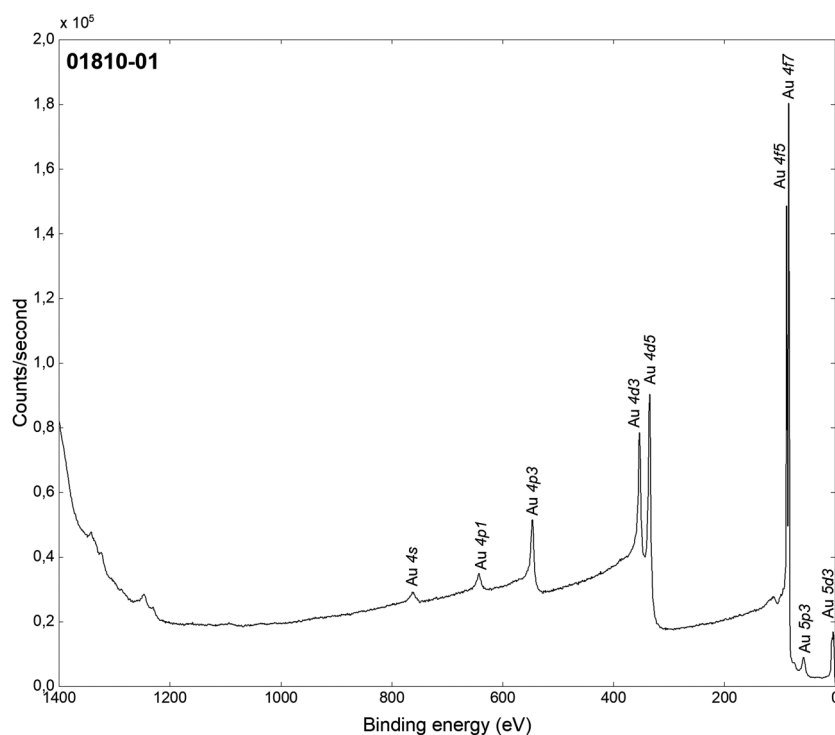
- Accession #: [01809-14](#)
- Host Material: $C_7H_{15}N_2O_4P$ ionic liquid
- Technique: XAES
- Spectral Region: P $KL_{2,3}L_{-2,3}$

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_{α} monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: $0.1 \times 0.1 \text{ mm}^2$
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 33 696 s
 Total Elapsed Time: 37 176 s
 Number of Scans: 360
 Effective Detector Width: 6.2 eV

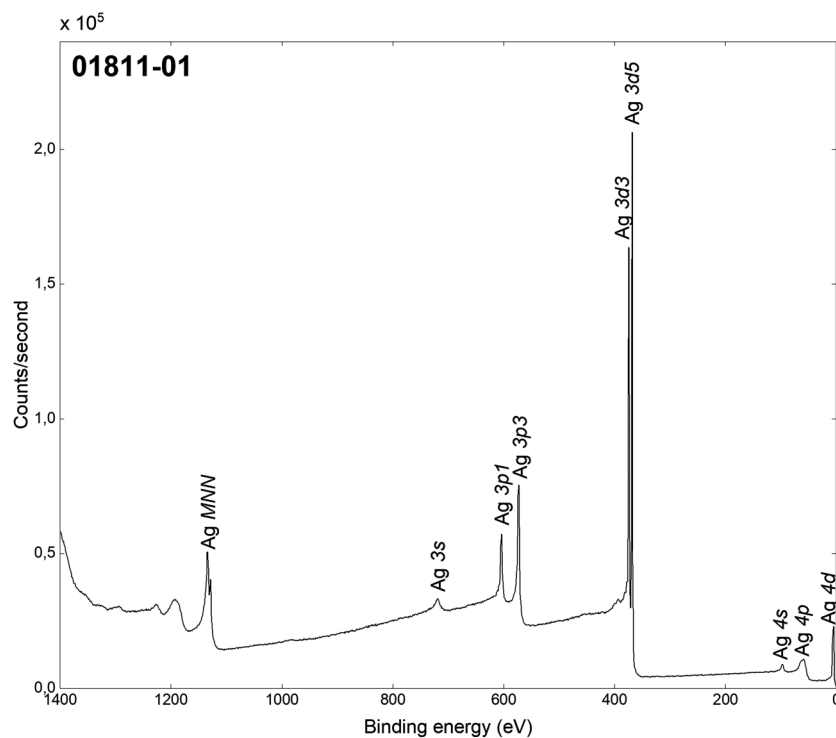


- Accession #: [01809-15](#)
- Host Material: $C_7H_{15}N_2O_4P$ ionic liquid
- Technique: XAES
- Spectral Region: P $KL_1L_{2,3}$

Instrument: ULVAC-PHI Quantes
 Excitation Source: Cr K_{α} monochromatic
 Source Energy: 5414.8 eV
 Source Strength: 51.4 W
 Source Size: $0.1 \times 0.1 \text{ mm}^2$
 Analyzer Type: Spherical sector
 Incident Angle: 22°
 Emission Angle: 45°
 Analyzer Pass Energy: 55 eV
 Analyzer Resolution: 0.43 eV
 Total Signal Accumulation Time: 49 140 s
 Total Elapsed Time: 54 210 s
 Number of Scans: 525
 Effective Detector Width: 6.2 eV



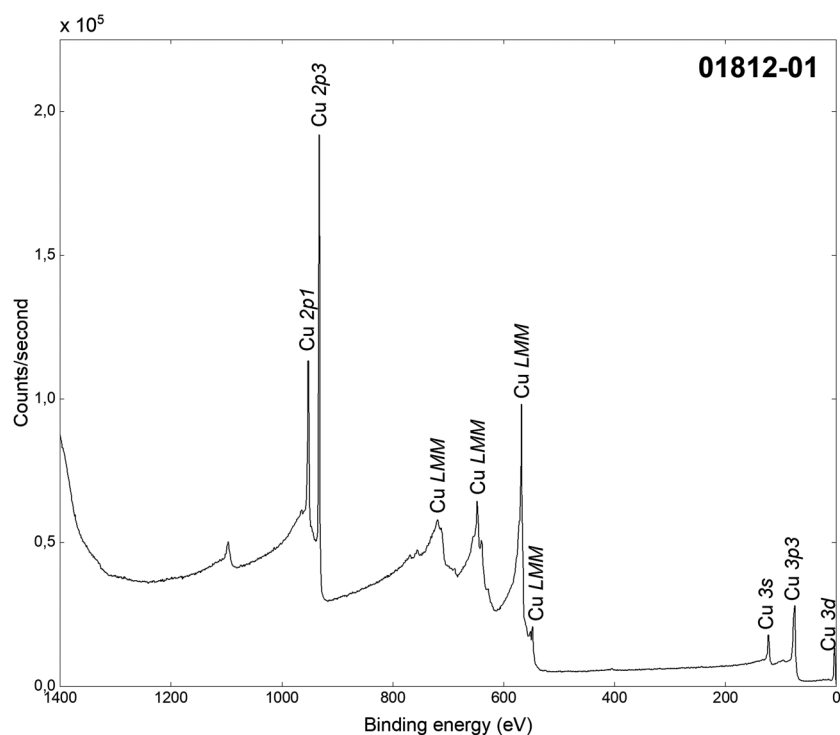
Accession #:	01810-01
Host Material:	Au
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Al K_{α} monochromatic
Source Energy:	1486.6 eV
Source Strength:	24.0 W
Source Size:	0.1 × 0.1 mm ²
Analyzer Type:	Spherical sector analyzer
Incident Angle:	0°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	1434 s
Total Elapsed Time:	1572 s
Number of Scans:	1
Effective Detector Width:	31 eV



Accession #:

01811-01

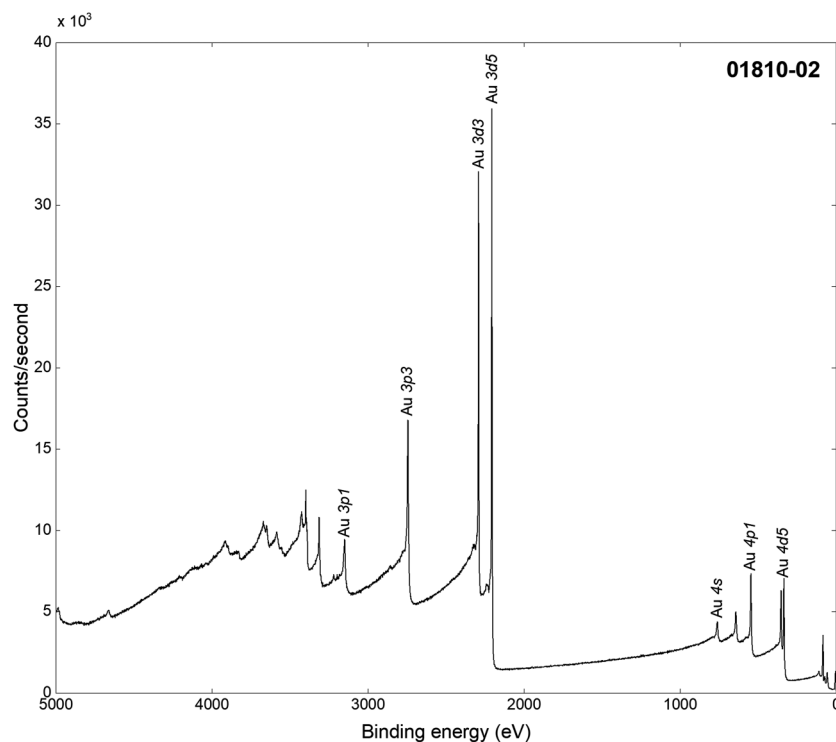
Host Material:	Ag
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Al K_{α} monochromatic
Source Energy:	1486.6 eV
Source Strength:	24.0 W
Source Size:	$0.1 \times 0.1 \text{ mm}^2$
Analyzer Type:	Spherical sector analyzer
Incident Angle:	0°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	1434 s
Total Elapsed Time:	1572 s
Number of Scans:	1
Effective Detector Width:	31 eV



Accession #:

01812-01

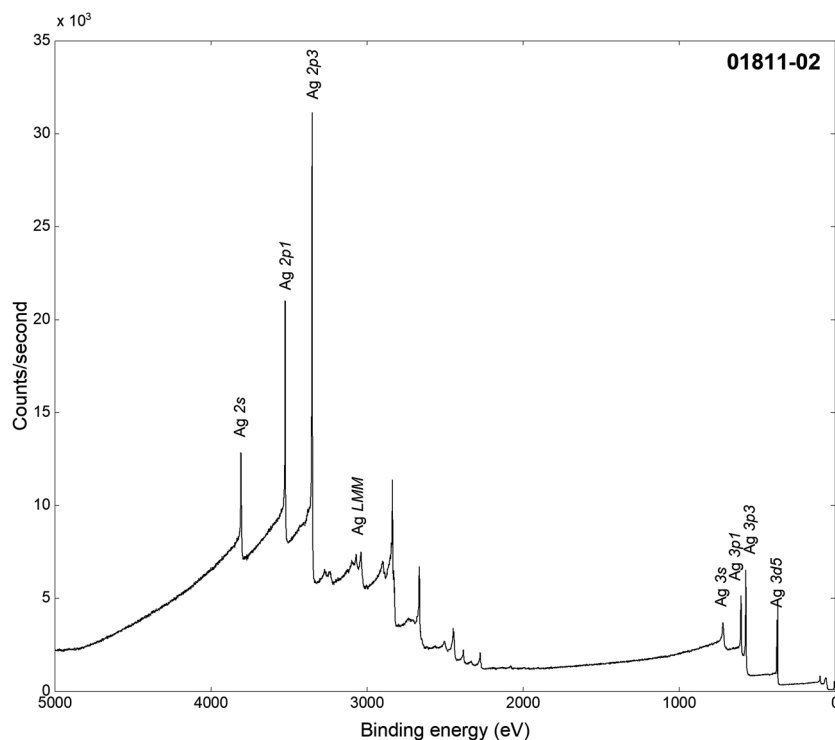
Host Material:	Cu
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Al K_{α} monochromatic
Source Energy:	1486.6 eV
Source Strength:	24.0 W
Source Size:	$0.1 \times 0.1 \text{ mm}^2$
Analyzer Type:	Spherical sector analyzer
Incident Angle:	0°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	1434 s
Total Elapsed Time:	1572 s
Number of Scans:	1
Effective Detector Width:	31 eV



Accession #:

01810-02

Host Material:	Au
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Cr K_{α} monochromatic
Source Energy:	5414.8 eV
Source Strength:	51.4 W
Source Size:	0.1 × 0.1 mm ²
Analyzer Type:	Spherical sector analyzer
Incident Angle:	22°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	19 980 s
Total Elapsed Time:	22 140 s
Number of Scans:	4
Effective Detector Width:	31 eV



Accession #:

01811-02

Host Material:

Ag

Technique:

XPS

Spectral Region:

Survey

Instrument:

ULVAC-PHI Quantes

Excitation Source:

Cr K_{α} monochromatic

Source Energy:

5414.8 eV

Source Strength:

51.4 W

Source Size:

0.1 × 0.1 mm

Analyzer Type:

Spherical sector analyzer

Incident Angle:

22°

Emission Angle:

45°

Analyzer Pass Energy:

280 eV

Analyzer Resolution:

1.9 eV

Total Signal Accumulation Time:

19 980 s

Total Elapsed Time:

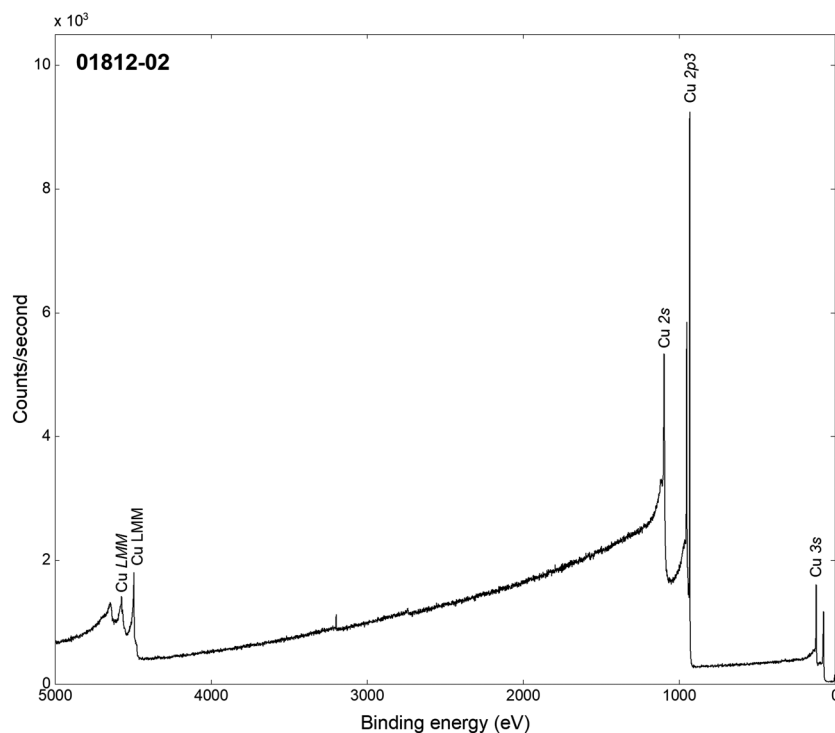
22 140 s

Number of Scans:

4

Effective Detector Width:

31 eV



Accession #:	01812-02
Host Material:	Cu
Technique:	XPS
Spectral Region:	Survey
Instrument:	ULVAC-PHI Quantes
Excitation Source:	Cr K_{α} monochromatic
Source Energy:	5414.8 eV
Source Strength:	51.4 W
Source Size:	$0.1 \times 0.1 \text{ mm}^2$
Analyzer Type:	Spherical sector analyzer
Incident Angle:	22°
Emission Angle:	45°
Analyzer Pass Energy:	280 eV
Analyzer Resolution:	1.9 eV
Total Signal Accumulation Time:	19 980 s
Total Elapsed Time:	22 140 s
Number of Scans:	4
Effective Detector Width:	31 eV