

IMSERC User Manual for XRF (Ex-Calibur)

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INTRODUCTION

Use of this instrument is allowed only by qualified users after receiving training by a staff member. Do not run this instrument without approval from IMSERC staff. Failure to do so may cause damage to the instrument, produce invalid data, and result in additional fees and/or removal of all IMSERC privileges. This short set of instructions is meant to serve as a guide for 'routine' data collection on the instrument. For custom experiments, contact a staff member. Please read this user manual and acquaint yourself with the instrument. If during the course of using the system, something happens that you do not understand, please **stop** and **get help**. In any event, be completely prepared to justify your actions. The cost of even minor repairs is considerable.

SAFETY

All users of IMSERC must review the general safety policies at <http://imserc.northwestern.edu/about-policies.html>. To become an independent user of this instrument, you must have the following safety training and certificates under your LUMEN profile:

- Laboratory Safety
- Personal Protective Equipment
- X-Ray Safety

You need the above certificates in order to be able to reserve time for this instrument on NUcore. Online classes and certification are offered at <https://learn.northwestern.edu>. Upon completion of the certificate, it will take an overnight to filter through the different systems and get into the files that NUcore uses. Additionally, familiarize yourself with the location of standard safety stations like eye wash and shower stations found in outside of room B172 at the north side. Protective eyewear is required in this room, and gloves should be removed when using the computer.

DATA MANAGEMENT

Your personal data folder is created during training. Please save data under your personal folder, which must be located under your supervisor's group folder. See a staff member if you do not have a personal folder on this instrument yet. For users that prefer to name their data folders using dates, use the order of YYYY-MM-DD or YYYYMMDD in the name, so that folders can be sorted chronologically by the operating system if needed.

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Since the XRF instrument is running on a very old operating system (Windows XP), instrument computer is not connected to the network. Please use a memory flash drive to retrieve your data. There are two USB ports on the left side of the monitor. Flash drives can be used only on this XRF instrument and not on any instrument in IMSERC.

SOFTWARE

Data acquisition, reduction, and analysis can be performed with the “nEXT” software. Software is installed on the instrument computer. Because of the old software, offline analysis is not available. Please see a staff if you’d like to analyze your data.

DEFAULT INSTRUMENT STATUS

The default working condition of XRF is as follows:

1. Computer screen is by default deactivated. You must start your reservation through NUcore in order to be able to turn on the computer screen. If screen is already on, start your reservation through NUcore
2. Vacuum pump for the sample chamber must be turned off

When you are done with your measurement, please remember to:

1. Close the acquisition software
2. End your reservation in NUcore
3. Leave lab tables clean and tools/accessories organized

If there is an error or problem with the instrument which is not addressed under the ‘[Troubleshooting](#)’ section, please report the issue by following at least one of the steps below:

1. If you have already started your reservation using NUcore, please end your reservation and select the error reporting option with a brief description about the issue
2. If you have not started your reservation using NUcore, please report problems with the instrument at <http://imserc.northwestern.edu/contact-issue.html> add place the ‘Stop’ sign near the instrument computer. ‘Stop’ signs are located on the shelf above the computers in BG51 and online at the link above
3. Email or talk to a staff member

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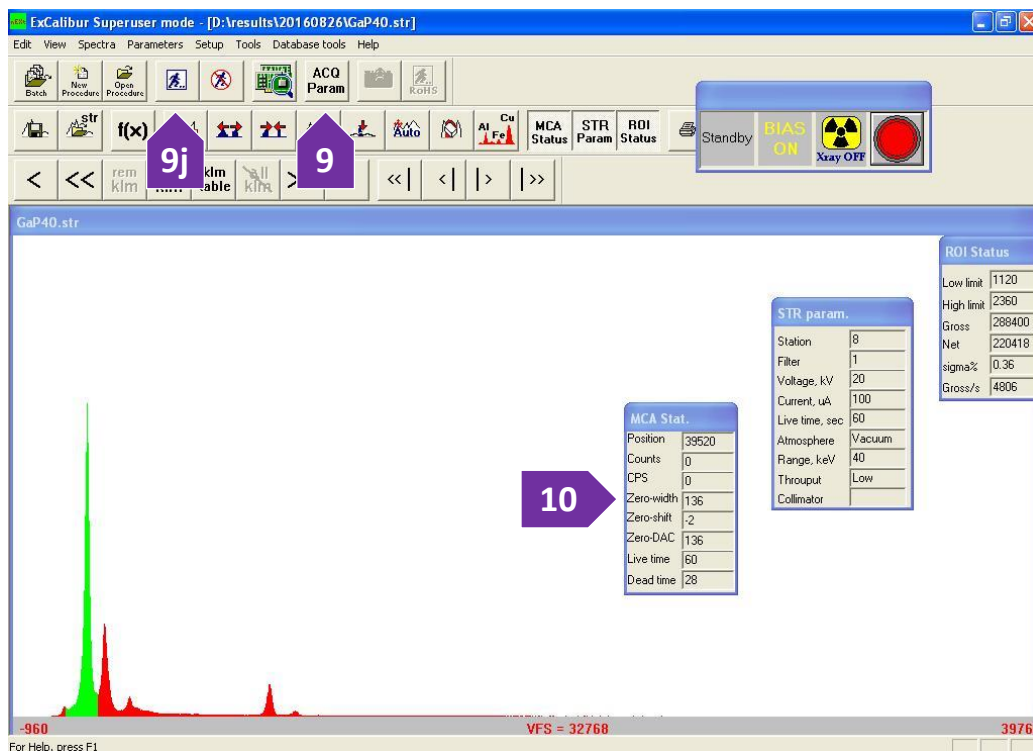
GENERAL STEPS FOR COLLECTING XRF DATA

1. Prepare the sample holder(s) for your measurement by installing a new Mylar film onto the plastic cups. Watch the ['xrf-cup-preparation'](#) video for a visual demonstration on how to prepare the plastic cups for an XRF measurement
2. Put your sample(s) into the cup(s). Sample can be in any form (fine powder, solid pellet, thin film, liquid, etc.). If you need to prepare standards for quantitative analysis (semi-quantitative measurements do not require standards), make sure that the standards have the same form with your samples (X-ray absorption coefficient must be similar)
3. Make sure instrument is idle by checking that the X-ray safety red light is turned off. Start your reservation in NUcore to have the screen of the computer turned on
4. Start the 'nEXT' software (icon on the desktop) and
 - a. Provide a user name (e.g., your first name)
 - b. Type the number seven (7) in the password field
 - c. Under 'Initialization Mode' select 'Full Initialization' (default)
 - d. Under 'Mode' select 'Superuser'
 - e. Press on the 'Next>>' button
 - f. Initialization will run for a few seconds, and 'MCA' and 'Controller' status should change to 'OK'
 - g. Press on the 'Superuser' button, 'Spectra view' window opens up
5. Open the sample tray door and install your sample's cup(s) in the appropriate tray positions numbered from 1 to 8. If sample chamber is under vacuum and you cannot open the door, in 'Spectra view', go to 'Tools' menu and select 'Vacuum off'. System will purge the chamber and you should be able to open the door now
6. Close the Autosampler door. Do not screw in the screw on the top of the door. If the door is not completely closed the interlock system will not allow the X-ray tube to be energized. Prepare the atmosphere for your measurement depending on the form of your sample:
 - Use vacuum for any form of sample except liquids. If the vacuum pump is switched off, press the red ON/OFF switch on the power strip at the bottom right side of the instrument table (figure 6)
 - For liquids, use either Helium or Air atmosphere. For using Helium, turn on the main valve of the Helium gas tank located between the pillar near the FTIR and table with the press
7. Move the X-ray Enable/Disable switch (on the top right corner of the instrument) to the 'Enable' position. Red light next to the switch turns on

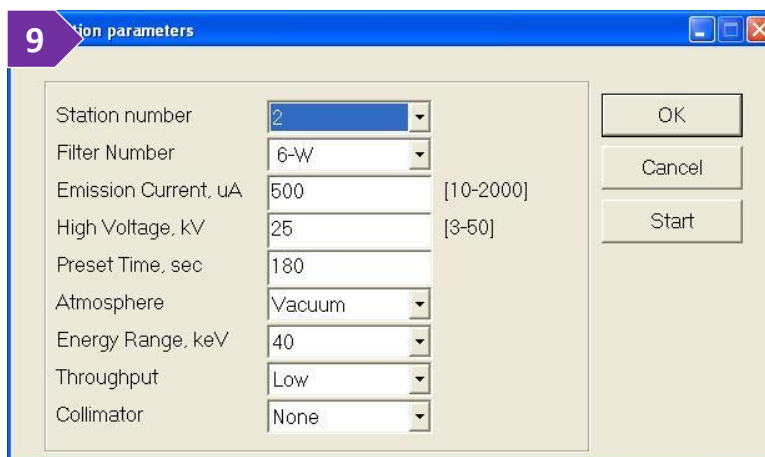


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8. When the instrument is not used for more than 24 hours it is necessary to gradually condition the X-ray tube before using very high voltage (>20 kV) acquisitions (for elements heavier than Rubidium). Warm up is not necessary for voltages below 20 kV (for Sodium to Bromine). Under 'Tools' menu, press on the 'Run Warmup batch' option if you want to operate above 20 kV



9. Set the acquisition parameters for your sample(s) by pressing on the 'ACQ Param' button (step 9 on the figure above) on the icon bar. In the acquisition parameter window (figure 9), you need to set:
- The position of your sample in the autosampler (1-8) under 'Station number'
 - Filter in front of the X-ray beam. When a filter is placed between the tube and the sample, then X-rays below the K-edge of the filter will be absorbed, improving the signal to background ratio for elements of interest and hence improving precision and detection limit. The filter reduces the beam intensity by eliminating X-rays which are not producing a useful signal. Based on the elements you have in your material, select:
 - '1-None' for all light elements (Cu and below) expect S and Cl




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- '2-Ti' for all light elements (Fe and below) except for Ti and Sc but including S and Cl
 - '3-Fe' for all light elements (V and below)
 - '4-Cu' for Fe and above (50 kV)
 - '5-Rh' for Ca to Mo (25-40 kV)
 - '6-W' for As to Ru (50 kV)
- c. 'Emission Current, uA' must be set high enough to have >500 counts per second (CPS) but at the same time keeping the detector dead time between 25% and 35%. Set the current at 10 uA and use your highest concentration sample to find the optimum current
 - d. 'High Voltage, kV' must be set approximately 1.5x to 2x the amount of energy required to excite the element of interest. Use the tables with the X-ray emission lines in [Appendix A](#) to look for the emission lines of your elements, e.g., K β 1 line of Cobalt is ~ 7.65 kV which means you must use a voltage value of at least 12 kV (1.5 x 7.6 kV) in order to excite Co efficiently
 - e. 'Preset time, sec' will vary depending on the concentration of the element of interest. If you are looking at high concentrations (%), use 60-180 s. If you are looking at ppm concentrations, 180-300 s would be used. For liquids, a good time would be 180-240 s due to sagging of the X-ray film in the cup, and evaporation
 - f. 'Atmosphere' can be set to 'Vacuum' for all forms of sample except for liquids which you need to select 'Helium'. Make sure the main valve on the Helium cylinder is opened
 - g. 'Energy Range, keV' can be either '10' or '40'. Depending on the [emission energies](#) of the elements of interest, choose the appropriate range
 - h. 'Throughput' at 'Low'
 - i. 'Collimator' at 'None'
 - j. Press on the 'Start' button and acquisition will start in a few seconds. Alternatively, you can press on 'OK' and press on the 'Run' button (figure 9j). Please check the ['Troubleshooting'](#) section in case a known error message appears on the screen
10. During acquisition, press on the 'MCA Status' button to see information such as CPS, dead time, etc. (figure 10). If dead time is too low (< 20) or too high (50>), or CPS is <500 you need to adjust the 'Emission Current, uA'. To stop the collection and change the acquisition parameter: Press on the 'Stop' button (icon with running person and a red line through) and set 'Emission Current, uA' to a higher value, e.g., 50 uA
 11. A good spectrum should have enough counts (> 5,000) and a high signal-to-noise ratio
 12. Collect spectra of your samples and standards using the same acquisition conditions. When measuring standards in solid form, making pellets of your standards is highly recommended for ensuring that the entire

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sample mass is illuminated by X-rays. Watch the '[pcm-making-pellets](#)' video for a visual demonstration on how to prepare pellets of your solid samples

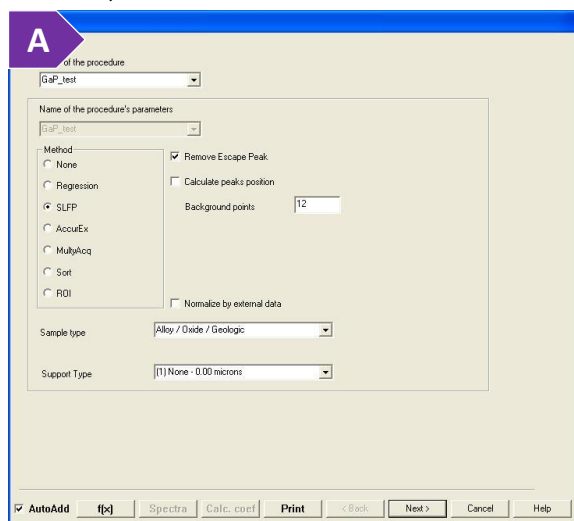
13. During or after a collection of a spectrum, you can identify all peaks by either right pressing on the spectrum and select 'Identify Peaks' or pressing on the Peak Identification icon . Identification process might not be accurate due to overlaps between peaks or weak intensity of some peaks. To reliably identify all peaks, press the 'add klm' button and on the window that appears choose elements from the periodic table to overlay their emission energies over your spectrum

USING THE SOFTWARE FOR (SEMI)QUANTIFICATION

Go to 'Edit' menu and select 'New procedure' to build a measurement procedure where you define the elements of interest to be quantified, acquisition parameter for the data collection, etc.

A. FOR SEMI-QUANTITATIVE ANALYSIS

1. Set the name of your procedure at 'Name of the procedure' (figure A)
2. Select 'SLFP' as a 'Method' (Standardless Fundamental Parameters)
3. Tick the 'Remove Escape Peak' option
4. Untick the 'Calculate peaks position'
5. Set 'Background points' to '12'
6. Select the appropriate sample type under 'Sample Type'
7. 'Support type' is typically Mylar. Press on the 'Next' button
8. Under 'Acquisition Parameter' tab, define all acquisition parameters using the optimum values determined in step 7 and press on the 'Next' button
9. Select your 'Elements of Interest' from the periodic table on the tab and press on the 'Next' button
10. To semi-quantify measured samples, load the spectrum of your sample, and press on the 'f(x)' button



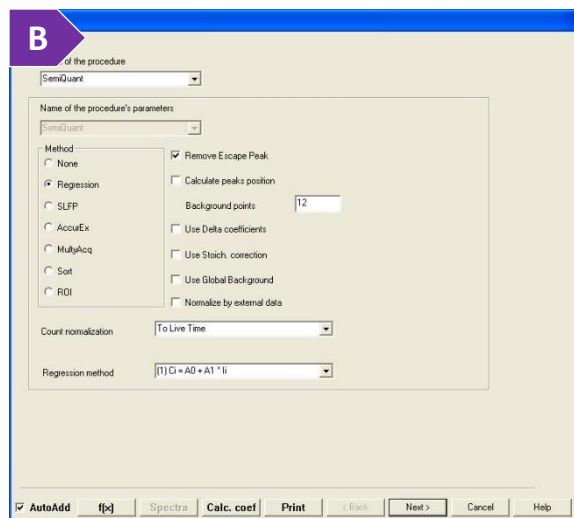
B. FOR QUANTITATIVE ANALYSIS

Measured standards for creating a calibration curve are required when quantitative analysis is needed:

1. Set the name of your procedure at 'Name of the procedure' (figure B)
2. Select 'Regression' as a 'Method'

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3. Tick the 'Remove Escape Peak' option
4. Untick the 'Calculate peaks position'
5. Tick the 'Use Stoich correction' box and put '100' if the concentration of all your elements adds up to 100%
6. Set 'Count normalization' to 'To Live Time'
7. Use linear equation (1) as a 'Regression method' and press on the 'Next' button
8. Define all acquisition parameters using the optimum values determined in step 7 and press on the 'Next' button
9. Select your 'Elements of Interest' from the periodic table on the tab and press on the 'Next' button
10. (Optional) Can you set concertation limits under the 'Criterion' tab
11. On the 'Standards' tab press on the 'Add standard' button and load one by one all the files measured for your standards by starting with your Blank spectrum
12. Enter the concentration next to each standard after you have added all files. After you have finished entering the standard concentration, press on another 'concentration box' to register the last number into the database
13. Press on the 'Calculate Coefficient' tab. An asterisk in the field indicates for the computer to calculate that term. 'A0' is the intercept and 'A1' is the slope. If you have more than 3 standards, put an asterisk on the 'A0' term
14. Press on the "Calc. coef" button at the bottom of the window. This will calculate the regression graph
15. Press on the 'Report' tab
 - 'Show Coefficient' button will show you the value of each linear term, standard deviation, correlation, etc.
 - 'Show Report' button will show the calculated and actual concentration comparisons
 - 'Show lines' will show the graph of the regression
16. Press on the 'Save' button to save the procedure
17. To quantify measured samples, load the spectrum of your sample and press on the 'f(x)' button



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EXPORTING SPECTRA AND FINISHING WORK

To export your collected spectra in ASCII format, please follow these steps:

1. Under the 'Spectra' menu, select 'Multi Spectra Operations', and then select 'Multi Save Spectra'
2. Browse to the location of where the spectra you would like to export are, select them, and press on the 'Open' button
3. Browse to the location of where the exported ASCII data will be saved, provide a filename, and press on the 'Save' button
4. A pop-up window will prompt for 'Enter Excel Path', press on the 'Cancel' button
5. The exported TXT file is the ASCII format of your spectrum. It contains one column with numbers per spectrum, these numbers are the number of photons in each channel of the detector. The energy scale (X-axis) is not printed in the file and you must create this axis when plotting data with your own software. Depending on the energy region selected during your measurement (0-10 keV or 0-40 keV), you need to manually create the corresponding energy-axis:
 - When a 40 keV energy region is selected, there are 2048 channels and each channel is 20 eV wide, i.e., create a column with increasing numbers starting from 20 and having a constant incremental step of 20
 - When a 10 keV energy region is selected, there are 1024 channels and each channel is 10 eV wide, i.e., create a column with increasing numbers starting from 10 and having a constant incremental step of 10

When measurement is done:

1. Remove the cup(s) with your sample(s) and take all used cups and samples back to your lab. You could reuse the plastic cups by disassemble each cup and replace the Mylar film with new one
2. If vacuum atmosphere is used, turn off the pump from the main switch on the power strip and leave the chamber under ambient pressure. If Helium atmosphere is used, close the main valve on the Helium gas tank
3. Move the X-ray Enable/Disable switch to the 'Disable' position. Red light next to the switch turns off
4. Remove any vials, weighing paper, etc. you may have left in the room
5. End your reservation in NUcore

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PUBLICATION

A. EXPERIMENTAL SECTION

Modify the text below according to the setup and conditions you used during the measurement:

“X-ray fluorescence spectroscopy was performed in a Xenometrix Ex-Calibur EX-2600 spectrometer equipped with an Rh X-ray tube and a silicon energy-dispersive detector. Sample was placed in a special plastic cup and powder was supported on a 6 μm Mylar film. Data collection was performed at room temperature ***under vacuum | air | Helium*** with a ***X-filter***. X-ray tube was operated at ***XX*** keV and ***YY*** μA , and fluorescence spectra were collected for ***ZZ*** s.”

B. ACKNOWLEDGEMENT

“This work made use of the IMSERC X-RAY facility at Northwestern University, which has received support from the Soft and Hybrid Nanotechnology Experimental (SHyNE) Resource (NSF ECCS-2025633), and Northwestern University.”

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TROUBLESHOOTING

A. THE COMPUTER SCREEN WILL NOT TURN ON

Begin your reservation in NUcore to initiate access to the instrument

B. ACQUISITION SOFTWARE REQUIRES LOGIN AND A PASSWORD

The username for the acquisition software 'nEXt' can be anything, e.g., your first name. The password is the number '7' (without the quotes)

C. ERROR MESSAGE RELATED TO 'NO RECORD'

During the tube warmup process or beginning of your first acquisition of the day, you might see a 'No record' error message. If this specific error message appears during:

- Your first collection of the day. Ensure that the X-ray Enable/Disable switch is pointing at the 'Enable' position and the light next to the switch is on
- The warmup sequence. Simply acknowledge the error message by pressing on the 'OK' button. You may have to acknowledge the same error message for each warmup step (there are 12 warmup steps in total)

D. THERE IS AN ERROR/PROBLEM WITH THE INSTRUMENT THAT IS NOT ADDRESSED UNDER THE TROUBLESHOOTING SECTION

If there is an error or problem with the instrument which is not addressed under the troubleshooting section, please report the issue by following at least one of the steps below:

1. If you have already started your reservation using NUcore, please end your reservation and select the error reporting option with a brief description about the issue
2. If you have not started your reservation using NUcore, please report problems with the instrument at <http://imserc.northwestern.edu/contact-issue.html> and place the 'Stop' sign near the instrument computer. 'Stop' signs are located on the shelf above the computers in BG51 and online at the link above. Email or talk to a staff member
3. Email or talk to a staff member

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APPENDICES

APPENDIX A: X-RAY EMISSION ENERGIES

Photon energies, in electron volts, of principal K-, L-, and M-shell emission lines (1/5)

Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma_1$	$M\alpha_1$
3 Li	54.3								
4 Be	108.5								
5 B	183.3								
6 C	277								
7 N	392.4								
8 O	524.9								
9 F	676.8								
10 Ne	848.6	848.6							
11 Na	1,040.98	1,040.98	1,071.1						
12 Mg	1,253.60	1,253.60	1,302.2						
13 Al	1,486.70	1,486.27	1,557.45						
14 Si	1,739.98	1,739.38	1,835.94						
15 P	2,013.7	2,012.7	2,139.1						
16 S	2,307.84	2,306.64	2,464.04						
17 Cl	2,622.39	2,620.78	2,815.6						
18 Ar	2,957.70	2,955.63	3,190.5						
19 K	3,313.8	3,311.1	3,589.6						
20 Ca	3,691.68	3,688.09	4,012.7	341.3	341.3	344.9			
21 Sc	4,090.6	4,086.1	4,460.5	395.4	395.4	399.6			

Tables were taken from the 'X-ray Data Booklet' and references therein by Jeffrey B. Kortright and Albert C. Thompson, Lawrence Berkeley National Laboratory (<https://xdb.lbl.gov/xdb.pdf>)

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Energies of x-ray emission lines (2/5)

Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma_1$	$M\alpha_1$
22 Ti	4,510.84	4,504.86	4,931.81	452.2	452.2	458.4			
23 V	4,952.20	4,944.64	5,427.29	511.3	511.3	519.2			
24 Cr	5,414.72	5,405.509	5,946.71	572.8	572.8	582.8			
25 Mn	5,898.75	5,887.65	6,490.45	637.4	637.4	648.8			
26 Fe	6,403.84	6,390.84	7,057.98	705.0	705.0	718.5			
27 Co	6,930.32	6,915.30	7,649.43	776.2	776.2	791.4			
28 Ni	7,478.15	7,460.89	8,264.66	851.5	851.5	868.8			
29 Cu	8,047.78	8,027.83	8,905.29	929.7	929.7	949.8			
30 Zn	8,638.86	8,615.78	9,572.0	1,011.7	1,011.7	1,034.7			
31 Ga	9,251.74	9,224.82	10,264.2	1,097.92	1,097.92	1,124.8			
32 Ge	9,886.42	9,855.32	10,982.1	1,188.00	1,188.00	1,218.5			
33 As	10,543.72	10,507.99	11,726.2	1,282.0	1,282.0	1,317.0			
34 Se	11,222.4	11,181.4	12,495.9	1,379.10	1,379.10	1,419.23			
35 Br	11,924.2	11,877.6	13,291.4	1,480.43	1,480.43	1,525.90			
36 Kr	12,649	12,598	14,112	1,586.0	1,586.0	1,636.6			
37 Rb	13,395.3	13,335.8	14,961.3	1,694.13	1,692.56	1,752.17			
38 Sr	14,165	14,097.9	15,835.7	1,806.56	1,804.74	1,871.72			
39 Y	14,958.4	14,882.9	16,737.8	1,922.56	1,920.47	1,995.84			
40 Zr	15,775.1	15,690.9	17,667.8	2,042.36	2,039.9	2,124.4	2,219.4	2,302.7	

Tables were taken from the 'X-ray Data Booklet' and references therein by Jeffrey B. Kortright and Albert C. Thompson, Lawrence Berkeley National Laboratory (<https://xdb.lbl.gov/xdb.pdf>)

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Energies of x-ray emission lines (3/5)

Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma$	$M\alpha_1$
41 Nb	16,615.1	16,521.0	18,622.5	2,165.89	2,163.0	2,257.4	2,367.0	2,461.8	
42 Mo	17,479.34	17,374.3	19,608.3	2,293.16	2,289.85	2,394.81	2,518.3	2,623.5	
43 Tc	18,367.1	18,250.8	20,619	2,424	2,420	2,538	2,674	2,792	
44 Ru	19,279.2	19,150.4	21,656.8	2,558.55	2,554.31	2,683.23	2,836.0	2,964.5	
45 Rh	20,216.1	20,073.7	22,723.6	2,696.74	2,692.05	2,834.41	3,001.3	3,143.8	
46 Pd	21,177.1	21,020.1	23,818.7	2,838.61	2,833.29	2,990.22	3,171.79	3,328.7	
47 Ag	22,162.92	21,990.3	24,942.4	2,984.31	2,978.21	3,150.94	3,347.81	3,519.59	
48 Cd	23,173.6	22,984.1	26,095.5	3,133.73	3,126.91	3,316.57	3,528.12	3,716.86	
49 In	24,209.7	24,002.0	27,275.9	3,286.94	3,279.29	3,487.21	3,713.81	3,920.81	
50 Sn	25,271.3	25,044.0	28,486.0	3,443.98	3,435.42	3,662.80	3,904.86	4,131.12	
51 Sb	26,359.1	26,110.8	29,725.6	3,604.72	3,595.32	3,843.57	4,100.78	4,347.79	
52 Te	27,472.3	27,201.7	30,995.7	3,769.33	3,758.8	4,029.58	4,301.7	4,570.9	
53 I	28,612.0	28,317.2	32,294.7	3,937.65	3,926.04	4,220.72	4,507.5	4,800.9	
54 Xe	29,779	29,458	33,624	4,109.9	—	—	—	—	
55 Cs	30,972.8	30,625.1	34,986.9	4,286.5	4,272.2	4,619.8	4,935.9	5,280.4	
56 Ba	32,193.6	31,817.1	36,378.2	4,466.26	4,450.90	4,827.53	5,156.5	5,531.1	
57 La	33,441.8	33,034.1	37,801.0	4,650.97	4,634.23	5,042.1	5,383.5	5,788.5	833
58 Ce	34,719.7	34,278.9	39,257.3	4,840.2	4,823.0	5,262.2	5,613.4	6,052	883
59 Pr	36,026.3	35,550.2	40,748.2	5,033.7	5,013.5	5,488.9	5,850	6,322.1	929
60 Nd	37,361.0	36,847.4	42,271.3	5,230.4	5,207.7	5,721.6	6,089.4	6,602.1	978
61 Pm	38,724.7	38,171.2	43,826	5,432.5	5,407.8	5,961	6,339	6,892	—
62 Sm	40,118.1	39,522.4	45,413	5,636.1	5,609.0	6,205.1	6,586	7,178	1,081

Tables were taken from the 'X-ray Data Booklet' and references therein by Jeffrey B. Kortright and Albert C. Thompson, Lawrence Berkeley National Laboratory (<https://xdb.lbl.gov/xdb.pdf>)

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Energies of x-ray emission lines (4/5)

Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma_1$	$M\alpha_1$
63 Eu	41,542.2	40,901.9	47,037.9	5,845.7	5,816.6	6,456.4	6,843.2	7,480.3	1,131
64 Gd	42,996.2	42,308.9	48,697	6,057.2	6,025.0	6,713.2	7,102.8	7,785.8	1,185
65 Tb	44,481.6	43,744.1	50,382	6,272.8	6,238.0	6,978	7,366.7	8,102	1,240
66 Dy	45,998.4	45,207.8	52,119	6,495.2	6,457.7	7,247.7	7,635.7	8,418.8	1,293
67 Ho	47,546.7	46,699.7	53,877	6,719.8	6,679.5	7,525.3	7,911	8,747	1,348
68 Er	49,127.7	48,221.1	55,681	6,948.7	6,905.0	7,810.9	8,189.0	9,089	1,406
69 Tm	50,741.6	49,772.6	57,517	7,179.9	7,133.1	8,101	8,468	9,426	1,462
70 Yb	52,388.9	51,354.0	59,370	7,415.6	7,367.3	8,401.8	8,758.8	9,780.1	1,521.4
71 Lu	54,069.8	52,965.0	61,283	7,655.5	7,604.9	8,709.0	9,048.9	10,143.4	1,581.3
72 Hf	55,790.2	54,611.4	63,234	7,899.0	7,844.6	9,022.7	9,347.3	10,515.8	1,644.6
73 Ta	57,532	56,277	65,223	8,146.1	8,087.9	9,343.1	9,651.8	10,895.2	1,710
74 W	59,318.24	57,981.7	67,244.3	8,397.6	8,335.2	9,672.35	9,961.5	11,285.9	1,775.4
75 Re	61,140.3	59,717.9	69,310	8,652.5	8,586.2	10,010.0	10,275.2	11,685.4	1,842.5
76 Os	63,000.5	61,486.7	71,413	8,911.7	8,841.0	10,355.3	10,598.5	12,095.3	1,910.2
77 Ir	64,895.6	63,286.7	73,560.8	9,175.1	9,099.5	10,708.3	10,920.3	12,512.6	1,979.9
78 Pt	66,832	65,112	75,748	9,442.3	9,361.8	11,070.7	11,250.5	12,942.0	2,050.5
79 Au	68,803.7	66,989.5	77,984	9,713.3	9,628.0	11,442.3	11,584.7	13,381.7	2,122.9
80 Hg	70,819	68,895	80,253	9,988.8	9,897.6	11,822.6	11,924.1	13,830.1	2,195.3
81 Tl	72,871.5	70,831.9	82,576	10,268.5	10,172.8	12,213.3	12,271.5	14,291.5	2,270.6

Tables were taken from the 'X-ray Data Booklet' and references therein by Jeffrey B. Kortright and Albert C. Thompson, Lawrence Berkeley National Laboratory (<https://xdb.lbl.gov/xdb.pdf>)

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Energies of x-ray emission lines (5/5)

Element	$K\alpha_1$	$K\alpha_2$	$K\beta_1$	$L\alpha_1$	$L\alpha_2$	$L\beta_1$	$L\beta_2$	$L\gamma$	$M\alpha_1$
82 Pb	74,969.4	72,804.2	84,936	10,551.5	10,449.5	12,613.7	12,622.6	14,764.4	2,345.5
83 Bi	77,107.9	74,814.8	87,343	10,838.8	10,730.91	13,023.5	12,979.9	15,247.7	2,422.6
84 Po	79,290	76,862	89,800	11,130.8	11,015.8	13,447	13,340.4	15,744	—
85 At	81,520	78,950	92,300	11,426.8	11,304.8	13,876	—	16,251	—
86 Rn	83,780	81,070	94,870	11,727.0	11,597.9	14,316	—	16,770	—
87 Fr	86,100	83,230	97,470	12,031.3	11,895.0	14,770	14,450	17,303	—
88 Ra	88,470	85,430	100,130	12,339.7	12,196.2	15,235.8	14,841.4	17,849	—
89 Ac	90,884	87,670	102,850	12,652.0	12,500.8	15,713	—	18,408	—
90 Th	93,350	89,953	105,609	12,968.7	12,809.6	16,202.2	15,623.7	18,982.5	2,996.1
91 Pa	95,868	92,287	108,427	13,290.7	13,122.2	16,702	16,024	19,568	3,082.3
92 U	98,439	94,665	111,300	13,614.7	13,438.8	17,220.0	16,428.3	20,167.1	3,170.8
93 Np	—	—	—	13,944.1	13,759.7	17,750.2	16,840.0	20,784.8	—
94 Pu	—	—	—	14,278.6	14,084.2	18,293.7	17,255.3	21,417.3	—
95 Am	—	—	—	14,617.2	14,411.9	18,852.0	17,676.5	22,065.2	—

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REVISIONS

v1.14 2021/09/22	<ul style="list-style-type: none">• Troubleshooting section updated• Training video files transferred from Box to OneDrive, and all relevant links were updated• Tables with X-ray emission lines were moved to Appendix A
v1.12 2020/08/26	<ul style="list-style-type: none">• Links to online video modules added for demonstrating sample cup and pellet preparations. More pictures were added• Award number on the SHyNE acknowledgement was updated
v1.10 2020/03/26	<ul style="list-style-type: none">• Reformatted according to the latest template. Sections about 'Safety', 'Data management', 'Software', 'Publication', and 'Troubleshooting' were added
v1.00 2016/08/29	<ul style="list-style-type: none">• Release of original version of the user manual
