# PEN-RAY® Rare Gas Lamp Spectra

ULTRA-VIOLET PRODUCTS, INC.®

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## PEN-RAY® Rare Gas Lamp Spectra

It is a pleasure to present in the following pages a report that fills a much needed gap in the present knowledge of spectra of the rare gases. We are indebted to Dr. Wilbur Kaye, Research Director of Beckman Instruments, Inc., Fullerton, California, for his interest in the rare gas forms of the PEN-RAY lamps. We thank Dr. Kaye and Beckman Instruments for their generosity in allowing us to publish the report and spectra.

### Preamble and comments on Dr. Kaye's report

PEN-RAY lamps have been manufactured for over 25 years in the standard Argon-mercury quartz lamp type. Because of remarkable stability, low operating temperature, and good, discrete spectra; PEN-RAY lamps have received wide recognition. Thousands are in use for calibrating various photometric instruments or as light sources in optical instrumentation.

Increased emphasis on aerospace studies have developed interest in modifications of the PEN-RAY lamps, relative to special gas fillings, sizes, and shapes of lamps. As many of the requirements were for noble gas lamps, the various rare gases have been made available as standard equipment.

The initial rare gas lamps, made available to several scientists for testing, caused considerable interest. The lamps were then displayed at three large gatherings of scientists with very favorable reactions.

The most important consideration pointed out by the various groups was the need for spectra of the lamps. The report and spectral data presented here is a result of this expressed need.

The PEN-RAY lamps were investigated with a Beckman DK-U (Universal) Prism-Grating Spectrophotometer. This versatile instrument was described by Dr. Kaye in *Applied Optics*, Vol 2, p. 1295, Dec. 1963, under the title, "A Universal Spectrophotometer."

In the report on the PEN-RAY® lamps which follows, the 10 ma power supply is mentioned as a probable compromise. It is true that lamps vary slightly in manufacture and that pure gas lamps are particularly sensitive in their current requirements. The investigator may find it desirable to operate the power supply from a variable transformer in order to make adjustments if a lamp does flicker slightly.

The Neon-mercury lamp, which was investigated, is not a rare gas lamp as under normal conditions the mercury spectrum is superior to the Neon spectrum. When the lamp is cooled sufficiently, the Neon spectrum becomes superior. However, it is interesting to note that several mercury spectral lines are stronger from the Neon-mercury lamp than from the standard Argon-mercury lamp.

As noted in the report the spectral lines of Xenon are relatively weak in a low pressure discharge lamp. These rare gas lamps, though they do not produce a continuum like high pressure arc lamps, are more valuable for certain applications in that they do produce discrete, sharp spectral lines.

The two basic areas of application are:

I. Reference Standards
II. Basic Research

As reference standards the lamps may be used in several areas.

1. Wavelength calibration and alignment of optical instruments, i.e., Spectrophotometers.
2. Calibration of spectrograph spectra by imposing spectra from the lamps onto the film.
3. Evaluation of performance, i.e., resolution of spectrophotometric instruments.
4. Checking output intensity of optical instrumentation.
5. Spectrochemical analysis with colorimeters.
6. Checking sensitivity of detectors as photocells, photomultipliers and thermopiles at specific known wavelengths.

In basic reseach some of the fields of interest may be:

1. Basic study of the emitted light itself.
2. Study of the light after passing through a system or media.
3. Reflection and irradiation studies with various monochromatic spectral lines.
4. Use of the light sources as devices for interferometric measuring of thin films and surface finishes. Also, for studying characteristics and structure of the light itself.

The PEN-RAY lamps used for the accompanying spectra were the basic 11SC-1 shape with a lighted length of approximately two inches. Other models with shorter lighted lengths are possible, as well as models of smaller and larger diameter. Single bore lamps can also be made in various configurations as required.

# Emission Spectra of Argon, Helium, Krypton, Neon and Xenon PEN-RAY® Lamps

by Wilbur Kaye, Beckman Instruments, Inc.

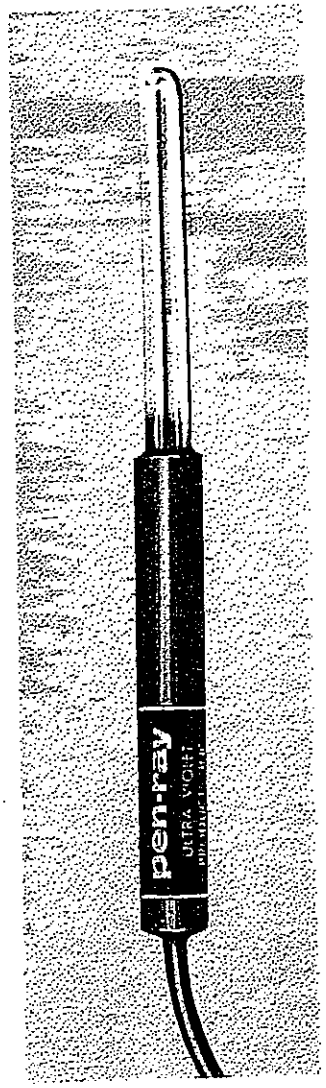
## Introduction

A number of new PEN-RAY lamps containing various gases was placed at our disposal by ULTRA-VIOLET PRODUCTS INC., San Gabriel, California. These lamps are of a convenient size and power for general laboratory use. The PEN-RAY lamp containing mercury vapor has long been used for alignment and wavelength checkout on spectrophotometers. The spectra of these lamps, obtained with a Beckman DK-U prism-grating spectrophotometer, are reproduced here.

## Lamps

PEN-RAY lamps were filled with the following gases: argon, helium, krypton, neon, xenon and a mercury-neon mixture. The lamps have a dual bore fused silica tube 2⅛ (5.39cm) inches long confining the arc. The lamps are powered by a small transfomer-ballast (SCT-3) providing the proper starting potential at 270 to 1000 volts at 10.0 ma during lamp operation. Total power consumption is 14 watts. The ideal power requirements of these lamps no doubt varies with the filling gas and the use of one power supply is a compromise. In particular, the neon and helium lamps flickered excessively and it was necessary to raise the primary voltage to 130 volts with a Variac to obtain acceptable stability.

The lamp containing the mercury-neon mixture exhibited an emission spectrum that was very sensitive to lamp temperature. At low temperatures (immediately after starting or when cooled with a jet of air) the neon spectrum is favored. At normal operating temperature the mercury emission predominates. Undoubtedly, this effect is due to the vapor pressure of mercury in the lamp.




Model 11-SC-1
PEN-RAY Lamp

## Spectra

Spectra were obtained on these lamps using the DK-U spectrophotometer and are found in figures 1-0. Both prism and grating monochromators were used for scanning the lamp emission above 3200 A and the prism alone was used for shorter wavelength scans. The RCA tri-alkali detector C70101 was used for all spectra employing the grating monochromator and the RCA 7200 detector was used when the prism monochromator alone was employed. The amplifier gain and dynode voltage was varied to give the best spectra. A pen response time of 0.1 second was used for all spectra. The

lamps were mounted in a high pressure xenon backplate (W128240). The slit width labeled on the figures refers to the grating monochromator except where "prism only" is noted. When both monochromators were employed, the slit width of the prism monochromator was kept at 2.0 mm.

In regions of intense emission, the spectra were run at two different slit widths in order to display both strong and weak likes. In general the wavelength scale has been expanded for the spectra obtained at the narrower slit widths. Wavelength intervals between 2000-8000 A containing no lines of appreciable intensity are not reproduced.

Wavelengths of the lines are given to the nearest 0.1 A. These values are taken from the 41st edition of the Handbook of Chemistry and Physics. Doubtful lines have been identified by comparison with the hydrogen emission spectrum. All wavelengths are given in standard air, except the mercury lines below 2000 A and these are corrected for nitrogen at 25° and 760 mm.

The intensities of the emission lines bear little relationship to the Handbook values. Apparently the excitation conditions are different. Close examination reveals that the emission from the PEN-RAY lamps arises almost exclusively from neutral atoms. In some cases numerous expected lines were completely absent. For example, the ultraviolet lines of argon are almost completely absent. The emission intensity from the xenon lamp appears unusually low and may be due to a faulty lamp.

The intense emission lines from these lamps are listed by wavelength in table I. These lines should be most useful.

The spectrum of the mercury-neon mixture is given only under the condition of a cooled lamp. The uncooled lamp exhibits very weak neon lines, hence, is essentially identical with a pure mercury lamp.

## Useful Wavelengths With PEN-RAY® Lamps

Table I

| (Air or $N_2$) | Lamp | (Air or $N_2$) | Lamp | (Air or $N_2$) | Lamp |
|---|---|---|---|---|---|
| | | 4319.6 | Kr | | |
| 1849.1 | Hg | 4333.6 | A | 6717.0 | Ne |
| 1941.7 | Hg | 4358.4 | Hg | 6929.5 | Ne |
| 2262.2 | Hg | 4362.6 | Kr | 6965.4 | A |
| 2378.3 | Hg | 4376.1 | Kr | 7024.1 | Ne |
| 2482.0 | Hg | 4387.6 | He | 7032.4 | Ne |
| 2536.5 | Hg | 4453.9 | K | 7059.1 | Ne |
| 2652.0 | Hg | 4463.7 | K | 7065.2 | He |
| 2803.5 | Hg | 4471.5 | He | 7067.2 | A |
| 2893.6 | Hg | 4502.4 | K | 7173.9 | Ne |
| 2967.3 | Hg | 4713.1 | He | 7245.2 | Ne |
| 3021.5 | Hg | 4921.9 | He | 7272.9 | A |
| 3125.7 | Hg | 5015.7 | He | 7281.4 | He |
| 3131.7 | Hg | 5047.7 | He | 7384.0 | A |
| 3187.7 | He | 5330.8 | Ne | 7438.9 | Ne |
| 3341.5 | Hg | 5341.1 | Ne | 7488.9 | Ne |
| 3369.9 | Ne | 5400.6 | Ne | 7503.9 | A |
| 3417.9 | Ne | 5460.7 | Hg | 7514.6 | A |
| 3447.7 | Ne | 5562.2 | K | 7535.8 | Ne |
| 3466.6 | Ne | 5570.3 | K | 7544.1 | Ne |
| 3472.6 | Ne | 5769.6 | Hg | 7587.4 | K |
| 3520.5 | Ne | 5790.7 | Hg | 7601.5 | K |
| 3593.5 | Ne | 5852.5 | Ne | 7635.1 | K |
| 3650.2 | Hg | 5870.9 | K | 7685.2 | K |
| 3654.4 | Hg | 5875.6 | He | 7694.5 | K |
| 3663.3 | Hg | 5881.9 | Ne | 7723.8 | A |
| 3888.7 | He | 5944.8 | Ne | 7854.8 | K |
| 3949.0 | A | 5975.5 | Ne | 7948.2 | A |
| 3964.7 | He | 6030.0 | Ne | 8006.2 | A |
| 4026.2 | He | 6074.3 | Ne | 8014.8 | A |
| 4044.4 | A | 6096.2 | Ne | 8059.5 | K |
| 4046.6 | Hg | 6143.1 | Ne | 8103.7 | A |
| 4077.8 | Hg | 6163.6 | Ne | 8104.4 | K |
| 4120.8 | He | 6217.3 | Ne | 8112.9 | K |
| 4158.6 | A | 6266.5 | Ne | 8115.3 | A |
| 4164.2 | A | 6304.8 | Ne | 8190.1 | K |
| 4181.9 | A | 6334.4 | Ne | 8231.6 | Xe |
| 4191.0 | A | 6383.0 | Ne | 8263.2 | K |
| 4198.3 | A | 6402.3 | Ne | 8264.5 | A |
| 4200.7 | A | 6506.5 | Ne | 8280.1 | Xe |
| 4259.4 | A | 6532.9 | Ne | 8298.1 | K |
| 4272.2 | A | 6599.0 | Ne | 8377.6 | Ne |
| 4274.0 | Kr | 6678.2 | He | 8408.2 | A |
| 4300.1 | A | 6678.3 | Ne | 8424.6 | A |

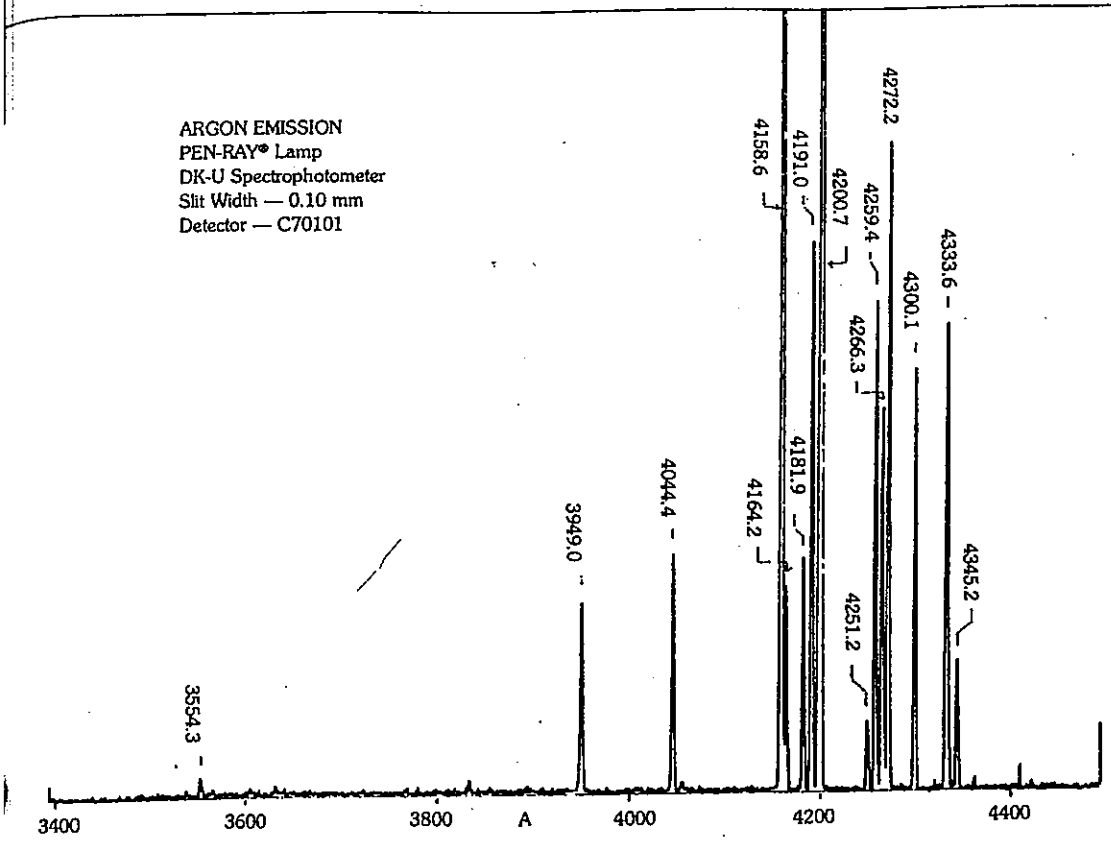
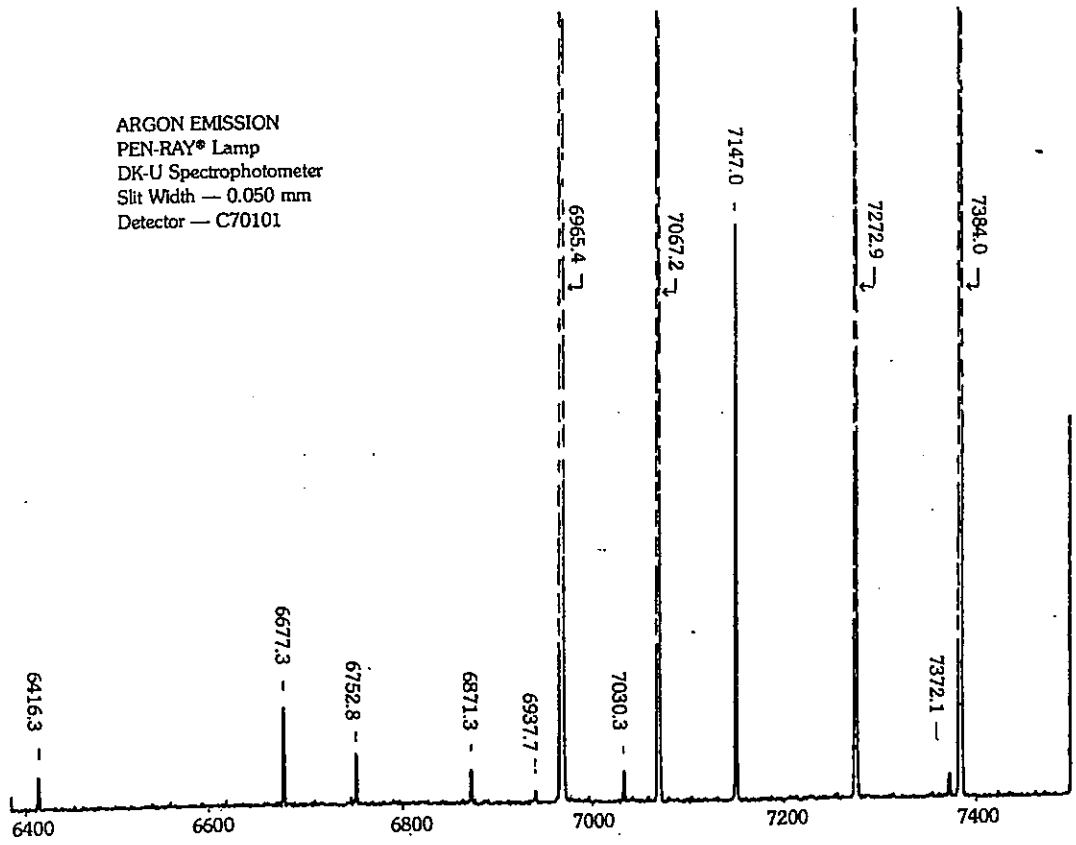



FIGURE 1

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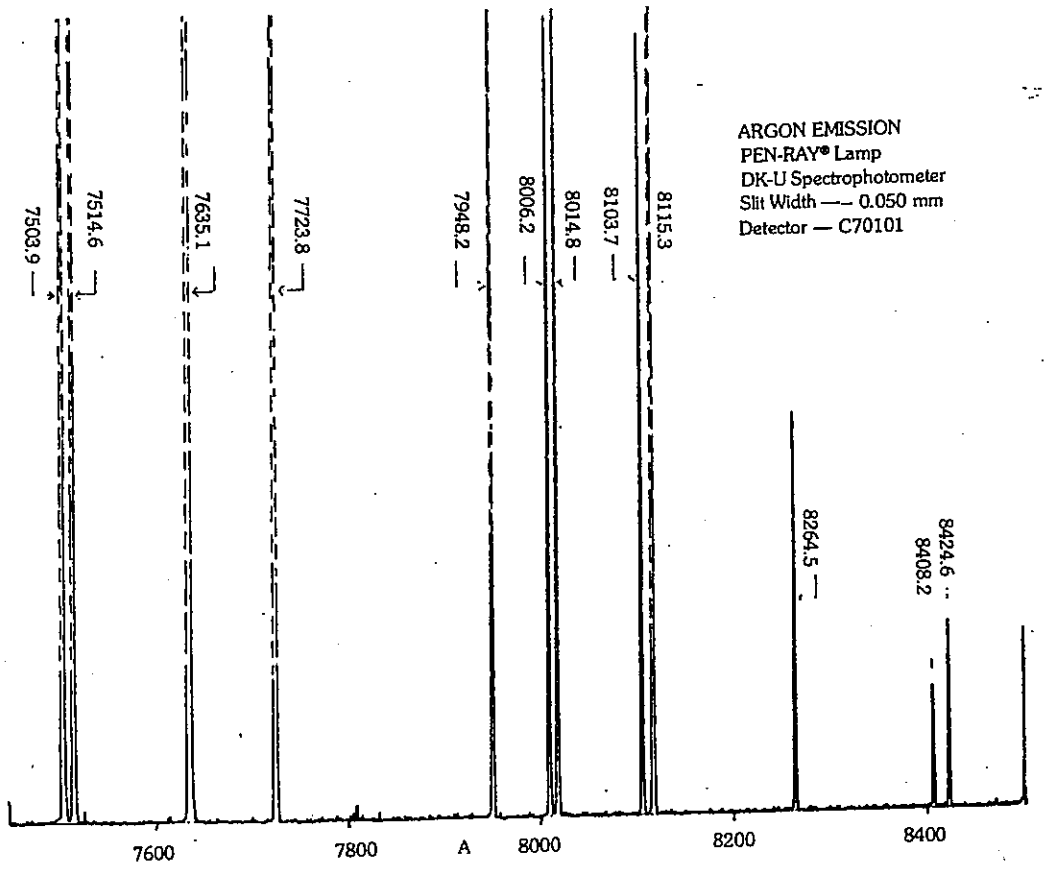


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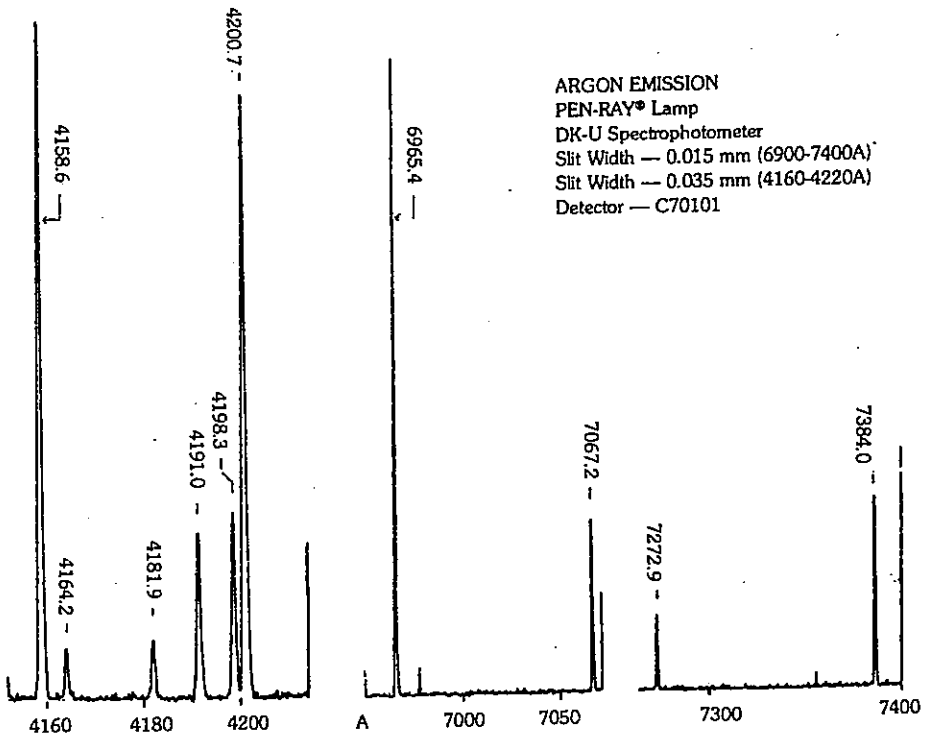


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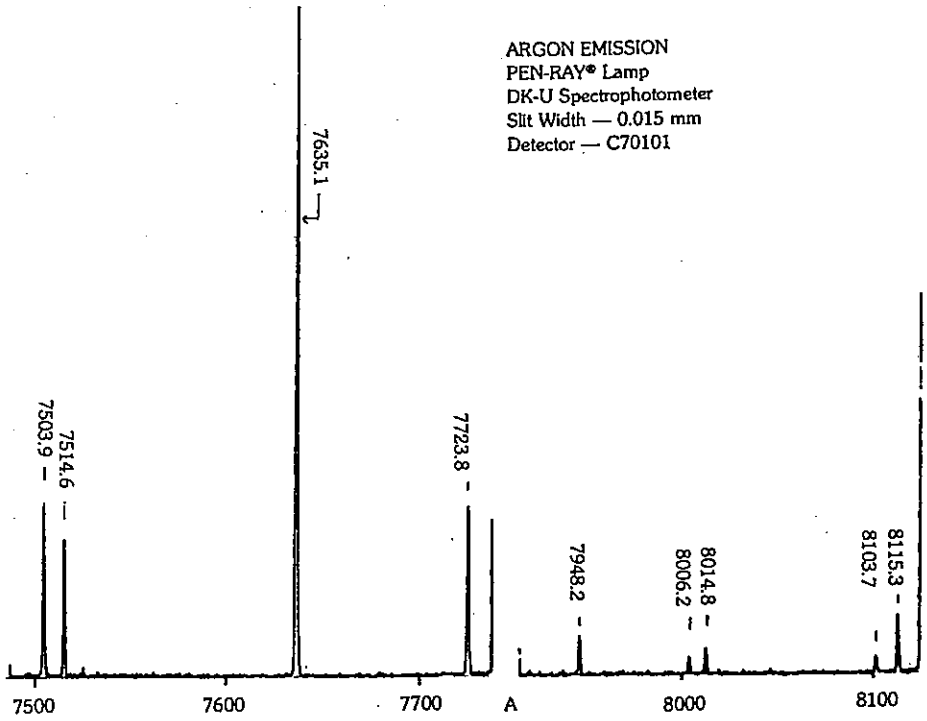


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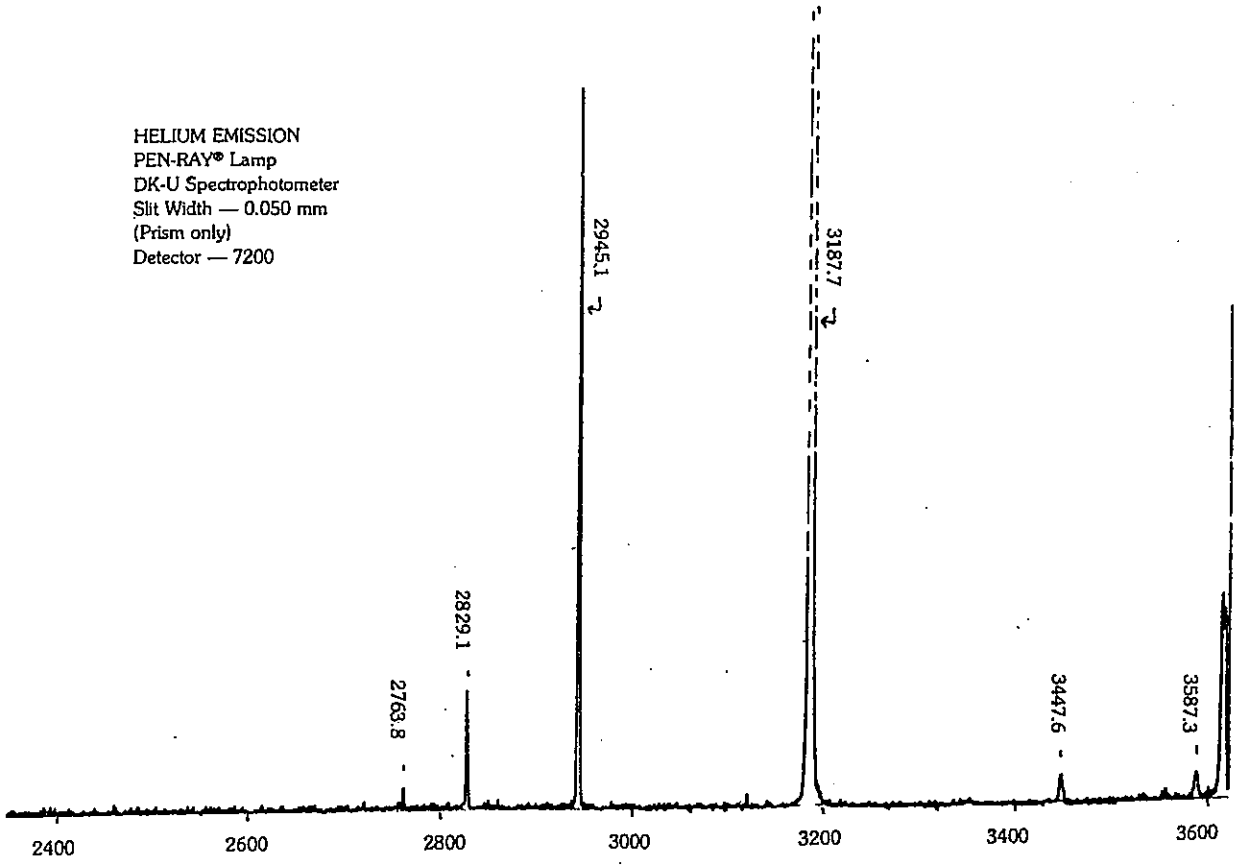
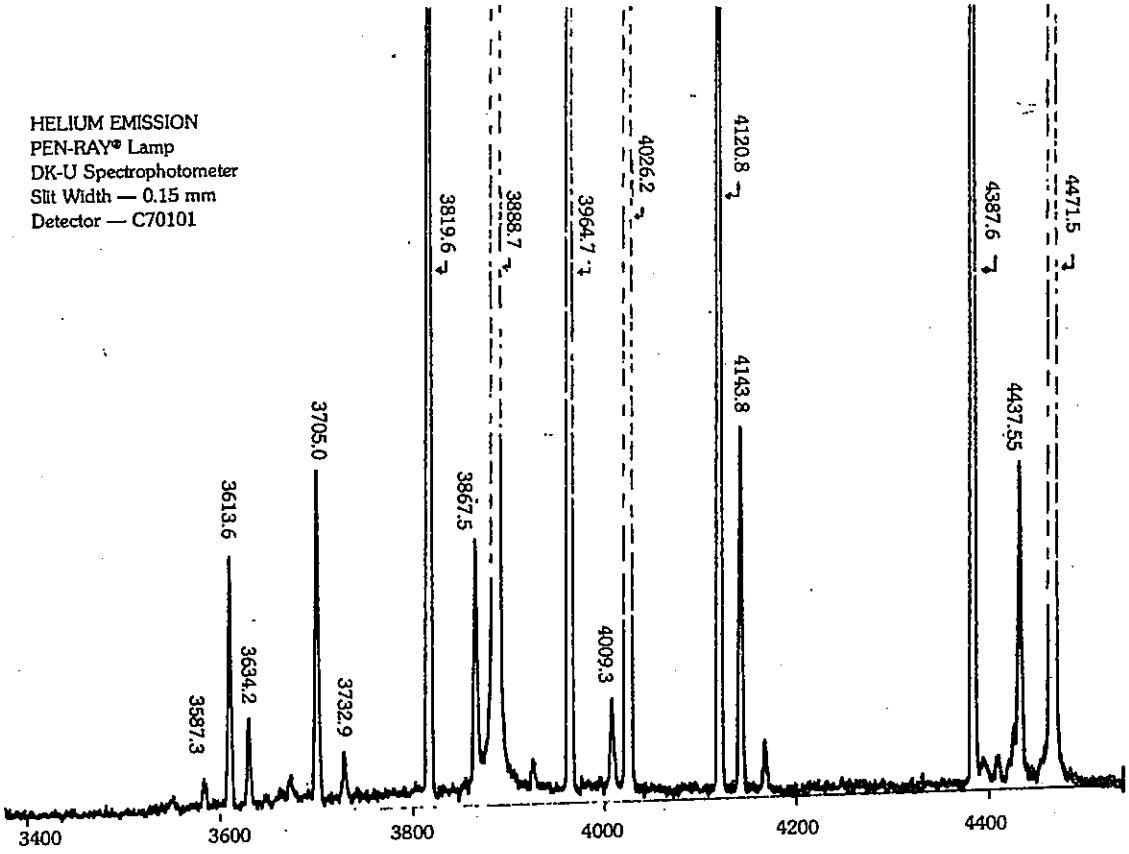



FIGURE 6

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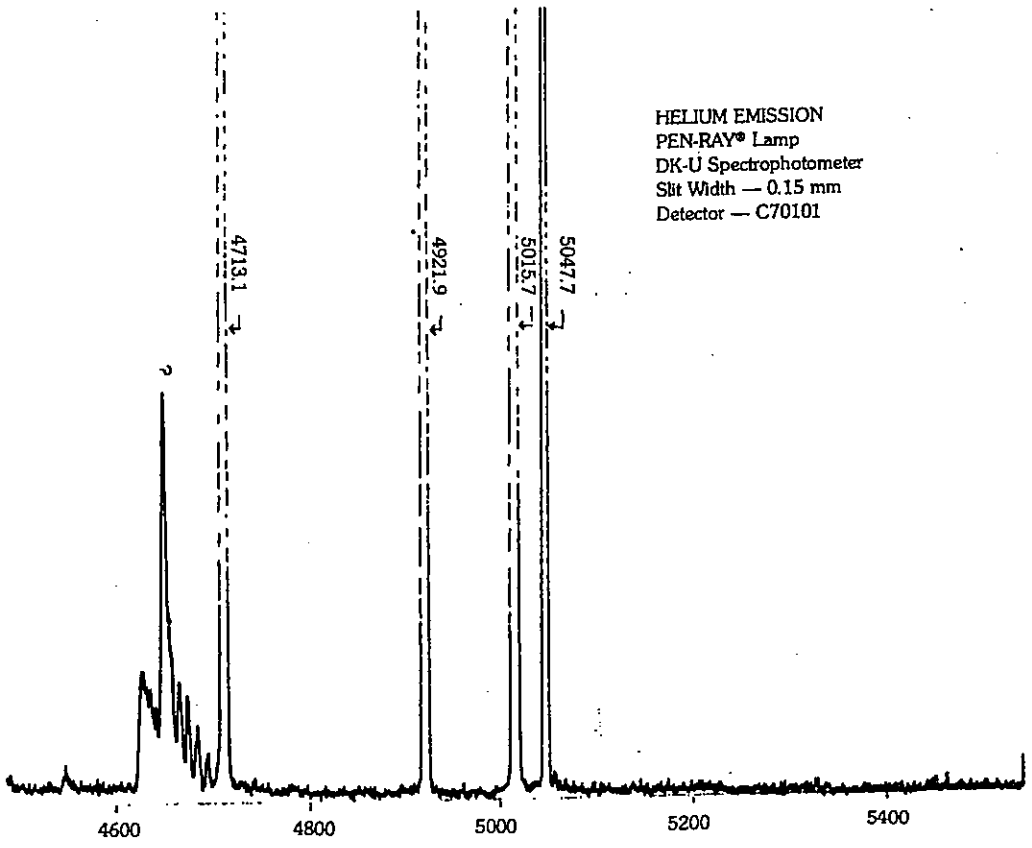


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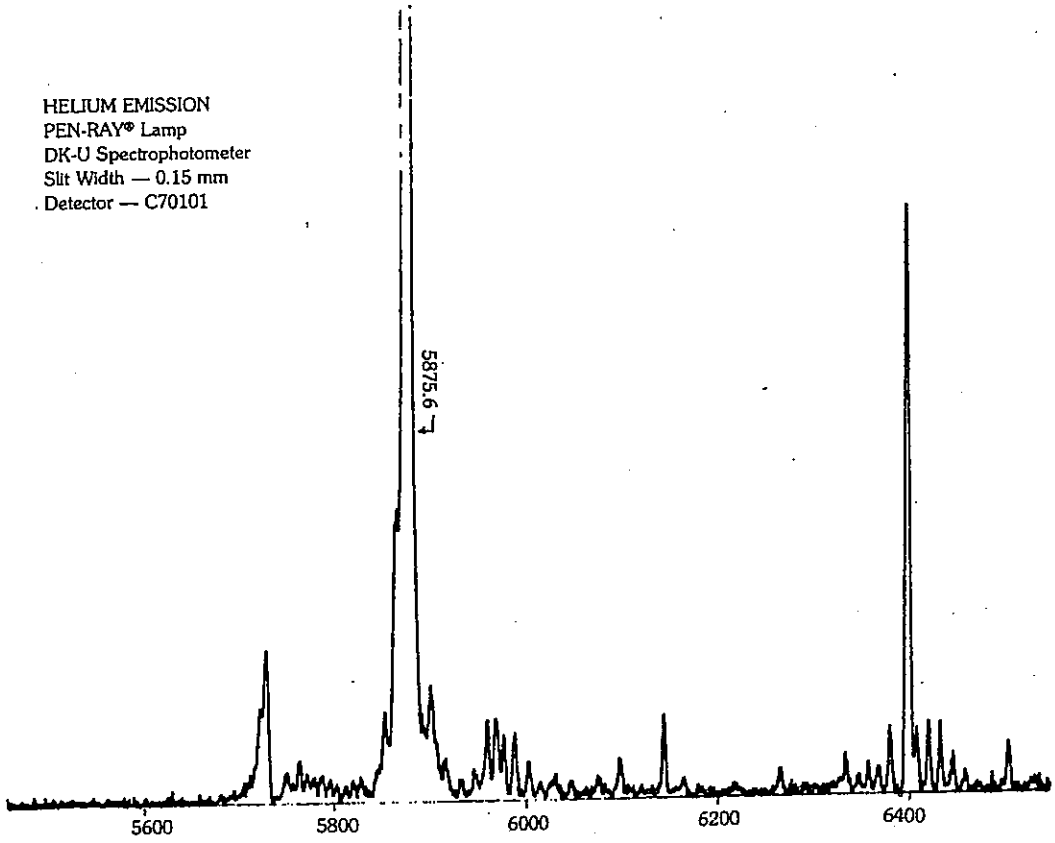


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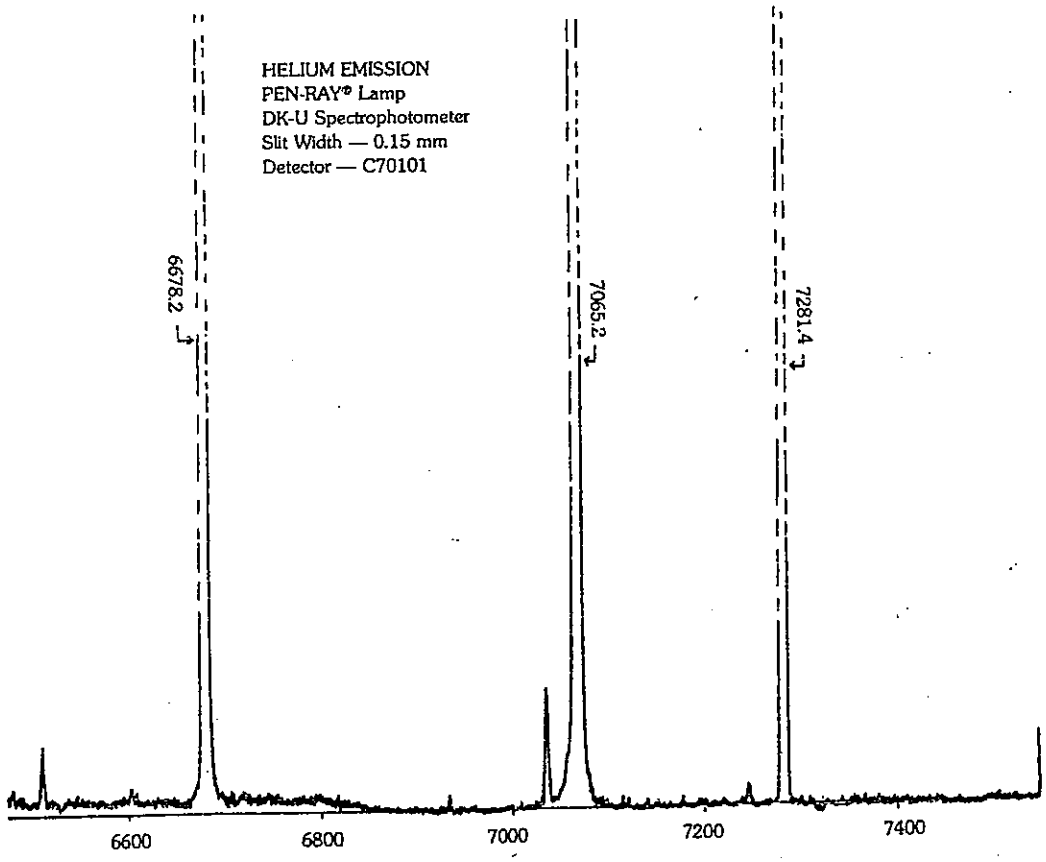


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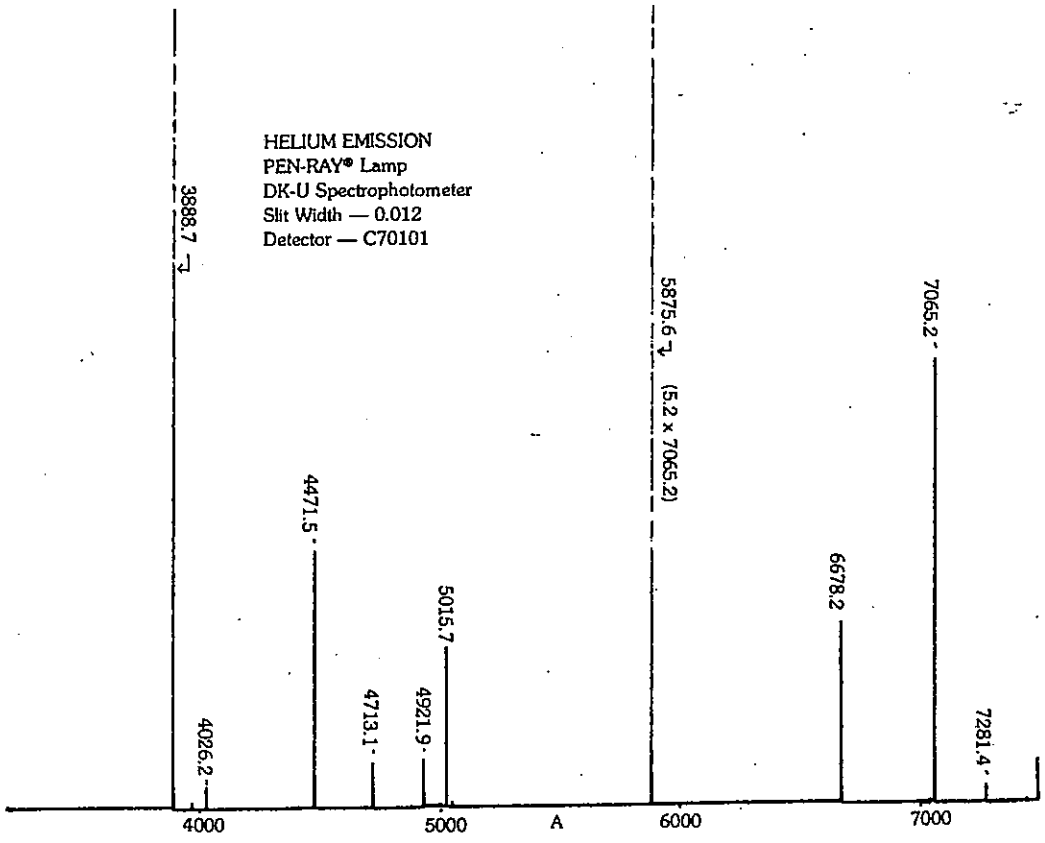


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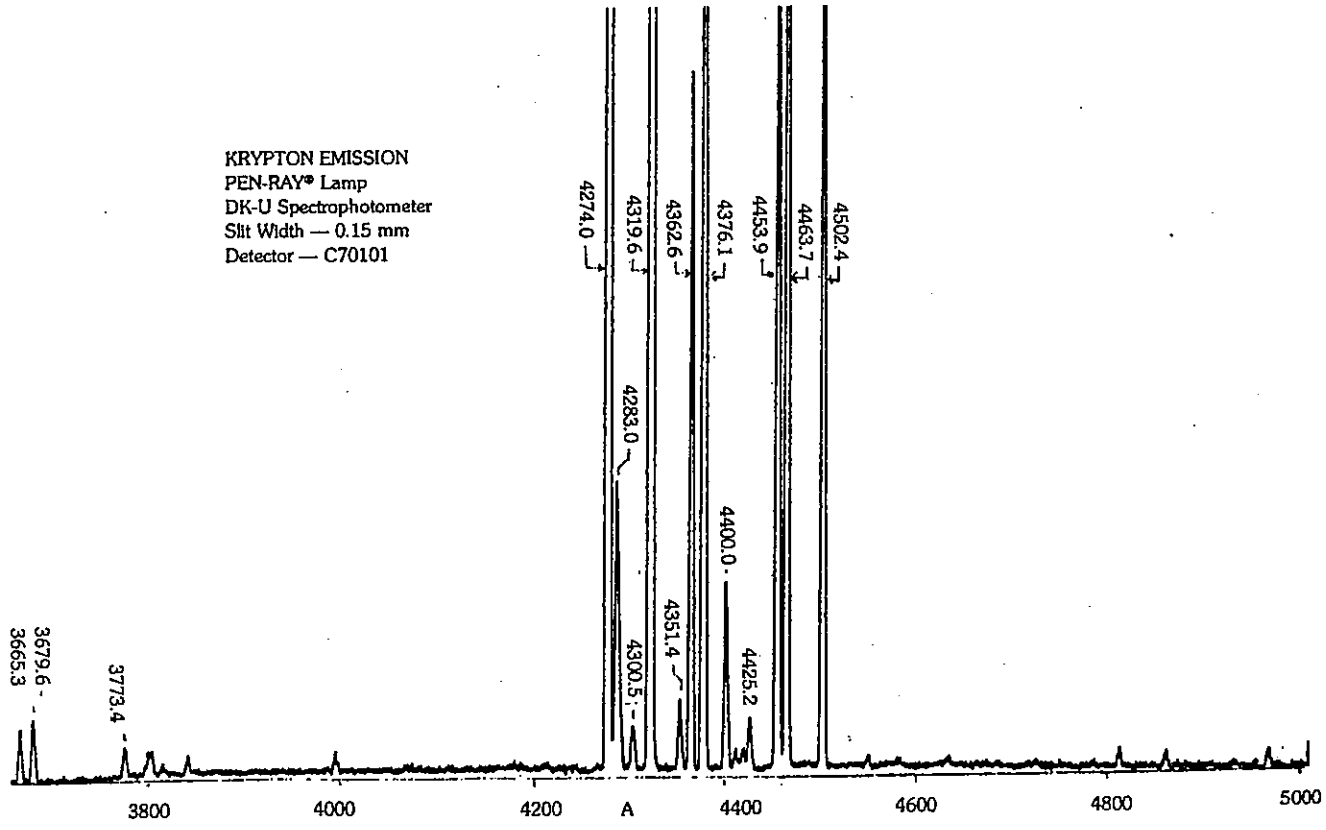
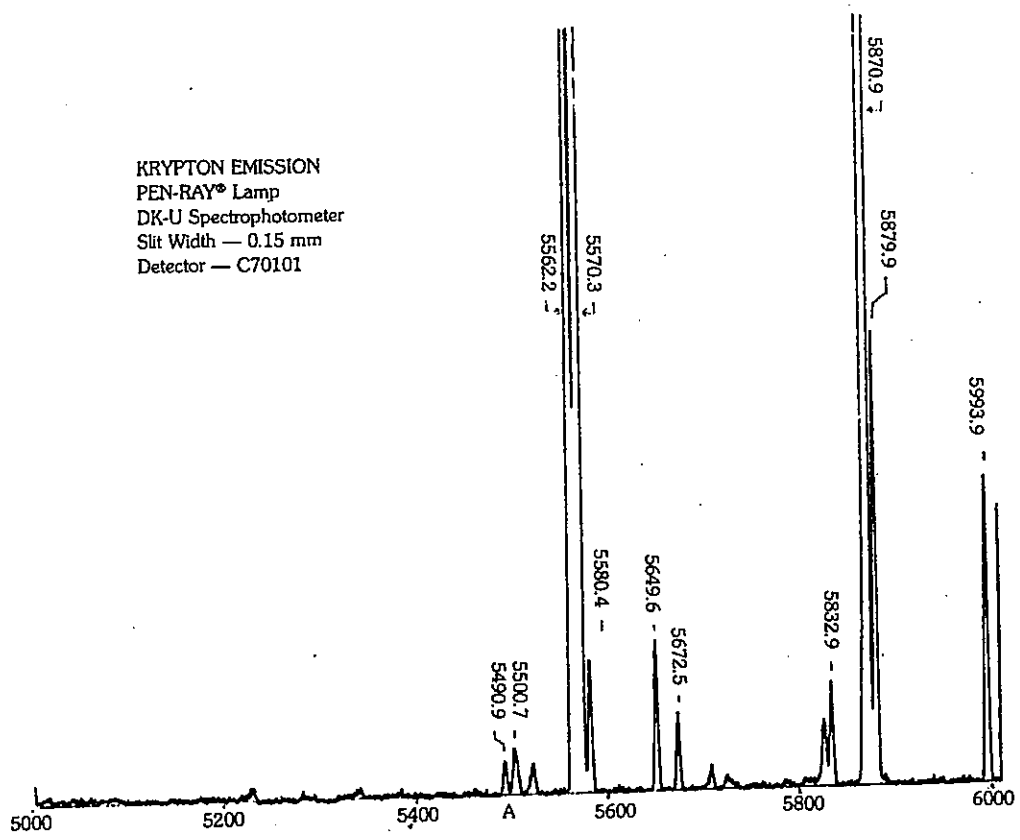



FIGURE 12

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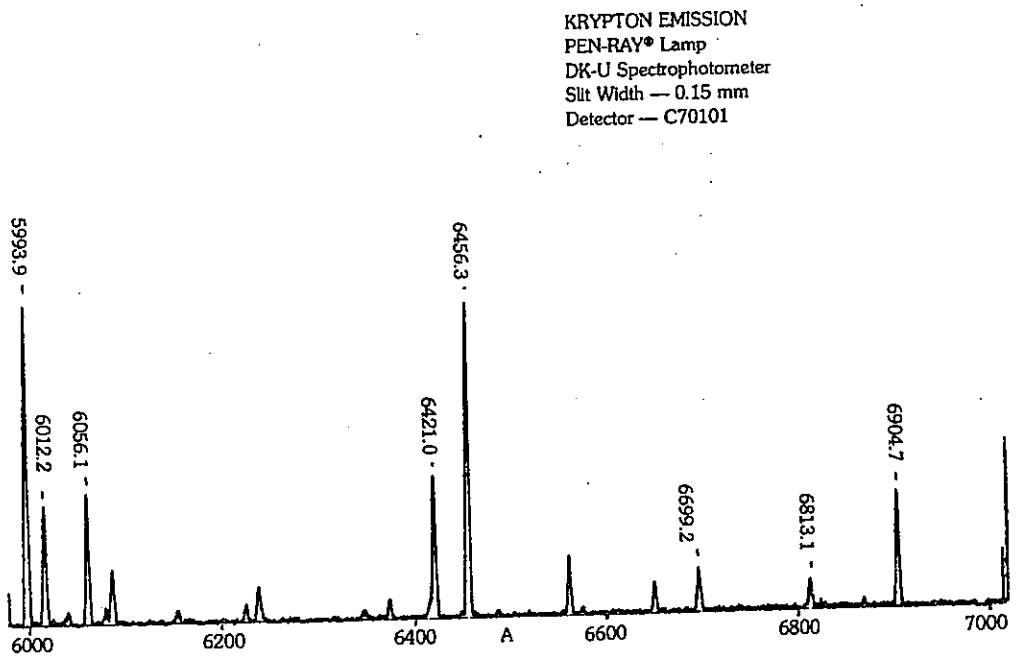


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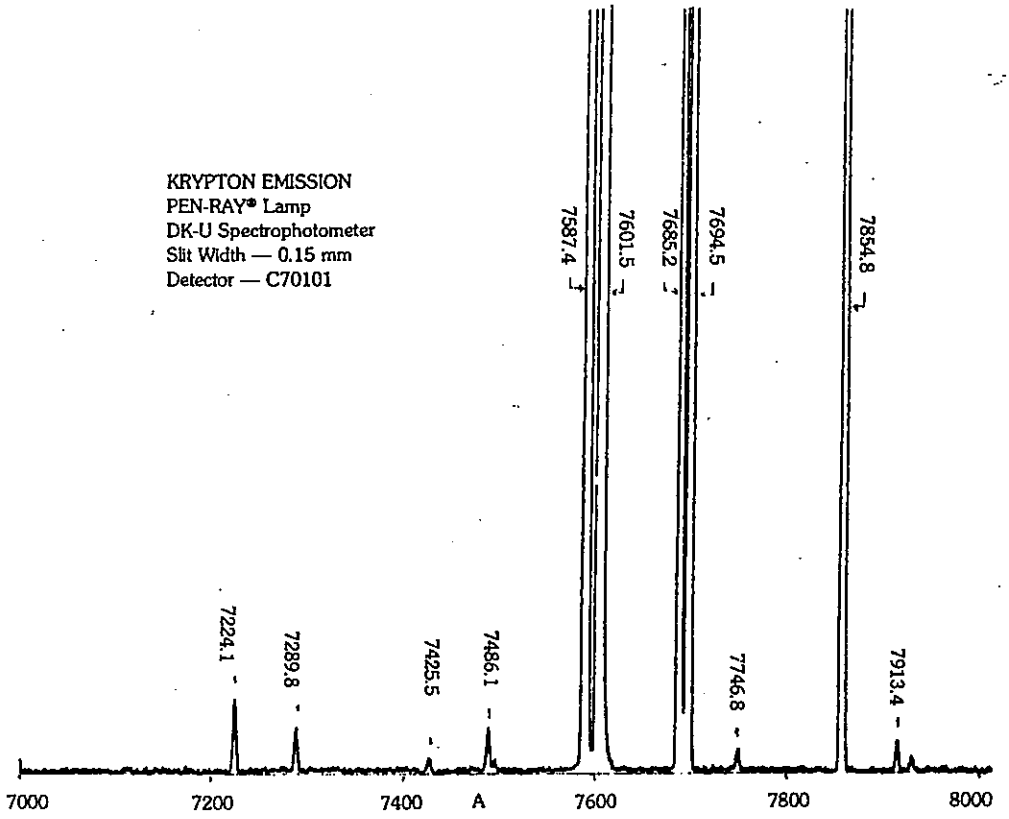


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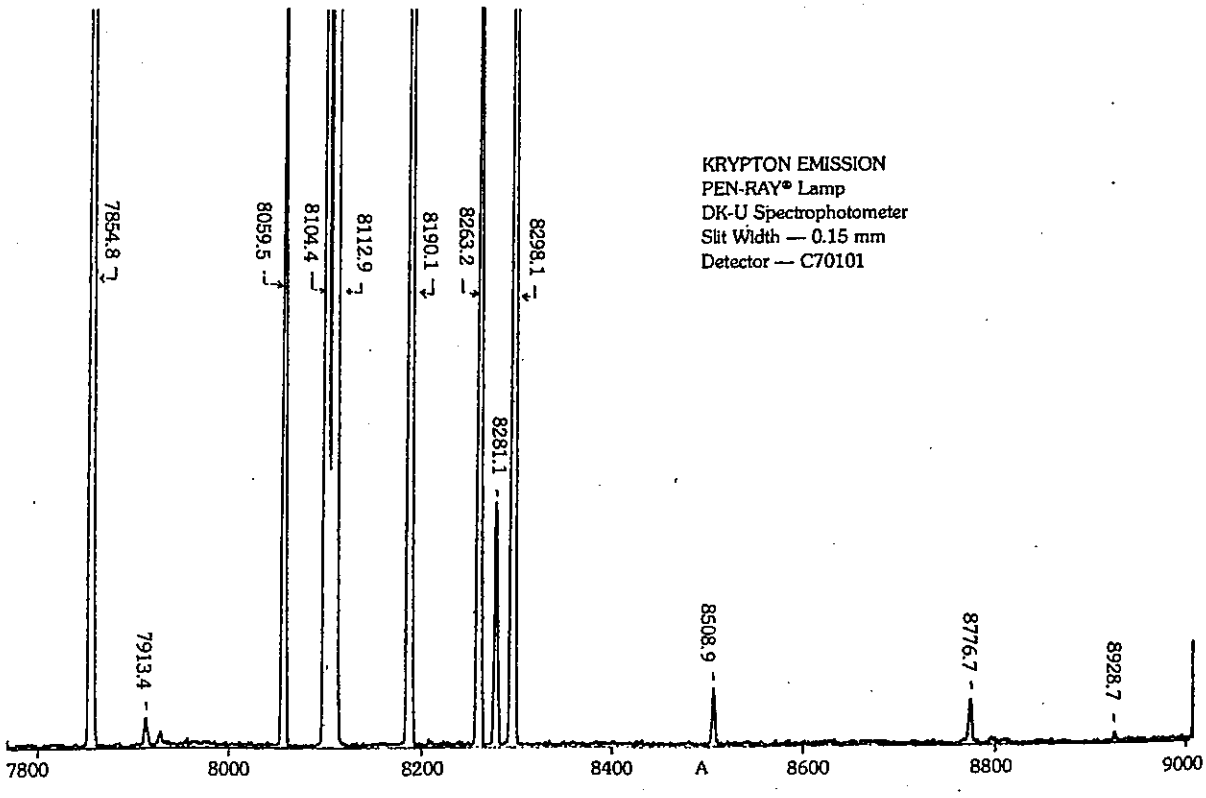


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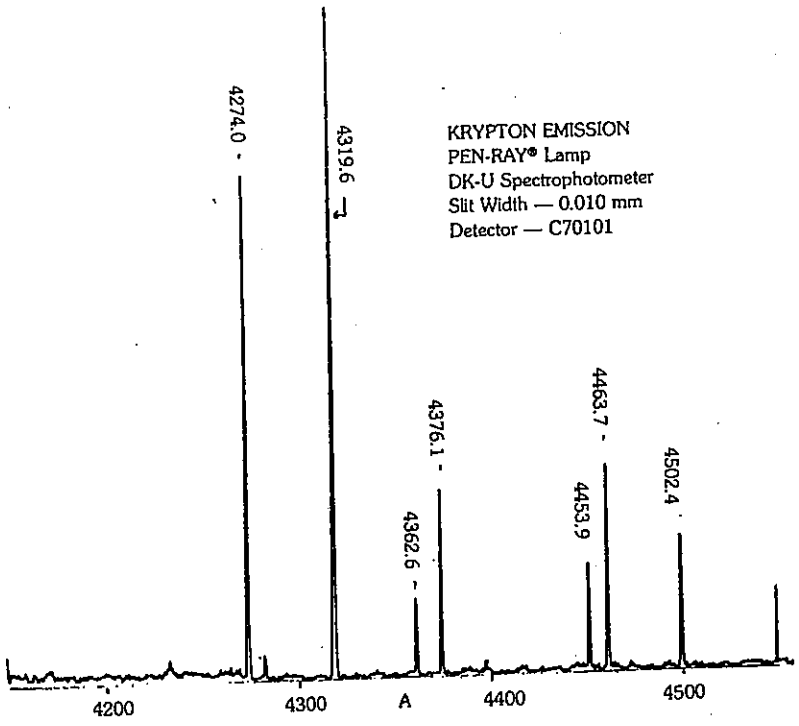


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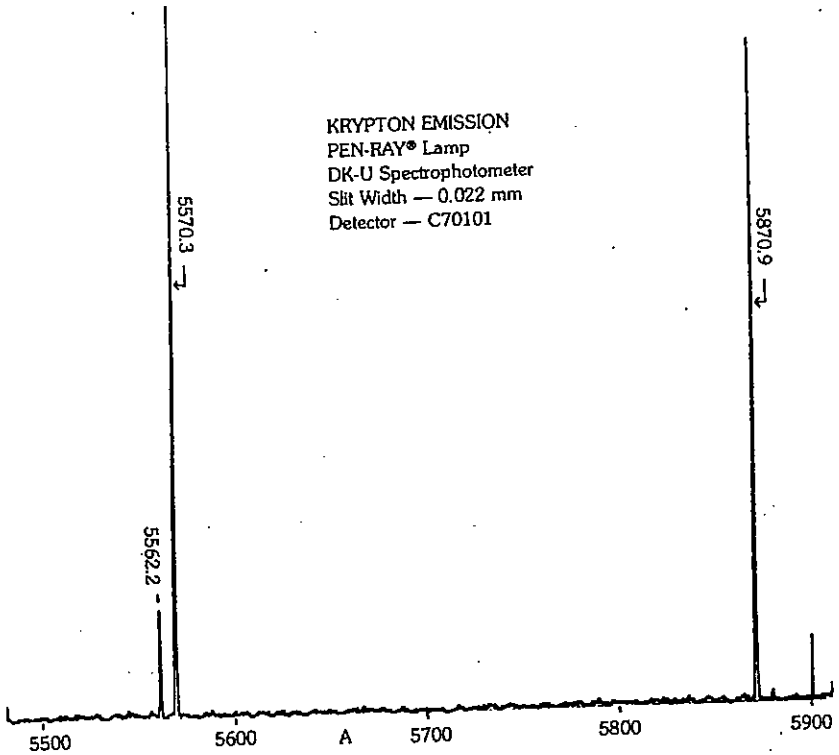


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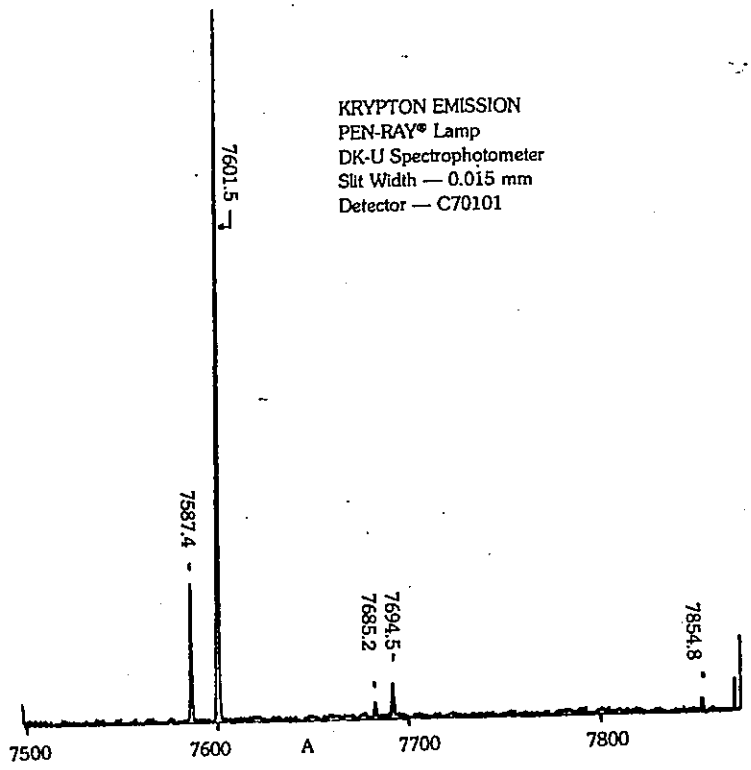


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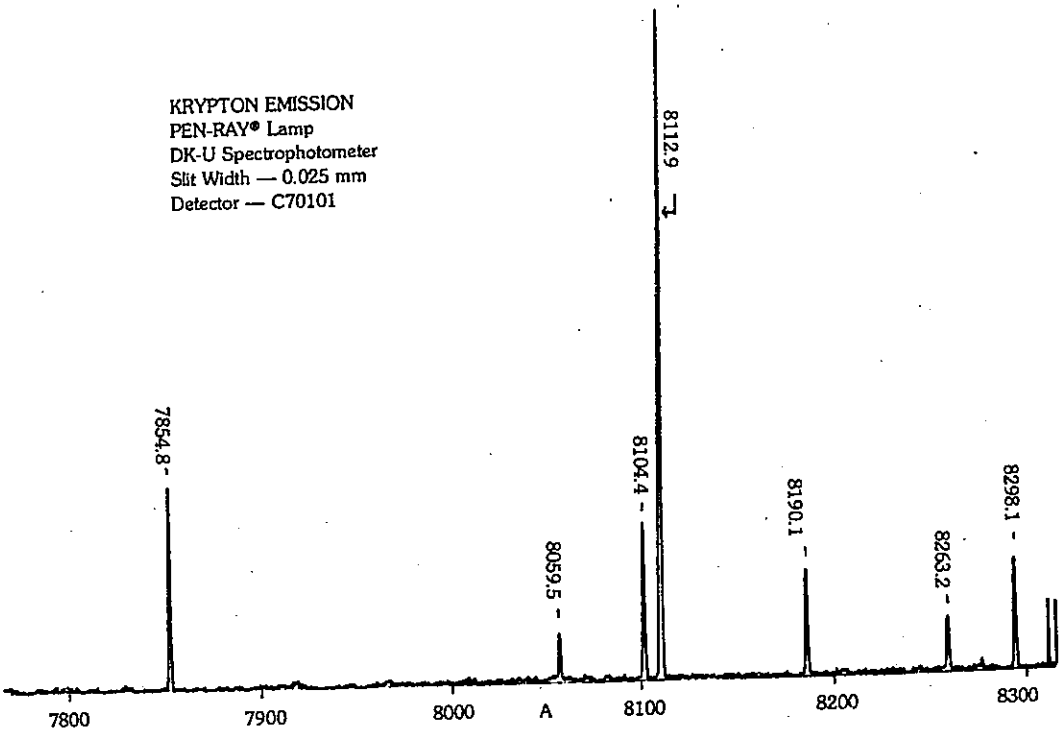



FIGURE 20

NEON EMISSIN
PEN-RAY® Lamp
DK-U Spectrophotometer
Slit Width 0.10 mm (2nd order)
Detector 1P28

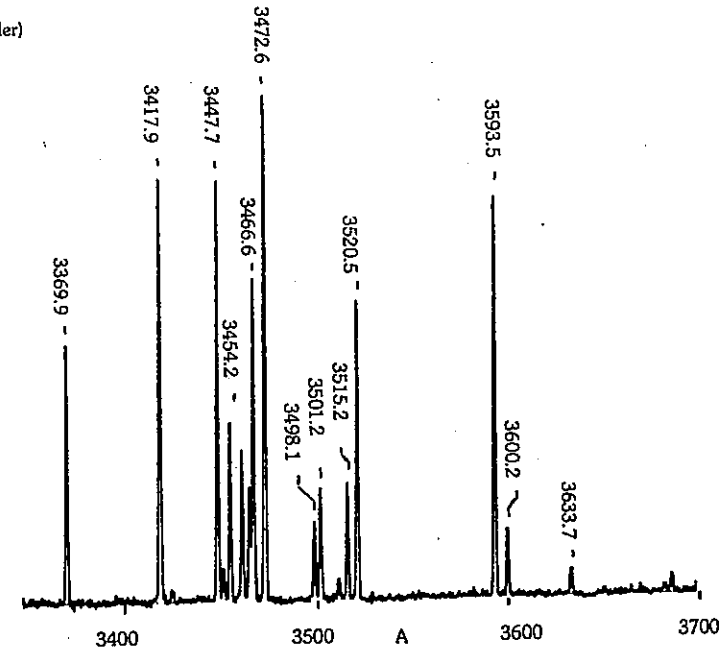
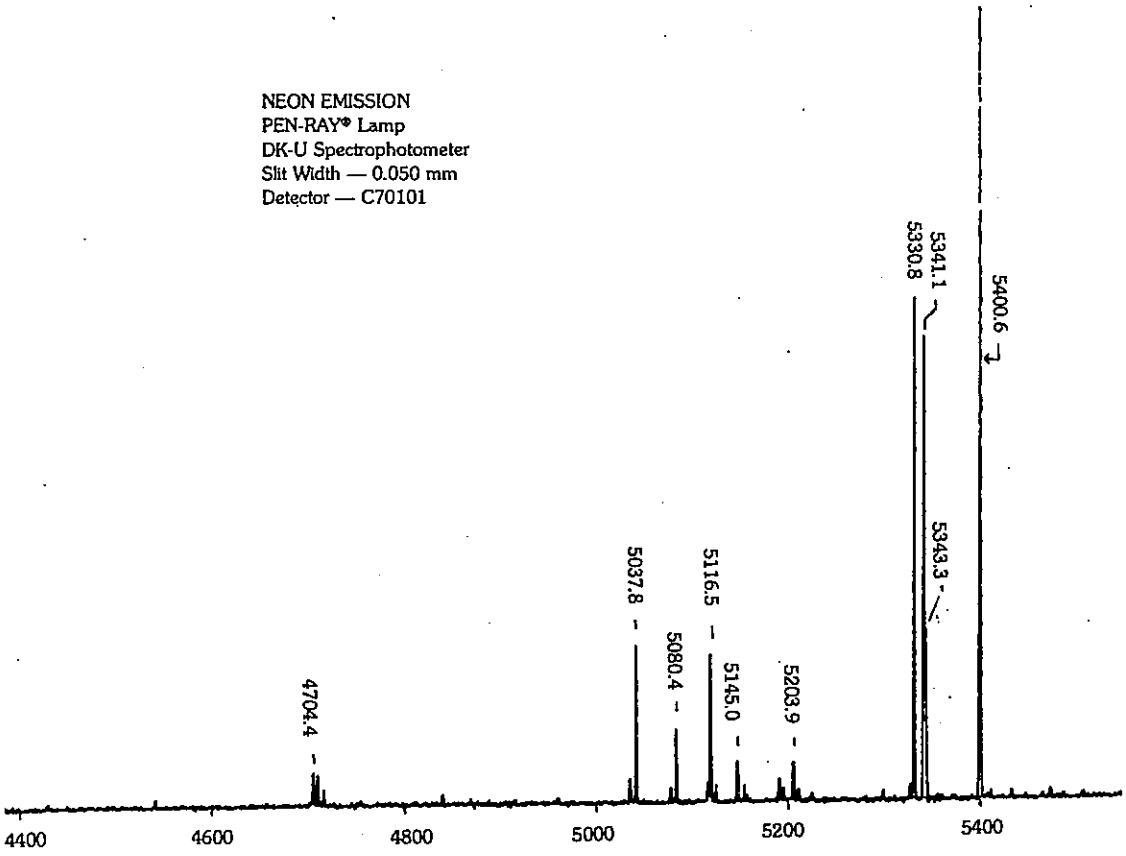



FIGURE 21

NEON EMISSION
PEN-RAY® Lamp
DK-U Spectrophotometer
Slit Width — 0.050 mm
Detector — C70101

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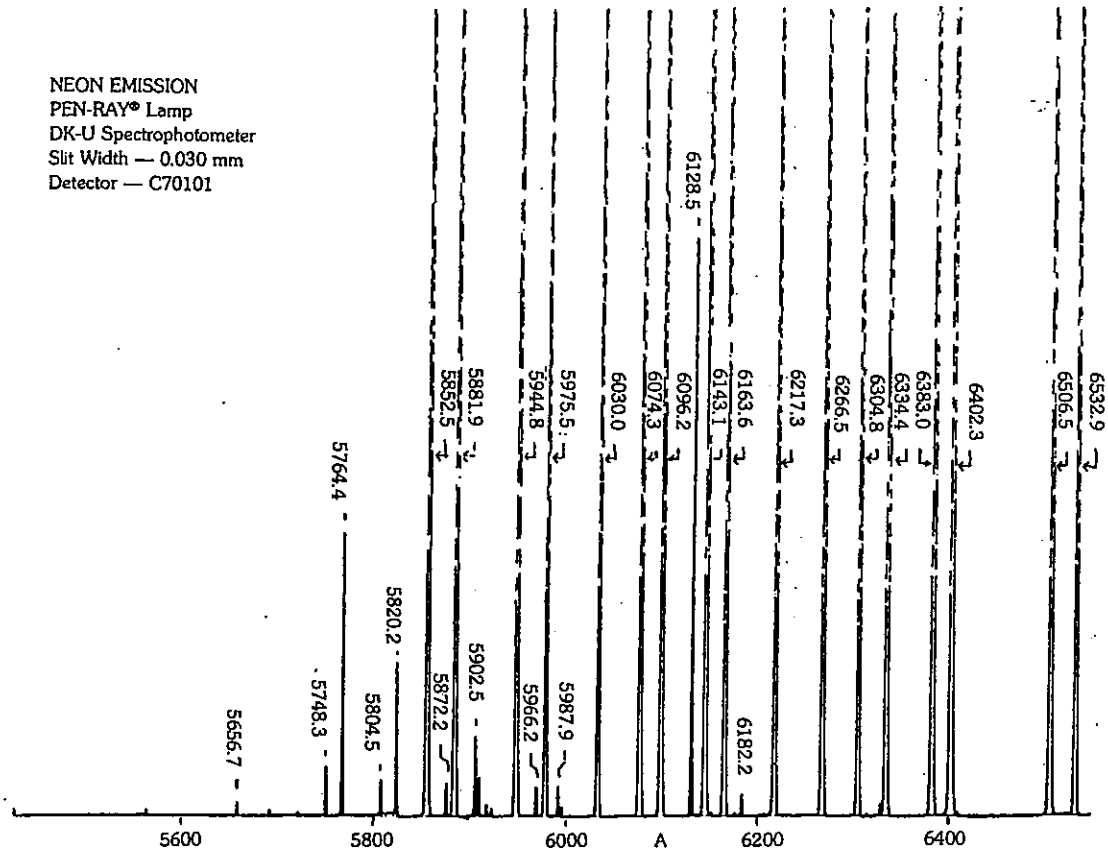


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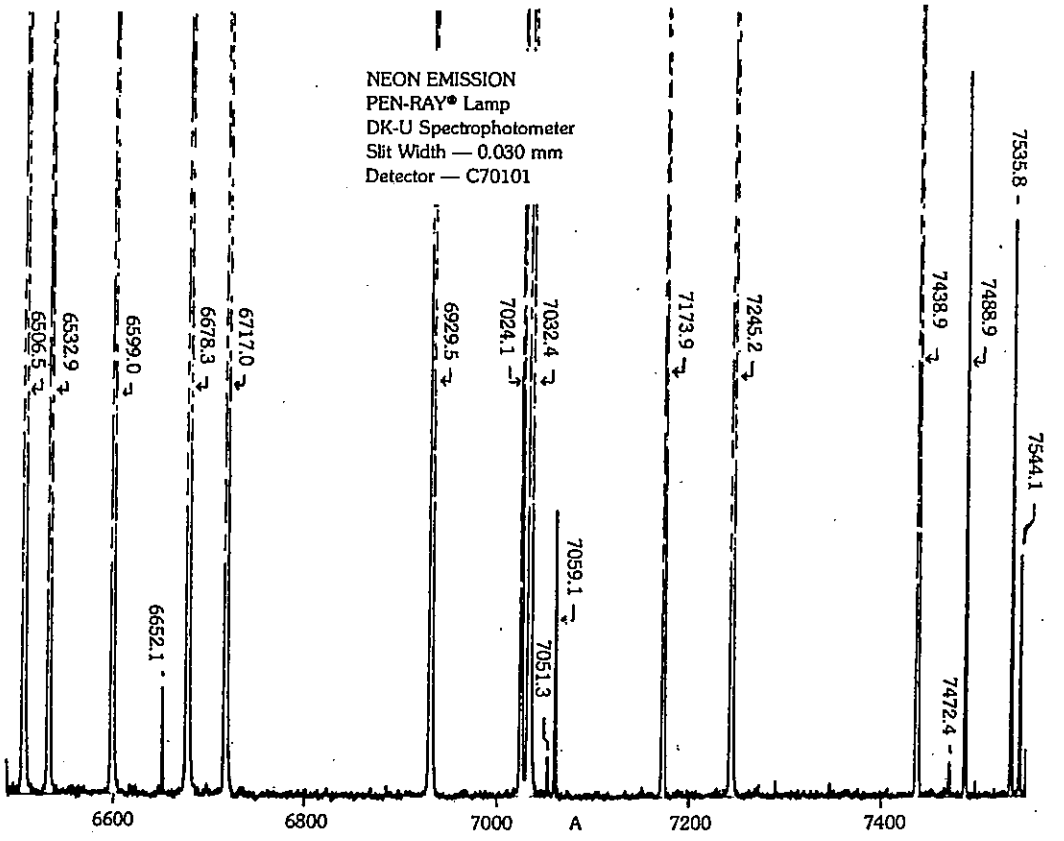


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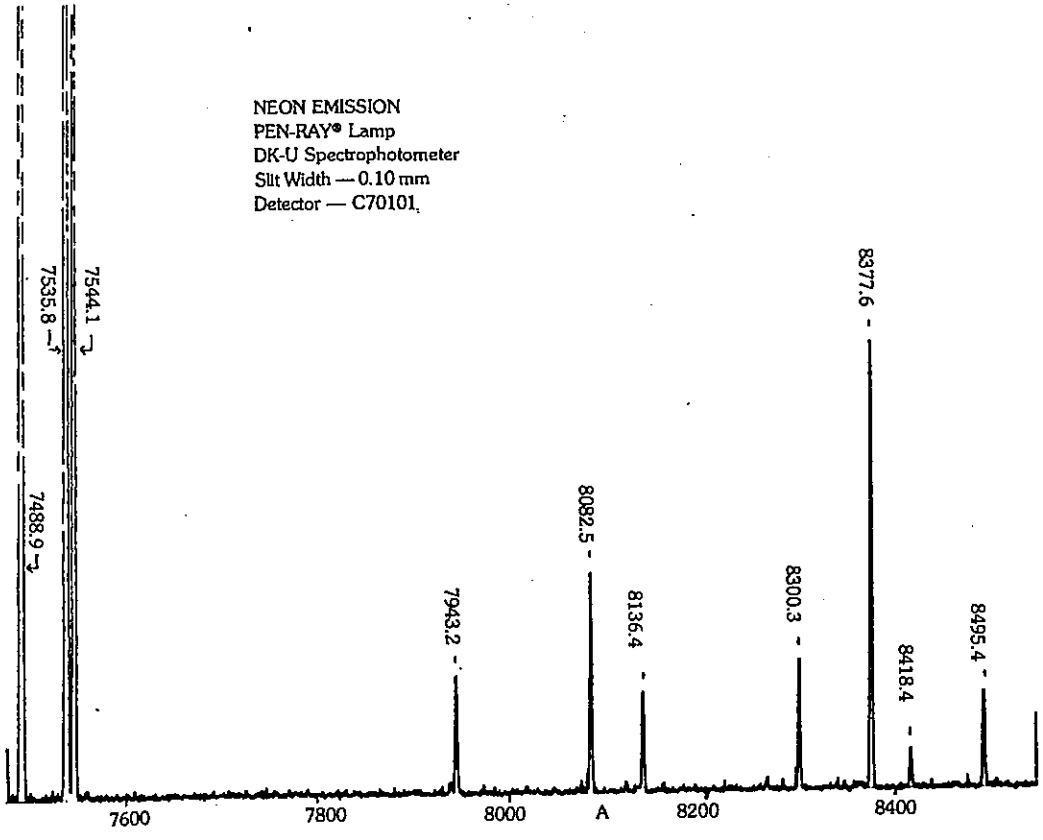


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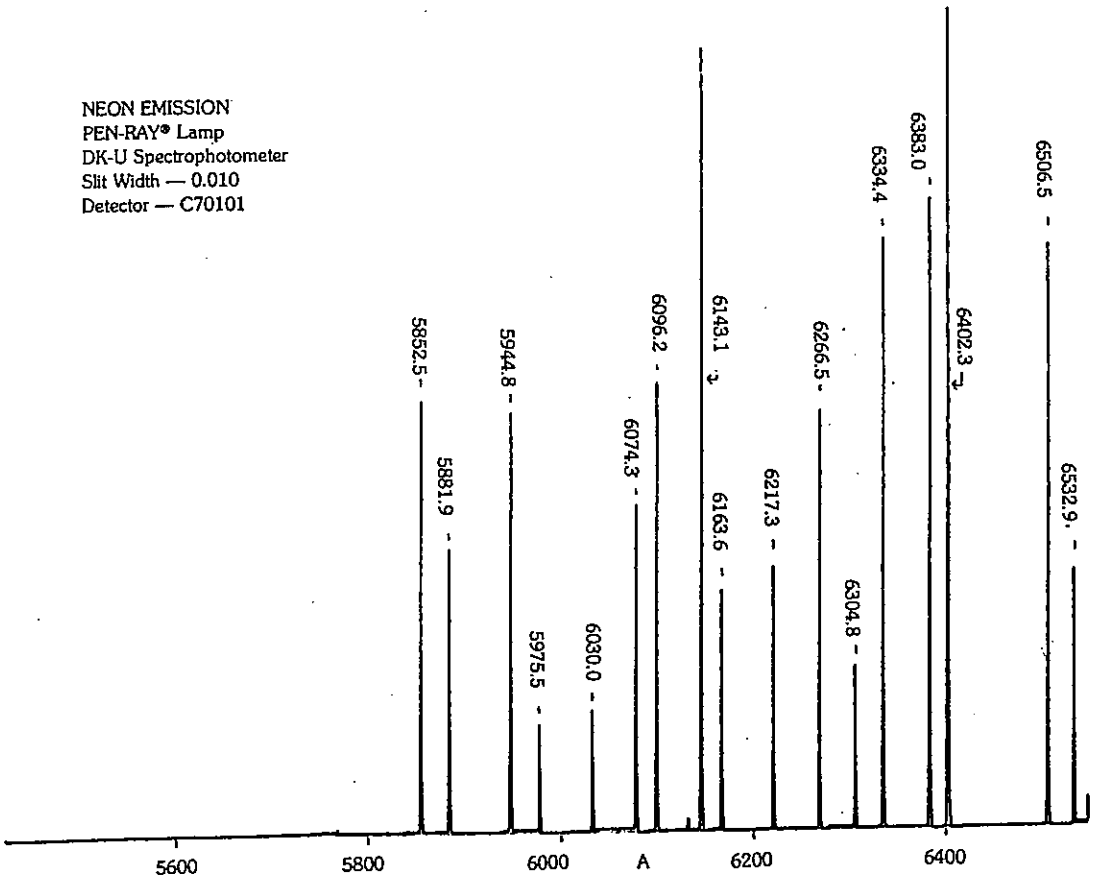


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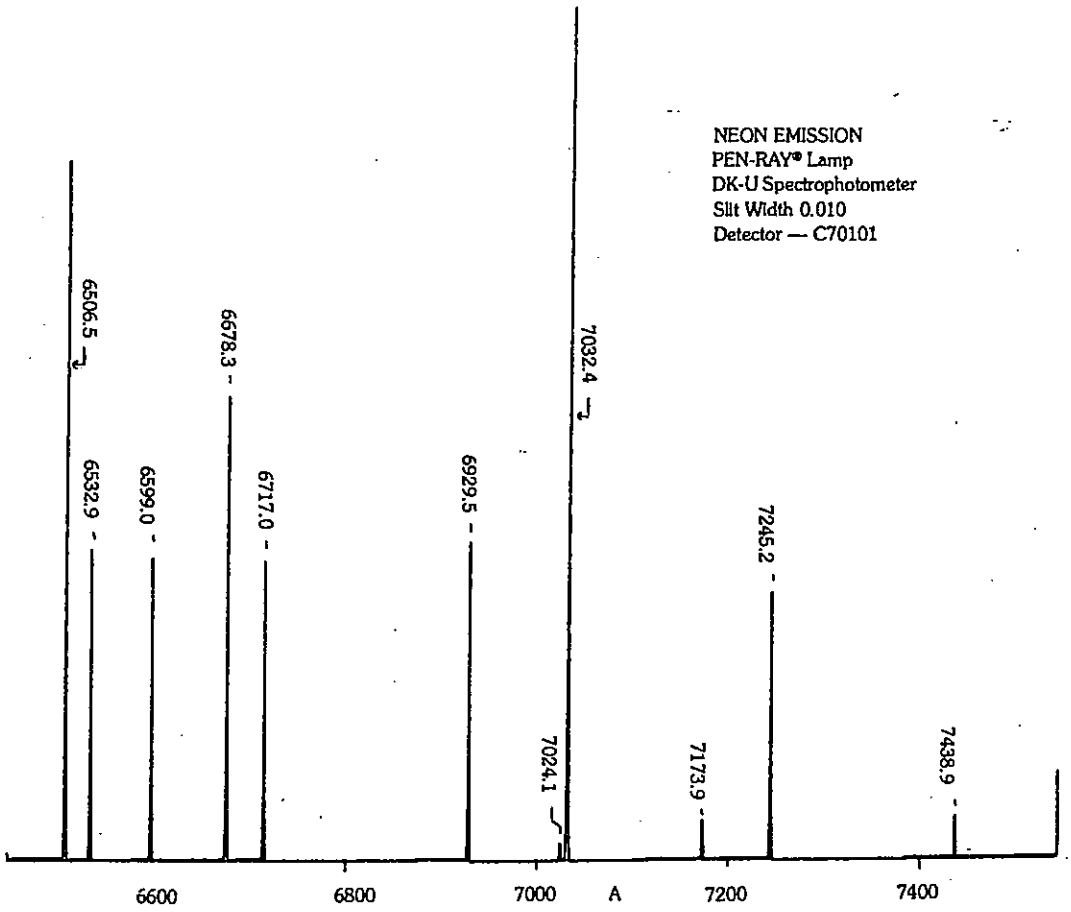


FIGURE 27

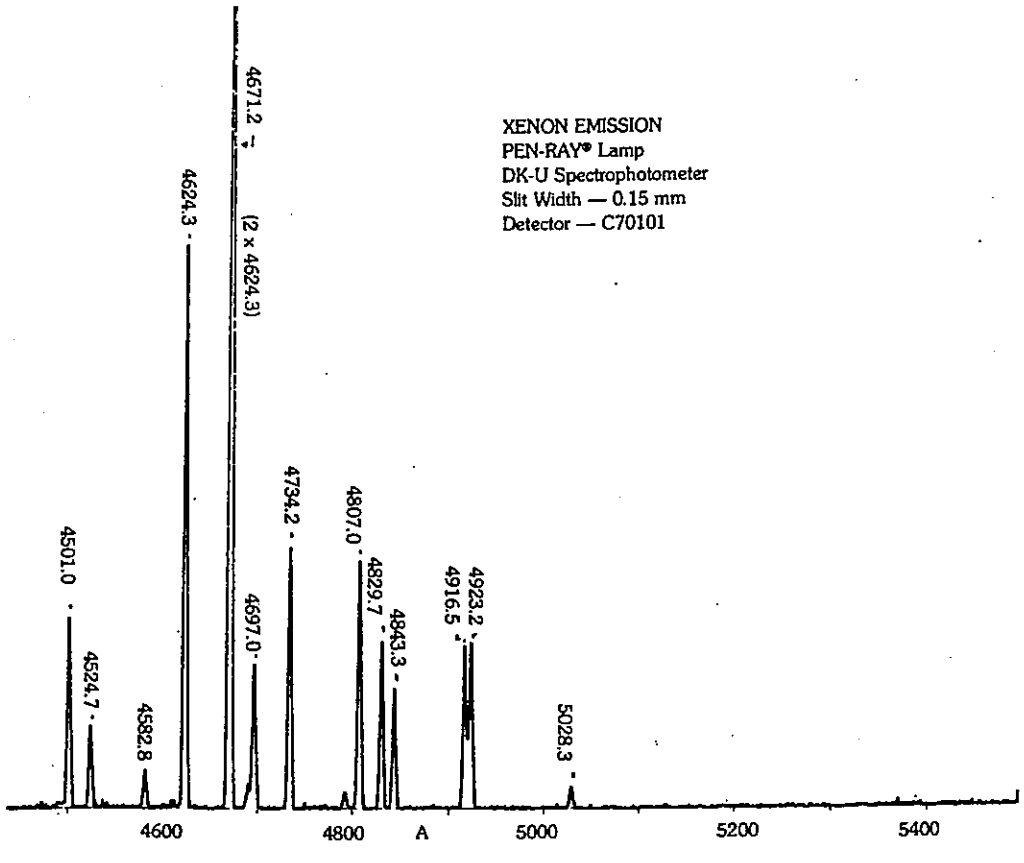


FIGURE 28

XENON EMISSION
PEN-RAY® Lamp
DK-U Spectrophotometer
Slit Width 0.15 mm
Detector — C70101

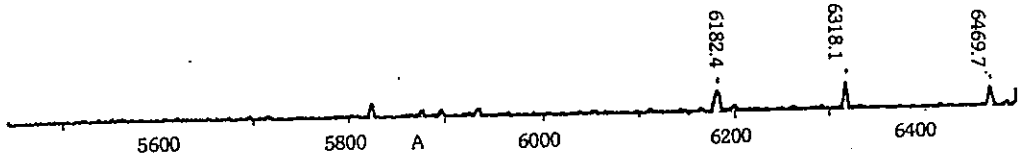


FIGURE 29

XENON EMISSION
PEN-RAY® Lamp
DK-U Spectrophotometer
Slit Width — 0.15 mm
Detector — C70101

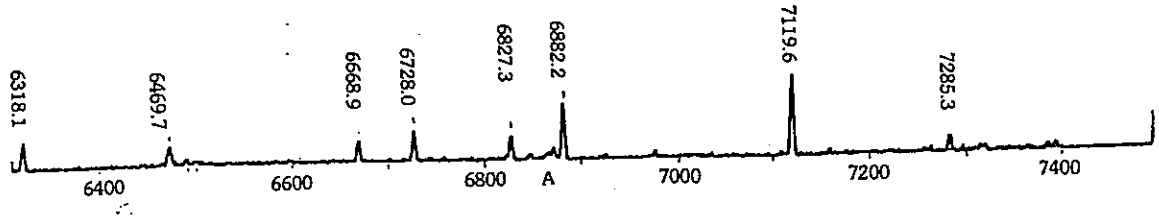


FIGURE 30

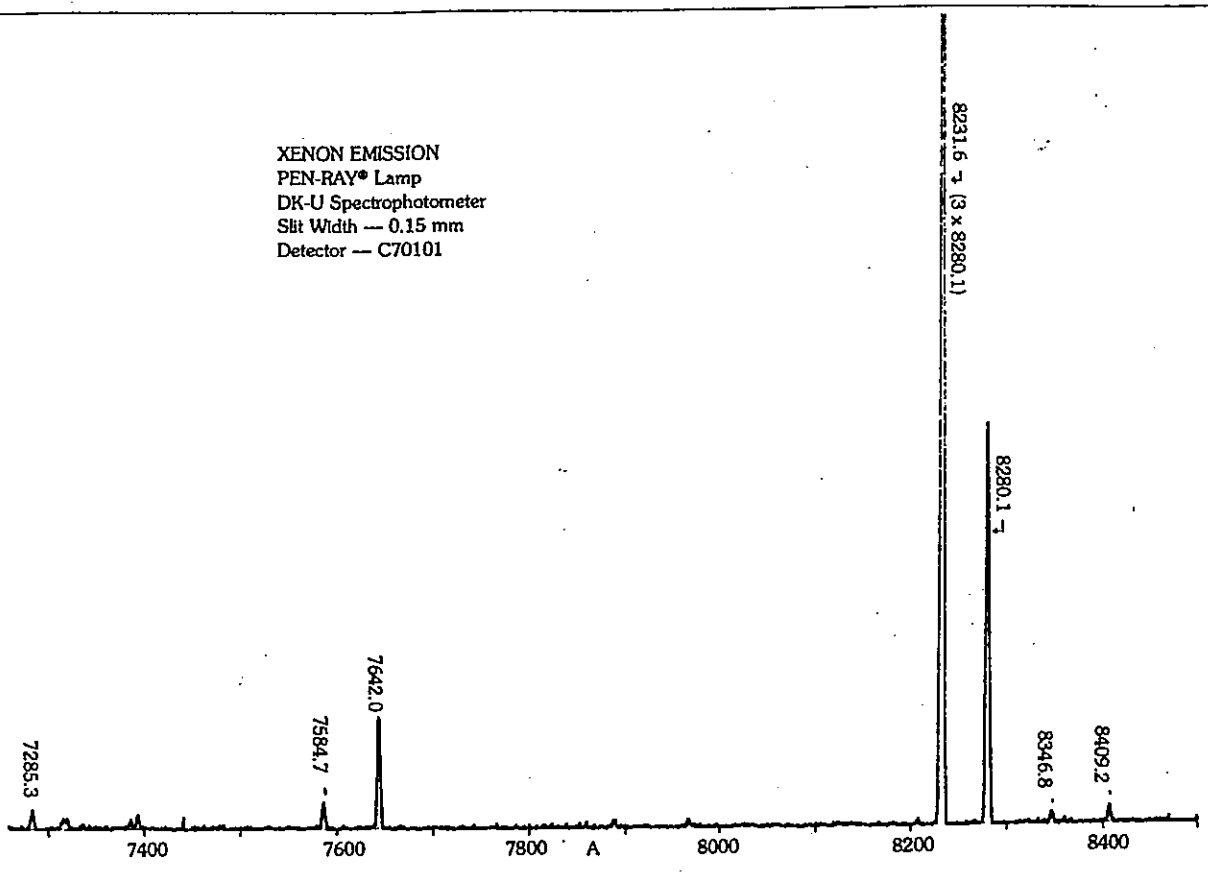


FIGURE 31

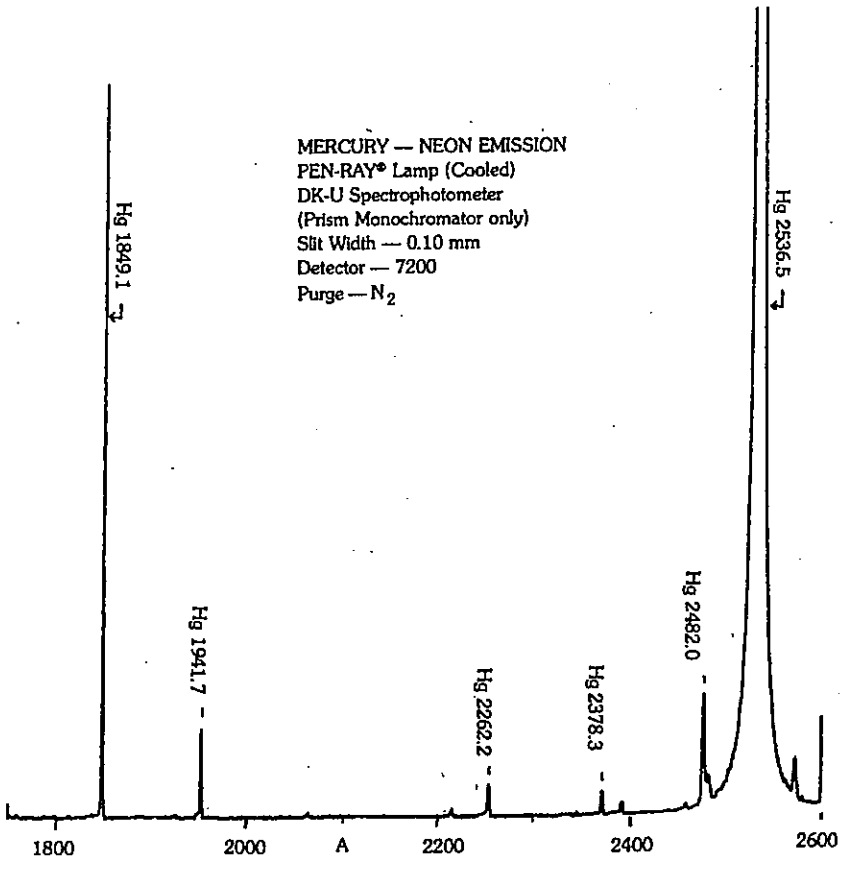


FIGURE 32

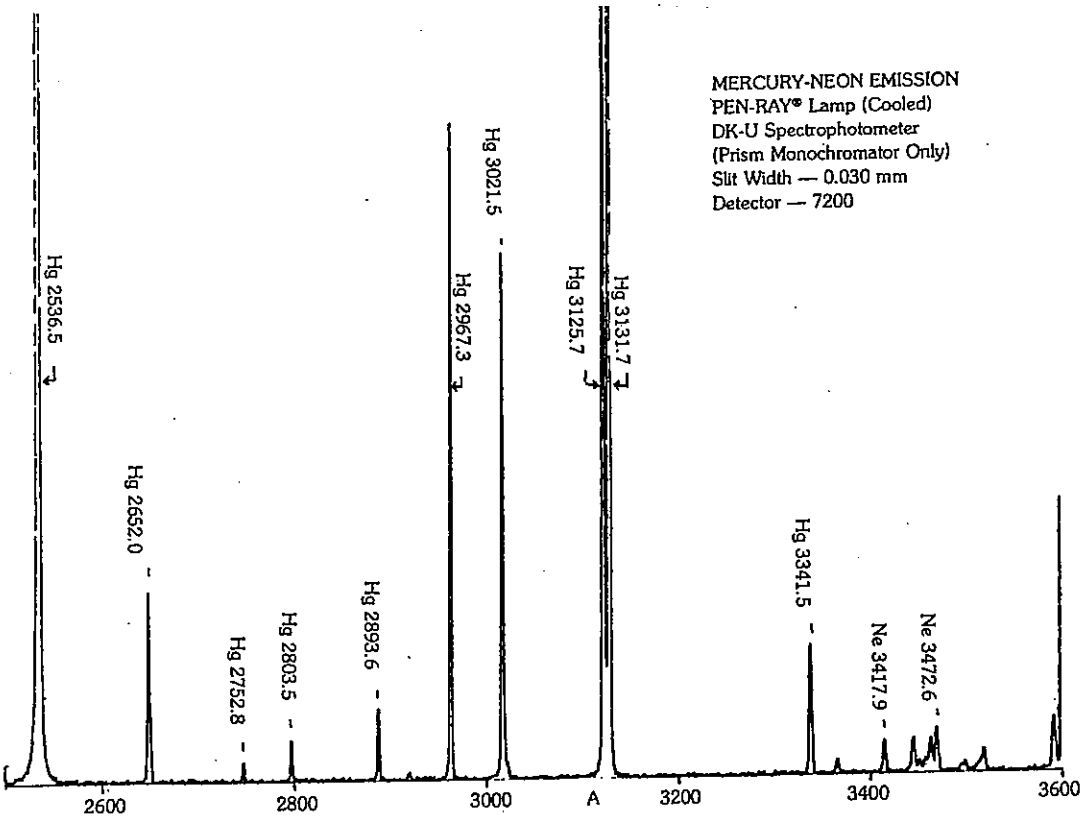


FIGURE 33

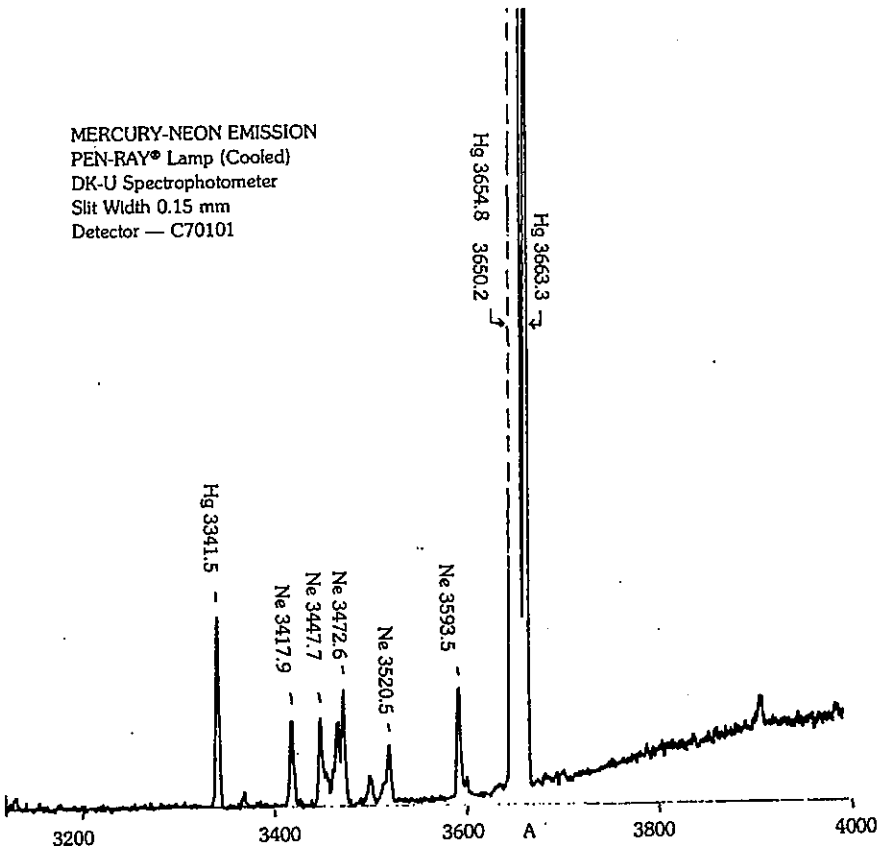


FIGURE 34

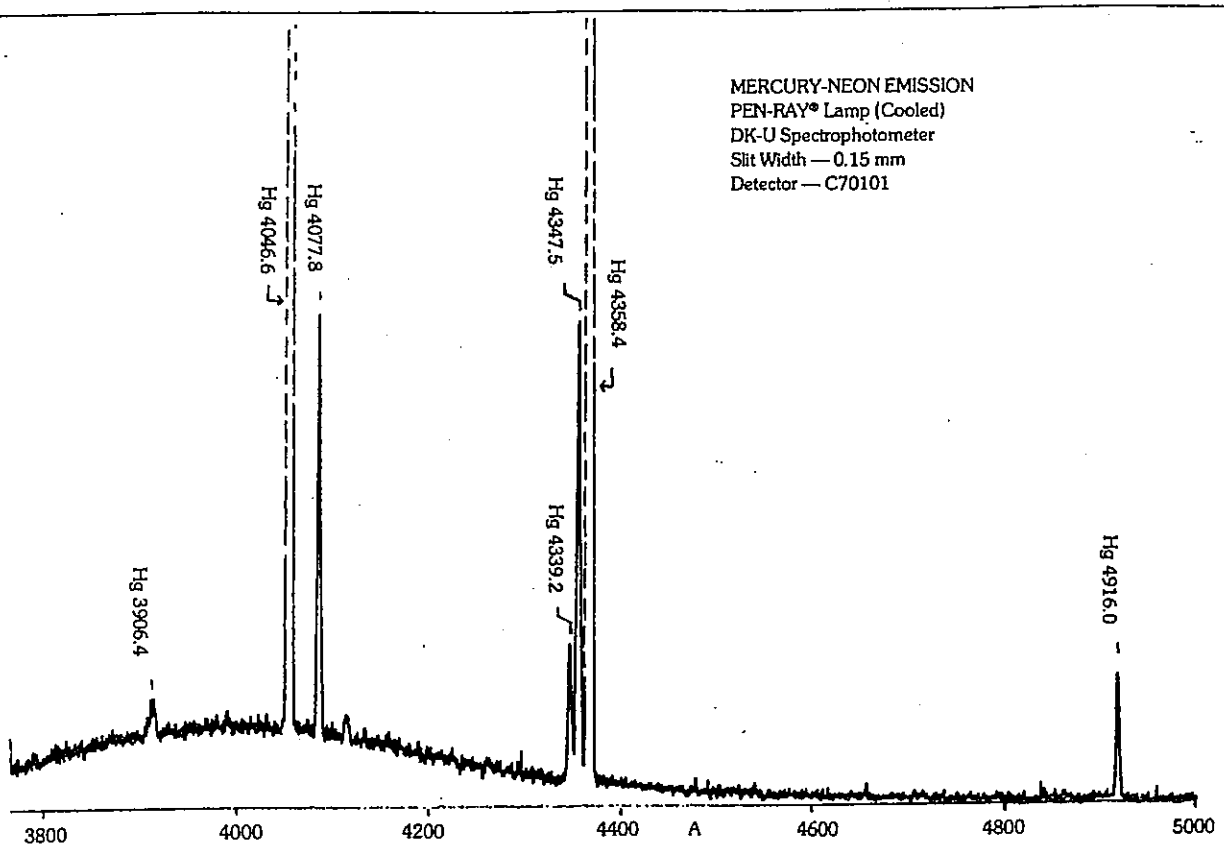


FIGURE 35

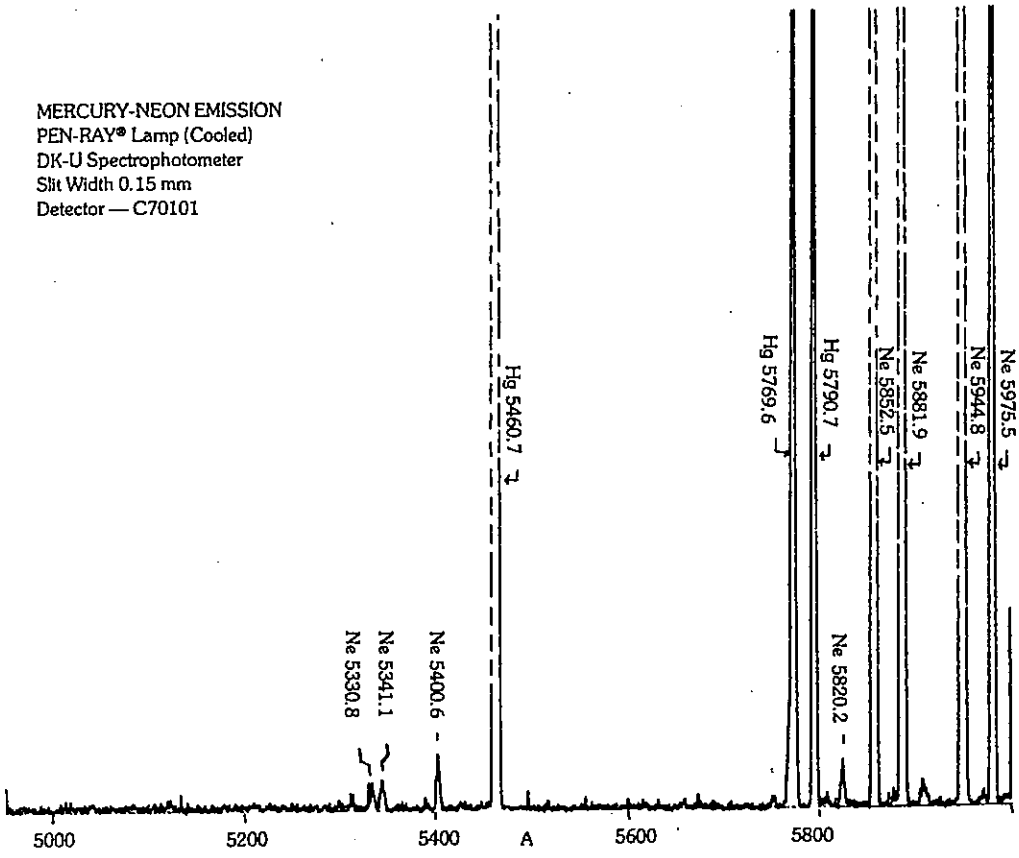


FIGURE 36

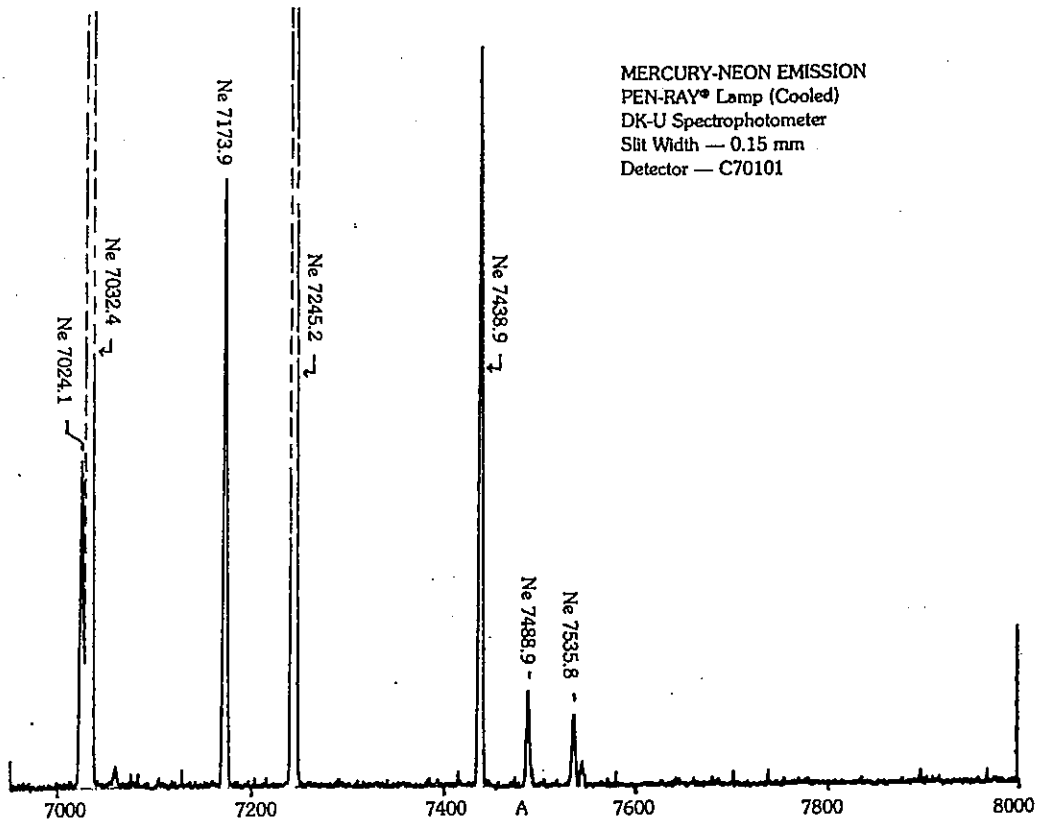


FIGURE 37

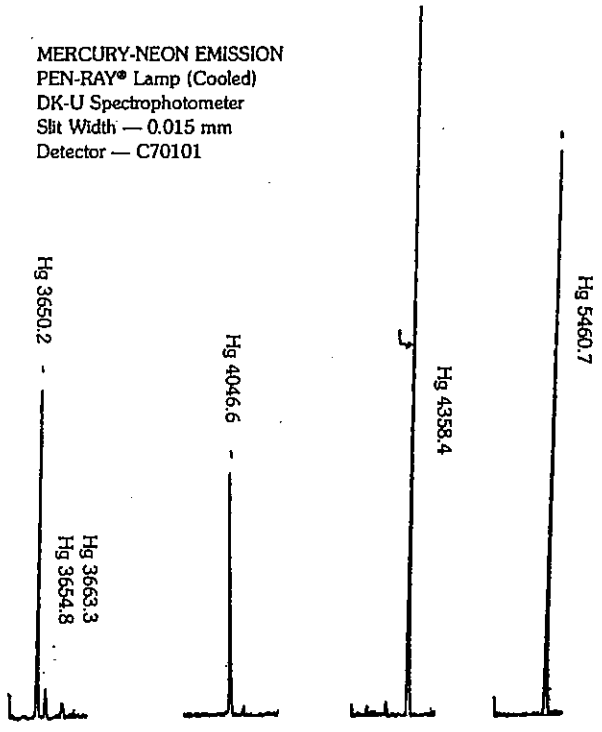


FIGURE 38

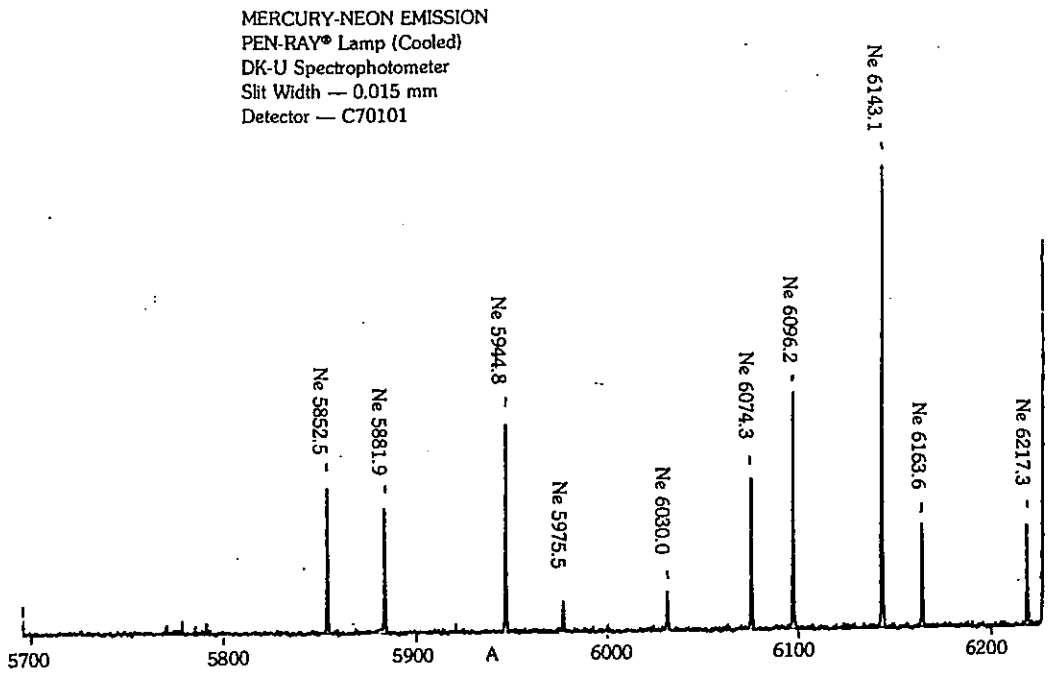


FIGURE 39

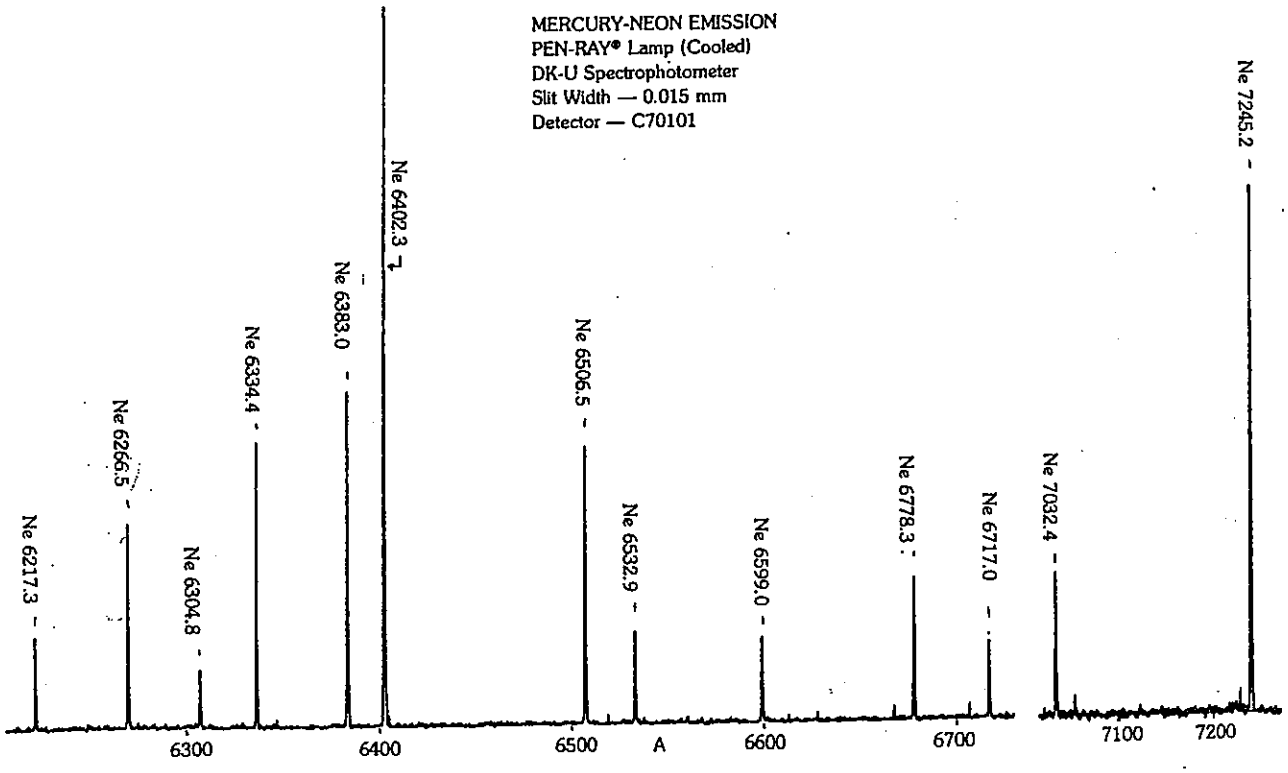


FIGURE 40