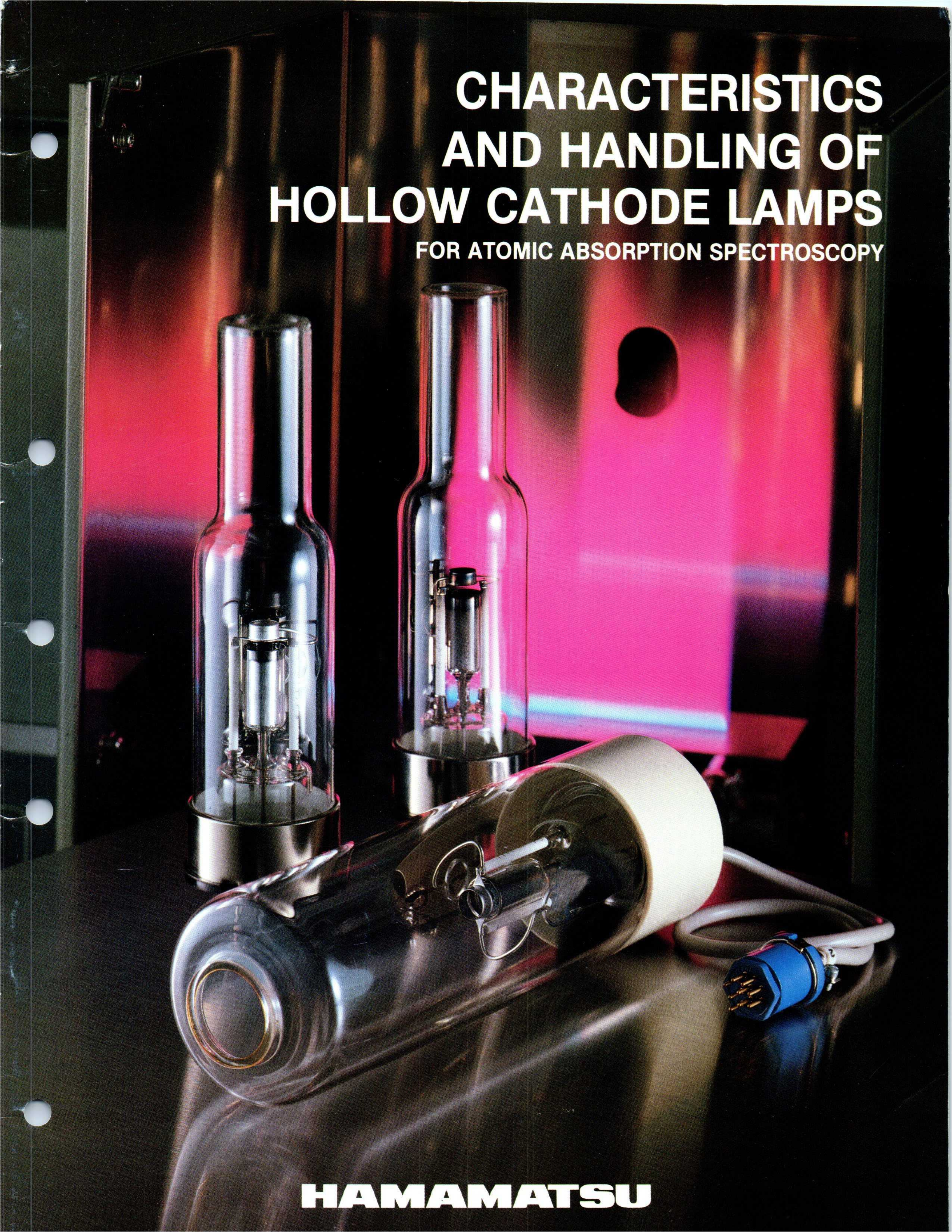
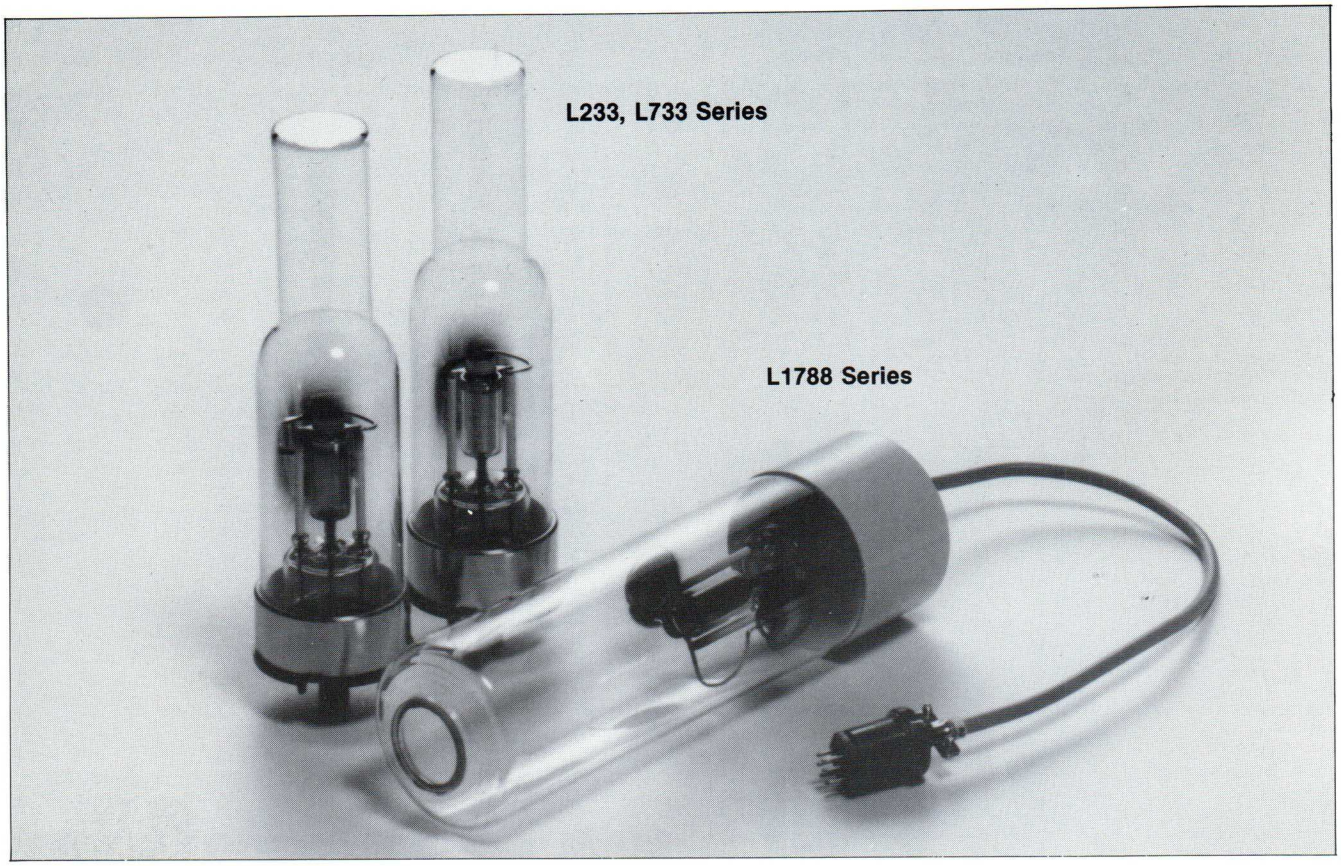
CHARACTERISTICS AND HANDLING OF HOLLOW CATHODE LAMPS

FOR ATOMIC ABSORPTION SPECTROSCOPY



HAMAMATSU



For the past 20 years Hamamatsu has continued the research, development and manufacture of hollow cathode lamps. Hamamatsu hollow cathode lamps offer spectral purity, stable operation, low noise, long life, and high output intensity even for such elements as arsenic and selenium, thus enhancing detection limits in atomic absorption analysis. In addition to the listed types, any other combination of window and gas fill is available. We also welcome requests for special lamps made to customer specifications.

Hamamatsu hollow cathode lamps can be used in most AA spectrophotometers currently on market:

L1788 Series:

Designed to be used directly in all **Perkin-Elmer** AA spectrophotometers with no adapters required.

L233, L733 Series:

Usable for most commercial AA spectrophotometers including;

- **Baird Atomic**
- **Beckman**
- **Corning E.E.L. (Evans)**
- **Fisher Jarrell-Ash**
- **Hitachi**
- **Instrumentation Laboratory***
- **JEDL**
- **Pye Unicam**
- **Rank-Hilger**
- **Seiko Denshi**
- **Shimadzu**
- **Varian Techtron**
- **Zeiss**

and others

(*: Except instruments using S-H method)

TABLE OF CONTENTS **Page**

BEFORE USING THE LAMP

OPERATING CURRENT

The maximum current is listed for each type of lamp, but optimum analysis sensitivity is usually obtained at a lower operating current. Since the operating current required for optimum sensitivity will vary depending on the instrument used, the value listed for the lamp indicates a typical value for most widely used instruments. Therefore, with this value as a reference, set the operating current to a level that provides the highest S/N ratio in your instrument.

MAXIMUM CURRENT

This value is the maximum dc or peak ac current which should be carried by the lamp. For pulse drive applications, the peak current should be limited to 2 to 4 times the maximum dc ratings according to current duty ratio (see Caution below) and a rectifier used to eliminate the inverse voltage. Maximum life will be obtained when the lamp is operated at the lowest current which will give a satisfactory S/N ratio.

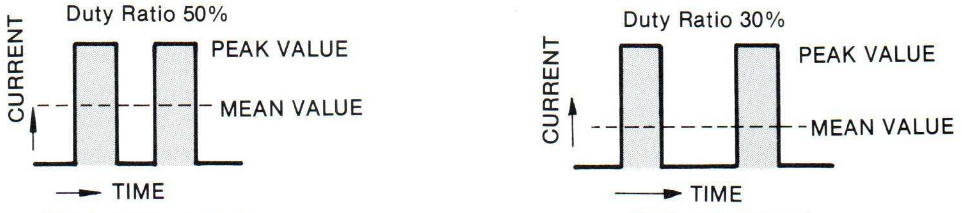
CAUTION WITH RESPECT TO OPERATING CURRENT

1. **L1788 Series** for Perkin-Elmer instruments: For double-beam instruments using dc drive (such as models 303, 305, 306, 403, 503, 2380, 3030, 4000 and 5000), the lamp should be operated at the listed dc (continuous) value in the catalog or lamp label, while for single-beam instruments using pulse drive (such as models 290 and 2280), the lamp should be operated at the listed modulated value.

---

2. **L233, L733 Series**: The maximum current and operating current for L233 and L733 series lamps are expressed as a peak current value. Pulse drive instruments, however, may indicate the lamp current value as the mean value (see the figure below). Therefore, when using such an instrument, verify which current value (mean or peak) the instrument displays, so the lamp can be used at the correct current value specified in the table below. (Example: for a Hitachi instrument using a lamp with the specified operating current value of 10 mApeak, the lamp will light when the instrument's current meter reads 3 or 4 mA.)

Lamp Current Waveform Examples at Different Duty Ratios



(Peak ≃ 2.5 × Mean)

(Peak ≃ 4 × Mean)

Lamp current indication method		AAS Manufacturers	Duty Ratio (%)	Lamp operating current listed in catalog or label (mApeak)				
				4~5	7	10	20	30
A	Peak Value (mAp)	Shimadzu (1) Nippon Jarrell-Ash (1) Seiko Denshi, JEDL, etc.	—	4~5	7	10	20	30
B	Mean Value (mAdc)	Hitachi (2), Varian-Techtron, etc.	30	1	2	3	5	8
			50	1~2	3	4	8	13

Notes

(1): The following models provide a mean current indication, so that the mean current values listed in section B of the tables above should be used.
Shimadzu model: AA-640, AA-645, AA-646, AA-650, AA-670
Nippon Jarrell-Ash models: AA-8200, AA-8500

(2): For instruments having a warm-up drive power supply LV/HV switch, always drive the lamp with this switch in the LV position for warm-up drive period.

Characteristics and Handling of Hollow Cathode Lamps

The method of atomic absorption spectroscopy was developed from a proposal by the Australian physicist Dr. A. Walsh in 1955. It is characterized by an operating principle and analysis method that provided relatively simple measurement with high accuracy. Since it is ideal for use in the analysis of minute quantities of metallic elements, it underwent rapid development. The range of applications for this analysis method is extremely wide, and includes the fields of petrochemicals, metallurgy and related industries, clinical and forensic medicine, mining, geology, public health, food and agricultural chemistry and areas such as environmental protection as well.

1. CONSTRUCTION

A hollow cathode lamp, as shown in Fig. 1, is constructed with a bulb having a window (Fig. 1-④) made of synthetic silica, UV transmitting glass or borosilicate glass, into which a hollow cylindrical cathode (Fig. 1-②) and ring-shaped anode (Fig. 1-①) have been inserted. The atmosphere within the bulb consists of a rare gas at several Torr pressures. The cathode is constructed of a single element or alloy of the element to be analyzed so as to ensure a sharp spectral line with a minimum of interfering spectral components.

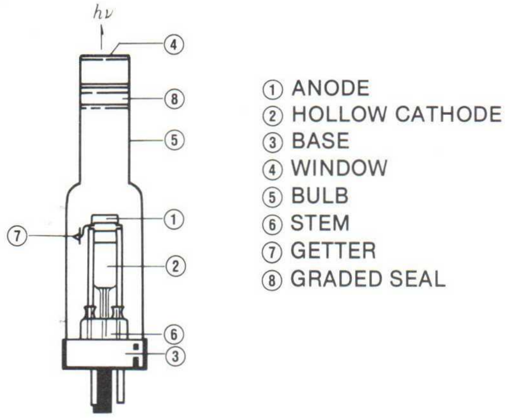


Fig.1 Construction of hollow cathode lamp

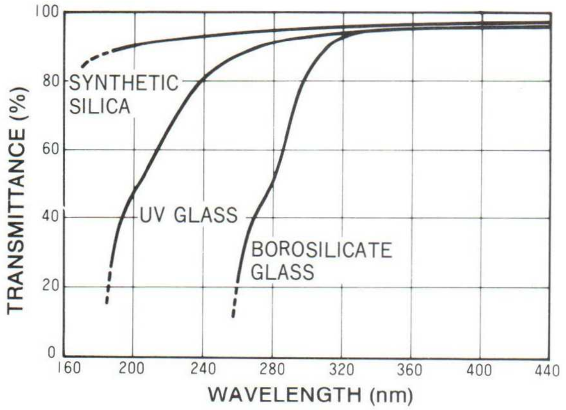


Fig.2 Spectral transmittance of window materials

2. OPERATING PRINCIPLE

The hollow cathode lamp is a type of glow discharge tube. The electrode construction has been designed to increase the negative glow portion current density, thereby achieving a high emitted spectral intensity for use as a light source.

The usual method of increasing the current density is to employ a hollow cathode. This results in a ten-fold or greater increase in current density over that achievable by using a parallel plate electrode. This increase in current density is accompanied by a significant increase in light intensity and a decrease in anode to cathode voltage drop. This is known as the hollow cathode effect. The hollow cathode lamp is designed to make effective use of this phenomenon to be usable as a light source with a high spectral line emission intensity.

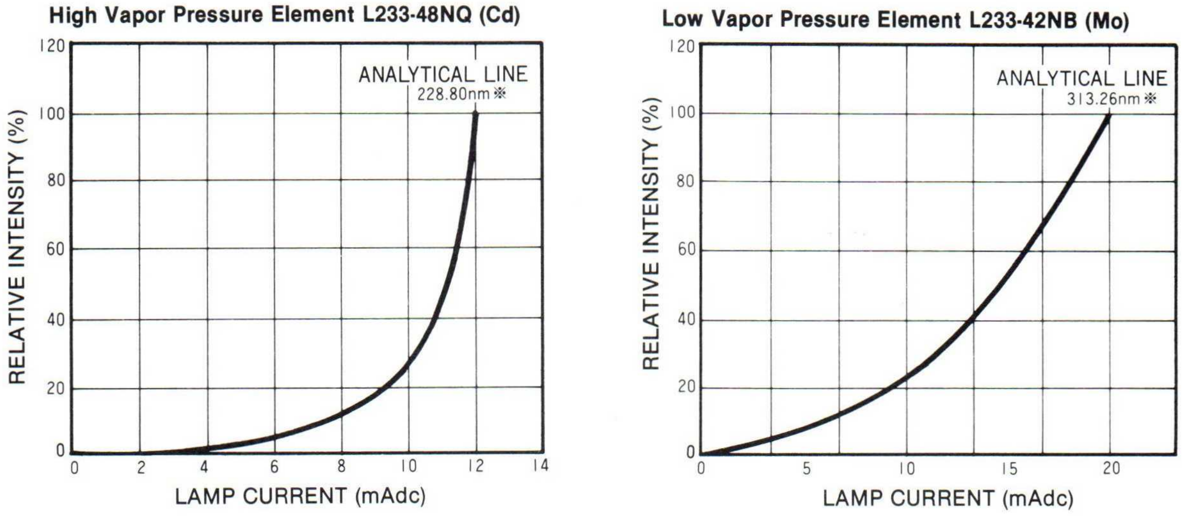
With a suitable voltage applied between the electrodes of a hollow cathode lamp a glow discharge occurs. Electrons pass from the interior of the cathode to the inner surface of the hollow cathode and flow through the negative glow region towards the anode. This causes ionization of the gas within the lamp through non-elastic collisions with the gas atoms. Positive gas ions are accelerated by the electric field and collide with the cathode surface. The kinetic energy of ion impact causes materials to be sputtered from the cathode surface in the form of an atomic metallic vapor. This vapor consists primarily of single atoms which are at the lowest energy or ground state and are thermally dispersed within the hollow cathode. Simultaneously, electrons accelerated by the electric field towards the anode collide with the diffused ground-state metallic atoms, thereby imparting energy to, or exciting the metallic atoms to a higher energy state. They return to the ground state once again in an extremely short time, (approximately 10^{-8} seconds) and the characteristic monochromatic light of the element is emitted. The emitted light energy corresponds to the energy difference from excited to ground state.

Many elemental spectral lines are observed, however, caused not only by this single electron transition but also by a variety of energy transitions occurring within the cathode material elements. This results in a multicomponent emission spectrum. The spectral lines for the gas sealed in the lamp may also be observed. Transition metal elements such as Ni, Co and Fe in particular result in an extremely large number of spectral lines, as listed at the end of this document in the major absorption line table.

The amount of material sputtered from the cathode due to collisions with positive ions depends upon many factors: the type of gas in the lamp, the gas pressure, the particular element used for the cathode and its surface state, the electrode construction and the discharge current and voltage. Hamamatsu designs and produces these lamps taking into consideration these factors to optimize the intensity, stability, lifetime and spectral emission profile.

3. LAMP CURRENT AND ANALYTICAL LINE OUTPUT

Differences in analytical line output characteristics will be observed depending upon whether the metallic vapor pressure is low or high and whether a single metal or alloy is used. Analytical line output is also affected by the gas pressure within the lamp and the cathode configuration. In general, the analytical line output intensity is proportional to the 2nd or 3rd power of the lamp current value. However, since lamp current greatly affects such characteristics as life, absorption sensitivity and output stability, it is essential that the current value be properly selected with a maximum current limit. Thus, Hamamatsu includes as part of this document a normal operating current (peak value) for each element as a guide in selecting the lamp current. Fig. 5 below shows an example of analytical line relative output intensity versus lamp current characteristics for a high vapor pressure element (Cd) and a low vapor pressure element (Mo). For such high vapor pressure elements as Hg, Cd and Zn, as is shown by this figure, the operating current has a larger influence on output.


High Vapor Pressure Element L233-48NQ (Cd)

Low Vapor Pressure Element L233-42NB (Mo)

Fig.5 Analytical line output intensity vs. lamp current

Light Radiation and Absorption

When an electron within an atom undergoes transition from a high energy level E_2 to a low energy level E_1, light is emitted of a wavelength corresponding to this energy difference ($E_2 - E_1$). Essentially, this is represented by the relationship $\lambda = hc/(E_2 - E_1)$, which governs this "light release" and this relationship forms the basic operating principle of the hollow cathode lamp. The higher energy level E_2 is known as the excited state and each element has its own characteristic excited energy levels. The lowest energy level E_1 is known as the ground state.

When an amount of light energy corresponding to a transition energy difference, $\Delta E = E_2 - E_1 = \frac{hc}{\lambda} = h\nu$, is received by an electron at the ground state energy level of E_1, the electron may absorb the light energy and jump to an excited state having an energy level of E_2. This is known as light absorption and forms the basic principle of atomic absorption spectroscopy.

h : Planck's constant 6.62619×10^{-34} J·s,
c : velocity of light in a vacuum 2.997926×10^8 m/s
ν : Frequency of light

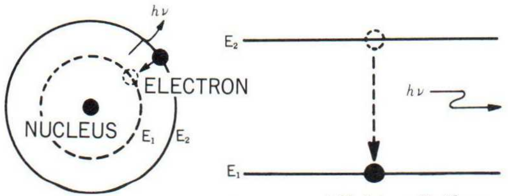


Fig.3 Conceptual diagram of light radiation

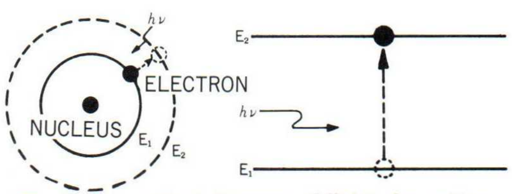


Fig.4 Conceptual diagram of light absorption

4. LAMP CURRENT AND ABSORPTION SENSITIVITY

The ideal analytical line profile for the light radiated by a hollow cathode lamp should exhibit no line broadening other than natural broadening. However, in actual operation, additional broadening of spectral lines occurs. The causes of such line broadening include Doppler broadening, self-absorption line width distortion, Lorentz broadening (pressure broadening), Holtzmark broadening (resonance broadening), Zeeman effect broadening and Stark effect broadening. Doppler broadening and self-absorption broadening are the major cause of line width distortion. Broadening related to the other causes is small enough to be ignored.

Doppler broadening is a function of gas temperature and creates no problem as long as the random thermal movement of radiating atoms is within a plane that is perpendicular to a line connecting the observation point and the light source. However, if movement is parallel to this line (i.e., forward and back as seen from the observation point), the frequency at the radiated light observation point will be increased (i.e., wavelength shortened) for motion towards the observation point and decreased (i.e., wavelength lengthened) for motion away from the observation point, causing the familiar Doppler shift. Since the motion or radiating atoms within the cathode hollow is random thermal movement, the component of this motion parallel to the above described line varies and thus causes Doppler broadening. The doppler broadening width λ_D for a central wavelength of λ_0, velocity of light c, gas constant R and absolute gas temperature T is given by the following expression for the atomic mass Ma.

$$\Delta\lambda_D = 1.67 \times \frac{\lambda_0}{c}\sqrt{\frac{2RT}{Ma}}$$

Self-absorption occurs when there is a temperature gradient within the atomic vapor layer inside the cathode hollow (i.e., when the atomic vapor within the cathode hollow is flowing out of the hollow) and the higher-temperature internal atomic vapor layer experiences more excitation than the lower-temperature external atomic vapor layer. The result is that, when the radiated light passes through the external relatively low temperature atomic vapor layer, re-absorption occurs by the ground state atoms. This phenomenon is termed self-absorption and, as the Doppler effect, results in a broadening of analytical lines and a loss of absorption sensitivity. In this manner, the deterioration of the analytical line profile depends upon the lamp current. Therefore, care must be taken that increasing the lamp current usually result in loss of absorption sensitivity. In actual measurements, it is essential to select the proper drive current with consideration given to both analytical line output intensity and absorption sensitivity.

In general, the effect of self-absorption is large for high vaporization pressure elements such as Cd and small for low vaporization pressure elements such as Mo, with the former usually dictating a low value of operating current. One example is shown in Fig. 6.

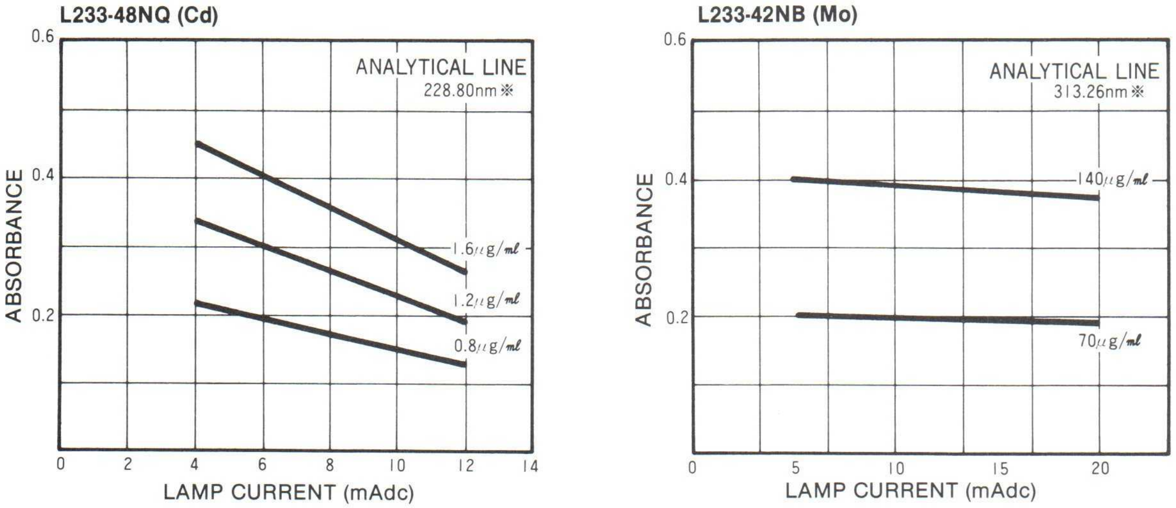


Fig.6 Absorbance vs. lamp current

5. ANALYTICAL LINE AND ABSORPTION SENSITIVITY

As shown in the major analytical line table at the end of this document, each element has a large number of spectral lines. The wavelength having the largest absorption sensitivity of these lines is indicated as the maximum absorption wavelength. Since there are spectral emission lines having low absorption sensitivity, selection of spectral lines can be made to suit the sample density, enabling analysis ranging from minute quantities to major component analysis. Fig. 7 shows examples of spectral lines and absorption sensitivities (the wavelength marked ※ is the maximum absorption wavelength).

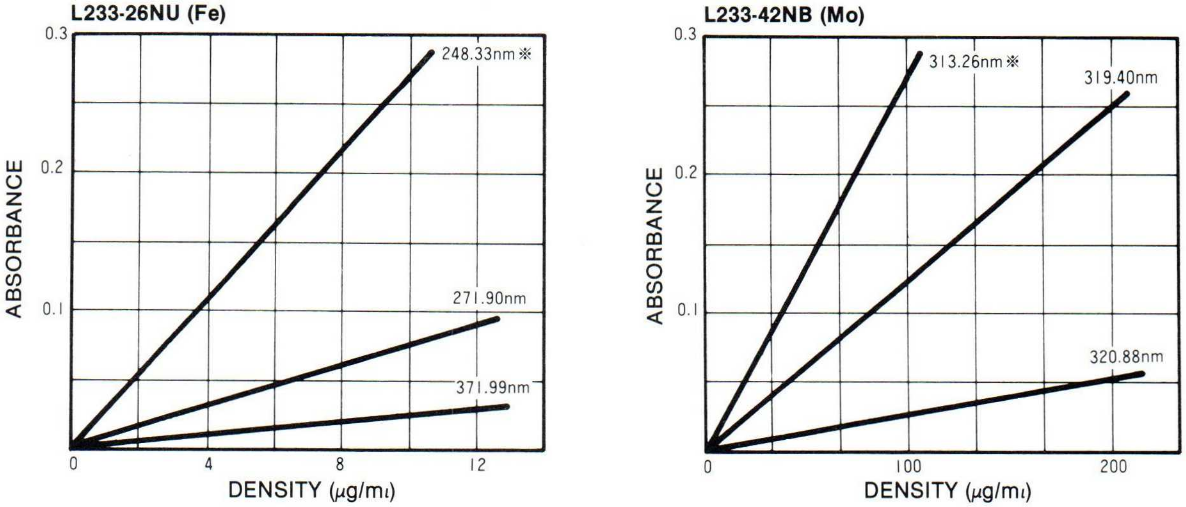


Fig.7 Absorbance at different analytical lines

6. SBW AND ABSORPTION SENSITIVITY

In the region of the analytical line, the presence of the other spectral lines from the same element or a different element will cause absorption sensitivity to drop. This type of spectral line is known as a proximity line.

When such proximity lines exist, it is necessary to make the spectral bandwidth (SBW) narrow to decrease the effect of the proximity line by decreasing the spectroscope slit width. Fig. 8 shows an analytical line profile and absorption sensitivity as a function of SBW.

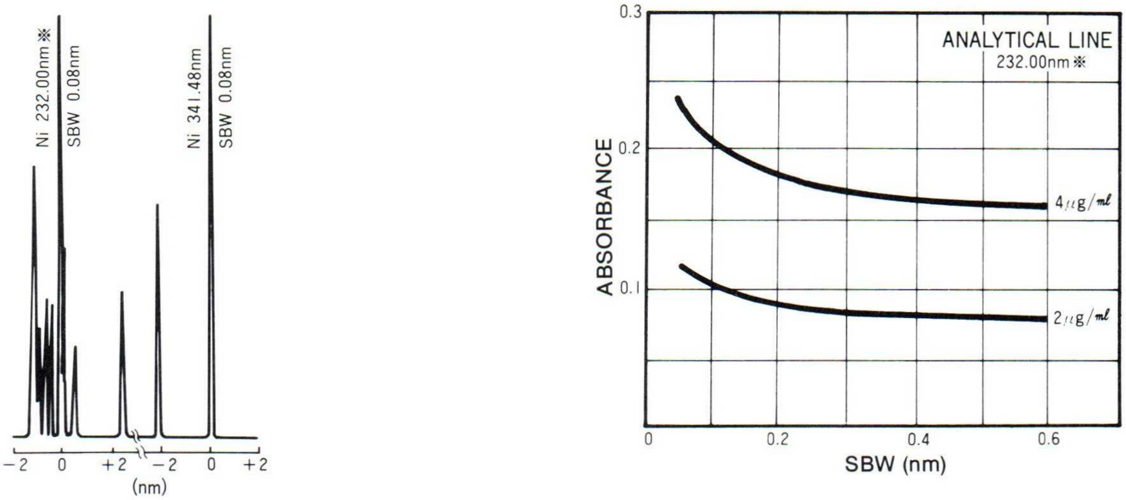


Fig.8 L233-28NQ (Ni) analytical line profile and absorbance as a function of SBW

7. TIME STABILITY OF ANALYTICAL LINE RADIATION INTENSITY

As described in the section of the emission of spectral lines, sputtered metal atoms collide repeatedly and non-elastically with electrons and are thermally dispersed. In this process, during the period required for the metallic atom density to reach equilibrium, there occur variations in the radiated output intensity of analytical lines. These variations are usually in the direction of increased output at the start of lamp drive for a period of apporximately 10 to 20 minutes, and will vary themselves depending upon the element and operating current. After reaching equilibrium, the radiated output intensity at the analytical line wavelength is extremely stable.

For high vapor pressure element lamps, operation at excessive current levels will cause excessive metal atom vaporization, with resulting overflow into the cathode hollow optical axis. This causes a temperature gradient to occur and may cause a decrease in radiated analytical line output intensity due to such phenomena as self-absorption.

If a lamp is left unused for a long period of time, for lamps of certain elements (in particular, alkaline elements) there may be an increase in the amount of time required for analytical line output intensity to reach initial stabilization, this being caused by the aging of the cathode surface. Fig. 9 shows an example of time stability in the analytical line output intensity.

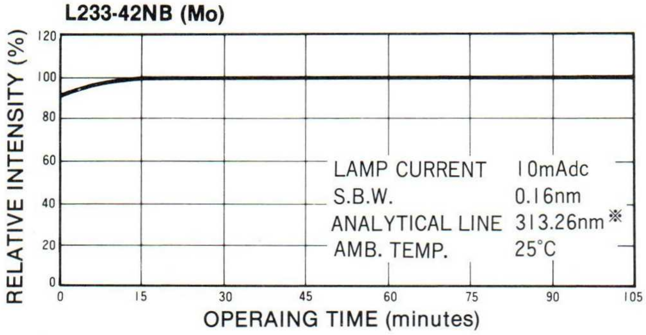


Fig.9 Time stablility in analytical line output intensity

8. SINGLE-ELEMENT AND MULTI-ELEMENT LAMPS

The Hamamatsu line of hollow cathode lamps consists of the L233 series of single-element lamps and the L733 series of multi-element lamps, and the L1788 series of lamps which includes both single-element and multi-element types for Perkin-Elmer instruments.

In general, single-element lamps exceed multi-element lamp in both absorption sensitivity and analytical line radiation intensity. Multi-element lamps offer the advantage of simultaneous analysis of several spectral lines, although they require sufficient consideration with respect to the combination of the metals used in the cathode and do not enable any arbitrary combination to be used. Hamamatsu offers the following five types of multi-element lamps.

Elements / Type No.	Na-K	Ca-Mg	Si-Al	Fe-Ni	Sr-Ba
L733-	201NB	202NU	203NU	204NQ	205NB
L1788-	201NB	202NQ	203NQ	204NQ	205NB

Table 1 Type No. of multi-element lamps

9. LIFE

The life of a hollow cathode lamp is greatly affected by the operating current. This is due to the increase in the energy of positive ions colliding with the cathode surface which causes violent sputtering. The life of a lamp is inversely proportional to the 2nd or 3rd power of the operating current. For pulse operation as well, since there is no change in the energy of the ions colliding with the cathode surface for each pulse, the life is determined by the peak current and the pulse width expressed in time.

The following phenomena may be observed when a lamp has reached its useful life end:

(1) Discharge does not occur at the hollow cathode and the actual current does not vary even if the current adjustment is changed. The analytical line output will not be detectable.

(2) Extreme variations occur in analytical line intensity and the lamp current may vary also.

(3) The analytical line intensity weakens significantly and the S/N ratio deteriorates.

The major cause of these phenomena is a drop in gas pressure within the lamp. This drop in gas pressure is caused by the gas clean-up phenomenon which occurs when cathode metal atoms which had been sputtered during discharge and scattered are attracted with gas to the bulb wall and electrode at a lower temperature.

As the lamp is used, the cathode hollow shape is gradually worn and deformed by sputtering from the discharge. Thus, the hollow cathode lamp should be treated as a disposable item with the guaranteed lifetime being determined by the product of operating current (peak value) and accumulated operating time. For Hamamatsu lamps, this value is 3000 mA·hrs for As, Ga and Hg of L233 series, and 5000 mA·hrs for other elements. Fig. 10 shows the time variations observed in relative spectral line (at maximum absorption wavelength) output intensity for continuous operation of the L233 series lamps operated at their recommended operating currernt (10 mAdc). These characteristics will vary depending upon the element and will exhibit small differences even for lamps of the same element.

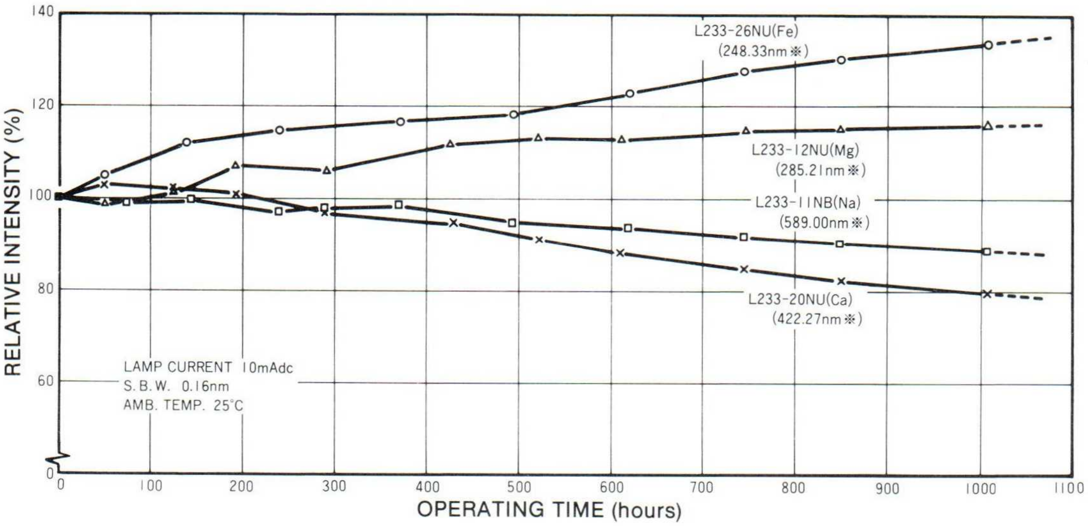


Fig.10 Analytical line output intensity vs. operating time

10. BACKGROUND COMPENSATION BY DEUTERIUM LAMPS

In the process of breaking the sample down into atoms, vaporization of components of the sample other than the component to be analyzed occurs. These other components can cause absorption of the desired analysis spectral lines and molecular dispersion, resulting in measurement errors. This phenomenon is known as background and must not be ignored in the analysis of minute quantities of elements.

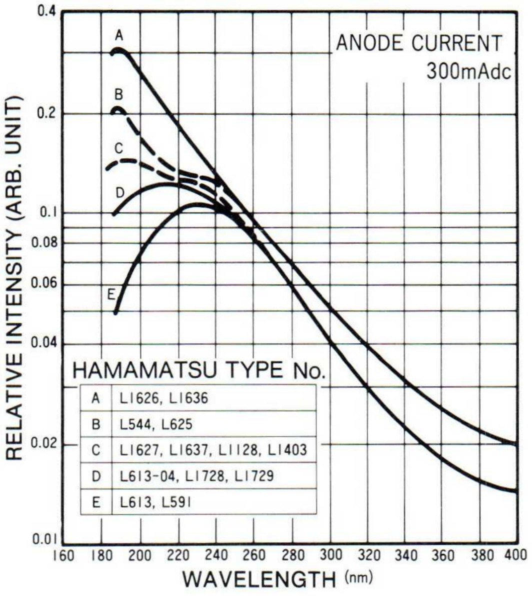


Fig.11 Spectral distribution of Hamamatsu deuterium lamps

One method of compensating for such measurement errors is that of using the continuous spectrum of a deuterium lamp. As shown in Fig. 11, this lamp exhibits a continuous radiated spectrum in the wavelength range of 185 to 400 nm, enabling background compensation for a large number of elements without the necessity of separating the desired elements using such techniques as using organic solvent extraction or ion exchange resins.

Since the deuterium lamp is usually used in an atomic absorption spectrophotometer in the pulse mode, a deuterium lamp is employed which uses electrodes specifically designed for pulse operation.

(Separate technical information and catalogs are available for Hamamatsu deuterium lamps upon request.)

11. PHOTOMULTIPLIER TUBES

A photomultiplier tube is a photoelectric tube which features a photosensitive cathode (photocathode) and secondary electron multiplying electrode to provide large amplification and high response speed with low noise. It is the best photosensitive device for use in detecting extremely low light levels. Hamamatsu photomultiplier tubes are designed for stable operation and precise measurements, and are widely used in a variety of spectroscopic instruments, densitometers, radiation measuring instruments and other photometric applications.

To ensure highly precise atomic absrоption spectroscopy, proper selection of the photomultiplier tube used as a light detector is essential. Hamamatsu recommends the types shown in Table 2 below, which have been selected as having characteristics suitable for use as detectors in this application. (Photomultiplier tube catalogs are available upon request.)

Operation for Background Compensation

In general, background appears as a broad wavelength band, and includes analytical lines of the element as well. Using a deuterium lamp, the following two methods may be employed to compensate for background.

(A) The spectroscope slit width can be increased to measure molecular absorption and dispersion which forms the background. This absorption is subtracted from the absorption of the element being analyzed to achieve compensation for the background.

(B) The spectroscope wavelength dial can be shifted approximately 1 nm and the same type of absorption and dispersion measurement is made. This absorption is subtracted from the absorption for the element being analyzed.

The above methods assume the following conditions.

Assumption 1: The molecular absorption spectrum is constant in the region of the absorption spectrum of the element being analyzed.

Assumption 2: The absorption of the element being analyzed caused by the deuterium spectrum is small enough to be ignored.

While method (A) is used since Assumption 1 normally is thought to apply, there are cases in which problems arise due to a complex molecular absorption spectrum. Assumption 2 is inherently disadvantageous if high accuracy is required. Also, if proximity lines exist near an analytical line or there is a high-intensity radiation spectrum close within the flame, this method cannot be used. Method (B) requires Assumption 1 although it does not require Assumption 2.

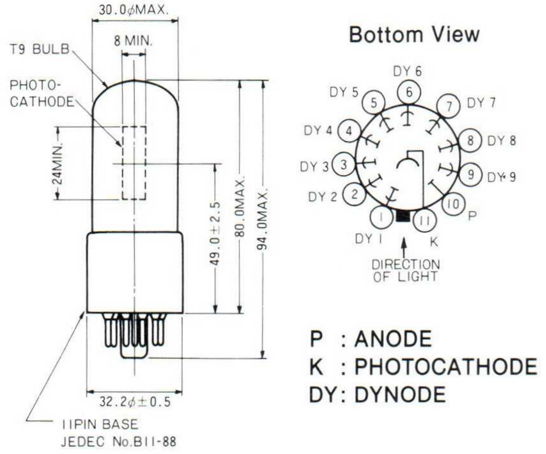


Fig.12 Dimensional outline and basing diagram of photomultiplier tube (Unit: mm)

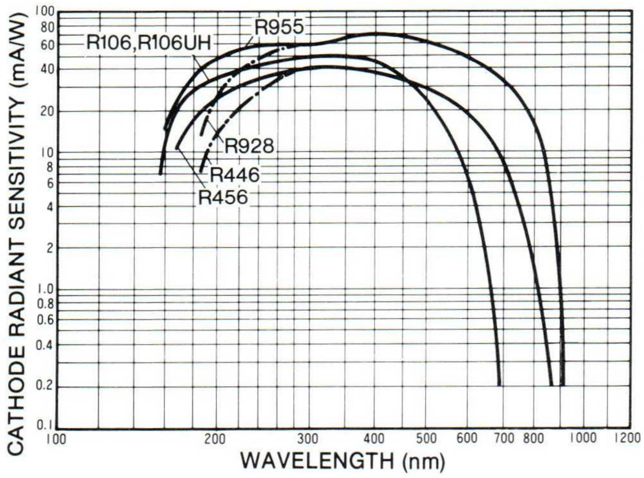


Fig.13 Typical spectral response of photomultiplier tubes

Since, in general, spectral response characteristics of a light detector are not flat with respect to wavelength, the light detector spectral response characteristics must be matched to the analytical line wavelength of the element. While many classifications of spectral response may be made with respect to cathode and glass window materials, atomic absorption spectroscopy applications are usually handled using photomultiplier tubes having an Sb-Cs photocathode (e.g., type R106) or a multialkali photocathode (e.g., types R446 and R928). Using type R456 or R955 which feature a multialkali photocathode and fused silica window, detection with high output is possible of analytical lines in the range As (193.70 nm) through Cs (852.11 nm).

12. PRECAUTIONS

1. Long-Term Storage

We recommend that these products be used shortly after delivery. If a long period of six or more months is allowed to elapse without use, the following precautions should be taken;

(a) Store lamps in low humidity and at normal room temperature. Lamps should not be stored in a helium or corrosive atmosphere.

(b) In order to stabilize the lamp characteristics, operate the lamp for approximately 3 hours once every three months at half of its recommended operating current.

2. Operation

(a) Personal Safety Precautions;
Electrical Shock—Operating voltages applied to this device present a shock hazard. Appropriate precautions should be taken to avoid electrical shock.

(b) Many hollow cathode lamps produce ultraviolet radiation which can be harmful to the eyes and other human tissue. For that reason it is suggested that eye protection and skin protective garb be worn when exposed to the ultraviolet radiation.

(c) Many hollow cathode lamps contain materials which can be harmful to plants and animals. Care must be exercised in disposing of discarded lamps.

(d) Do not touch the lamp window with the bare hands. If dirt from the hands is allowed to contact the window surface, analytical line output intensity will drop. If this occurs, wipe the window surface using gauze or oil-free cotton which has been soaked in high-purity alcohol and wrung out thoroughly. Note, however, the volatile vaporization of organic solvents

Type No.	Spectral Response		Photocathode Materials	Window Materials	Maximum Ratings		Anode Sensitivity^A		
	Range (nm)	Peak Wavelength (nm)			Anode to Cathode Voltage (Vdc)	Average Anode Current (mA)	Luminous (A/lm)		Radiant^B Typ. (A/W)
							Min.	Typ.	
R106	160 ~ 650	340	Sb-Cs	Fused Silica	1250	0.1	50	200	2.4×10^5
R106UH	160 ~ 650	340	Sb-Cs	Fused Silica	1000	0.1	1000	1500	18×10^5
R446	185 ~ 870	330	Multialkali	UV glass	1250	0.1	100	400	2.0×10^5
R456	160 ~ 870	330	Multialkali	Fused Silica	1250	0.1	100	400	2.0×10^5
R928	185 ~ 930	400	Multialkali	UV glass	1250	0.1	400	2000	6.8×10^5
R955	160 ~ 930	400	Multialkali	Fused Silica	1250	0.1	400	2000	6.8×10^5

A: Measured with an anode to cathode supply voltage of 1000V.
B: At peak wavelength

Table 2 Photomultiplier tubes for AA spectroscopy

will absorb analytical lines of such elements as As and Se, thus requiring care in use at the measurement site.

Upon delivery, the bulb wall or electrode may be observed to be in the blackened condition. This is caused by the dispersion of cathode material and this condition will differ, depending upon the element. In particular, this condition is noticed on lamps with such high vapor pressure elements as As, Se, Cd, Zn, Na and K. This condition occurs during the manufacturing process and does not effect operating characteristics of the product.

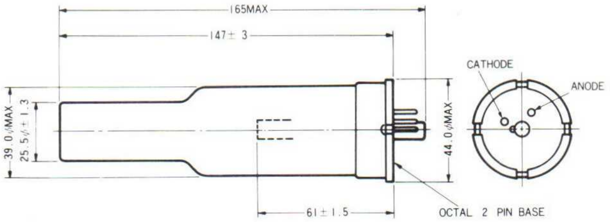
(e) The major analytical lines used in atomic absorption spectroscopy fall in the wavelength range of 200 to 300 nm. Since mirrors, lenses and other optical components generally have low reflection or transmission efficiency in this wavelength region, adjust the spectroscope wavelength dial for maximum stable output indication and the lamp position and wavelength dial alternately in a fine adjustment sequence to achieve the proper analytical line wavelength. Refer to the analytical line profile for the lamp to ensure accurate wavelength adjustment. If this analytical line wavelength adjustment is not made properly, high measurement accuracy will not be achieved.

(f) If a high current is passed through the lamp suddenly at the beginning of discharge or the power supply is cut off suddenly at the end of discharge, surge currents or other abnormal currents will flow in the lamp, causing excessive deterioration of the lamp. When driving the lamp, increase the lamp current gradually to the recommended value and when removing the lamp drive, decrease the current gradually to ensure a long lamp life with stable operation.

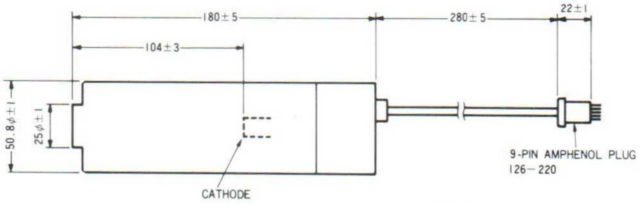
(g) Never exceed the absolute maximum current (which may be broadly taken as the guaranteed current which will cause no lamp damage) which is marked on the lamp. For lamps based on elements having high vapor pressure (e.g., Hg, Cd and Zn), this marking is set to a low current value. If this type of lamp is operated at currents in excess of this value, the resulting Joule heat may melt the cathode.

13. DIMENSIONS AND PIN CONNECTIONS

L233, L733 Series
(For general AA spectrophotometers)



L1788 Series
(For Perkin-Elmer AA spectrophotometers)



(Unit: mm)

14. WARRANTY

All Hamamatsu hollow cathode lamps are warranted to the original purchaser for a period of **24 months** following the date of shipment from Hamamatsu/dealer or the first **5,000 milliampere·hours** of operation, whichever comes first, except for the elements arsenic (As), mercury (Hg), and galium (Ga) of the L233 series for which **3,000 milliampere·hours** of operation are warranted.

The warranty is limited to repair or replacement of any defective material due to defects in workmanship or materials used in manufacture. No lamp will be replaced that has been used above maximum published current ratings for that element or used in a manner not expressly indicated by the published data for the lamp.

Should any manufacturing defect show up in the first 90 days or 1/2 of the above rated milliampere·hour life, the lamp will be replaced free of charge. After 90 days or 1/2 the rated milliampere·hour life the lamp will be replaced with the cost prorated on the basis of two years or the rated milliampere·hour life.

A. Any claim for damage of shipment must be made directly to the delivering carrier within five days.
B. Customers must inspect and test all lamps within 30 days after shipment. Failure to accomplish said incoming inspection shall limit all claim to 75% of invoice value.
C. No credit will be issued for broken lamps unless in the opinion of Hamamatsu the damage is due to a seal crack or a crack in a graded seal traceable to a manufacturing defect.
D. No credit will be issued for any lamp which in the judgement of Hamamatsu has been damaged, abused, modified, or which the serial number of the type numbers have been obliterated or defaced.
E. No lamps will be accepted for return unless permission has been obtained from Hamamatsu in writing, the shipment has been prepaid and insured, the lamps are packed in their original box and accompanied by the original datasheet furnished to the customer with the lamp, and a full written explanation of the reason for rejection of each lamp.
F. This warranty gives you specific legal rights and you may also have other rights which vary from state to state.

15. ELEMENTAL DATA ANALYSIS EXAMPLES

1. Notes on Data Listings

(a) Maximum Absorption Wavelength

The analytical line marked ※ indicates the maximum absorption wavelength for each element.

(b) Starting Voltage and Tube Drop Voltage

Typical values for each element are shown. There are slight variations between lamps even of the same element, and depending also upon the amount of operation.

(c) Measurement Conditions for Analysis Data

The lamp operating current was set at the specified operating current for each element lamp and the spectral bandwidth (SBW) was set to 0.16 nm as a reference. However, for elements greatly influenced by proximity lines the SBW was set to 0.08 nm and for those elements little effected by proximity lines, this was set to 0.32 nm for measurement.

2. Selection of Analytical Line (Dy, Ir and Lu Examples)

(a) Dy (Dysprosium)

Typical Dy analytical lines exist at 404.599 nm and 421.172 nm. Although the absorption sensitivity is slightly higher at 421.172 nm, at this wavelength, using a N_2O-C_2H_2 flame, overlap occurs with the emitted spectrum of the flame (CN band spectrum). This results in an increase in background noise. For this reason, either a N_2O-C_2H_2 flame is used with the 404.599 nm or a carbon furnace is used with either the 421.172 nm for analysis.

(b) Ir (Iridium)

Typical analytical lines for Ir exist at 208.882 nm and 266.479 nm. While the 208.882 nm absorption line has the highest absorption sensitivity, the emitted output intensity is low and, depending upon the equipment used, a good S/N ratio may not be achievable. Conversely, the sensitivity at 266.479 nm exhibits a relative drop to 1/3, although the output intensity is high, and S/N ratio is improved. For this reason, the latter line may be used. The equipment and sample will determine if this is possible.

(c) Lu (Lutetium)

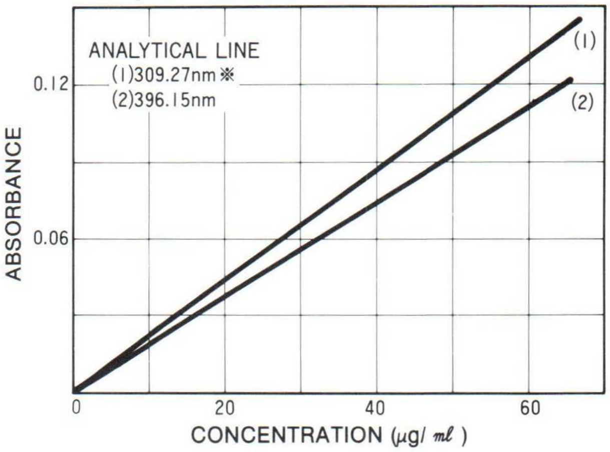
Typical analytical lines for Lu exist at 261.542 nm, 335.956 nm, 331.211 nm and 328.174 nm. At these wavelengths, although the absorption sensitivity is greatest at 261.542 nm, ion lines cause interference at this spectral line and if many other ions are present in the sample, care is required as absorption sensitivity will be greatly reduced.

The wavelength of next highest absorption sensitivity is 335.956 nm. However, if a N_2O-C_2H_2 flame is used, the flame's emitted spectrum (i.e., NH band spectrum) overlaps, causing an increase in background noise. For this reason, when using a carbon furnace for analysis, this analytical line should be used.

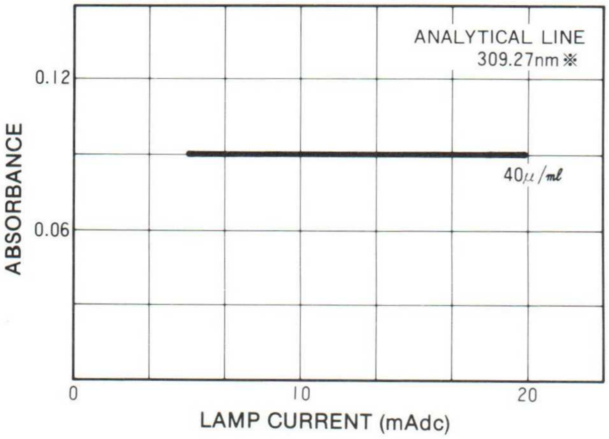
Aluminium (Al)

Type No.:	L233-13NB L1788-13NB
Analytical Lines	: 309.27 nm ※ 396.15 nm
Starting Voltage	: 210 Vdc
Tube Drop Voltage	: 152 Vdc
Flame	: N_2O-C_2H_2

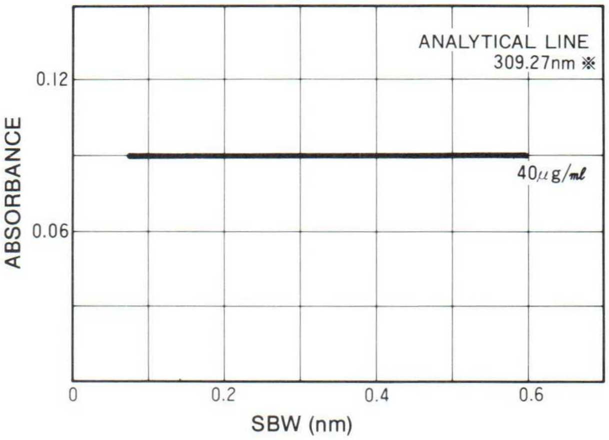
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

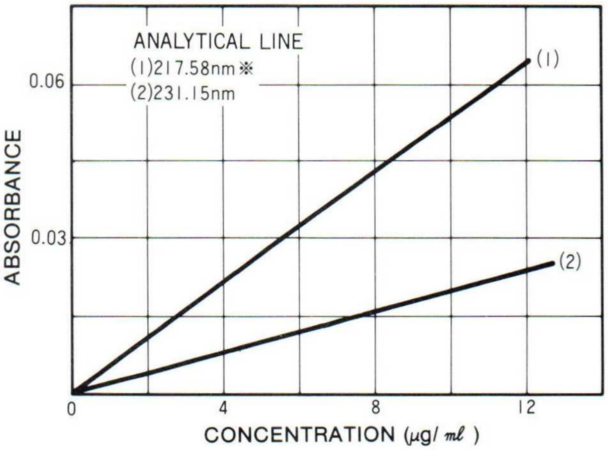


Antimony (Sb)

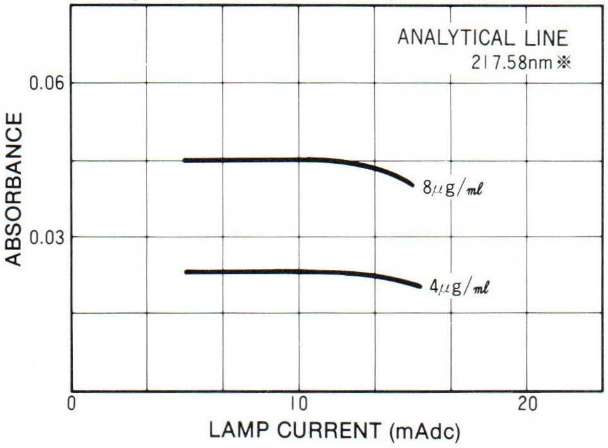
Type No.: L233-51NQ
L1788-51NQ

Analytical Lines : 217.58 nm ※
231.15 nm
Starting Voltage : 300 Vdc
Tube Drop Voltage : 195 Vdc
Flame : Air-C_2H_2

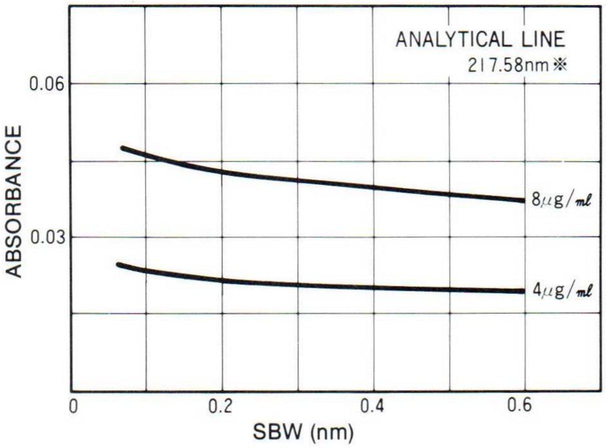
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

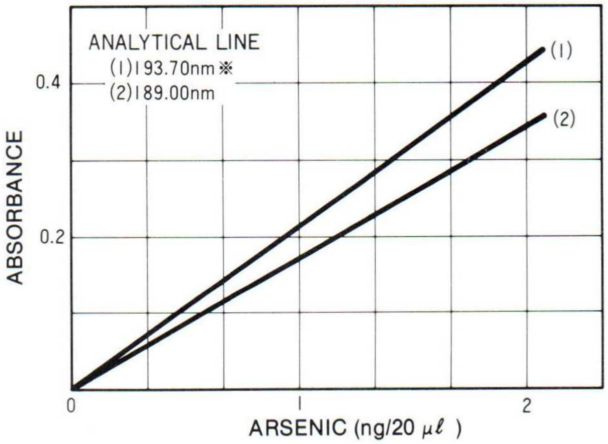


Arsenic (As)

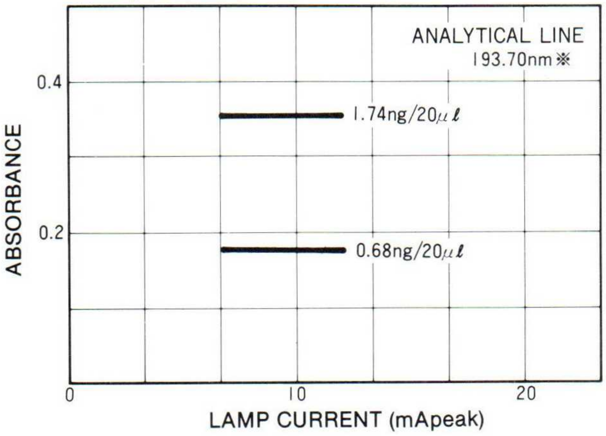
Type No.: L233-33NQ
L1788-33NQ

Analytical Lines : 193.70 nm ※
197.20 nm
Starting Voltage : 260 Vdc
Tube Drop Voltage : 202 Vdc
Graphite Furnace Method

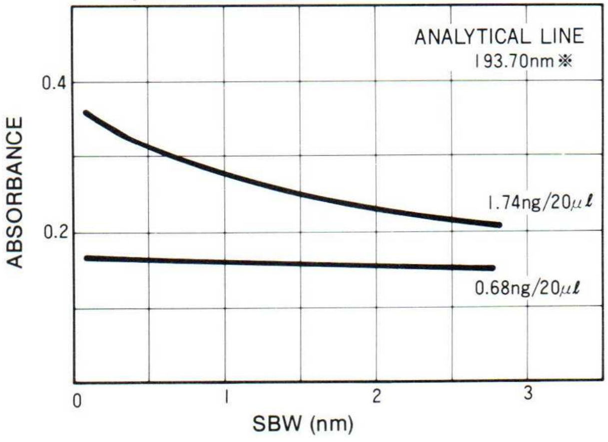
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

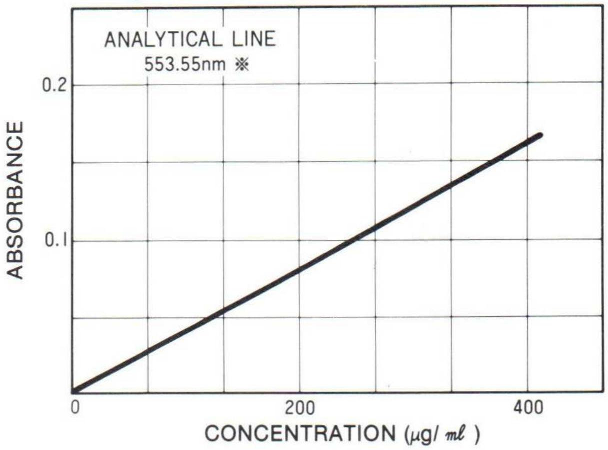


Barium (Ba)

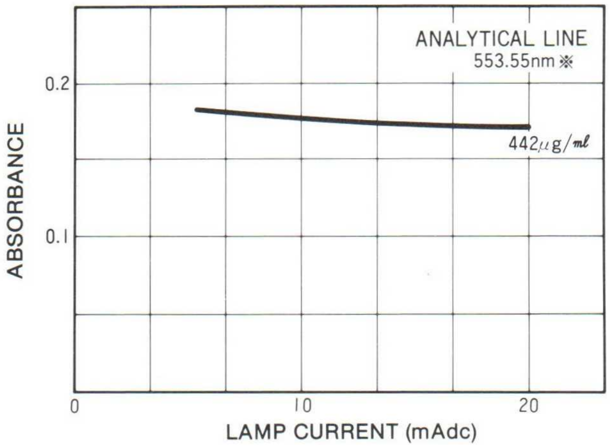
Type No.: L233-56NB
L1788-56NB

Analytical Lines : 553.55 nm※
Starting Voltage : 180 Vdc
Tube Drop Voltage : 140 Vdc
Flame : N_2O-C_2H_2

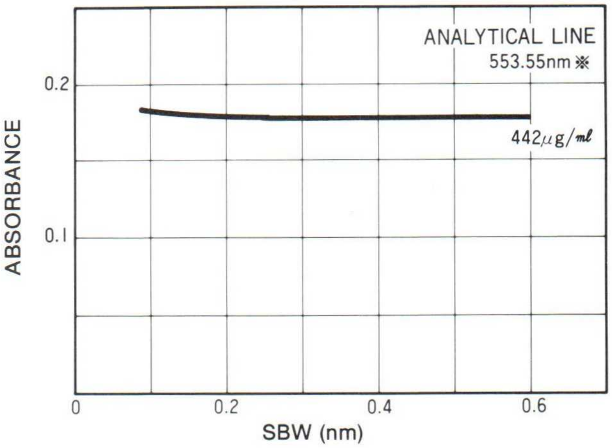
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

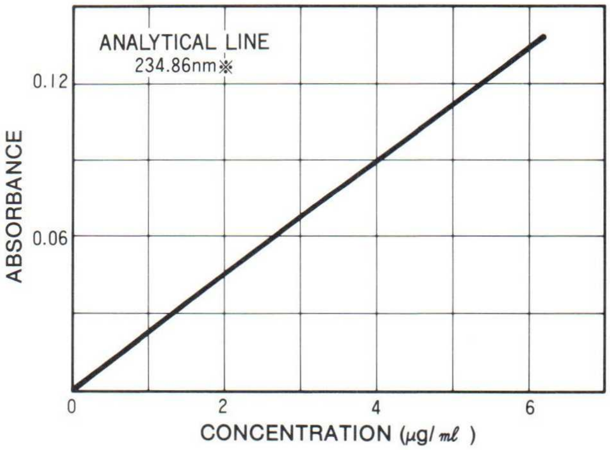


Beryllium (Be)

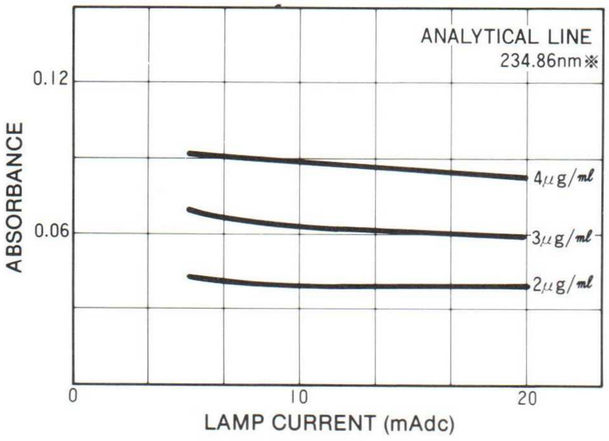
Type No.: L233-4NQ
L1788-4NQ

Analytical Lines : 234.86 nm※
Starting Voltage : 220 Vdc
Tube Drop Voltage : 191 Vdc
Flame : N_2O-C_2H_2

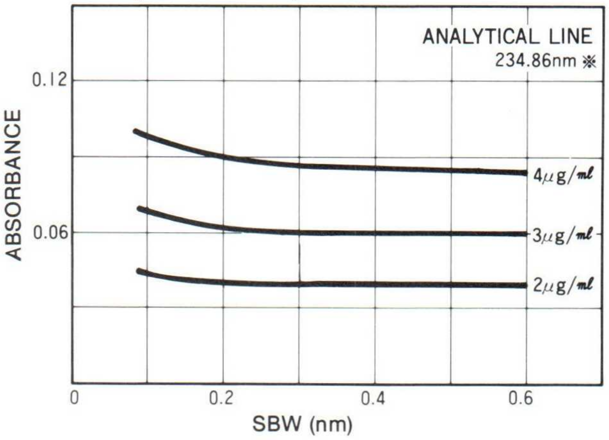
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

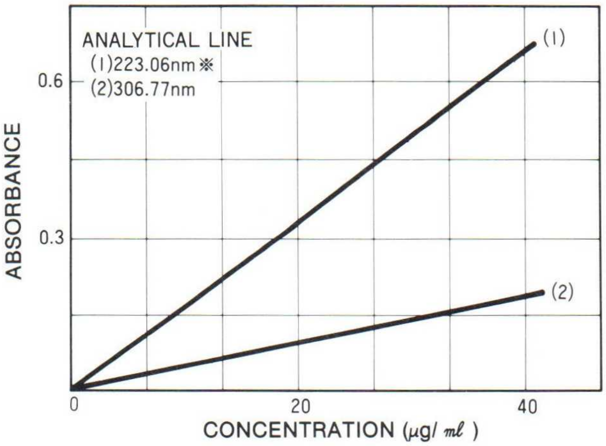


Bismuth (Bi)

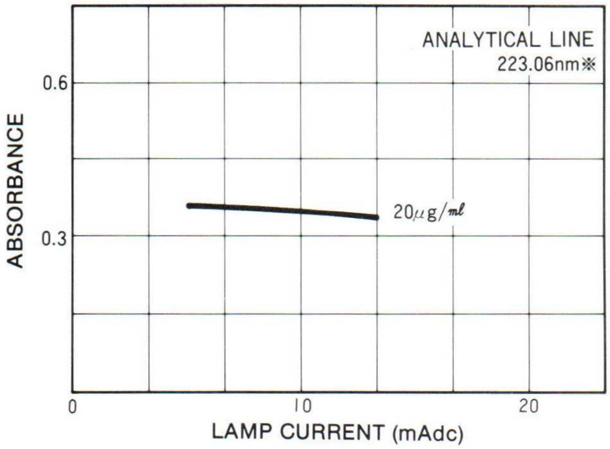
Type No.: L233-83NQ
L1788-83NQ

Analytical Lines : 223.06 nm※
306.77 nm
Starting Voltage : 220 Vdc
Tube Drop Voltage : 184 Vdc
Flame : Air-C_2H_2

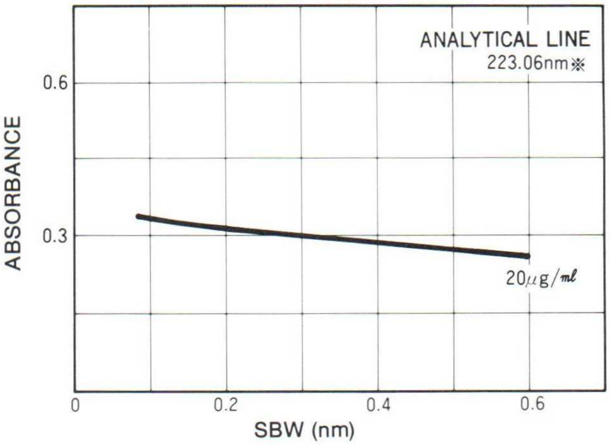
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

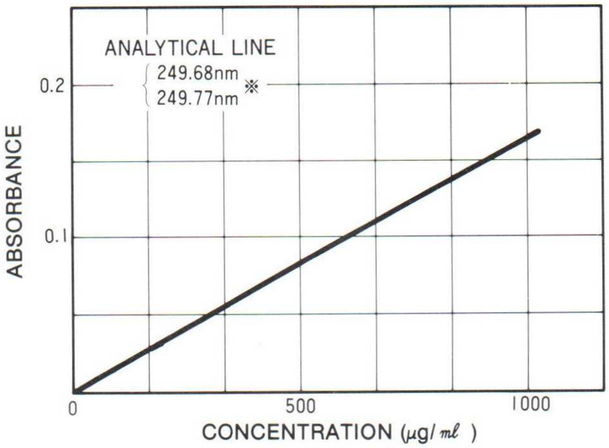


Boron (B)

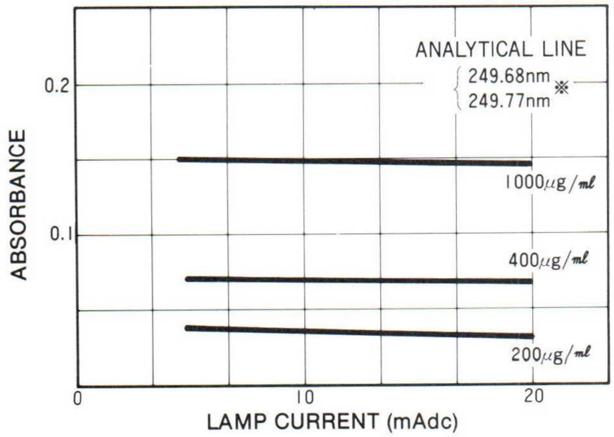
Type No.: L233-5NQ
L1788-5NQ

Analytical Lines : 249.68 nm ⎫ ※
249.77 nm ⎭
Starting Voltage : 265 Vdc
Tube Drop Voltage : 238 Vdc
Flame : N_2O-C_2H_2

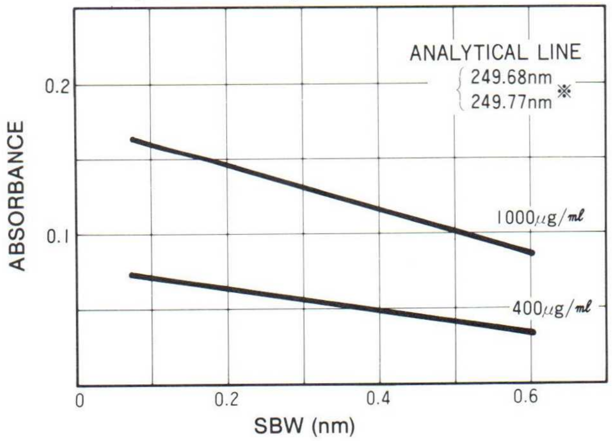
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

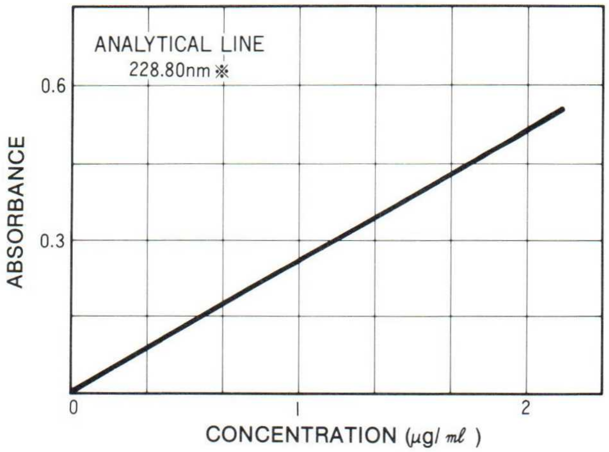


Cadmium (Cd)

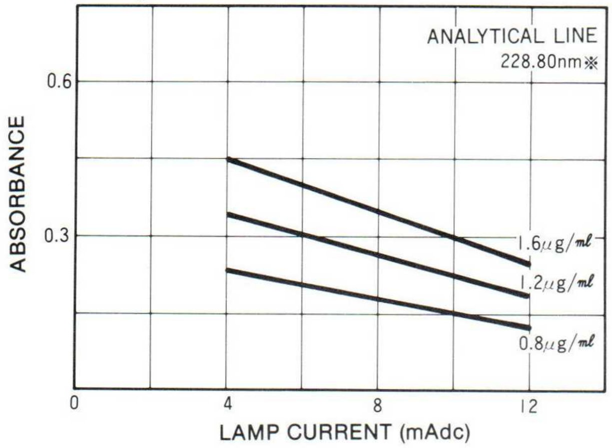
Type No.: L233-48NQ
L1788-48NQ

Analytical Lines : 228.80 nm ※
Starting Voltage : 230 Vdc
Tube Drop Voltage : 202 Vdc
Flame : Air-C_2H_2

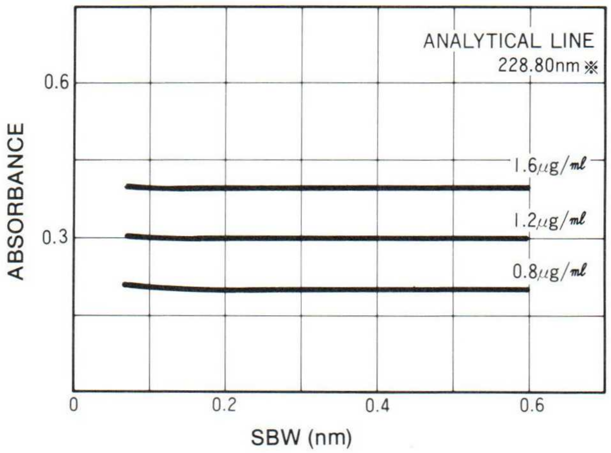
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

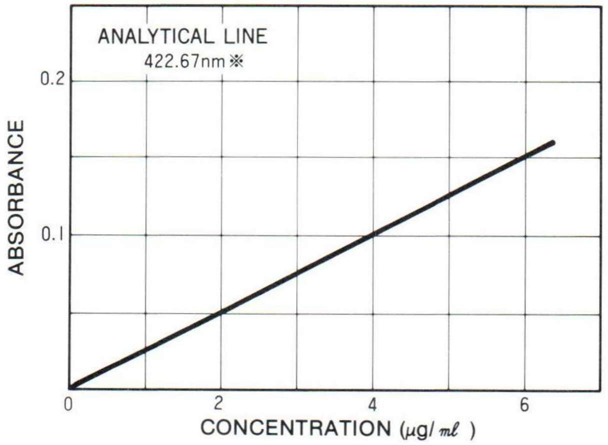


Calcium (Ca)

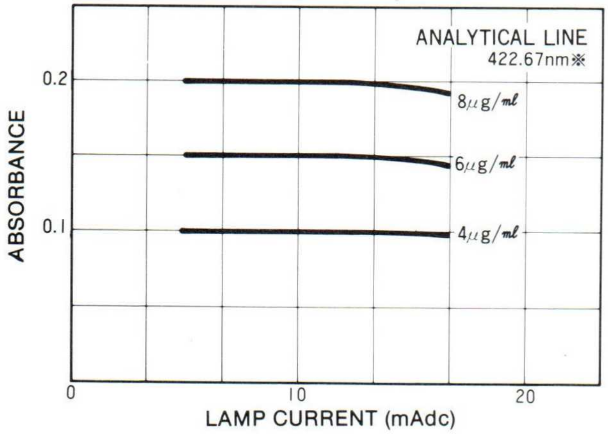
Type No.: L233-20NU
L1788-20NQ

Analytical Lines : 422.67 nm ※
Starting Voltage : 200 Vdc
Tube Drop Voltage : 142 Vdc
Flame : Air-C_2H_2

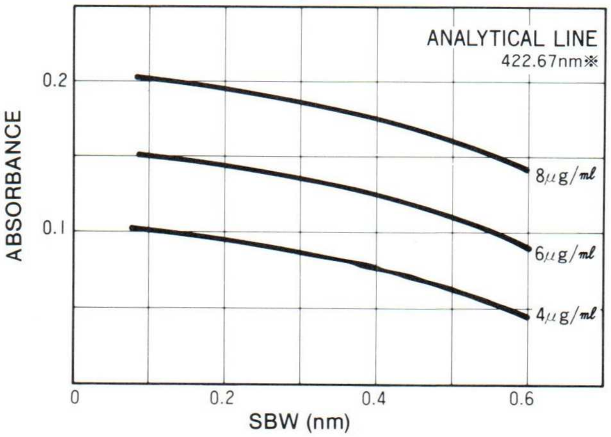
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



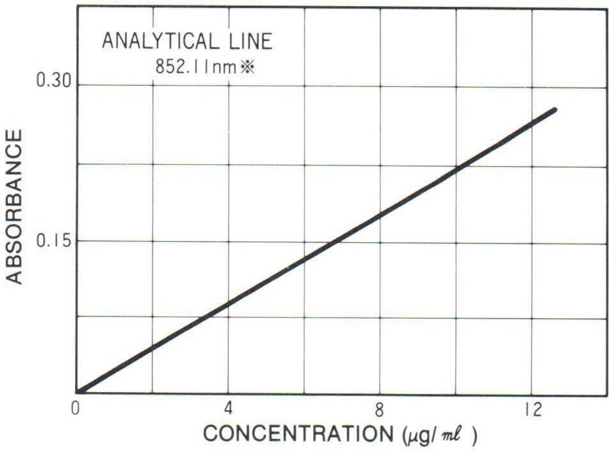
Absorption Sensitivity vs. SBW

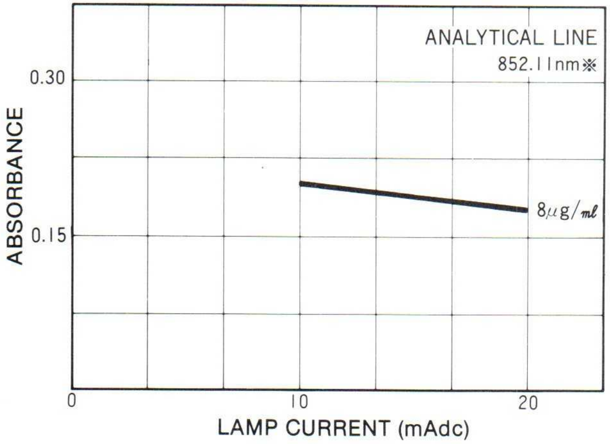


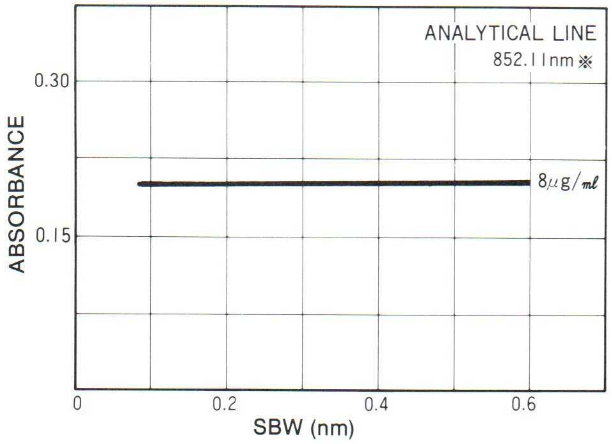
Cesium (Cs)

Type No.: L233-55NB
L1788-55NB

Analytical Lines	: 852.11 nm ※
Starting Voltage	: 210 Vdc
Tube Drop Voltage	: 140 Vdc
Flame	: Air-Propane


Absorption Sensitivity

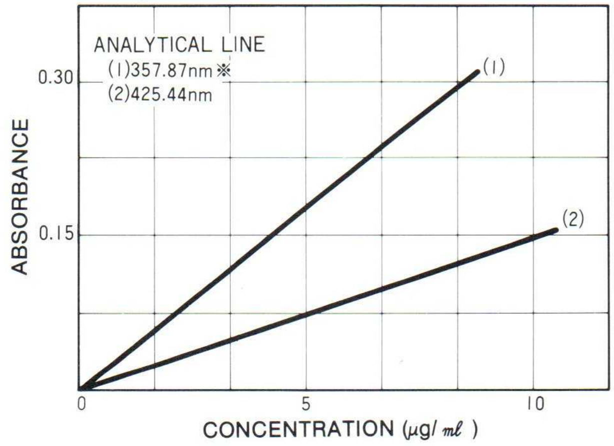

Absorption Sensitivity vs. Lamp Current

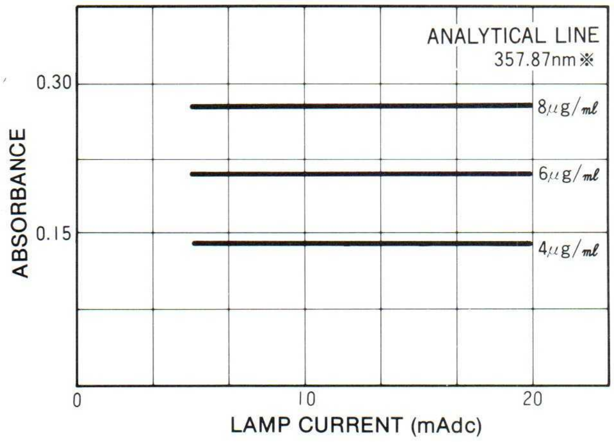

Absorption Sensitivity vs. SBW

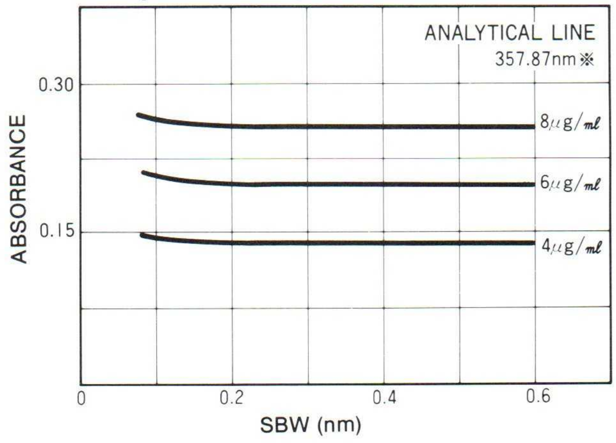
Chromium (Cr)

Type No.: L233-24NB
L1788-24NB

Analytical Lines	: 357.87 nm ※ 425.44 nm
Starting Voltage	: 235 Vdc
Tube Drop Voltage	: 171 Vdc
Flame	: Air-C_2H_2


Absorption Sensitivity


Absorption Sensitivity vs. Lamp Current


Absorption Sensitivity vs. SBW

Cobalt (Co)

Type No.: L233-27NU
L1788-27NQ

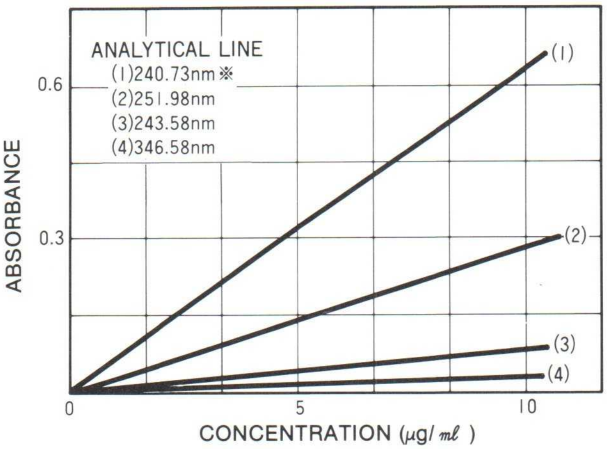
Analytical Lines : 240.73 nm ※
346.58 nm

Starting Voltage : 220 Vdc

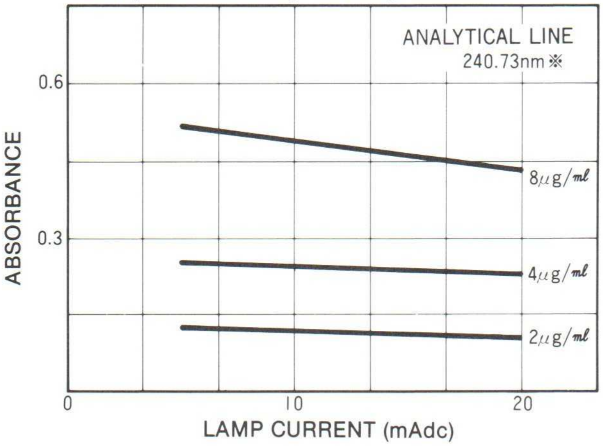
Tube Drop Voltage : 175 Vdc

Flame : Air-C_2H_2

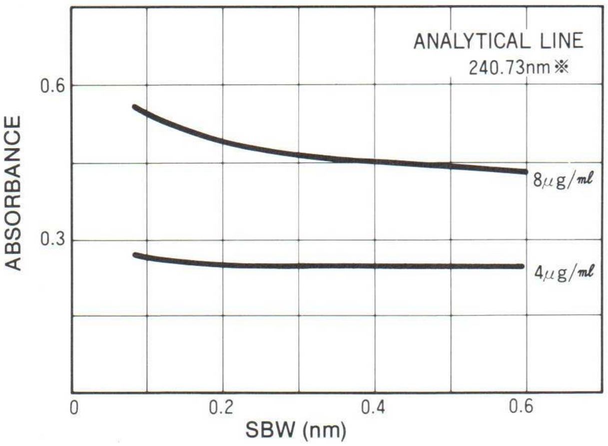
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW



Copper (Cu)

Type No.: L233-29NB
L1788-29NB

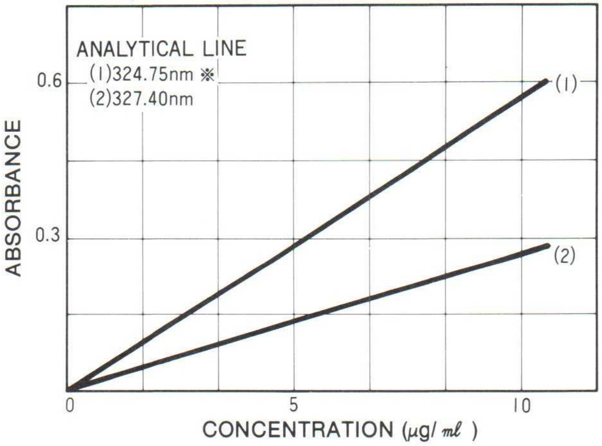
Analytical Lines : 324.75 nm ※
327.40 nm

Starting Voltage : 250 Vdc

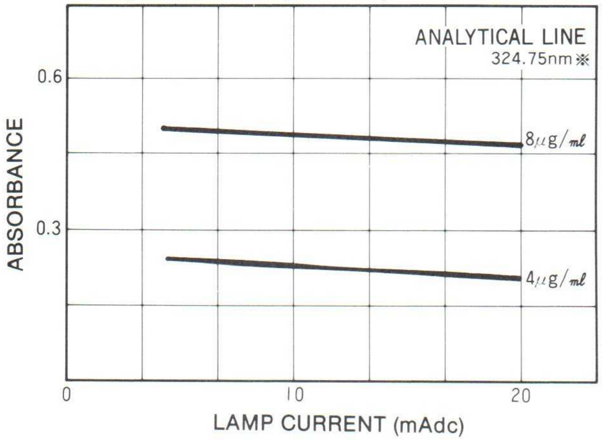
Tube Drop Voltage : 212 Vdc

Flame : Air-C_2H_2

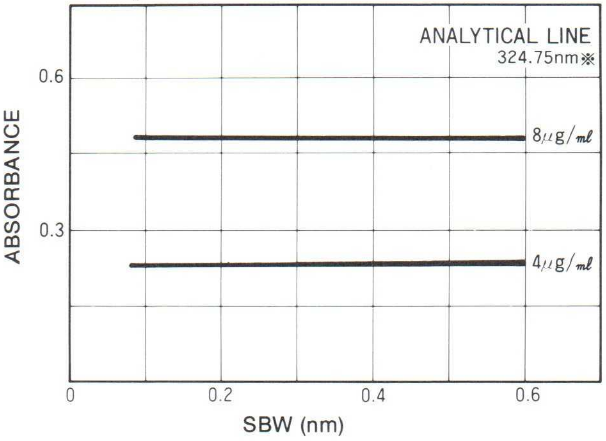
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

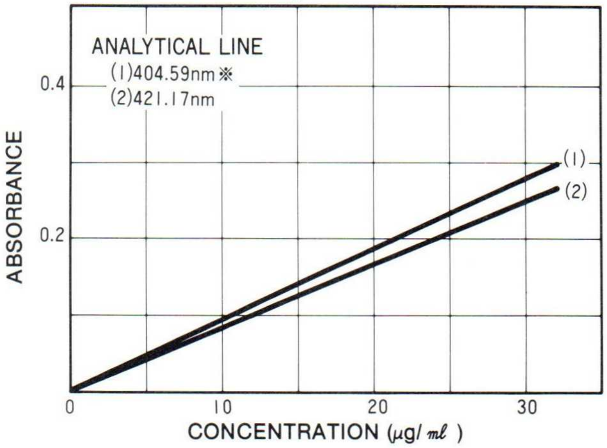


Dysprosium (Dy)

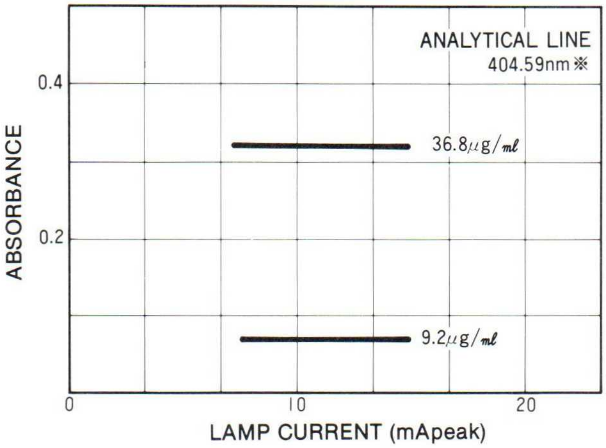
Type No.: L233-66NB
L1788-66NB

Analytical Lines	: 404.59 nm ※ 421.17 nm
Starting Voltage	: 230 Vdc
Tube Drop Voltage	: 139 Vdc
Flame	: N_2O-C_2H_2

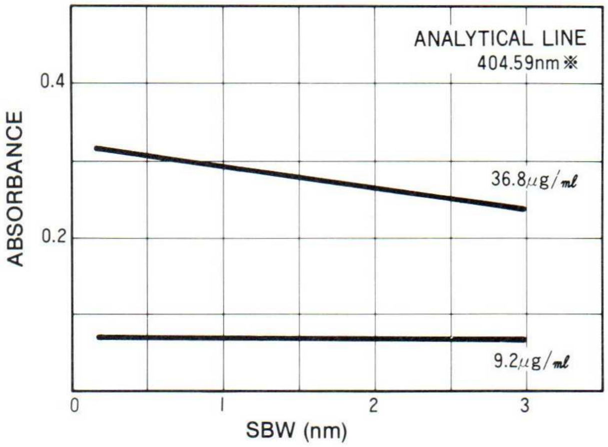
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

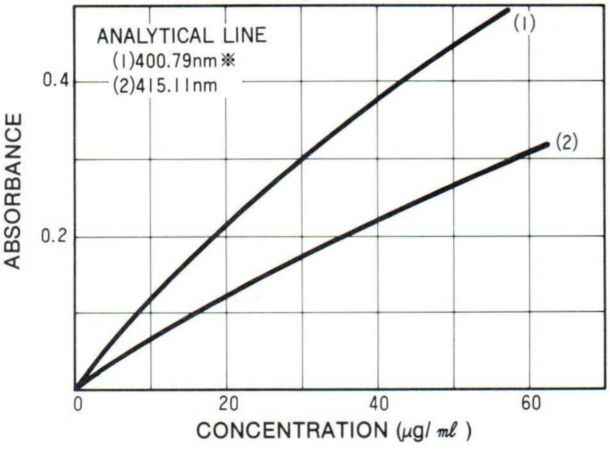


Erbium (Er)

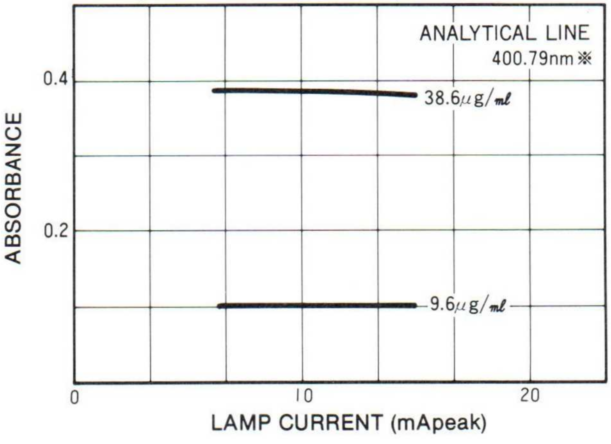
Type No.: L233-68NB
L1788-68NB

Analytical Lines	: 400.79 nm ※ 415.11 nm
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 140 Vdc
Flame	: N_2O-C_2H_2

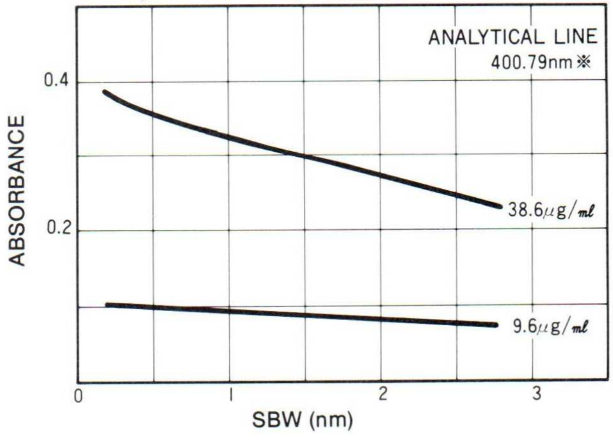
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

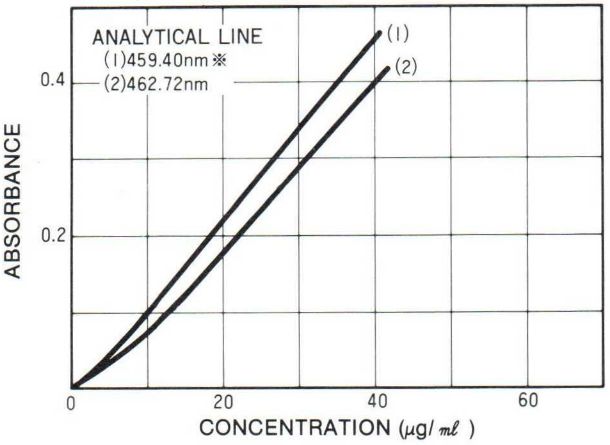


Europium (Eu)

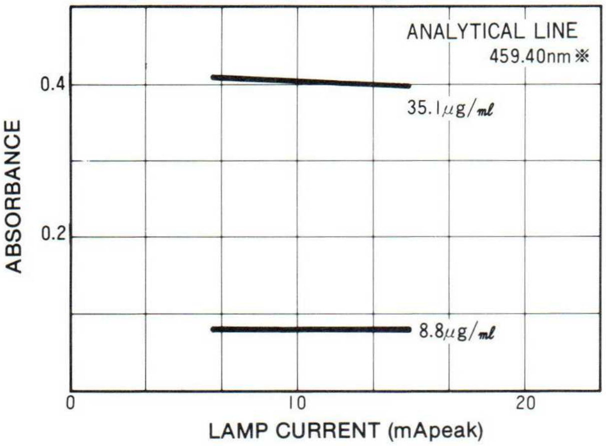
Type No.: L233-63NB
L1788-63NB

Analytical Lines : 459.40 nm ※
462.72 nm
Starting Voltage : 190 Vdc
Tube Drop Voltage : 176 Vdc
Flame : N_2O-C_2H_2

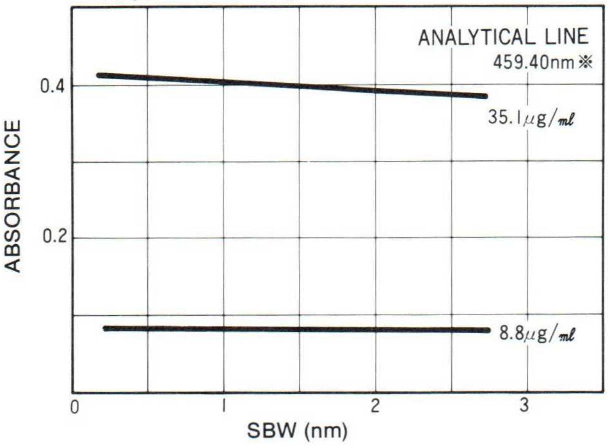
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

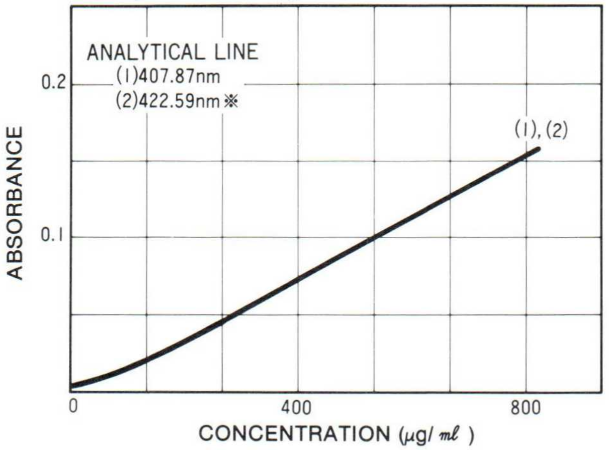


Gadolinium (Gd)

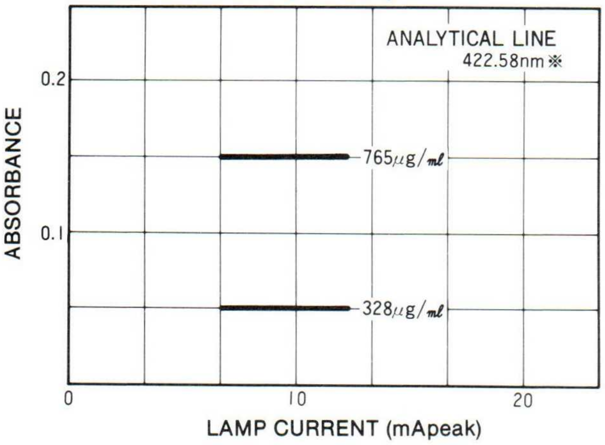
Type No.: L233-64NB
L1788-64NB

Analytical Lines : 407.87 nm
422.58 nm ※
Starting Voltage : 180 Vdc
Tube Drop Voltage : 150 Vdc
Flame : N_2O-C_2H_2

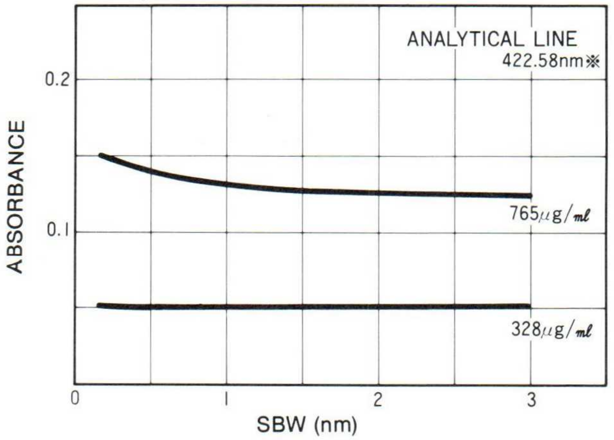
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

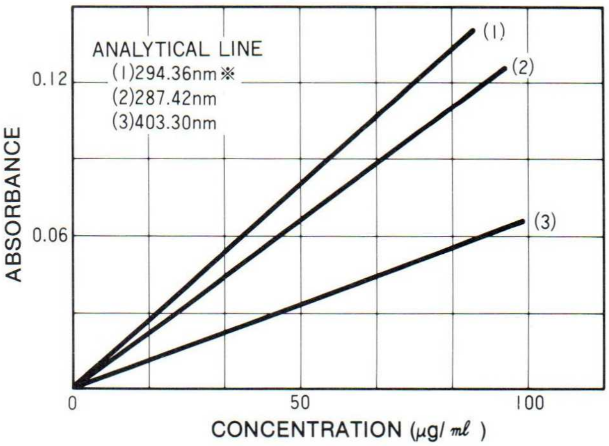


Gallium (Ga)

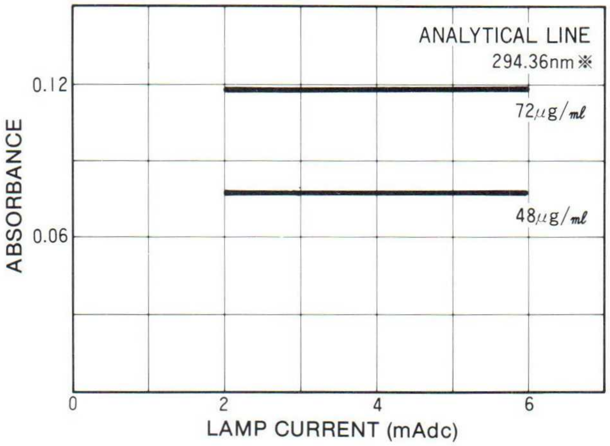
Type No.: L233-31NU
L1788-31NQ

Analytical Lines : 287.42 nm
294.36 nm ※
Starting Voltage : 215 Vdc
Tube Drop Voltage : 172 Vdc
Flame : Air-C_2H_2

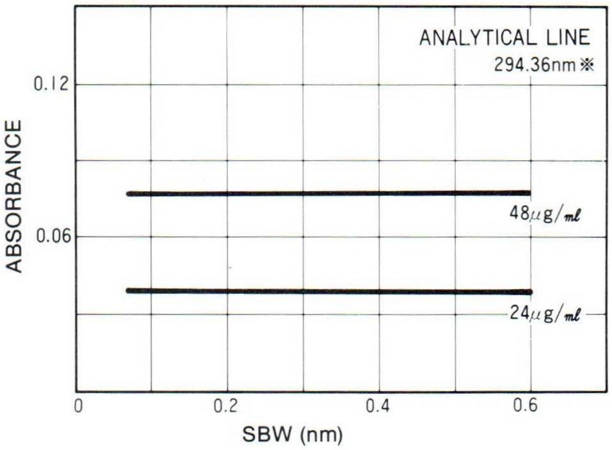
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

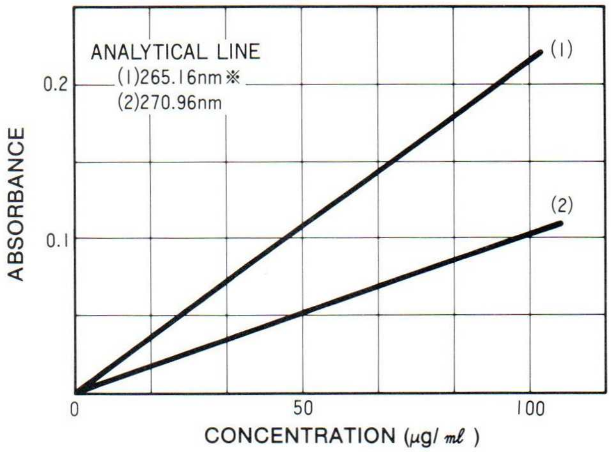


Germanium (Ge)

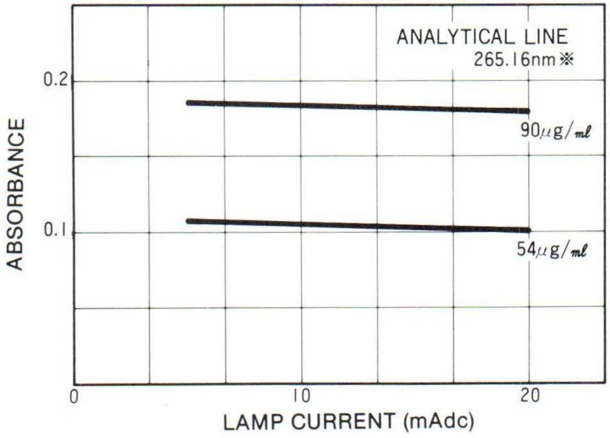
Type No.: L233-32NU
L1788-32NQ

Analytical Lines : 265.16 nm ※
Starting Voltage : 260 Vdc
Tube Drop Voltage : 228 Vdc
Flame : N_2O-C_2H_2

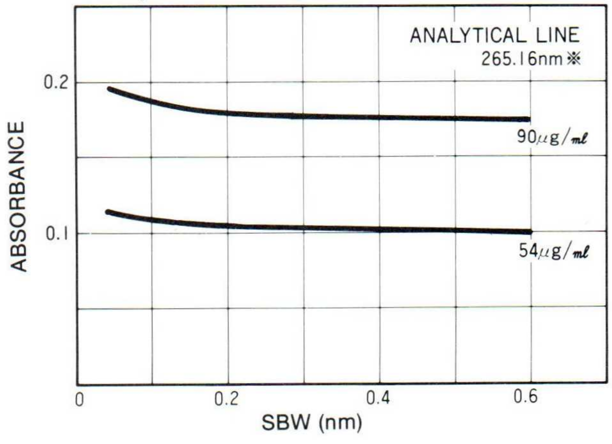
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW



Gold (Au)

Type No.: L233-79NQ
L1788-79NQ

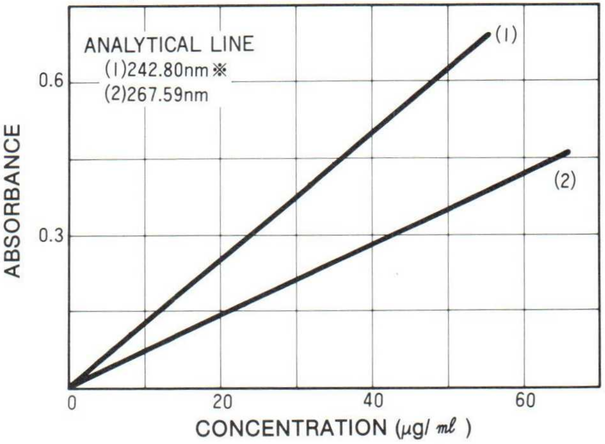
Analytical Lines : 242.80 nm ※
267.59 nm

Starting Voltage : 255 Vdc

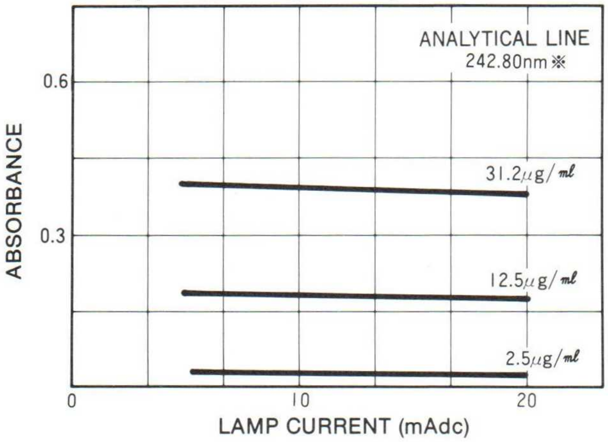
Tube Drop Voltage : 233 Vdc

Flame : Air-C_2H_2

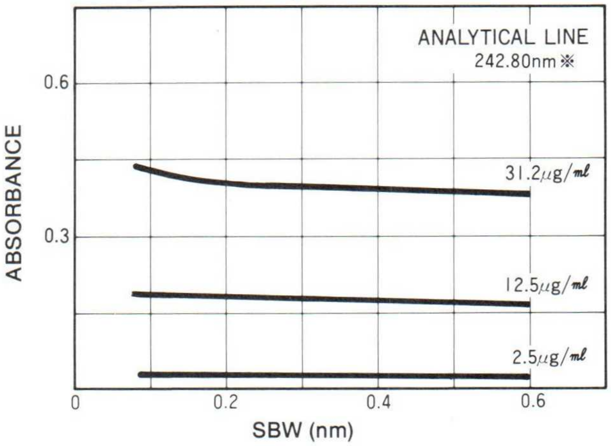
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW



Hafnium (Hf)

Type No.: L233-72NU
L1788-72NQ

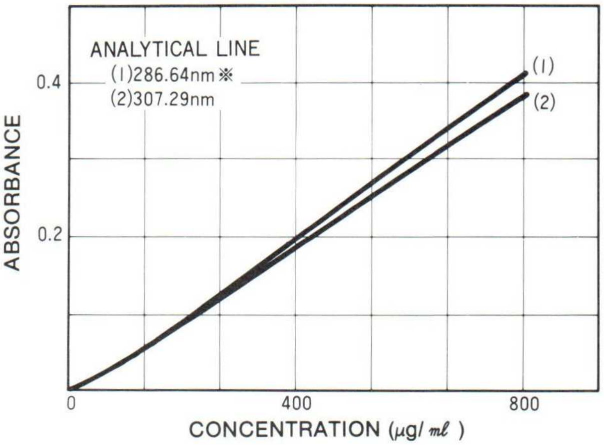
Analytical Lines : 286.64 nm ※
307.29 nm

Starting Voltage : 230 Vdc

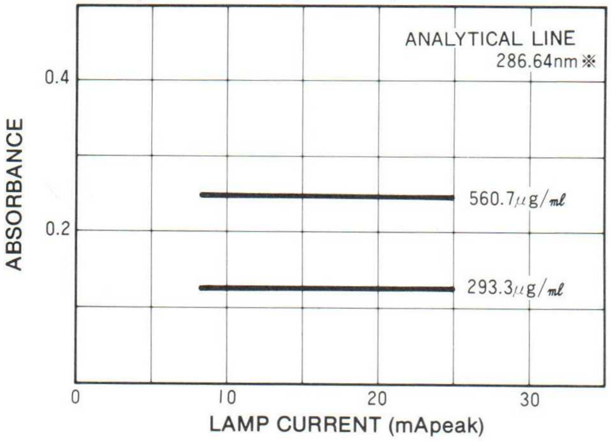
Tube Drop Voltage : 130 Vdc

Flame : N_2O-C_2H_2

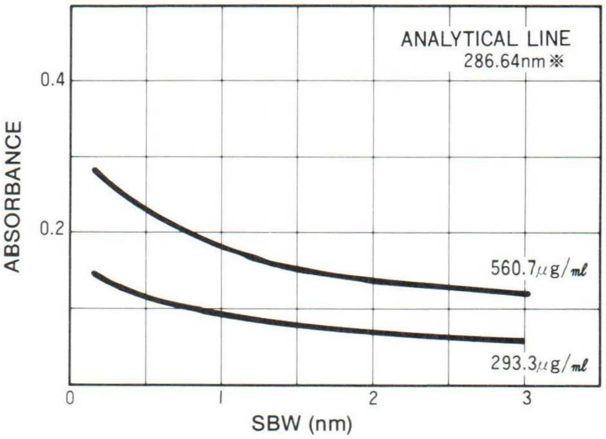
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

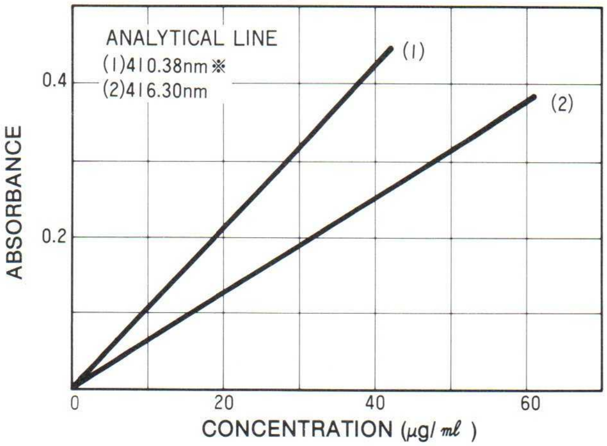


Holmium (Ho)

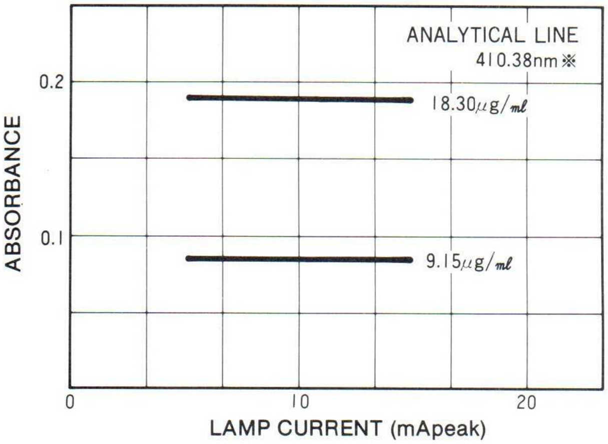
Type No.: L233-67NB
L1788-67NB

Analytical Lines : 410.38 nm ※
416.30 nm
Starting Voltage : 220 Vdc
Tube Drop Voltage : 147 Vdc
Flame : $N_2O - C_2H_2$

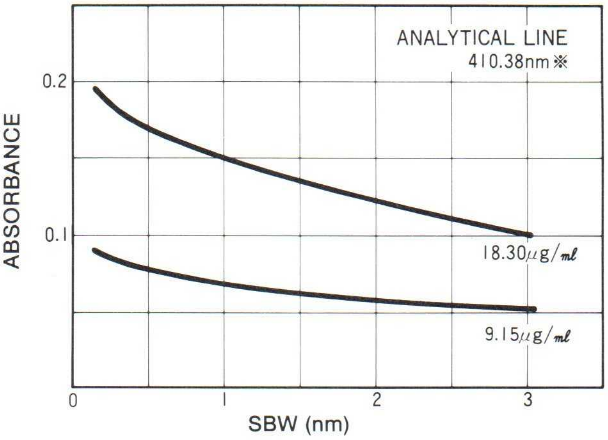
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

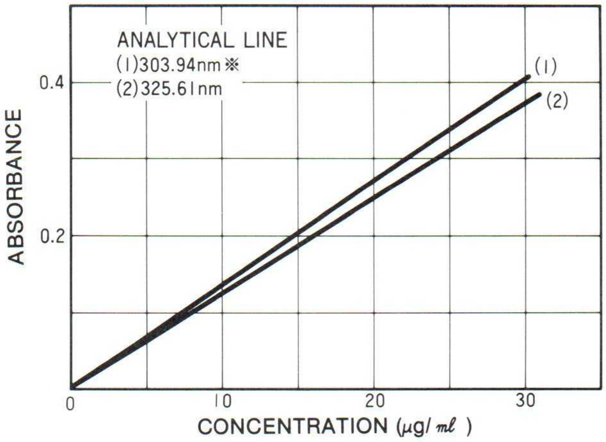


Indium (In)

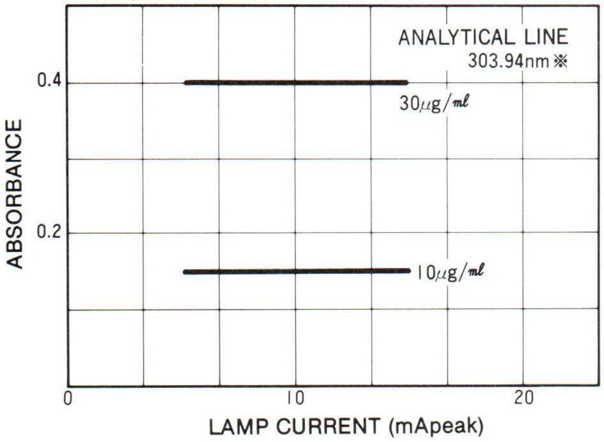
Type No.: L233-49NB
L1788-49NB

Analytical Lines : 303.94 nm ※
325.61 nm
Starting Voltage : 210 Vdc
Tube Drop Voltage : 171 Vdc
Flame : Air-C_2H_2

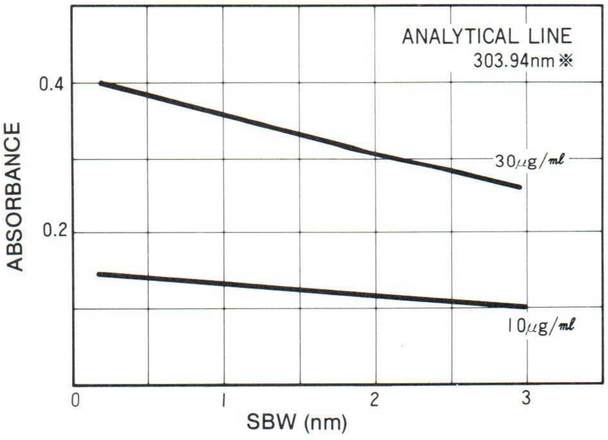
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

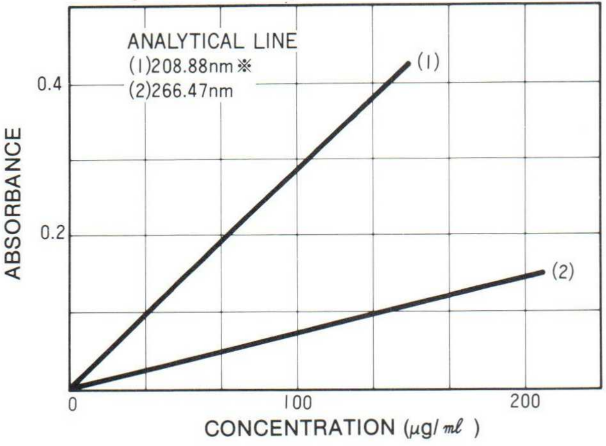


Iridium (Ir)

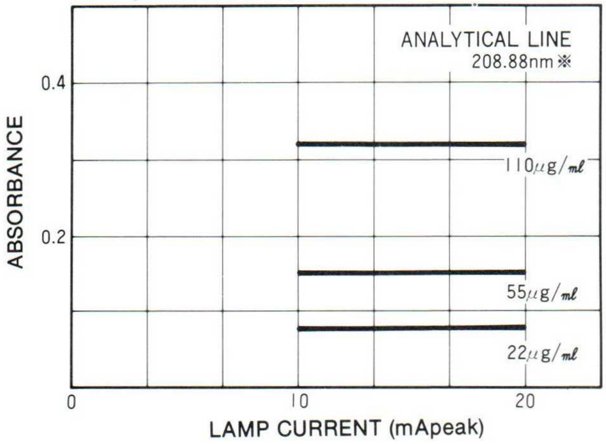
Type No.: L233-77NQ
L1788-77NQ

Analytical Lines	: 208.88 nm ※ 266.47 nm
Starting Voltage	: 230 Vdc
Tube Drop Voltage	: 162 Vdc
Flame	: Air-C_2H_2

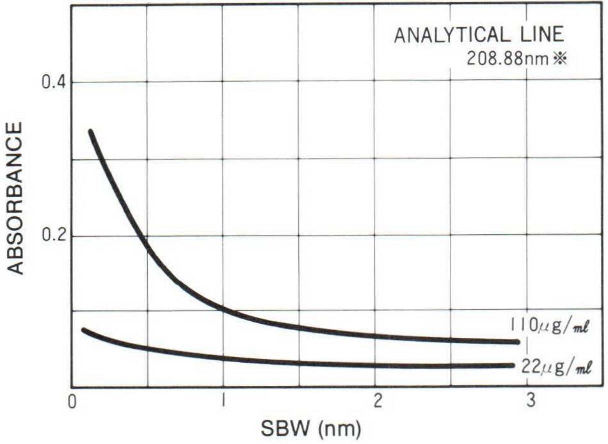
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

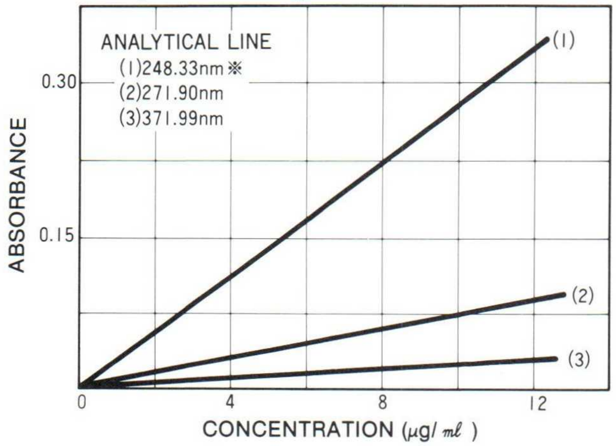


Iron (Fe)

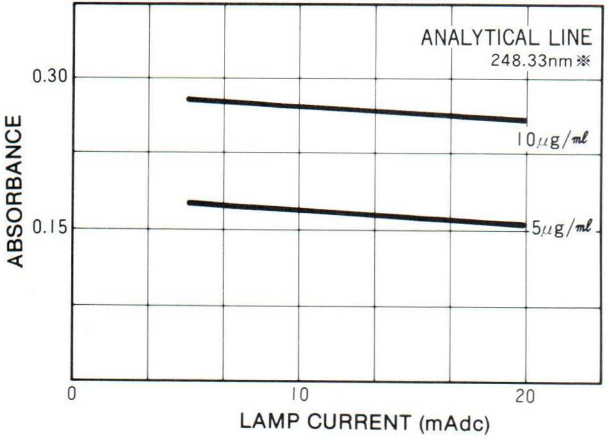
Type No.: L233-26NU
L1788-26NQ

Analytical Lines	: 248.33 nm ※ 371.99 nm
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 174 Vdc
Flame	: Air-C_2H_2

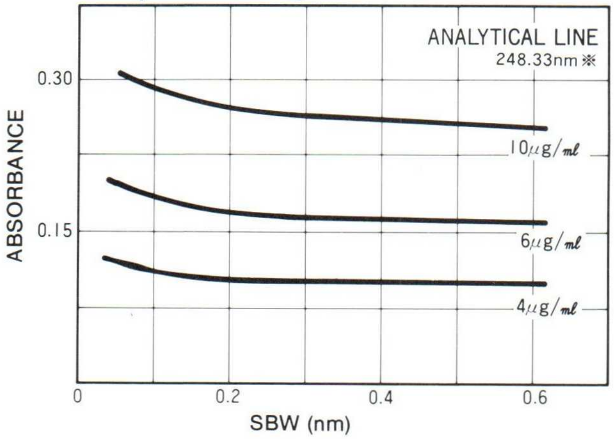
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



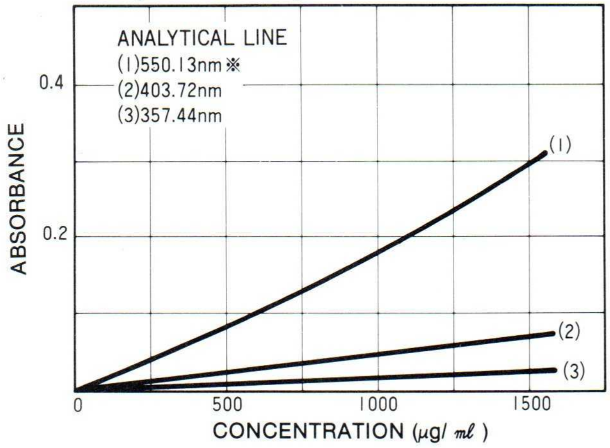
Absorption Sensitivity vs. SBW

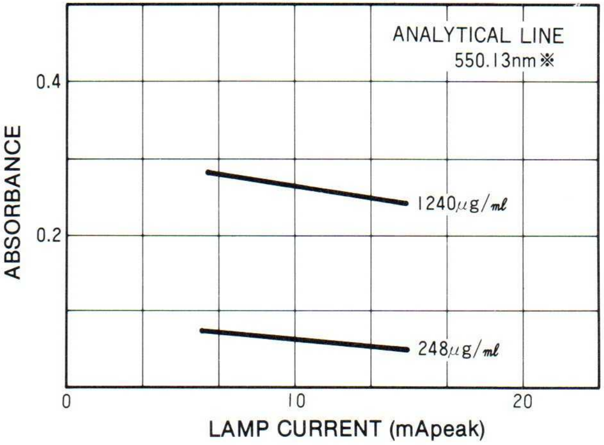


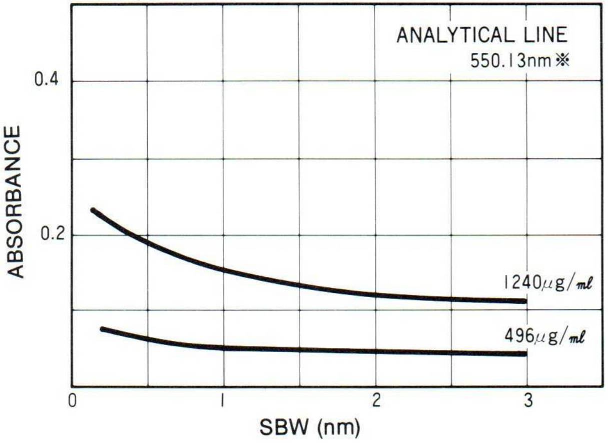
Lanthanum (La)

Type No.: L233-57NB
L1788-57NB

Analytical Lines : 357.44 nm
550.13 nm ※
Starting Voltage : 190 Vdc
Tube Drop Voltage : 158 Vdc
Flame : N_2O-C_2H_2


Absorption Sensitivity

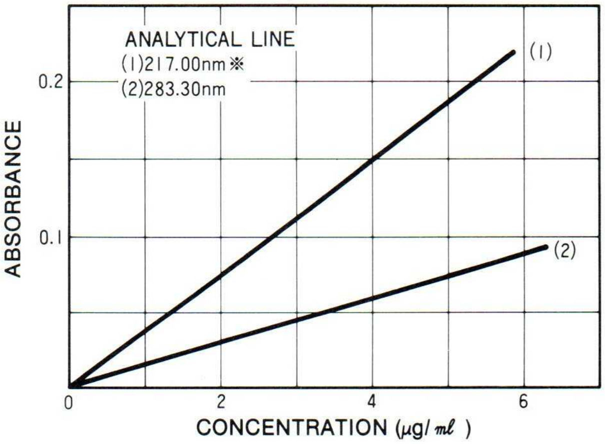

Absorption Sensitivity vs. Lamp Current

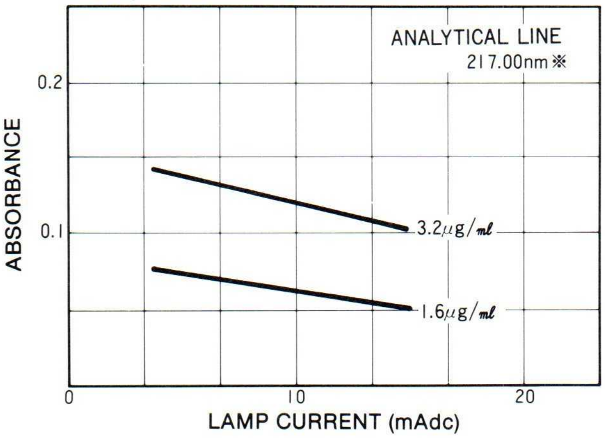

Absorption Sensitivity vs. SBW

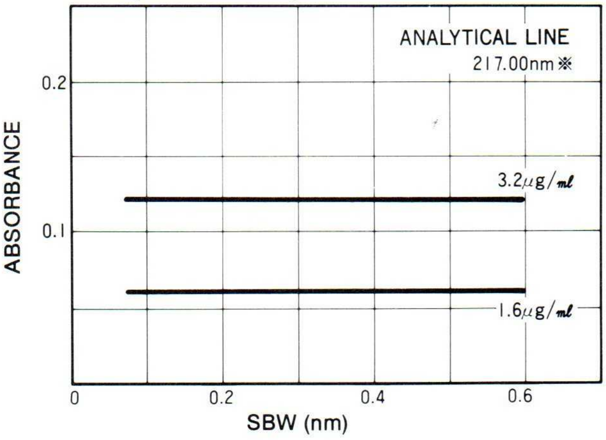
Lead (Pb)

Type No.: L233-82NQ
L1788-82NQ

Analytical Lines : 217.00 nm ※
283.30 nm
Starting Voltage : 215 Vdc
Tube Drop Voltage : 162 Vdc
Flame : Air-C_2H_2


Absorption Sensitivity

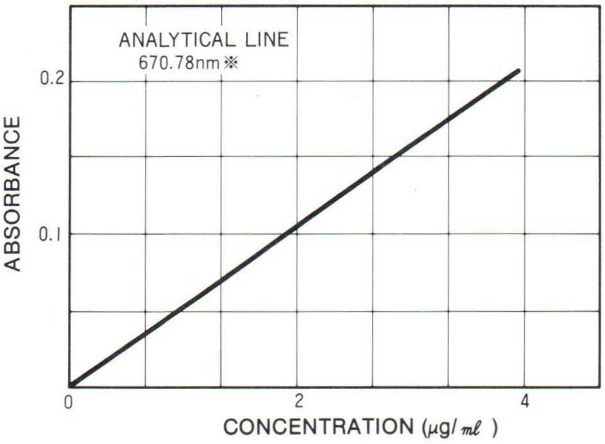

Absorption Sensitivity vs. Lamp Current


Absorption Sensitivity vs. SBW

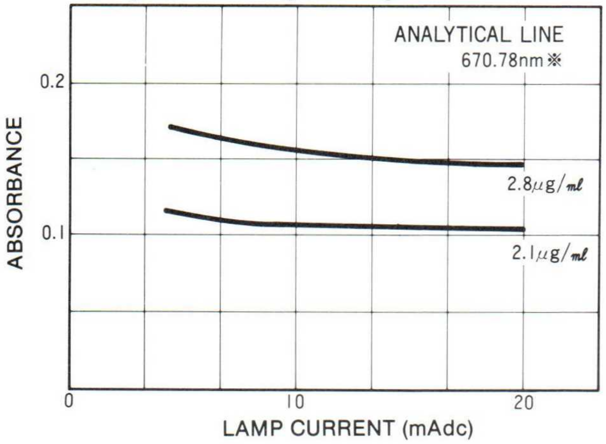
Lithium (Li)

Type No.:	L233-3NB L1788-3NB
Analytical Lines	: 610.36 nm 670.78 nm ※
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 183 Vdc
Flame	: Air-C_2H_2

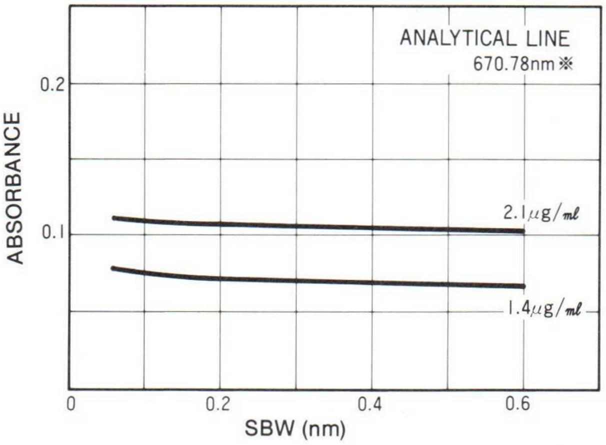
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



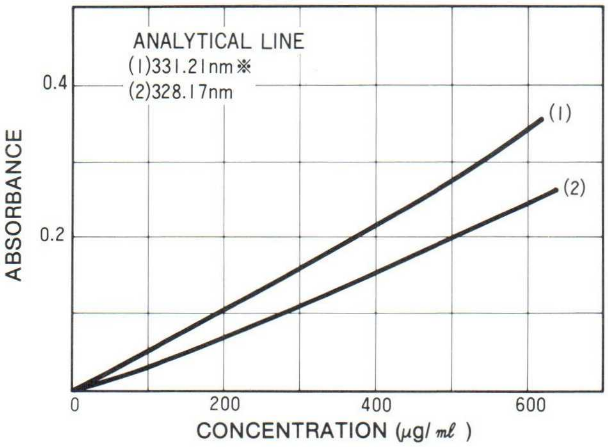
Absorption Sensitivity vs. SBW



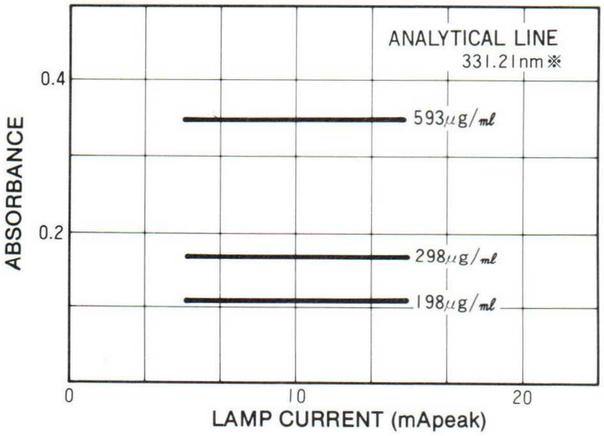
Lutetium (Lu)

Type No.:	L233-71NB L1788-71NB
Analytical Lines	: 328.17 nm 331.21 nm ※
Starting Voltage	: 230 Vdc
Tube Drop Voltage	: 132 Vdc
Flame	: N_2O-C_2H_2

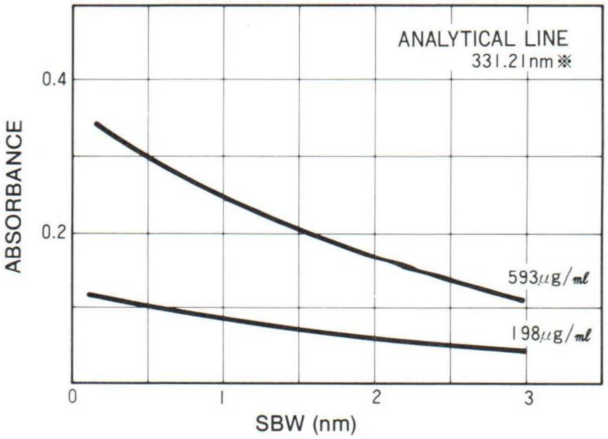
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

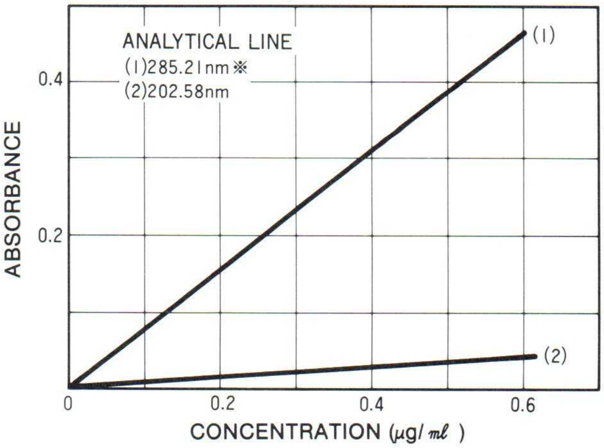


Magnesium (Mg)

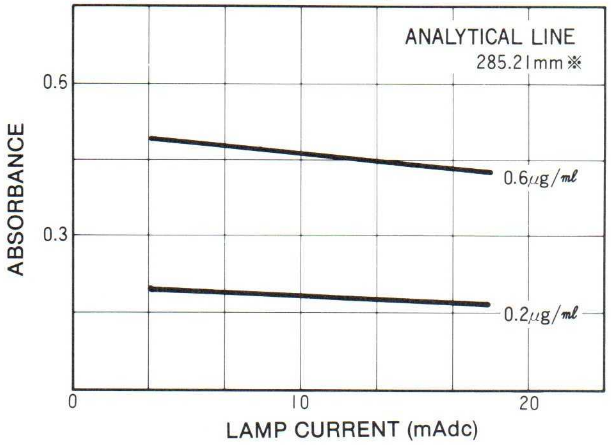
Type No.: L233-12NU
L1788-12NQ

Analytical Lines : 285.21 nm ※
Starting Voltage : 200 Vdc
Tube Drop Voltage : 142 Vdc
Flame : Air-C_2H_2

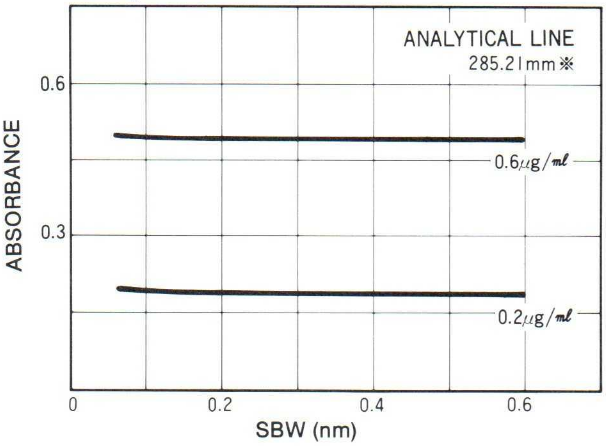
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

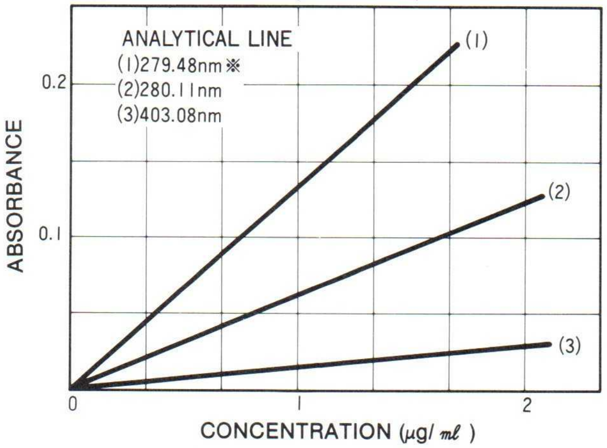


Manganese (Mn)

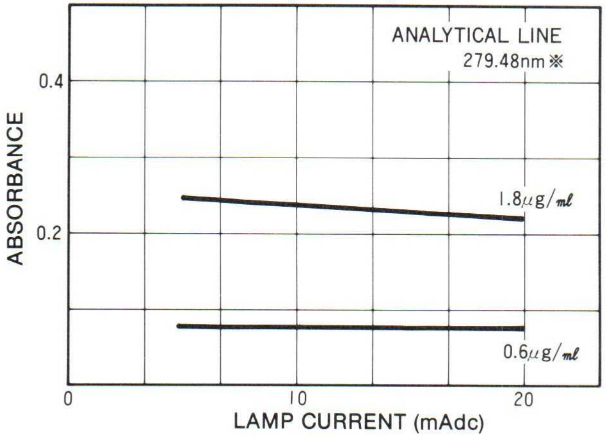
Type No.: L233-25NU
L1788-25NQ

Analytical Lines : 279.48 nm ※
403.08 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 162 Vdc
Flame : Air-C_2H_2

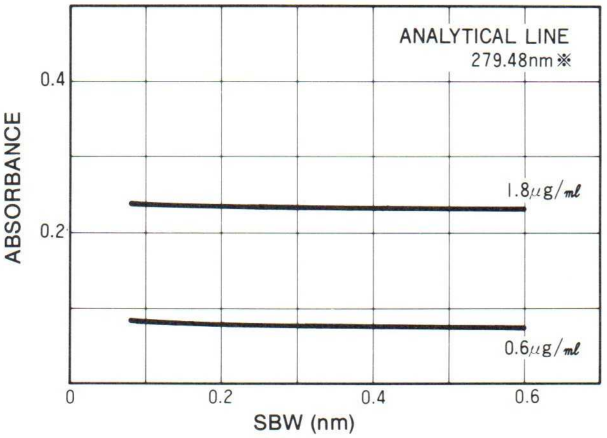
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

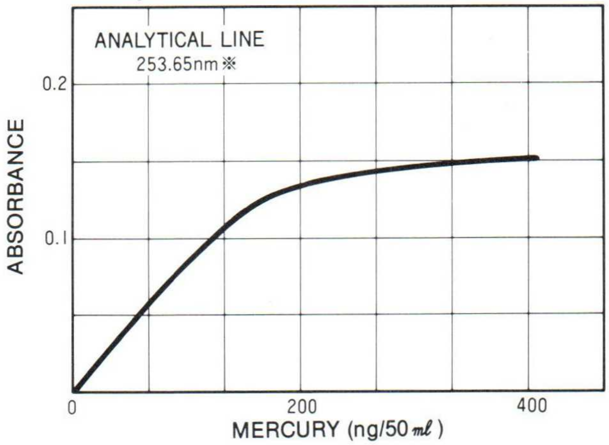


Mercury (Hg)

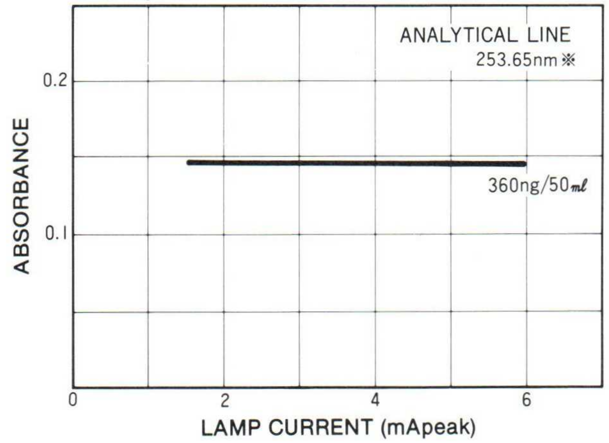
Type No.: L233-80NU
L1788-80NQ

Analytical Lines : 253.65 nm ※
Starting Voltage : 350 Vdc
Tube Drop Voltage : 159 Vdc
Cold Vapor Generation Method

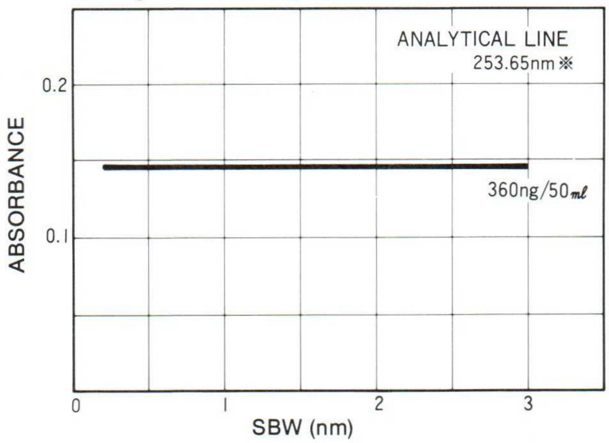
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

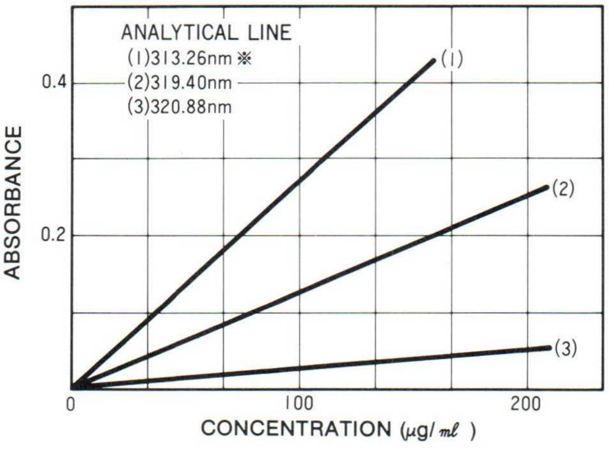


Molybdenum (Mo)

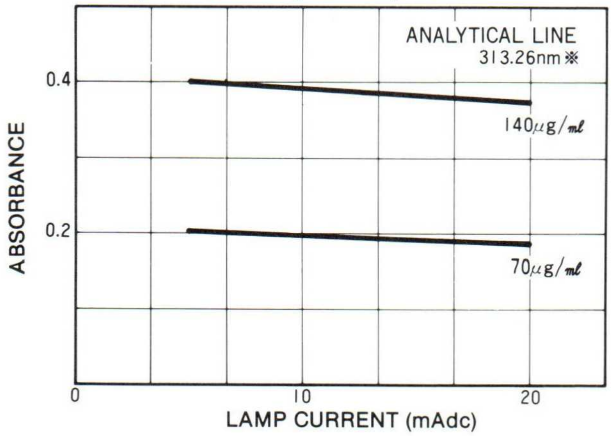
Type No.: L233-42NB
L1788-42NB

Analytical Lines : 313.26 nm ※
320.88 nm
Starting Voltage : 200 Vdc
Tube Drop Voltage : 128 Vdc
Flame : Air-C_2H_2

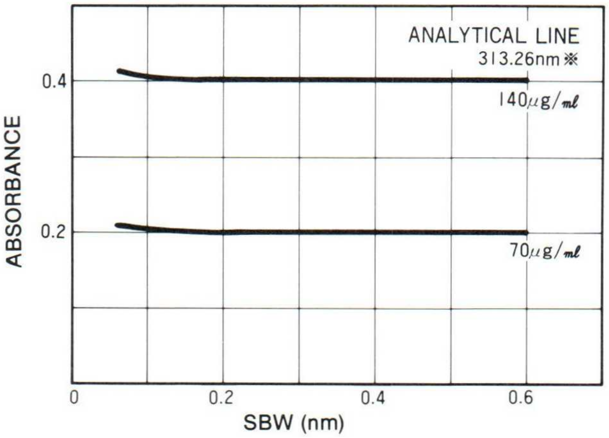
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

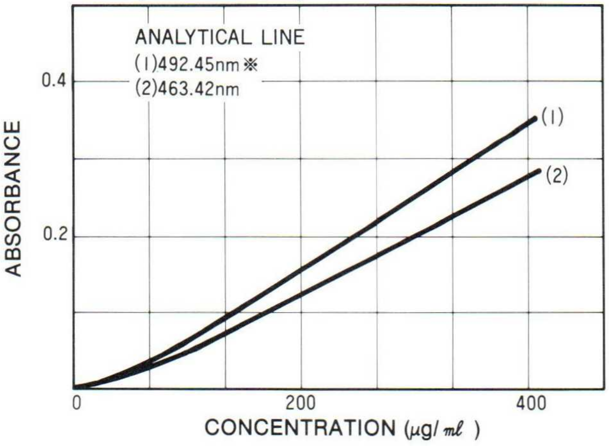


Neodymium (Nd)

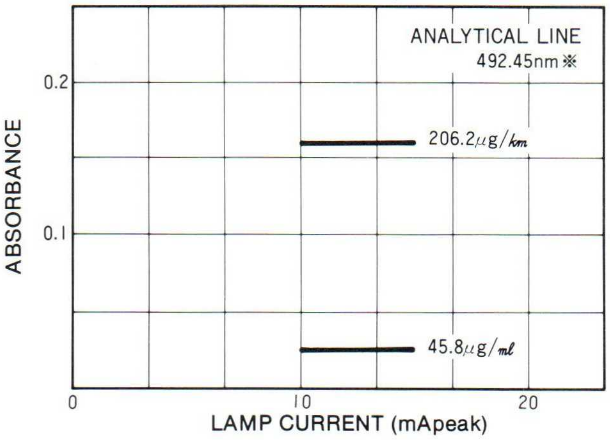
Type No.: L233-60NB
L1788-60NB

Analytical Lines : 463.42 nm
492.45 nm ※
Starting Voltage : 210 Vdc
Tube Drop Voltage : 143 Vdc
Flame : N_2O-C_2H_2

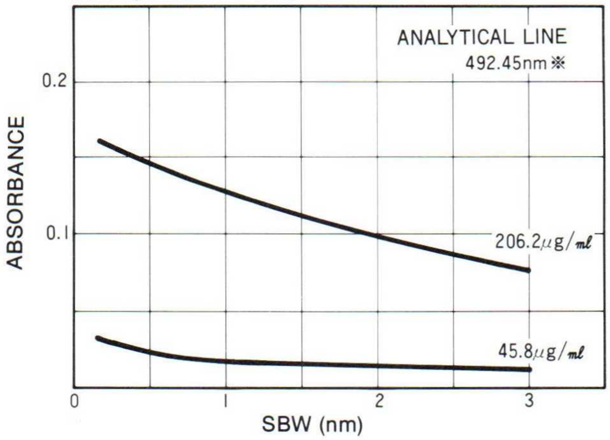
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

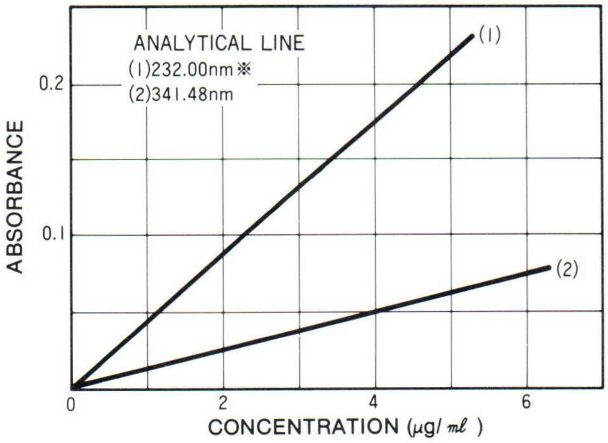


Nickel (Ni)

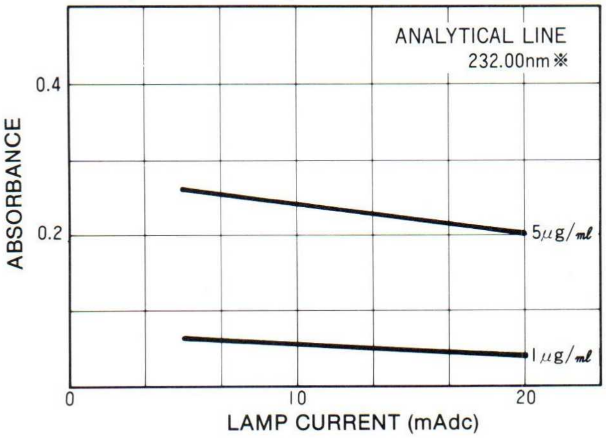
Type No.: L233-28NQ
L1788-28NQ

Analytical Lines : 232.00 nm ※
341.48 nm
Starting Voltage : 240 Vdc
Tube Drop Voltage : 186 Vdc
Flame : Air-C_2H_2

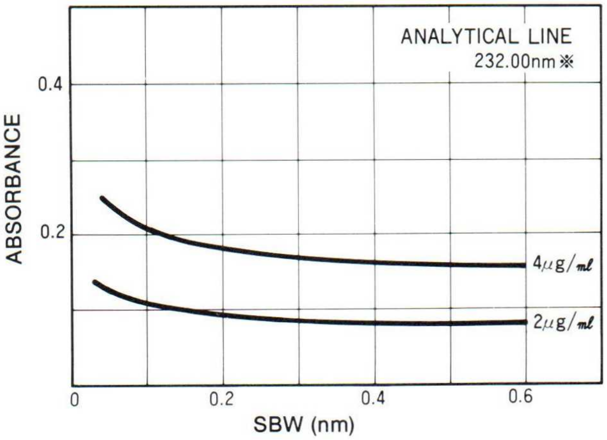
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

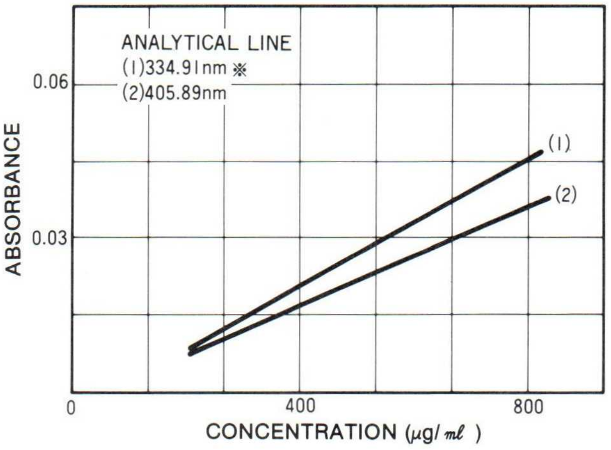


Niobium (Nb)

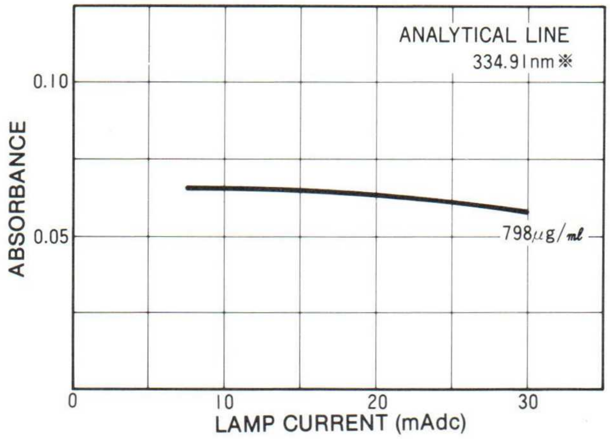
Type No.: L233-41NB
L1788-41NB

Analytical Lines : 334.91 nm ※
405.89 nm
Starting Voltage : 225 Vdc
Tube Drop Voltage : 134 Vdc
Flame : N_2O-C_2H_2

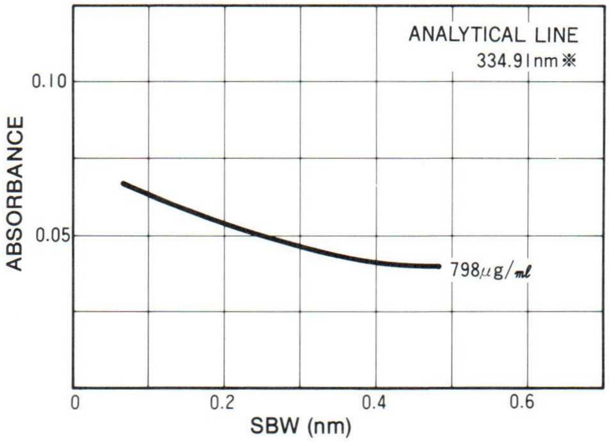
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

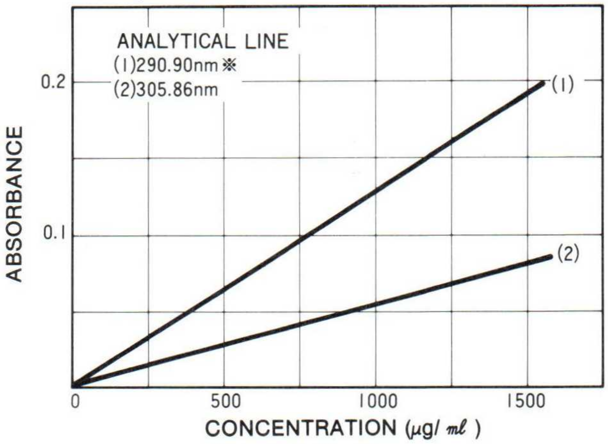


Osmium (Os)

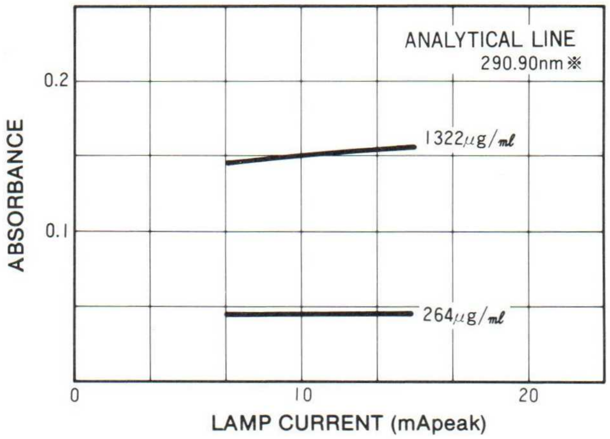
Type No.: L233-76NU
L1788-76NQ

Analytical Lines : 290.90 nm ※
305.86 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 124 Vdc
Flame : N_2O-C_2H_2

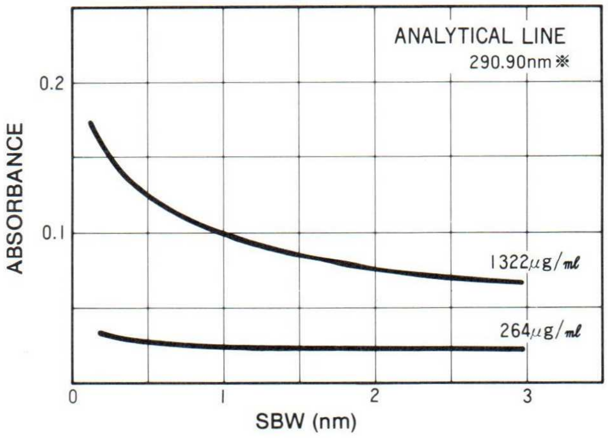
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

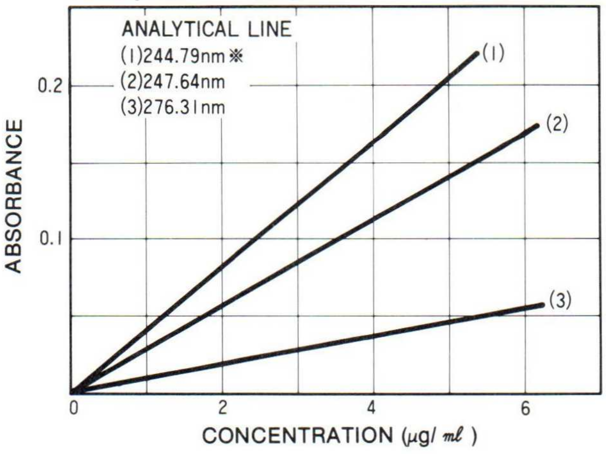


Palladium (Pd)

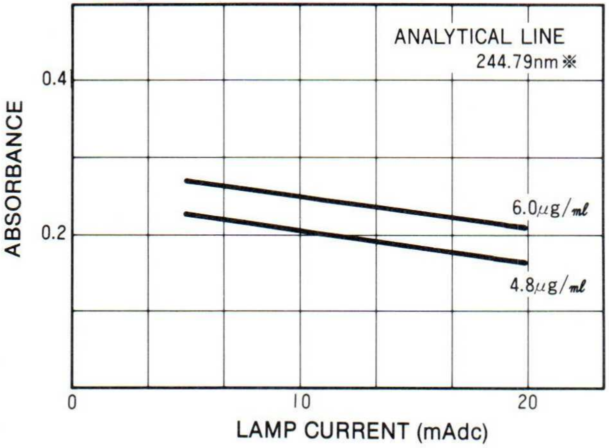
Type No.: L233-46NQ
L1788-46NQ

Analytical Lines	: 244.79 nm※ 247.64 nm
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 164 Vdc
Flame	: Air-C_2H_2

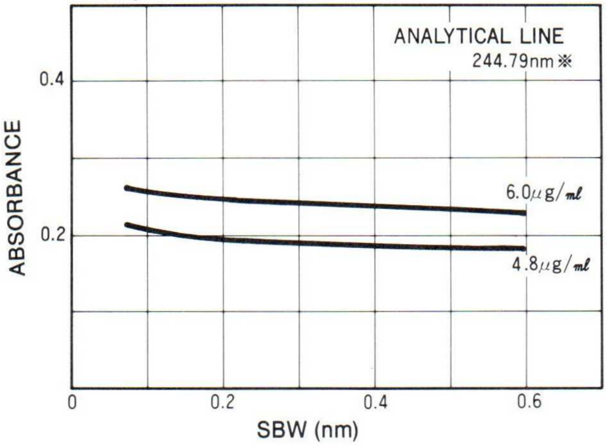
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

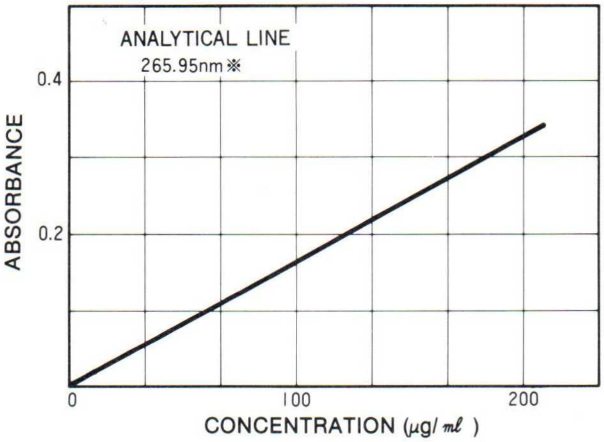


Platinum (Pt)

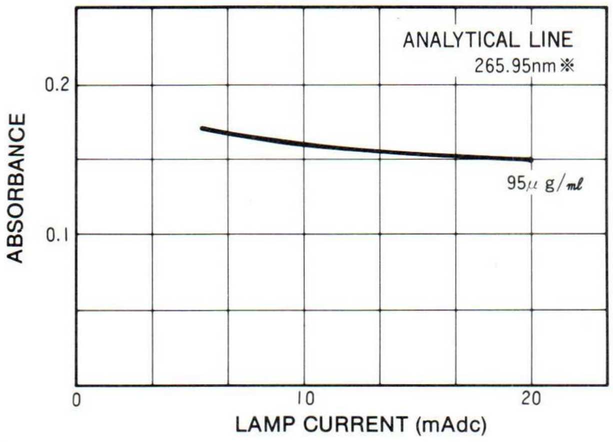
Type No.: L233-78NU
L1788-78NQ

Analytical Lines	: 265.95 nm※ 299.80 nm
Starting Voltage	: 200 Vdc
Tube Drop Voltage	: 181 Vdc
Flame	: Air-C_2H_2

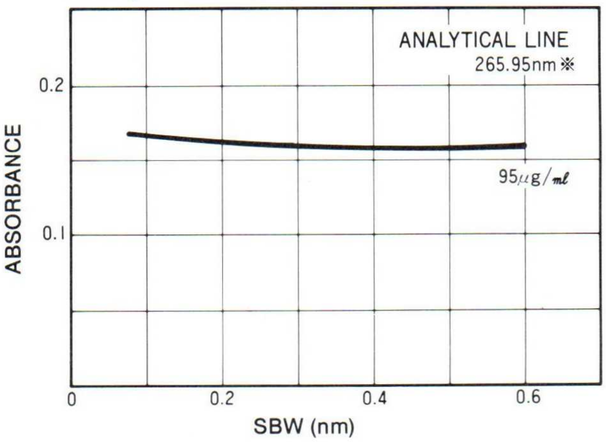
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

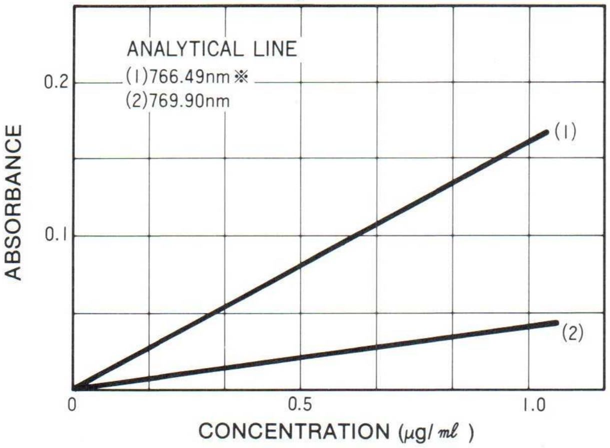


Potassium (K)

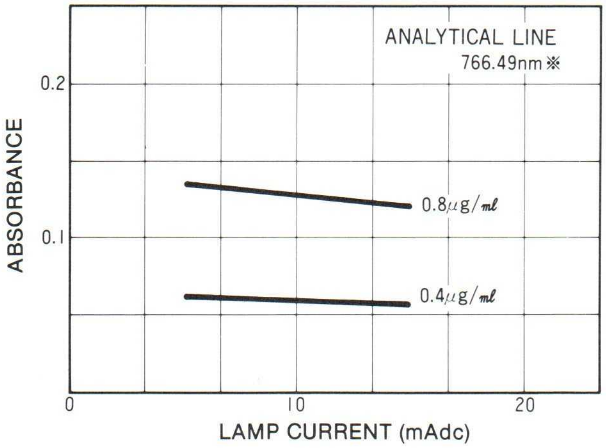
Type No.: L233-19NB
L1788-19NB

Analytical Lines	: 766.49 nm ※ 769.90 nm
Starting Voltage	: 190 Vdc
Tube Drop Voltage	: 145 Vdc
Flame	: Air-C_2H_2

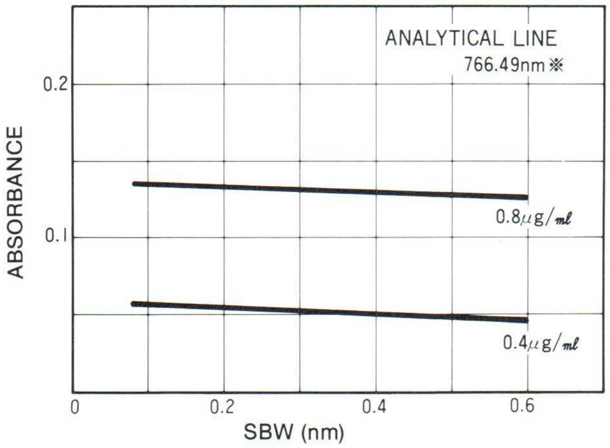
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

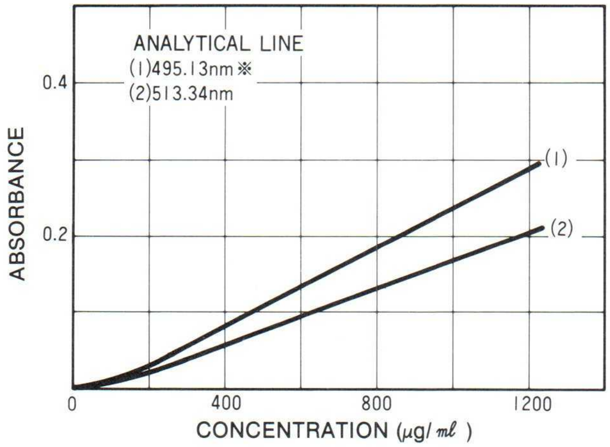


Praseodymium (Pr)

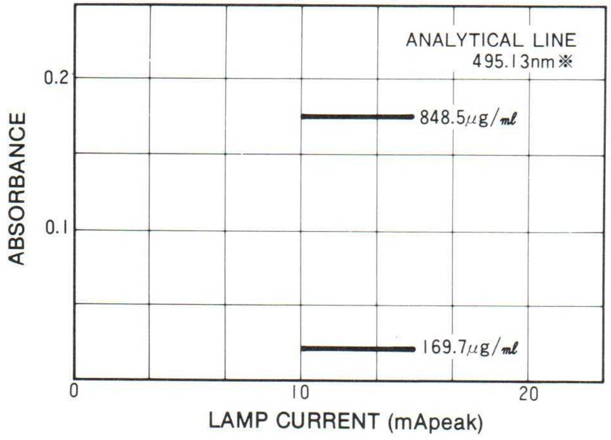
Type No.: L233-59NB
L1788-59NB

Analytical Lines	: 495.13 nm ※ 513.34 nm
Starting Voltage	: 200 Vdc
Tube Drop Voltage	: 145 Vdc
Flame	: N_2O-C_2H_2

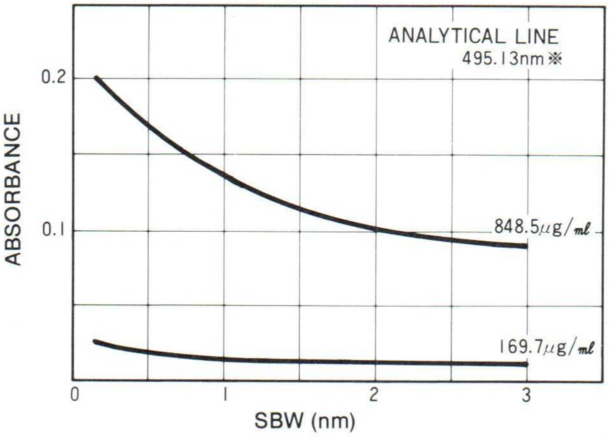
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

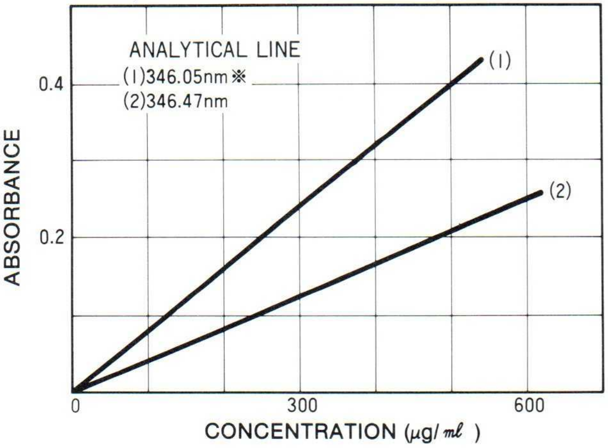


Rhenium (Re)

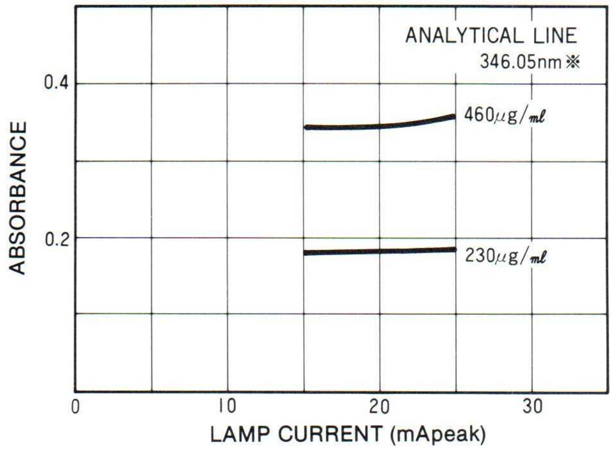
Type No.: L233-75NB
L1788-75NB

Analytical Lines : 346.05 nm ※
346.47 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 145 Vdc
Flame : N_2O-C_2H_2

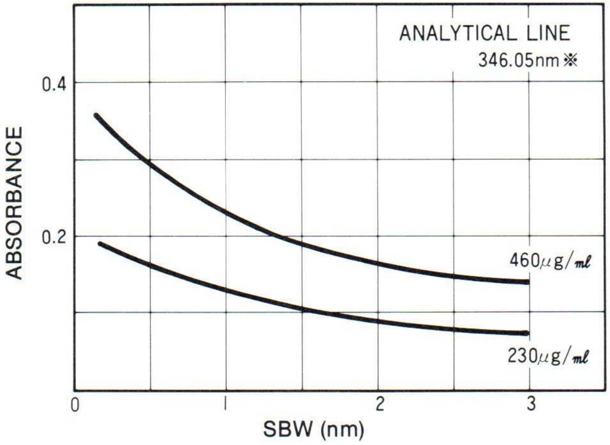
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

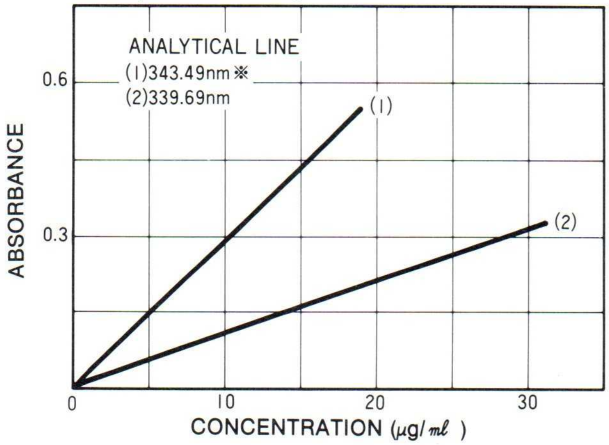


Rhodium (Rh)

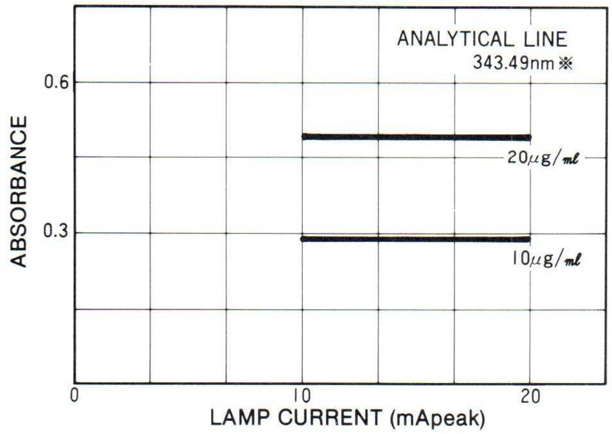
Type No.: L233-45NB
L1788-45NB

Analytical Lines : 343.49 nm ※
Starting Voltage : 250 Vdc
Tube Drop Voltage : 152 Vdc
Flame : Air-C_2H_2

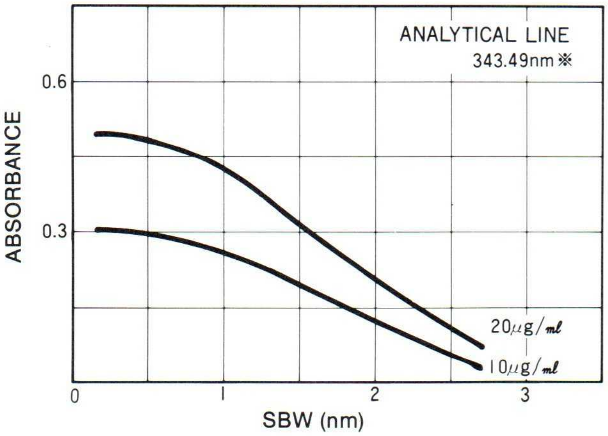
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

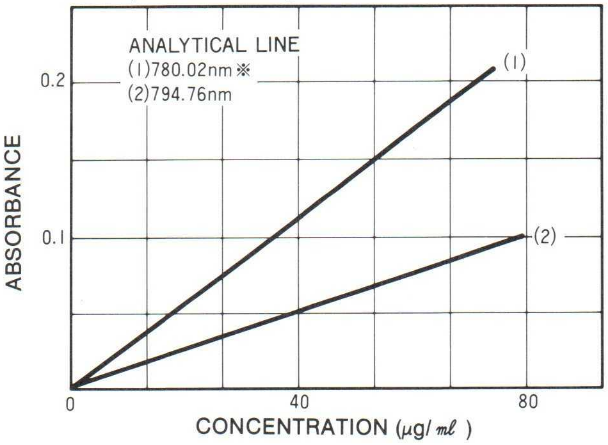


Rubidium (Rb)

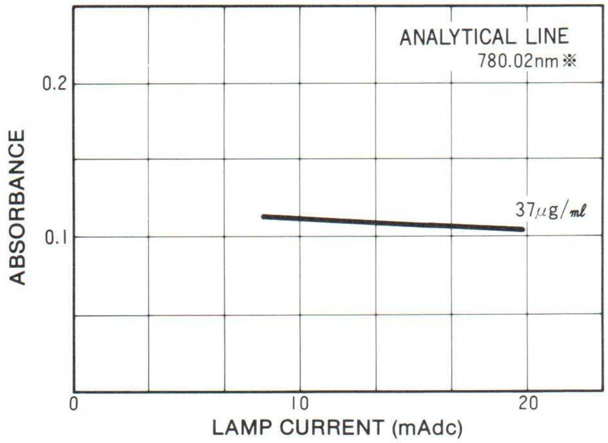
Type No.: L233-37NB
L1788-37NB

Analytical Lines : 780.02 nm ※
794.76 nm
Starting Voltage : 200 Vdc
Tube Drop Voltage : 155 Vdc
Flame : Air-Propane

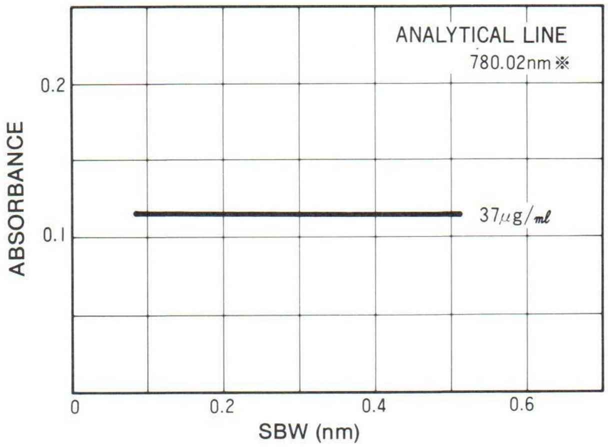
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

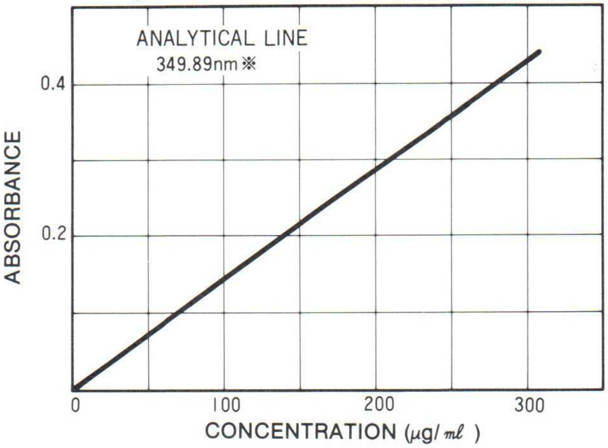


Ruthenium (Ru)

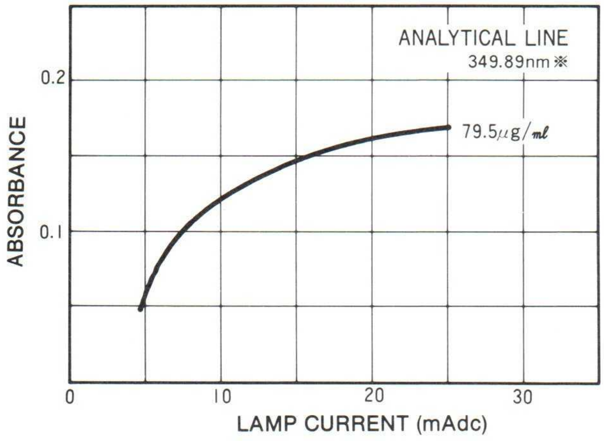
Type No.: L233-44NB
L1788-44NB

Analytical Lines : 349.89 nm ※
Starting Voltage : 220 Vdc
Tube Drop Voltage : 147Vdc
Flame : Air-C_2H_2

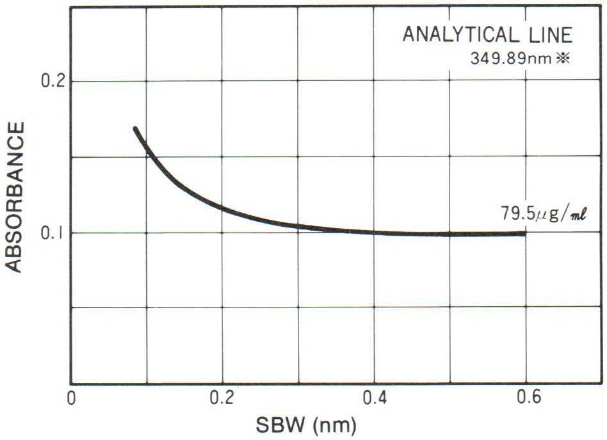
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW



Samarium (Sm)

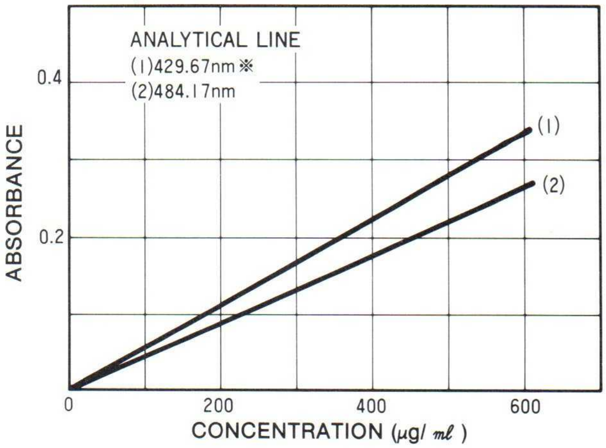
Type No.: L233-62NB
L1788-62NB

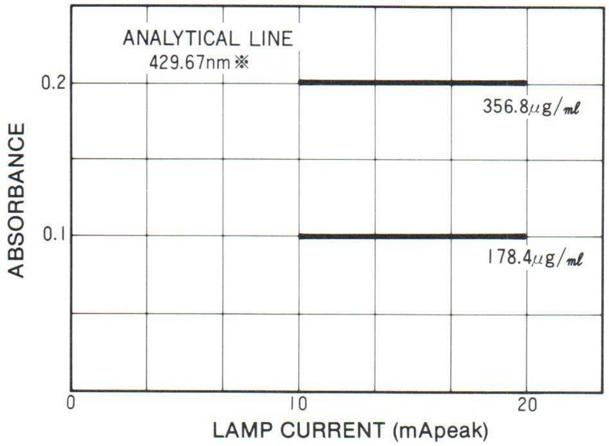
Analytical Lines : 429.67 nm ※
484.17 nm

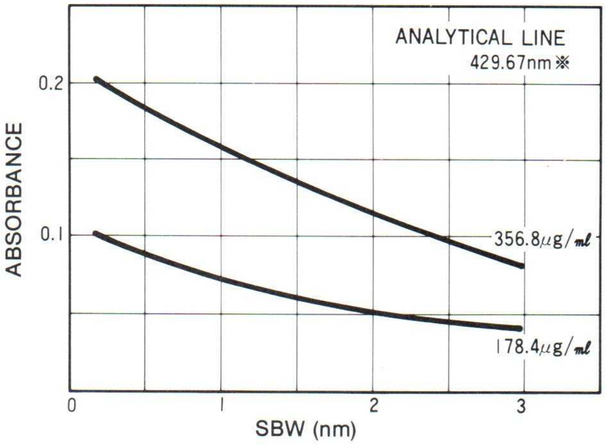
Starting Voltage : 200 Vdc

Tube Drop Voltage : 149 Vdc

Flame : N_2O-C_2H_2


Absorption Sensitivity


Absorption Sensitivity vs. Lamp Current


Absorption Sensitivity vs. SBW

Scandium (Sc)

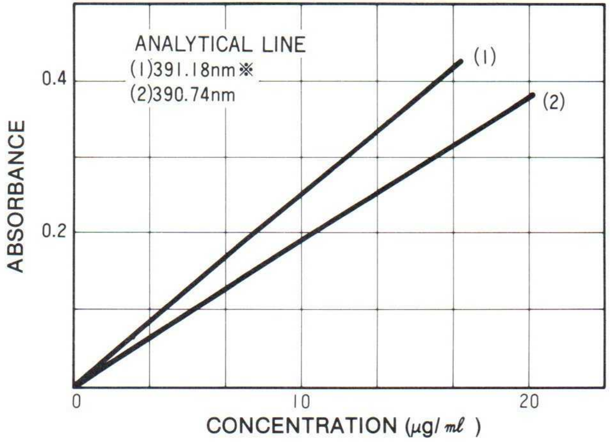
Type No.: L233-21NB
L1788-21NB

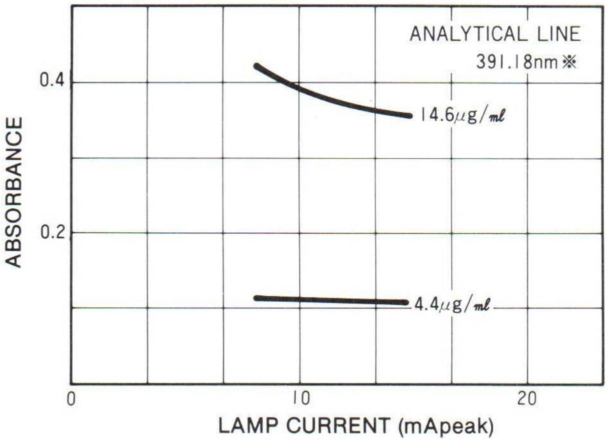
Analytical Lines : 390.74 nm
391.18 nm ※

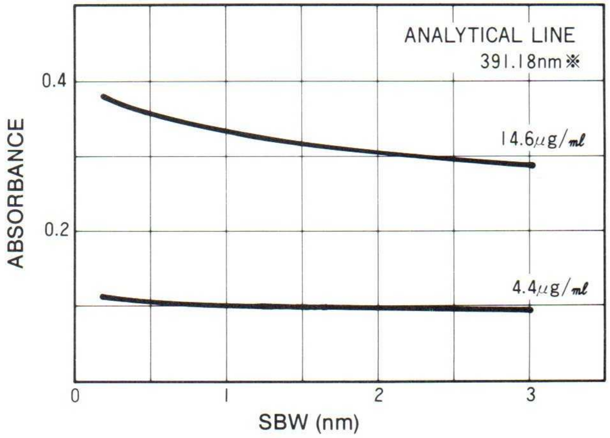
Starting Voltage : 240 Vdc

Tube Drop Voltage : 126 Vdc

Flame : N_2O-C_2H_2


Absorption Sensitivity


Absorption Sensitivity vs. Lamp Current

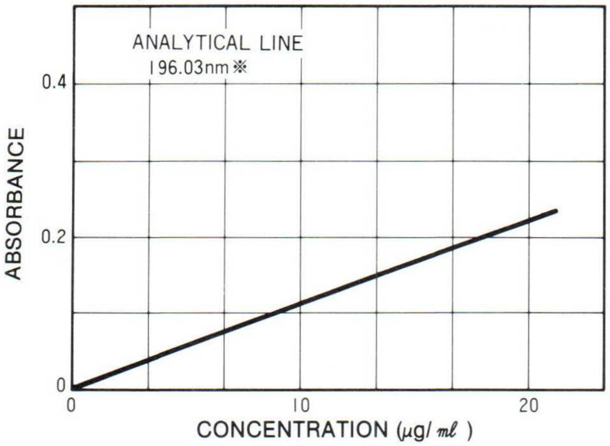

Absorption Sensitivity vs. SBW

Selenium (Se)

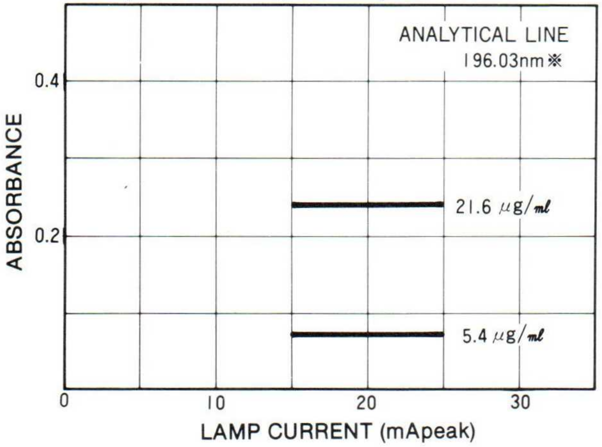
Type No.: L233-34NQ
L1788-34NQ

Analytical Lines : 196.03 nm ※
Starting Voltage : 240 Vdc
Tube Drop Voltage : 170 Vdc
Flame : Air-C_2H_2

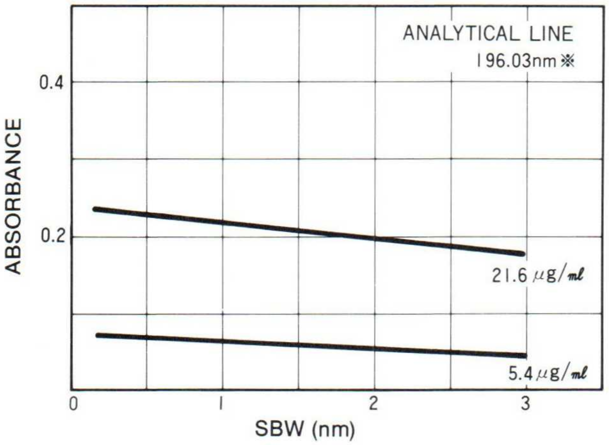
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

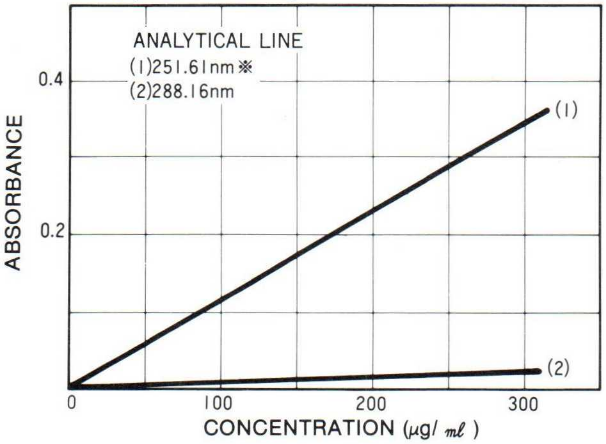


Silicon (Si)

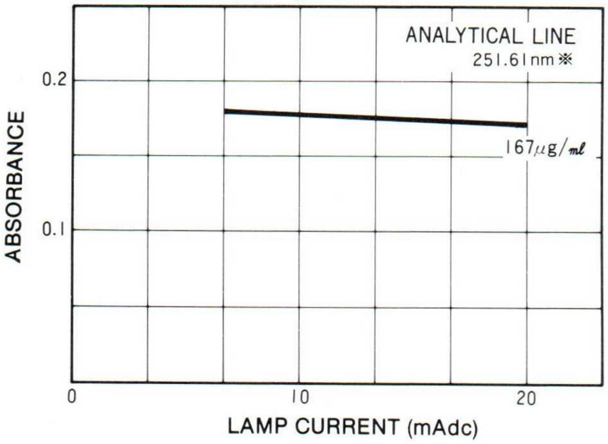
Type No.: L233-14NU
L1788-14NQ

Analytical Lines : 251.61 nm ※
288.16 nm
Starting Voltage : 235 Vdc
Tube Drop Voltage : 180 Vdc
Flame : N_2O-C_2H_2

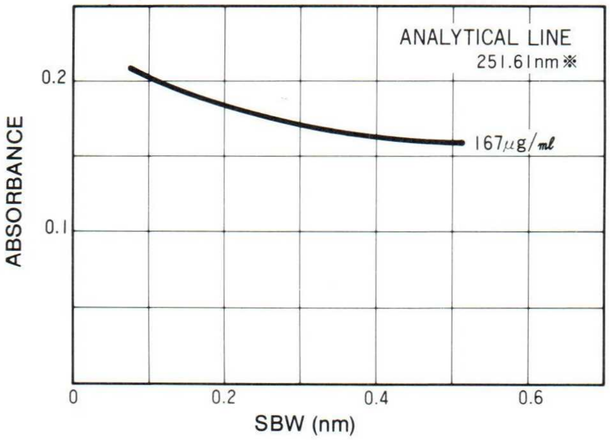
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

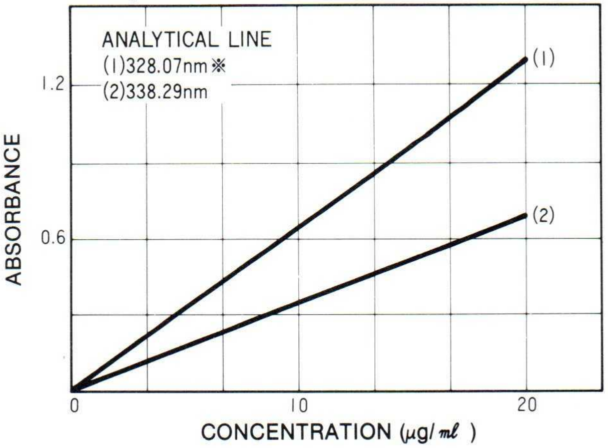


Silver (Ag)

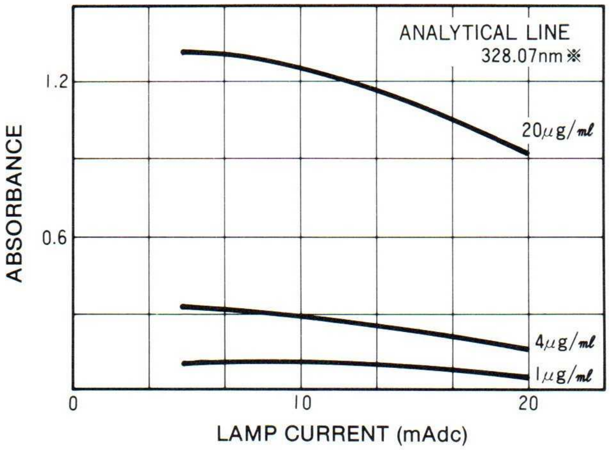
Type No.: L233-47NB
L1788-47NB

Analytical Lines : 328.07 nm ※
338.29 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 160 Vdc
Flame : Air-C_2H_2

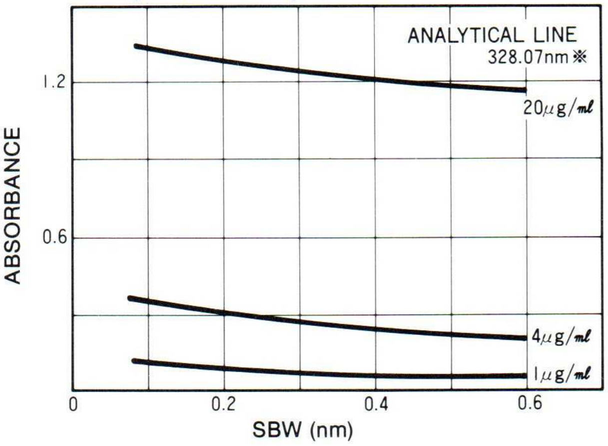
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

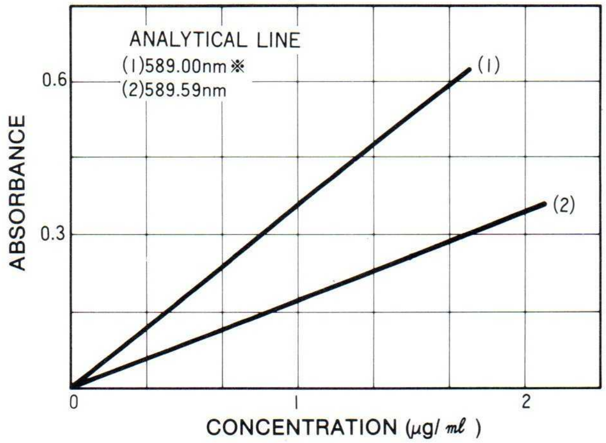


Sodium (Na)

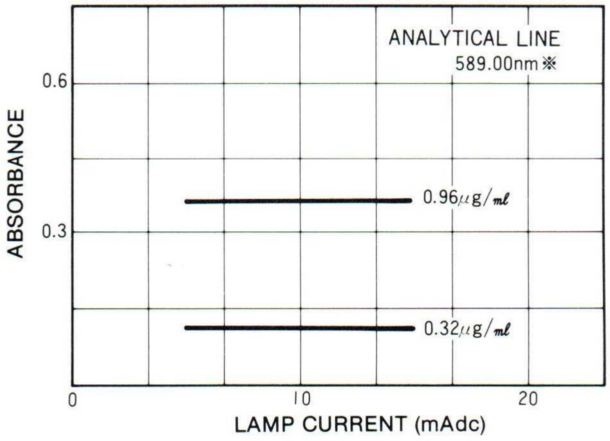
Type No.: L233-11NB
L1788-11NB

Analytical Lines : 589.00 nm ※
589.59 nm
Starting Voltage : 190 Vdc
Tube Drop Voltage : 145 Vdc
Flame : Air-C_2H_2

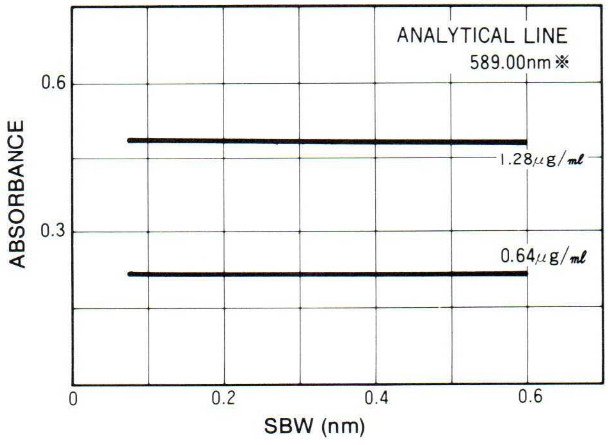
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

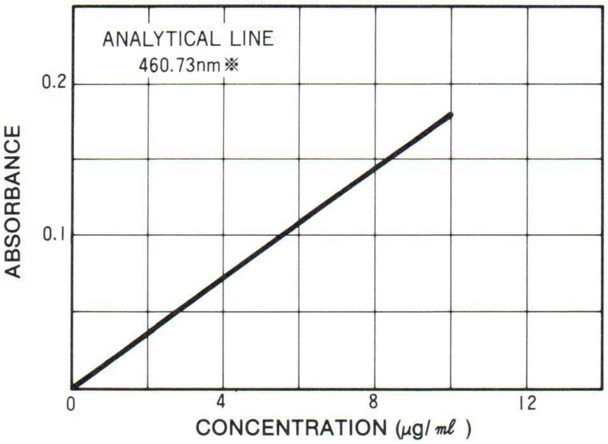


Strontium (Sr)

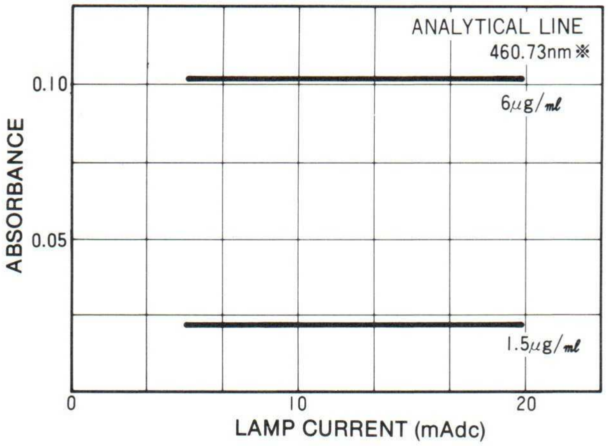
Type No.: L233-38NB
L1788-38NB

Analytical Lines : 460.73 nm ※
Starting Voltage : 170 Vdc
Tube Drop Voltage : 131 Vdc
Flame : Air-C_2H_2

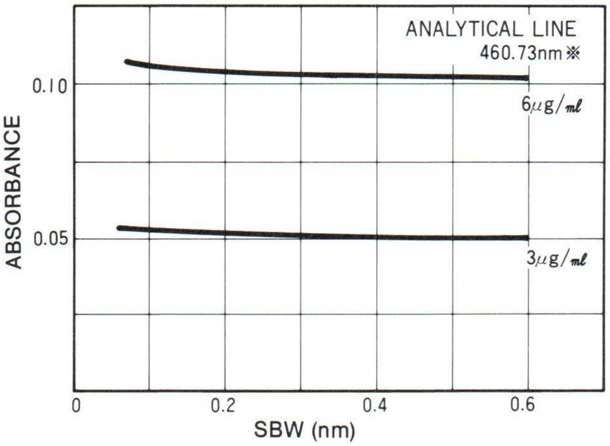
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

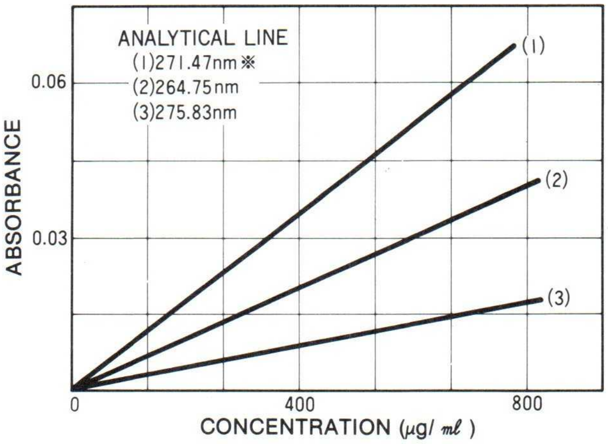


Tantalum (Ta)

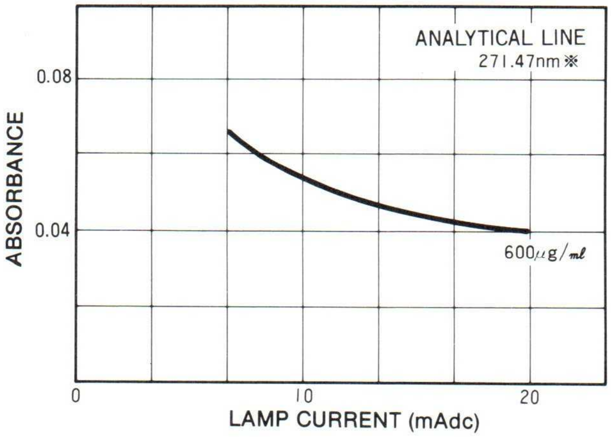
Type No.: L233-73NU
L1788-73NQ

Analytical Lines : 271.47 nm ※
275.83 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 160 Vdc
Flame : N_2O-C_2H_2

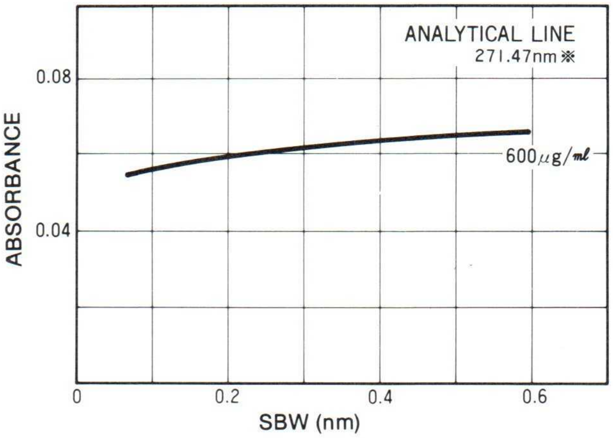
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

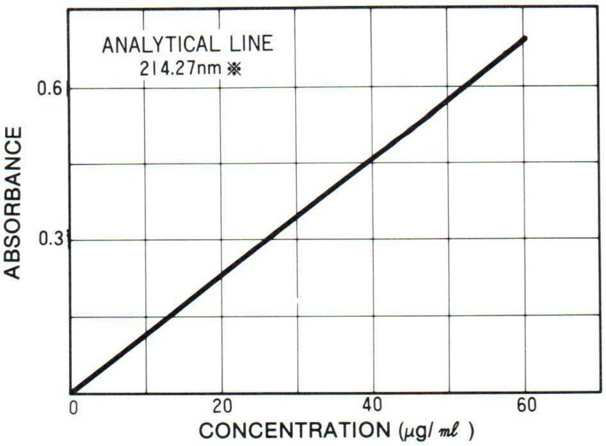


Tellurium (Te)

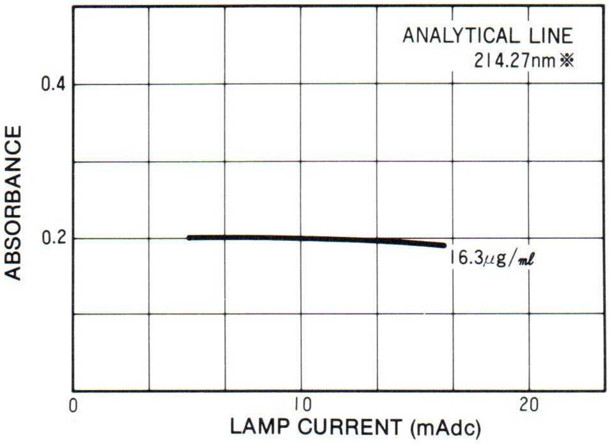
Type No.: L233-52NQ
L1788-52NQ

Analytical Lines : 214.27 nm ※
Starting Voltage : 265 Vdc
Tube Drop Voltage : 232 Vdc
Flame : Air-C_2H_2

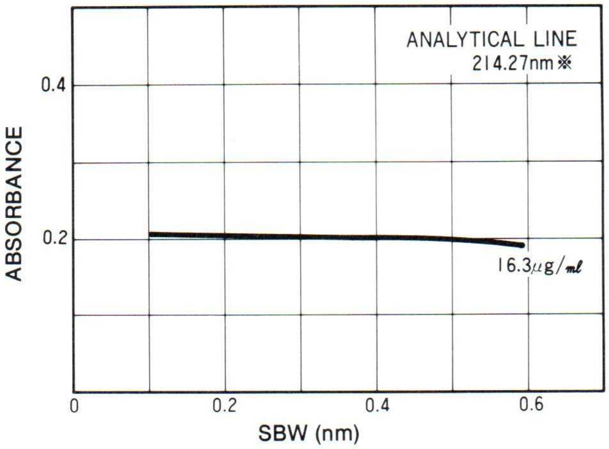
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

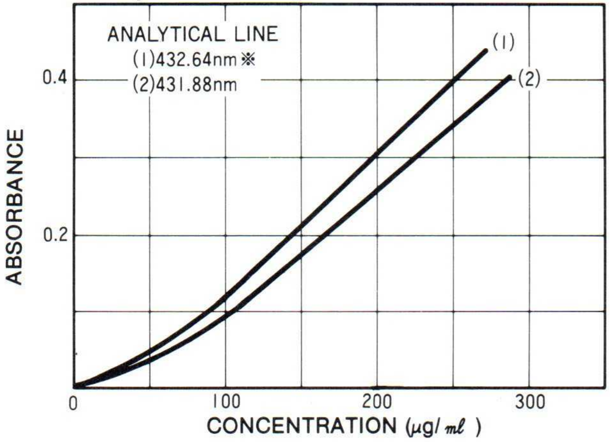


Terbium (Tb)

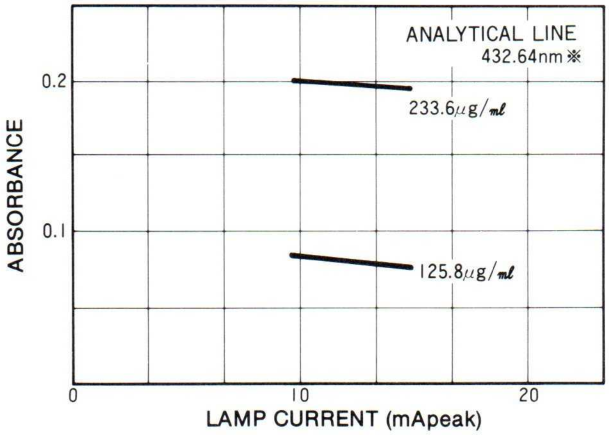
Type No.: L233-65NB
L1788-65NB

Analytical Lines : 431.88 nm
432.64 nm ※
Starting Voltage : 220 Vdc
Tube Drop Voltage : 137 Vdc
Flame : N_2O-C_2H_2

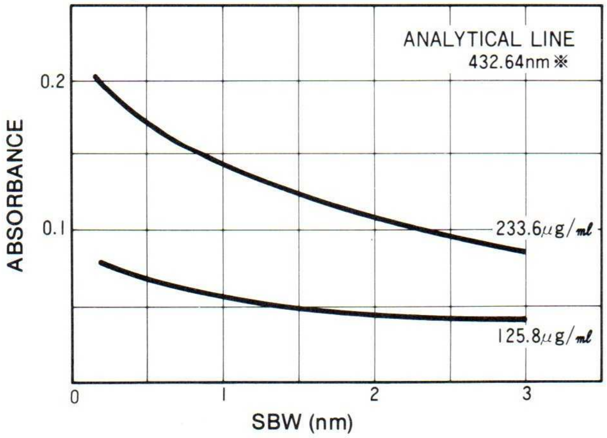
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

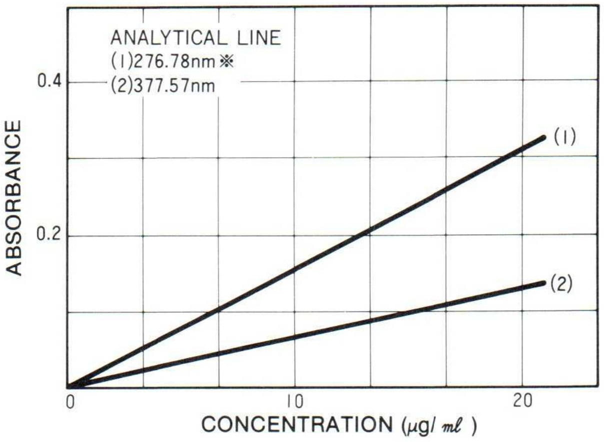


Thallium (Tl)

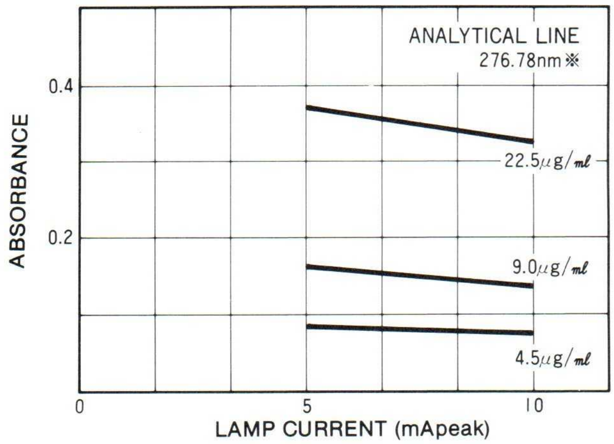
Type No.: L233-81NU
L1788-81NQ

Analytical Lines : 276.78 nm ※
377.57 nm
Starting Voltage : 270 Vdc
Tube Drop Voltage : 218 Vdc
Flame : Air-C_2H_2

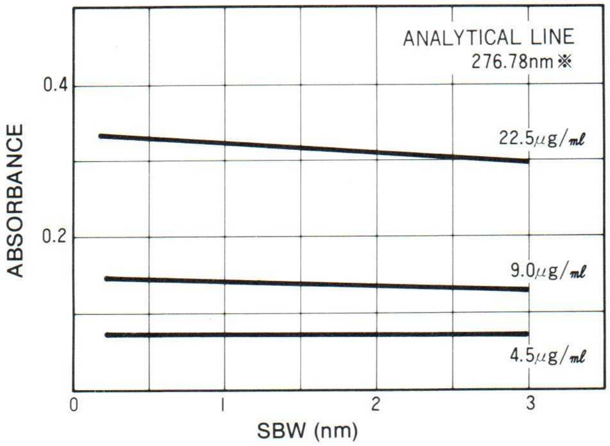
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

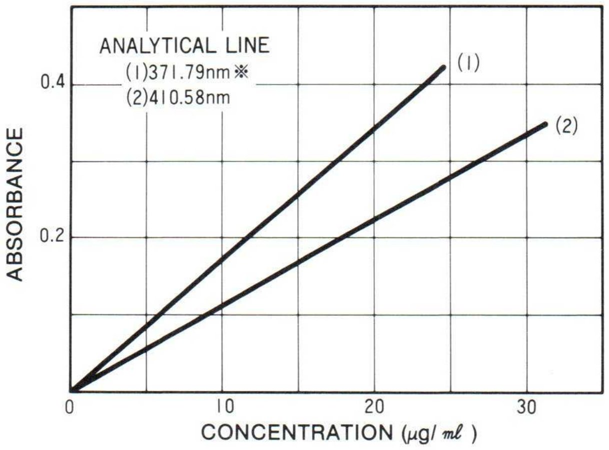


Thulium (Tm)

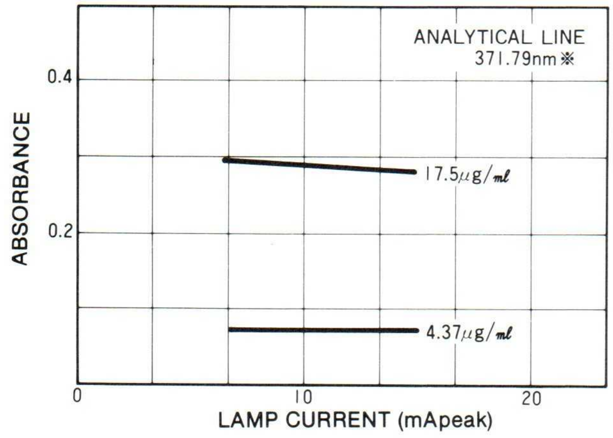
Type No.: L233-69NB
L1788-69NB

Analytical Lines : 371.79 nm ※
410.58 nm
Starting Voltage : 215 Vdc
Tube Drop Voltage : 122 Vdc
Flame : N_2O-C_2H_2

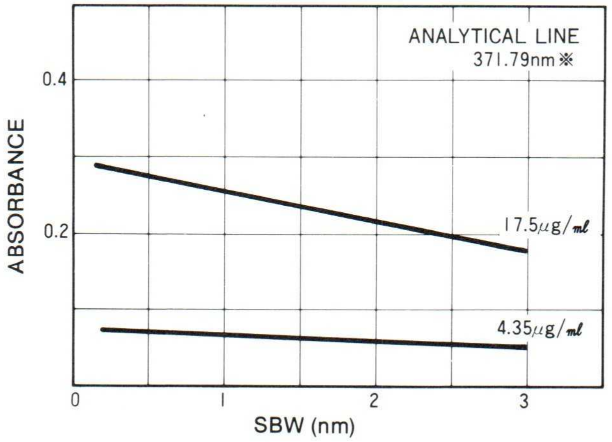
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

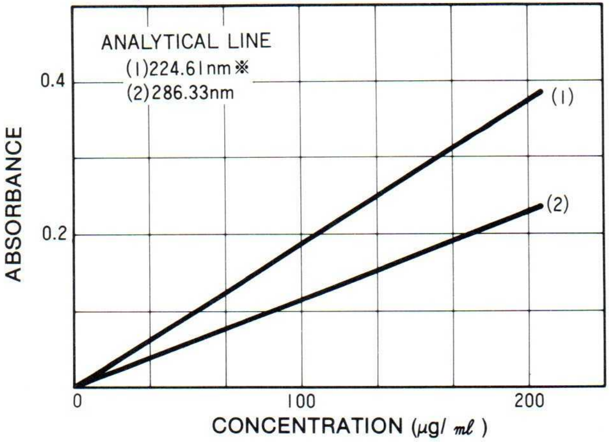


Tin (Sn)

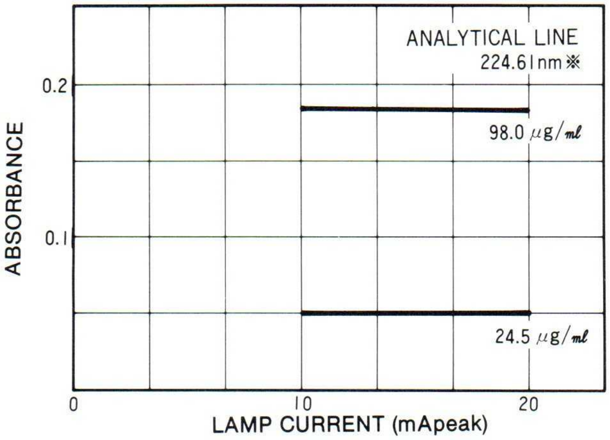
Type No.: L233-50NQ
L1788-50NQ

Analytical Lines : 224.61 nm ※
286.33 nm
Starting Voltage : 270 Vdc
Tube Drop Voltage : 236 Vdc
Flame : Air-C_2H_2

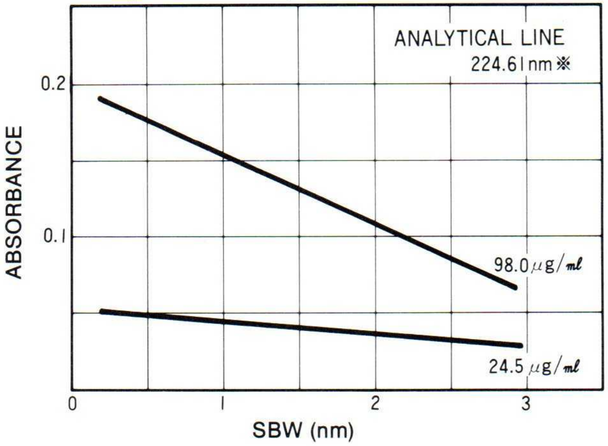
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

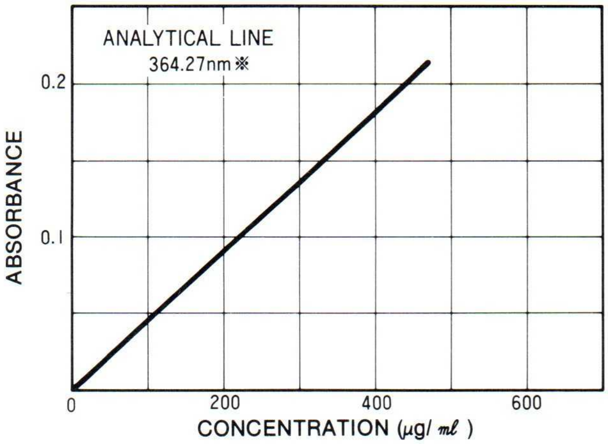


Titanium (Ti)

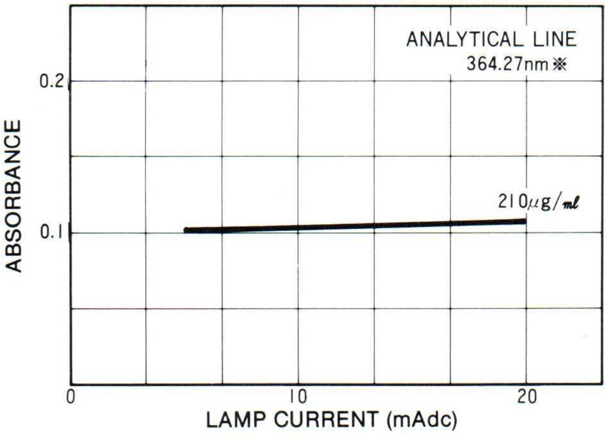
Type No.: L233-22NB
L1788-22NB

Analytical Lines : 364.27 nm ※
365.35 nm
Starting Voltage : 220 Vdc
Tube Drop Voltage : 152 Vdc
Flame : N_2O-C_2H_2

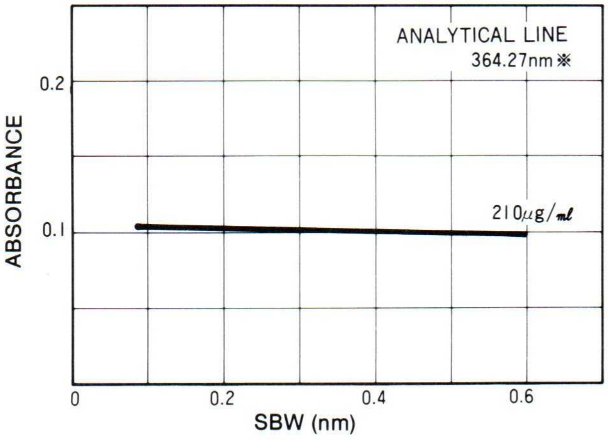
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

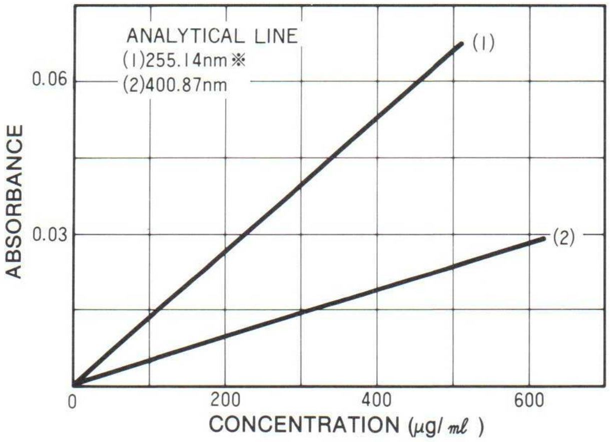


Tungsten (W)

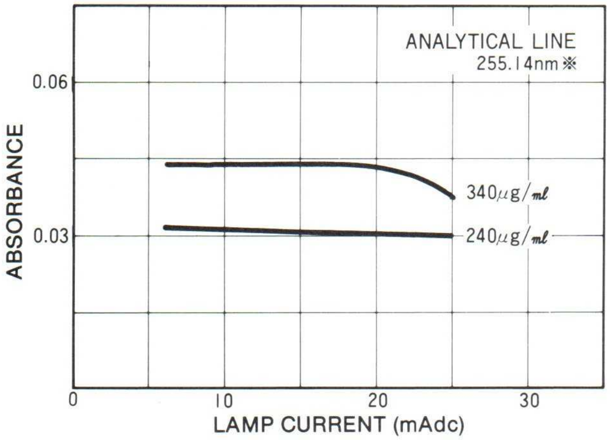
Type No.: L233-74NU
L1788-74NQ

Analytical Lines : 255.14 nm ※
400.87 nm
Starting Voltage : 230 Vdc
Tube Drop Voltage : 129 Vdc
Flame : N_2O-C_2H_2

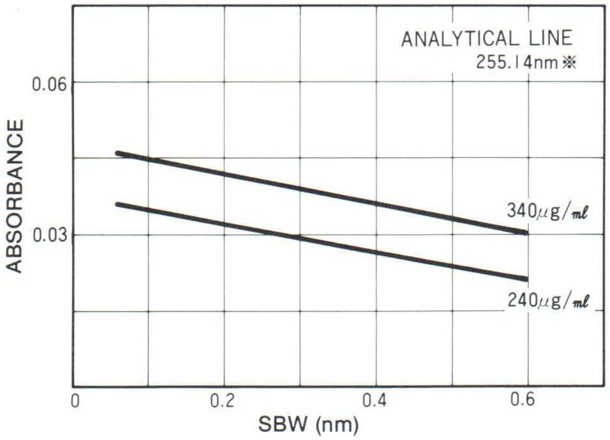
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

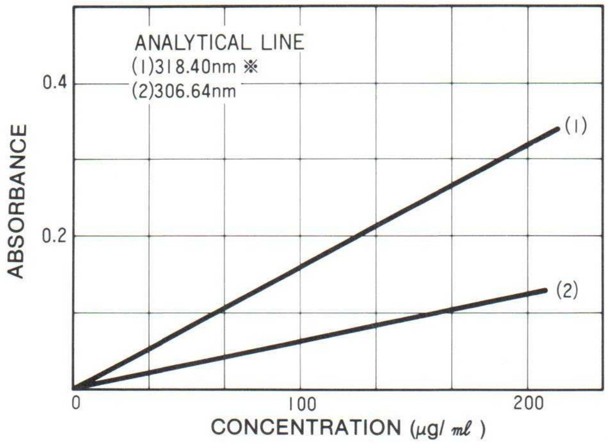


Vanadium (V)

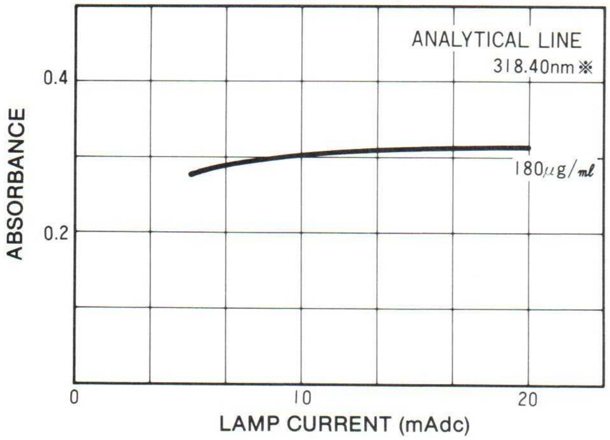
Type No.: L233-23NB
L1788-23NB

Analytical Lines : 306.64 nm
318.40 nm ※
Starting Voltage : 240 Vdc
Tube Drop Voltage : 157 Vdc
Flame : N_2O-C_2H_2

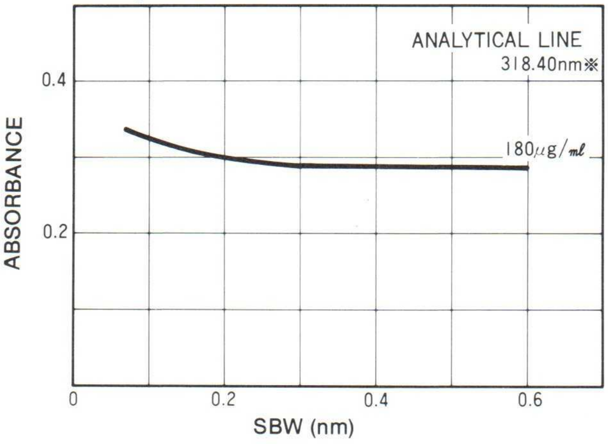
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

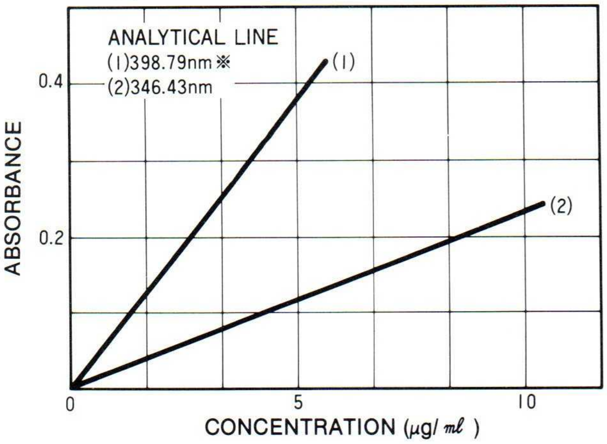


Ytterbium (Yb)

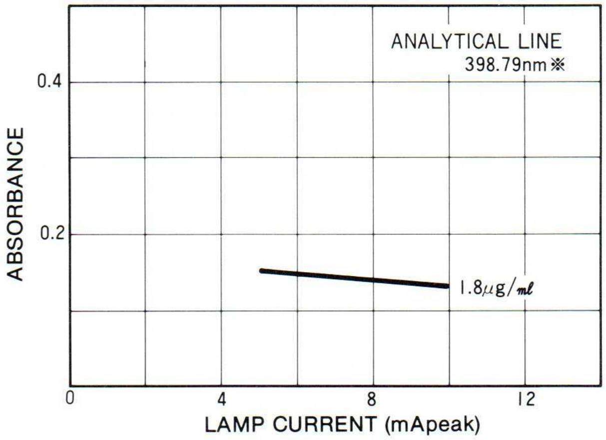
Type No.: L233-70NB
L1788-70NB

Analytical Lines : 346.43 nm
398.79 nm ※
Starting Voltage : 185 Vdc
Tube Drop Voltage : 135 Vdc
Flame : N_2O-C_2H_2

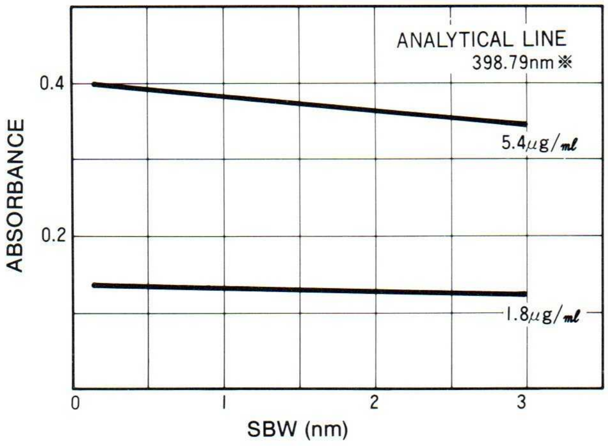
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

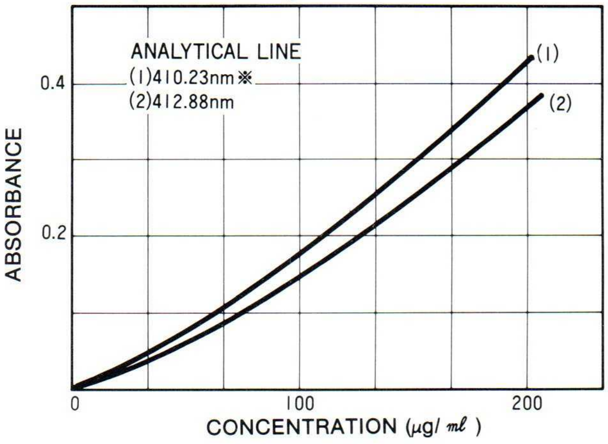


Yttrium (Y)

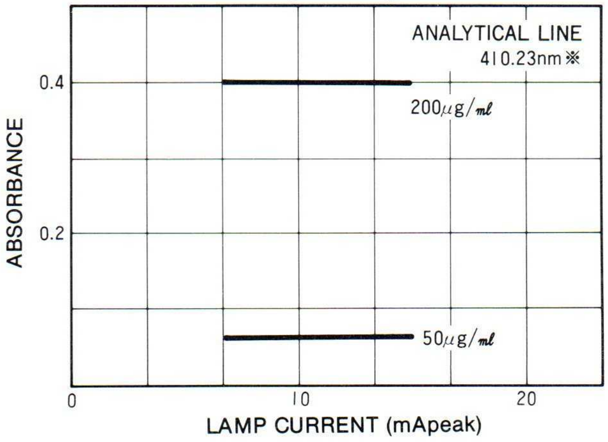
Type No.: L233-39NB
L1788-39NB

Analytical Lines : 410.23 nm ※
412.83 nm
Starting Voltage : 195 Vdc
Tube Drop Voltage : 125 Vdc
Flame : N_2O-C_2H_2

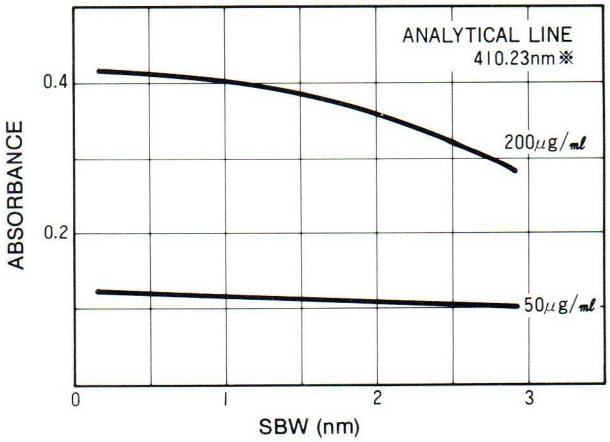
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

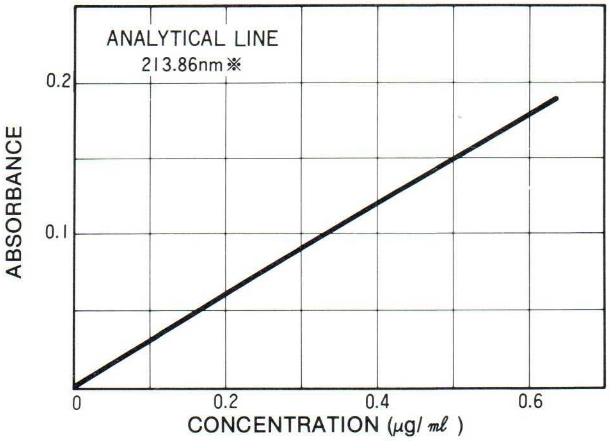


Zinc (Zn)

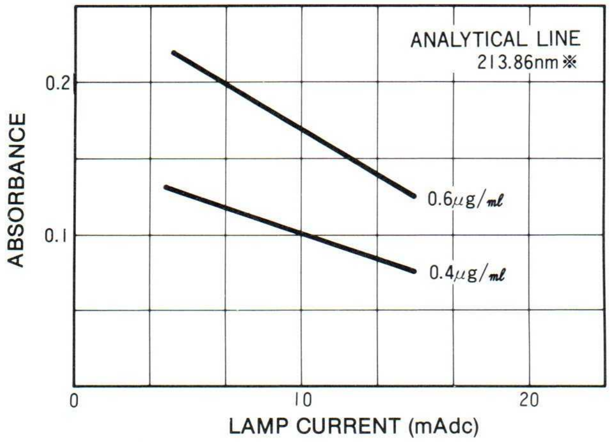
Type No.: L233-30NQ
L1788-30NQ

Analytical Lines	: 213.86 nm ※ 307.59 nm
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 209 Vdc
Flame	: Air-C_2H_2

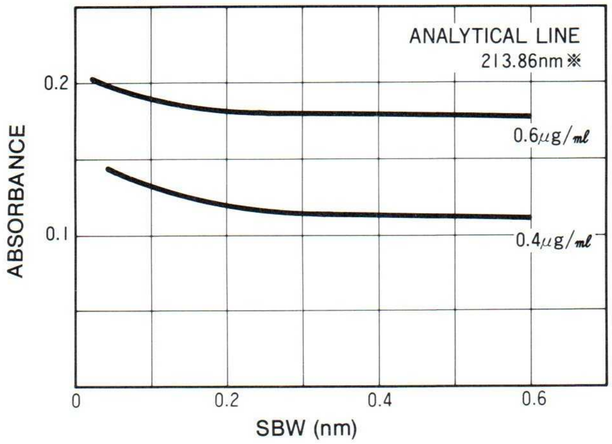
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW

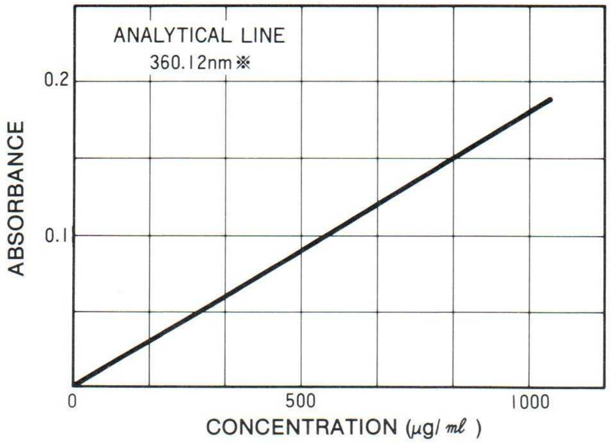


Zirconium (Zr)

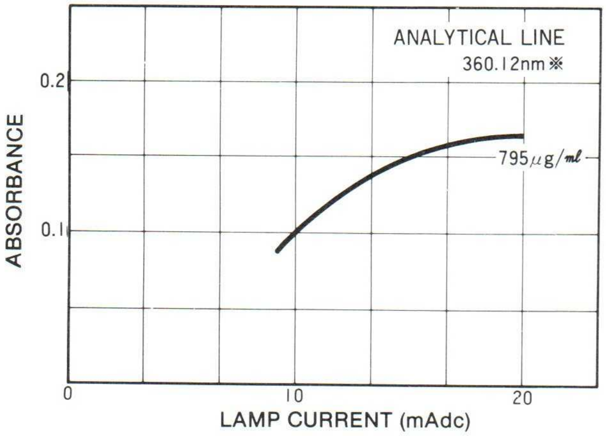
Type No.: L233-40NB
L1788-40NB

Analytical Lines	: 360.12 nm ※ 468.78 nm
Starting Voltage	: 220 Vdc
Tube Drop Voltage	: 130 Vdc
Flame	: N_2O-C_2H_2

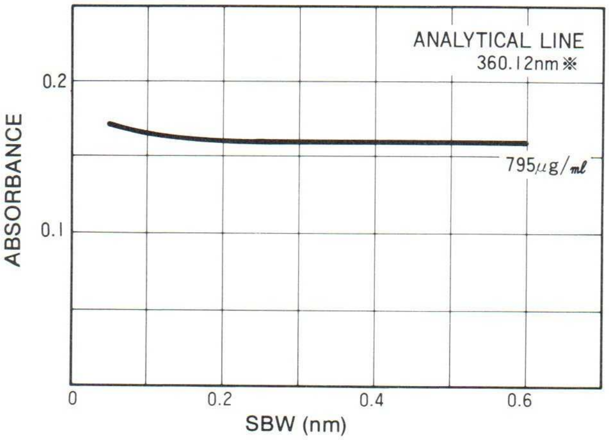
Absorption Sensitivity



Absorption Sensitivity vs. Lamp Current



Absorption Sensitivity vs. SBW



HAMAMATSU HOLLOW CATHODE LAMPS (1.5"Types)

Single Element Lamps - L233 Series (1.5" Types)

Elements		Type No.	Analytical Lines (nm) Ⓐ	Output (nA) Ⓑ	Recommended Current (mA) Ⓒ	Maximum Current (mA) Ⓒ	Flame
Aluminium	**Al**	L233-13NB	309.27※ 396.15	1360 1070	10	20	N_2O-C_2H_2
Antimony	**Sb**	-51NQ	217.58※ 231.15	80 80	10	15	Air-C_2H_2
Arsenic	**As**	-33NQ	193.70※ 197.20	15 17	10	12	Air-H_2 Ar-H_2
Barium	**Ba**	-56NB	553.55※	420	10	20	Air-C_2H_2 N_2O-C_2H_2
Beryllium	**Be**	- 4NQ	234.86※	3710	10	20	N_2O-C_2H_2
Bismuth	**Bi**	-83NQ	223.06※ 306.77	100 1200	10	12	Air-C_2H_2,
Boron	**B**	- 5NQ	249.68※ 249.77	120	10	20	N_2O-C_2H_2
Cadmium	**Cd**	-48NQ	228.80※	150	5	12	Air-C_2H_2
Calcium	**Ca**	-20NU	422.67※	1280	10	18	Air-C_2H_2 N_2O-C_2H_2
Cesium	**Cs**	-55NB	852.11※	10	10	20	Air-Coal gas Air-Propane
Chromium	**Cr**	-24NB	357.87※ 425.44	1650 1220	10	20	Air-C_2H_2
Cobalt	**Co**	-27NU	240.73※ 346.58	460 1770	10	20	Air-C_2H_2
Copper	**Cu**	-29NB	324.75※ 327.40	6800 4730	10	20	Air-C_2H_2
Dysprosium	**Dy**	-66NB	404.59※ 421.17	500 500	15	15	N_2O-C_2H_2
Erbium	**Er**	-68NB	400.79※ 415.11	1500 1200	15	15	N_2O-C_2H_2
Europium	**Eu**	-63NB	459.40※ 462.72	85 60	15	15	N_2O-C_2H_2
Gadolinium	**Gd**	-64NB	407.87 422.58※	190 270	12	12	N_2O-C_2H_2
Gallium	**Ga**	-31NU	287.42 294.36※	250 490	4	6	Air-C_2H_2
Germanium	**Ge**	-32NU	265.16※	165	10	20	N_2O-C_2H_2
Gold	**Au**	-79NQ	242.80※ 267.59	1380 1080	10	16	Air-C_2H_2
Hafnium	**Hf**	-72NU	286.64※ 307.29	200 180	20	25	N_2O-C_2H_2
Holmium	**Ho**	-67NB	410.38※ 416.30	1330 800	15	20	N_2O-C_2H_2
Indium	**In**	-49NB	303.94※ 325.61	550 960	10	15	Air-C_2H_2
Iridium	**Ir**	-77NQ	208.88※ 266.47	410 8000	20	20	Air-C_2H_2
Iron	**Fe**	-26NU	248.33※ 371.99	330 1930	10	20	Air-C_2H_2
Lanthanum	**La**	-57NB	357.44 550.13※	35 25	10	20	N_2O-C_2H_2
Lead	**Pb**	-82NQ	217.00※ 283.30	170 3740	10	15	Air-C_2H_2
Lithium	**Li**	- 3NB	610.36 670.78※	45 410	10	20	Air-C_2H_2 Air-Propane
Lutetium	**Lu**	-71NB	331.21※ 328.17	900 600	15	15	N_2O-C_2H_2
Magnesium	**Mg**	-12NU	285.21※	1880	10	18	Air-C_2H_2
Manganese	**Mn**	-25NU	279.48※ 403.08	1400 4300	10	20	Air-C_2H_2
Mercury	**Hg**	-80NU	253.65※	670	4	6	Flameless
Molybdenum	**Mo**	-42NB	313.26※ 320.88	325 70	10	20	N_2O-C_2H_2 Air-C_2H_2
Neodymium	**Nd**	-60NB	463.42 492.45※	25 40	15	15	N_2O-C_2H_2
Nickel	**Ni**	-28NQ	232.00※ 341.48	360 970	10	20	Air-C_2H_2
Niobium	**Nb**	-41NB	334.91※ 405.89	260 600	20	30	N_2O-C_2H_2
Osmium	**Os**	-76NU	290.90※ 305.86	30 10	15	15	N_2O-C_2H_2
Palladium	**Pd**	-46NQ	244.79※ 247.64	610 490	10	20	Air-C_2H_2
Platinum	**Pt**	-78NU	265.95※ 299.80	790 990	10	20	Air-C_2H_2
Potassium	**K**	-19NB	766.49※ 769.90	12 9	10	15	Air-C_2H_2 Air-Propane
Praseodymium	**Pr**	-59NB	495.13※ 513.34	140 120	15	15	N_2O-C_2H_2
Rhenium	**Re**	-75NB	346.05※ 346.47	1630 1250	20	25	Air-C_2H_2 N_2O-C_2H_2
Rhodium	**Rh**	L233-45NB	343.49※	1880	10	20	Air-C_2H_2
Rubidium	**Rb**	-37NB	780.02※ 794.76	95 20	10	20	Air-Propane Air-Coal gas
Ruthenium	**Ru**	-44NB	349.89※	1200	20	25	Air-C_2H_2
Samarium	**Sm**	-62NB	429.67※ 484.17	150 150	15	20	N_2O-C_2H_2
Scandium	**Sc**	-21NB	390.74 391.18	380 410	10	15	N_2O-C_2H_2
Selenium	**Se**	-34NQ	196.03※	55	20	25	Air-H_2 Ar-H_2
Silicon	**Si**	-14NU	251.61※ 288.16	95 95	10	20	N_2O-C_2H_2
Silver	**Ag**	-47NB	328.07※ 338.28	2500 1500	10	20	Air-C_2H_2
Sodium	**Na**	-11NB	589.00※ 589.59	600 470	10	15	Air-C_2H_2 Air-Propane
Strontium	**Sr**	-38NB	460.73※	500	10	20	Air-C_2H_2 N_2O-C_2H_2
Tantalum	**Ta**	-73NU	271.47※ 275.83	80 40	10	20	N_2O-C_2H_2
Tellurium	**Te**	-52NQ	214.27※	60	10	16	Air-C_2H_2
Terbium	**Tb**	-65NB	431.88 432.64※	50 60	15	15	N_2O-C_2H_2
Thallium	**Tl**	-81NU	276.78※ 377.57	600 700	7	10	Air-C_2H_2
Thulium	**Tm**	-69NB	371.79※ 410.58	80 60	10	15	N_2O-C_2H_2
Tin	**Sn**	-50NQ	224.61※ 286.33	35 120	20	20	Air-H_2 Air-C_2H_2
Titanium	**Ti**	-22NB	364.27※ 365.35	200 190	10	20	N_2O-C_2H_2
Tungsten	**W**	-74NU	255.14※ 400.87	40 320	10	25	N_2O-C_2H_2
Vanadium	**V**	-23NB	306.64 318.40※	110 810	10	20	N_2O-C_2H_2
Ytterbium	**Yb**	-70NB	398.79※ 346.43	410 150	10	10	N_2O-C_2H_2
Yttrium	**Y**	-39NB	410.23※ 412.83	200 190	15	15	N_2O-C_2H_2
Zinc	**Zn**	-30NQ	213.86※ 307.59	450 1290	7	15	Air-C_2H_2
Zirconium	**Zr**	-40NB	360.12※ 468.78	700 930	10	20	N_2O-C_2H_2
Deuterium	**D_2**	1DQ	240.00 (peak)	220	30	35	—

Multielement Lamps - L733 Series (1.5" Types)

Elements		Type No.	Analytical Lines (nm) Ⓐ	Output (nA) Ⓑ	Recommended Current (mA) Ⓒ	Maximum Current (mA) Ⓒ	Flame
Sodium Potassium	**Na-K**	L733-201NB	Na 589.00※ K 766.49※	600 12	10	15	Air-Propane Air-C_2H_2
Calcium Magnesium	**Ca-Mg**	-202NU	Ca 422.67※ Mg 285.21※	1280 1880	10	18	Air-C_2H_2
Silicon Aluminium	**Si-Al**	-203NU	Si 251.61※ Al 309.27※	95 190	10	20	N_2O-C_2H_2
Iron Nickel	**Fe-Ni**	-204NQ	Fe 248.33※ Ni 232.00※	200 270	10	20	Air-C_2H_2
Strontium Barium	**Sr-Ba**	-205NB	Sr 460.73※ Ba 553.55※	400 350	10	20	N_2O-C_2H_2 Air-C_2H_2

Ⓐ ※ : Maximum absorption wavelength.

Ⓑ Photomultiplier output current measured with lamps operating at their maximum currents.
Photomultiplier tube: Hamamatsu R456 (Sp = 760A *lm* at 1000V) operated at 600V
AA equipment : Nippon Jarrell-Ash AA-1E

Ⓒ DC or peak values

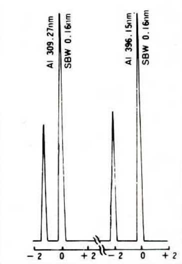
※ L233 and L733 series lamps can be used with AA equipments manufactured by Varian-Techtron, Jarrell-Ash, I. Lab., Unicam, Evans, Beckman, and all Japanese manufactures. For Perkin-Elmer L1788 series lamps are provided.

HAMAMATSU HOLLOW CATHODE LAMPS (1.5"Types)

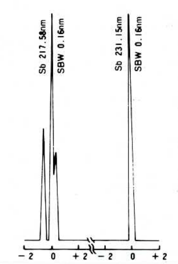
Single Element Hollow Cathode Lamps——Analytical Lines

(Unit : nanometers)

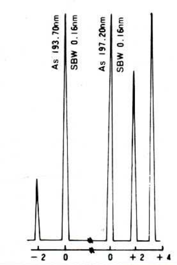
Aluminium **Al**



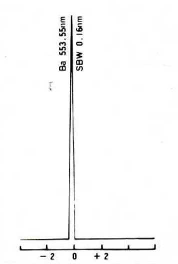
Antimony **Sb**



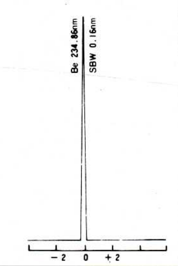
Arsenic **As**



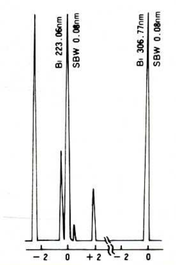
Barium **Ba**



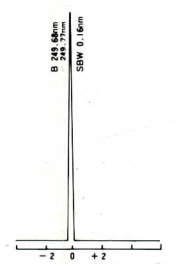
Beryllium **Be**



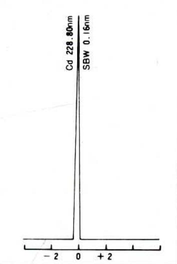
Bismuth **Bi**



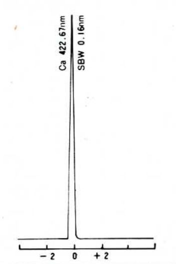
Boron **B**



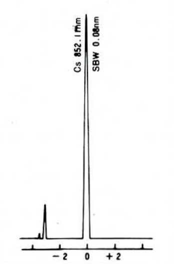
Cadmium **Cd**



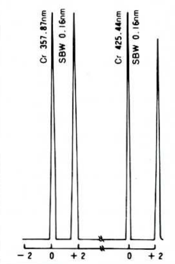
Calcium **Ca**



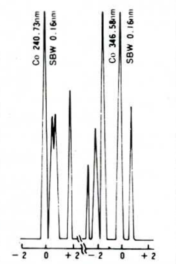
Cesium **Cs**



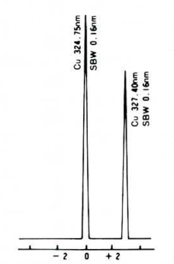
Chromium **Cr**



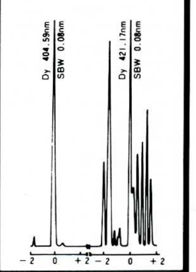
Cobalt **Co**



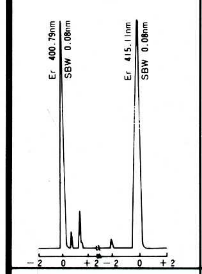
Copper **Cu**



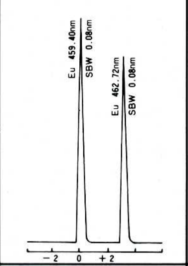
Dysprosium **Dy**



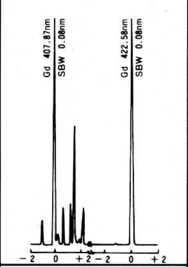
Erbium **Er**



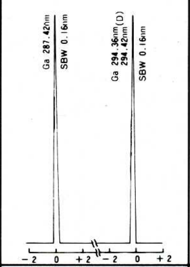
Europium **Eu**



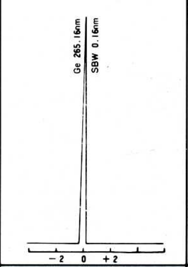
Gadolinium **Gd**



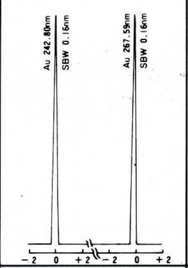
Gallium **Ga**



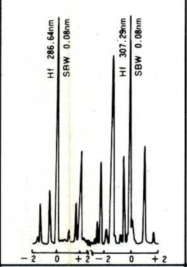
Germanium **Ge**



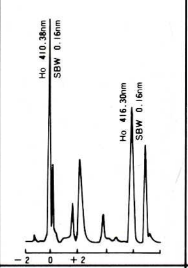
Gold **Au**



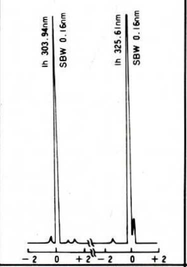
Hafnium **Hf**



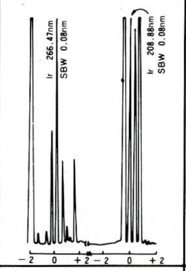
Holmium **Ho**



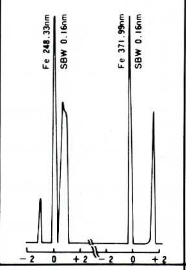
Indium **In**



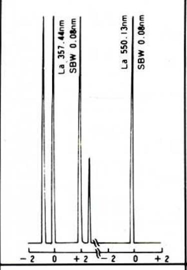
Iridium **Ir**



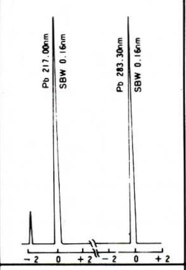
Iron **Fe**



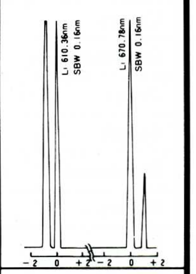
Lanthanum **La**



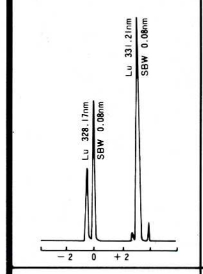
Lead **Pb**



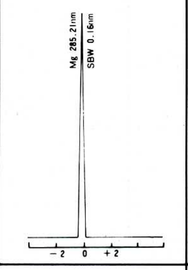
Lithium **Li**



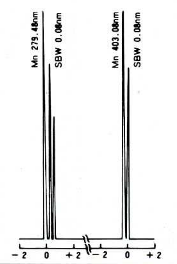
Lutecium **Lu**



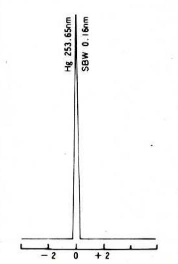
Magnesium **Mg**



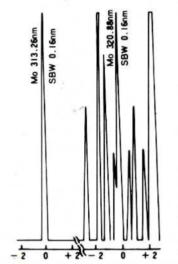
Manganese **Mn**



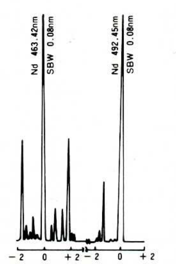
Mercury **Hg**



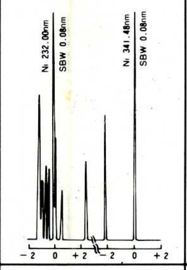
Molybdenum **Mo**



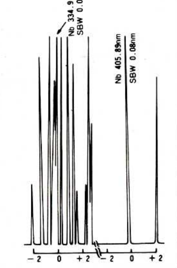
Neodymium **Nd**



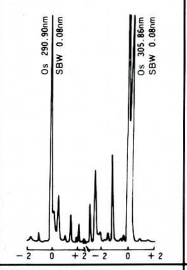
Nickel **Ni**



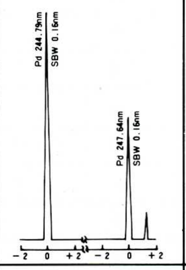
Niobium **Nb**



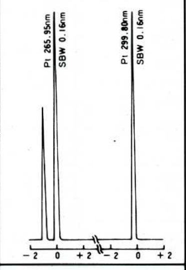
Osmium **Os**



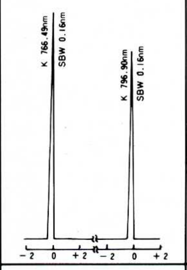
Palladium **Pd**



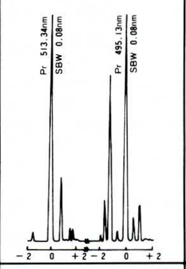
Platinum **Pt**



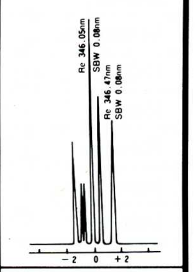
Potassium **K**



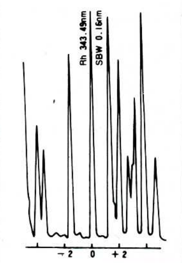
Praseodymium **Pr**



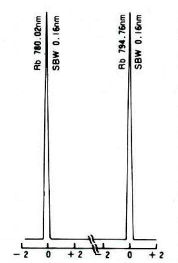
Rhenium **Re**



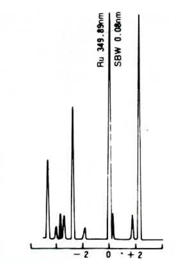
Rhodium **Rh**



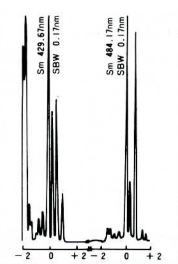
Rubidium **Rb**



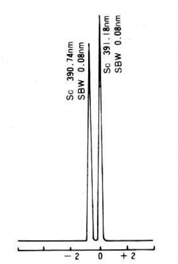
Ruthenium **Ru**



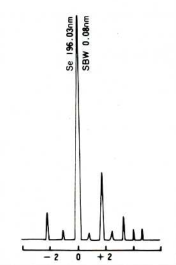
Samarium **Sm**



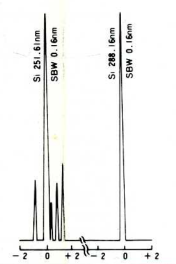
Scandium **Sc**



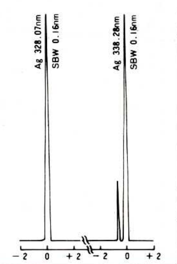
Selenium **Se**



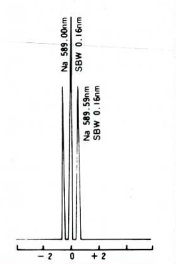
Silicon **Si**



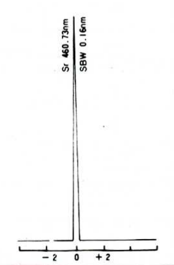
Silver **Ag**



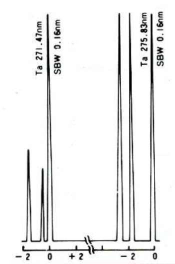
Sodium **Na**



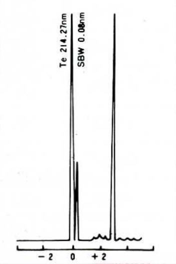
Strontium **Sr**



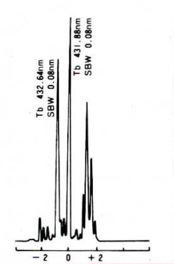
Tantalum **Ta**



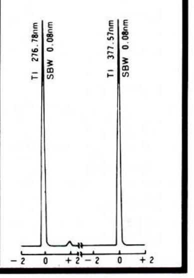
Tellurium **Te**



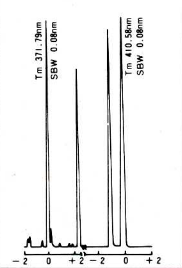
Terbium **Tb**



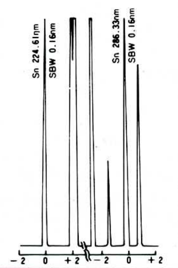
Thallium **Tl**



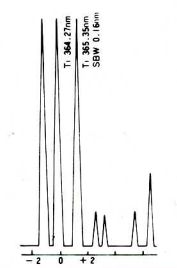
Thulium **Tm**



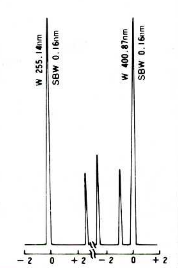
Tin **Sn**



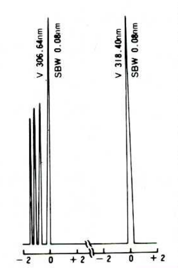
Titanium **Ti**



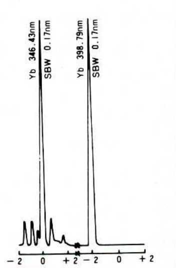
Tungsten **W**



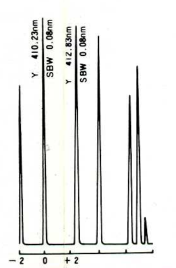
Vanadium **V**



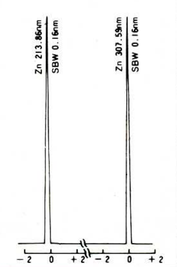
Ytterbium **Yb**



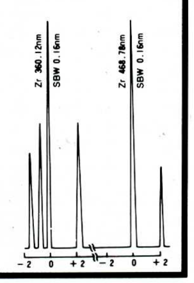
Yttrium **Y**



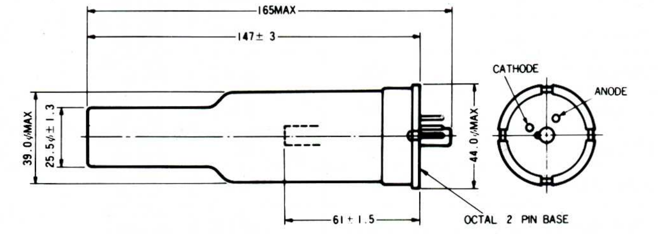
Zinc **Zn**



Zirconium **Zr**



Dimensional Outline (Unit : mm)



For background compensation, Hamamatsu also provides hot cathode deuterium lamps. Please contact us for further information.

HAMAMATSU HOLLOW CATHODE LAMPS (2"Types For Perkin-Elmer)

L1788 Series (2"Dia. Types) Single Element Lamps

Elements		Type No.	Analytical Lines (nm) Ⓐ	Output (nA) Ⓑ	Maximum Current		Operating Current		Flame
					Continuous (mA)	Modulated (mA)	Continuous (mA)	Modulated (mA)	
Aluminium	Al	L1788-13NB	309.27※ 396.15	1360 1070	20	8	20	8	N_2O-C_2H_2
Antimony	Sb	-51NQ	217.58※ 231.15	80 80	15	6	14	6	Air-C_2H_2
Arsenic	As	-33NQ	193.70※ 197.20	15 17	12	5	10	4	Air-H_2 Ar-H_2
Barium	Ba	-56NB	553.55※	420	20	8	16	6	Air-C_2H_2 N_2O-C_2H_2
Beryllium	Be	- 4NQ	234.86※	3710	20	8	14	5	N_2O-C_2H_2
Bismuth	Bi	-83NQ	223.06※ 306.77	100 1200	12	4	12	4	Air-C_2H_2
Boron	B	- 5NQ	249.68 } ※ 249.77 }	120	20	8	18	7	N_2O-C_2H_2
Cadmium	Cd	-48NQ	228.80※	150	12	4	5	2	Air-C_2H_2
Calcium	Ca	-20NQ	422.67※	1280	20	8	18	7	Air-C_2H_2 N_2O-C_2H_2
Cesium	Cs	-55NB	852.11※	10	20	8	16	6	Air-Coal gas Air-Propane
Chromium	Cr	-24NB	357.87※ 425.44	1650 1220	20	8	14	5	Air-C_2H_2
Cobalt	Co	-27NQ	240.73※ 346.58	460 1770	20	8	18	7	Air-C_2H_2
Copper	Cu	-29NB	324.75※ 327.40	6800 4730	20	8	18	7	Air-C_2H_2
Dysprosium	Dy	-66NB	404.59※ 421.17	500 500	15	6	15	6	N_2O-C_2H_2
Erbium	Er	-68NB	400.79※ 415.11	1500 1200	15	6	15	6	N_2O-C_2H_2
Europium	Eu	-63NB	459.40※ 462.72	85 60	15	6	15	6	N_2O-C_2H_2
Gadolinium	Gd	-64NB	407.87 422.58※	190 270	12	5	12	4	N_2O-C_2H_2
Gallium	Ga	-31NQ	287.42 294.36※	250 490	6	2	6	2	Air-C_2H_2
Germanium	Ge	-32NQ	265.16※	165	20	8	20	8	N_2O-C_2H_2
Gold	Au	-79NQ	242.80※ 267.59	1380 1080	16	6	14	5	Air-C_2H_2
Hafnium	Hf	-72NQ	286.64※ 307.29	200 180	25	10	20	8	N_2O-C_2H_2
Holmium	Ho	-67NB	410.38※ 416.30	1330 800	20	8	15	6	N_2O-C_2H_2
Indium	In	-49NB	303.94※ 325.61	550 960	15	6	14	5	Air-C_2H_2
Iridium	Ir	-77NQ	208.88※ 266.47	410 8000	20	8	20	8	Air-C_2H_2
Iron	Fe	-26NQ	248.33※ 371.99	330 1930	20	8	18	7	Air-C_2H_2
Lanthanum	La	-57NB	357.44 550.13※	35 25	20	8	18	7	N_2O-C_2H_2
Lead	Pb	-82NQ	217.00※ 283.30	170 3740	15	6	14	5	Air-C_2H_2
Lithium	Li	- 3NB	610.36 670.78※	45 410	20	8	16	6	Air-C_2H_2 Air-Propane
Lutetium	Lu	-71NB	328.17 331.21※	600 900	15	6	15	6	N_2O-C_2H_2
Magnesium	Mg	-12NQ	285.21※	1880	20	8	18	7	Air-C_2H_2
Manganese	Mn	-25NQ	279.48※ 403.08	1400 4300	20	8	18	7	Air-C_2H_2
Mercury	Hg	-80NQ	253.65※	670	6	2	6	2	Reducing Vaporization
Molybdenum	Mo	-42NB	313.26※ 320.88	325 70	20	8	18	7	Air-C_2H_2 N_2O-C_2H_2
Neodymium	Nd	-60NB	463.42 492.45※	25 40	15	6	15	6	N_2O-C_2H_2
Nickel	Ni	-28NQ	232.00※ 341.48	360 970	20	8	18	7	Air-C_2H_2
Niobium	Nb	-41NB	334.91※ 405.89	260 600	30	13	24	10	N_2O-C_2H_2
Osmium	Os	-76NQ	290.90※ 305.86	30 10	15	6	15	6	N_2O-C_2H_2
Palladium	Pd	-46NQ	244.79※ 247.64	610 490	20	8	20	8	Air-C_2H_2
Platinum	Pt	-78NQ	265.95※ 299.80	790 990	20	8	16	6	Air-C_2H_2
Potassium	K	-19NB	766.49※ 769.90	12 9	15	6	14	5	Air-C_2H_2 Air-Propane
Praseodymium	Pr	-59NB	495.13※ 513.34	140 120	15	6	15	6	N_2O-C_2H_2
Rhenium	Re	-75NB	346.05※ 346.47	1630 1250	25	10	20	8	Air-C_2H_2 N_2O-C_2H_2
Rhodium	Rh	L1788-45NB	343.49※	1880	20	8	15	6	Air-C_2H_2
Rubidium	Rb	-37NB	780.02※ 794.76	95 20	20	8	16	6	Air-Coal gas Air-Propane
Ruthenium	Ru	-44NB	349.89※	1200	25	10	20	8	Air-C_2H_2
Samarium	Sm	-62NB	429.67※ 484.17	150 150	20	8	15	6	N_2O-C_2H_2
Scandium	Sc	-21NB	390.74 391.18※	380 410	15	6	10	4	N_2O-C_2H_2
Selenium	Se	-34NQ	196.03※	55	25	10	20	8	Air-H_2 Ar-H_2
Silicon	Si	-14NQ	251.61※ 288.16	95 95	20	8	20	8	N_2O-C_2H_2
Silver	Ag	-47NB	328.07※ 338.28	2500 1500	20	8	16	6	Air-C_2H_2
Sodium	Na	-11NB	589.00※ 589.59	600 470	15	6	14	5	Air-C_2H_2 Air-Propane
Strontium	Sr	-38NB	460.73※	500	20	8	16	6	Air-C_2H_2 N_2O-C_2H_2
Tantalum	Ta	-73NQ	271.47※ 275.83	80 40	18	7	14	5	N_2O-C_2H_2
Tellurium	Te	-52NQ	214.27※	60	16	6	14	5	Air-C_2H_2
Terbium	Tb	-65NB	431.88 432.64※	50 60	15	6	15	6	N_2O-C_2H_2
Thallium	Tl	-81NQ	276.78※ 377.57	600 700	10	4	7	3	Air-C_2H_2
Thulium	Tm	-69NB	371.79※ 410.58	80 60	15	6	10	4	N_2O-C_2H_2
Tin	Sn	-50NQ	224.61※ 286.33	35 120	20	8	20	8	Air-H_2 Air-C_2H_2
Titanium	Ti	-22NB	364.27※ 365.35	200 190	20	8	18	7	N_2O-C_2H_2
Tungsten	W	-74NQ	255.14※ 400.87	40 320	25	10	20	8	N_2O-C_2H_2
Vanadium	V	-23NB	306.64 318.40※	110 810	20	8	16	6	N_2O-C_2H_2
Ytterbium	Yb	-70NB	346.43 398.79※	150 410	10	4	10	4	N_2O-C_2H_2
Yttrium	Y	-39NB	410.23※ 412.83	200 190	15	6	15	6	N_2O-C_2H_2
Zinc	Zn	-30NQ	213.86※ 307.59	450 1290	15	6	7	3	Air-C_2H_2
Zirconium	Zr	-40NB	360.12※ 468.78	700 930	20	8	16	6	N_2O-C_2H_2

L1788 Series (2"Dia. Types) Multielement Lamps

Elements		Type No.	Analytical Lines (nm) Ⓐ	Output (nA) Ⓑ	Maximum Current		Operating Current		Flame
					Continuous (mA)	Modulated (mA)	Continuous (mA)	Modulated (mA)	
Sodium Potassium	Na-K	L1788-201NB	Na 589.00※ K 766.49※	600 12	15	6	14	5	Air-C_2H_2 Air-Propane
Calcium Magnesium	Ca-Mg	-202NQ	Ca 422.67※ Mg 285.21※	1280 1880	20	8	18	7	Air-C_2H_2
Silicon Aluminium	Si-Al	-203NQ	Si 251.61※ Al 309.27※	95 190	20	8	20	8	N_2O-C_2H_2
Iron Nickel	Fe-Ni	-204NQ	Fe 248.33※ Ni 232.00※	200 270	20	8	18	7	Air-C_2H_2
Strontium Barium	Sr-Ba	-205NB	Sr 460.73※ Ba 553.55※	400 350	20	8	16	6	Air-C_2H_2 N_2O-C_2H_2

Ⓐ ※: Maximum absorption wavelength.

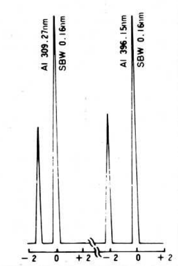
Ⓑ Photomultiplier output current measured with lamps operating at their maximum currents.
Photomultiplier tube: Hamamatsu R456 (Sp = 760 *lm* at 1000V) operated at 600V
AA equipment : Evert type (diffraction grating: 1180 g/mm, blaze: 300nm)

HAMAMATSU HOLLOW CATHODE LAMPS (2" Types For Perkin-Elmer)

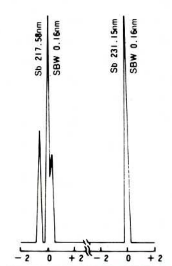
Single Element Hollow Cathode Lamps——Analytical Lines

(Unit : nanometers)

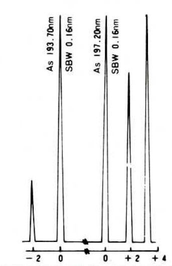
Aluminium **Al**



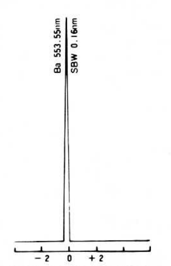
Antimony **Sb**



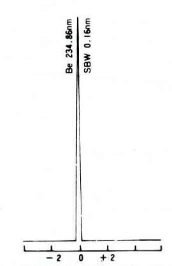
Arsenic **As**



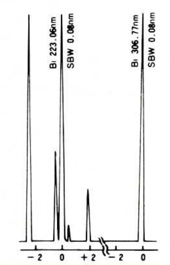
Barium **Ba**



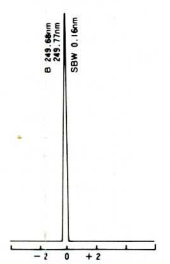
Beryllium **Be**



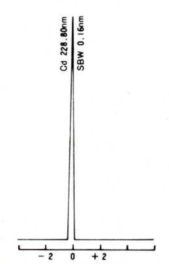
Bismuth **Bi**



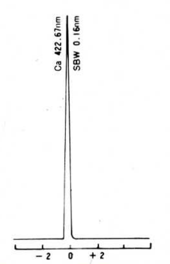
Boron **B**



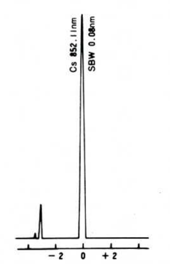
Cadmium **Cd**



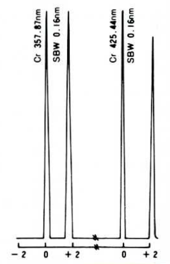
Calcium **Ca**



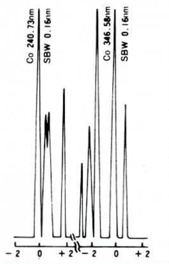
Cesium **Cs**



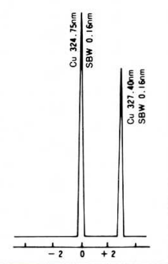
Chromium **Cr**



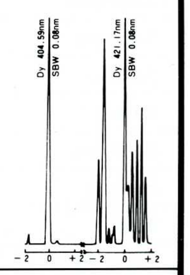
Cobalt **Co**



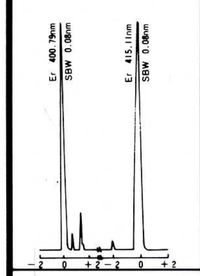
Copper **Cu**



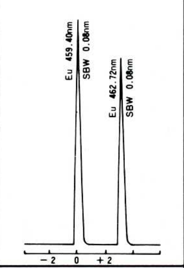
Dysprosium **Dy**



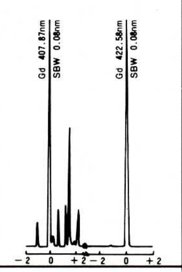
Erbium **Er**



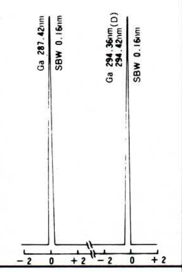
Europium **Eu**



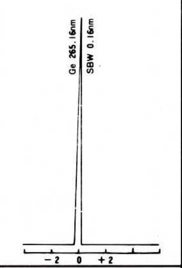
Gadolinium **Gd**



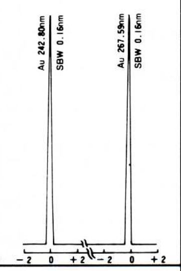
Gallium **Ga**



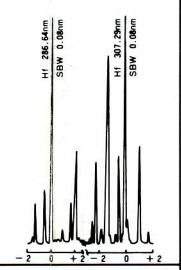
Germanium **Ge**



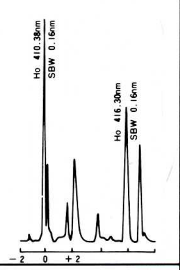
Gold **Au**



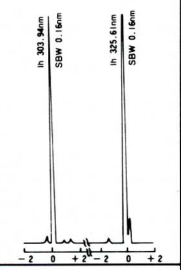
Hafnium **Hf**



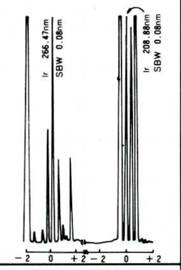
Holmium **Ho**



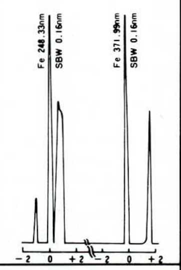
Indium **In**



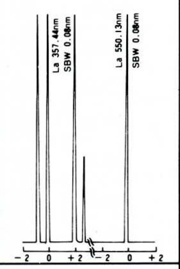
Iridium **Ir**



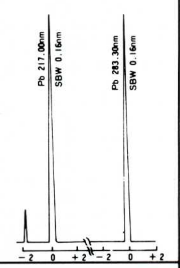
Iron **Fe**



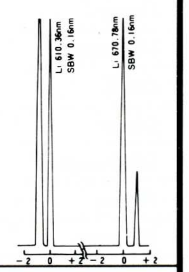
Lanthanum **La**



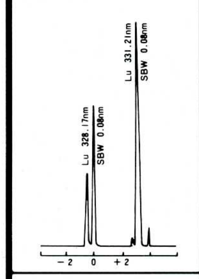
Lead **Pb**



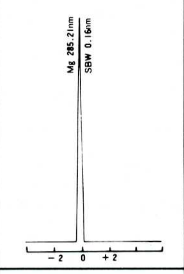
Lithium **Li**



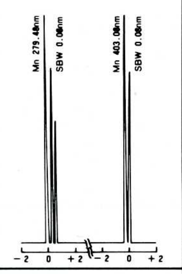
Lutecium **Lu**



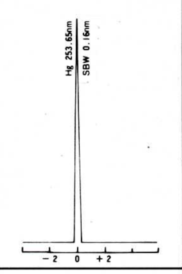
Magnesium **Mg**



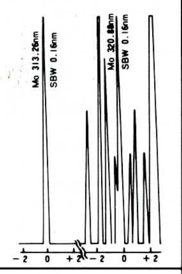
Manganese **Mn**



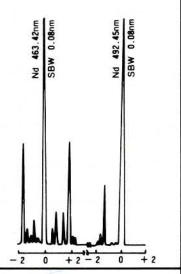
Mercury **Hg**



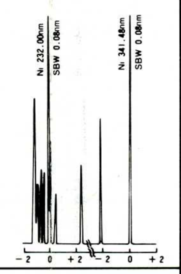
Molybdenum **Mo**



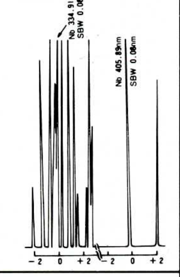
Neodymium **Nd**



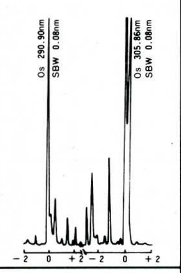
Nickel **Ni**



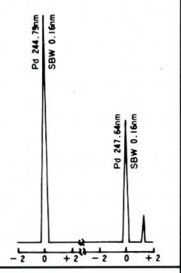
Niobium **Nb**



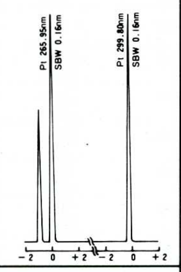
Osmium **Os**



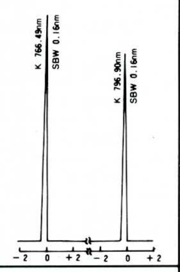
Palladium **Pd**



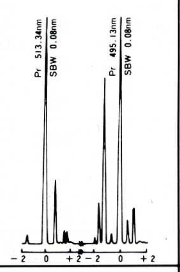
Platinum **Pt**



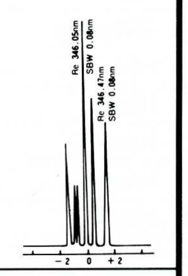
Potassium **K**



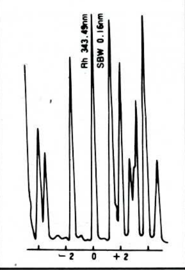
Praseodymium **Pr**



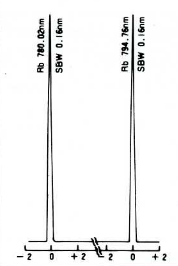
Rhenium **Re**



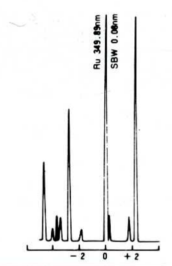
Rhodium **Rh**



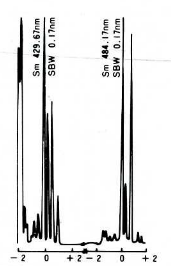
Rubidium **Rb**



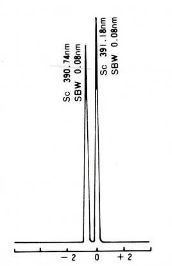
Ruthenium **Ru**



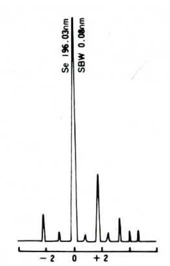
Samarium **Sm**



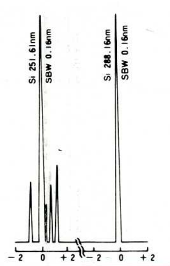
Scandium **Sc**



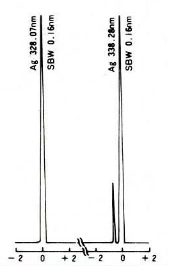
Selenium **Se**



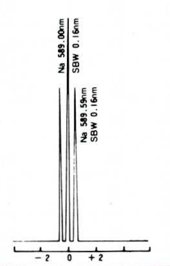
Silicon **Si**



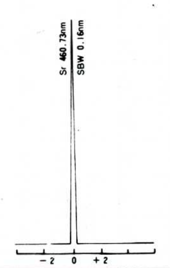
Silver **Ag**



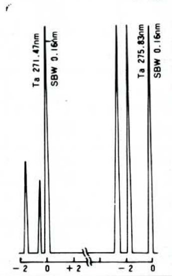
Sodium **Na**



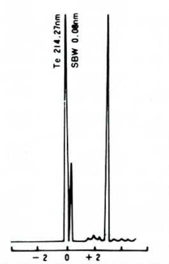
Strontium **Sr**



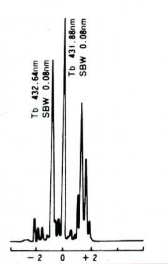
Tantalum **Ta**



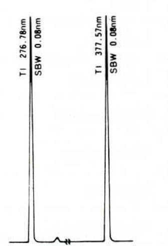
Tellurium **Te**



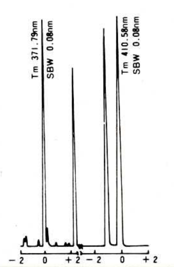
Terbium **Tb**



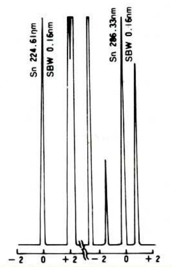
Thallium **Tl**



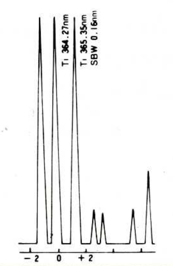
Thulium **Tm**



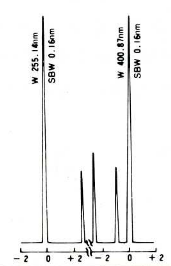
Tin **Sn**



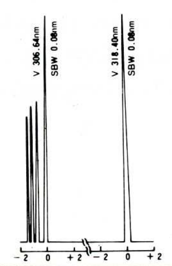
Titanium **Ti**



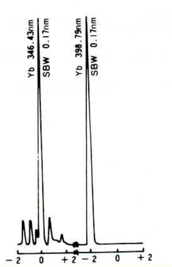
Tungsten **W**



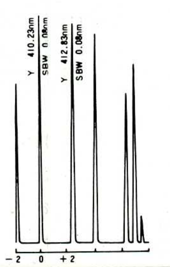
Vanadium **V**



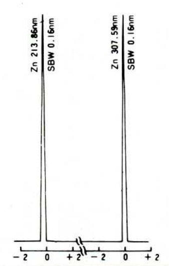
Ytterbium **Yb**



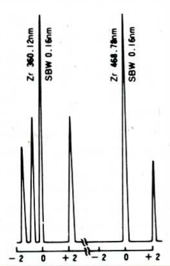
Yttrium **Y**



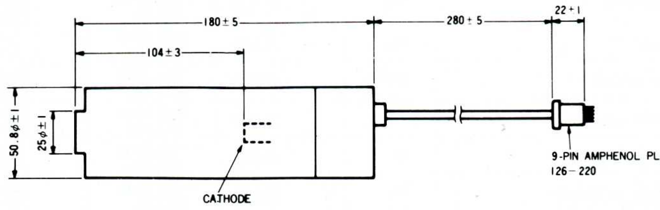
Zinc **Zn**



Zirconium **Zr**



Dimensional Outline (Unit:mm)



For background compensation, Hamamatsu also provides hot cathode deuterium lamps. Please contact us for further information.

MAJOR ABSORPTION LINES

Listed are normal atomic lines and singly ionized atomic lines. The boldface shows maximum absorption lines. However they may be different from those listed in this document.

Element	Absorption Lines (nm)
Ag	**328.068**, 338.289
Al	**309.271**, 236.706, 237.336, 256.799, 257.541, 265.249, 308.216, 394.403, 396.153
As	**193.696**, 197.197, 189.0
Au	**242.795**, 267.595, 274.826, 312.278
B	**249.678**, 249.773
Ba	**553.548**, 270.263, 307.158, 350.111, 388.933, 413.243, 455.403, 493.409, 791.134
Be	**234.861**, 313.042, 313.107
Bi	**223.061**, 195.389, 195.948, 202.121, 206.170, 211.026, 222.825, 227.658, 306.772
Ca	**422.673**, 239.856, 272.164, 393.367, 396.847, 657.278
Cd	**228.802**, 214.438, 226.502, 326.106
Co	**240.725**, 217.460, 227.449, 229.523, 230.902, 236.507, 238.486, 242.493, 243.583, 251.982, 292.881, 298.716, 298.956, 301.360, 304.400, 308.262, 322.142 341.263, 346.580, 347.402, 352.685
Cr	**357.869**, 205.552, 206.149, 206.542, 236.471, 335.197, 359.349, 360.533, 361.564, 373.081, 373.203, 425.435, 427.480, 428.972
Cs	**852.110**, 455.536, 459.318, 894.350
Cu	**324.754**, 202.434, 216.509, 217.894, 218.172, 222.570, 224.427, 244.164, 249.215, 327.396
Dy	**421.172**, 353.170, 364.541, 394.470, 396.842, 404.599, 407.798, 416.799, 418.678, 419.485
Er	**400.797**, 326.479, 331.242, 337.276, 349.911, 361.658, 369.264, 381.033, 386.282, 389.269, 390.544, 393.702, 394.441, 397.304, 397.360, 408.765, 415.110, 460.662
Eu	**459.403**, 311.143, 321.057, 321.281, 372.494, 412.970, 420.505, 462.722, 466.188
Fe	**248.327**, 208.412, 216.677, 234.349, 237.373, 238.204, 244.771, 246.264, 248.637, 250.113, 252.285, 258.588, 259.940, 271.902, 279.501, 282.569, 283.546, 287.417, 291.216, 293.690, 296.690, 298.357, 302.064, 319.166, 319.323, 344.061, 367.992, 371.994, 382.444, 385.991, 421.619, 437.593, 511.041
Ga	**294.363**, 229.420, 237.132, 245.007, 265.987, 287.421, 294.418, 403.298, 417.206
Gd	**368.413**, 336.223, 371.357, 371.748, 378.305, 405.364, 405.822, 407.870, 434.646, 434.662, (422.585※)
Ge	**265.158**, 259.254, 270.963, 275.459
Hf	**307.288**, 286.637, 289.826, 290.441, 294.077, 295.069, 296.488, 302.053, 368.224, 377.764
Hg	**253.652**
Ho	**410.384**, 345.600, 404.081, 405.393, 410.109, 410.862, 412.716, 416.303, 417.323
In	**303.936**, 230.606, 238.954, 246.008, 256.015, 275.388, 277.537, 285.814, 325.609, 410.476, 451.132
Ir	**208.882**, 209.263, 237.277, 247.512, 250.298, 254.397, 263.942, 263.971, 266.479, 284.972, 292.479
K	**766.491**, 404.414, 404.720, 769.898
La	**550.134**, 357.443, 364.953, 392.756, 403.721, 407.918, 408.672, 418.732, 494.977
Li	**670.784**、274.120, 323.261, (610.364)
Lu	**335.956**, 298.927, 308.147, 317.136, 327.897, 328.174, 331.211, 337.650, 356.784
Mg	**285.213**, 279.553, 280.270
Mn	**279.482**, 199.540, 199.886, 200.382, 209.213, 220.881, 221.385, 222.183, 257.610, 259.373, 260.569, 279.827, 280.106, 321.695, 403.076, 403.307, 403.449, 539.467, 543.255
Mo	**313.259**, 201.511, 202.030, 203.844, 204.598, 208.168, 294.421, 300.221, 311.212, 315.816, 317.035, 319.397, 320.883, 345.639, 346.683, 379.825, 386.411, 390.296
Na	**588.995**, 330.232, 330.299, 589.592
Nb	**334.906**, 334.197, 334.371, 335.842, 358.027, 372.624, 379.121, 405.894, 407.973, 410.040, 412.381
Nd	**463.424**, 468.345, 471.902, 489.693, 492.453, 494.483, 562.054
Ni	**232.003**, 228.998, 231.096, 233.749, 234.554, 234.752, 247.687, 298.413, 301.914, 303.187, 322.165, 323.296, 336.957, 339.105, 340.958, 341.480, 343.728, 350.260, 356.175, 362.473
Os	**290.906**, 305.866
Pb	**216.999**, 202.202, 205.327, 283.306
Pd	**244.791**, 247.642, 276.309, 340.458
Pr	**495.136**, 491.403, 504.553, 513.342
Pt	**265.945**, 214.423, 217.467, 246.744, 248.717, 262.803, 264.689, 270.240, 270.589, 273.396, 283.030, 299.797, 306.471
Rb	**780.023**, 420.185, 421.556, 794.760
Re	**346.046**, 345.188, 346.473
Rh	**343.489**, 339.685, 350.252, 350.732, 365.799, 369.236, 370.091
Ru	**349.894**, 372.803
Sb	**217.581**, 206.833. 212.739, 231.147
Sc	**391.181**, 325.569, 336.991, 327.363, 390.749, 393.338, 399.661, 402.040, 402.369, 405.455, 408.240
Se	**196.030**, 203.985, 206.279, 207.479
Si	**251.612**, 220.798, 221.091, 221.669, 250.690, 251.433, 251.921, 252.412, 252.852, 288.158
Sm	**429.674**, 458.158, 472.842, 476.027, 478.310, 488.377, 488.397, 511.716, 520.059, 527.140, 528.291, 532.060, 534.129, 540.370
Sn	**224.605**, 207.308, 235.448, 254.655, 270.651, 286.333, 303.412
Sr	**460.733**, 242.810, 256.947, 293.183, 407.771 421.552, 689.259
Ta	**271.467**, 255.943, 260.863, 264.747, 266.134, 275.831, 277.583
Tb	**432.647**, 390.135, 406.159, 410.537, 431.885, 433.845
Te	**214.275**, 225.904, 238.576
Ti	**364.268**, 318.651, 319.191, 319.990, 337.145, 363.546, 365.350, 372.982, 374.106, 375.285, 394.867, 395.634, 395.821, 398.176, 398.976, 399.864
Tl	**276.787**, 231.598, 237.969, 258.014, 377.572
U	**351.462**, 348.937, 355.082, 356.660, 358.488, 365.916, 394.382, 404.275, (415.398)
V	**306.638**, 318.341, 318.540, 382.856, 384.075, 385.584, 390.225, 411.178, 437.924, 438.472, 438.997, 318.398, (318.398※)
W	**255.135**, 265.654, 268.141, 272.435, 283.138, 294.440, 400.875
Y	**407.738**, 410.238, 412.831, 414.285
Yb	**398.799**, 266.449, 267.198, 346.437
Zn	**213.856**, 202.551, 206.191, 307.590
Zr	**360.119**, 298.539, 301.175, 302.952, 350.932, 351.961, 354.768, 362.386, 386.387, 389.032, 468.780

Wavelength in parentheses were added by Hamamatsu.

Reference: "Atomic Absorption Spectroscopy" by S. Takeuchi,
M. Suzuki (Nankou Dou)

Periodic Table of the Elements

🟨 : Hollow cathode lamps of these elements are available from Hamamatsu.

Atomic Number → 25 +2 +3 +4 +7 ← Oxidation States
Manganese ← Element
Element Symbol → Mn
54.9380 ← Atomic Weight
Analytical Line (nm) → (279.48)
-8-13-2 ← Electron Configuration

Group Period	I a	II a	III b	IV b	V b	VI b	VII b	VIII			I b	II b	III a	IV a	V a	VI a	VII a	0	Orbit
1	1 +1 -1 Hydrogen H 1.0079 1																	2 0 Helium He 4.00260 2	K
2	🟨 3 +1 Lithium Li 6.94 (670.78) 2-1	🟨 4 +2 Beryllium Be 9.01218 (234.86) 2-2											🟨 5 +3 Boron B 10.81 (249.77) 2-3	6 +2 +4 -4 Carbon C 12.011 2-4	7 +1 +2 +3 +4 +5 -1 -2 -3 Nitrogen N 14.0067 2-5	8 -2 Oxygen O 15.9994 2-6	9 -1 Fluorine F 18.998403 2-7	10 0 Neon Ne 20.17$_{9}$ 2-8	K-L
3	🟨 11 +1 Sodium Na 22.98977 (589.00) 2-8-1	🟨 12 +2 Magnesium Mg 24.305 (285.21) 2-8-2											🟨 13 +3 Aluminium Al 26.98154 (309.27) 2-8-3	🟨 14 +2 +4 -4 Silicon Si 28.0855 (251.61) 2-8-4	15 +3 +5 -3 Phosphorus P 30.97376 2-8-5	16 +4 +6 -2 Sulphur S 32.06 2-8-6	17 +1 +5 +7 -1 Chlorine Cl 35.453 2-8-7	18 0 Argon Ar 39.948 2-8-8	K-L-M
4	🟨 19 +1 Potassium K 39.0983 (766.49) -8-8-1	🟨 20 +2 Calcium Ca 40.08 (422.67) -8-8-2	🟨 21 +3 Scandium Sc 44.9559 (391.18) -8-9-2	🟨 22 +2 +3 +4 Titanium Ti 47.90 (364.27) -8-10-2	🟨 23 +2 +3 +4 +5 Vanadium V 50.9415 (318.40) -8-11-2	🟨 24 +2 +3 +6 Chromium Cr 51.996 (357.87) -8-13-1	🟨 25 +2 +3 +4 +7 Manganese Mn 54.9380 (279.48) -8-13-2	🟨 26 +2 +3 Iron Fe 55.847 (248.33) -8-14-2	🟨 27 +2 +3 Cobalt Co 58.9332 (240.73) -8-15-2	🟨 28 +2 +3 Nickel Ni 58.71 (232.00) -8-16-2	🟨 29 +1 +2 Copper Cu 63.546 (324.75) -8-18-1	🟨 30 +2 Zinc Zn 65.38 (213.86) -8-18-2	🟨 31 +3 Gallium Ga 69.735 (294.36) -8-18-3	🟨 32 +2 +4 Germanium Ge 72.59 (265.16) -8-18-4	🟨 33 +3 +5 -3 Arsenic As 74.9216 (193.70) -8-18-5	🟨 34 +4 +6 -2 Selenium Se 78.96 (196.03) -8-18-6	35 +1 +5 -1 Bromine Br 79.904 -8-18-7	36 0 Krypton Kr 83.80 -8-18-8	L-M-N
5	🟨 37 +1 Rubidium Rb 85.467$_{8}$ (780.02) -18-8-1	🟨 38 +2 Strontium Sr 87.62 (460.73) -18-8-2	🟨 39 +3 Yttrium Y 88.9059 (410.23) -18-9-2	🟨 40 +4 Zirconium Zr 91.22 (360.12) -18-10-2	🟨 41 +3 +5 Niobium Nb 92.9064 (334.91) -18-12-1	🟨 42 +6 Molybdenum Mo 95.94 (313.26) -18-13-1	43 +4 +6 +7 Technetium Tc 98.9062 -18-13-2	🟨 44 +3 Ruthenium Ru 101.07 (349.89) -18-15-1	🟨 45 +3 Rhodium Rh 102.9055 (343.49) -18-16-1	🟨 46 +2 +4 Palladium Pd 106.4 (244.79) -18-18-0	🟨 47 +1 Silver Ag 107.868 (328.07) -18-18-1	🟨 48 +2 Cadmium Cd 112.41 (228.80) -18-18-2	🟨 49 +3 Indium In 114.82 (303.94) -18-18-3	🟨 50 +2 +4 Tin Sn 118.69 (224.61) -18-18-4	🟨 51 +3 +5 -3 Antimony Sb 121.75 (217.58) -18-18-5	🟨 52 +4 +6 -2 Tellurium Te 127.60 (214.27) -18-18-6	53 +1 +5 +7 -1 Iodine I 126.9045 -18-18-7	54 0 Xenon Xe 131.30 -18-18-8	M-N-O
6	🟨 55 +1 Caesium Cs 132.9054 (852.11) -18-8-1	🟨 56 +2 Barium Ba 137.33 (553.55) -18-8-2	🟨 57 * +3 Lanthanum La 138.9055 (5501.3) -18-9-2	🟨 72 +4 Hafnium Hf 178.49 (286.64) -32-10-2	🟨 73 +5 Tantalum Ta 180.947$_{9}$ (271.14) -32-11-2	🟨 74 +6 Tungsten W 183.85 (255.14) -32-12-2	🟨 75 +4 +6 +7 Rhenium Re 186.207 (346.05) -32-13-2	🟨 76 +3 +4 Osmium Os 190.2 (290.90) -32-14-2	🟨 77 +3 +4 Iridium Ir 192.22 (208.88) -32-15-2	🟨 78 +2 +4 Platinum Pt 195.09 (265.95) -32-16-2	🟨 79 +1 +3 Gold Au 196.9665 (242.80) -32-18-1	🟨 80 +1 +2 Mercury Hg 200.59 (253.65) -32-18-2	🟨 81 +1 +3 Thallium Tl 204.37 (276.78) -32-18-3	🟨 82 +2 +4 Lead Pb 207.2 (217.00) -32-18-4	🟨 83 +3 +5 Bismuth Bi 208.9804 (223.06) -32-18-5	84 +2 +4 Polonium Po 〔209〕 -32-18-6	85 Astatine At 〔210〕 -32-18-7	86 0 Radon Rn 〔222〕 -32-18-8	N-O-P
7	87 +1 Francium Fr 〔223〕 -18-8-1	88 +2 Radium Ra 226.0254 -18-8-2	89 ** +3 Actinium Ac 〔227〕 -18-9-1	104 +4 Rutherfordium Rf 〔260〕 -32-10-2	105 Hahnium Ha 〔260〕 -32-11-2	106 〔263〕 -32-12-2													O-P-Q

* Lanthanides	58 +3 +4 Cerium Ce 140.12 -20-8-2	🟨 59 +3 Praseodymium Pr 140.9077 (495.13) -21-8-2	🟨 60 +3 Neodymium Nd 144.24 (492.45) -22-8-2	61 +3 Promethium Pm 〔145〕 -23-8-2	🟨 62 +2 +3 Samarium Sm 150.4 (429.67) -24-8-2	🟨 63 +2 +3 Europium Eu 151.96 (459.40) -25-8-2	🟨 64 +3 Gadolinium Gd 157.25 (422.58) -25-9-2	🟨 65 +3 Terbium Tb 158.9254 (432.64) -27-8-2	🟨 66 +3 Dysprosium Dy 162.50 (404.59) -28-8-2	🟨 67 +3 Holmium Ho 164.9304 (410.38) -29-8-2	🟨 68 +3 Erbium Er 167.26 (400.79) -30-8-2	🟨 69 +3 Thulium Tm 168.9342 (371.79) -31-8-2	🟨 70 +2 +3 Ytterbium Yb 173.04 (398.79) -32-8-2	🟨 71 +3 Lutetium Lu 174.967 ±0.003 (331.21) -32-9-2	N-O-P
** Actinides	90 +4 Thorium Th 232.0381 -18-10-2	91 +5 +4 Protactinium Pa 231.0359 -20-9-2	92 +3 +4 +5 +6 Uranium U 238.029 -21-9-2	93 +3 +4 +5 +6 Neptunium Np 237.0482 -22-9-2	94 +3 +4 +5 +6 Plutonium Pu 〔244〕 -24-8-2	95 +3 +4 +5 +6 Americium Am 〔243〕 -25-8-2	96 +3 Curium Cm 〔247〕 -25-9-2	97 +3 +4 Berkelium Bk 〔247〕 -27-8-2	98 +3 Californium Cf 〔251〕 -28-8-2	99 +3 Einsteinium Es 〔254〕 -29-8-2	100 +3 Fermium Fm 〔257〕 -30-8-2	101 +2 +3 Mendelevium Md 〔258〕 -31-8-2	102 +2 +3 Nobelium No 〔259〕 -32-8-2	103 +3 Lawrencium Lr 〔260〕 -32-9-2	O-P-Q

(Reference: CRC Handbook of Chemistry and Physics 64th Edition)

HAMAMATSU

Asia: Hamamatsu Photonics K.K., 1126 Ichino-cho, Hamamatsu City, Japan,
Telephone: 0534/34-3311, Telex: 4225-185, Fax: 0534/35-1037
U.S.A.: Hamamatsu Corporation, 420 South Avenue, Middlesex, N.J. 08846,
Telephone: 201/469-6640, Telex: 833-403, Fax: 201/526-8822
Western Office, 2444 Moorpark Avenue, San Jose, Calif. 95128,
Telephone: 408/292-8603, Fax: 408/279-1886

AGENT

DEC/84 T-2000 Printed in Japan