Welcome to 3.091

Lecture 17

October 19, 2009

X-Ray Emission & Absorption


Bertha Röntgen’s hand
photo credit: Wilhelm Röntgen

bounding surface of the metal in which the light absorption takes place are the determining factors in this displacement.

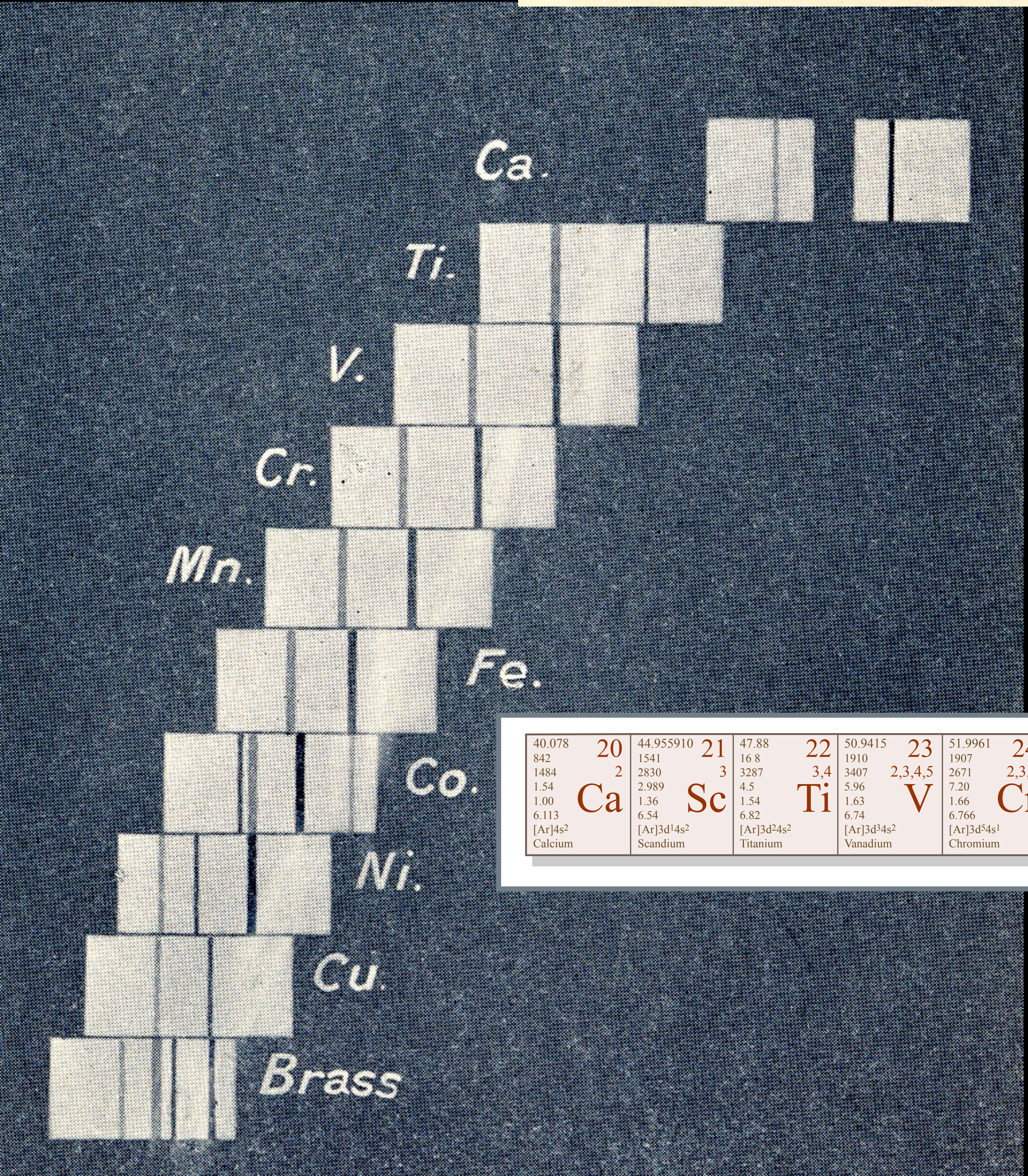
Berlin, Physikalisches Institut
der Universität, July 1913.

XCIII. *The High-Frequency Spectra of the Elements.* *By* H. G. J. Moseley, *M.A.**

[Plate XXIII.]

IN the absence of any available method of spectrum analysis, the characteristic types of X radiation, which an atom emits when suitably excited, have hitherto been described in terms of their absorption in aluminium †. The interference phenomena exhibited by X rays when scattered by a crystal have now, however, made possible the accurate determination of the frequencies of the various types of radiation. This was shown by W. H. and W. L. Bragg ‡, who by this method analysed the line spectrum emitted by the platinum target of an X-ray tube. C. G. Darwin and the author § extended this analysis and also examined the continuous spectrum, which in this case constitutes the greater part of the radiation. Recently Prof. Bragg ‖ has also

MOSELEY. Phil. Mag. Ser. 6, Vol. 26, Pl. XXIII.



20	21	22	23	24	25	26	27	28	29	30
Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
40.078	44.955910	47.88	50.9415	51.9961	54.93805	55.847	58.93320	58.6934	63.546	65.39
842	1541	16 8	1910	1907	1246	1538	1495	1455	1084.62	419.53
1484	2830	3287	3407	2671	2061	2861	2927	2913	2562	907
2	3	3,4	2,3,4,5	2,3,6	2,3,4,6,7	2,3	2,3	2,3	1,2	2
1.54	2.989	4.5	5.96	7.20	7.47	7.86	8.92	8.90	8.94	$7.14^{25\%}$
1.00	1.36	1.54	1.63	1.66	1.55	1.83	1.88	1.91	1.90	1.65
6.113	6.54	6.82	6.74	6.766	7.435	7.870	7.86	7.635	7.726	9.394
$[Ar]4s^2$	$[Ar]3d^14s^2$	$[Ar]3d^24s^2$	$[Ar]3d^34s^2$	$[Ar]3d^54s^1$	$[Ar]3d^54s^2$	$[Ar]3d^64s^2$	$[Ar]3d^74s^2$	$[Ar]3d^84s^2$	$[Ar]3d^{10}4s^1$	$[Ar]3d^{10}4s^2$
Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc

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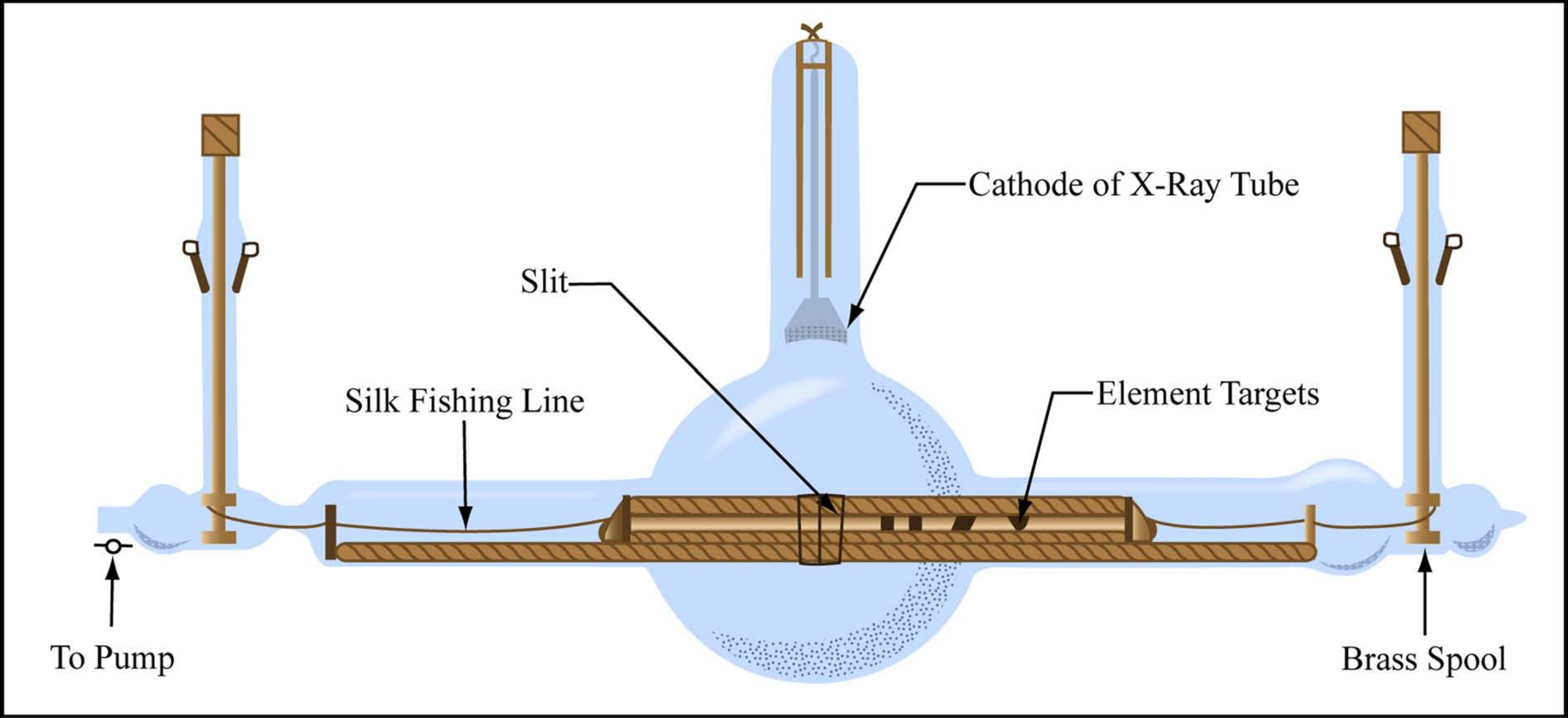

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effect in the case of many metals and alloys are subject to variations as great as an octave and more. This difficulty is all the more real in that as yet we are not in a position to determine what influences on and in the extremely thin bounding surface of the metal in which the light absorption takes place are the determining factors in this displacement.

Berlin, Physikalisches Institut
der Universität, July 1913.

XCIII. *The High-Frequency Spectra of the Elements.* *By* H. G. J. Moseley, *M.A.**

[Plate XXIII.]

IN the absence of any available method of spectrum analysis, the characteristic types of X radiation, which an atom emits when suitably excited, have hitherto been described in terms of their absorption in aluminium †. The interference phenomena exhibited by X rays when scattered by a crystal have now, however, made possible the accurate determination of the frequencies of the various types of radiation. This was shown by W. H. and W. L. Bragg ‡, who by this method analysed the line spectrum emitted by the platinum target of an X-ray tube. C. G. Darwin and the author § extended this analysis and also examined the continuous spectrum, which in this case constitutes the greater part of the radiation. Recently Prof. Bragg ‖ has also determined the wave-lengths of the strongest lines in the spectra of nickel, tungsten, and rhodium. The electrical methods which have hitherto been employed are, however, only successful where a constant source of radiation is available. The present paper contains a description of a method of photographing these spectra, which makes the analysis of the X rays as simple as any other branch of spectroscopy. The author intends first to make a general survey of the principal types of high-frequency radiation, and then to examine the spectra of a few elements in greater detail and with greater accuracy. The results already obtained show that such data have an important bearing on the question of

the internal structure of the atom, and strongly support the views of Rutherford and of Bohr.

* Communicated by Prof. E. Rutherford, F.R.S.
† *Cf.* Barkla, Phil. Mag. xxii. p. 396 (1911).
‡ Proc. Roy. Soc. A. lxxxviii. p. 428 (1913).
§ Phil. Mag. xxvi. p. 210 (1913).
‖ Proc. Roy. Soc. A. lxxxix. p. 246 (1913).

The reason for introducing this particular constant will be given later. It is at once evident that Q increases by a constant amount as we pass from one element to the next, using the chemical order of the elements in the periodic system. Except in the case of nickel and cobalt *, this is also the order of the atomic weights. While, however, Q increases uniformly the atomic weights vary in an apparently arbitrary manner, so that an exception in their order does not come as a surprise. We have here a proof that there is in the atom a fundamental quantity, which increases by regular steps as we pass from one element to the next. This quantity can only be the charge on the central positive nucleus, of the existence of which we already have definite proof. Rutherford has shown, from the magnitude of the scattering of α particles by matter, that this nucleus carries a + charge approximately equal to that of $\frac{A}{2}$ electrons, where A is the atomic weight. Barkla, from the scattering of X rays by matter, has shown that the number of electrons in an atom is roughly $\frac{A}{2}$, which for an electrically neutral atom comes to the same thing. Now atomic weights increase on the average by about 2 units at a time, and this strongly suggests the view that N increases from atom to atom always by a single electronic unit. We are therefore led by experiment to the view that N is the same as the number of the place occupied by the element in the periodic system. This atomic number is then for H 1 for He 2 for Li 3 . . . for Ca 20 . . . for Zn 30, &c. This theory was originated by Broek † and since used by Bohr ‡. We can confidently predict that in the few cases in which the order of the atomic weights A clashes with the chemical order of the periodic system, the chemical properties are governed by N; while A is itself probably a complicated function of N. The very close similarity between the X-ray spectra of the different elements shows that these radiations originate inside the atom, and have no direct connexion with the complicated light-spectra and chemical properties which are governed by the structure of its surface.

Ar	18		39.948	-189.35	-185.85	1.784	-	15.759	$[Ne]3s^2p^6$	Argon
K	19	1	39.0983	63.38	759	0.86	0.82	4.341	$[Ar]4s^1$	Potassium
Co	27	2,3	58.93320	1495	2927	8.92	1.88	7.86	$[Ar]3d^74s^2$	Cobalt
Ni	28	2,3	58.6934	1455	2913	8.90	1.91	7.635	$[Ar]3d^84s^2$	Nickel
Te	52	-2,4,6	127.60	449.51	988	6.25	2.1	9.009	$[Kr]4d^{10}5s^2p^4$	Tellurium
I	53	±1,5,7	126.90447	113.7	184.4	4.93	2.66	10.451	$[Kr]4d^{10}5s^2p^5$	Iodine
U	92	3,4,5,6	238.0289	1135	4131	19.05+0.02	1.38	6.05	$[Rn]5f^36d^17s^2$	Uranium
Np	93	3,4,5,6	(237.0482)	644	-	20.45	1.36	6.19	$[Rn]5f^46d^17s^2$	Neptunium

We will now examine the relation

$$Q = \sqrt{\frac{\nu}{\frac{3}{4}\nu_0}}$$

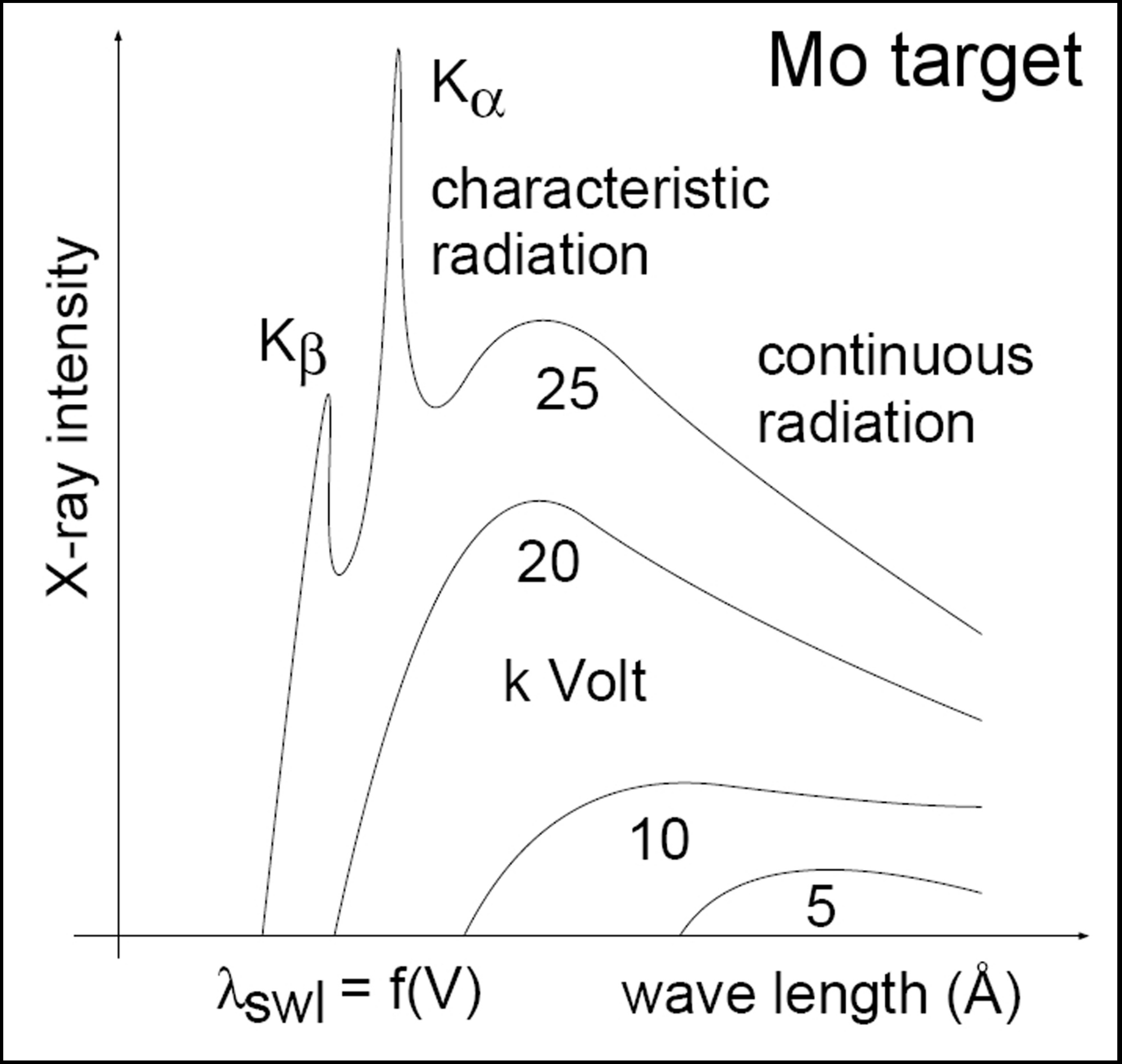
more closely. So far the argument has relied on the fact that Q is a quantity which increases from atom to atom by equal steps. Now Q has been obtained by multiplying $\nu^{\frac{1}{2}}$ by a constant factor so chosen as to make the steps equal to unity. We have, therefore,

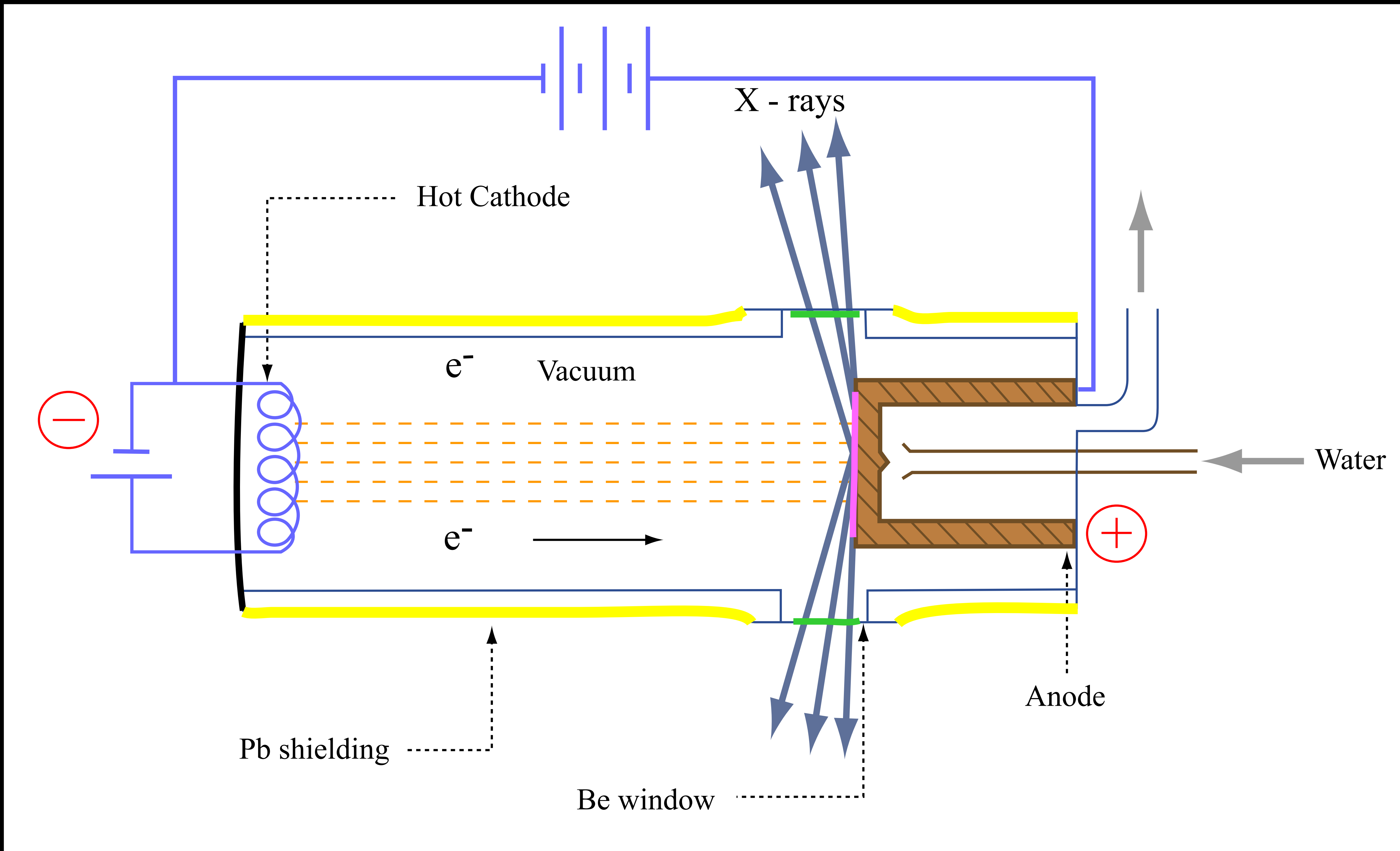
$$Q = N - k,$$

where k is a constant. Hence the frequency ν varies as $(N-k)^2$. If N for calcium is really 20 then $k=1$.

There is good reason to believe that the X-ray spectra with which we are now dealing come from the innermost ring of electrons *.

Henry G.W. Moseley


Mo target
Kα
characteristic
radiation
Kβ
25
continuous
radiation
X-ray intensity
20
k Volt
10
5
λSWL = f(V)
wave length (Å)


X - rays
Hot Cathode
e-
Vacuum
e-
Water
Anode
Pb shielding
Be window

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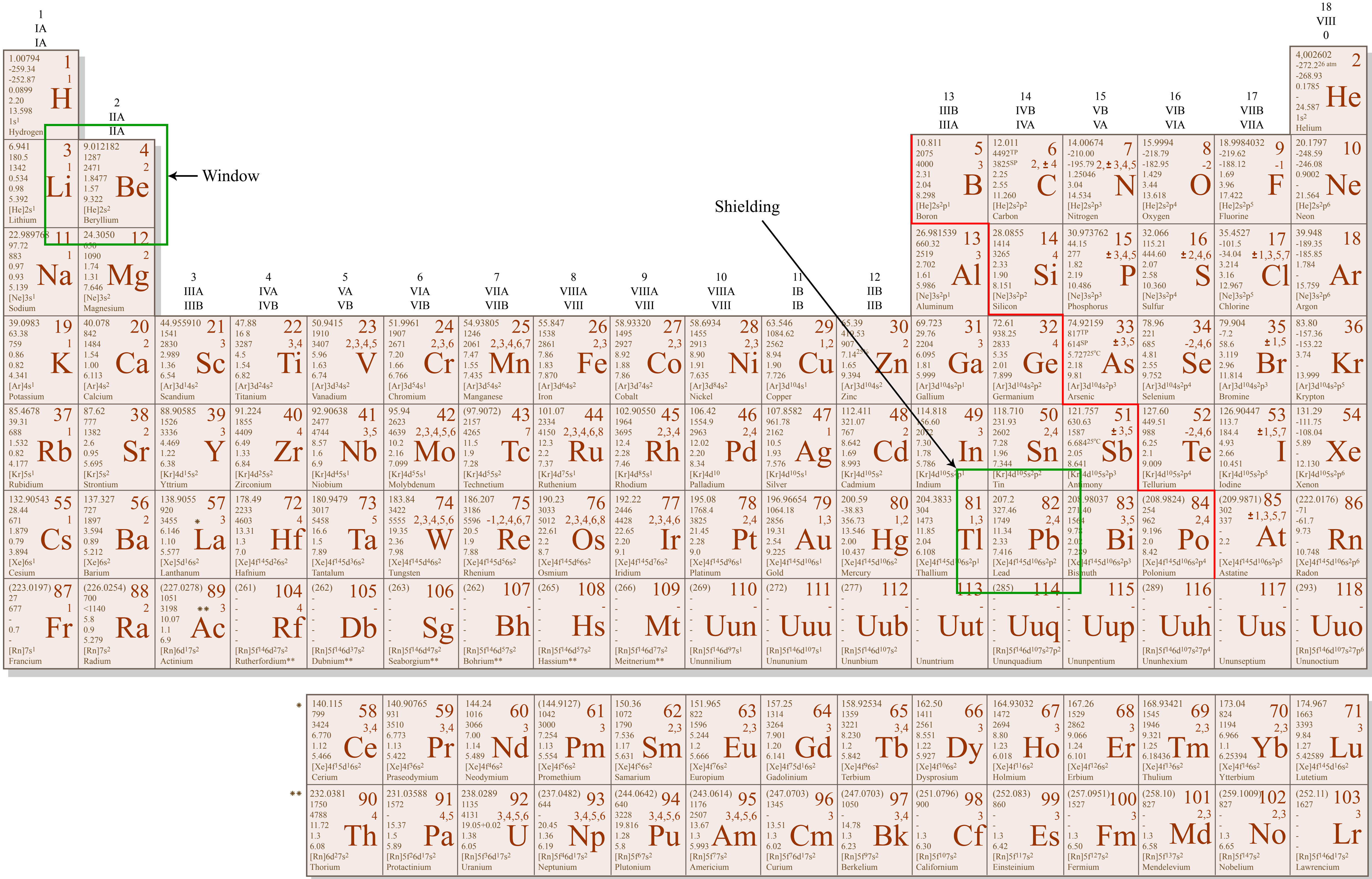
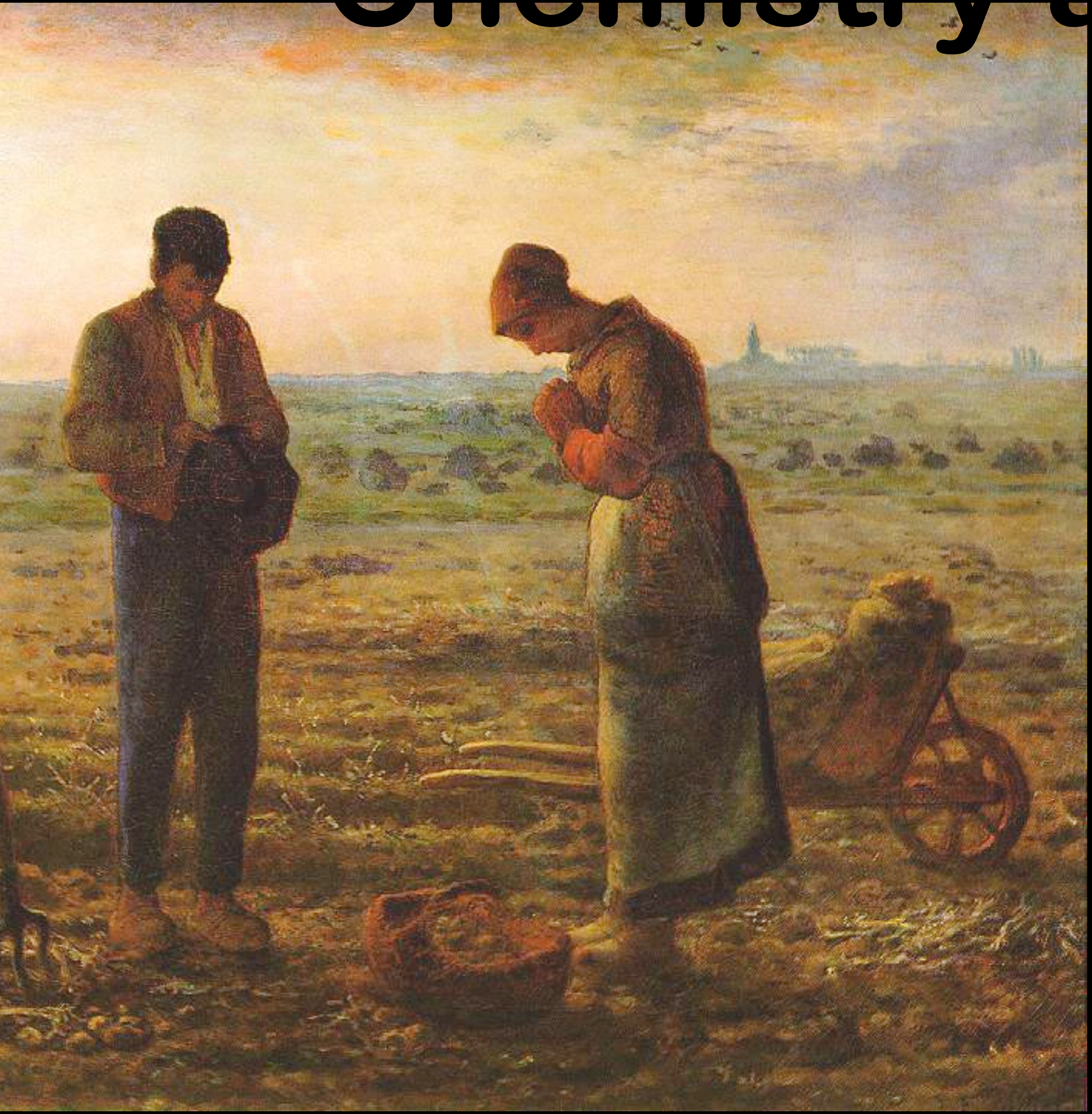

Window
Shielding

The Angelus 1857-1859

Jean-François Millet



“Adorazione del Bambino”
Fra’ Bartolomeo
Galleria Borghese
Rome

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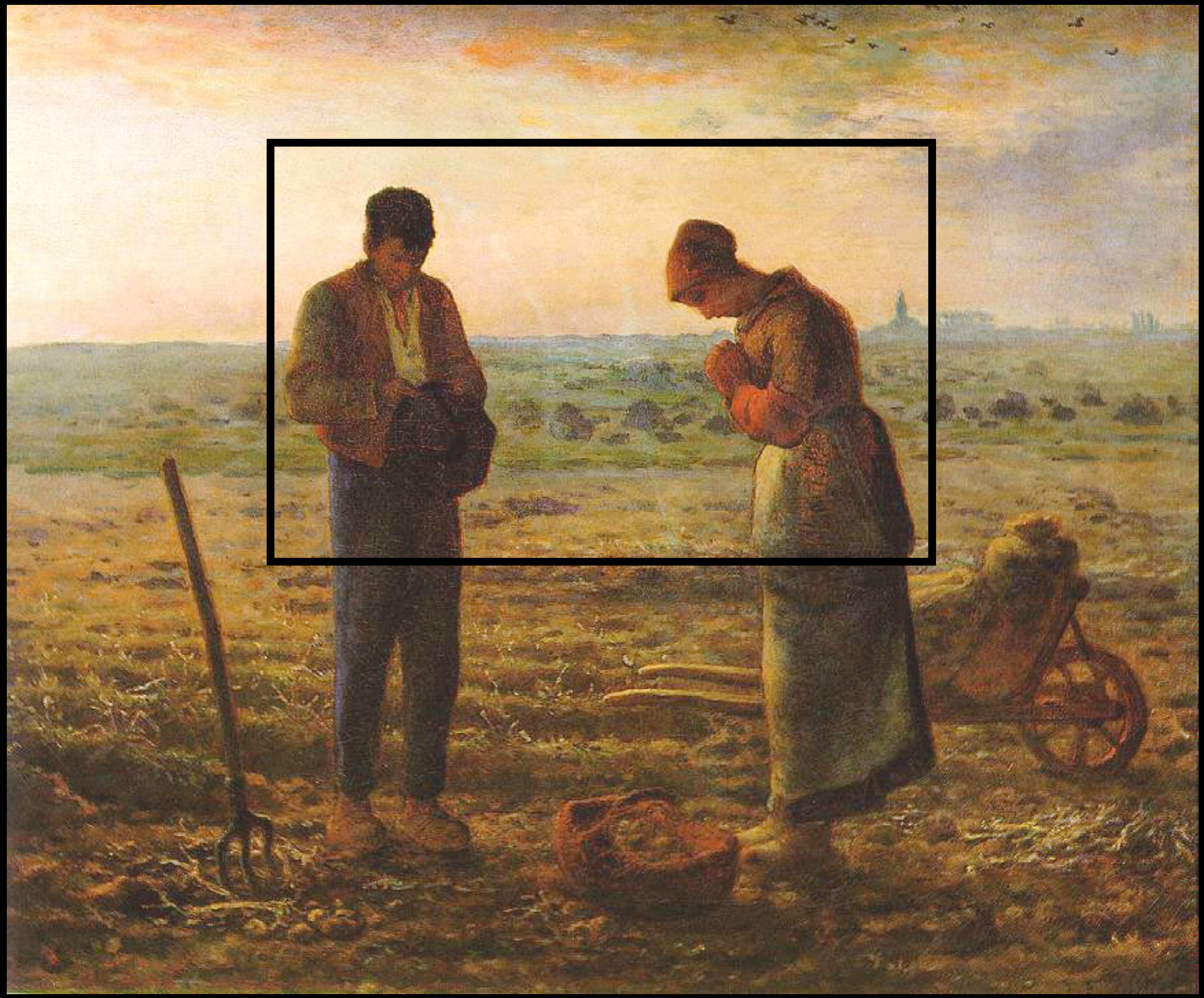

The Hallucinogenic Toreador

Salvador Dalí

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