TABLE I.

Gamma-ray energy	$3.89n+c$
22.19	$3.89\times6-1.14=22.20$
17.78	$3.89\times5-1.64=17.81$
14.26	$3.89\times4-1.30=14.26$
11.67	$3.89\times3\quad=11.67$
6.13	$3.89\times2-1.64=\ 6.14$
4.29	$3.89\times1+0.38=\ 4.27$

it is shown that the disintegration energies of the radium C′ atom can be represented by the expression $3.85n\pm c$. The constant 3.85 is used here instead of 3.89 because the more recent values of the γ-ray energies are slightly lower than those used in getting $3.89n\pm c$.

TABLE II.

Element	Disintegration energy	Mean c's
Radon	$55.80=14q+1.90$	
Actinium A	$75.08=20q-1.92$	
Actinium Cα	$67.39=18q-1.91$	1.91
Radium Cα	$56.15=15q-1.60$	
Radium Cα_1	$55.52=14q+1.62$	
Radium C′	$98.44=26q-1.66$	
Actinium Cα_1	$63.83=17q-1.62$	
Thoron	$63.94=17q-1.51$	1.63
Radium C′	$78.29=20q+1.29$	
Actinon α_1	$66.65=17q+1.20$	
Actinium C′	$75.81=20q-1.19$	
Radium C′	$91.12=24q-1.28$	
Radium C′	$94.93=25q-1.32$	
Radium C′	$102.69=27q-1.26$	
Radium C′	$105.26=27q+1.31$	1.27
Thorium C′	$89.47=23q+0.92$	
Radium C′	$100.97=26q+0.87$	0.89
Radium A	$61.09=16q-0.51$	
Radium C′	$103.42=27q-0.53$	
Radium C′	$107.09=28q-0.71$	
Radium C′	$96.73=25q+0.48$	0.55
Radium C′	$84.37=22q-0.33$	
Thorium A	$68.97=18q-0.33$	
Thorium Cα_1	$62.04=16q+0.44$	
Thorium C′	$96.61=25q+0.36$	
Thorium C′	$107.41=28q-0.39$	
Radium C′	$99.68=26q-0.42$	0.38
Polonium	$54.06=14q+0.16$	
Actinon α_2	$65.31=17q-0.14$	0.15
Radium C′	$92.41=24q+0.01$	
Thorium Cα	$61.64=16q+0.04$	
Actinon α	$69.37=18q+0.07$	0.04

I now find that all the disintegration energies can be represented by the same expression. This is shown in Table II where $q=3.85$. The mean values of the differences between the disintegration energies and the multiples of 3.85 agree nearly with the c's found for the γ-rays of radium C′. This is shown in Table III.

TABLE III.

c's from γ-rays of radium C′	c's from disintegration energies	Differences
1.89	1.91	+0.02
1.64	1.63	−0.01
1.30	1.27	−0.03
1.14		
0.89	0.89	0.00
0.55	0.55	0.00
0.38	0.38	0.00
	0.15	
0.00	0.04	+0.04

The mean deviation corresponds to an error of about 1 part in 4000 in the values of the disintegration energies. The value $c=1.14$ does not appear among the disintegration c's and the value $c=0.15$ was not found for the γ-ray energies.

There seems to be little doubt that the expression $3.85n\pm c$ represents the disintegration energies of all the atoms and the γ-ray energies of radium C′ with the same values of the c's. It seems probable therefore that it will also represent the γ-ray energies of the other atoms but this question has not yet been examined.

It seems probable that there is some process which takes place in all the radioactive atoms which releases an amount of energy 3.85×10^5 electron-volts. The uranium nucleus contains 92 protons and 146 neutrons. We might suppose that the neutrons are not combined with the protons as closely as possible and that when a proton combines as closely as possible with a neutron energy 3.84×10^5 electron-volts is released. This would give $92\times3.85\times10^5=35.4\times10^6$ electron-volts for all the disintegrations of the uranium series. The total disintegration energy of the eight α-rays of the uranium series, however, is about 43×10^6 electron-volts which is about 20 percent greater than 35.4×10^6.

The c's probably represent energy exchanges with the electrons or some other secondary action between the γ-rays or α-rays emitted by the nucleus and the rest of the atom.

H. A. WILSON

Rice Institute,
Houston, Texas,
October 31, 1933.

Discrepancy Between Theory and Experiment in Cold Emission

Numerous writers on cold emission have mentioned that the electron currents drawn from cold cathodes by extremely high electric fields are much larger than is expected on the basis of the wave-mechanical calculation by Fowler and Nordheim. To explain this, the assumption is usually made that there are submicroscopic sharp points on the cathode at which the field is much more intense than the average value in that vicinity, and where the current density may be as high as 100,000 amperes per square centimeter. Some measurements at this laboratory show

that this is not the only factor to be considered, but that rather, if the emitted electrons can strike glass, substances removed from such a target can be ionized and move back along the electron stream. They are deposited on the cold cathode surface and reduce the work function of the cathode thus giving much larger currents than those calculated for a clean surface.

The apparatus was similar to that used in an investigation reported in this journal,[1] except that a glass disk was fastened on the anode with the center of the disk opposite the emitting point. The same kind of disk was used as is used for cover glasses on bacteriological slides. The emission was drawn from sharp copper cathodes held about 2 mm from the glass disk, while magnetic fields of about 5000 gauss were applied at right angles to the electric field, as before.

Although the magnetic field applied was several times stronger than sufficient to deflect the electrons away from the glass, a fluorescent spot appeared on the glass. As explained in the above-mentioned paper, this shows that there were positive ions in the stream. This spot did not gradually disappear as it did in the case of the metal anodes, so the material drawn from the glass is not nearly so exhaustible as it was in the case of the metal anodes.

The kinds of characteristics observed were very similar to those observed for a magnesium anode shown as Fig. 5, p. 420 of reference 1, except that with the glass disk, either kind of field-current characteristics could be produced at will. The characteristics were either like curve 1, or like curve 2, depending on whether the field was gradually decreased from the higher value, or suddenly dropped to zero. Although the effort was made by varying the field irregularly to get the cathode to give a characteristic lying between these two groups, this was unsuccessful. (The current is limited by space charge at current above 10^{-6} ampere with these cathodes.)

In the paper by Stern, Gossling and Fowler,[2] it is shown that if the logarithm of the current is plotted against the reciprocal of the field, the slope of the characteristic is proportional to the work function to the three-halves power and inversely proportional to the factor by which the measured field must be multiplied to give the true field at the tip of the emitting submicroscopic sharp point. Now if the characteristics were changed by repeated ruptures of the cathode surface, the sharpness of such points would have been quite accidental and continued observations would have yielded a quite random variety of slopes, instead of the two distinct groups typified by curves 1 and 2, respectively. (See Fig. 1.) The only explanation seems to be that continued operation did not rupture the cathode repeatedly, but that some of the time the surface had one work function, and the rest of the time it had another.

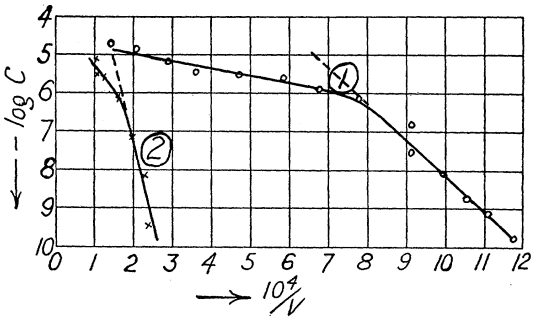

FIG. 1.

This observation leads to the conclusion that even when the best of vacuum conditions prevail, yet if electrons can readily miss the anode and strike glass, the emission is apt to be characteristic of a contaminated surface. This effect will probably explain the large discrepancies between theory and experiment found by previous observers, without the assumption of submicroscopic points impossibly small from space charge considerations. By taking particular care to keep the electrons from striking glass, we have been able to obtain characteristics near the theoretical value.

WILLARD H. BENNETT

Mendenhall Laboratory of Physics,
Ohio State University,
Columbus, Ohio,
November 1, 1933.

[1] W. H. Bennett, Phys. Rev. **40**, 416 (1932).

[2] Stern, Gossling and Fowler, Proc. Roy. Soc. **A124**, 699 (1929).