frog the assumption of homozygosity of the female is inadequate if not excluded. If we assume that the female is heterozygous for sex, and that it has the chromosome constitution $24 + x + y$ (where y may be missing), the male must have the chromosome constitution $24 + 2x$. The haploid number in the egg would be[5] $12 + x$, and the diploid number either $24 + 2x$ or $24 + x + y$. The diploid number $24 + 2x$ would give rise to a male, while a female might be produced by either the haploid number $12 + x$ or the diploid number $24 + x + y$. It is, therefore, of some interest to find out whether or not the female has the haploid number $12 + x$ chromosomes. It is useless to enter into further speculation until this point is decided, which the writer hopes may be possible in the near future.

Summary.—The author has raised twenty leopard frogs produced by the methods of artificial parthenogenesis from unfertilized eggs to the age of from ten to eighteen months. Nine of these frogs are still alive. Some have reached the size of the full grown normal adult male. Both sexes are represented among the parthenogenetic frogs. Seven of the nine older frogs whose gonads were examined were males, and two were females. The parthenogenetic males possess the diploid number of chromosomes.

[1] Loeb, J., and Bancroft, F. W., *J. Exp. Zoöl., Wistar Inst., Philadelphia,* **14,** 1913, (275); **15,** 1913, (379).

[2] Loeb, J., these PROCEEDINGS, **2,** 1916, (313); *The Organism as a Whole,* New York, 1916.

[3] Swingle, W. W., *Biol. Bull., Wood's Hole,* **33,** 1917, (70).

[4] Brachet, A., *Arch. Biol., Paris-Bruxelles,* **26,** 1911, (362).

[5] The other haploid number $12 + y$ may be left out of consideration for the present since it is possible that such eggs may not be able to develop.

THE RESOLVING POWERS OF X-RAY SPECTROMETERS AND THE TUNGSTEN X-RAY SPECTRUM

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Communicated by R. A. Millikan, February 11, 1918

This work was undertaken at the University of Iowa with the purpose of determining the wave lengths and the number of lines in the X-ray spectrum of tungsten with greater precision than had heretofore been done.

The method adopted was the well known photographic one in which the crystal is slowly rotated so that it will progressively pass through all the angular positions which are required for reflection of the incident X-rays as demanded by the formula $n\lambda = 2d \sin \theta$, in which n is the order of the spectrum, λ the wave length, d the grating constant, and θ the glancing angle of reflection.

Some of the conditions affecting the resolving power of an X-ray spectrometer, that is the ability of the instrument to separate two waves of nearly the same length may be derived by the aid of the diagram (fig. 1).

Assume a source, i.e., a slit, of width s and a crystal of thickness t and assume that the absorption in the crystal is not so great but that some of the rays may penetrate entirely through the crystal and being reflected from the planes on the lower side again traverse the crystal and finally reach the photographic plate $B'A'C'D'$. It is easily seen that there will be an image on the plate equal in width to the width of the source s, due to reflection from the upper surface alone. In addition there is a widening of the line due to the part reflected from the lower planes equal to the line DE which is drawn from P perpendicular to AA'. Then since $DF = t =$ the thickness of the crystal, $t = AD \sin \theta$ and $AD = DE/\sin 2\theta$ and by substitution $t = DE/\sin\theta = \frac{1}{2} DE/\cos\theta$. Whence $DE = 2t\cos\theta$.

Since DE is the width of beam due to penetration into the crystal the total width of beam is $s + 2t\cos\theta$ and this is the width of line on the photographic plate.

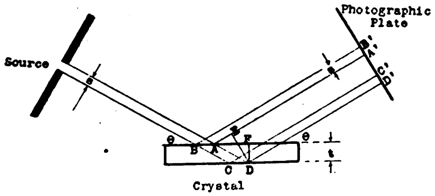

FIG. 1

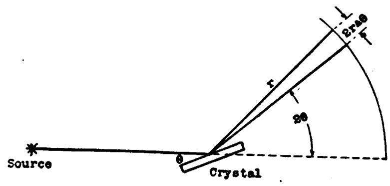

FIG. 2

In order to resolve two lines of nearly the same wave length it is necessary that their images on the photographic plate should not overlap, that is the centers of their images must be further apart than the width of beam, $s + 2t\cos\theta$.

Assume two wave lengths, λ and $\lambda + \Delta\lambda$, then to find how small $\Delta\lambda$ may be and still have the two wave lengths clearly separated on the plate: Using the formula $n\lambda = 2d\sin\theta$ let λ take on a small increment $\Delta\lambda$ and θ the corresponding increment $\Delta\theta$. Then by differentiation we obtain $n\Delta\lambda = d\cos\theta\,\Delta\theta$.

From figure 2 we see that the angle of the crystal must be changed by the amount $\Delta\theta$ in order to reflect the wave of length $\lambda + \Delta\lambda$ instead of the one of length λ and that the reflected ray being rotated through twice this amount is rotated through the angle $2\Delta\theta$. If the distance from the crystal to the plate is r then the distance the beam has moved along the plate in changing from λ to $\lambda + \Delta\lambda$ is $2r\Delta\theta$ and this distance must be greater than the width of beam, $s + 2t\cos\theta$. Thus

$$2r\Delta\theta > s + 2t\cos\theta$$

But

$$\Delta\theta = \frac{n\Delta\lambda}{2d \cos \theta}$$

Whence

$$\frac{nr\Delta\lambda}{d \cos \theta} > s + 2t \cos \theta,$$

$$\Delta\lambda > \frac{d \cos \theta}{nr} (s + 2t \cos \theta).$$

Defining, as usual, the resolving power to be $\lambda/\Delta\lambda$, we have by dividing λ by each side of the inequality

$$\frac{\lambda}{\Delta\lambda} < \frac{nr\lambda}{d \cos \theta \, (s + 2t \cos \theta)}$$

From this it is apparent that the resolving power may be increased by increasing the order of the spectrum and the distance between the crystal and the plate and also by decreasing the width of the source and the thickness of the crystal. To increase the resolving power by any of these means results in a loss of intensity which must be compensated for by an increased time of exposure. To secure the best results in any given case requires a selection by experience of the best relative values of these quantities which will depend upon the kind of crystal used and the hardness of the X-rays.

It is also apparent by an inspection of figure 1 that the true position of the line on the photographic plate is to be obtained by measuring to the outer or most deviated side of the image and then subtracting one half of the width of the source. This does not in general coincide with the position of the most intense part of the image and since the point of greatest intensity is the one obtained by an ionization chamber method the latter can never give results of the greatest accuracy.

In the experimental work the endeavor was made to obtain as high resolving power and as accurate measurements as possible. A Coolidge tube with a tungsten target was used with a rock salt crystal to obtain the results given in the table. These results are certainly accurate to within 0.1% in the case of the L radiations and 0.8% in the case of the K radiations.

By the use of a crystal of rock salt which was first waxed to glass and then ground to a thickness of 0.019 cm. the widening of the K lines due to penetration into the crystal was reduced to such an extent as to cause the doublets to be clearly separated in the spectrum of the first order and this is not possible if the thickness of the crystal is not limited.

In the case of the L group of lines the resolving power as defined by the above formula was less than 170 but nevertheless 19 separate and distinct lines were obtained and this very naturally suggests that if it were possible to obtain such resolving powers in X-ray spectroscopy as have been obtained in

The Tungsten X-ray spectrum

GLANCING ANGLE OF REFLECTION FROM ROCK SALT	WAVE LENGTH IN ÅNGSTROM UNITS	REMARKS
	Lines of the L group	
15° 16.3′	1.482^{8}	Weak
15° 9.9′	1.472^{2}	Strong
14° 34.5′	1.416^{3}	Very faint
13° 19.9′	1.297^{7}	Medium
13° 13.1′	1.286^{8}	Very faint
13° 7.7′	1.278^{4}	Strong
12° 54.4′	1.258^{6}	Medium
12° 44.6′	1.241^{6}	Strong
12° 31.3′	1.220^{2}	Very faint
12° 24.8′	1.209^{8}	Very faint
12° 4.5′	1.177^{3}	Very faint
11° 34.4′	1.129^{2}	Weak
11° 13.3′	1.095^{3}	Strong
10° 57.9′	1.070^{5}	Faint
10° 54.3′	1.064^{8}	Medium
10° 50.5′	1.058^{7}	Medium
10° 40.6′	1.042^{7}	Very faint
10° 29.8′	1.025^{3}	Medium
9° 22.0′	0.915^{9}	Bromine absorption line
7° 12.9′	0.706^{8}	Medium
4° 55.5′	0.483^{3}	Silver absorption line
	Lines of the K group	
2° 9.7′	0.212^{4}	Strong
2° 6.8′	0.207^{6}	Strong
1° 52.0′	0.183^{4}	Strong
1° 49.0′	0.178^{4}	Medium

the case of light by the aid of the grating and echelon the number of characteristic X-ray lines would be found to be as great as the number of light spectral lines are now known to be.

Many thanks are due to Professor Stewart and the Staff of the Physics Department of the University of Iowa where this work was performed for assistance in this research.