1) Book II p (56)

(1) thermal factor in f from the old calculations

(2) Resonance factor from Wigner formula

(3) f (no fast neutrons, no res. impor. in C_1)

(8) f adding the fast neutron effect

Metal spheres – Density 18-20

R	③ g_0	④ rad. of cell	⑤ V(c)	⑥ $\frac{w(U)}{w(C)}$	⑦ $\mathcal{E}(\nu=2.6)$	⑧ $g(2.6)$	⑨ $\mathcal{E}(\nu=3.6)$	⑩ $g(3.6)$	⑪ $\frac{\bar{\rho}}{\rho(R)}$ (thermal)
3 cms	0.741	11.2 cms	6,605 cm³	0.210	1.115	0.826	1.202	0.891	0.829
4	0.724	14.8	13,190	0.250	1.140	0.825	1.250	0.905	0.743
5	0.707	17.3	20,990	0.306	1.160	0.820	1.288	0.911	0.663
6	0.691	19.8	31,380	0.354	1.176	0.813	1.321	0.913	0.595
7	0.678	22.0	43,165	0.409	1.190	0.807	1.350	0.915	0.536
8	0.666	24.2	57,610	0.457	1.195	0.796	1.362	0.907	0.487

$u = 1.6$

includes surface res. old methode for thermals. $g_0 = g$ without taking into account the fast contribution or impoverishment of res. neutrons in carbon. – res. neutrons down taken in the taken: (holds for oxide)

Metal planes – density 18

t = thickness	$\frac{\bar{\rho}}{\rho(\text{surf})}$ [u = 1.63]	[u = 1.2]
2.0 cm	0.891	0.819
2.5	0.841	0.747
3.0	0.789	0.679
3.5	0.737	0.615
4.0	0.686	0.559
5.0	0.594	0.465

May 6th Sheet 1

Metal Spheres

R	① thermal factor	② resonance factor	g_0	⑫ $\frac{\bar{\rho}^*}{\rho^*(R)}$ (from Primakoff exp. on oxide)
3	0.859	0.857	0.741	0.908
4	0.849	~~0.849~~ 0.853	0.724	0.854
5	0.845	0.837	0.707	0.794
6	0.835	0828	0.691	0.736
7	0.828	0.820	0.678	0.679
8	0.818	0.813	0.666	0.632

$u^* = 2.4$

Feld – May 5th 1942

for 5 cm spheres about 4% loss minus res. abs. due to impoverishment of res. neutrons in carbon

2) Book II - p 67

do not include mass resonance absorption

neglect impoverishment in the carbon.

calculated from the simplest possible ~~fo~~ formula.

calculation of ϵ (neglecting impoverishment in the carbon) (at the ends and resonance)

R	thermal factor	× ϵ (ν=2.6)	× surface factor	u=1.63	surface factor
3	0.873	0.973	0.956	0.829	0.982
4	0.861	0.981	0.968	0.743	0.987
5	0.846	0.981	0.970	0.663	0.989
6	0.831	0.977	0.968	0.595	0.991
7	0.817	0.972	0.965	0.536	0.992
8	0.800	0.956	0.950	0.487	0.993

thermal factor ($x=1$) = 0.892

$\frac{N_c}{N_U} = 133$ in both thermal and resonance surface factor

$x = \frac{\bar{\rho}}{\rho(c)}$ [thermal]

surface factor $= e^{-\beta \frac{N_0}{N_c}}$

$\beta = \frac{8.6}{.158 \times 3.8} \times \frac{9}{18 \times 2}$

wrong ratio — Therm. × ϵ × surface f.

thermal factor

$$f(x) = \frac{x}{x + \frac{\sigma_c(\text{abs}) N_c}{\sigma_U(\text{abs}) N_U}}$$

$f(1) = 0.892$

Sheet 2

May 6th

(0.87)

0.75

3) Bach II p (68)

5/9/42

$\frac{\bar{P}}{\rho_0}$ (thermal) for different geometries

$u = 1.63$

R = half thickness (plane)	$\frac{\bar{P}}{\rho_0}$ (plane)
1.00	0.891
1.25	0.841
1.50	0.789
1.75	0.737
2.00	0.686
2.50	0.594
3.00	0.517
3.50	0.461

R (cyl)	$\frac{\bar{P}}{\rho_0}$ (cyl)
3	0.728
4	0.620
5	0.531
6	0.462

R (sphere)	$\frac{\bar{P}}{\rho_0}$ (sphere)
3	0.829
4	0.743
5	0.663
6	0.595
7	0.536
8	0.487

[illegible]

Spheres, Cylinders

4) Book II – p (69)

$$q = e^{-\frac{a\rho\rho^*}{x}} \left(\frac{1}{1 + \frac{c x}{\rho e}} \right)$$

and for a max q

$$x = \sqrt{\frac{a\nu\rho\rho^*}{c}}$$

1) neglects impoverishment in the carbon for both thermal and resonance

2) neglects surface resonance absorption

3) is not exactly on the max.

actually – we may make a better approximation

$$x_{opt} = \frac{a\rho\rho^*}{2} + \sqrt{\frac{a\nu\rho\rho^*}{c}}$$

this is put into the 3rd collumn

the value of q_{max} calculated with the better value of x_{opt} is substantially the same as that given.

Calculation of q_{max} – simple formula, neglect impoverishment in carbon

Spherical case

R	$x = \frac{N_c}{N_u}$ (optimum) 1st approx	2nd approx	$q_{max} = 1 - 2\sqrt{ac}\sqrt{\frac{\gamma^*}{\gamma}}$	$q_{max} = e^{-\sqrt{ac}\sqrt{\frac{\gamma^*}{\gamma}}}\left(\frac{1}{1+\sqrt{ac}\sqrt{\frac{\gamma^*}{\gamma}}}\right)$ (exact)
3	108.8	115.3	0.761	0.793
4	99.9	106.0	0.755	0.788
5	91.0	96.7	0.750	0.785
6	83.0	88.3	0.746	0.782
7	75.6	80.5	0.743	0.779
8	69.6	74.1	0.740	0.777

(leads to same q_{max})

$q_{max}(\gamma = \gamma^*) \cong 0.772$

$q_{max}(\gamma = \gamma^*)_{exact} = 0.801$

if $\gamma^* = \gamma = 1$

$x = 125$

R	$\gamma^* = \frac{\bar{\rho}}{\rho_0}$ (resonance)	$\gamma = \frac{\rho}{\rho_0}$ (thermal)	$\sqrt{ac}\sqrt{\frac{\gamma^*}{\gamma}}$	thermal factor ρ (exact)	resonance ρ^* (exact)	both – inexact $1 - \sqrt{ac}\sqrt{\frac{\rho^*}{\gamma}}$	$\frac{wt(U)}{wt(C)}$
3	0.909	0.829	0.1191	0.8933	0.8873	0.8805	0.182
4	0.854	0.743	0.1223	0.8902	0.8848	0.8777	0.199
5	0.794	0.663	0.1249	0.8890	0.8827	0.8751	0.218
6	0.736	0.595	0.1269	0.8874	0.8809	0.8731	0.239
7	0.679	0.536	0.1284	0.8862	0.8794	0.8716	0.262
8	0.632	0.487	0.1300	0.8850	0.8782	0.8700	0.285

5) Book II - p 71

5/21/42

ρ_{max} – spherical case – no impoverishment in the lattice for both thermal & resonance

R	thermal × resonance ρ_{max}	× surface resonance factor	× $\varepsilon(2.6)$	× $\varepsilon(3.6)$
3	0.793	0.775	0.865	0.932
4	0.788	0.774	0.883	0.968
5	0.785	0.773	0.896	0.995
6	0.782	0.771	0.906	1.018
7	0.779	0.769	0.915	1.038
8	0.777	0.767	0.917	1.045

6) Book II - p (93)

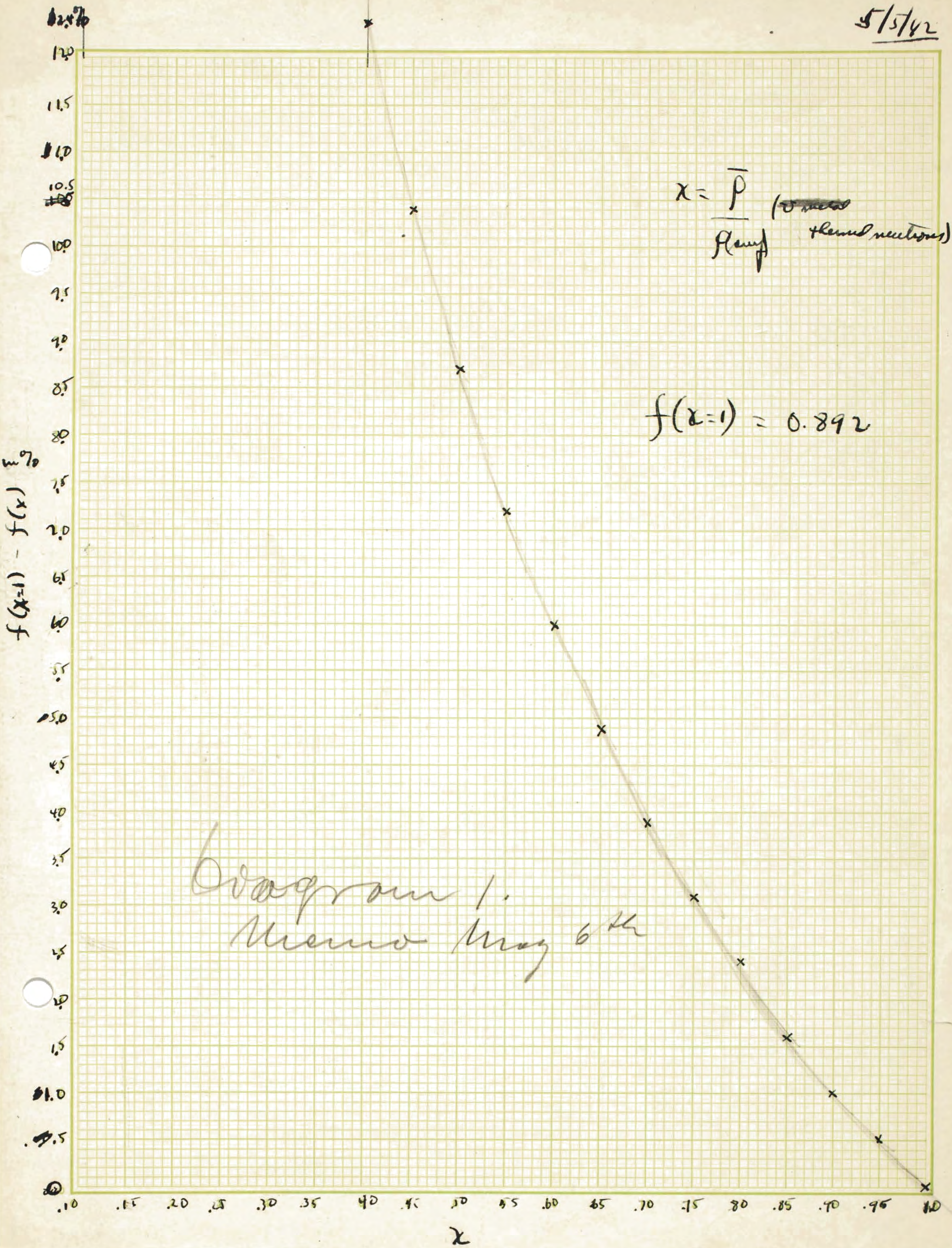
presumably the ultimate.

Old thermal values taken

Resonance factor calculated by ~~the~~ a complicated ruse designed to take into account impoverishment in the Carbon as well as in the ~~[illegible]~~ uranium — and including surface and mass absorption.

5/20/42 – q taking into account the impoverishment of both thermal and resonance neutrons in both U and carbon and also the fast neutron effect:

R cm	(thermal) $(1-p)$	(resonance) $(1-p^2)$	thermal & resonance q_0	fast $\varepsilon(\nu=2.6)$	$q_0 \times$ fast q	optimum cell size $A4$ cm
3	0.867	0.882	0.764	1.1154	0.852	11.1
4	0.862	0.877	0.754	1.1403	0.860	13.7
5	0.849	0.878	0.745	1.1598	0.864	16.2
6	0.851	0.864	0.735	1.1758	0.864	18.6
7	0.855	0.850	0.727	1.1898	0.865	20.7
8	0.843	0.856	0.722	1.1952	0.863	22.4


$x = \frac{\bar{\rho}}{\rho_{liquid}}$ (thermal neutrons)
$f(x=1) = 0.892$
Diagram 1.
Memo May 6th
$f(x=1) - f(x)$ in %
x
12.5%
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
.10
.15
.20
.25
.30
.35
.40
.45
.50
.55
.60
.65
.70
.75
.80
.85
.90
.95
1.0

Feld & Szilard

Contribution of fast fission neutrons.–

Apr. 28th 1942

$\nu = 2.6$

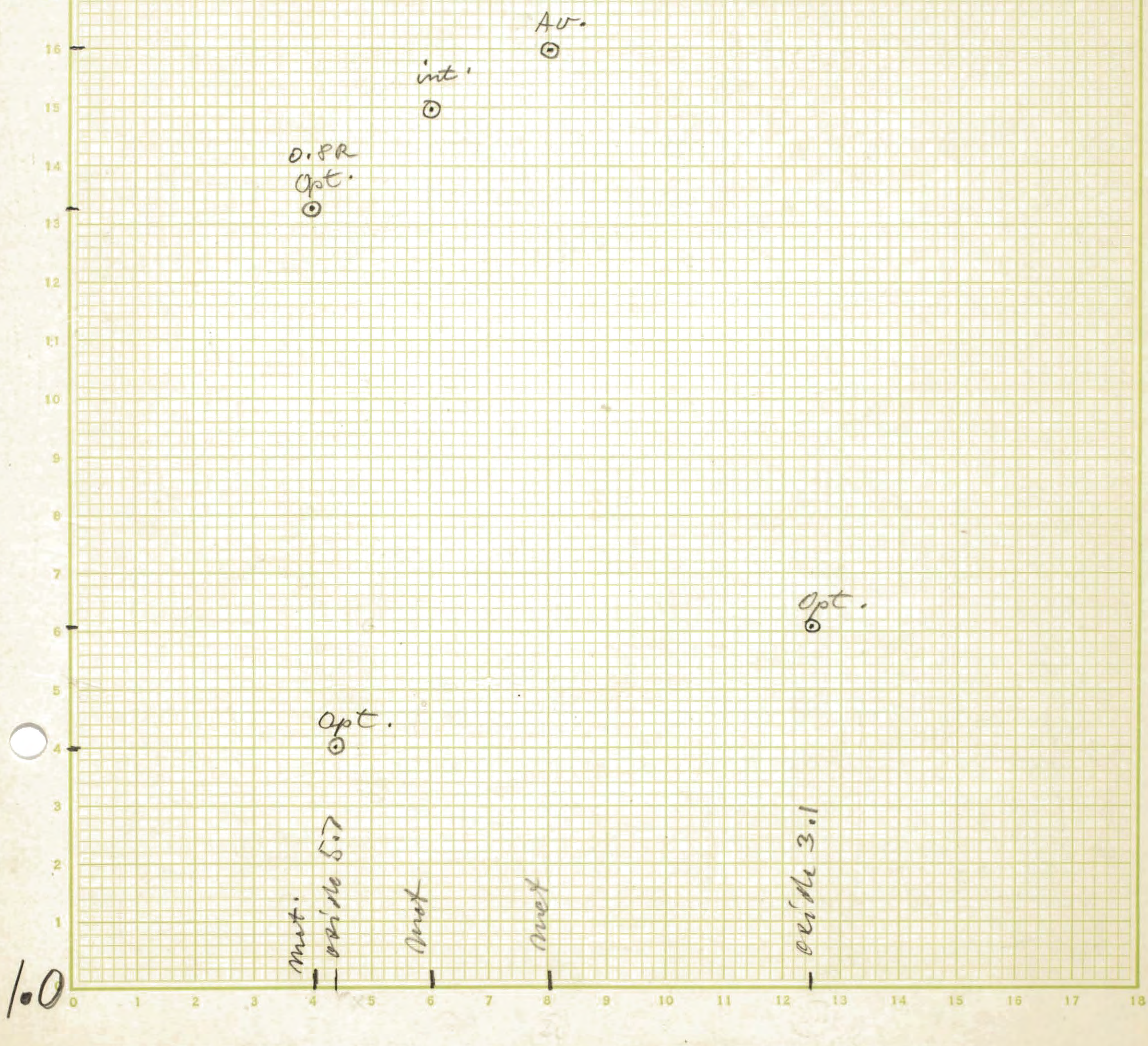


Table I

R (U sphere) cms	T(U) °K	T(C) °K	Φ	q_{max} (prim.)	q_{max} (cellular)	$\bar{V}$ (of cell) cm³
4	300	300	0.6110*	0.633	0.665	22,000
	300	3000	0.6110†	0.768	0.793	33,000
	600	1200	0.5237*	0.701Δ		25,000
	600	1800	0.5244*	0.725	0.746	28,500
5	300	300	0.5957	0.619	0.655	28,200
	600	1800	0.5663*	0.725	0.750	38,300
8	300	300	0.7232	0.621	0.675	57,000
	600	1200	0.6893	0.703	0.743	74,000

therm fact 0.80

Table II

R cm	q_{max}	V (of cell) cm³	method
4	0.746	28,500	I
	0.740	28,500	II
5	0.750	38,300	I
	0.747	38,300	II

(0.857)

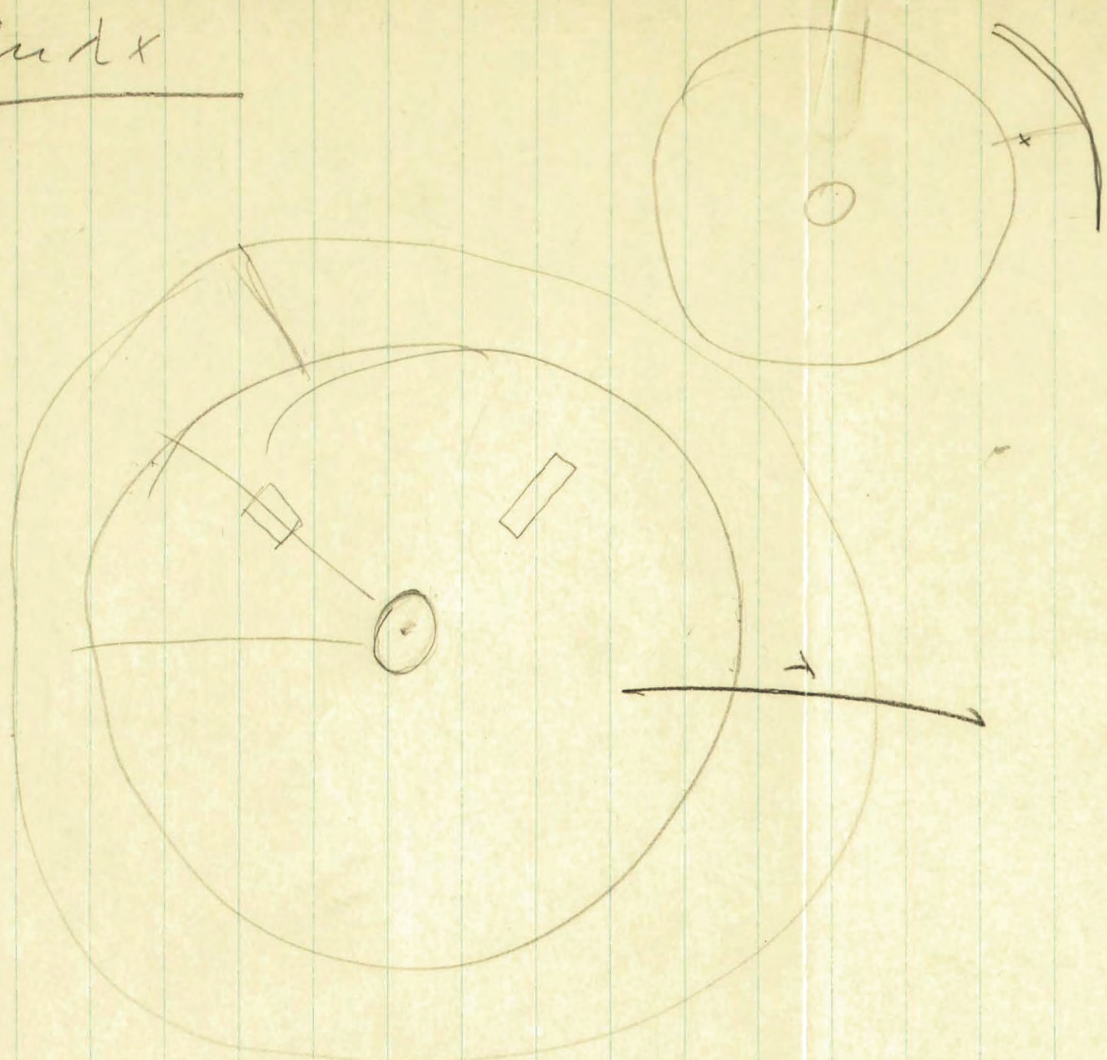
at 600 × 1800 and V = 22000 Then 0.885

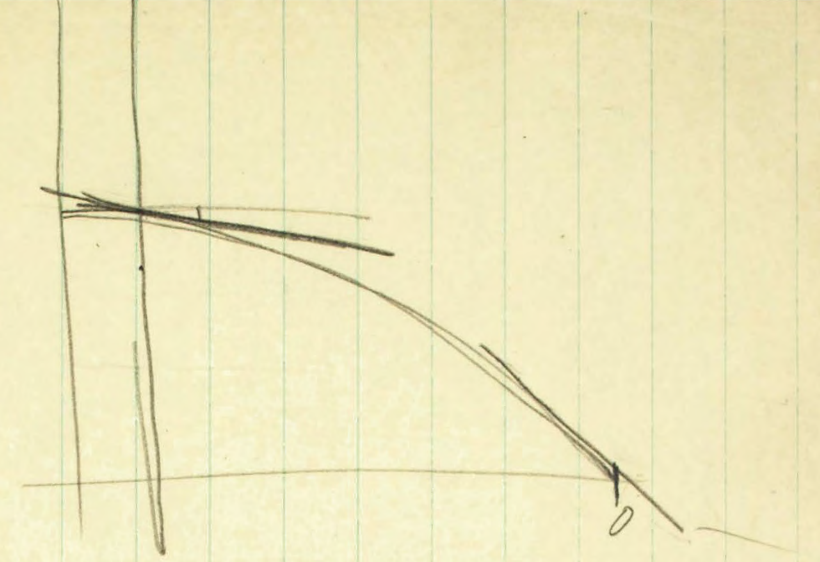
* this is the mean of the values gotten from 1) diffusion approximation (large spheres)
2) Optical " (small spheres)

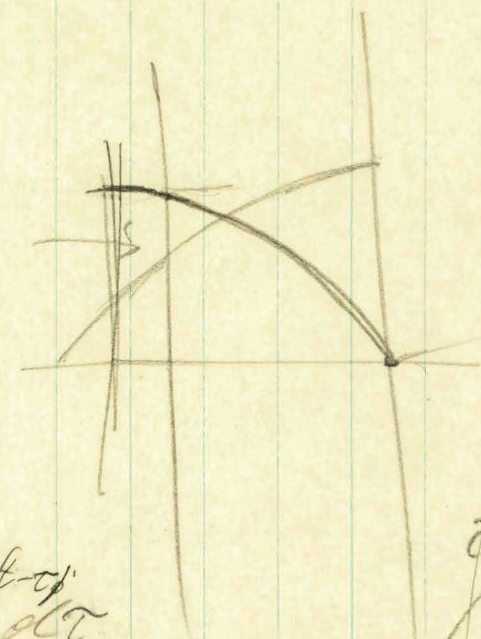
† this value was just taken arbitrarily to be the same as the room temp. case.

Δ this has only been calculated from the primitive formula.

sin λx







$$\frac{\partial \rho}{\partial t} = D \frac{\partial^2 \rho(t)}{\partial x^2} + A \rho(t) + B \int_{-\infty}^{t} \rho(\tau) e^{-a(t-\tau)} d\tau$$

$$\int_0^{\tau = t} \rho(\tau) e^{-a\tau} d\tau$$

$a' =$

$e^{-at} \frac{e}{a - a'}$

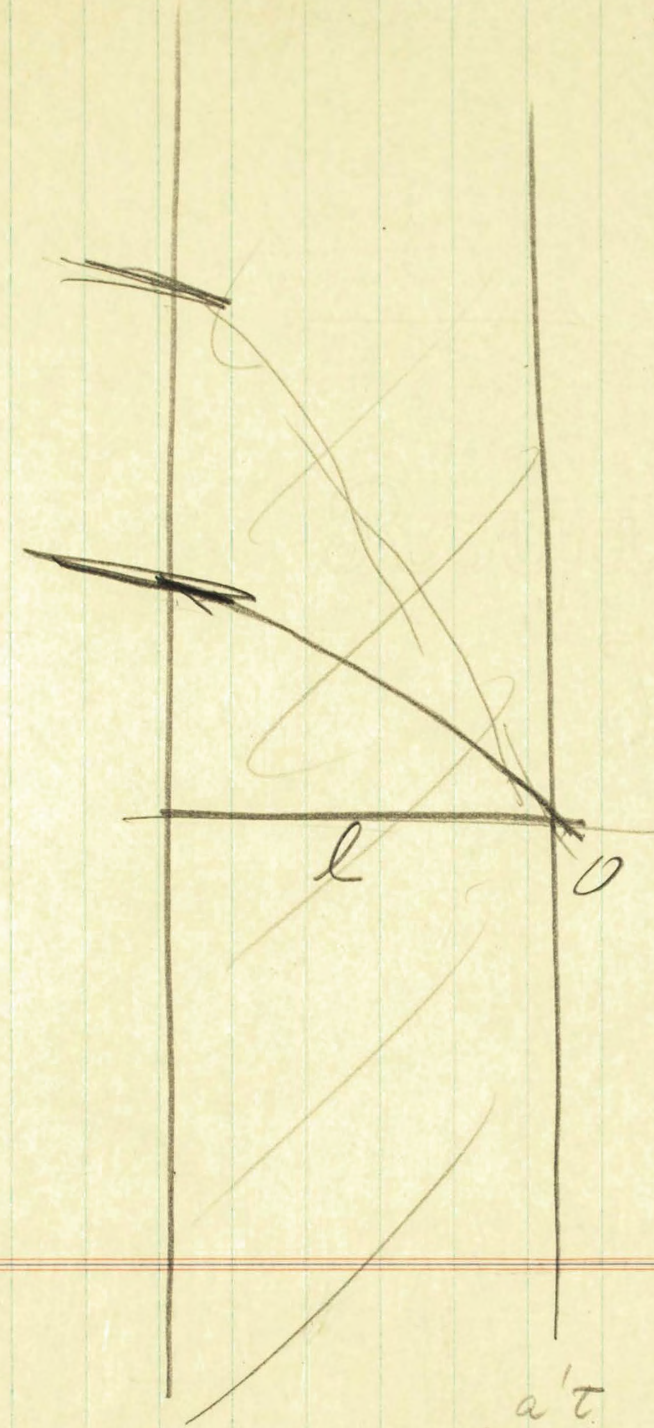
$e^{a'\tau}$ e^{-at} $e^{(a+a')\tau}$

$$\rho = e^{at} \sin \lambda x$$

$$\int_{-\infty}^{t} e^{-a\tau} \sin \lambda x \, d\tau$$

$$\frac{e^{-a\tau}}{-a} \qquad a \; \frac{e^{-at}}{-a}$$

*



$e^{a't} \; e^{-at} \; \frac{e^{at}}{a}$

$e^{a'\tau} \; e^{-at}$

$$\int_{-\infty}^{t} e^{+a\tau}\,d\tau \quad \Big| \quad \frac{e^{at}}{a}$$

$$\rho = e^{a't} \sin \lambda x$$

$$e^{a't} \lambda \cos l\lambda = h$$

$$a' = -D\lambda^2 + A + \frac{B}{a+a'}$$

$$e^{(a'-a)t} \int_{-\infty}^{t} e^{a\tau}\,d\tau = e^{(a'-a)t} \frac{e^{at}}{a}$$

$$\frac{e^{a't}}{a}$$

$$l\lambda = \frac{\pi}{2} - \xi \qquad e^{a't} \lambda \sin \xi = h$$

$$\xi = \frac{h}{\lambda} e^{-a't}$$

$$\xi = \frac{2hl}{\pi} e^{-a't}$$

$$l\lambda = \frac{\pi}{2} - \frac{2hl}{\pi} e^{-a't}$$

$$\rho = e^{a't} \sin\left(\frac{\pi}{2l} - \frac{2hl}{\pi} e^{-a't}\right) x$$

$$a' \sin + \cos . x . \frac{2hl}{\pi} e^{-a't} a'$$

$$0 = -D\lambda^2 + A$$

$2h$ $\boxed{hl^2 < e^{a't}}$

l

$$\rho > hl^2 \qquad a'' = -D\lambda^2 + A$$

$$\frac{1}{\tau_0} = A \qquad \frac{v w}{3} = D \quad \boxed{\frac{cm^2}{sec}} \quad \lambda^2 = \frac{A}{D} = \frac{1}{\tau v w} = \frac{\pi}{2l}$$

10^{-3}

a
e

$$e^{a'\tau} e^{-at} e^{a\tau} = e^{-at} \frac{e^{(a'+a)t}}{a'+a} = \frac{e^{a't}}{a+a'}$$

$$a' = -D\lambda^2 + A + \frac{B}{a+a'}$$

$$D\lambda_0^2 = A + \frac{B}{a} \qquad D\lambda^2 = \left(A + \frac{B}{a}\right)(1-\varkappa)^2$$

$$-\left(A + \frac{B}{a}\right) + 2\varkappa\left(A + \frac{B}{a}\right) + A + \frac{B}{a+a'} = a'$$

$$\frac{B}{a+a'} - \frac{B}{a} + 2\varkappa\left(A + \frac{B}{a}\right) = a'$$

$$+\frac{B}{2a} + a = 2\varkappa\left(A + \frac{B}{a}\right)$$

$$a = \frac{1}{12} \qquad A = 10^{-5}$$

$$\boxed{2\varkappa = \frac{\frac{B}{2a} + a}{A + \frac{B}{a}}}$$

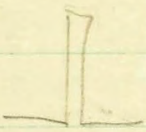
$$\frac{B}{a} = 10^{+5}\rho$$

$$A$$

$$\frac{\frac{1}{12} + 10^{+3}}{10^{5} + 10^{3}} = 10^{-2}$$

$$a' = -D\lambda^2 + \frac{B}{a+a'} \qquad (a+a')a' = B$$

$$\frac{a'}{a}\left(1 + \frac{a'}{a}\right) = \frac{B}{a^2} \qquad \frac{a'}{a} = \sqrt{\frac{B}{a^2}}$$



$$\boxed{B = \frac{\rho}{t_0} a}$$

$$\frac{10^5}{10}$$

$$\frac{a'}{a} = \sqrt{\frac{\rho a}{t_0 a^2}}$$

$$a' = \sqrt{\frac{\rho}{\tau a}}\, a$$

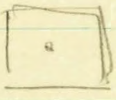
$$t \qquad B e^{-at} dt \qquad \Big| \qquad \frac{a'}{a} = \sqrt{\frac{B}{a^2}}$$

10^8

$10\ \mathrm{cm}$

10^{-8}

$10^{-1}\ \mathrm{cm}$



$$\frac{\frac{1}{12}}{300} \qquad 10^5 \cdot 10^{-2} \cdot 10^2$$

$$\frac{a'}{a} = 300$$

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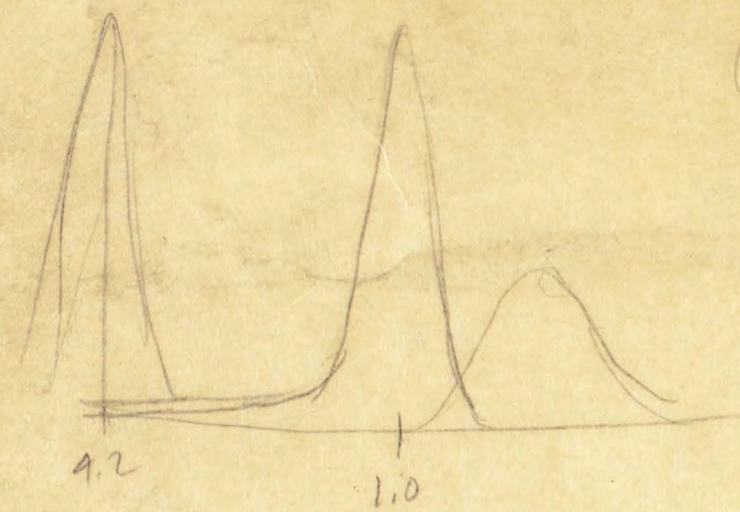

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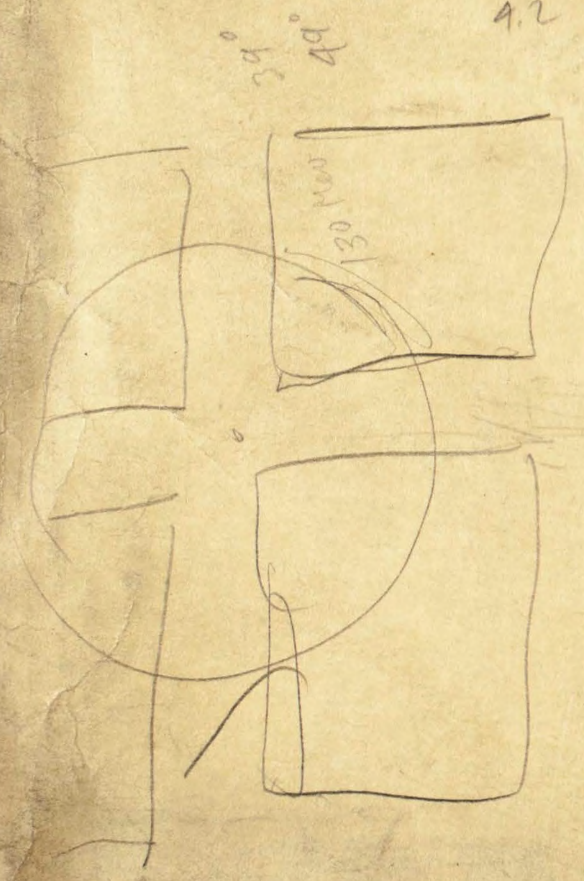

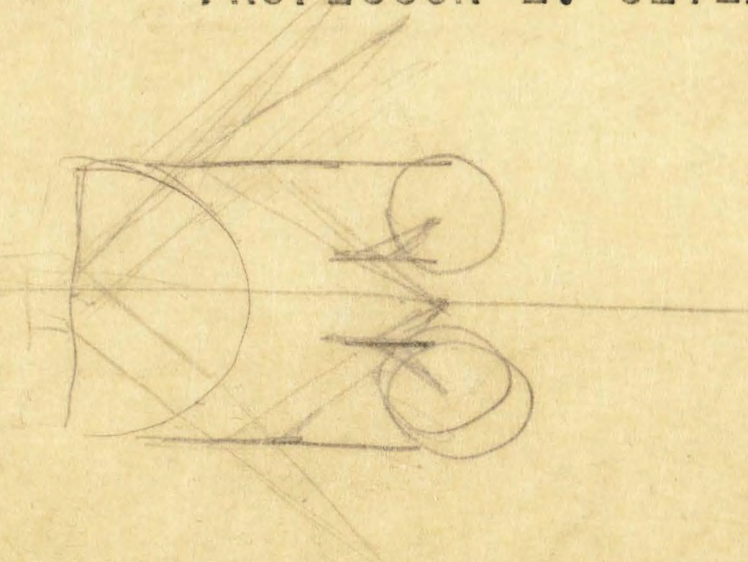

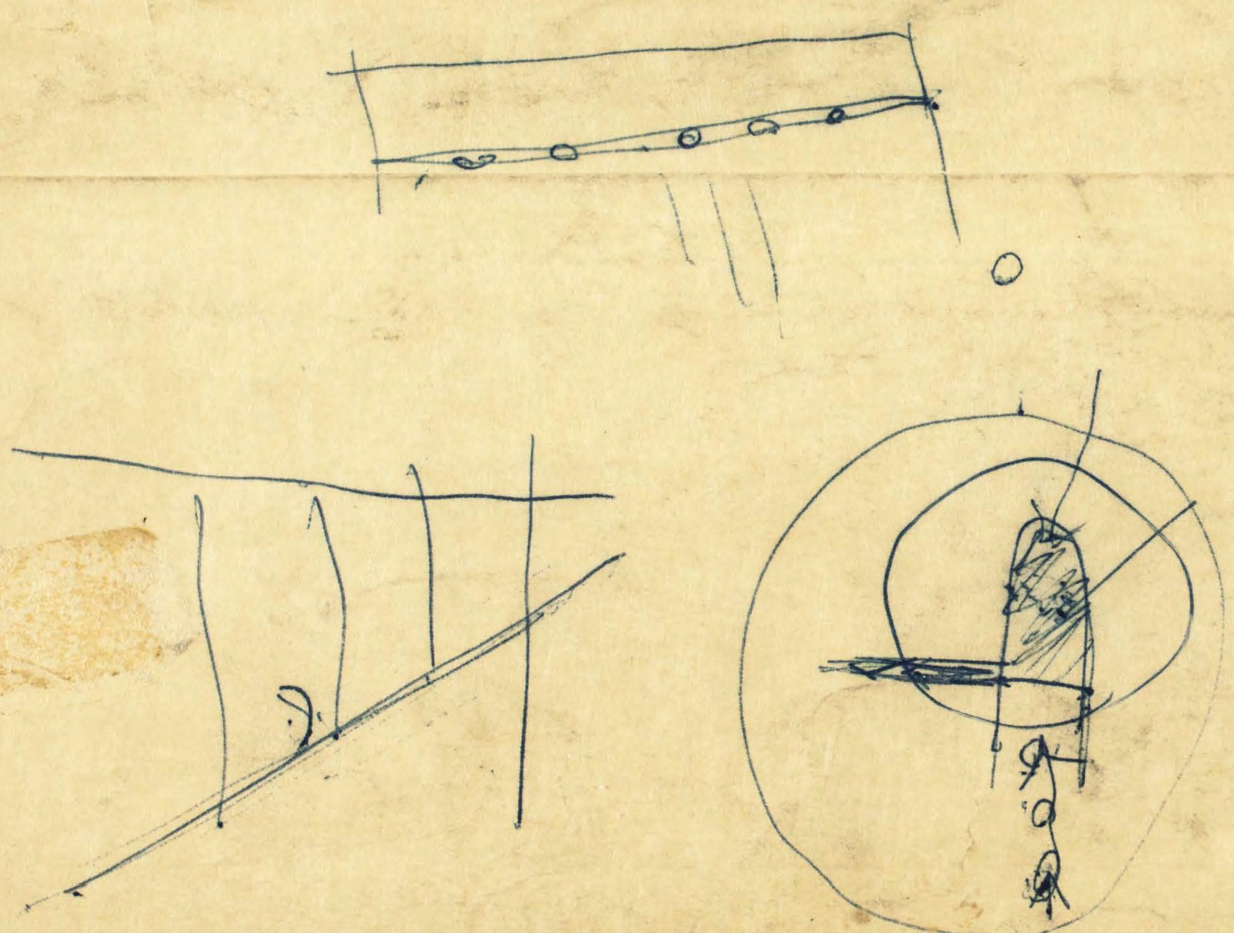

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