THE PARTICLE NATURE OF RADIATION

PLANCK'S CONSTANT, $h = 6.63 \times 10^{-34}$ J·SEC
$= 4.14 \times 10^{-15}$ eV·SEC

1. CALCULATE THE ENERGY AND THE MOMENTUM OF A PHOTON OF YELLOW, SODIUM LIGHT WHOSE WAVELENGTH IS 5890 Å (3.377×10^{-19} J = 2.11 eV, 1.126×10^{-27})

2. ULTRAVIOLET LIGHT OF WAVELENGTH 400 Å IS NEEDED TO CAUSE THE CHEMICAL REACTION WHICH PRODUCES A SUNTAN. CALCULATE THE ENERGY OF THIS TANNING PHOTON. (4.97×10^{-18} J = 31 eV)

3. KODACHROME® FILM IS COATED WITH AgBr, WHICH REQUIRES A PHOTON OF ENERGY 2.38 eV TO DECOMPOSE, i.e. TO BE "EXPOSED." EXPLAIN WHY THIS FILM CAN BE DEVELOPED IN A "DARK ROOM" ILLUMINATED WITH RED LIGHT WHOSE FREQUENCY IS 4×10^{14} Hz, BUT NOT IN A ROOM ILLUMINATED WITH GREEN LIGHT WHOSE FREQUENCY IS 6×10^{14} Hz. (1.66 vs. 2.49 eV)

4. THE VERY LOWEST POWER THAT AN EYE CAN DETECT IS 1×10^{-18} WATTS. THE EYE IS MOST SENSITIVE TO YELLOW LIGHT, WHOSE $\lambda = 5.7 \times 10^{-7}$ m. CALCULATE THE MINIMUM RATE OF PHOTONS STRIKING THE RETINA THAT WILL STIMULATE THE GRAY MATTER. ($2.9 \frac{\text{PHOTONS}}{\text{SEC}}$)

5. SOLAR RADIATION ILLUMINATES THE EARTH WITH AN INTENSITY OF 1340 WATTS/m².

a) ASSUMING A TYPICAL WAVELENGTH OF 5500 Å, CALCULATE THE RATE AT WHICH PHOTONS STRIKE MR. HARVIE'S BACK AS HE NAPS ON LA JOLLA SHORES. HIS AREA IS 1.5 m². (5.56×10^{21} PHOTONS/SEC)

b) CALCULATE THE MOMENTUM OF ONE PHOTON. (1.206×10^{-27} kg m/s)

c) CALCULATE THE FORCE EXERTED ON MR. H. IF:

1) LIGHT IS TOTALLY ABSORBED. (6.7×10^{-6} N)

2) LIGHT IS TOTALLY REFLECTED. (1.34×10^{-5} N)

HINT: $\Delta P/\Delta t = \Sigma F$

6. SOLAR RADIATION AT 1340 WATTS/m^2 IS USED AT 1.5% EFFICIENCY BY A LEAF WHOSE AREA IS 18 cm^2. THE NET EQUATION FOR PHOTOSYNTHESIS IS:

$$48 \text{ PHOTONS} + 6\,CO_2 + 6\,H_2O \longrightarrow 6\,O_2 + C_6H_{12}O_6$$

WHERE THE PHOTONS HAVE AN AVERAGE WAVELENGTH OF 690 nm. CALCULATE THE TIME FOR THE LEAF TO PRODUCE 12 g, THAT IS, ONE TEASPOON, OF GLUCOSE. THE MOLECULAR WEIGHT OF GLUCOSE IS 180 g/mole. (4260 HRS)

7. A BLUE STAR EMITS BLACKBODY RADIATION OF FREQUENCY 6.5×10^{14} Hz.

a) CALCULATE THE λ OF THIS LIGHT. (4.62×10^{-7} m)

b) WEIN'S LAW STATES THAT A RADIATOR OF TEMPERATURE T WILL EMIT MOST OF ITS ELECTROMAGNETIC RADIATION WITH A WAVELENGTH OF λ WHERE:

$$\lambda T = 2.9 \times 10^{-3} \text{ m K}$$

CALCULATE THE TEMPERATURE OF THE STAR. (6277 K)

8. T.V. SETS ACCELERATE ELECTRONS THROUGH 30,000 V, AFTER WHICH THEY STRIKE THE SCREEN. LOSING THEIR ENERGY, THE ELECTRONS EMIT PHOTONS. COULD THE T.V. EMIT X-RAYS, WHOSE MINIMUM FREQ. IS 3×10^{17} Hz?

(YES, OF $f = 7.24 \times 10^{18}$ Hz)

Photoelectric Effect

1. Ultraviolet radiation of wavelength 200 nm impinges on a piece of tungsten, whose work function is 4.52 eV. Calculate the maximum kinetic energy of the photoelectrons which are ejected. (1.68 eV)

2. Light of wavelength 420 nm shines on a thin, metal surface. The ejected photoelectrons have K.E. equal to .62 eV. Calculate the work function. (2.33 eV)

3. Find the threshold wavelength for a tungsten surface whose work function is 4.52 eV. (274 nm)

4. As the wavelength of light striking a metal surface is gradually decreased, emission of photoelectrons starts when $\lambda = 500$ nm. Find the maximum kinetic energy of the emitted photoelectrons when $\lambda = 400$ nm. (.62 eV)

$h = 4.14 \times 10^{-15}$ eV · sec

KE electron = hf photon $- \phi$

Bohr Model of the Hydrogen Atom

1. Astronomers analyze red-shifts in stars as a way of measuring the speed of these celestial bodies. They are observing the spectral line of hydrogen produced by an electron dropping from the third to the second energy level. Calculate the wavelength of the emitted photon. (6563 Å = 656.3 nm)
2. Calculate the frequency of the most energetic photon that can be emitted as an electron falls into a hydrogen atom. (3.289×10^{15} Hz)
3. The ionization energy of the innermost electron in hydrogen is 13.60 eV. Calculate the ionization energy for the last electron torn off a $^{133}_{55}Cs$ atom. (41.14 keV)
4. A free electron falls toward a bare nucleus and emits a 500 Å photon as it reaches the M-shell. Find the wavelength of the emitted photon if it had fallen to the L-shell. (222 Å)

Matter Waves

1. Calculate the de Broglie wavelength of a 20g Ping Pong ball whose speed is 400 cm/s. (8.29×10^{-33} m)

2. A beam of electrons is accelerated through a potential difference of 50 kV.

a) Calculate their speed. (1.325×10^{8} m/s)

b) Calculate their de Broglie wavelength. (5.5×10^{-12} m)

Recall for electrons: $m = 9.11 \times 10^{-31}$ kg

$q = 1.6 \times 10^{-19}$ C

3. A proton scanning microscope uses protons accelerated through 55 kV. Calculate the theoretical limit of its resolution. (1.22×10^{-13} m)

Recall for protons: $m = 1.67 \times 10^{-27}$ kg

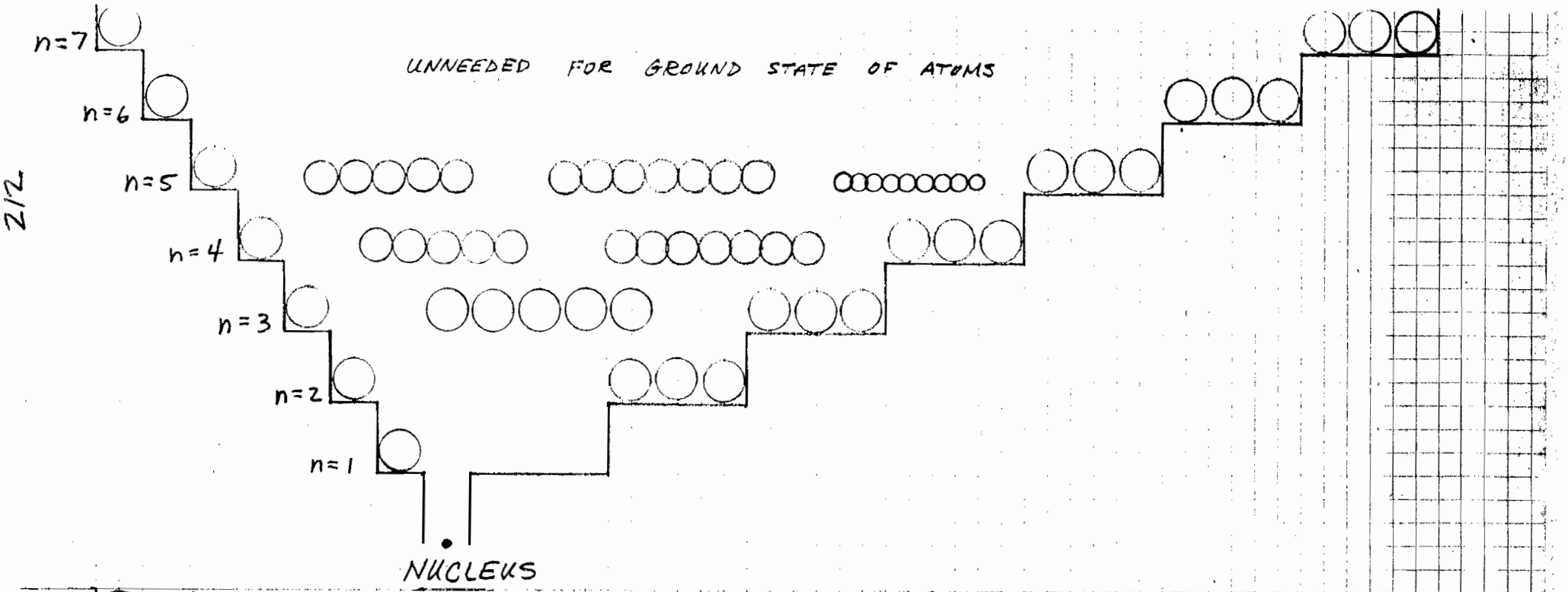
$q = 1.6 \times 10^{-19}$ C

ELECTRON ARRANGEMENT OF THE ELEMENTS

	Shells	K	L		M			N				O				P				Q
	Sublevels	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	6f	7s
1	hydrogen	1																		
2	helium	2																		
3	lithium	2	1																	
4	beryllium	2	2																	
5	boron	2	2	1																
6	carbon	2	2	2																
7	nitrogen	2	2	3																
8	oxygen	2	2	4																
9	fluorine	2	2	5																
10	neon	2	2	6																
11	sodium	2	2	6	1															
12	magnesium	2	2	6	2															
13	aluminum	2	2	6	2	1														
14	silicon	2	2	6	2	2														
15	phosphorus	2	2	6	2	3														
16	sulfur	2	2	6	2	4														
17	chlorine	2	2	6	2	5														
18	argon	2	2	6	2	6														
19	potassium	2	2	6	2	6		1												
20	calcium	2	2	6	2	6		2												
21	scandium	2	2	6	2	6	1	2												
22	titanium	2	2	6	2	6	2	2												
23	vanadium	2	2	6	2	6	3	2												
24	chromium	2	2	6	2	6	5	1												
25	manganese	2	2	6	2	6	5	2												
26	iron	2	2	6	2	6	6	2												
27	cobalt	2	2	6	2	6	7	2												
28	nickel	2	2	6	2	6	8	2												
29	copper	2	2	6	2	6	10	1												
30	zinc	2	2	6	2	6	10	2												
31	gallium	2	2	6	2	6	10	2	1											
32	germanium	2	2	6	2	6	10	2	2											
33	arsenic	2	2	6	2	6	10	2	3											
34	selenium	2	2	6	2	6	10	2	4											
35	bromine	2	2	6	2	6	10	2	5											
36	krypton	2	2	6	2	6	10	2	6											
37	rubidium	2	2	6	2	6	10	2	6			1								
38	strontium	2	2	6	2	6	10	2	6			2								
39	yttrium	2	2	6	2	6	10	2	6	1		2								
40	zirconium	2	2	6	2	6	10	2	6	2		2								
41	niobium	2	2	6	2	6	10	2	6	4		1								
42	molybdenum	2	2	6	2	6	10	2	6	5		1								
43	technetium	2	2	6	2	6	10	2	6	5		2								
44	ruthenium	2	2	6	2	6	10	2	6	7		1								
45	rhodium	2	2	6	2	6	10	2	6	8		1								
46	palladium	2	2	6	2	6	10	2	6	10										
47	silver	2	2	6	2	6	10	2	6	10		1								
48	cadmium	2	2	6	2	6	10	2	6	10		2								
49	indium	2	2	6	2	6	10	2	6	10		2	1							
50	tin	2	2	6	2	6	10	2	6	10		2	2							
51	antimony	2	2	6	2	6	10	2	6	10		2	3							
52	tellurium	2	2	6	2	6	10	2	6	10		2	4							

ELECTRON ARRANGEMENT OF THE ELEMENTS (cont'd)

	Shells	K	L		M			N				O				P				Q
	Sublevels	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	6f	7s
53	iodine	2	2	6	2	6	10	2	6	10		2	5							
54	xenon	2	2	6	2	6	10	2	6	10		2	6							
55	cesium	2	2	6	2	6	10	2	6	10		2	6			1				
56	barium	2	2	6	2	6	10	2	6	10		2	6			2				
57	lanthanum	2	2	6	2	6	10	2	6	10		2	6	1		2				
58	cerium	2	2	6	2	6	10	2	6	10	1	2	6	1		2				
59	praseodymium	2	2	6	2	6	10	2	6	10	3	2	6			2				
60	neodymium	2	2	6	2	6	10	2	6	10	4	2	6			2				
61	promethium	2	2	6	2	6	10	2	6	10	5	2	6			2				
62	samarium	2	2	6	2	6	10	2	6	10	6	2	6			2				
63	europium	2	2	6	2	6	10	2	6	10	7	2	6			2				
64	gadolinium	2	2	6	2	6	10	2	6	10	7	2	6	1		2				
65	terbium	2	2	6	2	6	10	2	6	10	9	2	6			2				
66	dysprosium	2	2	6	2	6	10	2	6	10	10	2	6			2				
67	holmium	2	2	6	2	6	10	2	6	10	11	2	6			2				
68	erbium	2	2	6	2	6	10	2	6	10	12	2	6			2				
69	thulium	2	2	6	2	6	10	2	6	10	13	2	6			2				
70	ytterbium	2	2	6	2	6	10	2	6	10	14	2	6			2				
71	lutetium	2	2	6	2	6	10	2	6	10	14	2	6	1		2				
72	hafnium	2	2	6	2	6	10	2	6	10	14	2	6	2		2				
73	tantalum	2	2	6	2	6	10	2	6	10	14	2	6	3		2				
74	tungsten	2	2	6	2	6	10	2	6	10	14	2	6	4		2				
75	rhenium	2	2	6	2	6	10	2	6	10	14	2	6	5		2				
76	osmium	2	2	6	2	6	10	2	6	10	14	2	6	6		2				
77	iridium	2	2	6	2	6	10	2	6	10	14	2	6	7		2				
78	platinum	2	2	6	2	6	10	2	6	10	14	2	6	9		1				
79	gold	2	2	6	2	6	10	2	6	10	14	2	6	10		1				
80	mercury	2	2	6	2	6	10	2	6	10	14	2	6	10		2				
81	thallium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	1			
82	lead	2	2	6	2	6	10	2	6	10	14	2	6	10		2	2			
83	bismuth	2	2	6	2	6	10	2	6	10	14	2	6	10		2	3			
84	polonium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	4			
85	astatine	2	2	6	2	6	10	2	6	10	14	2	6	10		2	5			
86	radon	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			
87	francium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			1
88	radium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			2
89	actinium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	1		2
90	thorium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	2		2
91	protactinium	2	2	6	2	6	10	2	6	10	14	2	6	10	2	2	6	1		2
92	uranium	2	2	6	2	6	10	2	6	10	14	2	6	10	3	2	6	1		2
93	neptunium	2	2	6	2	6	10	2	6	10	14	2	6	10	4	2	6	1		2
94	plutonium	2	2	6	2	6	10	2	6	10	14	2	6	10	6	2	6			2
95	americium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6			2
96	curium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	1		2
97	berkelium	2	2	6	2	6	10	2	6	10	14	2	6	10	8	2	6	1		2
98	californium	2	2	6	2	6	10	2	6	10	14	2	6	10	10	2	6			2
99	einsteinium	2	2	6	2	6	10	2	6	10	14	2	6	10	11	2	6			2
100	fermium	2	2	6	2	6	10	2	6	10	14	2	6	10	12	2	6			2
101	mendelevium	2	2	6	2	6	10	2	6	10	14	2	6	10	13	2	6			2
102	nobelium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6			2
103	lawrencium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	1		2
104	unnilquadium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	2		2?
105	unnilpentium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	3		2?
106	unnilhexium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	4		2?
107	unnilseptium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	5		2?


UNNEEDED FOR GROUND STATE OF ATOMS
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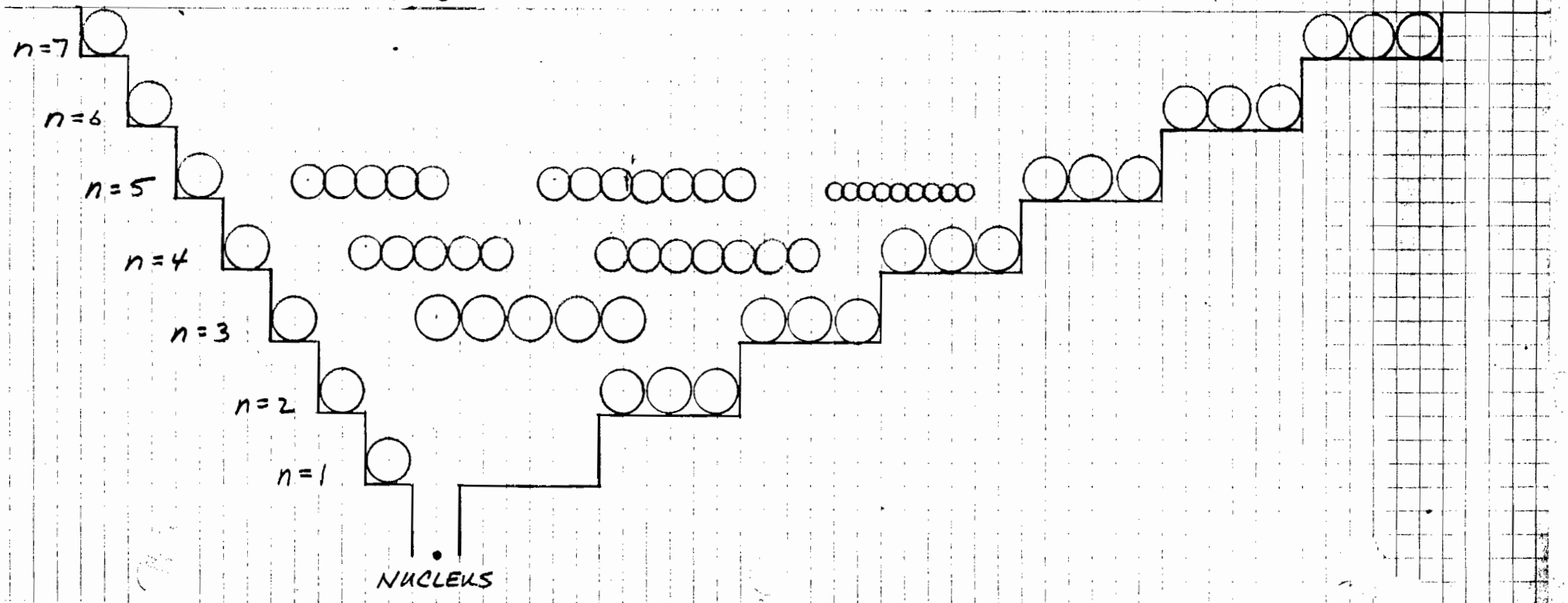
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