

Physics Formula Sheet

Your Name

2023/ 2024

Constants

Constant	Symbol	Value
Speed of light	c	3.00×10^8 m/s
Gravitational constant	G	6.674×10^{-11} N(m/kg) ²
Planck's constant	h	6.626×10^{-34} J.s
Mass of the electron	m_e	9.10939×10^{-31} kg
Mass of the proton	m_p	1.67262×10^{-27} kg
Charge of the electron	$-e$	-1.60218×10^{-19} C
Permittivity of free space	ϵ_0	8.85419×10^{-12} C ² /J m
Boltzmann constant	k_B	1.38066×10^{-23} J/ K
Avogadro's constant	N_A	6.022×10^{23} 1/mol

Classical Physics

Title	Equation
Bragg's Reflection	$n\lambda = 2d \sin(\theta)$
Diffraction (Single Slit)	$\lambda = d \sin(\theta)$
Young's Double Slit	$\frac{\Delta x}{L} = \frac{\lambda}{d} \approx \sin \theta$
Heat Transfer (Fourier's Law)	$\dot{Q} = mC_v \Delta T$
Continuity Equation	$\nabla \cdot \mathbf{J} = -\frac{dq}{dt}$
Force of Gravity	$F = G \frac{m_1 m_2}{r^2}$
Coulomb Force	$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$
Special Relativity (Time Dilation)	$E^2 = (pc)^2 + (m_0 c^2)^2$

Nuclear and magnetic physics

Magnetic Field	$: E_B = -\mu B,$ $\mu = \frac{e\hbar}{2m} L$ $F_z = -\frac{\partial V}{\partial z} = \mu \frac{\partial B}{\partial z}$
Rigid rotator	$: E_{\text{rot}} = \frac{L^2}{2I}$ $I = \frac{m_1 m_2}{m_1 + m_2} R^2$
Radioactive decay	$N(t) = N(0) \exp^{-\lambda t} = N(0) (\frac{1}{2})^{t/\tau_{1/2}}$ $\tau_{1/2} = \ln(2)/\lambda$

Thermodynamics

Black body:

Insert or link to a detailed periodic table here. $D(k)dk = \frac{\partial N(k)}{\partial k} \frac{dk}{V} = \frac{k^2}{\pi^2} dk$

$D(\omega)d\omega = \frac{\omega^2}{\pi^2 c^3} d\omega$

$u(\omega)d\omega = \frac{\omega^2}{\pi^2 c^3} k_B T d\omega$ classical limit

$u(\omega)d\omega = \frac{\hbar \omega^3}{\pi^2 c^3} \frac{1}{\exp(\frac{\hbar \omega}{k_B T}) - 1} d\omega$

$I(\omega) = cu(\omega)d\omega$

Quantum Mechanics

Time-dependent Schrodinger's Equation : $i\hbar \frac{\partial}{\partial t} \Psi(\vec{r}, t) = [-\frac{\hbar^2}{2m}(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}) + V(x)]$

Energy of a photon : $E = hf$

Time-independent Schrodinger's Equation : $E\phi = \hat{H}\phi = \left(-\frac{\hbar^2}{2m}\nabla^2 + V(x)\right) \cdot \phi$

Energy of a photon : $E = hf$

Infinite potential well : $E_n = \frac{\hbar^2}{2m} k_n^2 = \frac{\hbar^2 \pi^2 n^2}{2mL^2} = n^2 E_0, \psi_n(x) = \sqrt{\frac{2}{L}} \sin(\frac{n\pi x}{L}), E_0 = \frac{\hbar^2 \pi^2}{2mL^2}$

Transmission through a barrier : $T = \frac{4E(V_0 - E)}{4E(V_0 - E) + V_0^2 \sinh^2[\sqrt{2m(V_0 - E)}\frac{L}{\hbar}]}$

$T \approx \frac{16E(V_0 - E)}{V_0^2} e^{-2\rho_2 L}, \text{ with } \rho_2 = \sqrt{\frac{2m(V_0 - E)}{\hbar^2}}, \rho_2 \cdot L \gg 1$

De Broglie wavelength : $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

Photoelectric effect : $h\nu - \phi_0 = \frac{1}{2}mv^2 = eV$

Bohr-Sommerfeldt condition : $\oint_C \mathbf{p} \cdot d\mathbf{s} = nh, 2\pi r = nh$ (circular orbit)

Probability current : $j = \frac{\hbar}{2mi}(\psi^* \frac{\partial \Psi}{\partial x} - \Psi \frac{\partial \Psi^*}{\partial x})$

Compton scattering : $\lambda_2 - \lambda_1 = \frac{h}{m_0 c}(1 - \cos \theta)$

$\mathbf{p}_{h\nu 1} = \mathbf{p}_{h\nu 2} + \mathbf{p}_e$

$h\nu_1 + m_0 c^2 = h\nu_2 + \sqrt{m_0^2 c^4 + p_e^2 c^2}$

Mathematical equations

Trigonometric functions:

$$\int \sin^n ax dx = -\frac{1}{a} \cos ax \, {}_2F_1\left[\frac{1}{2}, \frac{1-n}{2}, \frac{3}{2}, \cos^2 ax\right]$$

$$\int \sin^2 ax dx = \frac{x}{2} - \frac{1}{4a} \sin 2ax + C$$

$$\int x \sin^2 ax dx = \frac{x^2}{4} - \frac{x}{4a} \sin 2ax - \frac{1}{8a^2} \cos 2ax + C$$

$$\int x^2 \sin^2 ax dx = \frac{x^3}{6} - \left(\frac{x^2}{4a} - \frac{1}{8a^3}\right) \sin 2ax - \frac{x}{4a^2} \cos 2ax + C$$

$$\int \tan ax dx = -\frac{1}{a} \ln |\cos ax| + C = \frac{1}{a} \ln |\sec ax| + C$$

$$\int \frac{\cos ax}{x} dx = \ln |ax| + \sum_1^{\infty} (-)^k \frac{(ax)^{2k}}{2k(2k)!} + C$$

$$\int \cos^2 ax dx = \frac{x}{2} + \frac{1}{4a} \sin 2ax + C$$

$$\int \sin^3 ax dx = \frac{\cos 3ax}{12a} - \frac{3 \cos ax}{4a} + C$$

$$\int \tan^2 x dx = \tan x - x + C$$

$$\int \sin ax \cos ax dx = -\frac{\cos^2 ax}{2a} + C$$

$$\int x \cos ax dx = \frac{\cos ax}{a^2} + \frac{x \sin ax}{a} + C$$

$$\int \cos ax dx = \frac{1}{a} \sin ax + C$$

$$\int x \sin ax dx = \frac{\sin ax}{a^2} - \frac{x \cos ax}{a} + C$$

$$\int (\sin ax)(\cos^n ax) dx = -\frac{1}{a(n+1)} \cos^{n+1} ax + C$$

Exponential functions:

$$\int_{-\infty}^{\infty} e^{-ax^2} dx = \frac{\sqrt{\pi}}{a} \quad (a > 0)$$

$$\int_{-\infty}^{\infty} x e^{-ax^2+bx} dx = \frac{\sqrt{\pi} b}{2a^{3/2}} e^{\frac{b^2}{4a}} \quad (\Re(a) > 0)$$

$$\int_{-\infty}^{\infty} x^n e^{-ax} dx = \begin{cases} \frac{\Gamma(n+1)}{a^{n+1}} & (n > -1, a > 0) \\ \frac{n!}{a^{n+1}} & (n = 0, 1, 2, \dots, a > 0) \end{cases}$$

$$\int_{-\infty}^{\infty} x^2 e^{-ax^2} dx = \frac{1}{2} \sqrt{\frac{\pi}{a^3}} \quad (a > 0)$$

$$\int x e^{cx} dx = \left(\frac{x}{c} - \frac{1}{c^2}\right) e^{cx}$$

$$\int x^2 e^{cx} dx = \left(\frac{x^2}{c} - \frac{2x}{c^2} + \frac{2}{c^3}\right) e^{cx}$$

$$\int x^4 e^{-ax^2} dx = \sqrt{\frac{\pi}{a}} \frac{3}{4a^2}$$

Spherical coordinates

$$\begin{aligned} x &= r \sin \theta \cos \phi \\ y &= r \sin \theta \sin \phi \\ z &= r \cos \theta \end{aligned}$$

Volume fraction:

$$dV = r^2 \sin \theta dr d\theta d\phi$$

Solid angle:

$$d\Omega = \frac{dS_r}{r^2} = \sin \theta d\theta d\phi$$

Surface element:

$$dS_r = r^2 \sin \theta d\theta d\phi$$

$$\nabla f = \frac{\partial f}{\partial r} \hat{r} + \frac{1}{r} \frac{1}{\sin \theta} \frac{\partial f}{\partial \phi} \hat{\phi}$$

$$\operatorname{div} \mathbf{F} = \nabla \cdot \mathbf{F} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 F_r) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (\sin \theta F_\theta) + \frac{1}{r \sin \theta} \frac{\partial F_\phi}{\partial \phi}.$$

$$\begin{aligned} \nabla \times \mathbf{F} &= \frac{1}{r \sin \theta} \left(\frac{\partial}{\partial \theta} (A_\phi \sin \theta) - \frac{\partial A_\theta}{\partial \phi} \right) \hat{r} \\ &\quad + \frac{1}{r} \left(\frac{1}{\sin \theta} \frac{\partial A_r}{\partial \phi} - \frac{\partial}{\partial r} (r A_\phi) \right) \hat{\theta} \\ &\quad + \frac{1}{r} \left(\frac{\partial}{\partial r} (r A_\theta) - \frac{\partial A_r}{\partial \theta} \right) \hat{\phi} \end{aligned}$$

$$\begin{aligned} \nabla^2 f &= \frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial f}{\partial r} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 f}{\partial \phi^2} = \\ &= \left(\frac{\partial^2}{\partial r^2} + \frac{2}{r} \frac{\partial}{\partial r} \right) f + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial}{\partial \theta} \right) f + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2}{\partial \phi^2} f \end{aligned}$$

Harmonic oscillator:

First four harmonic oscillator wavefunction	Hermite polynomials	E _n
$\psi_0(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} e^{-\frac{1}{2}\xi^2}$	1	$\frac{1}{2}\hbar\omega$
$\psi_1(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \sqrt{2}\xi e^{-\frac{1}{2}\xi^2}$	2y	$\frac{3}{2}\hbar\omega$
$\psi_2(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \frac{1}{\sqrt{2}} (2\xi^2 - 1) e^{-\frac{1}{2}\xi^2}$	4y ² - 2	$\frac{5}{2}\hbar\omega$
$\psi_3(\xi) = \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} \frac{1}{\sqrt{3}} (2\xi^3 - 3\xi) e^{-\frac{1}{2}\xi^2}$	8y ³ - 12y	$\frac{7}{2}\hbar\omega$
Harmonic oscillator	$\psi_n(x) = \frac{1}{\sqrt{2^n n!}} \left(\frac{m\omega}{\pi\hbar}\right)^{\frac{1}{4}} (a^\dagger)^n e^{-\frac{1}{2}\frac{m\omega}{\hbar}x^2} \psi_0(x)$	
Raising operator	$a^\dagger = \frac{1}{\sqrt{2\hbar m\omega}} (m\omega x - ip)$	
Lowering operator	$a = \frac{1}{\sqrt{2\hbar m\omega}} (m\omega x + ip)$	
$a^\dagger n\rangle = \sqrt{n+1} n+1\rangle$	$a n\rangle = \sqrt{n} n-1\rangle$	
Number operator	$\hat{N} = a^\dagger a, \hat{N} n\rangle = n n\rangle$	
Commutation relation	$[a, a^\dagger] = aa^\dagger - a^\dagger a = 1$	
Hamiltonian	$\hat{H} = \hbar\omega \left(\hat{N} + \frac{1}{2} \right)$	

Inner product and expectation

Expectation value (discrete)

$\langle f_i \rangle = \sum_i P_i f_i$

Expectation value (continuous)

$\langle f(x) \rangle = \int_{-\infty}^{\infty} f(x) P(x) \, dx$

$\langle \hat{O} \rangle = \int \psi^*(\mathbf{r}) \hat{O} \psi(\mathbf{r}) \, d^3r$

Inner product

$\langle \psi | \phi \rangle = \int \psi^*(x) \phi(x) \, dx$

Variance

$\sigma_f^2 = \langle f^2 \rangle - \langle f \rangle^2$

Commutation relations

$[A, B] = AB - BA$
 $[AB, C] = A[B, C] + [A, C]B$
 $[x, p_x] = i\hbar$
 $[y, p_y] = i\hbar$
 $[x, y] = [x, p_y] = [y, p_x] = 0$

Hydrogen atom

Fine structure constant:

$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} \approx \frac{1}{137}$

Bohr radius:

$a_0 = \frac{\hbar}{m_e c \alpha} \approx 0.529 \times 10^{-10} \text{m}$

Bohr energy:

$E_n = -\frac{2\pi^2 k^2 e^4 m_e}{\hbar^2 n^2}$

Ground state energy:

$E_1 = -13.6 \text{eV}$

Wave function:

$\psi_{n\ell m}(r, \theta, \phi) = R_{n\ell}(r) Y_{\ell m}(\theta, \phi)$

Rydberg formula:

$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$

Rydberg constant:

$R_H \approx 1.097 \times 10^7 \text{m}^{-1}$

Radial wavefunctions:

$R_{n\ell}(r) = N_{n\ell} r^\ell e^{-\rho/2} L_{n-\ell-1}^{2\ell+1}(\rho)$

Legendre polynomials

Angular momentum

$L_+ = L_x + iL_y$

$L_- = L_x - iL_y$

$L^2 = L_z^2 + \frac{1}{2}(L_+ L_- + L_- L_+)$

$[L_x, L_y] = i\hbar L_z$

$[L^2, L_i] = 0 \quad \text{where } i = x, y, \text{ or } z$

$L_x = -i\hbar \left(\sin\phi \frac{\partial}{\partial\theta} + \cot\theta \cos\phi \frac{\partial}{\partial\phi} \right), L_y = i\hbar \left(\cos\phi \frac{\partial}{\partial\theta} - \cot\theta \sin\phi \frac{\partial}{\partial\phi} \right), L_z = -i\hbar \frac{\partial}{\partial\phi}$

$L_+ = \hbar e^{i\phi} \left(\frac{\partial}{\partial\theta} + i \cot\theta \frac{\partial}{\partial\phi} \right), L_- = \hbar e^{-i\phi} \left(-\frac{\partial}{\partial\theta} + i \cot\theta \frac{\partial}{\partial\phi} \right)$

$L^2 = -\hbar^2 \left(\frac{1}{\sin\theta} \frac{\partial}{\partial\theta} \left(\sin\theta \frac{\partial}{\partial\theta} \right) + \frac{1}{\sin^2\theta} \frac{\partial^2}{\partial\phi^2} \right)$

Hund’s rule

- 1: All other thing being equal, the state with the highest total spin (S), will have the lowest.
- 2: For a given spin, the state the highest total orbital angular momentum (L), consistent with overall anti-symmetrization, will have the lowest energy.
- 3: If a subshell (n,l) is no more than half filled, then the lowest energy level has J = |L - S|: if it is more than half filled, then J = L + S has the lowest energy.

Spin

Two particle spin states

$|0, 0\rangle = \frac{1}{\sqrt{2}} (|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle)$ s = 0 singlet
 $|1, 0\rangle = \frac{1}{\sqrt{2}} (|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle)$, s = 1 triplet
 $|1, -1\rangle = |\downarrow\downarrow\rangle$

$S_z = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad S_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad S^2 = \frac{3}{4}\hbar^2 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad S_+ = \hbar \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \quad S_- = \hbar \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix}$

Two particle Hamiltonian:

$\hat{H} = -\frac{\hbar^2}{2m_1} \nabla_1^2 - \frac{\hbar^2}{2m_2} \nabla_2^2 + V(\mathbf{r}_1, \mathbf{r}_2)$

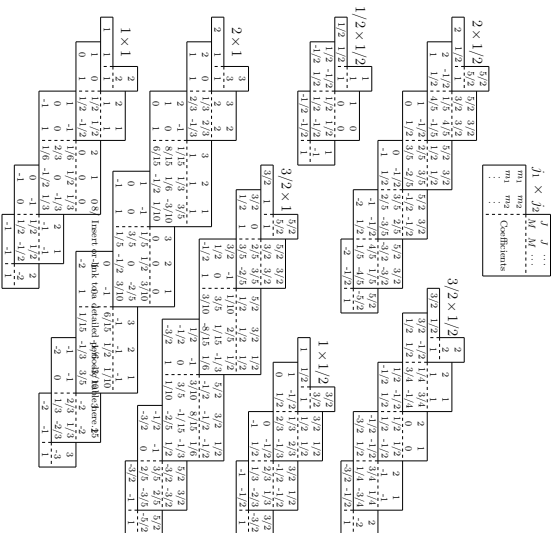
Hamiltonian with an atom with atomic number Z:

$\hat{H} = -\frac{\hbar^2}{2m_e} \nabla^2 - \frac{Ze^2}{4\pi\epsilon_0 r}$

Clebsch-Gordan coefficients

Condensed Matter

Free electron gas:



Periodic Table of Elements

1 IA

110079

1

H

Hydrogen

2 IIA

6941

3

Li

Lithium

2 IIA

90122

4

Be

Beryllium

2 IIA

22090

11

Na

Sodium

2 IIA

39098

19

K

Potassium

2 IIA

85468

37

Rb

Rubidium

2 IIA

8762

55

Cs

Cesium

2 IIA

226

87

Fr

Francium

3 IIIA

44956

21

Sc

Scandium

3 IIIA

47867

22

Ti

Titanium

3 IIIA

50942

23

V

Vanadium

3 IIIA

51996

24

Cr

Chromium

3 IIIA

54938

25

Mn

Manganese

3 IIIA

55845

26

Fe

Iron

3 IIIA

58933

27

Co

Cobalt

3 IIIA

58933

28

Ni

Nickel

3 IIIA

63546

29

Cu

Copper

3 IIIA

6539

30

Zn

Zinc

3 IIIA

69723

31

Ga

Gallium

3 IIIA

7264

32

Ge

Germanium

3 IIIA

74922

33

As

Arsenic

3 IIIA

7896

34

Se

Selenium

3 IIIA

12176

52

Te

Tellurium

3 IIIA

20438

81

In

Indium

3 IIIA

2072

82

Sn

Tin

3 IIIA

20898

83

Sb

Antimony

3 IIIA

209

84

Po

Polonium

3 IIIA

20898

85

Bi

Bismuth

3 IIIA

209

86

Po

Polonium

3 IIIA

209

87

Po

Polonium

3 IIIA

209

88

Po

Polonium

3 IIIA

209

89

Po

Polonium

3 IIIA

209

90

Po

Polonium

3 IIIA

209

91

Po

Polonium

3 IIIA

209

92

Po

Polonium

3 IIIA

209

93

Po

Polonium

3 IIIA

209

94

Po

Polonium

3 IIIA

209

95

Po

Polonium

3 IIIA

209

96

Po

Polonium

3 IIIA

209

97

Po

Polonium

3 IIIA

209

98

Po

Polonium

3 IIIA

209

99

Po

Polonium

3 IIIA

209

100

Po

Polonium

3 IIIA

209

101

Po

Polonium

3 IIIA

209

102

Po

Polonium

3 IIIA

209

103

Po

Polonium

3 IIIA

209

104

Po

Polonium

3 IIIA

209

105

Po

Polonium

3 IIIA

209

106

Po

Polonium

3 IIIA

209

107

Po

Polonium

3 IIIA

209

108

Po

Polonium

3 IIIA

209

109

Po

Polonium

3 IIIA

209

110

Po

Polonium

3 IIIA

209

111

Po

Polonium

3 IIIA

209

112

Po

Polonium

3 IIIA

209

113

Po

Polonium

3 IIIA

209

114

Po

Polonium

3 IIIA

209

115

Po

Polonium

3 IIIA

209

116

Po

Polonium

3 IIIA

209

117

Po

Polonium

3 IIIA

209

118

Po

Polonium

3 IIIA

209

119

Po

Polonium

3 IIIA

209

120

Po

Polonium

3 IIIA

209

121

Po

Polonium

3 IIIA

209

122

Po

Polonium

3 IIIA

209

123

Po

Polonium

3 IIIA

209

124

Po

Polonium

3 IIIA

209

125

Po

Polonium

3 IIIA

209

126

Po

Polonium

3 IIIA

209

127

Po

Polonium

3 IIIA

209

128

Po

Polonium

3 IIIA

209

129

Po

Polonium

3 IIIA

209

130

Po

Polonium

3 IIIA

209

131

Po

Polonium

3 IIIA

209

132

Po

Polonium

3 IIIA

209

133

Po

Polonium

3 IIIA

209

134

Po

Polonium

3 IIIA

209

135

Po

Polonium

3 IIIA

209

136

Po

Polonium

3 IIIA

209

137

Po

Polonium

3 IIIA

209

138

Po

Polonium

3 IIIA

209

139

Po

Polonium

3 IIIA

209

140

Po

Polonium

3 IIIA

209

141

Po

Polonium

3 IIIA

209

142

Po

Polonium

3 IIIA

209

143

Po

Polonium

3 IIIA

209

144

Po

Polonium

3 IIIA

209

145

Po

Polonium

3 IIIA

209

146

Po

Polonium

3 IIIA

209

147

Po

Polonium

3 IIIA

209

148

Po

Polonium

3 IIIA

209

149

Po

Polonium

3 IIIA

209

150

Po

Polonium

3 IIIA

209

151

Po

Polonium

3 IIIA

209

152

Po

Polonium

3 IIIA

209

153

Po

Polonium

3 IIIA

209

154

Po

Polonium

3 IIIA

209

155

Po

Polonium

3 IIIA

209

156

Po

Polonium

3 IIIA

209

157

Po

Polonium

3 IIIA

209

158

Po

Polonium

3 IIIA

209

159

Po

Polonium

3 IIIA

209

160

Po

Polonium

3 IIIA

209

161

Po

Polonium

3 IIIA

209

162

Po

Polonium

3 IIIA

209

163

Po

Polonium

3 IIIA

209

164

Po

Polonium

3 IIIA

209

165

Po

Polonium

3 IIIA

209

166

Po

Polonium

3 IIIA

209

167

Po

Polonium

3 IIIA

209

168

Po

Polonium

3 IIIA

209

169

Po

Polonium

3 IIIA

209

170

Po

Polonium

3 IIIA

209

171

Po

Polonium

3 IIIA

209

172

Po

Polonium

3 IIIA

209

173

Po

Polonium

3 IIIA

209

174

Po

Polonium

3 IIIA

209

175

Po

Polonium

3 IIIA

209

176

Po

Polonium

3 IIIA

209

177

Po

Polonium

3 IIIA

209

178

Po

Polonium

3 IIIA

209

179

Po

Polonium

3 IIIA

209

180

Po

Polonium

3 IIIA

209

181

Po

Polonium

3 IIIA

209

182

Po

Polonium

3 IIIA

209

183

Po

Polonium

3 IIIA

209

184

Po

Polonium

3 IIIA

209

185

Po

Polonium

3 IIIA

209

186

Po

Polonium

3 IIIA

209

187

Po

Polonium

3 IIIA

209

188

Po

Polonium

3 IIIA

209

189

Po

Polonium

3 IIIA

209

190

Po

Polonium

3 IIIA

209

191

Po

Polonium

3 IIIA

209

192

Po

Polonium

3 IIIA

209

193

Po

Polonium

3 IIIA

209

194

Po

Polonium

3 IIIA

209

195

Po

Polonium

3 IIIA

209

196

Po

Polonium

3 IIIA

209

197

Po

Polonium

3 IIIA

209

198

Po

Polonium

3 IIIA

209

199

Po

Polonium

3 IIIA

209

200

Po

Polonium

3 IIIA

209

201

Po

Polonium

3 IIIA

209

202

Po

Polonium

3 IIIA

209

203

Po

Polonium

3 IIIA

209

204

Po

Polonium

3 IIIA

209

205

Po

Polonium

3 IIIA

209

206

Po

Polonium

3 IIIA

209

207

Po

Polonium

3 IIIA

209

208

Po

Polonium

3 IIIA

209

209

Po

Polonium

3 IIIA

209

210

Po

Polonium

3 IIIA

209

211

Po

Polonium

3 IIIA

209

212

Po

Polonium

3 IIIA

209

213

Po

Polonium

3 IIIA

209

214

Po

Polonium

3 IIIA

209

215

Po

Polonium

3 IIIA

209

216

Po

Polonium

3 IIIA

209

217

Po

Polonium

3 IIIA

209

218

Po

Polonium

3 IIIA

209

219

Po

Polonium

3 IIIA

209

220

Po

Polonium

3 IIIA

209

221

Po

Polonium

3 IIIA

209

222

Po

Polonium

3 IIIA

209

223

Po

Polonium

3 IIIA

209

224

Po

Polonium

3 IIIA

209

225

Po

Polonium

3 IIIA

209

226

Po

Polonium

3 IIIA

209

227

Po

Polonium

3 IIIA

209

228

Po

Polonium

3 IIIA

209

229

Po

Polonium

3 IIIA

209

230

Po

Polonium

3 IIIA

209

231

Po

Polonium

3 IIIA

209

232

Po

Polonium

3 IIIA

209

233

Po

Polonium

3 IIIA

209

234

Po

Polonium

3 IIIA

209

235

Po

Polonium

3 IIIA

209

236

Po

Polonium

3 IIIA

209

237

Po

Polonium

3 IIIA

209

238

Po

Polonium

3 IIIA

209

239

Po

Polonium

3 IIIA

209

240

Po

Polonium

3 IIIA

209

241

Po

Polonium

3 IIIA

209

242

Po

Polonium

3 IIIA

209

243

Po

Polonium

3 IIIA

209

244

Po

Polonium

3 IIIA

209

245

Po

Polonium

3 IIIA

209

246

Po

Polonium

3 IIIA

209

247

Po

Polonium

3 IIIA

209

248

Po

Polonium

3 IIIA

209

249

Po

Polonium

3 IIIA

209

250

Po

Polonium

3 IIIA

209

251

Po

Polonium

3 IIIA

209

252

Po

Polonium

3 IIIA

209

253

Po

Polonium

3 IIIA

209

254

Po

Polonium

3 IIIA

209

255

Po

Polonium

3 IIIA

209

256

Po

Polonium

3 IIIA

209

257

Po

Polonium

3 IIIA

209

258

Po

Polonium

3 IIIA

209

259

Po

Polonium

3 IIIA

209

260

Po

Polonium

3 IIIA

209

261

Po

Polonium

3 IIIA

209

262

Po

Polonium

3 IIIA

209

263

Po

Polonium

3 IIIA

209

264

Po

Polonium

3 IIIA

209

265

Po

Polonium

3 IIIA

209

266

Po

Polonium

3 IIIA

209

267

Po

Polonium

3 IIIA

209

268

Po

Polonium

3 IIIA

209

269

Po

Polonium

3 IIIA

209

270

Po

Polonium

3 IIIA

209

271

Po

Polonium

3 IIIA

209

272

Po

Polonium

3 IIIA

209

273

Po

Polonium

3 IIIA

209

274

Po

Polonium

3 IIIA

209

275

Po

Polonium

3 IIIA

209

276

Po

Polonium

3 IIIA

209

277

Po

Polonium

3 IIIA

209

278

Po

Polonium

3 IIIA

209

279

Po

Polonium

3 IIIA

209

280

Po

Polonium

3 IIIA

209

281

Po

Polonium

3 IIIA

209

282

Po

Polonium

3 IIIA

209

283

Po

Polonium

3 IIIA

209

284

Po

Polonium

3 IIIA

209

285

Po

Polonium

3 IIIA

209

286

Po

Polonium

3 IIIA

209

287

Po

Polonium

3 IIIA

209

288

Po

Polonium

3 IIIA

209

289

Po

Polonium

3 IIIA

209

290

Po

Polonium

3 IIIA

209

291

Po

Polonium

3 IIIA

209

292

Po

Polonium

3 IIIA

209

293

Po

Polonium

3 IIIA

209

294

Po

Polonium

3 IIIA

209

295

Po

Polonium

3 IIIA

209

296

Po

Polonium

3 IIIA

209

297

Po

Polonium

3 IIIA

209

298

Po

Polonium

3 IIIA

209

299

Po

Polonium

3 IIIA

209

300

Po

Polonium

3 IIIA

209

301

Po

Polonium

3 IIIA

209

302

Po

Polonium

3 IIIA

209

303

Po

Polonium

3 IIIA

209

304

Po

Polonium

3 IIIA

209

305

Po

Polonium

3 IIIA

209

306

Po

Polonium

3 IIIA

209

307

Po

Polonium

3 IIIA

209

308

Po

Polonium

3 IIIA

209

309

Po

Polonium

3 IIIA

209

310

Po

Polonium

3 IIIA

209

311

Po

Polonium

3 IIIA

209

312

Po

Polonium

3 IIIA

209

313

Po

Polonium

3 IIIA

209

314

Po

Polonium

3 IIIA

209

315

Po

Polonium

3 IIIA

209

316

Po

Polonium

3 IIIA

209

317

Po

Polonium

3 IIIA

209

318

Po

Polonium

3 IIIA

209

319

Po

Polonium

3 IIIA

209

320

Po

Polonium

3 IIIA

209

321

Po

Polonium

3 IIIA

209

322

Po

Polonium

3 IIIA

209

323

Po

Polonium

3 IIIA

209

324

Po

Polonium

3 IIIA

209

325

Po

Polonium

3 IIIA

209

326

Po

Polonium

3 IIIA

209

327

Po

Polonium

3 IIIA

209

328

Po

Polonium

3 IIIA

209

329

Po

Polonium

3 IIIA

209

330

Po

Polonium

3 IIIA

209

331

Po

Polonium

3 IIIA

209

332

Po

Polonium

3 IIIA

209

333

Po

Polonium

3 IIIA

209

334

Po

Polonium

3 IIIA

209

335

Po

Polonium

3 IIIA

209

336

Po

Polonium

3 IIIA

209

337

Po

Polonium

3 IIIA

209

338

Po

Polonium

3 IIIA

209

339

Po

Polonium

3 IIIA

209

340

Po

Polonium

3 IIIA

209

341

Po

Polonium

3 IIIA

209

342

Po

Polonium

3 IIIA

209

343

Po

Polonium

3 IIIA

209

344

Po

Polonium

3 IIIA

209

345

Po

Polonium

3 IIIA

209

346

Po

Polonium

3 IIIA

209

347

Po

Polonium

3 IIIA

209

348

Po

Polonium

3 IIIA

209

349

Po

Polonium

3 IIIA

209

350

Po

Polonium

3 IIIA

209

351

Po

Polonium

3 IIIA

209

352

Po

Polonium

3 IIIA

209

353

Po

Polonium

3 IIIA

209

354

Po

Polonium

3 IIIA

209

355

Po

Polonium

3 IIIA

209

356

Po

Polonium

3 IIIA

209

357

Po

Polonium

3 IIIA

209

358

Po

Polonium

3 IIIA

209

359

Po

Polonium

3 IIIA