

# 1 物理定数表

## 1.1 基礎定数

真空中の光速 <sup>†</sup>	$c$	$2.997\,924\,58 \times 10^8 \text{ m s}^{-1}$ (SI)
単位電荷 <sup>†</sup>	$e = q_e/\sqrt{4\pi\epsilon_0}$ $q_e = e\sqrt{4\pi\epsilon_0}$ $[e^2] = [(q_e/4\pi\epsilon_0)^2]$	$4.80 \times 10^{-10} \text{ esu}$ (CGS) $1.602\,176\,634 \times 10^{-19} \text{ C}$ (SI) $[\text{ML}^3\text{T}^{-2}]$
真空の誘電率	$\epsilon_0 = (1/4\pi c^2) \times 10^7$ $1/4\pi\epsilon_0 = c^2 \times 10^{-7}$ $q_e^2/4\pi\epsilon_0$	$8.85 \times 10^{-12} \text{ Fm}^{-1}$ (SI) $8.99 \times 10^9 \text{ kg m}^3 \text{ s}^{-2} \text{ C}^{-2}$ (SI) $2.31 \times 10^{-28} \text{ kg m}^3 \text{ s}^{-2}$ (SI)
真空の透磁率	$\mu_0 = 4\pi \times 10^{-7}$	$1.26 \times 10^{-6} \text{ Hm}^{-1}$ (SI)
プランク定数 <sup>†</sup>	$h$ $\hbar = h/2\pi$ $[h]$	$6.626\,070\,15 \times 10^{-34} \text{ J s} = 4.14 \times 10^{-15} \text{ eV s}$ $1.05 \times 10^{-27} \text{ erg s} = 6.58 \times 10^{-16} \text{ eVs}$ $[\text{ML}^2\text{T}^{-1}]$
重力定数	$G$ $[G]$	$6.67 \times 10^{-8} \text{ dyn cm}^2 \text{ g}^{-2}$ $[\text{M}^{-1}\text{L}^3\text{T}^{-2}]$
微細構造定数	$\alpha_e = e^2/\hbar c$ (CGS) $= q_e^2/4\pi\epsilon_0\hbar c$ (SI)	$1/(1.37 \times 10^2) = 7.30 \times 10^{-3}$
重力微細構造定数	$\alpha_g = Gm_p^2/\hbar c$	$5.90 \times 10^{-39}$
アボガドロ数 <sup>†</sup>	$N_A$	$6.022\,140\,76 \times 10^{23} \text{ mol}^{-1}$
ボルツマン定数 <sup>†</sup>	$k$	$1.380\,649 \times 10^{-23} \text{ J K}^{-1} = 8.62 \times 10^{-5} \text{ eV K}^{-1}$
ボーア磁子	$\mu_B = e\hbar/2m_e$	$9.27 \times 10^{-21} \text{ gauss cm}^3$

(†: 2019 年からの新 SI 単位系で  $c$ ,  $q_e$ ,  $h$ ,  $N_A$ ,  $k$  は不確かさのない定義値として全桁を表示。それ以外は有効数字 2 桁で表記。)

## 1.2 長さと面積

	cm	pc	light year	AU
cm	1	$3.24 \times 10^{-19}$	$1.06 \times 10^{-18}$	$6.69 \times 10^{-14}$
pc (パーセク)	$3.09 \times 10^{18}$	1	3.26	$2.06 \times 10^5$
light year (光年)	$9.46 \times 10^{17}$	0.307	1	$6.32 \times 10^4$
AU (天文単位)	$1.50 \times 10^{13}$	$4.85 \times 10^{-6}$	$1.58 \times 10^{-5}$	1
電子のコンプトン波長	$\lambda_e = h/m_e c$	$2.43 \times 10^{-10} \text{ cm}$	$(\lambda_e/2\pi = 3.84 \times 10^{-11} \text{ cm})$	
陽子のコンプトン波長	$\lambda_p = h/m_p c$	$1.32 \times 10^{-13} \text{ cm}$	$(\lambda_p/2\pi = 2.10 \times 10^{-14} \text{ cm})$	
古典電子半径	$r_e = e^2/m_e c^2$	$2.82 \times 10^{-13} \text{ cm}$		
ボーア半径	$a_0 = \hbar^2/m_e e^2$	$0.529 \times 10^{-8} \text{ cm}$	$(\pi a_0^2 = 0.880 \times 10^{-16} \text{ cm}^2)$	
リュードベリ定数	$R_\infty = 2\pi^2 m_e e^4 / \hbar^3 c$	$1.10 \times 10^5 \text{ cm}^{-1}$		
1 keV の光子の波長	$hc/1\text{keV}$	$12.4 \times 10^{-8} \text{ cm}$	$= 12.4 \text{ \AA}$	
ラーモア半径	$r_g = p_\perp / qB$	$3.3 \times 10^2 (\gamma mc^2 / \text{GeV}) (v_\perp / c) (q/e)^{-1} (B/\text{T})^{-1} \text{ cm}$		
地球半径	$R_\oplus$	$6.38 \times 10^8 \text{ cm}$	$(4\pi R_\oplus^2 = 5.11 \times 10^{18} \text{ cm}^2)$	
太陽半径	$R_\odot$	$6.96 \times 10^{10} \text{ cm}$	$(4\pi R_\odot^2 = 6.09 \times 10^{22} \text{ cm}^2)$	
シュバルツシルト半径	$R_s = 2GM/c^2$	$2.95 \times 10^5 (M/M_\odot) \text{ cm}$	$\sim 3 \text{ km}$	
銀河系中心から太陽の距離		$\sim 10 \text{ kpc}$	$(\text{c.f., IAU } 8.5 \text{ kpc})$	
銀河系の直径		$\sim 25 \text{ kpc}$		
銀河団の平均直径		$\sim 3 \text{ Mpc}$		
プランク長	$(G\hbar/c^3)^{1/2}$	$1.62 \times 10^{-33} \text{ cm}$		
トムソン散乱断面積	$\sigma_T = 8\pi r_e^2/3$	$6.65 \times 10^{-25} \text{ cm}^2$		
バーン (barn, 反応断面積)	b	$10^{-24} \text{ cm}^2 = 10^{-28} \text{ m}^2$		

## 1.3 時間

1 ユリウス年	$365.25 \text{ days (SI day)} = 31,557,600 \text{ s}$
1 日	$24 \text{ h} = 1,440 \text{ min} = 86,400 \text{ s}$
光の伝搬時間	$3.33(r/1 \text{ m}) \text{ ns} = 500(r/1 \text{ AU}) \text{ s}$
ハッブル時間 $1/H_0$	$9.8 \times 10^9 h^{-1} \text{ year} = 3.09 \times 10^{17} h^{-1} \text{ s}$ (宇宙年齢の目安)
宇宙年齢	138 億年 [Planck Collaboration A&A (2016), Table 4]
プランク時間 $(G\hbar/c^5)^{1/2}$	$5.39 \times 10^{-44} \text{ s}$

## 1.4 質量とエネルギー

電子の質量	$m_e$	$9.11 \times 10^{-28}$ g	電子の静止質量エネルギー	$m_e c^2$	0.511 MeV
陽子の質量	$m_p$	$1.67 \times 10^{-24}$ g	陽子の静止質量エネルギー	$m_p c^2$	938 MeV
陽子電子質量比	$m_n/m_e$	$1.84 \times 10^3$	水素の基底状態エネルギー	$m_e c^2 (\alpha_e^2/2)$	13.6 eV
地球質量	$M_\oplus$	$5.98 \times 10^{27}$ g		=1Ry	912 Å
太陽質量	$M_\odot$	$1.99 \times 10^{33}$ g			
銀河系質量	$M_{\text{gal}}$	$\sim 2 \times 10^{11} M_\odot$	$E\lambda = 12.39842$ keV Å		
宇宙の質量	$M_U$	$10^{54}\text{--}10^{56}$ g	$\hbar c = 1.973$ keV Å=197.3 MeV fm		
プランク質量	$(\hbar c/G)^{1/2}$	$2.18 \times 10^{-5}$ g	1 J = $1 \times 10^7$ ergs, 1 cal=4.19 J		

	eV	erg	cm <sup>-1</sup>	Hz	K
eV	1	$1.60 \times 10^{-12}$	$8.07 \times 10^3$	$2.42 \times 10^{14}$	$1.16 \times 10^4$
erg	$6.24 \times 10^{11}$	1	$5.03 \times 10^{15}$	$1.51 \times 10^{26}$	$7.24 \times 10^{15}$
cm <sup>-1</sup>	$1.24 \times 10^{-4}$	$1.99 \times 10^{-16}$	1	$3.00 \times 10^{10}$	1.44
Hz	$4.14 \times 10^{-15}$	$6.63 \times 10^{-27}$	$3.34 \times 10^{-11}$	1	$4.80 \times 10^{-11}$
K	$8.62 \times 10^{-5}$	$1.38 \times 10^{-16}$	$6.95 \times 10^{-1}$	$2.08 \times 10^{10}$	1

## 1.5 輻射

黒体放射の輻射密度定数	$a = \pi^2 k^4 / 15 c^3 \hbar^3$	$7.57 \times 10^{-15}$ erg cm <sup>-3</sup> K <sup>-4</sup>
シュテファン-ボルツマン定数	$\sigma_{\text{sb}} = ac/4$	$5.67 \times 10^{-5}$ erg cm <sup>-2</sup> K <sup>-4</sup> s <sup>-1</sup>
黒体放射の最大強度波長	$T\lambda_{\text{max}}$	0.290 cm K
黒体放射の光度	$L_x = 4\pi R^2 \sigma_{\text{sb}} T^4 = 1.045 \times 10^{35} (R/10 \text{ km})^2 (kT/0.3 \text{ keV})^4$	erg s <sup>-1</sup>
太陽光度	$L_\odot$	$3.8 \times 10^{33}$ erg s <sup>-1</sup> = $3.8 \times 10^{26}$ W
絶対輻射等級	$M_{\text{bol}} = 4.75 - 2.5 \log (L/L_\odot)$	
絶対輻射等級 0 等星の輻射		$3.0 \times 10^{35}$ erg s <sup>-1</sup>
輻射等級 0 等星の明るさ		$2.5 \times 10^{-5}$ erg cm <sup>-2</sup> s <sup>-1</sup>
見かけの等級	$m = M + 5 \log (D/\text{pc}) - 5 + \text{空間吸収の大きさ}$	
X線光度	$L_x = 4\pi d^2 F_x = 1.200 \times 10^{32} (d/1 \text{ kpc})^2 (F_x/10^{-12} \text{ erg s cm}^{-2})$	erg s <sup>-1</sup>
エディントン光度	$L_{\text{Edd}} \sim 1.3 \times 10^{38} (M/M_\odot)$	erg s <sup>-1</sup>
スピンドウン光度	$L_{\text{sd}} = 3.94 \times 10^{35} \text{ erg s}^{-1} (P/1 \text{ s})^{-3} (\dot{P}/10^{-11} \text{ s s}^{-1})$	(at $I = 10^{45} \text{ g cm}^2$ )
かに星雲のX線強度	1 Crab	$\sim 2.3 \times 10^{-8}$ erg s cm <sup>-2</sup> (2-10 keV)

## 1.6 磁場

量子電磁力学の臨界磁場	$B_{\text{cr}} = m_e^2 c^3 / \hbar e$	$4.414 \times 10^{13}$ G
パルサーの表面磁場強度	$B_d = (3c^3 I P \dot{P} / 2\pi^2 R_{\text{ns}}^6)^{1/2}$	$1.0 \times 10^{14} (P/1 \text{ s})^{1/2} (\dot{P}/10^{-11} \text{ s s}^{-1})^{1/2}$ G
電子サイクロトロン共鳴	$E_{\text{cyc}} = m_e c^2 (1 + B/B_{\text{cr}})$	11.6 (B/10 <sup>12</sup> G) keV
磁気エネルギー密度	$U_{\text{mag}} = B^2 / 8\pi$ (CGS)	$3.98 \times 10^{-2} (B/1 \text{ G})^2$ erg cm <sup>-3</sup> (1T=10 <sup>4</sup> G)

## 1.7 宇宙論

ハッブル定数	$H_0$	$100h \text{ km s}^{-1} \text{ Mpc}^{-1} = 3.2h \times 10^{-18} \text{ s}^{-1}$ ( $h \sim 0.70$ )
ハッブル距離	$c/H_0$	$3000h^{-1} \text{ Mpc} = 9.26 \times 10^{27} h^{-1} \text{ cm}$
臨界密度	$\rho_c = (3H_0^2) / (8\pi G)$	$1.9 \times 10^{-29} h^2 \text{ g cm}^{-3} = 2.8 \times 10^{11} h^2 M_\odot \text{ Mpc}^{-3}$
宇宙黒体輻射密度	$\rho_{r0} = aT_{r0}^4$	$4.0 \times 10^{-13} [T_{r0}/2.7\text{K}]^4$ erg cm <sup>-3</sup>
宇宙黒体輻射光子数密度	$n_{r0}$	$4.0 \times 10^2 [T_{r0}/2.7\text{K}]^3$ cm <sup>-3</sup>
宇宙論的赤方偏移 (近傍)	$z \sim (H_0/c)d$	$3.3 \times 10^{-4} h (d/\text{Mpc})$ ( $z < 0.05$ )
運動学的赤方偏移	$1+z = \sqrt{(1+\beta)/(1-\beta)}$	$E' = \gamma(1-\beta)E = \{(1-\beta)/(1+\beta)\}^{1/2} E$
重力赤方偏移	$1+z = (1 - R_s/R)^{-1/2}$	

## 1.8 その他

[力] = [MLT <sup>-2</sup> ], [エネルギー] = [ML <sup>2</sup> T <sup>-2</sup> ], [圧力] = [ML <sup>-1</sup> T <sup>-2</sup> ]	
1 g cm <sup>-3</sup> = $5.99 \times 10^{23}$ proton cm <sup>-3</sup> = $5.61 \times 10^{32}$ eV cm <sup>-3</sup> = $1.48 \times 10^{40} M_\odot \text{ Mpc}^{-3}$	
1 Jy = $10^{-23}$ erg cm <sup>-2</sup> s <sup>-1</sup> Hz <sup>-1</sup> = $10^{-26}$ J m <sup>-2</sup> s <sup>-1</sup> Hz <sup>-1</sup>	
760 torr = $1.013 \times 10^6$ dyn cm <sup>-2</sup> = 1 atmos = 1.013 bars = $1.013 \times 10^5$ Nm <sup>-2</sup> (Pa)	
1 radian = 57.296 degrees, 1 arcsec = $4.848 \times 10^{-6}$ radians, 1 sr ~ 3282.806 degrees <sup>2</sup>	
天体の赤経と赤緯を ( $\alpha, \delta$ ) として、人工衛星のオイラー角は ( $\alpha, 90^\circ - \delta, 90^\circ - [\text{ロール角}]$ )	

## 2 中性原子や高階電離イオンからの代表的な輝線

Table 1: 中性原子、ヘリウム様イオン、水素様イオンの輝線エネルギーと K 殻束縛エネルギー (単位 eV)

Neutral atom		$\rho$ (g cm <sup>-3</sup> )	Fluorescence						
Element	Z		K $\alpha_1$	K $\alpha_2$	K $\beta_1$	L $\alpha_1$	L $\alpha_2$	L $\beta_1$	K-edge
C	6	1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>2</sup>	2.27	277.					284.2
N	7	1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>3</sup>	1.25	392.4					409.9
O	8	1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>4</sup>	1.42	524.9					543.1
Ne	10	1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup>	0.90	848.6	848.6				870.2
Na	11	[Ne]3s <sup>1</sup>	0.97	1,040.9	1,040.9	1,071.1			1,070.8
Mg	12	[Ne]3s <sup>2</sup>	1.74	1,253.6	1,253.6	1,302.2			1,303.0
Al	13	[Ne]3s <sup>2</sup> 3p <sup>1</sup>	2.70	1,486.7	1,486.2	1,557.4			1,559.6
Si	14	[Ne]3s <sup>2</sup> 3p <sup>2</sup>	2.33	1,739.9	1,739.3	1,835.9			1,839.
S	16	[Ne]3s <sup>2</sup> 3p <sup>4</sup>	2.09	2,307.8	2,306.6	2,464.0			2,472.
Ar	18	[Ne]3s <sup>2</sup> 3p <sup>6</sup>	1.78	2,957.7	2,955.6	3,190.5			3,205.9
Ca	20	[Ar]4s <sup>2</sup>	1.53	3,691.6	3,688.0	4,012.7	341.3	341.3	344.9
Fe	26	[Ar]3d <sup>6</sup> 4s <sup>2</sup>	7.87	6,403.8	6,390.8	7,057.9	705.0	705.0	718.5
Ni	28	[Ar]3d <sup>8</sup> 4s <sup>2</sup>	8.91	7,478.1	7,460.8	8,264.6	851.5	851.5	868.8

Ion	He-like					H-like				
	F or z	I1 or y	I2 or x	R or w	K-edge	Ly $\alpha_2$	Ly $\alpha_1$	Ly $\beta_2$	Ly $\beta_1$	K-edge
C	298.9	304.4	304.4	307.9	392.0	367.4	367.5	435.5	435.5	489.9
N	419.8	426.3	426.3	430.7	552.0	500.2	500.3	592.9	592.9	667.0
O	560.9	568.5	568.6	573.9	739.3	653.4	653.6	774.5	774.6	871.4
Ne	905.0	914.8	915.0	922.0	1,195.8	1,021.5	1,021.9	1,210.8	1,210.9	1,362.1
Na	1,107.8	1,118.7	1,119.0	1,126.8	1,465.1	1,236.3	1,236.9	1,465.4	1,465.6	1,648.7
Mg	1,331.1	1,343.1	1,343.5	1,352.2	1,761.8	1,471.6	1,472.6	1,744.5	1,744.8	1,962.6
Al	1,574.9	1,588.1	1,588.7	1,598.2	2,085.9	1,727.6	1,728.9	2,048.0	2,048.4	2,304.1
Si	1,839.4	1,853.7	1,854.6	1,864.9	2,437.6	2,004.3	2,006.0	2,376.1	2,376.6	2,673.1
S	2,430.3	2,447.1	2,448.7	2,460.6	3,223.7	2,619.7	2,622.7	3,105.8	3,106.7	3,494.1
Ar	3,104.1	3,123.5	3,126.2	3,139.5	4,120.6	3,318.1	3,322.9	3,934.2	3,935.7	4,426.2
Ca	3,861.1	3,883.3	3,887.7	3,902.2	5,128.8	4,100.1	4,107.5	4,861.9	4,864.1	5,469.8
Fe	6,636.6	6,667.5	6,682.3	6,700.4	8,828.1	6,951.9	6,973.1	8,246.3	8,252.6	9,277.6
Ni	7,731.6	7,765.7	7,786.4	7,805.5	10,288.8	8,073.1	8,101.7	9,577.5	9,586.0	10,775.3

X-ray Data Booklet (<http://xdb.lbl.gov>) are used for line and K-edge (ionization) energies of neutral elements, NIST Atomic Spectra Database version 5.6 (<https://www.nist.gov/pml/atomic-spectra-database>) for K-edge (ionization) energies of He-like and H-like ions, and AtomDB v3.0.9 <http://www.atomdb.org> for emission line energies of He-like and H-like ions. The energies are shown to one place of decimal without rounding values. Note: Inner shell lines are denoted by K $\alpha$  ( $n=1$  to 2), K $\beta$  ( $n=1$  to 3) for Li-like or higher ions, but called Ly $\alpha$  and Ly $\beta$  for He-like and H-like ions.

Table 2: An incomplete list of astrophysically important X-ray spectral features (keV)

Energy		Energy		Energy		Energy	
Ne VII	0.127	O VII	0.574	Fe XX	0.996	Fe I K $\alpha_1$	6.404
Si XI	0.283	O VIII	0.654	Ne X	1.022	Fe XXV	6.64
C I K edge	0.284	O VII	0.666	Mg I K edge	1.305	Fe XXV	6.68
Si XII	0.303	O VII	0.698	Mg XI	1.340	Fe XXV	6.70
C V	0.308	Fe I LIII edge	0.707	Mg XI	1.352	Fe XXVI	6.93
N I K edge	0.402	Fe I LII edge	0.721	Si K edge	1.839	Fe I K $\beta$	7.058
N VI	0.431	Fe XVII	0.826	Si XIII	1.86	Fe I Kedge	7.111
N VII	0.500	Ne I K edge	0.867	S I K edge	2.472		
O I K edge	0.532	Ne IX	0.915	Ar I K edge	3.203		
O VII	0.569	Ne IX	0.922	Fe I K $\alpha_2$	6.391		

3 原子核からの代表的な輝線

Table 3: 放射線源 (校正用、環境放射線) からのガンマ線

	Decay	Half-life	Energy	$I_g$		Decay	Half-life	Energy	$I_g$
		$T_{1/2}$	(keV)	(%)			$T_{1/2}$	(keV)	(%)
$^{22}\text{Na}$	$\text{EC}/\beta^+$	2.6019 y	511.	181.4	$^{152}\text{Eu}$	$\text{EC}/\beta^-$	13.53 y	121.78	28.58
			1274.5	99.94				244.69	7.58
$^{40}\text{K}$	$\text{EC}/\beta^+$	$1.27 \times 10^9$ y	1460.83	11				344.27	26.5
$^{55}\text{Fe}$	EC	2.73 y	5.888	8.5				778.90	12.94
			5.899	16.9				867.37	4.24
			6.490	2.99				964.07	14.60
$^{57}\text{Co}$	EC	271.79 d	14.41	9.16				1085.86	10.20
			122.06	85.60				1112.07	13.64
			136.47	10.68				1408.00	21.00
$^{60}\text{Co}$	$\beta^-$	5.27 y	1173.23	99.97	$^{241}\text{Am}$	$\alpha$	432.2 y	59.54	35.9
			1332.50	99.98	$^{214}\text{Bi}$	$\alpha/\beta^-$	19.9 m	609.31	46.1
$^{88}\text{Y}$	$\text{EC}/\beta^+$	106.65 d	898.04	93.7				768.35	4.94
			1836.06	99.2				934.06	3.03
$^{133}\text{Ba}$	EC	10.51 y	53.16	2.19				1120.28	15.1
			79.61	2.62				1238.11	5.79
			80.99	34.06				1764.49	15.4
			276.39	7.16	$^{208}\text{Tl}$	$\beta^-$	3.05 m	277.35	6.31
			302.85	18.33				510.77	22.6
			356.01	62.05				583.19	84.5
			383.85	8.94				860.56	12.42
$^{137}\text{Cs}$	$\beta^-$	30.07 y	661.65	85.1				2614.53	99

Data from the Lund/LBNL Nuclear Data Search Version 2.0 (1999) <http://nucleardata.nuclear.lu.se/toi/>, shown for  $I_g \gtrsim 5\%$ . Lines from  $^{55}\text{Fe}$  are Mn K $\alpha$ 2 (5.888 keV), Mn K $\alpha$ 1 (5.899 keV), and Mn K $\beta$ 1+Mn K $\beta$ 3 (6.490 keV).

4 周期表

Periodic Table of the Elements

<div><div><div>2201s</div><div>H</div><div>Hydrogen</div><div>1.00784-1.00811</div></div><div><div>2</div><div>He</div><div>Helium</div><div>4.002602(2)</div></div></div>																	
<div><div><div>30.982s</div><div>Li</div><div>Lithium</div><div>6.938-6.997</div></div><div><div>41.572s</div><div>Be</div><div>Beryllium</div><div>9.0121831(5)</div></div><div><div>Z</div><div>eng</div><div>ss</div><div>Sy</div><div>Name</div><div>saw</div></div><div><div>Z = atomic number; eng = electronegativity; ss = subshell; Sy = Symbol, Name = element name, saw = standard atomic weight</div></div></div>																	
<div><div><div>110.933s</div><div>Na</div><div>Sodium</div><div>22.98976928(2)</div></div><div><div>121.313s</div><div>Mg</div><div>Magnesium</div><div>24.304-24.307</div></div></div>																	
<div><div><div>190.824s</div><div>K</div><div>Potassium</div><div>39.0983(1)</div></div><div><div>201.004s</div><div>Ca</div><div>Calcium</div><div>40.078(4)</div></div><div><div>211.363d</div><div>Sc</div><div>Scandium</div><div>44.955908(5)</div></div><div><div>221.543d</div><div>Ti</div><div>Titanium</div><div>47.867(1)</div></div><div><div>231.633d</div><div>V</div><div>Vanadium</div><div>50.9415(1)</div></div><div><div>241.663d*</div><div>Cr</div><div>Chromium</div><div>51.9961(6)</div></div><div><div>251.553d</div><div>Mn</div><div>Manganese</div><div>54.938044(3)</div></div><div><div>261.834s</div><div>Fe</div><div>Iron</div><div>55.845(2)</div></div><div><div>271.883d</div><div>Co</div><div>Cobalt</div><div>58.933194(4)</div></div><div><div>281.913d</div><div>Ni</div><div>Nickel</div><div>58.9334(4)</div></div><div><div>291.903d*</div><div>Cu</div><div>Copper</div><div>63.546(3)</div></div><div><div>301.653d</div><div>Zn</div><div>Zinc</div><div>65.38(2)</div></div><div><div>311.814p</div><div>Ga</div><div>Gallium</div><div>69.723(1)</div></div><div><div>322.014p</div><div>Ge</div><div>Germanium</div><div>72.630(8)</div></div><div><div>332.184p</div><div>As</div><div>Arsenic</div><div>74.921595(6)</div></div><div><div>342.554p</div><div>Se</div><div>Selenium</div><div>78.971(8)</div></div><div><div>352.964p</div><div>Br</div><div>Bromine</div><div>79.901-79.907</div></div><div><div>363.004p</div><div>Kr</div><div>Krypton</div><div>83.798(2)</div></div></div>																	
<div><div><div>370.825s</div><div>Rb</div><div>Rubidium</div><div>85.4678(3)</div></div><div><div>380.955s</div><div>Sr</div><div>Strontium</div><div>87.62(1)</div></div><div><div>391.224d</div><div>Y</div><div>Yttrium</div><div>88.90584(2)</div></div><div><div>401.334d</div><div>Zr</div><div>Zirconium</div><div>91.224(2)</div></div><div><div>411.64d*</div><div>Nb</div><div>Niobium</div><div>92.90637(2)</div></div><div><div>422.164d*</div><div>Mo</div><div>Molybdenum</div><div>95.95(1)</div></div><div><div>431.94d</div><div>Tc</div><div>Technetium</div><div>(98)</div></div><div><div>442.24d*</div><div>Ru</div><div>Ruthenium</div><div>101.07(2)</div></div><div><div>452.284d*</div><div>Rh</div><div>Rhodium</div><div>102.90550(2)</div></div><div><div>462.204d*</div><div>Pd</div><div>Palladium</div><div>106.42(1)</div></div><div><div>471.934d</div><div>Ag</div><div>Silver</div><div>107.8682(2)</div></div><div><div>481.604d</div><div>Cd</div><div>Cadmium</div><div>112.414(4)</div></div><div><div>491.785p</div><div>In</div><div>Indium</div><div>114.818(1)</div></div><div><div>501.965p</div><div>Sn</div><div>Tin</div><div>118.710(7)</div></div><div><div>512.055p</div><div>Sb</div><div>Antimony</div><div>121.760(1)</div></div><div><div>522.15p</div><div>Te</div><div>Tellurium</div><div>127.60(3)</div></div><div><div>532.665p</div><div>I</div><div>Iodine</div><div>126.90447(3)</div></div><div><div>542.605p</div><div>Xe</div><div>Xenon</div><div>131.293(6)</div></div></div>																	
<div><div><div>550.763d</div><div>Cs</div><div>Cesium</div><div>132.90545196(6)</div></div><div><div>560.896s</div><div>Ba</div><div>Barium</div><div>137.327(7)</div></div><div><div>57-71</div><div>*</div><div>Lanthanides</div></div><div><div>721.35d</div><div>Hf</div><div>Hafnium</div><div>178.49(2)</div></div><div><div>731.53d</div><div>Ta</div><div>Tantalum</div><div>180.94788(2)</div></div><div><div>742.365d</div><div>W</div><div>Tungsten</div><div>183.84(1)</div></div><div><div>751.95d</div><div>Re</div><div>Rhenium</div><div>186.207(1)</div></div><div><div>762.225d</div><div>Os</div><div>Osmium</div><div>190.23(3)</div></div><div><div>772.285d*</div><div>Ir</div><div>Iridium</div><div>192.217(3)</div></div><div><div>782.285d*</div><div>Pt</div><div>Platinum</div><div>195.084(9)</div></div><div><div>792.545d</div><div>Au</div><div>Gold</div><div>196.966569(5)</div></div><div><div>802.005p</div><div>Hg</div><div>Mercury</div><div>200.592(3)</div></div><div><div>811.626p</div><div>Tl</div><div>Thallium</div><div>204.382-204.385</div></div><div><div>821.876p</div><div>Pb</div><div>Lead</div><div>207.2(1)</div></div><div><div>832.026p</div><div>Bi</div><div>Bismuth</div><div>208.98040(1)</div></div><div><div>842.606p</div><div>Po</div><div>Polonium</div><div>(209)</div></div><div><div>852.26p</div><div>At</div><div>Astatine</div><div>(210)</div></div><div><div>862.26p</div><div>Rn</div><div>Radon</div><div>(222)</div></div></div>																	
<div><div><div>870.75p</div><div>Fr</div><div>Francium</div><div>(223)</div></div><div><div>880.92s</div><div>Ra</div><div>Radium</div><div>(226)</div></div><div><div>89-103</div><div>**</div><div>Actinides</div></div><div><div>1041.64d</div><div>Rf</div><div>Rutherfordium</div><div>(261)</div></div><div><div>1051.65d</div><div>Db</div><div>Dubnium</div><div>(268)</div></div><div><div>1061.66d</div><div>Sg</div><div>Seaborgium</div><div>(269)</div></div><div><div>1071.67d</div><div>Bh</div><div>Bohrium</div><div>(270)</div></div><div><div>1081.68d</div><div>Hs</div><div>Hassium</div><div>(269)</div></div><div><div>1091.69d</div><div>Mt</div><div>Meitnerium</div><div>(278)</div></div><div><div>1101.70d</div><div>Ds</div><div>Darmstadtium</div><div>(281)</div></div><div><div>1111.71d</div><div>Rg</div><div>Roentgenium</div><div>(282)</div></div><div><div>1121.72d</div><div>Cn</div><div>Copernicium</div><div>(285)</div></div><div><div>1131.73d</div><div>Nh</div><div>Nihonium</div><div>(286)</div></div><div><div>1141.74p</div><div>Fl</div><div>Flerovium</div><div>(289)</div></div><div><div>1151.75p</div><div>Mc</div><div>Moscovium</div><div>(289)</div></div><div><div>1161.76p</div><div>Lv</div><div>Livermorium</div><div>(293)</div></div><div><div>1171.77p</div><div>Ts</div><div>Tennessine</div><div>(294)</div></div><div><div>1181.78p</div><div>Og</div><div>Oganesson</div><div>(294)</div></div></div>																	
<div><div><div>571.15d*</div><div>La</div><div>Lanthanum</div><div>138.90547(7)</div></div><div><div>581.124f</div><div>Ce</div><div>Cerium</div><div>140.116(1)</div></div><div><div>591.133f</div><div>Pr</div><div>Praseodymium</div><div>140.90766(2)</div></div><div><div>601.144f</div><div>Nd</div><div>Neodymium</div><div>144.242(3)</div></div><div><div>611.134f</div><div>Pm</div><div>Promethium</div><div>(145)</div></div><div><div>621.174f</div><div>Sm</div><div>Samarium</div><div>150.36(2)</div></div><div><div>631.24f</div><div>Eu</div><div>Europium</div><div>151.964(1)</div></div><div><div>641.244f*</div><div>Gd</div><div>Gadolinium</div><div>157.25(3)</div></div><div><div>651.144f</div><div>Tb</div><div>Terbium</div><div>158.92535(2)</div></div><div><div>661.224f</div><div>Dy</div><div>Dysprosium</div><div>162.500(1)</div></div><div><div>671.234f</div><div>Ho</div><div>Holmium</div><div>164.93033(2)</div></div><div><div>681.244f</div><div>Er</div><div>Erbium</div><div>167.259(3)</div></div><div><div>691.254f</div><div>Tm</div><div>Thulium</div><div>168.93422(2)</div></div><div><div>701.144f</div><div>Yb</div><div>Ytterbium</div><div>173.045(10)</div></div><div><div>711.274f</div><div>Lu</div><div>Lutetium</div><div>174.9668(1)</div></div></div>																	
<div><div><div>891.16d*</div><div>Ac</div><div>Actinium</div><div>(227)</div></div><div><div>901.35f</div><div>Th</div><div>Thorium</div><div>232.0377(4)</div></div><div><div>911.35f</div><div>Pa</div><div>Protactinium</div><div>231.03588(2)</div></div><div><div>921.385f</div><div>U</div><div>Uranium</div><div>238.02891(3)</div></div><div><div>931.365f*</div><div>Np</div><div>Neptunium</div><div>(237)</div></div><div><div>941.285f</div><div>Pu</div><div>Plutonium</div><div>(244)</div></div><div><div>951.285f</div><div>Am</div><div>Americium</div><div>(243)</div></div><div><div>961.285f</div><div>Cm</div><div>Curium</div><div>(247)</div></div><div><div>971.35f</div><div>Bk</div><div>Berkelium</div><div>(247)</div></div><div><div>981.35f</div><div>Cf</div><div>Californium</div><div>(251)</div></div><div><div>991.35f</div><div>Es</div><div>Einsteinium</div><div>(252)</div></div><div><div>1001.35f</div><div>Fm</div><div>Fermium</div><div>(257)</div></div><div><div>1011.35f</div><div>Md</div><div>Mendelevium</div><div>(258)</div></div><div><div>1021.35f</div><div>No</div><div>Nobelium</div><div>(259)</div></div><div><div>1031.35f</div><div>Lr</div><div>Lawrencium</div><div>(260)</div></div></div>																	

Standard atomic weights taken from the Commission on Isotopic Abundances and Atomic Weights (ciaw.org/atomic-weights.htm). Adapted from Ivan Griffin's L<sup>A</sup>T<sub>E</sub>X Periodic Table. © 2017 Paul Danese

An asterisk (\*) next to a subshell indicates an anomalous (Aufbau rule-breaking) ground state electron configuration.

## 5 天文学の便利な TIPS

### 5.1 覚えておきたい数値

(距離)

$$\text{pc} \approx 3 \times 10^{18} \text{ cm}$$

$$\text{AU} \approx 500 \text{ light-seconds}$$

$$R_{\text{earth}} \approx R_{\text{jupiter}}/10 \approx R_{\odot}/100$$

$$2GM_{\odot}/c^2 \approx 3 \text{ km}$$

(質量とエネルギー)

$$m_{\text{p}} \sim m_{\text{n}} \sim 940 \text{ MeV} \approx 1 \text{ GeV}$$

$$m_{\text{e}} \approx 0.511 \text{ MeV}/c^2 \approx m_{\text{p}}/2000$$

$$\hbar c \approx 2000 \text{ eV } \text{\AA}$$

$$\alpha = e^2/(\hbar c) \text{ [ガウス単位系]} \approx 1/137 \text{ } (\hbar c \text{ と微細構造定数 } \alpha \text{ から基本パラメータを導出できる})$$

$$1 \text{ \AA} \rightarrow 12.4 \text{ keV}$$

$$1 \text{ eV} \approx 1.6 \times 10^{-12} \text{ erg} \rightarrow 1,200 \text{ nm} \rightarrow 240 \text{ THz} \rightarrow 10^4 \text{ K}$$

(天文学では依然として CGS 単位系に揃えると便利なことも多い)

$$\text{ボルツマン定数 } k \sim 1.38 \times 10^{-16} \text{ erg/K}$$

$$\text{ステファン-ボルツマン定数 } \sigma \sim 1.03 \times 10^{24} \text{ erg/s/cm}^2/\text{keV}^4$$

$$\text{典型的な星間密度} \approx 1 \text{ Hydrogen atom/cm}^3$$

$$\text{距離 } d \text{ までの水素柱密度 (hydrogen column density) } N_{\text{H}} \approx 3 \times 10^{21} (d/\text{kpc}) \text{ cm}^{-2}$$

### 5.2 便利な近似

桁で議論する封筒の裏の精度である [確認が必要, 2022-04-21]

$$\text{year} \approx 3.15 \times 10^7 \text{ seconds} \approx \pi \cdot 10^7 \text{ seconds}$$

$$\text{km/s} \approx \text{pc/Myr}$$

$$G \approx 40 \text{ AU}^3/(M_{\text{sun}} \text{ year}^2)$$

$$1'' \approx 5 \text{ } \mu\text{rad}$$

$$\text{sphere} \approx 60^6/(100\pi) \text{ arcmin}^2$$