6. ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS

Table 6.1. Table revised June 1994. Gases are evaluated at 20°C, 1 atm, (in parentheses) or at STP [square brackets].

Material	Z	A	Nuclear [a] total cross section σ_T [barn]	Nuclear [b] inelastic cross section σ_I [barn]	Nuclear [c] collision length λ_T [g/cm^2]	Nuclear [c] interaction length λ_I [g/cm^2]	$dE/dx\|_{\rm min}$ [d] $\left[\frac{\rm MeV}{\rm g/cm^2}\right]$ () is for gas	Radiation length [e] X_0 [g/cm^2] () is for gas	X_0 [cm] () is for gas	Density [f] [g/cm^3] () is for gas [g/ℓ]	Refractive index n [f] () is $(n$–1)×10^6 for gas
H_2 gas	1	1.01	0.0387	0.033	43.3	50.8	(4.103)	61.28	865	(0.0838)[0.090]	[140]
H_2 (B.C., 26K)	1	1.01	0.0387	0.033	43.3	50.8	4.045	61.28	865	0.0708	1.112
D_2	1	2.01	0.073	0.061	45.7	54.7	(2.052)	122.6	757	0.162[0.177]	1.128
He	2	4.00	0.133	0.102	49.9	65.1	(1.937)	94.32	755	0.125[0.178]	1.024[35]
Li	3	6.94	0.211	0.157	54.6	73.4	1.639	82.76	155	0.534	—
Be	4	9.01	0.268	0.199	55.8	75.2	1.594	65.19	35.3	1.848	—
C	6	12.01	0.331	0.231	60.2	86.3	1.745	42.70	18.8	2.265 [g]	—
N_2	7	14.01	0.379	0.265	61.4	87.8	(1.825)	37.99	47.0	0.808[1.25]	1.205[300]
O_2	8	16.00	0.420	0.292	63.2	91.0	(1.801)	34.24	30.0	1.14[1.43]	1.22[266]
Ne	10	20.18	0.507	0.347	66.1	96.6	(1.724)	28.94	24.0	1.207[0.900]	1.092[67]
Al	13	26.98	0.634	0.421	70.6	106.4	1.615	24.01	8.9	2.70	—
Si	14	28.09	0.660	0.440	70.6	106.0	1.664	21.82	9.36	2.33	—
Ar	18	39.95	0.868	0.566	76.4	117.2	(1.519)	19.55	14.0	1.40[1.782]	1.233[283]
Ti	22	47.88	0.995	0.637	79.9	124.9	1.476	16.17	3.56	4.54	—
Fe	26	55.85	1.120	0.703	82.8	131.9	1.451	13.84	1.76	7.87	—
Cu	29	63.55	1.232	0.782	85.6	134.9	1.403	12.86	1.43	8.96	—
Ge	32	72.59	1.365	0.858	88.3	140.5	1.371	12.25	2.30	5.323	—
Sn	50	118.69	1.967	1.21	100.2	163	1.264	8.82	1.21	7.31	—
Xe	54	131.29	2.120	1.29	102.8	169	(1.255)	8.48	2.77	3.057[5.858]	[705]
W	74	183.85	2.767	1.65	110.3	185	1.145	6.76	0.35	19.3	—
Pt	78	195.08	2.861	1.708	113.3	189.7	1.129	6.54	0.305	21.45	—
Pb	82	207.19	2.960	1.77	116.2	194	1.123	6.37	0.56	11.35	—
U	92	238.03	3.378	1.98	117.0	199	1.082	6.00	≈0.32	≈18.95	—
Air, (20°C, 1 atm.), [STP]					62.0	90.0	(1.815)	36.66	[30420]	(1.205)[1.29]	(273)[293]
H_2O					60.1	84.9	1.991	36.08	36.1	1.00	1.33
CO_2					62.4	90.5	(1.819)	36.2	[18310]	[1.977]	[410]
Shielding concrete [h]					67.4	99.9	1.711	26.7	10.7	2.5	—
Borosilicate glass (Pyrex) [ℓ]					66.2	97.6	1.695	28.3	12.7	2.23	1.474
SiO_2 (fused quartz) [m]					67.0	99.2	1.697	27.05	11.7	2.32 [m]	1.458
Methane (CH_4)					54.7	74.0	(2.417)	46.5	[64850]	0.423[0.717]	[444]
Ethane (C_2H_6)					55.73	75.71	(2.304)	45.66	[34035]	0.509(1.356) [n]	(1.038) [n]
Propane (C_3H_8)					—	—	(2.262)	—	—	(1.879)	
Isobutane ($(CH_3)_2CHCH_3$)					56.3	77.4	(2.239)	45.2	[16930]	[2.67]	[1900]
Octane, liquid ($CH_3(CH_2)_6CH_3$)					—	—	2.123	—	—	0.703	
Paraffin wax ($CH_3(CH_2)_nCH_3, \langle n\rangle \approx 25$)					—	—	2.087	—	—	0.93	
Nylon, type 6					—	—	1.974	—	—	1.14	
Polycarbonate (Lexan)					—	—	1.886	—	—	1.200	
Polyethylene terephthlate (Mylar) ($C_5H_4O_2$)					60.2	85.7	1.848	39.95	28.7	1.39	—
Polyethylene (monomer $CH_2=CH_2$)					56.9	78.8	2.076	44.8	≈47.9	0.92–0.95	—
Polyimide film (Kapton)					—	—	1.820	—	—	1.420	
Polymethylmethacralate (Lucite, Plexiglas) (monomer $(CH_2=C(CH_3)CO_2CH_3)$)					59.2	83.6	1.929	40.55	≈34.4	1.16–1.20	≈1.49
Polystyrene, scintillator (monomer $C_6H_5CH=CH_2$)					58.4	82.0	1.936	43.8	42.4	1.032	1.581
Polytetrafluoroethylene (Teflon) (monomer $CF_2=CF_2$)					—	—	1.671	—	—	2.20	
Polyvinyltolulene, scintillator (monomer 2-$CH_3C_6H_4CH=CH_2$)					—	—	1.956	—	—	1.032	
Barium fluoride (BaF_2)					92.1	146	1.303	9.91	2.05	4.89	1.56
Bismuth germanate (BGO) ($Bi_4Ge_3O_{12}$)					97.4	156	1.251	7.98	1.12	7.1	2.15
Cesium iodide (CsI)					—	—	1.243	—	—	4.51	
Lithium fluoride (LiF)					62.00	88.24	1.614	39.25	14.91	2.632	1.392
Sodium fluoride (NaF)					66.78	97.57	1.69	29.87	11.68	2.558	1.336
Sodium iodide (NaI)					94.8	152	1.305	9.49	2.59	3.67	1.775
Silica Aerogel [o]					65.5	95.7	1.83	29.85	≈150	0.1–0.3	1.0+0.25ρ
NEMA G10 plate [p]					62.6	90.2	1.87	33.0	19.4	1.7	—