

## 4. PRODUCTION AND PROPERTIES OF RADIATIONS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ )

Radiation	Energy (MeV)	1 Hydrogen	2 Helium	3 Lithium	4 Beryllium	5 Boron	6 Carbon	7 Nitrogen	8 Oxygen
Ag $K\beta_1$	2.494E-02	3.63E-01	1.89E-01	1.72E-01	1.95E-01	2.37E-01	3.15E-01	4.04E-01	3.29E-01
Pd $K\beta_1$	2.382E-02	3.65E-01	1.90E-01	1.74E-01	2.00E-01	2.47E-01	3.35E-01	4.37E-01	5.82E-01
Rh $K\beta_1$	2.272E-02	3.66E-01	1.92E-01	1.77E-01	2.05E-01	2.59E-01	3.58E-01	4.77E-01	6.44E-01
Ag $K\alpha$	2.210E-02	3.67E-01	1.93E-01	1.79E-01	2.09E-01	2.67E-01	3.74E-01	5.03E-01	6.85E-01
Pd $K\alpha$	2.112E-02	3.68E-01	1.94E-01	1.82E-01	2.16E-01	2.81E-01	4.02E-01	5.51E-01	7.60E-01
Rh $K\alpha$	2.017E-02	3.69E-01	1.96E-01	1.85E-01	2.24E-01	2.98E-01	4.35E-01	6.07E-01	8.48E-01
Mo $K\beta_1$	1.961E-02	3.70E-01	1.97E-01	1.87E-01	2.29E-01	3.09E-01	4.58E-01	6.45E-01	9.08E-01
Mo $K\alpha$	1.744E-02	3.73E-01	2.02E-01	1.98E-01	2.56E-01	3.68E-01	5.76E-01	8.45E-01	1.22E+00
Zn $K\beta_1$	9.572E-03	3.86E-01	2.55E-01	3.64E-01	7.16E-01	1.41E+00	2.69E+00	4.42E+00	6.78E+00
Cu $K\beta_1$	8.905E-03	3.88E-01	2.68E-01	4.12E-01	8.53E-01	1.73E+00	3.33E+00	5.48E+00	8.42E+00
Zn $K\alpha$	8.631E-03	3.89E-01	2.74E-01	4.36E-01	9.23E-01	1.89E+00	3.65E+00	6.01E+00	9.25E+00
Ni $K\beta_1$	8.265E-03	3.90E-01	2.85E-01	4.73E-01	1.03E+00	2.14E+00	4.15E+00	6.85E+00	1.05E+01
Cu $K\alpha$	8.041E-03	3.91E-01	2.92E-01	5.00E-01	1.11E+00	2.31E+00	4.51E+00	7.44E+00	1.15E+01
Co $K\beta_1$	7.649E-03	3.93E-01	3.07E-01	5.55E-01	1.27E+00	2.67E+00	5.24E+00	8.66E+00	1.33E+01
Ni $K\alpha$	7.472E-03	3.94E-01	3.14E-01	5.84E-01	1.35E+00	2.87E+00	5.62E+00	9.29E+00	1.43E+01
Fe $K\beta_1$	7.058E-03	3.96E-01	3.35E-01	6.63E-01	1.58E+00	3.39E+00	6.68E+00	1.10E+01	1.70E+01
Co $K\alpha$	6.925E-03	3.97E-01	3.43E-01	6.93E-01	1.67E+00	3.59E+00	7.07E+00	1.17E+01	1.80E+01
Mn $K\beta_1$	6.490E-03	4.00E-01	3.74E-01	8.10E-01	2.01E+00	4.37E+00	8.62E+00	1.42E+01	2.19E+01
Fe $K\alpha$	6.400E-03	4.00E-01	3.81E-01	8.39E-01	2.09E+00	4.55E+00	8.99E+00	1.49E+01	2.28E+01
Cr $K\beta_1$	5.947E-03	4.05E-01	4.25E-01	1.01E+00	2.59E+00	5.69E+00	1.12E+01	1.86E+01	2.84E+01
Mn $K\alpha$	5.895E-03	4.05E-01	4.31E-01	1.03E+00	2.66E+00	5.84E+00	1.16E+01	1.91E+01	2.92E+01
Cr $K\alpha$	5.412E-03	4.12E-01	4.98E-01	1.30E+00	3.44E+00	7.59E+00	1.50E+01	2.47E+01	3.78E+01
Ti $K\beta_1$	4.932E-03	4.21E-01	5.92E-01	1.68E+00	4.56E+00	1.01E+01	1.99E+01	3.28E+01	4.99E+01
Ti $K\alpha$	4.509E-03	4.33E-01	7.12E-01	2.18E+00	6.00E+00	1.33E+01	2.62E+01	4.30E+01	6.52E+01
		9 Fluorine	10 Neon	11 Sodium	12 Magnesium	13 Aluminium	14 Silicon	15 Phosphorus	16 Sulfur
Ag $K\beta_1$	2.494E-02	6.60E-01	9.06E-01	1.13E+00	1.50E+00	1.85E+00	2.38E+00	2.84E+00	3.55E+00
Pd $K\beta_1$	2.382E-02	7.35E-01	1.02E+00	1.28E+00	1.70E+00	2.10E+00	2.71E+00	3.24E+00	4.05E+00
Rh $K\beta_1$	2.272E-02	8.22E-01	1.15E+00	1.45E+00	1.93E+00	2.39E+00	3.09E+00	3.70E+00	4.64E+00
Ag $K\alpha$	2.210E-02	8.79E-01	1.23E+00	1.56E+00	2.09E+00	2.59E+00	3.35E+00	4.01E+00	5.02E+00
Pd $K\alpha$	2.112E-02	9.84E-01	1.39E+00	1.77E+00	2.37E+00	2.94E+00	3.81E+00	4.57E+00	5.72E+00
Rh $K\alpha$	2.017E-02	1.11E+00	1.57E+00	2.01E+00	2.70E+00	3.36E+00	4.36E+00	5.23E+00	6.55E+00
Mo $K\beta_1$	1.961E-02	1.19E+00	1.69E+00	2.17E+00	2.92E+00	3.64E+00	4.73E+00	5.67E+00	7.11E+00
Mo $K\alpha$	1.744E-02	1.63E+00	2.35E+00	3.03E+00	4.09E+00	5.11E+00	6.64E+00	7.97E+00	9.99E+00
Zn $K\beta_1$	9.572E-03	9.35E+00	1.36E+01	1.77E+01	2.40E+01	2.98E+01	3.85E+01	4.58E+01	5.68E+01
Cu $K\beta_1$	8.905E-03	1.16E+01	1.69E+01	2.20E+01	2.96E+01	3.68E+01	4.75E+01	5.64E+01	6.98E+01
Zn $K\alpha$	8.631E-03	1.28E+01	1.86E+01	2.41E+01	3.25E+01	4.03E+01	5.20E+01	6.17E+01	7.63E+01
Ni $K\beta_1$	8.265E-03	1.45E+01	2.11E+01	2.74E+01	3.69E+01	4.58E+01	5.89E+01	6.98E+01	8.63E+01
Cu $K\alpha$	8.041E-03	1.58E+01	2.29E+01	2.97E+01	4.00E+01	4.96E+01	6.37E+01	7.55E+01	9.33E+01
Co $K\beta_1$	7.649E-03	1.83E+01	2.66E+01	3.45E+01	4.63E+01	5.73E+01	7.36E+01	8.70E+01	1.07E+02
Ni $K\alpha$	7.472E-03	1.97E+01	2.85E+01	3.69E+01	4.96E+01	6.13E+01	7.87E+01	9.30E+01	1.15E+02
Fe $K\beta_1$	7.058E-03	2.33E+01	3.38E+01	4.37E+01	5.85E+01	7.23E+01	9.27E+01	1.09E+02	1.35E+02
Co $K\alpha$	6.925E-03	2.47E+01	3.58E+01	4.62E+01	6.19E+01	7.64E+01	9.78E+01	1.15E+02	1.42E+02
Mn $K\beta_1$	6.490E-03	3.00E+01	4.34E+01	5.59E+01	7.47E+01	9.21E+01	1.18E+02	1.39E+02	1.70E+02
Fe $K\alpha$	6.400E-03	3.13E+01	4.52E+01	5.82E+01	7.78E+01	9.59E+01	1.22E+02	1.44E+02	1.77E+02
Cr $K\beta_1$	5.947E-03	3.89E+01	5.61E+01	7.21E+01	9.62E+01	1.18E+02	1.51E+02	1.77E+02	2.17E+02
Mn $K\alpha$	5.895E-03	3.99E+01	5.76E+01	7.40E+01	9.87E+01	1.21E+02	1.54E+02	1.81E+02	2.22E+02
Cr $K\alpha$	5.412E-03	5.15E+01	7.41E+01	9.49E+01	1.26E+02	1.55E+02	1.96E+02	2.30E+02	2.81E+02
Ti $K\beta_1$	4.932E-03	6.78E+01	9.72E+01	1.24E+02	1.65E+02	2.01E+02	2.55E+02	2.97E+02	3.62E+02
Ti $K\alpha$	4.509E-03	8.84E+01	1.26E+02	1.61E+02	2.12E+02	2.59E+02	3.27E+02	3.79E+02	4.60E+02

## 4.2. X-RAYS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ ) (cont.)

Radiation	Energy (MeV)	17 Chlorine	18 Argon	19 Potassium	20 Calcium	21 Scandium	22 Titanium	23 Vanadium	24 Chromium
Ag $K\beta_1$	2.494E-02	4.09E+00	4.56E+00	5.78E+00	6.92E+00	7.47E+00	8.43E+00	9.42E+00	1.09E+01
Pd $K\beta_1$	2.382E-02	4.67E+00	5.21E+00	6.60E+00	7.90E+00	8.53E+00	9.61E+00	1.07E+01	1.24E+01
Rh $K\beta_1$	2.272E-02	5.35E+00	5.96E+00	7.56E+00	9.04E+00	9.76E+00	1.10E+01	1.23E+01	1.42E+01
Ag $K\alpha$	2.210E-02	5.79E+00	6.46E+00	8.19E+00	9.79E+00	1.06E+01	1.19E+01	1.33E+01	1.54E+01
Pd $K\alpha$	2.112E-02	6.61E+00	7.37E+00	9.33E+00	1.12E+01	1.20E+01	1.36E+01	1.51E+01	1.75E+01
Rh $K\alpha$	2.017E-02	7.55E+00	8.42E+00	1.07E+01	1.27E+01	1.38E+01	1.55E+01	1.73E+01	1.99E+01
Mo $K\beta_1$	1.961E-02	8.20E+00	9.14E+00	1.16E+01	1.38E+01	1.49E+01	1.68E+01	1.87E+01	2.15E+01
Mo $K\alpha$	1.744E-02	1.15E+01	1.28E+01	1.62E+01	1.93E+01	2.08E+01	2.34E+01	2.60E+01	2.99E+01
Zn $K\beta_1$	9.572E-03	6.48E+01	7.14E+01	8.94E+01	1.05E+02	1.12E+02	1.25E+02	1.37E+02	1.55E+02
Cu $K\beta_1$	8.905E-03	7.95E+01	8.75E+01	1.09E+02	1.29E+02	1.37E+02	1.52E+02	1.66E+02	1.85E+02
Zn $K\alpha$	8.631E-03	8.69E+01	9.55E+01	1.19E+02	1.40E+02	1.49E+02	1.66E+02	1.81E+02	2.01E+02
Ni $K\beta_1$	8.265E-03	9.81E+01	1.08E+02	1.34E+02	1.58E+02	1.67E+02	1.86E+02	2.03E+02	2.27E+02
Cu $K\alpha$	8.041E-03	1.06E+02	1.16E+02	1.45E+02	1.70E+02	1.80E+02	2.00E+02	2.19E+02	2.47E+02
Co $K\beta_1$	7.649E-03	1.22E+02	1.34E+02	1.66E+02	1.95E+02	2.06E+02	2.27E+02	2.50E+02	2.93E+02
Ni $K\alpha$	7.472E-03	1.30E+02	1.43E+02	1.77E+02	2.08E+02	2.20E+02	2.40E+02	2.66E+02	3.18E+02
Fe $K\beta_1$	7.058E-03	1.52E+02	1.67E+02	2.07E+02	2.42E+02	2.56E+02	2.77E+02	3.09E+02	3.85E+02
Co $K\alpha$	6.925E-03	1.61E+02	1.76E+02	2.18E+02	2.55E+02	2.69E+02	2.91E+02	3.25E+02	4.08E+02
Mn $K\beta_1$	6.490E-03	1.92E+02	2.10E+02	2.60E+02	3.03E+02	3.19E+02	3.45E+02	3.85E+02	4.80E+02
Fe $K\alpha$	6.400E-03	2.00E+02	2.18E+02	2.70E+02	3.14E+02	3.32E+02	3.58E+02	3.99E+02	4.92E+02
Cr $K\beta_1$	5.947E-03	2.44E+02	2.66E+02	3.28E+02	3.82E+02	4.03E+02	4.44E+02	4.79E+02	6.70E+01
Mn $K\alpha$	5.895E-03	2.50E+02	2.72E+02	3.36E+02	3.91E+02	4.12E+02	4.57E+02	4.89E+02	6.86E+01
Cr $K\alpha$	5.412E-03	3.16E+02	3.42E+02	4.21E+02	4.90E+02	5.16E+02	5.90E+02	7.47E+01	8.68E+01
Ti $K\beta_1$	4.932E-03	4.04E+02	4.38E+02	5.38E+02	6.24E+02	6.52E+02	8.54E+01	9.65E+01	1.12E+02
Ti $K\alpha$	4.509E-03	5.11E+02	5.56E+02	6.80E+02	7.81E+02	8.08E+02	1.09E+02	1.23E+02	1.43E+02
		25 Manganese	26 Iron	27 Cobalt	28 Nickel	29 Copper	30 Zinc	31 Gallium	32 Germanium
Ag $K\beta_1$	2.494E-02	1.21E+01	1.38E+01	1.51E+01	1.74E+01	1.83E+01	2.02E+01	2.14E+01	2.31E+01
Pd $K\beta_1$	2.382E-02	1.37E+01	1.57E+01	1.72E+01	1.98E+01	2.08E+01	2.30E+01	2.43E+01	2.62E+01
Rh $K\beta_1$	2.272E-02	1.57E+01	1.79E+01	1.96E+01	2.26E+01	2.38E+01	2.62E+01	2.77E+01	2.98E+01
Ag $K\alpha$	2.210E-02	1.70E+01	1.94E+01	2.12E+01	2.44E+01	2.56E+01	2.82E+01	2.98E+01	3.21E+01
Pd $K\alpha$	2.112E-02	1.93E+01	2.20E+01	2.41E+01	2.77E+01	2.91E+01	3.20E+01	3.38E+01	3.64E+01
Rh $K\alpha$	2.017E-02	2.20E+01	2.51E+01	2.74E+01	3.15E+01	3.30E+01	3.63E+01	3.84E+01	4.13E+01
Mo $K\beta_1$	1.961E-02	2.38E+01	2.71E+01	2.96E+01	3.40E+01	3.57E+01	3.93E+01	4.15E+01	4.46E+01
Mo $K\alpha$	1.744E-02	3.31E+01	3.76E+01	4.10E+01	4.69E+01	4.91E+01	5.40E+01	5.70E+01	6.12E+01
Zn $K\beta_1$	9.572E-03	1.70E+02	1.92E+02	2.06E+02	2.33E+02	2.40E+02	3.59E+01	3.85E+01	4.22E+01
Cu $K\beta_1$	8.905E-03	2.07E+02	2.32E+02	2.48E+02	2.79E+02	3.92E+01	4.38E+01	4.70E+01	5.14E+01
Zn $K\alpha$	8.631E-03	2.24E+02	2.52E+02	2.69E+02	3.02E+02	4.27E+01	4.77E+01	5.12E+01	5.59E+01
Ni $K\beta_1$	8.265E-03	2.51E+02	2.81E+02	3.00E+02	4.53E+01	4.80E+01	5.37E+01	5.76E+01	6.30E+01
Cu $K\alpha$	8.041E-03	2.70E+02	3.02E+02	3.21E+02	4.88E+01	5.18E+01	5.79E+01	6.21E+01	6.79E+01
Co $K\beta_1$	7.649E-03	3.06E+02	3.42E+02	4.81E+01	5.60E+01	5.94E+01	6.64E+01	7.12E+01	7.78E+01
Ni $K\alpha$	7.472E-03	3.25E+02	3.62E+02	5.13E+01	5.97E+01	6.33E+01	7.08E+01	7.59E+01	8.29E+01
Fe $K\beta_1$	7.058E-03	3.75E+02	5.43E+01	6.00E+01	6.98E+01	7.40E+01	8.27E+01	8.86E+01	9.69E+01
Co $K\alpha$	6.925E-03	3.93E+02	5.72E+01	6.32E+01	7.35E+01	7.80E+01	8.71E+01	9.34E+01	1.02E+02
Mn $K\beta_1$	6.490E-03	5.92E+01	6.84E+01	7.55E+01	8.78E+01	9.31E+01	1.04E+02	1.11E+02	1.22E+02
Fe $K\alpha$	6.400E-03	6.16E+01	7.10E+01	7.85E+01	9.13E+01	9.68E+01	1.08E+02	1.16E+02	1.27E+02
Cr $K\beta_1$	5.947E-03	7.53E+01	8.69E+01	9.60E+01	1.12E+02	1.18E+02	1.32E+02	1.42E+02	1.55E+02
Mn $K\alpha$	5.895E-03	7.72E+01	8.90E+01	9.83E+01	1.14E+02	1.21E+02	1.35E+02	1.45E+02	1.58E+02
Cr $K\alpha$	5.412E-03	9.75E+01	1.13E+02	1.24E+02	1.44E+02	1.53E+02	1.71E+02	1.83E+02	1.99E+02
Ti $K\beta_1$	4.932E-03	1.26E+02	1.45E+02	1.60E+02	1.86E+02	1.97E+02	2.20E+02	2.35E+02	2.56E+02
Ti $K\alpha$	4.509E-03	1.61E+02	1.85E+02	2.04E+02	2.37E+02	2.51E+02	2.80E+02	2.99E+02	3.26E+02

#### 4. PRODUCTION AND PROPERTIES OF RADIATIONS

Table 4.2.4.3. *Mass attenuation coefficients (cm<sup>2</sup> g<sup>-1</sup>) (cont.)*

Radiation	Energy (MeV)	33	34	35	36	37	38	39	40
		Arsenic	Selenium	Bromine	Krypton	Rubidium	Strontium	Yttrium	Zirconium
Ag $K\beta_1$	2.494E-02	2.50E+01	2.65E+01	2.91E+01	3.07E+01	3.32E+01	3.56E+01	3.84E+01	4.07E+01
Pd $K\beta_1$	2.382E-02	2.84E+01	3.00E+01	3.29E+01	3.48E+01	3.76E+01	4.03E+01	4.34E+01	4.60E+01
Rh $K\beta_1$	2.272E-02	3.23E+01	3.41E+01	3.74E+01	3.95E+01	4.27E+01	4.57E+01	4.91E+01	5.20E+01
Ag $K\alpha$	2.210E-02	3.48E+01	3.68E+01	4.03E+01	4.25E+01	4.59E+01	4.91E+01	5.29E+01	5.59E+01
Pd $K\alpha$	2.112E-02	3.93E+01	4.16E+01	4.55E+01	4.80E+01	5.18E+01	5.54E+01	5.95E+01	6.29E+01
Rh $K\alpha$	2.017E-02	4.46E+01	4.71E+01	5.15E+01	5.43E+01	5.85E+01	6.25E+01	6.71E+01	7.05E+01
Mo $K\beta_1$	1.961E-02	4.82E+01	5.08E+01	5.55E+01	5.84E+01	6.30E+01	6.72E+01	7.21E+01	7.61E+01
Mo $K\alpha$	1.744E-02	6.61E+01	6.95E+01	7.56E+01	7.93E+01	8.51E+01	9.06E+01	9.70E+01	1.03E+02
Zn $K\beta_1$	9.572E-03	4.64E+01	4.97E+01	5.53E+01	5.92E+01	6.49E+01	7.06E+01	7.73E+01	8.35E+01
Cu $K\beta_1$	8.905E-03	5.65E+01	6.05E+01	6.74E+01	7.21E+01	7.90E+01	8.59E+01	9.40E+01	1.01E+02
Zn $K\alpha$	8.631E-03	6.15E+01	6.59E+01	7.33E+01	7.85E+01	8.60E+01	9.35E+01	1.02E+02	1.10E+02
Ni $K\beta_1$	8.265E-03	6.93E+01	7.42E+01	8.26E+01	8.83E+01	9.68E+01	1.05E+02	1.15E+02	1.24E+02
Cu $K\alpha$	8.041E-03	7.47E+01	8.00E+01	8.90E+01	9.52E+01	1.04E+02	1.13E+02	1.24E+02	1.39E+02
Co $K\beta_1$	7.649E-03	8.55E+01	9.16E+01	1.02E+02	1.09E+02	1.19E+02	1.30E+02	1.42E+02	1.54E+02
Ni $K\alpha$	7.472E-03	9.11E+01	9.76E+01	1.09E+02	1.16E+02	1.27E+02	1.38E+02	1.51E+02	1.63E+02
Fe $K\beta_1$	7.058E-03	1.06E+02	1.14E+02	1.27E+02	1.35E+02	1.48E+02	1.61E+02	1.76E+02	1.91E+02
Co $K\alpha$	6.925E-03	1.12E+02	1.20E+02	1.33E+02	1.42E+02	1.56E+02	1.70E+02	1.85E+02	2.00E+02
Mn $K\beta_1$	6.490E-03	1.34E+02	1.43E+02	1.59E+02	1.70E+02	1.86E+02	2.02E+02	2.21E+02	2.38E+02
Fe $K\alpha$	6.400E-03	1.39E+02	1.49E+02	1.65E+02	1.76E+02	1.93E+02	2.10E+02	2.29E+02	2.47E+02
Cr $K\beta_1$	5.947E-03	1.70E+02	1.82E+02	2.02E+02	2.15E+02	2.36E+02	2.56E+02	2.79E+02	3.00E+02
Mn $K\alpha$	5.895E-03	1.74E+02	1.86E+02	2.06E+02	2.20E+02	2.41E+02	2.62E+02	2.86E+02	3.08E+02
Cr $K\alpha$	5.412E-03	2.19E+02	2.34E+02	2.60E+02	2.77E+02	3.03E+02	3.28E+02	3.58E+02	3.86E+02
Ti $K\beta_1$	4.932E-03	2.81E+02	3.00E+02	3.33E+02	3.55E+02	3.88E+02	4.21E+02	4.59E+02	4.93E+02
Ti $K\alpha$	4.509E-03	3.57E+02	3.81E+02	4.23E+02	4.50E+02	4.92E+02	5.32E+02	5.80E+02	6.22E+02
		41	42	43	44	45	46	47	48
		Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium
Ag $K\beta_1$	2.494E-02	4.36E+01	5.25E+01	4.84E+01	5.06E+01	5.35E+01	5.55E+01	1.01E+01	1.06E+01
Pd $K\beta_1$	2.382E-02	4.92E+01	6.03E+01	5.45E+01	5.69E+01	6.01E+01	1.06E+01	1.15E+01	1.20E+01
Rh $K\beta_1$	2.272E-02	5.56E+01	6.80E+01	6.15E+01	7.00E+01	1.14E+01	1.21E+01	1.30E+01	1.36E+01
Ag $K\alpha$	2.210E-02	5.98E+01	7.20E+01	6.60E+01	1.14E+01	1.23E+01	1.30E+01	1.40E+01	1.46E+01
Pd $K\alpha$	2.112E-02	6.71E+01	7.71E+01	7.41E+01	1.29E+01	1.39E+01	1.47E+01	1.58E+01	1.66E+01
Rh $K\alpha$	2.017E-02	7.55E+01	7.95E+01	1.38E+01	1.47E+01	1.58E+01	1.67E+01	1.79E+01	1.88E+01
Mo $K\beta_1$	1.961E-02	8.10E+01	1.38E+01	1.49E+01	1.58E+01	1.70E+01	1.80E+01	1.94E+01	2.02E+01
Mo $K\alpha$	1.744E-02	1.77E+01	1.88E+01	2.04E+01	2.17E+01	2.33E+01	2.47E+01	2.65E+01	2.78E+01
Zn $K\beta_1$	9.572E-03	9.04E+01	9.65E+01	1.04E+02	1.10E+02	1.18E+02	1.25E+02	1.34E+02	1.40E+02
Cu $K\beta_1$	8.905E-03	1.10E+02	1.17E+02	1.26E+02	1.34E+02	1.44E+02	1.51E+02	1.63E+02	1.69E+02
Zn $K\alpha$	8.631E-03	1.20E+02	1.27E+02	1.37E+02	1.46E+02	1.56E+02	1.65E+02	1.77E+02	1.84E+02
Ni $K\beta_1$	8.265E-03	1.34E+02	1.43E+02	1.54E+02	1.63E+02	1.75E+02	1.85E+02	1.98E+02	2.07E+02
Cu $K\alpha$	8.041E-03	1.45E+02	1.54E+02	1.66E+02	1.76E+02	1.89E+02	1.99E+02	2.13E+02	2.22E+02
Co $K\beta_1$	7.649E-03	1.66E+02	1.76E+02	1.90E+02	2.01E+02	2.16E+02	2.27E+02	2.43E+02	2.53E+02
Ni $K\alpha$	7.472E-03	1.76E+02	1.88E+02	2.02E+02	2.14E+02	2.29E+02	2.41E+02	2.59E+02	2.69E+02
Fe $K\beta_1$	7.058E-03	2.05E+02	2.19E+02	2.35E+02	2.49E+02	2.67E+02	2.81E+02	3.01E+02	3.13E+02
Co $K\alpha$	6.925E-03	2.16E+02	2.30E+02	2.47E+02	2.62E+02	2.80E+02	2.95E+02	3.16E+02	3.29E+02
Mn $K\beta_1$	6.490E-03	2.57E+02	2.73E+02	2.94E+02	3.11E+02	3.33E+02	3.50E+02	3.75E+02	3.90E+02
Fe $K\alpha$	6.400E-03	2.67E+02	2.84E+02	3.05E+02	3.23E+02	3.46E+02	3.63E+02	3.89E+02	4.05E+02
Cr $K\beta_1$	5.947E-03	3.25E+02	3.45E+02	3.70E+02	3.92E+02	4.20E+02	4.41E+02	4.72E+02	4.90E+02
Mn $K\alpha$	5.895E-03	3.32E+02	3.53E+02	3.79E+02	4.01E+02	4.29E+02	4.51E+02	4.83E+02	5.02E+02
Cr $K\alpha$	5.412E-03	4.16E+02	4.42E+02	4.74E+02	5.01E+02	5.36E+02	5.63E+02	6.02E+02	6.26E+02
Ti $K\beta_1$	4.932E-03	5.32E+02	5.65E+02	6.04E+02	6.39E+02	6.83E+02	7.16E+02	7.65E+02	7.95E+02
Ti $K\alpha$	4.509E-03	6.71E+02	7.12E+02	7.61E+02	8.04E+02	8.60E+02	9.01E+02	9.61E+02	9.95E+02

## 4.2. X-RAYS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ ) (cont.)

Radiation	Energy (MeV)	49	50	51	52	53	54	55	56
		Indium	Tin	Antimony	Tellurium	Iodine	Xenon	Caesium	Barium
Ag $K\beta_1$	2.494E-02	1.13E+01	1.18E+01	1.25E+01	1.29E+01	1.40E+01	1.46E+01	1.56E+01	1.62E+01
Pd $K\beta_1$	2.382E-02	1.27E+01	1.34E+01	1.41E+01	1.46E+01	1.59E+01	1.65E+01	1.76E+01	1.83E+01
Rh $K\beta_1$	2.272E-02	1.45E+01	1.52E+01	1.60E+01	1.66E+01	1.80E+01	1.88E+01	2.00E+01	2.08E+01
Ag $K\alpha$	2.210E-02	1.56E+01	1.64E+01	1.73E+01	1.79E+01	1.94E+01	2.02E+01	2.15E+01	2.24E+01
Pd $K\alpha$	2.112E-02	1.76E+01	1.85E+01	1.96E+01	2.02E+01	2.19E+01	2.29E+01	2.43E+01	2.54E+01
Rh $K\alpha$	2.017E-02	2.00E+01	2.10E+01	2.22E+01	2.29E+01	2.18E+01	2.27E+01	2.42E+01	2.52E+01
Mo $K\beta_1$	1.961E-02	2.16E+01	2.26E+01	2.39E+01	2.47E+01	2.68E+01	2.80E+01	2.98E+01	3.10E+01
Mo $K\alpha$	1.744E-02	2.95E+01	3.10E+01	3.27E+01	3.38E+01	3.67E+01	3.82E+01	4.07E+01	4.23E+01
Zn $K\beta_1$	9.572E-03	1.48E+02	1.55E+02	1.64E+02	1.68E+02	1.82E+02	1.90E+02	2.01E+02	2.09E+02
Cu $K\beta_1$	8.905E-03	1.80E+02	1.88E+02	1.98E+02	2.04E+02	2.20E+02	2.29E+02	2.43E+02	2.52E+02
Zn $K\alpha$	8.631E-03	1.95E+02	2.04E+02	2.15E+02	2.21E+02	2.39E+02	2.49E+02	2.63E+02	2.73E+02
Ni $K\beta_1$	8.265E-03	2.19E+02	2.29E+02	2.41E+02	2.48E+02	2.68E+02	2.78E+02	2.95E+02	3.06E+02
Cu $K\alpha$	8.041E-03	2.36E+02	2.47E+02	2.59E+02	2.67E+02	2.88E+02	2.99E+02	3.17E+02	3.25E+02
Co $K\beta_1$	7.649E-03	2.69E+02	2.81E+02	2.96E+02	3.04E+02	3.30E+02	3.43E+02	3.63E+02	3.76E+02
Ni $K\alpha$	7.472E-03	2.86E+02	2.99E+02	3.14E+02	3.23E+02	3.49E+02	3.62E+02	3.83E+02	3.96E+02
Fe $K\beta_1$	7.058E-03	3.32E+02	3.47E+02	3.65E+02	3.74E+02	4.08E+02	4.22E+02	4.46E+02	4.61E+02
Co $K\alpha$	6.925E-03	3.49E+02	3.64E+02	3.83E+02	3.94E+02	4.25E+02	4.40E+02	4.65E+02	4.80E+02
Mn $K\beta_1$	6.490E-03	4.13E+02	4.31E+02	4.54E+02	4.66E+02	5.03E+02	5.20E+02	5.49E+02	5.66E+02
Fe $K\alpha$	6.400E-03	4.28E+02	4.47E+02	4.71E+02	4.83E+02	5.22E+02	5.40E+02	5.69E+02	5.86E+02
Cr $K\beta_1$	5.947E-03	5.19E+02	5.42E+02	5.70E+02	5.85E+02	6.31E+02	6.52E+02	6.86E+02	6.45E+02
Mn $K\alpha$	5.895E-03	5.31E+02	5.54E+02	5.82E+02	5.98E+02	6.45E+02	6.66E+02	7.00E+02	6.60E+02
Cr $K\alpha$	5.412E-03	6.63E+02	6.91E+02	7.23E+02	7.40E+02	7.96E+02	7.21E+02	7.60E+02	5.70E+02
Ti $K\beta_1$	4.932E-03	8.41E+02	8.76E+02	9.15E+02	9.32E+02	1.00E+03	1.03E+03	2.60E+02	3.14E+02
Ti $K\alpha$	4.509E-03	1.05E+03	1.09E+03	9.91E+02	7.51E+02	2.83E+02	2.65E+02	3.30E+02	3.34E+02
		57	58	59	60	61	62	63	64
		Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium
Ag $K\beta_1$	2.494E-02	1.72E+01	1.83E+01	1.95E+01	2.04E+01	2.17E+01	2.23E+01	2.35E+01	2.42E+01
Pd $K\beta_1$	2.382E-02	1.95E+01	2.07E+01	2.20E+01	2.30E+01	2.45E+01	2.52E+01	2.66E+01	2.74E+01
Rh $K\beta_1$	2.272E-02	2.21E+01	2.35E+01	2.50E+01	2.61E+01	2.78E+01	2.86E+01	3.01E+01	3.10E+01
Ag $K\alpha$	2.210E-02	2.38E+01	2.53E+01	2.69E+01	2.81E+01	2.99E+01	3.08E+01	3.24E+01	3.34E+01
Pd $K\alpha$	2.112E-02	2.69E+01	2.86E+01	3.04E+01	3.18E+01	3.38E+01	3.48E+01	3.66E+01	3.77E+01
Rh $K\alpha$	2.017E-02	3.05E+01	3.24E+01	3.45E+01	3.60E+01	3.83E+01	3.94E+01	4.15E+01	4.27E+01
Mo $K\beta_1$	1.961E-02	3.29E+01	3.49E+01	3.72E+01	3.88E+01	4.13E+01	4.24E+01	4.47E+01	4.60E+01
Mo $K\alpha$	1.744E-02	4.49E+01	4.77E+01	5.07E+01	5.30E+01	5.63E+01	5.78E+01	6.09E+01	6.26E+01
Zn $K\beta_1$	9.572E-03	2.21E+02	2.33E+02	2.47E+02	2.57E+02	2.73E+02	2.79E+02	2.93E+02	3.00E+02
Cu $K\beta_1$	8.905E-03	2.66E+02	2.82E+02	2.99E+02	3.10E+02	3.28E+02	3.35E+02	3.52E+02	3.60E+02
Zn $K\alpha$	8.631E-03	2.89E+02	3.06E+02	3.24E+02	3.36E+02	3.55E+02	3.63E+02	3.80E+02	3.89E+02
Ni $K\beta_1$	8.265E-03	3.24E+02	3.43E+02	3.63E+02	3.76E+02	3.97E+02	4.05E+02	4.24E+02	4.33E+02
Cu $K\alpha$	8.041E-03	3.48E+02	3.68E+02	3.90E+02	4.04E+02	4.26E+02	4.34E+02	4.34E+02	4.03E+02
Co $K\beta_1$	7.649E-03	3.95E+02	4.17E+02	4.41E+02	4.57E+02	4.82E+02	3.54E+02	4.80E+02	3.35E+02
Ni $K\alpha$	7.472E-03	4.19E+02	4.42E+02	4.68E+02	4.84E+02	5.11E+02	3.71E+02	3.75E+02	3.56E+02
Fe $K\beta_1$	7.058E-03	4.83E+02	5.10E+02	5.39E+02	4.92E+02	5.88E+02	1.63E+02	4.08E+02	1.53E+02
Co $K\alpha$	6.925E-03	5.07E+02	5.35E+02	5.65E+02	5.05E+02	4.00E+02	1.76E+02	4.19E+02	1.61E+02
Mn $K\beta_1$	6.490E-03	5.97E+02	5.47E+02	6.16E+02	4.39E+02	4.68E+02	1.66E+02	1.95E+02	1.89E+02
Fe $K\alpha$	6.400E-03	6.18E+02	5.61E+02	4.48E+02	4.55E+02	1.94E+02	2.04E+02	2.03E+02	1.95E+02
Cr $K\beta_1$	5.947E-03	7.44E+02	4.94E+02	1.88E+02	1.98E+02	2.32E+02	2.21E+02	2.44E+02	2.35E+02
Mn $K\alpha$	5.895E-03	7.60E+02	5.12E+02	1.93E+02	2.03E+02	2.37E+02	2.25E+02	2.49E+02	2.41E+02
Cr $K\alpha$	5.412E-03	2.25E+02	2.38E+02	2.38E+02	2.51E+02	2.94E+02	2.79E+02	3.09E+02	2.98E+02
Ti $K\beta_1$	4.932E-03	2.84E+02	3.00E+02	3.00E+02	3.14E+02	3.69E+02	3.50E+02	3.90E+02	3.74E+02
Ti $K\alpha$	4.509E-03	3.55E+02	3.57E+02	3.75E+02	3.97E+02	4.62E+02	4.35E+02	4.88E+02	4.69E+02

## 4. PRODUCTION AND PROPERTIES OF RADIATIONS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ ) (cont.)

Radiation	Energy (MeV)	65	66	67	68	69	70	71	72
		Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	Hafnium
Ag $K\beta_1$	2.494E-02	2.55E+01	2.65E+01	2.77E+01	2.90E+01	3.04E+01	3.14E+01	3.28E+01	3.40E+01
Pd $K\beta_1$	2.382E-02	2.88E+01	2.99E+01	3.13E+01	3.27E+01	3.43E+01	3.54E+01	3.71E+01	3.84E+01
Rh $K\beta_1$	2.272E-02	3.26E+01	3.39E+01	3.54E+01	3.71E+01	3.89E+01	4.01E+01	4.20E+01	4.35E+01
Ag $K\alpha$	2.210E-02	3.51E+01	3.65E+01	3.81E+01	3.99E+01	4.18E+01	4.32E+01	4.51E+01	4.67E+01
Pd $K\alpha$	2.112E-02	3.96E+01	4.12E+01	4.30E+01	4.50E+01	4.71E+01	4.87E+01	5.09E+01	5.27E+01
Rh $K\alpha$	2.017E-02	4.49E+01	4.66E+01	4.87E+01	5.09E+01	5.33E+01	5.50E+01	5.75E+01	5.95E+01
Mo $K\beta_1$	1.961E-02	4.83E+01	5.02E+01	5.24E+01	5.48E+01	5.74E+01	5.93E+01	6.19E+01	6.41E+01
Mo $K\alpha$	1.744E-02	6.58E+01	6.83E+01	7.13E+01	7.44E+01	7.79E+01	8.04E+01	8.40E+01	8.69E+01
Zn $K\beta_1$	9.572E-03	3.14E+02	3.24E+02	3.36E+02	3.49E+02	3.65E+02	3.75E+02	3.91E+02	1.00E+02
Cu $K\beta_1$	8.905E-03	3.76E+02	3.87E+02	4.02E+02	4.17E+02	1.08E+02	1.08E+02	1.21E+02	1.20E+02
Zn $K\alpha$	8.631E-03	4.06E+02	4.19E+02	3.98E+02	2.87E+02	1.17E+02	1.17E+02	1.31E+02	1.30E+02
Ni $K\beta_1$	8.265E-03	4.52E+02	3.36E+02	4.44E+02	1.23E+02	1.31E+02	1.31E+02	1.46E+02	1.45E+02
Cu $K\alpha$	8.041E-03	3.21E+02	3.62E+02	1.29E+02	1.32E+02	1.40E+02	1.42E+02	1.56E+02	1.55E+02
Co $K\beta_1$	7.649E-03	3.60E+02	1.38E+02	1.46E+02	1.49E+02	1.59E+02	1.59E+02	1.78E+02	1.76E+02
Ni $K\alpha$	7.472E-03	1.49E+02	1.46E+02	1.55E+02	1.58E+02	1.69E+02	1.69E+02	1.89E+02	1.87E+02
Fe $K\beta_1$	7.058E-03	1.71E+02	1.68E+02	1.78E+02	1.82E+02	1.96E+02	1.96E+02	2.18E+02	2.16E+02
Co $K\alpha$	6.925E-03	1.80E+02	1.76E+02	1.87E+02	1.91E+02	2.06E+02	2.06E+02	2.29E+02	2.27E+02
Mn $K\beta_1$	6.490E-03	2.11E+02	2.07E+02	2.20E+02	2.24E+02	2.43E+02	2.44E+02	2.70E+02	2.67E+02
Fe $K\alpha$	6.400E-03	2.19E+02	2.14E+02	2.28E+02	2.32E+02	2.53E+02	2.51E+02	2.80E+02	2.77E+02
Cr $K\beta_1$	5.947E-03	2.63E+02	2.57E+02	2.72E+02	2.78E+02	3.05E+02	3.04E+02	3.39E+02	3.34E+02
Mn $K\alpha$	5.895E-03	2.69E+02	2.62E+02	2.80E+02	2.85E+02	3.12E+02	3.11E+02	3.47E+02	3.41E+02
Cr $K\alpha$	5.412E-03	3.32E+02	3.25E+02	3.47E+02	3.52E+02	3.86E+02	3.87E+02	4.31E+02	4.25E+02
Ti $K\beta_1$	4.932E-03	4.19E+02	4.10E+02	4.38E+02	4.43E+02	4.94E+02	4.92E+02	5.47E+02	5.39E+02
Ti $K\alpha$	4.509E-03	5.24E+02	5.15E+02	5.47E+02	5.54E+02	6.21E+02	6.19E+02	6.88E+02	6.78E+02
		73	74	75	76	77	78	79	80
		Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury
Ag $K\beta_1$	2.494E-02	3.54E+01	3.68E+01	3.83E+01	3.95E+01	4.11E+01	4.26E+01	4.44E+01	4.58E+01
Pd $K\beta_1$	2.382E-02	4.00E+01	4.15E+01	4.32E+01	4.45E+01	4.64E+01	4.80E+01	5.00E+01	5.16E+01
Rh $K\beta_1$	2.272E-02	4.53E+01	4.70E+01	4.89E+01	5.04E+01	5.24E+01	5.43E+01	5.65E+01	5.83E+01
Ag $K\alpha$	2.210E-02	4.87E+01	5.05E+01	5.25E+01	5.41E+01	5.63E+01	5.83E+01	6.07E+01	6.26E+01
Pd $K\alpha$	2.112E-02	5.48E+01	5.69E+01	5.92E+01	6.10E+01	6.34E+01	6.57E+01	6.83E+01	7.04E+01
Rh $K\alpha$	2.017E-02	6.20E+01	6.43E+01	6.69E+01	6.89E+01	7.16E+01	7.41E+01	7.71E+01	7.95E+01
Mo $K\beta_1$	1.961E-02	6.67E+01	6.92E+01	7.19E+01	7.41E+01	7.70E+01	7.97E+01	8.29E+01	8.54E+01
Mo $K\alpha$	1.744E-02	9.04E+01	9.38E+01	9.74E+01	1.00E+02	1.04E+02	1.07E+02	1.12E+02	1.15E+02
Zn $K\beta_1$	9.572E-03	1.02E+02	1.08E+02	1.19E+02	1.18E+02	1.23E+02	1.21E+02	1.30E+02	1.16E+02
Cu $K\beta_1$	8.905E-03	1.22E+02	1.30E+02	1.43E+02	1.42E+02	1.48E+02	1.45E+02	1.55E+02	1.41E+02
Zn $K\alpha$	8.631E-03	1.32E+02	1.41E+02	1.55E+02	1.54E+02	1.60E+02	1.57E+02	1.68E+02	1.54E+02
Ni $K\beta_1$	8.265E-03	1.47E+02	1.57E+02	1.72E+02	1.71E+02	1.78E+02	1.75E+02	1.88E+02	1.74E+02
Cu $K\alpha$	8.041E-03	1.58E+02	1.68E+02	1.87E+02	1.84E+02	1.91E+02	1.88E+02	2.01E+02	1.88E+02
Co $K\beta_1$	7.649E-03	1.79E+02	1.91E+02	2.09E+02	2.09E+02	2.16E+02	2.14E+02	2.29E+02	2.16E+02
Ni $K\alpha$	7.472E-03	1.90E+02	2.03E+02	2.22E+02	2.21E+02	2.30E+02	2.27E+02	2.43E+02	2.30E+02
Fe $K\beta_1$	7.058E-03	2.20E+02	2.34E+02	2.57E+02	2.55E+02	2.65E+02	2.61E+02	2.79E+02	2.60E+02
Co $K\alpha$	6.925E-03	2.31E+02	2.46E+02	2.68E+02	2.68E+02	2.78E+02	2.76E+02	2.95E+02	2.73E+02
Mn $K\beta_1$	6.490E-03	2.73E+02	2.88E+02	3.16E+02	3.14E+02	3.30E+02	3.25E+02	3.48E+02	3.27E+02
Fe $K\alpha$	6.400E-03	2.83E+02	3.01E+02	3.27E+02	3.27E+02	3.40E+02	3.57E+02	3.61E+02	3.39E+02
Cr $K\beta_1$	5.947E-03	3.39E+02	3.61E+02	3.94E+02	3.92E+02	4.11E+02	4.23E+02	4.34E+02	4.16E+02
Mn $K\alpha$	5.895E-03	3.46E+02	3.69E+02	4.05E+02	4.03E+02	4.18E+02	4.34E+02	4.45E+02	4.27E+02
Cr $K\alpha$	5.412E-03	4.32E+02	4.57E+02	5.01E+02	4.99E+02	5.20E+02	5.41E+02	5.51E+02	5.41E+02
Ti $K\beta_1$	4.932E-03	5.46E+02	5.79E+02	6.33E+02	6.31E+02	6.59E+02	6.83E+02	6.99E+02	6.99E+02
Ti $K\alpha$	4.509E-03	6.85E+02	7.25E+02	7.94E+02	7.92E+02	8.26E+02	8.19E+02	8.76E+02	8.97E+02

## 4.2. X-RAYS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ ) (cont.)

Radiation	Energy (MeV)	81	82	83	84	85	86	87	88
		Thallium	Lead	Bismuth	Polonium	Astatine	Radon	Francium	Radium
Ag $K\beta_1$	2.494E-02	4.72E+01	4.88E+01	5.06E+01	5.30E+01	5.51E+01	5.45E+01	5.67E+01	5.84E+01
Pd $K\beta_1$	2.382E-02	5.31E+01	5.49E+01	5.70E+01	5.96E+01	6.20E+01	6.12E+01	6.37E+01	6.56E+01
Rh $K\beta_1$	2.272E-02	6.00E+01	6.20E+01	6.44E+01	6.73E+01	7.00E+01	6.90E+01	7.18E+01	7.40E+01
Ag $K\alpha$	2.210E-02	6.45E+01	6.66E+01	6.91E+01	7.23E+01	7.51E+01	7.21E+01	7.70E+01	7.93E+01
Pd $K\alpha$	2.112E-02	7.25E+01	7.49E+01	7.77E+01	8.12E+01	8.43E+01	8.32E+01	8.64E+01	8.90E+01
Rh $K\alpha$	2.017E-02	8.18E+01	8.45E+01	8.76E+01	9.15E+01	9.50E+01	9.36E+01	9.72E+01	1.00E+02
Mo $K\beta_1$	1.961E-02	8.79E+01	9.08E+01	9.41E+01	9.83E+01	1.02E+02	1.01E+02	1.04E+02	1.08E+01
Mo $K\alpha$	1.744E-02	1.18E+02	1.22E+02	1.26E+02	1.32E+02	1.17E+02	1.08E+02	8.70E+01	8.80E+01
Zn $K\beta_1$	9.572E-03	1.45E+02	1.51E+02	1.57E+02	1.63E+02	1.71E+02	1.71E+02	1.77E+02	1.75E+02
Cu $K\beta_1$	8.905E-03	1.75E+02	1.81E+02	1.88E+02	1.96E+02	1.86E+02	2.05E+02	2.13E+02	2.10E+02
Zn $K\alpha$	8.631E-03	1.89E+02	1.96E+02	2.04E+02	2.12E+02	2.07E+02	2.23E+02	2.30E+02	2.28E+02
Ni $K\beta_1$	8.265E-03	2.11E+02	2.16E+02	2.28E+02	2.37E+02	2.31E+02	2.49E+02	2.57E+02	2.54E+02
Cu $K\alpha$	8.041E-03	2.26E+02	2.35E+02	2.44E+02	2.54E+02	2.48E+02	2.67E+02	2.77E+02	2.73E+02
Co $K\beta_1$	7.649E-03	2.57E+02	2.67E+02	2.76E+02	2.88E+02	2.82E+02	3.04E+02	3.12E+02	3.10E+02
Ni $K\alpha$	7.472E-03	2.71E+02	2.83E+02	2.95E+02	3.05E+02	2.99E+02	3.21E+02	3.32E+02	3.29E+02
Fe $K\beta_1$	7.058E-03	3.14E+02	3.27E+02	3.39E+02	3.54E+02	3.45E+02	3.73E+02	3.84E+02	3.80E+02
Co $K\alpha$	6.925E-03	3.31E+02	3.43E+02	3.55E+02	3.70E+02	3.63E+02	3.92E+02	4.03E+02	3.98E+02
Mn $K\beta_1$	6.490E-03	3.90E+02	4.06E+02	4.21E+02	4.35E+02	4.26E+02	4.60E+02	4.77E+02	4.70E+02
Fe $K\alpha$	6.400E-03	4.03E+02	4.20E+02	4.34E+02	4.52E+02	4.44E+02	4.77E+02	4.93E+02	4.87E+02
Cr $K\beta_1$	5.947E-03	4.87E+02	5.07E+02	5.24E+02	5.44E+02	5.33E+02	5.76E+02	5.97E+02	5.85E+02
Mn $K\alpha$	5.895E-03	5.00E+02	5.18E+02	5.35E+02	5.58E+02	5.45E+02	5.89E+02	6.02E+02	5.99E+02
Cr $K\alpha$	5.412E-03	5.97E+02	6.43E+02	6.66E+02	6.91E+02	6.80E+02	7.34E+02	7.58E+02	7.43E+02
Ti $K\beta_1$	4.932E-03	7.15E+02	8.15E+02	8.44E+02	8.30E+02	8.60E+02	9.32E+02	9.61E+02	9.41E+02
Ti $K\alpha$	4.509E-03	9.89E+02	1.03E+03	1.06E+03	1.10E+03	1.08E+03	1.18E+03	1.21E+03	1.33E+03
		89	90	91	92	93	94	95	96
		Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium
Ag $K\beta_1$	2.494E-02	6.07E+01	6.19E+01	6.48E+01	6.55E+01	6.84E+01	7.05E+01	7.20E+01	7.35E+01
Pd $K\beta_1$	2.382E-02	6.82E+01	6.95E+01	7.27E+01	7.35E+01	7.67E+01	7.91E+01	8.08E+01	8.24E+01
Rh $K\beta_1$	2.272E-02	7.68E+01	7.82E+01	8.19E+01	8.27E+01	8.63E+01	8.89E+01	9.08E+01	6.00E+01
Ag $K\alpha$	2.210E-02	8.24E+01	8.39E+01	8.78E+01	8.86E+01	9.25E+01	5.60E+01	5.95E+01	6.43E+01
Pd $K\alpha$	2.112E-02	9.24E+01	9.41E+01	9.84E+01	9.93E+01	1.04E+02	1.07E+02	1.09E+02	1.11E+02
Rh $K\alpha$	2.017E-02	1.04E+02	1.06E+02	1.11E+02	1.12E+02	1.16E+02	1.20E+02	1.22E+02	1.10E+02
Mo $K\beta_1$	1.961E-02	1.10E+02	9.87E+01	1.19E+02	7.49E+01	1.25E+02	1.29E+02	1.31E+02	1.34E+02
Mo $K\alpha$	1.744E-02	9.08E+01	9.65E+01	1.01E+02	1.02E+02	4.22E+01	3.99E+01	4.81E+01	4.90E+01
Zn $K\beta_1$	9.572E-03	2.49E+02	1.70E+02	1.73E+02	1.85E+02	1.90E+02	1.80E+02	1.89E+02	1.94E+02
Cu $K\beta_1$	8.905E-03	2.85E+02	2.19E+02	2.08E+02	2.22E+02	2.27E+02	2.16E+02	2.27E+02	2.32E+02
Zn $K\alpha$	8.631E-03	3.03E+02	2.55E+02	2.25E+02	2.40E+02	2.46E+02	2.34E+02	2.41E+02	2.51E+02
Ni $K\beta_1$	8.265E-03	3.09E+02	2.85E+02	2.52E+02	2.68E+02	2.75E+02	2.62E+02	2.73E+02	2.80E+02
Cu $K\alpha$	8.041E-03	3.17E+02	3.06E+02	2.71E+02	2.88E+02	3.14E+02	2.80E+02	3.22E+02	3.38E+02
Co $K\beta_1$	7.649E-03	3.81E+02	3.48E+02	3.06E+02	3.26E+02	3.35E+02	3.17E+02	3.33E+02	3.43E+02
Ni $K\alpha$	7.472E-03	3.99E+02	3.69E+02	3.25E+02	3.47E+02	3.55E+02	3.36E+02	3.52E+02	3.60E+02
Fe $K\beta_1$	7.058E-03	4.44E+02	3.89E+02	3.75E+02	4.00E+02	4.10E+02	3.89E+02	4.07E+02	4.21E+02
Co $K\alpha$	6.925E-03	4.61E+02	4.06E+02	3.94E+02	4.20E+02	4.30E+02	4.08E+02	4.26E+02	4.37E+02
Mn $K\beta_1$	6.490E-03	5.21E+02	4.46E+02	4.65E+02	4.96E+02	5.05E+02	4.08E+02	5.03E+02	5.15E+02
Fe $K\alpha$	6.400E-03	5.30E+02	4.85E+02	4.82E+02	5.28E+02	5.52E+02	4.98E+02	5.81E+02	5.90E+02
Cr $K\beta_1$	5.947E-03	6.18E+02	5.09E+02	5.82E+02	6.17E+02	6.30E+02	6.00E+02	6.27E+02	6.40E+02
Mn $K\alpha$	5.895E-03	6.29E+02	6.23E+02	5.93E+02	6.32E+02	6.45E+02	6.12E+02	6.42E+02	6.55E+02
Cr $K\alpha$	5.412E-03	7.39E+02	7.68E+02	7.38E+02	7.66E+02	8.00E+02	7.60E+02	7.95E+02	8.12E+02
Ti $K\beta_1$	4.932E-03	8.83E+02	9.78E+02	9.83E+02	9.66E+02	1.01E+03	9.62E+02	1.03E+03	1.03E+03
Ti $K\alpha$	4.509E-03	1.05E+03	1.23E+03	1.24E+03	1.23E+03	9.65E+02	9.00E+02	9.55E+02	9.84E+02

#### 4. PRODUCTION AND PROPERTIES OF RADIATIONS

Table 4.2.4.3. Mass attenuation coefficients ( $\text{cm}^2 \text{g}^{-1}$ ) (cont.)

Radiation	Energy (MeV)	97	
		Berkelium	Californium
Ag $K\beta_1$	2.494E-02	6.66E+01	7.35E+01
Pd $K\beta_1$	2.382E-02	7.52E+01	8.24E+01
Rh $K\beta_1$	2.272E-02	8.51E+01	9.26E+01
Ag $K\alpha$	2.210E-02	6.10E+01	6.92E+01
Pd $K\alpha$	2.112E-02	1.03E+02	1.11E+02
Rh $K\alpha$	2.017E-02	1.02E+02	1.25E+02
Mo $K\beta_1$	1.961E-02	1.25E+02	1.34E+02
Mo $K\alpha$	1.744E-02	4.90E+01	5.00E+01
Zn $K\beta_1$	9.572E-03	1.86E+02	2.08E+02
Cu $K\beta_1$	8.905E-03	2.26E+02	2.49E+02
Zn $K\alpha$	8.631E-03	2.46E+02	2.70E+02
Ni $K\beta_1$	8.265E-03	2.77E+02	3.01E+02
Cu $K\alpha$	8.041E-03	3.52E+02	3.60E+02
Co $K\beta_1$	7.649E-03	3.57E+02	3.66E+02
Ni $K\alpha$	7.472E-03	3.62E+02	3.86E+02
Fe $K\beta_1$	7.058E-03	4.22E+02	4.48E+02
Co $K\alpha$	6.925E-03	4.43E+02	4.69E+02
Mn $K\beta_1$	6.490E-03	5.26E+02	5.52E+02
Fe $K\alpha$	6.400E-03	5.92E+02	6.07E+02
Cr $K\beta_1$	5.947E-03	6.64E+02	6.87E+02
Mn $K\alpha$	5.895E-03	6.78E+02	7.03E+02
Cr $K\alpha$	5.412E-03	8.52E+02	8.71E+02
Ti $K\beta_1$	4.932E-03	1.09E+03	1.10E+03
Ti $K\alpha$	4.509E-03	1.04E+03	1.05E+03

involve the use of filters, mirrors, and Laue and Bragg crystal monochromators, chosen so as to provide the best compromise between flux and spectral purity in a particular experiment. In other chapters, authors have discussed the use of techniques to improve the spectral purity of X-ray sources. This section does not purport to be a comprehensive exposition on the topic of filters and monochromators. Rather, it seeks to point the reader towards the information given elsewhere in this volume, and to add complementary information where necessary. A search of the Subject Index will find references to filters and monochromators that are not explicitly mentioned in the text of this section.

The ability to select photon energies, or bands of energies, depends on the scattering power of the atoms from which the monochromator is made and the arrangement of the atoms within the monochromator. The scattering powers of the atoms and their dependence on the energy of the incident photons were discussed in Sections 4.2.3 and 4.2.4 and are discussed more fully in Section 4.2.6. In brief, the scattering power of the atom, or *atomic scattering factor*, is defined, for a given incident photon energy, as the ratio of the scattering power of the atom to that of a free Thomson electron. The scattering power is denoted by the symbol  $f(\omega, \Delta)$  and is a complex quantity, the real part of which,  $f'(\omega, \Delta)$ , is related to the elastic scattering cross section, and the imaginary part of which,  $f''(\omega, \Delta)$ , is related directly to the photoelectric scattering cross section and therefore the linear attenuation coefficient  $\mu_l$ .

At an interface between, say, air and the material from which the monochromator is made, reflection and refraction of the incident photons can occur, as dictated by Maxwell's equations. There is an associated refractive index  $n$  given by

$$n = (1 + \chi)^{1/2}, \quad (4.2.5.1)$$

where

$$\chi = -(r_e \lambda^2 / \pi) \sum_j N_j f_j(\omega, \Delta), \quad (4.2.5.2)$$

$r_e$  is the classical radius of the electron, and  $N_j$  is the number density of atoms of type  $j$ .

An angle of total external reflection  $\alpha_c$  exists for the material, which is a function of the incident photon energy, since  $f_j(\omega, \Delta)$  is a function of photon energy. Thus, a polychromatic beam incident at the critical angle of one of the photon energies ( $E$ ) will reflect totally those components having energies less than  $E$ , and transmit those components with energies greater than  $E$ . Fig. 4.2.5.1 shows calculations by Fukumachi, Nakano & Kawamura (1986) for the reflectivity of single layers of aluminium, copper and platinum as a function of incident energy for a fixed angle of incidence ( $0.2^\circ$ ). For the aluminium specimen, the reflectivity curve shows the rapid decrease in reflectivity as the critical angle is exceeded. The reflectivity in this region varies as  $E^{-2}$ . The effect of increasing atomic number can be seen: the higher the atomic factor  $f(\omega, \Delta)$ , the greater the energy that can be reflected from the surface. Also visible are the effects of the dispersion corrections  $f'(\omega, \Delta)$  and  $f''(\omega, \Delta)$  on reflectivity. For copper, the  $K$  shell is excited, and for platinum the  $L_I$ ,  $L_{II}$  and  $L_{III}$  shells are excited by the polychromatic beam.

Interfaces can therefore be used to act as low-pass energy filters. The surface roughness and the existence of impurities and contaminants on the interface will, however, influence the characteristics of the reflecting surface, sometimes significantly.

#### 4.2.5.2. Mirrors and capillaries

Whilst neither of these classes of X-ray optical device is strictly speaking a monochromator, they nevertheless form component parts of monochromator systems in the laboratory and at synchrotron-radiation sources.

##### 4.2.5.2.1. Mirrors

In the laboratory, mirrors are used in conjunction with conventional sealed tubes and rotating-anode sources, the emission from which consists of *Bremsstrahlung* upon which is superimposed the characteristic spectrum of the anode material (Subsection 2.3.5.2). The shape of the *Bremsstrahlung* spectrum can be significantly modified by mirrors, and the intensity emitted at harmonics of the characteristic wavelength can be

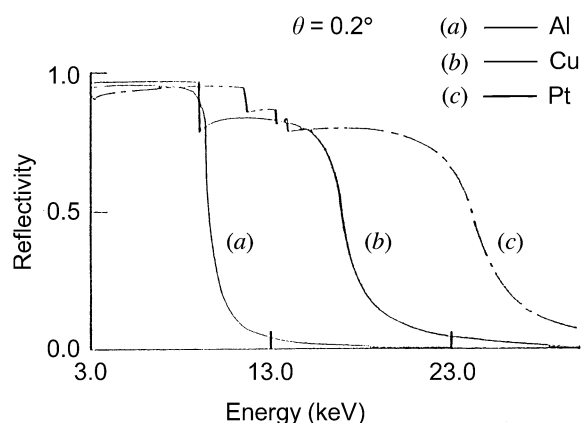


Fig. 4.2.5.1. The variation of specular reflectivity with incident photon energy is shown for materials of different atomic number and a constant angle of incidence of  $0.2^\circ$ . (a) Aluminium: note the rapid decrease of reflectivity with energy. (b) Copper: the sudden decrease of reflectivity is due to the modification of the scattering-length density owing to absorption at the  $K$ -absorption edge. (c) Platinum: the three discontinuities in the reflectivity curve are due to absorption at the  $L_I$ -,  $L_{II}$ -, and  $L_{III}$ -absorption edges.