Appendix
Useful Numbers

Two types of data are listed below. Data of the first type are very accurately known, generally to better than ±1%. These include conversion factors relating different units of measurement (which are usually definitions and hence known perfectly); fundamental physical constants such as the Stefan-Boltzmann constant; and parameters characterizing physical properties of air, water, and radioactive isotopes. Data of the second type include rates of flows of energy and nutrients on Earth, concentrations of trace substance in various media, estimates of fossil fuel and biomass resources, and many others. These are known with less certainty—usually to no better than ±20%, and in some very important cases only to an order of magnitude. In cases where the degree of uncertainty is not likely to be obvious to the reader, explanatory notes are provided.

The data were culled from a wide variety of sources. Incorrect estimates and even typographical errors sometimes propagate through the literature. Thus two sources will occasionally differ about the value of a parameter by an amount greater than the experimental error. In such cases, I have exercised my best judgment about which value to use. A complete list of source material used for each subsection of the Appendix is provided at the end.

Appendix Contents

10	deka (da)	10^{-1}	deci (d)
10^2	hecto (h)	10^{-2}	centi (c)
10^3	kilo (k)	10^{-3}	milli (m)
10^6	mega (M)	10^{-6}	micro (μ)
10^9	giga (G)	10^{-9}	nano (n)
10^{12}	tera (T)	10^{-12}	pico (p)
10^{15}	peta (P)	10^{-15}	femto (f)
10^{18}	exa (E)	10^{-18}	atto (a)

2. Length

1 meter (m) = 100 centimeters (cm) = 3.281 feet (ft) = 39.37 inches (in)
1 mile = 5280 ft = 1.609 kilometers (km)
1 micron (μ) = 10^{-6} m
1 angstrom (Å) = 10^{-10} m

3. Area

1 hectare (ha) = 10^4 square meters (m^2) = 2.47 acres
1 acre = 43,560 square feet (ft^2)
1 barn (b) = 10^{-24} cm^2

4. Volume

1 cubic meter (m^3) = 1000 liters = 264.2 U.S. gallons = 35.31 cubic feet (ft^3)
1 liter (l) = 10^3 cubic centimeters (cm^3 or ml) = 1.057 U.S. quarts
1 acre foot = 1.234×10^3 m^3
1 cord = 128 ft^3
1 board foot = 2.36×10^{-3} m^3
1 cubic mile = 4.17 cubic kilometers (km^3)
1 barrel of petroleum (bbl) = 42 U.S. gallons = 0.159 m^3

5. Angles

360 degrees (°) = 2π radians
1 degree = 60 minutes (′) of arc
1 minute of arc = 60 seconds (″) of arc

6. Time

1 year (y or yr) = 3.1536×10^7 seconds (s or sec)
= 8.76×10^3 hours (h or hr)
1 day (d) = 8.64×10^4 sec = 1440 minutes (min)

7. Mass

1 kilogram (kg) = 2.205 pounds (lb)
1 metric ton (tonne or MT) = 10^3 kilograms (kg)
= 1.102 short tons
= 0.9842 long tons
1 pound (lb) = 16 ounces avoirdupois (oz) = 453.6 grams (g)

8. Energy

1 joule (J) = 1 kg m^2/sec^2
= 10^7 ergs = 0.2390 calories (cal)
= 9.484×10^{-4} British thermal units (Btu)
= 1 watt-second (Ws)
= 6.242×10^{18} electron volts (eV)
= 1 newton-meter (Nm)
1 kilowatt-hour (kWh) = 3.6×10^6 J
= 3414 Btu
1 quad = 10^{15} Btu = 1.05×10^{18} J
1 Calorie = 1 kilocalorie (Kcal) = 10^3 cal
1 therm = 10^5 Btu
1 foot pound = 1.356 J
1 kiloton of TNT (KT) = 4.2×10^{12} J

9. Power

1 watt (W) = 1 joule/second
1 horsepower (hp) = 0.746 kilowatts (kW)

10. Force

1 newton (N) = 1 kg m/sec^2 = 10^5 dynes (dyn)

11. Pressure

1 pascal = 1 N/m^2 = 1 J/m^3
1 bar = 10^5 pascal = 0.9869 atmospheres (atm)
1 atmosphere (atm) = 76 cm of mercury
= 14.7 lb/in^2
= 760 torr

12. Viscosity

1 poise (p) = 1 dyn-sec/cm^2 = 0.1 kg/m sec

13. Temperature

degrees Celsius* (°C) = 5/9 [degrees Fahrenheit (°F) − 32]
degrees Fahrenheit (°F) = 1.8 degrees Celsius (°C) + 32
Kelvin or absolute temperature scale. Kelvins (K) = degrees Celsius + 273.15

*Sometimes designated Centigrade

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14. Radiation units

1 becquerel (Bq) = 1 nuclear transformation/sec
1 curie (Ci) = 3.7×10^{10} transformations/sec
1 rad (rd) = an absorbed radiation dose of 100 ergs/g of absorbing material
1 gray (Gy) = 100 rd
1 roentgen (R) = an exposure to gamma or X radiation that produces 2.58×10^{-4} coulomb (C) of electric charge (counting either positive or negative but not both) per kg of dry air.
rem: a measure of "dose equivalent," is given by the dose in rads multiplied by the Quality Factor (QF):
rems = rads × QF
QF = 1 for gamma rays (photons) and beta rays (electrons and positrons)
= 10 for fission neutrons and protons
= 20 for alpha particles (nuclei of helium atoms)
1 sievert (Sv) = 100 rem

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15. Mathematical symbols

$=$	equals
$\neq$	not equal to
$>$	is greater than
$\geqslant$	is greater than or equal to
$>>$	is much greater than
∞	infinity
$\pm$	plus or minus (e.g., 11 ± 2 is the range of real numbers between 9 and 13)
$a:b$	the ratio of a to b
ppm	parts per million (10^6)
ppb	parts per billion (10^9)
ppm(v)	parts per million by volume
$\propto$	proportional to

$\approx$ or $\cong$	equals approximately
$\equiv$	identical to
$<$	is less than
$\leqslant$	is less than or equal to
$<<$	is much less than
$\sum_{i=1}^{n}$	sum over i from 1 to n
$\prod_{i=1}^{n}$	product over i from 1 to n
ΔX	a small change in X
$\left.\frac{\partial f(x,y)}{\partial x}\right\vert_{x=a,\ y=b}$	the partial derivative of the function, f, with respect to x evaluated at $x = a$ and $y = b$

e = base of natural logarithm = 2.718281828

II. Some Fundamental Constants of Physics and Chemistry

constants	values
Stefan-Boltzmann constant (σ)	$5.669 \times 10^{-8} \frac{J}{m^2\text{-}K^4\text{-}sec}$
Avogadro's number (A or N)	6.02×10^{23} molecules/mole*
Ideal Gas constant (R)	$8.310 \frac{J}{\text{mole K}}$
Boltzmann's constant (k)	1.38×10^{-23} J/K
Speed of light in vacuum (c)	2.9979×10^{8} m/sec
Planck's constant (h)	6.626×10^{-34} J sec
gravitational constant (G)	$6.67 \times 10^{-11} \frac{N\,m^2}{kg^2}$
mass of electron (M_e)	9.110×10^{-28} g
mass of proton (M_p)	1.673×10^{-24} g
mass of neutron (M_n)	1.675×10^{-24} g
charge of electron (e)	1.60210×10^{-19} coulombs (C)

*Throughout this appendix and the text, "mole" refers to a gram-mole, i.e., M grams of a substance where M is the substance's molecular mass. One mole of any gas at STP occupies a volume of 22.4 liters and contains Avogadro's number of molecules.

III. Earth's Vital Statistics

parameter	value
mass of Earth	5.98×10^{24} kg
mass of atmosphere	5.14×10^{18} kg
mass of stratosphere	0.5×10^{18} kg
mass of oceans	1.4×10^{21} kg
mass of water in atmosphere	1.3×10^{16} kg
mass of surface fresh water	1.26×10^{17} kg
mass of living organisms (dry weight)	1.3×10^{15} kg
number of moles of dry air in atmosphere	1.8×10^{20}
average height in atmosphere at which pressure is one half of sea level pressure	5,600 m
average elevation of top of troposphere	12,000 m
mean oceanic depth	3,730 m
mean depth of oceanic mixed surface layer	75 m
mean elevation of continents	840 m
average distance between Earth and Sun	1.495×10^{11} m
equatorial radius	6.38×10^{6} m
polar radius	6.36×10^{6} m
total area	5.10×10^{14} m^2
area of continents	1.48×10^{14} m^2
Eurasia	0.536×10^{14} m^2
Africa	0.298×10^{14} m^2
North and Central America	0.238×10^{14} m^2
South America	0.179×10^{14} m^2

Antarctica	0.149×10^{14} m^2
Oceania	0.089×10^{14} m^2
ice-free land	1.33×10^{14} m^2
area of oceans	3.61×10^{14} m^2
ice-free Pacific Ocean	1.66×10^{14} m^2
ice-free Atlantic Ocean	0.83×10^{14} m^2
Indian Ocean	0.65×10^{14} m^2
ice-free Arctic ocean	0.14×10^{14} m^2
sea ice (average)	0.33×10^{14} m^2
volume of oceans	1.35×10^{18} m^3
volume of mixed ocean layer	2.7×10^{16} m^3
mean density of Earth	5,500 kg/m^3
surface seawater density (15°C)	1,026 kg/m^3
acceleration of gravity at Earth's surface	9.8 m/sec^2
mean surface air temperature	288 K

IV. Astronomical Data

unit	value
1 parsec	3.084×10^{16} m
1 light year (ly)	9.46×10^{15} m
1 astronomical unit (AU) (mean radius of Earth's orbit)	1.49×10^{11} m
number of nucleons in the universe	10^{80}
radius of universe	10^{26} m
radius of sun	6.96×10^{8} m
mass of sun	1.99×10^{30} kg
mean distance from Earth to moon	3.84×10^{8} m
radius of moon	1.74×10^{6} m
mass of moon	7.34×10^{22} kg
period of lunar revolution about Earth	2.36×10^{6} sec

V. Air

1. Physical constants for dry air at STP*

constant	value
average molecular weight	28.96
specific heat	
at constant pressure	1,004.2 J/kg °C
at constant volume	719.6 J/kg °C
density	1.293 kg/m^3
viscosity	1.72×10^{-4} poise
coefficient of heat conductivity	0.0209 W/m °C
speed of sound in air	331.4 m/sec

*Standard temperature and pressure, denoted STP, is a temperature of 0°C and a pressure of 1 atm.

2. Composition of Earth's dry atmosphere (1983)*

gas	fraction by number of moles	fraction by weight
Nitrogen (N_2)	0.7808	0.7549
Oxygen (O_2)	0.2095	0.2314
Argon (Ar)	0.0093	0.0128
Carbon Dioxide (CO_2)	340 ppm	516 ppm
Neon (Ne)	18 ppm	12 ppm
Helium (He)	5.2 ppm	0.7 ppm
Methane (CH_4)	1.5 ppm	0.8 ppm
Krypton (Kr)	1.1 ppm	3.2 ppm
Hydrogen (H_2)	0.5 ppm	0.03 ppm
Nitrous Oxide (N_2O)	0.3 ppm	0.45 ppm
Carbon Monoxide (CO)	0.1 ppm	0.1 ppm
Ozone (O_3)	0.01 ppm	0.015 ppm
Nitrogen Dioxide (NO_2)	0.2 ppb	0.3 ppb
Sulfur Dioxide (SO_2)	0.2 ppb	0.4 ppb
Hydrogen Sulfide (H_2S)	0.05 ppb	0.05 ppb
Nitric Oxide (NO)	0.05 ppb	0.05 ppb
Ammonia (NH_3)	$<$ 0.05 ppb	$<$ 0.03 ppb

*Concentrations less than 1 ppm(v) are uncertain to $\pm 50\%$; all others are believed to be known to better than $\pm 10\%$. The mean fraction, by weight, of water vapor and cloud water in Earth's atmosphere is about 0.0025.

3. Some atmospheric time constants (order of magnitude only)

typical tropospheric residence time of particles with $>$ 20 micron diameter	$<$ 1 day
tropospheric residence time of many reactive or very soluble gases (e.g., SO_2, H_2S, NO_2, NO)	1 day
time for gases to mix vertically in the troposphere	10 days
typical tropospheric residence time of particles of $<$ 1 micron diameter	$>$ 100 days
time for interhemispheric mixing of tropospheric gases	1 year
mixing time within the stratosphere	10 years
tropospheric residence time of CO_2	10 years
tropospheric residence time of nonreactive gases that exit to stratosphere	10 years

VI. Water

1. General properties

property		value
density at 0°C		999.87 kg/m^3
	at 3.98°C	1,000.00 kg/m^3
	at 15°C	999.13 kg/m^3
	at 25°C	997.07 kg/m^3
molecular weight		18.015
latent heat of fusion at 0°C		3.33×10^5 J/kg or 79.6 cal/g
latent heat of vaporization		
	at 100°C	2.258×10^6 J/kg or 539.6 cal/g
	at 17°C	2.459×10^6 J/kg
	at 0°C	2.499×10^6 J/kg
specific heat of liquid water		
	at 15° C	4,184 J/kg °C or 1 cal/g °C
specific heat of water vapor		
	at 100°C, constant pressure	2,008.3 J/kg °C or 0.48 cal/g °C
specific heat of ice		
	at −2°C	2,100.4 J/kg °C or 0.502 cal/g °C
coefficient of heat conductivity		
	at 100°C	0.683 W/m °C
	at 17°C	0.595 W/m °C
	at 0°C	0.563 W/m °C
viscosity		
	at 100°C	2.8 millipoise
	at 17°C	11.0 millipoise
	at 0°C	17.5 millipoise

2. Stocks of water on Earth

stock	value (10^{15} m^3)
oceans	1,350
ice	29
groundwater*	8.3
freshwater lakes	0.125
saline lakes and inland seas	0.104
soil water	0.067
atmosphere	0.013

water in living biomass	0.003
average amount in stream channels	0.001

*About one half of the stock lies within a depth of 1 km.

3. Mean annual flows of water on Earth

flow	value (10^{12} m^3/yr)
world precipitation on land	108
world precipitation on the sea	410
world evaporation from the sea	456
world evapotranspiration from the land	62
world runoff	46
U.S. precipitation*	5.6
U.S. evapotranspiration*	3.95
U.S. runoff*	1.65

*Excluding Alaska and Hawaii

4. Water used by human beings

use	withdrawal (10^9 m^3/yr)*		consumption (10^9 m^3/yr)*	
	world	*U.S.*†	*world*	*U.S.*†
municipal and domestic	220	42	75	10
mining and manufacturing	390	52	40	6
electric power plant cooling	620	180	8	2.6
irrigation and live stock	2,100	205	1,100	125

*Water consumed is water rendered unavailable for direct further use; water withdrawn is water taken from a water supply but not necessarily consumed. Values here are estimated for 1980 and are uncertain to ± 10% for the United States, and ± 25% for the world.
†Excluding Alaska and Hawaii

VII. Energy

1. Energy flows*

flow	value (10^{12} W)
energy radiated by sun into space	3.7×10^{14}
solar radiation incident on the top of Earth's atmosphere	175,000
solar radiation reflected back to space from Earth	53,000
solar radiation reflected back to space from Earth's atmosphere	46,000

solar radiation absorbed in atmosphere (about 80% of this is absorbed in air and dust, and about 20% in cloud water)	44,000
rate at which latent heat flows from Earth's surface to atmosphere	42,000
rate at which infrared radiation leaving Earth's surface flows directly to space	10,200
rate at which convective heat flows from Earth's surface to atmosphere	8,600
wind, waves, ocean currents	500–2,000
net primary productivity on Earth	75–125
energy conducted from Earth's interior to its surface	20–40
world energy consumption (1980)	10
U.S. energy consumption (1980)	2.5
energy content of food consumed by world's human population (1980)	0.55
world electricity production (1980)	0.87
U.S. electricity production (1980)	0.26

*Values are uncertain to roughly ± 5% or less, except as indicated.

2. Earth's nonrenewable energy resources

resource	estimated stock (1980) (10^{21} J)	consumption (1980) (10^{18} J/yr)*	
		world	*U.S.*
petroleum	10	135	41
natural gas	10	60	20
coal	250	90	15
tar sands	>2	0	0
oil shale	2,000	0	0
uranium in non-breeding light water reactors	20	6.3	3.1
thorium and uranium in breeder reactors	10,000	0	0
deuterium and lithium in seawater (for fusion power)	10^{10}	0	0

*When fuels are used for electricity generation, the heat energy rather than the electrial energy is quoted. When the world figures are summed, the total is less than the value given in Table VI.1 for world energy consumption because Table VI.2 does not include use of renewables. Worldwide combustion of fuel wood and dung in 1980 produced about 30×10^{18} J and hydroelectric power produced about 6.1×10^{18} J of electricity. In the United States, hydropower yielded about 1.0×10^{18} J of electricity. Stocks are uncertain to ± 50%; consumption figures are reliable to ±1% in the United States and ±10% worldwide.

3. Average composition of fossil fuels

fuel	constituent	percentage*
coal†	$CH_{0.8}$	75
	H_2O	13
	ash	9
	S	2.5
	N	1.0
	Al	0.5
	Ca	0.5
	Mn	0.01
	Zn	0.005
	Pb	0.001
	Ni	0.001
	Cr	0.001
	Cu	0.001
	As	0.001
	Mo	0.0005
	Se	0.0001
	U	0.0001
	Hg	0.00001
	Cd	0.00001
petroleum (crude)	$CH_{1.5}$	98
	S	1.5
	N, O_2	<0.5
	Ni	0.001
	Mo	0.001
	Ca	0.001
natural gas	CH_4	75
	C_2H_6	6
	C_3H_8	4
	C_4H_{10}	2
	C_5H_{12}	1
	noncombustibles	12

*Percentages are by weight for coal and petroleum, and by number of moles for natural gas.
†Percentages add up to greater than 100 because the ash fraction includes some of the trace quantities listed below ash.

4. Energy content of selected substances

substance	energy content (10^6 J/kg)*
natural gas	3.9×10^7 J/m^3 (STP)
gasoline	48
petroleum (crude)	43 (6.1×10^9 J/bbl)
typical animal fat	38
coal	29.3
charcoal	29
paper	20
dry biomass	16
air-dried wood or dung	15
crop wastes (20% moisture)	13
bread	12
milk	3.0
beer	1.8

*Except where noted

VIII. The Elements

1. Abundance of the elements

element	Earth's crust (ppm)*	seawater (ppm)*	biomass (ppm)*†
O	456,000	857,000	630,000
Si	273,000	3	15,000
Al	83,600	0.01	500
Fe	62,200	0.01	1,000
Ca	46,600	400	40,000
Mg	27,640	1,350	4,000
Na	22,700	10,500	2,000
K	18,400	380	20,000
Ti	6,320	0.001	100
H	1,520	108,000	80,000
P	1,120	0.07	5,000
Mn	1,060	0.0002	100
F	554	1.3	50
Ba	390	0.03	300
Sr	384	8.1	200
S	340	885	5,000
C	180	28	200,000
V	136	0.002	—
Cl	131	19,000	2,000
Cr	122	0.00005	—
Ni	99	0.005	5
Zn	76	0.01	5
Cu	68	0.003	20
N	19	0.50	20,000
Pb	13	0.000005	< 0.2
B	9	4.6	100
Br	2.5	65	10
U	2.3	0.003	—
As	1.8	0.003	3
Hg	0.09	0.00003	—

* Parts per million on a weight-per-weight basis ✓

† Based on assumption of 50% water content of global biomass stock

2. Physical properties of the elements

name	symbol	atomic number	average atomic weight	atomic* weight of dominant isotopes	boiling† point (°C)	melting† point (°C)	density‡ $10^3 kg/m^3$	specific heat J/(kg) (K)
Actinium	Ac	89	**227**	**227**	—	1,050	—	—
Aluminum	Al	13	26.98	27	2,450	660	2.70	899
Americium	Am	95	**243**	**	—	—	11.7	138
Antimony	Sb	51	121.8	121, 123	1,380	630.5	6.62	205
Argon	Ar	18	39.95	40, 36, 38	−185.8	−189.2	1.40	523
Arsenic	As	33	74.92	75	613	817	5.72	343
Astatine	At	85	**210**	**219**	—	(302)	—	—
Barium	Ba	56	137.3	138, 137, 136, 135, 134, 130, 132	1,640	714	3.5	284
Berkelium	Bk	97	**247**	**	—	—	—	—
Beryllium	Be	4	9.01	9	2,770	1,277	1.85	1,881
Bismuth	Bi	83	**209**	**209**	1,560	271.3	9.8	142
Boron	B	5	10.81	11, 10	—	(2,030)	2.34	1,292
Bromine	Br	35	79.90	79, 81	58	−7.2	3.12	293
Cadmium	Cd	48	112.4	114, 112, 111, 110, 113, 116, 106, 108	765	320.9	8.65	230

				113, 116, 106, 108				
Calcium	Ca	20	40.08	40, 44, 42, 48, 43	1,440	838	1.55	623
Californium	Cf	98	**249**	**	—	—	—	—
Carbon	C	6	12.01	12, 13, **14**	48.3	3,727	2.26	690
Cerium	Ce	58	140.1	140, 142, 138, 136	3,468	795	6.67	176
Cesium	Cs	55	132.9	133	690	28.7	1.90	217
Chlorine	Cl	17	35.45	35, 37	−34.7	−101.0	1.56	485
Chromium	Cr	24	52.00	52, 53, 50, 54	2,665	1,875	7.19	460
Cobalt	Co	27	58.93	59	2,900	1,495	8.9	414
Copper	Cu	29	63.55	63, 65	2,595	1,083	8.96	385
Curium	Cm	96	**247**	**	—	—	—	—
Dysprosium	Dy	66	162.5	164, 162, 163, 161, 160, 158, 156	2,600	1,407	8.54	171

*This column includes the weights of naturally occurring isotopes. Stable isotopes that occur at levels of abundance greater than 0.01% are listed in order of decreasing abundance. Naturally occurring radioactive isotopes are listed in boldface and they follow the stable isotopes except in those cases where they occur at levels comparable to those of the stable isotopes. For properties of some of the more important artificial, radioactive isotopes, see Section XI, Table 1, of this Appendix.

**Indicates a synthetically produced element with no naturally occurring isotopes.

†Values are for 1 atmosphere pressure. Parentheses indicate that the value is for the most stable or best known isotope.

‡For elements that are solid or liquid at standard temperature and pressure (STP), these values reflect density at STP. Where elements occur in the gas phase at STP, the value listed is the density of that element's liquid phase at the boiling point under 1 atmosphere pressure.

name	symbol	atomic number	average atomic weight	atomic* weight of dominant isotopes	boiling† point (°C)	melting† point (°C)	density‡ 10^3kg/m³	specific heat (J/kg)
Einsteinium	Es	99	**254**	**	—	—	—	—
Erbium	Er	68	167.3	166, 168, 167, 170, 164, 162	2,900	1,497	9.05	167
Europium	Eu	63	152.0	153, 151	1,439	826	5.26	163
Fermium	Fm	100	**257**	**	—	—	—	—
Fluorine	F	9	19.00	19	−188.2	−219.6	1.51	752
Francium	Fr	87	**223**	**223**	—	(27)	—	—
Gadolinium	Gd	64	157.3	158, 160, 156, 157, 155, 154, 152	3,000	1,312	7.89	297
Gallium	Ga	31	69.72	69, 71	2,237	29.8	5.91	330
Germanium	Ge	32	72.59	74, 72, 70, 73, 76	2,830	937.4	5.32	305
Gold	Au	79	197.0	197	2,970	1,063	19.3	130
Hafnium	Hf	72	178.5	180, 178, 177, 179, 176, 174	5,400	2,222	13.1	146
Hahnium	Ha	105	**260**	**	—	—	—	—
Helium	He	2	4.00	4	−268.9	−269.7	0.12	5,225
Holmium	Ho	67	164.9	165	2,600	1,461	8.80	163

[illegible]			[illegible]	[illegible]	−268.9	−269.7	0.12	5,225
Holmium	Ho	67	164.9	165	2,600	1,461	8.80	163
Hydrogen	H	1	1.01	1, 2, **3**	−252.7	−259.2	0.07	14,421
Indium	In	49	114.8	**115,** 113	2,000	156.2	7.31	238
Iodine	I	53	126.9	127	183	113.7	4.94	217
Iridium	Ir	77	192.2	193, 191	5,300	2,454	22.5	130
Iron	Fe	26	55.85	56, 54, 57, 58	3,000	1,536	7.86	460
Krypton	Kr	36	83.80	84, 86 83, 82, 80, 78	−152	−157.3	2.6	—
Kurchatorium	Ku	104	**260**	**	—	—	—	—
Lanthanum	La	57	138.9	139, **138**	3,470	920	6.17	188
Lawrencium	Lr	103	**257**	**	—	—	—	—
Lead	Pb	82	207.2	208, 206, 207, 204, **210**	1,725	327.4	1.4	130
Lithium	Li	3	6.94	7, 6	1,330	180.5	0.53	3,302
Lutetium	Lu	71	175.0	175, **176**	3,327	1,652	9.84	155
Magnesium	Mg	12	24.31	24, 26, 25	1,107	650	1.74	1,045
Manganese	Mn	25	54.94	55	2,150	1,245	7.43	481
Mendelevium	Md	101	**256**	**	—	—	—	—
Mercury	Hg	80	200.6	202, 200, 199, 201, 198, 204, 196	357	−38.4	13.6	138

name	symbol	atomic number	average atomic weight	atomic* weight of dominant isotopes	boiling† point (°C)	melting† point (°C)	density‡ $10^3 kg/m^3$	specific heat (J/kg)
Molybdenum	Mo	42	95.94	98, 96, 95, 92, 100, 97, 94	5,560	2,610	10.2	255
Neodymium	Nd	60	144.2	142, 144, 146, 143, 145, 148, 150, **147**	3,027	1,024	7.00	188
Neon	Ne	10	20.18	20, 22, 21	−246	−248.6	1.20	—
Neptunium	Np	93	**237**	**	—	637	19.5	—
Nickel	Ni	28	58.71	58, 60 62, 61, 64	2,730	1,453	8.9	439
Niobium	Nb	41	92.91	93	3,300	2,468	8.4	272
Nitrogen	N	7	14.01	14, 15	−195.8	−210	0.81	1,033
Nobelium	No	102	**254**	**	—	—	—	—
Osmium	Os	76	190.2	192, 190, 189, 188, 187, 186, 184	5,500	3,000	22.6	130
Oxygen	O	8	16.00	16, 18, 17	−183	−218.8	1.14	911

				184				
Oxygen	O	8	16.00	16, 18, 17	−183	−218.8	1.14	911
Palladium	Pd	46	106.4	106, 108, 105, 110, 104, 102	3,980	1,552	12.0	242
Phosphorus	P	15	30.97	31	280	44.2	1.82	740
Platinum	Pt	78	195.09	195, 194, 196, 198, **190**	4,530	1,769	21.4	134
Plutonium	Pu	94	**244**	**	3,235	640	—	—
Polonium	Po	84	**209**	**210**	—	254	9.2	—
Potassium	K	19	39.10	39, 41, **40**	760	63.7	0.86	740
Praseodymium	Pr	59	140.9	141	3,127	935	6.77	201
Promethium	Pm	61	**145**	**	—	(1,027)	—	—
Protactinium	Pa	91	**231**	**231**	—	(1,230)	15.4	—
Radium	Ra	88	**226**	**226**	—	700	5.0	—
Radon	Rn	86	**222**	**222**	(−61.8)	(−71)	—	—
Rhenium	Re	75	186.2	**187**, 185	5,900	3,180	21.0	138
Rhodium	Rh	45	102.9	103	4,500	1,966	12.4	247
Rubidium	Rb	37	85.46	85, **87**	688	38.9	1.53	334
Ruthenium	Ru	44	101.1	102, 104, 101, 100, 99, 96, 98	4,900	2,500	12.2	238
Samarium	Sm	62	150.4	152, 154, **147**, 147, 148, 150, 144	1,900	1,072	7.54	176

name	symbol	atomic number	average atomic weight	atomic* weight of dominant isotopes	boiling† point (°C)	melting† point (°C)	density‡ $10^3 kg/m^3$	specific heat (J/kg)
Scandium	Sc	21	44.96	45	2,730	1,539	3.0	543
Selenium	Se	34	78.96	80, 78, 76, 82, 77, 74	685	217	4.79	351
Silicon	Si	14	26.09	28, 29 30	2,680	1,410	2.33	677
Silver	Ag	47	107.9	107, 109	2,210	960.8	10.5	234
Sodium	Na	11	22.99	23	892	97.8	0.97	1,233
Strontium	Sr	38	87.62	88, 86, 87, 84	1,380	768	2.6	736
Sulfur	S	16	32.06	32, 34, 33, 36	444.6	119.0	2.07	732
Tantalum	Ta	73	180.9	181, 180	5,425	2,996	16.6	151
Technetium	Tc	43	**96.91**	**	—	2,140	11.5	—
Tellurium	Te	52	127.6	130, 128, 126, 125, 124, 122, 123, 120	989.8	449.5	6.24	197
Terbium	Tb	65	158.9	159	2,800	1,356	8.27	184
Thallium	Tl	81	204.4	205, 203,	1,457	303	11.85	130
Thorium	Th	90	**232**	**232, 228**	3,850	1,750	11.7	142
Thulium	Tm	69	168.9	169	1,727	1,545	9.33	159

[illegible]	[illegible]	69	168.9	169	1,727	1,545	9.33	159
Tin	Sn	50	118.7	120, 118, 116, 119, 117, 124, 122, 112, 114, 115	2,270	231.9	7.3	226
Titanium	Ti	22	47.90	48, 49, 50, 46, 47	3,260	1,668	4.51	527
Uranium	U	92	**238**	**238, 235**	3,818	1,132	19.07	117
Vanadium	V	23	50.94	51, 50	3,450	1,900	6.1	502
Wolfram	W	74	183.9	184, 186, 182, 183, **180**	5,930	3,410	19.3	134
Xenon	Xe	54	131.3	132, 129, 131, 134, 136, 130, 128, 124, 126	−108.0	−111.9	3.06	—
Ytterbium	Yb	70	173.0	174, 172, 173, 171, 176, 170, 168	1,427	824	6.98	146
Yttrium	Y	39	88.91	89	2,927	1,509	4.47	297
Zinc	Zn	30	65.38	64, 66, 68, 67, 70	906	419.5	7.14	383
Zirconium	Zr	40	91.22	90, 94, 92, 91, 96	3,580	1,852	6.49	276

IX. Global Natural Background Flow to the Atmosphere of Selected Substances*

substance	rate (kg of substance/yr)†
CH_4	7×10^{11}
H_2S and SO_2	10^{11} kg(S)/yr
SO_4^{-2}	5×10^{10} kg(S)/yr
NO_x and NH_3	5×10^{11} kg(N)/yr
particles less than 20 microns in diameter	3×10^{12}
arsenic	2×10^7
cadmium	3×10^5
chromium	6×10^7
copper	2×10^7
lead	6×10^6
manganese	6×10^8
mercury	3×10^7
nickel	3×10^7
selenium	3×10^6
vanadium	7×10^7
zinc	4×10^7

*This includes dust emissions, volcanic eruptions, biological processes, and volatilization from land and water. The first three entries in the table are believed to be known to ± 30%. The others are far more uncertain and are order-of-magnitude estimates only.

†Except where noted

X. Chemical Reactions and Constants

1. Some important chemical reactions*

$106\ CO_2 + 16\ NO_3^- + HPO_4^{-2} + 18\ H^+ + 122\ H_2O \rightleftharpoons C_{106}H_{263}O_{110}N_{16}P_1 + 138\ O_2$	photosynthesis, respiration
$2\ N_2 + 6\ H_2O \rightarrow 4\ NH_3 + 3\ O_2$	nitrogen fixation
$NH_4^+ + 2\ O_2 \rightarrow NO_3^- + 2\ H^+ + H_2O$	nitrification
$4\ HNO_3 + 5\ CH_2O \rightarrow 5\ CO_2 + 7\ H_2O + 2\ N_2$	denitrification
$H_2SO_4 + 2\ CH_2O \rightarrow H_2S + 2\ H_2O + 2\ CO_2$	bacterial reduction of sulfate
$4\ FeS + 6\ H_2O + 11\ O_2 \rightarrow 4\ Fe(OH)_3 + 4\ H_2SO_4$ $4\ FeS_2 + 8\ H_2O + 15\ O_2 \rightarrow 2\ Fe_2O_3 + 8\ H_2SO_4$	acid production from ores (acid mine drainage)

$NO_2 + \text{light} \rightarrow NO + O$ $O + O_2 \rightarrow O_3$	ozone formation (in presence of hydrocarbon radicals, this reaction can lead to a significant increase in tropospheric ozone)
$NO + O_3 \rightarrow NO_2 + O_2$ $NO_2 + O \rightarrow NO + O_2$	catalytic cycle by which NO_x reduces stratospheric ozone
$6\ NO + 4\ NH_3 \rightarrow 6\ H_2O + 5\ N_2$	scrubbing of NO with ammonia
$H_2O + SO_2 + CaCO_3 \rightarrow CaSO_4 + H_2CO_3$	scrubbing of SO_2 with limestone
$SiO_2 + 2\ H_2O \rightarrow H_4SiO_4$	dissolution of quartz
$CaCO_3 + H_2O \rightarrow Ca^{+2} + HCO_3^- + OH^-$	dissolution of calcite
$CaCO_3 + H_2CO_3 \rightarrow Ca^{+2} + 2\ HCO_3^-$	carbonic acid weathering of calcite
$2\ KAlSi_3O_8 + 2\ H_2CO_3 + H_2O$ $\rightarrow Al_2Si_2O_5(OH)_4 + 4\ SiO_2 + 2\ K^+ + 2\ HCO_3^-$	carbonic acid weathering of feldspar to kaolinite
$3\ Ca_{0.33}Al_{4.67}Si_{7.33}O_{20}(OH)_4 + 2\ H^+ + 23\ H_2O$ $\rightarrow 7\ Al_2Si_2O_5(OH)_4 + 8\ H_4SiO_4 + Ca^{+2}$	acid weathering of calcium montmorillonite to kaolinite
$Al_2Si_2O_5(OH)_4 + 5\ H_2O$ $\rightarrow 2\ H_4SiO_4 + Al_2O_3 \cdot 3\ H_2O$	dissolution of kaolinite to gibbsite
$Al_2O_3 \cdot 3\ H_2O + 2\ H_2O \rightarrow 2\ Al(OH)_4^- + 2\ H^+$	dissolution of gibbsite

*The first six of these reactions are carried out biologically. The actual processes are more complex than is indicated by the expressions above, which represent the net reaction only. For example, nitrification is carried out in two steps: the bacteria, *Nitrosomonas*, converts NH_4^+ to NO_2^-, and *Nitrobacter* converts NO_2^- to NO_3^-.

2. Some chemical equilibrium dissociation constants (at 25°C)*

reaction	10^{-pK}
$H_2O \rightleftharpoons H^+ + OH^-$	10^{-14}
$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	$10^{-6.35}$
$HCO_3^- \rightleftharpoons H^+ + CO_3^{-2}$	$10^{-10.33}$
$HCl \rightleftharpoons H^+ + Cl^-$	$10^{3.0}$
$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$	$10^{3.0}$
$HNO_3 \rightleftharpoons H^+ + NO_3^-$	$10^{1.0}$
$HSO_4^- \rightleftharpoons H^+ + SO_4^-$	$10^{-1.9}$
$H_2SO_3 \rightleftharpoons H^+ + HSO_3^-$	$10^{-1.77}$
$HSO_3^- \rightleftharpoons H^+ + SO_3^{-2}$	$10^{-7.21}$
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$	$10^{-4.74}$
$H_3BO_3 \rightleftharpoons H^+ + H_2BO_3^-$	$10^{-9.3}$

*See the introduction to Chapter II, Section C for a discussion of how these are used in chemical equilibrium calculations.

3. Some values of Henry's constant* (at 25°C)

equilibrium ratio	Henry's constant (moles/liter-atm)
$\frac{[H_2SO_3]}{p(SO_2)}$	$10^{0.096}$
$\frac{[H_2CO_3]}{p(CO_2)}$	$10^{-1.47}$
$\frac{[H_2NO_3]}{p(NO_2)}$	$10^{-1.6}$
$\frac{[NH_3]}{p(NH_3)}$	$10^{1.76}$
$\frac{[CO]}{p(CO)}$	$10^{-3.0}$
$\frac{[N_2O]}{p(N_2O)}$	$10^{-1.59}$
$\frac{[H_2S]}{p(H_2S)}$	$10^{-0.97}$

*See the introduction to Chapter II, Section C for a discussion of how these are used in chemical equilibrium calculations.

4. Solubility products for solids* (at 25°C)

solid	solubility product (moles²/liter²)†	
calcite	$[Ca^{+2}][CO_3^{-2}] = 10^{-8.42}$	(fresh water)
aragonite	$[Ca^{+2}][CO_3^{-2}] = 10^{-8.22}$	(fresh water)
	$= 10^{-6.05}$	(seawater)
gypsum	$[Ca^{+2}][SO_4^{-2}] = 10^{-4.6}$	(fresh water)
dolomite	$[Ca^{+2}][Mg^{+2}][CO_3^{-2}]^2 = 10^{-16.7}$	(fresh water)

*See the introduction to Chapter II, Section C for a discussion of how these are used in chemical equilibrium calculations.
†The solubility product for dolomite has units of (moles⁴/liter⁴).

5. Equilibrium constants for acid-induced metal mobilization*

reaction	constant (liters/mole)†
$2\,H^+ + CuO \rightleftharpoons Cu^{+2} + H_2O$	$\frac{[Cu^{+2}]}{[H^+]^2} = 10^{7.7}$
$2\,H^+ + ZnO \rightleftharpoons Zn^{+2} + H_2O$	$\frac{[Zn^{+2}]}{[H^+]^2} = 10^{11.1}$
$2\,H^+ + Fe(OH)_2 \rightleftharpoons Fe^{+2} + 2\,H_2O$	$\frac{[Fe^{+2}]}{[H^+]^2} = 10^{12.9}$
$2\,H^+ + Cd(OH)_2 \rightleftharpoons Cd^{+2} + 2\,H_2O$	$\frac{[Cd^{+2}]}{[H^+]^2} = 10^{13.5}$
$2\,H^+ + Mn(OH)_2 \rightleftharpoons Mn^{+2} + 2\,H_2O$	$\frac{[Mn^{+2}]}{[H^+]^2} = 10^{15.2}$
$2\,H^+ + Mg(OH)_2 \rightleftharpoons Mg^{+2} + 2\,H_2O$	$\frac{[Mg^{+2}]}{[H^+]^2} = 10^{16.8}$
$2\,H^+ + Ca(OH)_2 \rightleftharpoons Ca^{+2} + 2\,H_2O$	$\frac{[Ca^{+2}]}{[H^+]^2} = 10^{22.8}$
$3\,H^+ + Al(OH)_3 \rightleftharpoons Al^{+3} + 3\,H_2O$	$\frac{[Al^{+3}]}{[H^+]^3} = 10^{8.5}$

*See Problem III.2 for a discussion of how these constants are used to estimate the effects of acidification on dissolved metal concentrations.
†The last reaction (aluminum) has an equilibrium constant in units of liters²/mole².

XI. Radiation and Radioactivity

1. Some important radioactive decay processes*

isotope	half-life	decay product	emitted radiation	maximum energy of radiation (MeV)
I^{131}	8.1 days	Xe^{131}	β^-	0.81
			γ	0.72
Sr^{89}	52 days	Y^{89}	β^-	1.5
Sr^{90}	28 yr	Y^{90}	β^-	0.59
Cs^{137}	30 yr	Ba^{137}	β^-	1.18
			γ	0.66
Pu^{239}	24,400 yr	U^{235}	α	5.15
			γ	0.05
U^{238}	4.5×10^9 yr	Th^{234}	α	4.18
			γ	0.05
C^{14}	5,700 yr	N^{14}	β^-	0.16
H^3 (tritium)	12.3 yr	He^3	β^-	0.018
Rn^{222}	3.8 days	Po^{218}	α	5.5
Po^{218}	3 min	Pb^{214}	α	6.0
Pb^{214}	27 min	Bi^{214}	β^-	0.7
			γ	0.35
Bi^{214}	20 min	Po^{214}	β^-	3.17
Po^{214}	0.00016 sec	Pb^{210}	α	7.68
Pb^{210}	22 yr	Bi^{210}	β^-	0.02
			γ	0.047

*The first four isotopes listed are among the major radioactive substances present in reactor cores or in radioactive wastes removed from these nuclear reactors; U^{238} is the dominant natural isotope of uranium; C^{14} is an important tracer in the environmental sciences and in archeology; and tritium is an important part of the radioactive debris from a hydrogen bomb explosion. The last six isotopes, which form a chain, are the critical reactions needed to estimate indoor air exposure from radioactive radon.

2. Human radiation exposure in the United States

natural sources	whole body annual dose (millirem/yr)
cosmic radiation*	30
C^{14}	1
terrestrial radionuclides†	
external to body	30
internal isotopes except radon daughters (mostly K^{40})	20
radon daughters in lungs††	100
anthropogenic sources	
diagnostic X rays	
dental	3
medical	95

therapeutic radiation	14
fallout from past atmospheric testing of nuclear weapons (dose in 1982)	2
television receivers	0.5
airline travel	0.5
nuclear energy (1980, worldwide general public only)	0.01

*This is the altitude-weighted average for the U.S. population.
†These figures vary geographically by a factor of at least two.
††Lung dose may be considerably higher for smokers.

XII. The Biosphere

1. Global biomass and productivity

location	living biomass stocks [10^{12} kg(C)]	dead organic matter [10^{12} kg(C)]	net primary productivity [10^{12} kg(C)/yr]
continental	560 + 300 − 100	1,500 ± 1,000	50 ± 15
oceanic	2 ± 1	2,000 ± 1,000	25 ± 10

2. Area, biomass, and productivity of ecosystem types

ecosystem type*	area (10^{12} m^2)	mean plant biomass [kg(C)/m^2]	average net primary productivity [kg(C)/m^2/yr]
tropical forests	24.5	18.8	0.83
temperate forests	12.0	14.6	0.56
boreal forests	12.0	9.0	0.36
woodland and shrubland	8.0	2.7	0.27
savanna	15.0	1.8	0.32
grassland	9.0	0.7	0.23
tundra and alpine meadow	8.0	0.3	0.065
desert scrub	18.0	0.3	0.032
rock, ice, and sand	24.0	0.01	0.015
cultivated land	14.0	0.5	0.29
swamp and marsh	2.0	6.8	1.13
lake and stream	2.5	0.01	0.23
open ocean	332.0	0.0014	0.057
upwelling zones	0.4	0.01	0.23
continental shelf	26.6	0.005	0.16
algal bed and reef	0.6	0.9	0.90
estuaries	1.4	0.45	0.81

*For a description of each of the major types of ecosystems (deserts, boreal forests, estuaries, etc.), see Whittaker (1970), Whittaker and Likens (1973), and Ehrlich et al. (1977).

XIII. Flows and Stocks of Carbon, Nitrogen, Phosphorus, and Sulfur on Earth*

1. Carbon flow

flow	magnitude 10^{12} kg(C)/yr
CO_2 flux to the atmosphere from decomposition and combustion of terrestrial organic matter and from animal respiration [This flow is nearly exactly balanced by a flow of inorganic carbon from the atmosphere to terrestrial living biomass in net primary productivity.]	50
inorganic carbon production in the oceanic mixed layer from decomposition of oceanic organic matter and animal respiration [This and the subsequent flow are nearly exactly balanced by a flow of inorganic carbon from seawater to living organisms in oceanic net primary productivity.]	20
inorganic carbon production in the deep ocean from decomposition of oceanic organic matter	5.0
net upwelling of inorganic carbon from deep ocean to the mixed oceanic layer	5.0
CO_2 flux to the atmosphere from fossil fuel burning and cement manufacturing	5.3
river flow of organic carbon to the oceans	0.2
deposition of carbon to oceanic sediment from sinking oceanic detritus	0.1
inorganic carbon production from weathering of rock and sediment	0.1

*Anthropogenic flows are believed to be known to within ±15%. Natural flows are often only crudely known. Most are uncertain to ±50%; and some, like the global biological nitrogen fixation rate, could be wrong by a factor of three (i.e., a value of 3 has a range of uncertainty from 1 to 9). Stocks in organic matter and in soil, rock, fuel, and sediments are believed to be known to within a factor of two. Atmospheric CO_2 and N_2 stocks are known to better than ±1%.

2. Nitrogen flow

flow	magnitude [10^{12} kg(N)/yr]
ammonification (production of NH_4^+ from organic nitrogen, the end stage of decomposition)	5
assimilation (conversion of NH_4^+ and NO_3^- to protein by vegetation and microbes; very roughly, one half of the nitrogen is assimilated as NH_4^+ and one half as NO_3^-, which was nitrified from NH_4^+)	5

natural background flow of NH_3 and NO_x from soil and water to the atmosphere	0.5
precipitation of NH_4^+ and NO_x to Earth's surface in rain and snow	0.1
denitrification (conversion of soil and water NO_3^- to atmospheric N_2 or N_2O, whose production rates are very roughly equal)	0.1
biological nitrogen fixation (about two thirds by continental organisms, one third by marine)	0.2
global anthropogenic nitrogen fixation in 1980 [Contributions from fossil fuel combustion was about one third of total; the remainder is mostly fertilizer production.]	0.1
river flow of fixed nitrogen to sea	0.01
fixation of atmospheric N_2 by lightning	0.01
production of stratospheric NO from N_2O	0.001

3. Sulfur flow

flow	magnitude [10^{12} kg(S)/yr]
plant uptake of sulfur	
continents	0.15
oceans	0.6
flow of SO_2 and SO_4^{-2} to Earth's surface, mostly in precipitation as H_2SO_4 and by dry deposition of aerosols	0.24
flow of S to the atmosphere from biological sources, sea spray, and volcanoes [about 33% of this flow is SO_4^{-2}, the remainder being H_2S and SO_2; the volcanic contribution is about 20% and the sea spray contribution is 25%.]	0.15
emissions to the atmosphere of SO_2 from fossil fuel burning, and metal-ore smelting (1980)	0.085
river flow of sulfur to the sea	0.1
fertilizer and industrial SO_4^{-2} production (1980)	0.03

4. Phosphorus flow

flow	magnitude [10^{12} kg(P)/yr]
uptake of PO_4^{-2} by living organisms (balanced by nearly equal rates of loss of phosphorus from living organisms by excretion and death)	
continental	0.2
marine	1.0

extraction of PO_4^{-2} from sediment for fertilizer, detergents, etc. (1980)	0.02
phosphorus in river flow to the sea	0.02
rate of guano deposition on land	0.0004
rate of extraction of phosphorus from the sea in harvested fish (1980)	0.0004

5. Major stocks of carbon

stock	magnitude [10^{12} kg(C)]
carbon in rock and sediment	10^7
carbon in fossil fuels	9,600
dissolved inorganic carbon in seawater	40,000
carbon in dead organic matter	
continental	1,500
marine	
deep ocean	2,000
mixed layer	40
CO_2 in the atmosphere (1980)	735
carbon in living organisms	
continental	560
marine	2

6. Major stocks of nitrogen

stock	magnitude [10^{12} kg(N)]
N_2 in the atmosphere	3.9×10^6
inorganic fixed nitrogen	
in soil	150
in seawater	350
in atmosphere	1.4
nitrogen in dead organic matter	
continental	100
marine	300
nitrogen in living organisms	
continental	7.5
marine	0.3

7. Major stocks of sulfur

stock	magnitude [10^{12} kg(S)]
dissolved SO_4^{-2} in seawater	1.4×10^6
sulfur in dead organic matter	50
sulfur in living organisms	3
sulfur in atmosphere (mostly SO_2, H_2S, SO_4^{-2})	0.004

8. Major stocks of phosphorus

stock	magnitude [10^{12} kg(P)]
phosphorus in living organisms	3
phosphorus in dead organic matter	25
inorganic phosphate in soil	200
dissolved and suspended phosphorus	
in the mixed ocean layer	3
in the deep ocean	100

XIV. Climate Data (see also Table VI.1)

1. Zonal climate parameters

latitude	surface air mean temperature (°C)		average albedo	precipitation (m/yr)	area of zone ($10^{12}m^2$)	net flow of energy to zone (W/m^2)*			
	January	*July*				Q_r	Q_e	Q_c	Q_o
80–90° N	−31	−1	0.65	0.19	3.9	−83	15	68	0
70–80° N	−25	2	0.5	0.26	11.5	−80	20	60	0
60–70° N	−22	12	0.41	0.97	18.8	−65	11	43	11
50–60° N	−10	14	0.39	0.72	25.5	−40	20	5	15
40–50° N	−1	20	0.35	0.78	31.6	−16	12	−5	9
30–40° N	11	26	0.32	0.77	36.7	5	−17	0	12
20–30° N	19	20	0.28	0.70	40.3	19	−41	21	1
10–20° N	25	28	0.25	1.17	42.8	31	−15	−3	−13
0–10° N	27	27	0.25	1.92	44.4	39	44	−51	−32
0–10° S	27	25	0.23	1.47	44.4	41	19	−32	−28
10–20° S	26	24	0.22	1.29	42.8	37	−21	−12	−4
20–30° S	25	18	0.25	0.85	40.3	27	−43	11	5
30–40° S	20	14	0.31	0.92	36.7	12	−25	5	8
40–50° S	12	8	0.34	1.02	31.6	−11	11	−8	8
50–60° S	5	1	0.41	0.97	25.5	−39	36	−12	15
60–70° S	0	−12	0.48	0.67	18.8	−81	40	41	0
70–80° S	−8	−30	0.57	0.25	11.5	−95	19	76	0
80–90° S	−13	−42	0.65	0.11	3.9	−95	8	87	0

*Q_r is the net radiation at the top of the atmosphere above the zone. A negative value means outgoing infrared plus reflected solar energy exceeds incoming solar energy. Q_e is the net latent heat flow to the zone, derived by subtracting annual evapotranspiration from precipitation and multiplying the difference by the latent heat of vaporization. Q_c is the net heat inflow to the zone convected poleward by atmospheric motions. Q_o is the net inflow of heat to the zone convected by ocean currents. A positive number represents an inflow to the zone; a negative number is an outflow. Within any zone, energy conservation leads to $Q_r + Q_e + Q_c + Q_o = 0$.

2. Albedos of selected surfaces on Earth

surface	albedo
snow	0.7 ± 0.2
sand	0.25 ± 0.05
grasslands	0.23 ± 0.03
bare soil	0.2 ± 0.05
forest	0.15 ± 0.1
water (highly dependent on surface roughness and incident angle of sunlight)	$0.2^{+0.6}_{-0.2}$

XV. Characteristics of "Standard" Adult Persons

characteristic	man	woman
mass (kg)	70	58
surface area (m^2)	1.8	1.6
total body water (% of mass)	60	50
total blood mass (kg)	5.5	4.1
breathing rate, resting (liters/min) (6–8 breaths/min)	7.5	6.0
breathing, light activity (liters/min) (12–14 breaths/min)	20	19
daily air intake (m^3)	22.8	21.1
daily water intake (kg)		
milk	0.30	0.20
tap water	0.15	0.10
other fluids	1.5	1.1
free water in food	0.70	0.45
from oxidation of food	0.35	0.25
protein intake (kg/day)	0.095	0.066
carbohydrate intake (kg/day)	0.39	0.27
fat intake (kg/day)	0.12	0.08
resting metabolic rate (J/sec-kg)	1.19	1.12
average food energy intake (J/day)	11.7×10^6	9.20×10^6
(or in terms of cal/day)	2.8×10^6	2.2×10^6
carbon dioxide exhaled (kg/day)	1.0	0.90

XVI. Human Population Estimates

year	global population (10^9 people)	U.S. population (10^9 people)
1650	0.5	
1850	1.1	0.023
1900	1.6	0.076
1910	1.7	0.092
1930	2.0	0.123
1950	2.5	0.152
1960	3.0	0.181
1970	3.6	0.205
1980	4.5	0.227
1983	4.7	0.234

Sources of the Data in the Appendix

References for each section are listed below, followed by the numbers of the subsections for which they were used. (Not all sections are subdivided.) Full references are listed in the Bibliography.

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