Appendix 1
Useful Information About the Earth

Metric System, Conversion Factors, Etc.

Conversions of common units

Abbreviations	
cm = centimeter, mi = mile, m = meter, ft = feet, gm = gram, kg = kilogram, lbs = pounds	kWh = kilowatt hour, kcal = kilo-calory
Length	
1 mi = 1.6 km 1 km = 0.62 mi 1 nautical mile (nm) = 1.85 km	1 foot = 0.3 m 1 m = 3.3 ft (also 1 fathom = 6 ft)
1 inch = 2.54 centimeters 1 centimeter = 0.39	1 kg = 2.2 pounds 1 pound = 0.45 kg
Volume	
1 liter = 10^3 cm^3 = 1.06 quarts = 0.264 US gallons = 1.0567 quarts	1 m^3 = 35.3 ft^3 = 264 US gallons
Mass and weight	
1 kg = 2.2 pounds	1 Tonne (metric ton) =10^6 gms = 2205 pounds
1 ton (short) = 2000lbs (this is the US ton we are accustomed to)	1 ton (long) = 2240lbs (this is used in US and Britain)
Speed	
1 knot (nautical mile per hour) = 1.15 statute miles per hour = 0.51 m/sec	
Energy	
1 gm calorie = 1/360 watt-hr = 1/252 BTU = 4.18 joules	1 joule = 2.7778×10^{-7} kWh = 2.39×10^{-4} kcal = 9.48×10^{-4} BTU
1 kWh = 3.6×10^6 joules	
Power = energy/time	
1 watt = 1 joule/sec = 0.056896 BTU/minute	
Pressure	
1 bar = 0.98692 atm = 14.5 lbs/in^3	

Temperature in Celsius or Centigrade vs. Fahrenheit

1˚C = 5/9 ˚F
1˚F = 9/5˚C

water boils at 100˚C (212˚F)
water freezes at 0˚C (32˚F)

to get a temperature in ˚C from one in ˚F,
subtract 32, then multiply by 5/9
to get a temperature in ˚F from one in ˚C,
multiply by 9/5, then add 32

for those who are up on their algebra, the actual conversion formulas are:

$C = 5/9\,(F-32)$

$F = 9/5C + 32$

SCIENTIFIC NOTATION

See also Lab 1 homework

10^3 = one thousand
10^6 = one million
10^9 = one billion

1 km = 10^3 m (kilometers, meters)
1 m = 10^2 cm (centimeters)
1 m = 10^3 mm (millimeters)

Conversion factors between fuel burned and kg of CO_2 put into the atmosphere

Fuel Type		CO2 conversion factor	
Natural Gas:		2.2 kg/m^3	
Oil:		3.0 kg/liter (1 liter = 0.264 US Gallons - see below)	
Gasoline		2.5 kg/liter	
Electricity		0.22 kg/kw-hr (depends on mix of fuels used in generating plant.	
Public transit		0.04 kg/km (depends on average number of riders)	
Railway		0.17 kg/km (depends on number of passengers)	
Air travel		0.25 kg/km (depends on occupancy)	

Related energy conversion factors:

1 petajoule = 10^15 joules = 20.778x10^8 kilowatt-hrs

= 9,478x10^-7 Quads = 9.478x10^11 BTUs

1 petaJoule = 163,400 "UN Standard" barrels of oil, or 34,140 "UN Standard" metric tons of coal.

Mass of CO2 = 3.664*(Mass of Carbon)

CO2 release from burning oil= 1.5*(C)2 released by burning natural gas)

Other conversions needed to interpret global energy and CO_2 data:

1 liter = 0.264 US Gallons = 0.001 cub1ic meter = 1,000 cubic cm

1 metric ton (tonne)= 2204.62 pounds = 1,000 kg

1 ton (US) = 2,000 pounds = 907.185 kg

1 barrel of crude oil produces about 19.5 gallons of gasoline

'Three to five trees planted will fix about one tonne of CO_2*

*Although it is impossible to reach a precise formula, every three to five trees planted will 'fix' about one tonne of CO_2 over time.

Data About the Earth and Oceans

Dimensions of the Earth:

SIZE AND SHAPE OF THE EARTH		
Dimensions	Miles	Kilometers
Equatorial radius	3963	6378
Polar radius	3950	6357
Average radius	3956	6371
Equatorial circumference	24,902	40,077

AREAS OF THE EARTH, LAND, AND OCEAN		
PART OF EARTH	Millions of square miles	Millions of square kilometers
Land (29.22%)	57.5	149
Ice sheets and glaciers	6	15.6
Oceans and seas (70.78%)	139.4	361
Land plus continental shelf	68.5	177.4
Oceans and seas minus continental shelf	128.4	332.6
Total area of the Earth	196.9	510.0

DISTRIBUTION OF LAND AND WATER ON THE EARTH'S SURFACE*		
HEMISPHERE	LAND (percent)	OCEAN (percent)
Northern	39.3	60.7
Southern	19.1	80.9

*After Sverdrup, Johnson, and Fleming. 1942. p. 13.

Heights and Depths of the Earth's Surface

LAND			OCEANS AND SEAS		
HEIGHT	FEET	METERS	DEPTH	FEET	METERS
Greatest height:			**Greatest known depth:**		
Mount Everest	29,028	8848	Mariana Trench	36,200	11,035
Average height	2757	840	Average depth	12,460	3800

Volume, Density, and Mass of the Earth and Its Parts*

PART OF EARTH	AVERAGE THICKNESS OR RADIUS (km)	VOLUME (x 10^6 km^3)	MEAN DENSITY (g/cm^3)	MASS (x 10^{24} g)	RELATIVE ABUNDANCE (percent)
Atmosphere	—	—	—	0.005	0.00008
Oceans and seas	3.8	1370	1.03	1.41	0.023
Ice sheets and glaciers	1.6	25	0.90	0.023	0.0004
Continental crust†	35	6210	2.8	17.39	0.29
Oceanic crust‡	8	2660	2.9	7.71	0.13
Mantle	2881	898,000	4.53	4068	68.1
Core	3473	175,500	10.72	1881	31.5
Whole Earth	6371	1,083,230	5.517	5976	

* From Holmes. 1965
† Including continental shelves.
‡ Excluding continental shelves.

Ocean Provinces*

OCEAN†	SHELF AND SLOPE (percent)	CONTINENTAL RISE (percent)	DEEP-OCEAN FLOOR (percent)	VOLCANOES AND VOLCANIC RIDGES (percent)	RISE AND RIDGE (percent)	TRENCHES (percent)
Pacific	13.1	2.7	43.0	2.5	35.9	2.9
Atlantic	19.4	8.5	38.0	2.1	31.2	0.7
Indian	9.1	5.7	49.2	5.4	30.2	0.3
World ocean	15.3	5.3	41.8	3.1	32.7	1.7
Earth's surface	10.8	3.7	29.5	2.2	23.1	1.2

* After H. W. Menard and S. M. Smith. 1966. Hypsometry of ocean basin provinces. *J. Geophys. Res.* 71:4305.
† Includes adjacent seas—for example, Arctic Sea included in Atlantic Ocean.

Taken from:
Oceanography A View of the Earth 5th edition by M. Grant Gross.

Surface and Drainage Areas of Ocean Basins and Their Average Depths*

OCEAN†	OCEAN AREA (millions of square kilometers)	LAND AREA DRAINED‡ (millions of square kilometers)	RATIO OI OCEAN AREA TC DRAINAG AREA	AVERAGI DEPTH† (meters)
Pacific	180	19	11	3940
Atlantic	107	69	1.5	3310
Indian	74	13	5.7	3840

*From H. W. Menard and S. M. Smith. 1966. Hypsometry of ocean basin provinces. *J. Geophys. Res*. 71.4305.
† Includes adjacent seas, Arctic, Mediterranean, and Black seas included in the Atlantic Ocean.
‡ Excludes Antarctic and continental areas with no exterior drainage.

Average Temperatures and Salinity of the Oceans. Excluding Adjacent Seas*

	TEMPERATURE (˚C)	SALINITY (Parts per thousand)
Pacific (total)	3.14	34.60
North Pacific	3.13	34.57
South Pacific	3.50	34.63
Indian (total)	3.88	34.78
Atlantic (total)	3.99	34.92
North Atlantic	5.08	35.09
South Atlantic	3.81	34.84
Southern Ocean†	0.71	34.65
World ocean (total)	3.51	34.72

*After L. V. Worthington. 1981. The water masses of the world ocean: some results of a fine-scale census. pp. 42-69. In *Evolution of Physical Oceanography*. ed. B. A. Warren and C. Wunsch Cambridge, Mass.: MIT Press. 623 pp.
†Ocean area surrounding Antarctica. South of 55˚S.

Water Sources for the Major Ocean Basins (centimeters per year)*

OCEAN	PRECIPITATION	RUNOFF FROM ADJOINING LAND AREAS	EVAPORATION	WATER EXCHANGE WITH OTHER OCEANS
Atlantic	78	20	104	6
Arctic	24	23	12	35
Indian	101	7	138	30
Pacific	121	6	114	13

*From M. I. Budyko. 1958. *The Heat Balance of Earth's Surface*. Trans. N. A. Stepanova. Office of Technical Services. Department of Commerce. Washington, D. C.

Characteristics of Trenches*

TRENCH	DEPTH (kilometers)	LENGTH (kilometers)	AVERAGE WIDTH (kilometers)
Pacific Ocean			
Kurile-Kamchatka Trench	10.5	2200	120
Japan Trench	8.4	800	100
Bonin Trench	9.8	800	90
Mariana Trench	11.0	2550	70
Philippine Trench	10.5	1400	60
Tonga Trench	10.8	1400	55
Kermadec Trench	10.0	1500	40
Aleutian Trench	7.7	3700	50
Middle America Trench	6.7	2800	40
Peru-Chile Trench	8.1	5900	100
Indian Ocean			
Java Trench	7.5	4500	80
Atlantic Ocean			
Puerto Rico Trench	8.4	1550	120
South Sandwich Trench	8.4	1450	90

*After R. W. Fairbridge. 1966. Trenches and related deep sea troughs. In *The Encyclopedia of Oceanography*. ed. R. W. Fairbridge. pp. 929-38. New York: Reinhold Publishing Corporation.

Some Elements in Seawater

Arrows indicate most abundant elements in seawater

m mol = 10^{-3} moles
μ mol = 10^{-6} moles
n mol = 10^{-9} moles
p mol = 10^{-12} moles

		Element	Most Common Chemical Form in Seawater	Average Concentration at 35%	Depth Distributio
	Ag	silver	$AgCl_4^{2-}$	25 pmol/kg‡	N
	Al	aluminum	$Al(OH)_4^-$, $Al(OH)_3^0$	20 nmol/kg	M
	Ar	argon	Ar (gas)		
	As	arsenic	AsO_4H^{2-}	23 nmol/kg	B
	Au	gold	$AuCl_4^-$	?	?
→	B	boron	$B(OH)_3$	0.42mnol/kg	C
	Ba	barium	Ba^{21}	100 nmol/kg	N
	Be	beryllium	BeOH-, $Be(OH)_2^0$	20 pmol/kg	NS
	Bi	bismuth	$BiOH^-$, $Bi(OH)_2^-$	0.1-0.2 pmol/kg	ND
→	Br	bromine	Br^-	.84 mnol/kg	C
→	C	carbon	CO_3H^-, organic C	2.3 mmol/kg	NS
→	Ca	calcium	$Ca2^-$	10.3 mmol/kg	S
	Cd	cadmium	$CdCl_2^0$	0.7 nmol/kg	N
	Ce	cerium	$CeCO_3^-$, Ce^{3+},$CeCl^{2+}$	20 pmol/kg	S
→	Cl	chlorine	Cl^-	0.546 mol/kg	C
	Co	cobalt	$Co2^-$, $CoCO_3^0$, $CoCL^+$	0.02 nmol/kg	S, ND
	Cr	Chromium	$CrOO_4^{2-}$, $NaCrO_4$	4 nmol/kg	N
	Cs	cesium	Cs^-	2.2 nmol/kg	N, NS
	Cu	copper	$CuCO_3^0$, $CuOH^-$, Cu^{2+}	4 nmol/kg	N
	F	fluorine	F^-, MgF^+	68µmol/kg	C
	Fe	iron	$Fe(OH)_3^0$	1 nmol/kg	S, ND
	Ga	gallium	Ga(OH)	?	?
→	H	hydrogen	H_2O		
	He	helium	He (gas)		
	Hf	hafnium			

		Element	Chemical Form	Average Concentration at 35%	Depth Distribution
	Hg	mercury	$HgCl_4^{1-}$	5 pmol/kg	?
	I	iodine	IO_2^-	0.4 µmol/kg	N
	In	indium	In(OH)1	?	?
→	K	potassium	K^-	0.2 mmol/kg	C
	Kr	krypton	Kr (gas)		
	La	lanthanum	La^{2-}, $LaCO_3^-$, $LaCl^{2-}$	30 pmol/kg	S
	Li	lithium	Li^-	2.5 µmol/kg	C
→	Mg	magnesium	Mg^{2-}, $MnCl^-$	53.2 mnol/kg	C
	Mn	manganese	Mn^2,MnC^-	0.5 nmol/kg	ND
	Mo	molybdenum	MoO_4^{2-}	0.11 µmol/kg	C
	N	nitrogen	NO_3^-, NH_4^-, N_2 (gas)	30 µmol/kg	N
	Na	sodium	Na^-	0.468 mol/kg	C
	Nd	neodymium	$NdCO_3^-$, $NdSO_4^-$	20 pmol/kg	S
	Ne	neon	Ne (gas)		
	Ni	nickel	Ni^{2-}, $NiCO_1^0$, $NiCl^-$	8 nmol/kg	N
→	O	oxygen	OH_2, SO_4^{2-}, O_2 (gas)	0-300 µmol/kg	-
	P	phosphorus	HPO_4^{2-}, $NaHPO_4^-$, $MgHPO_4^0$	2.3 µmol/kg	N
	Pa	protoactinium			
	Pb	lead	$PbCO_1^0$, $Pb(CO_1)_2^1$, $PbCl^-$	10 pmol/kg	ND
	Ra	radium			
	Rb	rubidium	Rb^-	1.4 µmol/kg	C
	Rn	radon	Rn (gas)		
→	S	sulfur	SO_4^{2-}, $NaSO_4^-$, $MgSO_4^0$	28.2 mmol/kg	C
	Sb	antimony	$Sb(OH)_3^-$	?	?
	Sc	scandium	$Sc(OH)_3^0$	15 pmol/kg	S
	Se	selenium	SeO_4^{2-}, $HSeO_3^-$	1.7 nmol/kg	N
	Si	silicon	$Si(OH)_4$	100 µmol/kg	N
	Sn	tin	$SnO(OH)_3^-$	4 pmol/kg	++
	Sr	strontium	Sr^{2-}	90 µmol/kg	S
	Ta	tantalum			
	Th	thorium			
	Ti	titanium	$Ti(OH)_4^0$	<20 nmol/kg	?
	Tl	thallium	Tl^-		
	U	uranium	$UO_2(CO_3)_1^{4-}$		
	V	vanadium	HVO_4^{2-}, $H_2VO_4^-$	30 nmol/kg	S
	W	tungsten	WO_4^{2-}		
	Xe	xenon	Xe (gas)		
	Y	yttrium	YCO_3^+,YOH^+, Y^{1+}	?	?
	Zn	zinc	Zn^{2+}, $ZnOH^+$, $ZnCO_1^0$, $ZnCl^+$	6 nmol/kg	N
	Zr	zirconium	$Zr(OH)_4^0$.$Zr(OH)_4^-$	?	

* After K. Bruland. 1983. *Trace Elements in Seawater*. *Chemical Oceanography.* ed. J. P. Riles and R. Chester. 8:157-221. New York: Academic Press.
C - conservative: S - surface depletion: M - middepth minima
N - nonconservative, depleted in surface waters, enriched at depth (nutrient-type)
ND - nonconservative, depleted at depth
NS - nonconservative, scavenging
++ - high in surface waters
+ - mirror image of nutrient-type concentration
m mol = 10^{-3} moles, µ mol = 10^{-6} moles,
n mol = 10^{-9} moles, p mol = 10^{-12} moles

Taken from: Oceanography A View of the Earth 5th edition by M. Grant Gross

Major Types of Oceanic Phytoplankton

TYPE AND CHARACTERISTICS	LOCATION	COLOR AND APPEARANCE	METHOD OF REPRODUCTION
DIATOMS:			
silica and pectin "pill-box" cell wall, sculptured designs: of major importance for coastal ocean productivity; has floating and attached forms	Everywhere in surface ocean, especially in colder waters, upwelling areas, even in polar ice; some heterotrophic below photic zone; some form "resting spore" under adverse conditions	Size: 0.01-0.2 mm Yellow-green or brownish: single cells or chains of cells; radial or bilateral symmetry; many have spines or other floatation devices	Division, splitting of nuclear material; average reduction of one cell-wall thickness at each division when limiting size is reached, cell contents escape, form new cell
Dinoflagellates:			
next to diatoms in productivity; many heterotrophic, ingest particulate food; some have cellulose "armor"; very small open-ocean species are naked	In all seas, and below photic zone; some parasitic; warm-water species very divers; some have resting stage for protection; sometimes abundant in coastal areas as "red tide"	Size: 0.005-0.1 mm Usually brownish, one-celled; have two whiplike flagellae for locomotion; many are luminescent	Simple, longitudinal, or oblique divisions; daughter cells achieve size of parent before diving
Coccolithophores:			
covered with calcareous plates, embedded in gelatinous sheath; important source of food for filter-feeding animals	Mainly in opens seas, topical and semitropical; sometimes proliferate near coasts' some heterotrophic forms at depths to 3000 meters	Size: 0.005-0.05 mm Many flagellated; often round or oval single cells; when present in great numbers, they give the water a milky appearance	Simple cell division
Cyanobacteria (also called Blue-Green Algae):			
small, relatively simple cell structure: cell wall of chitin	Mainly inshore, warmer surface waters, tropics	Size: filaments to 0.1 mm or more Blue-green or red rafts of mottled filaments; can cause a colored "bloom" in water	Simple division of each cell

Taken from:
<u>Oceanography A View of the Earth</u> 5th edition by M. Grant Gross

Classification of Marine Organisms

Biologists categorize organisms using taxomonic classification to identify and describe similarities among marine organisms. After basic similarities in external form, internal anatomy, and biochemical characteristics are determined, groups are fitted into a system of increasingly more inclusive categories.

Taxonomic classification is used to study evolutionary relationships of organisms. It also shows the many different kinds of organisms that live in the ocean. Indeed, most of the organisms that ever lived on Earth inhabited the ocean. Life has existed in the ocean for at least 3800 million years, compared with only 450 million years on land.

The fundamental unit of taxonomy is the species, de-fined as a group of closely related individuals that can and usually do interbreed. (Many marine organisms are known only from preserved (dead) specimens.)

Some 75 million species have appeared since life bebegan on Earth. More than 2 million are living today. In this appendix, we are primarily concerned with major groups of marine organisms, which are classified as follows:

- Kingdom
  - Phylum
    - Subphylum
      - Class
        - Order
          - Family
            - Genus
              - Species

KINGDOM MONERA- dominantly unicellular organisms, lacking nuclear membranes. Nuclear materials occur throughout the cells.

Phylum Schizophyta--smallest cells, bacteria.
Phylum Cyanophyta--green algae.
Phylum Phaeophyta--brown algae.
Phylum Rhodophyta--red algae.
Phylum Protozoa--heterotrophs.
Class Sarcodina--ameboid, includes foramini-ferans and radiolarians.
Class Mastigophora--flagellated; includes di-noflagellates.

KINGDOM FUNGI
Phylum Mycophyta--fungi and lichens.

KINGDOM METAPHYTA--multicellular plants.
Phylum Tracheophyta--vascular plants with roots, stems, and leaves; separate liquid transport system.
Class Angiospermae--flowering plants, with seeds.

KINGDOM METAZOA--multicellular animals.
Phylum Porifera -- sponges.
Class Calcarea --calcium carbonate spicules.
Class Hexacinellida -- glass sponges.
Phylum Cnidaria -- radially symmetrical, polyp (benthic) and medusa (planktonic) stages.
Class Hydrozoa -- polyp colonies, includes Portuguese man-of-war.
Class Scyphozoa--jellyfish.
Class Anthozoa--corals and anemones.
Phylum Ctenophora--planktonic comb jellies; eight-sided radial symmetry with secondary bilateral symmetry.
Phylum Platyhelminthes--flatworms, bilateral symmetry.
Phylum Nemertea--ribbon worms, benthic and pelagic.
Phylum Nematoda--roundworms, free-living benthic; mostly meiofauna.
Phylum Branchiopoda--lamp shells, benthic bivalves.
Phylum Phoronida--horsehoe worms, shallow-water benthic.
Phylum Sipuncula--peanut worms, benthic.
Phylum Echiura--spoon worms, benthic.
Phylum Pogonophora--tube-dwelling, gutless worms; absorb organic matter through skin.
Phylum Tardigrada--marine meiofauna.
Phylum Mollusca--soft bodies; posses muscular foot and mantle; usually secrete calcium carbonate shell.
Class Polyplacophora--chitons, oval, flattened body covered by eight overlapping plates.
Class Gastropoda--snails and related forms; many with spiral shell.
Class Bivalvia--clams, mussels, oysters and scallops; mostly filter feeding.
Class Aplacophora--tusk shells; benthic; feed on meiofauna.
Class Cephalopoda--octopus, squid and cuttlefish; possess no external

shell (except Nautilus).

Phylum Annelida--segmented worms, mostly benthic.

Phylum Arthropoda--joint-legged, segmented bodies; covered by exoskeleton.

Subphylum Crustacea--calcareous exoskeletons; two pairs of antenae; includes copepods, ostracods, barnacles, shrimp, lobsters, and crabs.

Phylum Chaetognatha-arrow worms; mostly plankton.

Phylum Hemichordata--acorn worms and pterobranchs; primitive nerve chord; benthic.

Phylum Echinodermata--spiny skinned; secondary radial symmetry; water vascular system; benthic.

Class Astreoidea--starfishes, flattened body with five or more rays; tube feet used for locomotion.

Class Ophiuroidea--brittle stars, basket stars; central disc with slender rays; tube feet used for feeding.

Class Echinoidea--sea urchins, sand dollars; calcium carbonate tests.

Class Holothuroidea--sea cucumbers; soft bodies with radial symmetry.

Class Crinoidea--sea lillies; cup-shaped body attached to bottom by jointed stalk or appendages.

Phylum Chordata--notochord; nerve chord and gills or gill slits.

Subphylum Vertebrata--internal skeleton; spinal column; brain.

Class Agnatha--lampreys and hagfishes; most primitive vertebrates; cartilaginous skeletons, no jaws, no scales.

Class Chondrichthyes--sharks, skates and rays; cartilaginous skeletons.

Class Osteichthyes--bony fishes, covered gill openings, swim bladder common.

Class Reptilia--snakes, turtles, lizards, and alligators.

Class Aves--birds.

Class Mammalia--warm-blooded; hair; mammary glands; bear live young.

* Adapted after H. V. Thurman and H. H. Webber. 1984. *Marine Biology*. Columbus, Ohio: Charles E. Merrill Publishing Company.

From: Oceanography A View of the Earth 5th edition by M. Grant Gross

Table 6.1
Estimated Relative Abundances of the 20 Most Common Elements in the Universe, In Terms of the Number of Atoms of That Element per Million Hydrogen Atoms

Other than hydrogen and helium, the abundances of the elements are a reflection of nuclear reactions in stars. It is seen that hydrogen and helium comprise the vast majority of all materials. Presumably, the earth and inner planets are made of the small residue left over when the hydrogen and helium escaped.

Element	Atomic Number[a]	Atomic Weight[b]	Abundance Relative to 10^6 Hydrogen Atoms
Hydrogen (H)	1	1	1,000,000
Helium (He)	2	4	80,000
Oxygen (O)	8	16	690
Carbon (C)	6	12	420
Nitrogen (N)	7	14	87
Silicon (Si)	14	28	40
Neon (Ne)	10	20	37
Magnesium (Mg)	12	24	32
Iron (Fe)	26	56	25
Sulphur (S)	16	32	16
Aluminum (Al)	13	27	3.3
Calcium (Ca)	20	40	2.5
Nickel (Ni)	28	59	2.1
Sodium (Na)	11	23	1.9
Argon (Ar)	18	40	1.0
Chromium (Cr)	24	62	0.69
Phosphorus (P)	15	31	0.39
Manganese (Mn)	25	55	0.26
Chlorine (Cl)	17	35	0.22
Potassium (K)	19	39	0.12

[a]Atomic number is the number of protons in the nucleus or equivalently, the number of electrons in the electron cloud.
[b]Atomic weight is the total number of nucleons (i.e., protons and neutrons) in the nucleus, given here for the most common isotope of each.

TABLE 6.2
Dissociation of the Most Common Ions in Seawater

Ion	Percent as a Free Ion
Positive	
Sodium (Na^-)	99
Magnesium (Mg^{2-})	87
Calcium (Ca^{2-})	91
Potassium (K^-)	99
Negative	
Chloride (Cl^-)	100
Sulfate ($SO_4{}^{2-}$)	50
Bicarbonate ($HCO_3{}^-$)	67
Bromide (Br^-)	100

THE WATER MOLECULE

TABLE 6.3
The Melting and Boiling Points for Materials with Light Molecules
At atmospheric pressure, heavier molecules move more slowly, which is reflected in higher melting and boiling points, usually. Notice that the melting and boiling points for water are extremely high for a molecule so light. This is because it is electrically polarized and therefore "sticky." The two organic materials are included to show that for fairly symmetrical molecules, their masses must be roughly six times heavier to have similarly high melting and boiling points.

Material	Molecular Weight	Melting Point (K)	Boiling Point (K)
H_2	2	14	20
He	4	—	5.2
CH_4	16	90	111
H_2O	18	273	373
N_2	28	63	77
O_2	32	55	90
HCl	36	161	189
CO_2	44	(Sublimes)	194
C_2H_5OH (ethyl alcohol)	46	161	351
C_8H_{18}(octane)	114	216	399

from "Essentials of Oceanography" by Stowe, Pub Wiley, 1987

TABLE 6.12
Comparison of the Abundances of Various Gases in Seawater with their Abundances in the Atmosphere

Gas	Abundance in Dry Air (%)	Abundance in Seawater (ppm)	Ratio of Total Amount in the Oceans to Total Amount in the Atmosphere
N_2	78.0	12.0	0.004
O_2	21.0	7.0	0.01
CO_2	0.03	90.0	62.0

TABLE 6.4
The Average Molecular Velocities for the Inert Gases at Various Temperatures
For comparison, the escape velocity from the earth is 11.2 km/sec.

Inert Gas	Molecular	Average speeds (km/sec)		
		T = 300 K	*T* = 1200 K	*T = 4800 K*
Helium	4	1.26	2.52	5.04
Neon	20	0.56	1.12	2.24
Argon	40	0.40	0.80	1.60
Krypton	84	0.28	0.55	1.10
Xenon	131	0.22	0.44	0.88

TABLE 6.5
Tabulation of the Average Speeds of Various Gas Molecules at Temperatures Typical of Our Present Environment (0∈C)
Notice that heavier molecules move more slowly. Notice also that the motion is extremely fast.

Molecule	Molecular Weight	Average Speed (km/sec)	Root Mean Square Speed (km/sec)
H_2	2	1.70	1.84
He	4	1.20	1.30
CH_4	16	0.60	0.65
NH_3	17	0.58	0.63
H_2O	18	0.56	0.61
N_2	28	0.45	0.49
O_2	32	0.42	0.46
CO_2	44	0.36	0.39

TABLE 6.6
Molecular Weights of Some Lighter Molecules That Might Be Found in Planetary Atmospheres. Using the Most Common Isotope for Each Element
A common mineral in ordinary crustal rocks is included for comparison.

Molecule	Constituents	Molecular Weight of Molecule
H_2	2(H^{1})	2
He	1(He^{4})	4
CH_4	1 (C^{12}) + 4 (H^{1})	16
NH_3	1 (N^{14}) + 3 (H^{1})	17
H_2O	1 (O^{16}) + 3 (H^{1})	18
N_2	2 (N^{14})	28
O_2	2 (O^{16})	32
CO_2	1 (C^{12}) + 2 (O^{16})	44
$FeMgSiO_4$	1 (Fe^{56}) + 1 (Mg^{24}) + 1 (Si^{28}) + 4 (O^{16})	172

from "Essential of Oceanography" by Stowe, Pub Wiley, 1987

TABLE 6.7
Abundances of Various Elements in Seawater

Element		Concentration (parts per billion)	Element		Concentration (parts per billion)
Oxygen	O	857,000,000	Nickel	Ni	2
Hydrogen	H	108,000,000	Vanadium	V	2
Chlorine	Cl	19,000,000	Manganese	Mn	2
Sodium	Na	10,500,000	Titanium	Ti	1
Magnesium	Mg	1,350,000	Tin	Sn	0.8
Sulfur	S	890,000	Cesium	Cs	0.5
Calcium	Ca	400,000	Antimony	Sb	0.5
Potassium	K	380,000	Selenium	Se	0.4
Bromine	Br	65,000	Yttrium	Y	0.3
Carbon	C	28,000	Cadmium	Cd	0.1
Strontium	Sr	8,000	Tungsten	W	0.1
Boron	B	4,600	Cobalt	Co	0.1
Silicon	Si	3,000	Germanium	Ge	0.06
Fluorine	F	1,300	Chromium	Cr	0.05
Argon	A	600	Thorium	Th	0.05
Nitrogen[a]	N	500	Silver	Ag	0.04
Lithium	Li	170	Scandium	Sc	0.04
Rubidium	Rb	120	Lead	Pb	0.03
Phosphorus	P	70	Mercury	Hg	0.03
Iodine	I	60	Gallium	Ga	0.03
Barium	Ba	30	Bismuth	Bi	0.02
Indium	In	20	Niobium	Nb	0.01
Zinc	Zn	10	Lanthanum	La	0.01
Iron	Fe	10	Thallium	Tl	<0.01
Aluminum	Al	10	Gold	Au	0.004
Molybdenum	Mo	10	Cerium	Ce	0.005
Copper	Cu	3	Rare earths		0.003-0.0005
Arsenic	As	3	Protoactinium	Pa	2×10^{-6}
Uranium	U	3	Radium	Ra	1×10^{-7}

TABLE 6.8
Maximum Amounts of Various Excess Volatiles That Could Have Come from Crustal Rocks

Material	Fraction That Could Have Come from the Crust
Water (H_2O)	1%
Carbon (C)	1%
Chlorine (Cl)	2%
Nitrogen	1%
Sulfur (S)	20%

from "Essentials of Oceanography" by Stowe, Pub Wiley, 1987

TABLE 6.9
Some Typical Values for the Concentrations of Some of the Important Members of Each of the Four Categories of Seawater Constituents, by Weight

	Parts per Thousand	Parts per Million	Parts per Billion
Major constituents			
Cl^-	19.3	19,300	19,300,000
Na^-	10.7	10,700	10,700,000
$SO4^{2-}$	2.7	2,700	2,700,000
Mg+	1.3	1,300	1,300,000
Dissolved gases			
CO_2	0.09	90	90,000
N_2	0.014	14	14,000
O_2	0.005	5	5,000
Nutrients			
Si	0.003	3	3,000
N	0.0005	0.5	500
P	0.00007	0.07	70
Trace elements			
I	0.000060	0.060	60
Fe	0.000010	0.010	10
Mn	0.000002	0.002	2
Pb	0.00000003	0.00003	0.03
Hg	0.00000003	0.00003	0.03

TABLE 6.10
Amounts of the Principal Salts and Ions in Seawater of Salinity 34.32%

Material	Grams per Kilogram of Seawater	Percent of Total Salt by Weight
Chloride (Cl-)	18.98	55.04
Sodium (Na^-)	10.556	30.61
Sulfate (SO_4^{2-})	2.649	7.68
Magnesium (Mg^{2-})	1.272	3.69
Calcium (Ca^{2-})	0.400	1.16
Potassium (K^+)	0.380	1.10
Bicarbonate (HCO_3^-)	0.140	0.41
Bromide (Br^-)	0.065	0.19
Boric Acid	0.026	0.07
Strontium (Sr^{2+})	0.013	0.04
Fluoride (F^-)	0.001	.003

* From Sverdrup, Johnson, and Fleming. *The Oceans*. Englewood cliffs, NJ: Prentice-Hall, copyright 1942, renewed 1970.

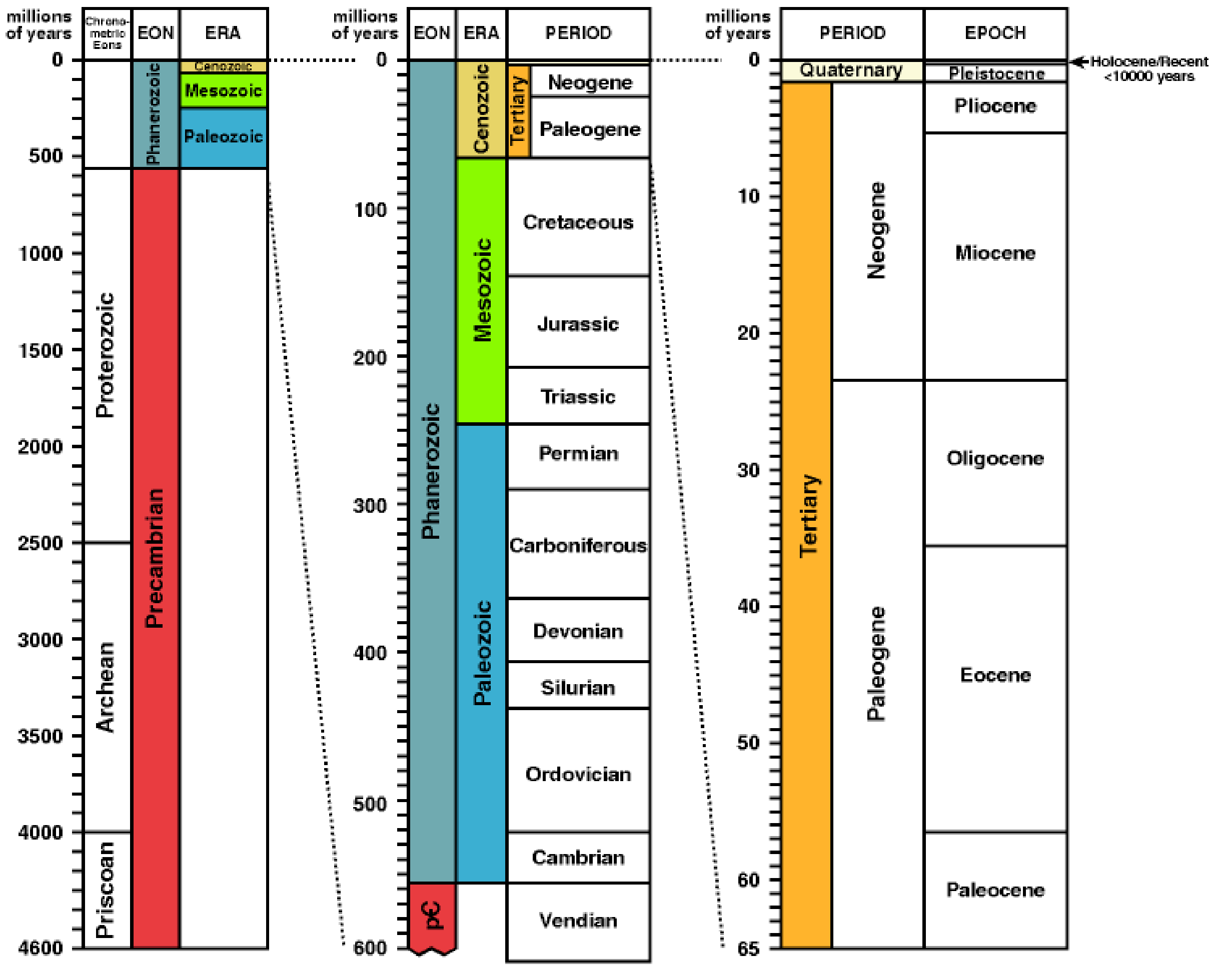
TABLE 6.11
The Three Common Units for Measuring the Concentrations of Dissolved Gases

Gas	Milliliters per Liter	Parts per Million	Millimoles per Liter
	Conversion from 1 ml/l		
CO_2	1	1.96	0.045
N_2	1	1.35	0.045
O_2	1	1.43	0.045
	Typical concentrations		
CO_2	40	78	1.79
N_2	10	12.5	0.45
O_2	5	7.2	0.23

[3] You may think that a unit of Ml/l should be parts per thousand. However, a milliliter of a gas has much less material than a milliliter of a liquid or solid. A milliliter of gas per liter of liquid is typically on or two parts per million by weight (Table 6.11).

from "Essentials of Oceanography" by Stowe, Pub Wiley, 1987

Geologic Time Scale



from http://www.talkorigins.org/faqs/timescale.html

See the "Preparation for Lab 2 page to get more informative links to the geological time scale.