ภาคผนวก

ภาคผนวก 1

INTERNATIONAL SYSTEM OF UNITS (SI)

SI BASE UNITS

MEASUREMENT	UNIT	SYMBOL
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	amp[b]
temperature[a]	kelvin	K
amount of substance	mole	mol
luminous inrensity	candela	cd

[a]Temperature may also be expressed in degrees Celsius. (symbol °C).
[b]The SI symbol for ampere is A.

SI SUPPLEMENTARY UNITS

MEASUREMENT	SI UNIT NAME	SI UNIT SYMBOL
plane angle	radian	rad
solid angle	steradian	sr

SI PREFIXES

FACTOR		PREFIX	SYMBOL
10^{12}	1 000 000 000.000	tera-	T-
10^{9}	1 000 000 000	giga-	G-
10^{6}	1 000 000	mega-	M-
10^{3}	1 000	kilo-	k-
10^{2}	100	hecto-	h-
10^{1}	10	deka-	da-
10^{-1}	0.1	deci-	d-
10^{-2}	0.01	centi-	c-
10^{-3}	0.001	milli-	m-
10^{-6}	0.000 001	micro-	μ-
10^{-9}	0.000 000 001	nano-	n-
10^{-12}	0.000 000 000 001	pico-	p-
10^{-15}	0.000 000 000 000 001	femto-	f-
10^{-18}	0.000 000 000 000 000 001	atto-	a-

Definition of Other Units in Terms of SI Units

Quantity	Definition*	Quantity	Definition*
Length	1 mi = 1.609 km	Pressure	1 dyn cm^{-2} = 0.1 Pa
	1 yd = 0.914 m		1 lb in^{-2} = 6.69 kPa
	1 ft = 0 305 m		1 atm = 101.325 kPa
	39.37 in = 1 m		760 mmHg = 101.325 kPa
	1 in = 2.54 cm		1 bar = 10^2 kPa
	1 angstrom (A) = 10^{-10} m		760 torr = 101.325 kPa
	1 Å = 100 pm	Energy	1 British thermal unit (Btu) = 1055 J
Mass	1 ton (U.S. long) = 1.106 Mg		1 erg 10^{-7} J
	I tonne (metric) = 1 Mg		1 calorie (cal) = 4.184 J
	I ron (U.S short) = 0.907 Mg		1 Calorie (nutritional) = 4.184 × 10^3 J
	2 205 lb (avdp) = 1 kg		1 liter atm = 101.325 J
	1 lb (avdp) = 453.6 g		1 kilowatt. hour (kwh) = 3.600 × 10" J
	1 oz avdp) = 28.35 g	Volume	1 barrel (U.S. petroleum) (bbl) = 0.159 m^3
Time	I year = 3 16 x 10^7 s		1 gal (U.S. liquid) = 3.79 dm^3
	I day = 8 64 × 10^4 s		1 liter = 1 dm^3
	1 h = 3600 s		1 qt = 0.947 dm^3
	1 min = 60 s		1 pt = 0.474 dm^3
Area	1 ft^2 = 0.093 m^2		1 in^3 = 16.4 cm^3
	1 in' = 6 45 cm'		1 ml = 1 cm^3
Force	1 dyne (dyn) = 10^{-5} N		
Power	1 horsepower (hp) = 745.7 W		

* The equalities in this column may be used to obtain unity factors which convert from one type of unit to mother.

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VALUES OF SOME CONSTANTS AND CONVERSION FACTORS

PHYSICAL CONSTANTS

CONSTANT	SYMBOL	VALUE
Avogadro's number	N	6.0222×10^{23}/mol
Bohr radius	a_0	5.2917×10^{-9} cm
coulomb	COUP	amp·s
electron rest mass	m	9.1096×10^{-28} g S.4859 x 10-' u
electronic charge, unit charge	e	1.6022×10^{-19} coul 4.8033×10^{-10} $g^{1/2}cm^{3/2}/s$ (or esu)
Faraday	F	9.6487×10^{4} coul/mol
gas constant	R	8.2056×10^{-2} liter·atm/K·mol 8.3143 J/K·mol

joule	J	$N \cdot m = kg \cdot m^2/s^2 = V \cdot coul$
molar volume, ideal gas at STP	—	22.4136 liter
neutron rest mass		1.6749×10^{-24} g 1.008665 u
newton	N	$kg \cdot m/s^2$
pascal	Pa	$N/m^2 = kg/s^2 \cdot m$
Planck's constant	h	6.6262×10^{-27} erg·s 6.6262×10^{-34} J·s
proton rest mass	—	1.6726×10^{-24} g 1.007277 u
speed of light in vacuum	c	2.9979×10^{10} cm/s
volt	V	$J/coul = kg \cdot m^2/amp \cdot s^2$

*The SI symbol for coulomb is C.

CONVERSION FACTORS

UNIT	ABBREVIATION	DEFINITION OR EQUIVALENT
angstrom	A	10^{-8} cm = 10^{-10} m = 0.1 nm= 100 pm
atmosphere	atm	760 torr (or mm of mercury 1.01325×10^5 N/m* (or Pa)
calorie	cal	4.1840 J
curie	Ci	3.7×10^{10}/s
electron volt	eV	1.6022 x IO ^{19} J
electrostatic unit	esu	3.33564×10^{-10} coul
erg	erg	IO-'J
joule	J	10^7 erg
Kelvin temperature scale	K	K = °C + 273.15 Triple point of water (0.01°C) is 273.16 K Freezing point of water (0°C) is 273.15 K
torr (or mm of mercury)	torr	1.31579×10^{-3} atm
unified atomic mass unit	u	1.6605×10^{-24}g 931.48 MeV

CHAPTER 3

NOTES ON MATHEMATICAL OPERATIONS

3.1 EXPONENTS

An exponent is a superscript added to a base. It indicates a mathematical operation that is to be performed on the base. In the expression a^n the exponent is n and the base is a. The following types of exponents are frequently encountered.

1. *Exponent* is a *positive integer*. In the expression a^n the exponent n is the number of times that the base a is to be taken as a factor in the expansion. Therefore, $(n \quad 1)$ is the number of times the base is to he multiplied by itself. Hence,

$$a^4 = a \times a \times a \times a$$

2. *Exponent* is a *negative integer*. The expression a^{-n} is the reciprocal of a": For example,

$$a^{-4} = \frac{1}{a^4} = \frac{1}{a \times a \times a \times a}$$

3. *Exponent is a fraction of rhe type* $1/n$. **The value of** n **is the index of a root of the base. Thus.**

$$a^{1/2} = \sqrt{a}$$
$$a^{1/3} = \sqrt[3]{a}$$

4. *Exponent* **is** *a fraction of the rypr* m/n. **This exponent indicates two operations (those of parts I and 3). Hence.** $a^{m/n}$ **is** $\sqrt[n]{a^m}$, **and**

$$a^{3/2} = \sqrt{a^3} = \sqrt{a \times a \times a}$$

5. *Exponent* **is** *zero*. **Provided the base is not zero. the value of the expression is unify. Thus.**

$$a^0 = 1 \qquad (a \neq 0)$$

Some properties of exponents are summarized in the following equations.

1. $a^m a^n = a^{m+n}$ **Thus.** $a^1 a^2 = a^6$
2. $(a^m)^n = a^{mn}$ **Thus.** $(a^1)^2 = a^2$
3. $(ab)^n = a^n b^n$ **Thus.** $(ab)^3 = a^3 b^3$
4. $\frac{a^m}{a^n} = a^{m-n}$ Thus, $\frac{a^5}{a^2} = a^3; \frac{a^2}{a^5} = a^{-3} = \frac{1}{a^3}$
5. $\frac{a^n}{a^n} = 1$ Thus, $\frac{a^3}{a^3} = 1$

3.2 SCIENTIFIC NOTATION

Very large and very small numhers arc frequently encountered in scientific studies. The velocity of light in a vacuum. for example. is

29.979.000.000 cm/s

and the distance between the centers of two hydrogen atoms in an H_2 **molecule is**

0.000000075 cm

Scientific notation is used to simplify the handling of cumbersome values such as these. When scientific notation is employed. rhe value is expressed in the form

$$a \times 10^n$$

where a, **the decimal part, is a number with one digit to the left of the**

decimal point and all others to the tight, and n, the exponent of 10. is a positive or negative integer or zero.

A number can be converted into this form by moving the decimal point until there is only one nonzero digit to the left of it. For each place the decimal point is moved to the *left*, n is increased by one. For each place the decimal point is moved to the *right*, n is *decreased* by one. For example,

$$29.979.000.000 \text{ cm/s} = 2.9979 \times 10^{10} \text{ cm/s}$$
$$0.0000000075 \text{ cm} = 7.5 \times 10^{-9} \text{ cm}$$

Mathematical operations involving numbers expressed in this manner arc carried out in the following ways.

1. *Multiplication* The decimal parts are multiplied and the exponents of IO are added algebraically.

$$(3.0 \times 10^{5})(2.0 \times 10^{2}) = (3.0 \times 2.0) \times 10^{5+2}$$
$$= 6.0 \times \text{IO}^{7}$$
$$(4.0 \times 10^{7})(5.0 \times 10^{-3}) = (4.0 \times 5.0) \times 10^{7+(-3)}$$
$$= 20 \times 10^{4}$$
$$= 2.0 \times 10^{5}$$

2. *Division* The decimal parts are divided. and the exponent of 10 in the denominator is algebraically subtracted from the exponent of IO in the numerator.

$$\frac{6.89 \times IO^{-7}}{3.36 \times 10^{3}} = \left(\frac{6.89}{3.36}\right) \times 10^{(-7)-(+3)}$$
$$= 2.0s \times 10^{-10}$$

3. *Addition and subtraction* The numbers must all be expressed with the same power of IO. The answer. which has this same power of IO. is found by adding or subtracting the decimal parts.

$$(6.25 \times 10^{3}) + 13.0 \times 10^{2}) = (6.25 \times \text{Io}^{3}) + (0.30 \times 10^{3})$$
$$= 6.55 \times \text{IO}^{3}$$

4. Taking a *root* When a square root is taken. the number is written in such a way that the exponent of IO is perfectly divisible by 2. The answer is obtained by taking the square root of the decimal part and dividing the power of IO by 2.

$$\sqrt{2.21 \times 10^{-7}} = \sqrt{22.1 \times 10^{-8}}$$
$$= 4.70 \times 10^{-4}$$

When a cube root is taken, the cube root of the decimal part is obtained and the exponent of 10 is divided by 3.

$$\sqrt[3]{1.86 \times 10^8} = \sqrt[3]{186 \times 10^6}$$
$$= 5.71 \times 10^2$$

5. *Raising to* a power When a number is squared, the decimal part is squared and the exponent of IO is multiplied by 2.

$$(1.36 \times 10^4)^2 = (1.36)^2 \times 10^{2(+4)}$$
$$= 1.85 \times 10^8$$

When a number is cubed, the decimal part is cubed and the exponent of IO is multiplied by 3.

$$(2.06 \times 10^{-5})^3 = (2.06)^3 \times 10^{3(-5)}$$
$$= 8.74 \times 10^{-15}$$

In general,

$$(a \times 10^n)^p = a^p \times 10^{p(n)}$$

3.3 LOGARITHMS

The logarithm of a number is the power to which a base must be raised in order to secure the number. Common logarithms (abbreviated log) employ the base IO. If

$$a = 10^n$$
$$\log a = n$$

and. therefore,

$$\log 1000 = \log 10^3 = 3$$
$$\log 0.01 = \log 10^{-2} = -2$$

The logarithm of a number that is merely IO raised to a power is the exponent of 10. The logarithm of a number such as 3.540, however, cannot be determined by inspection. The logarithms of numbers from I to 10 can be obtained from the table of logarithms found in Appendix D. Decimal points are omitted from this table. Each of the numbers listed is assumed to have a decimal point following the first digit. Each of the logarithms should have a decimal point preceding the value listed. The logarithm of 3.540 is 0.5490.

The logarithm of a number greater than 10 or less than 1 can be obtained in the following way. The number is expressed in scientific notation. For example, consider

$$3.540 \times 10^{12}$$

Since logarithms are exponents and since $a^m a^n = a^{m+n}$, the logarithm of this value is obtained by adding the logarithm of 3.540 to the logarithm of 10^{12}. Hence,

$$\begin{aligned}\log (3.540 \times 10^{12}) &= \log 3.540 + \log 10^{12} \\ &= 0.5490 + 12 \\ &= 12.5490\end{aligned}$$

Another example is

$$\begin{aligned}\log (2.00 \times 10^{-5}) &= \log 2.00 + \log \text{IO} \\ &= 0.310 + (-5) \\ &= -4.699\end{aligned}$$

Notice that the number of digits that follow the decimal point in the recorded logarithm is equal to the number of significant figures in the original value.

Sometimes it is necessary to find an antilogarithm, the number that corresponds to a given logarithm. In such instances the procedure used to find a logarithm is reversed. The given logarithm is written in two parts: a decimal fraction (called a mantissa) and a positive or negative whole number (called a characteristic). For example,

$$\text{antilog } (3.740) = \text{antilog } (0.740 + 3)$$

The antilogarithm of the mantissa (0.740) is obtained by finding the number corresponding to this logarithm in the table (it is 5.50). and the antilogarithm of the characteristic (3) is merely 10^3. Therefore,

$$\text{antilog } (3.740) = 5.50 \times 10^3$$

or

$$3.740 = \log (5.50 \times 10^3)$$

All the mantissas recorded in a table of logarithms are *positive*. This fact must be taken into account when an antilogarithm of a negative number is found. For example. to take the antilogarithm of -3.158. we must write the number in such a way that the mantissa is positive. Thus.

$$\begin{aligned}\text{antilog } (-3.158) &= \text{antilog } (0.842 \quad 4) \\ &= 6.95 \times 10^{-4}\end{aligned}$$

or

$$-3.158 = \log (6.95 \times \text{IO-'})$$

Since logarithms are exponents, mathematical operations involving logarithms follow the rules for the use of exponents. When each of the following operations is performed. the logarithms of the values involved are found, the logarithms are treated as indicated. and the antilogarithm of the result is secured as the final answer.

1. *Multiplication.*	$\log (ab) = \log a + \log b$
2. *Division.*	$\log (a/b) = \log a - \log b$
3. *Extraction of a roof.*	$\log (a^{1/n}) = \frac{1}{n} \log a$
4. *Raising to a power.*	$\log (a^n) = n \log a$

Logarithms that employ the base 10 are called common logarithms Natural logarithms (abbreviated ln) employ the base e, where

$$e = 2.71828\ldots$$

The relation between natural logarithms and common logarithms is

$$\ln a = 2.303 \log a$$

Thus, to find the natural logarithm of 6.040, we multiply the common logarithm of 6.040 by 2.303.

$$\begin{aligned} \ln 6.040 &= 2.393 \log 6.040 \\ &= 2.303(0.7810) \\ &= 1.7986 \end{aligned}$$

Logarithms can he used to evaluate an expression of the type e^n, where e is the base of natural logarithms. Since

$$\ln a = 2.303 \log a$$

$$\log a = \frac{\ln a}{2.303}$$

and since

$$\ln e^n = n$$

$$\log e^n = \frac{n}{2.303}$$

Therefore,

$$e^n = \text{antilog } \frac{n}{2.303}$$

For example. the value of $e^{2.209}$ can be found in the following way.

$$e^{2.209} = \text{antilog}\ \frac{2.209}{2.303} \quad \text{antilog}\ 0.9590$$
$$= 9.100$$

3.4 QUADRATIC EQUATIONS

An algebraic equation in the form

$$ax^2 + bx + c = 0$$

is called a quadratic equation in one variable. An equation of this type has two solutions given by the quadratic formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

When the quadratic formula is used to find the answer to a chemical problem, two solutions are obtained. One of them, however, must be discarded because it represents a physical impossibility.

Assume that x in the equation

$$x^2 + 0.50\,x - 0.15 = 0$$

is the number of moles of a gas that dissociate under a given set of conditions. The values of the coefficients are: $a = 1$, $b = 0.50$, and $c = -0.15$; and

$$x = \frac{-0.50 \pm \sqrt{(0.50)^2 - 4(1)(-0.15)}}{2(1)}$$
$$x = \frac{-0.50 \pm 0.92}{2}$$
$$x = +0.21, -0.71$$

The value -0.71 is discarded because a negative mount of a substance is physically impossible.

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LOGARITHMS 1

	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3285	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3184
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4737
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5739	5740	5752	5762	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
13	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7233
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
14	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396

	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7421	7435	7443	7451	1459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	1582	7589	7597	1604	7612	7619	1621
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7761	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	1896	7903	7910	1917
62	7924	7931	7938	7945	7952	1959	1966	7913	7980	7987
63	1993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8214	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	0686
14	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	a797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	R927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	a993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	920 1	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9209
85	9294	9299	9304	9309	9315	932C	9325	933C	9335	9340
86	9345	9350	9355	9360	9365	937c	9315	9380	9385	9390
87	9395	9400	9405	9410	9415	942C	9425	943a	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	95211	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9653	966 |	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	970%	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9195	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9914	9978	9983	9987	9991	9996

SECTION 5

EQUILIBRIUM CONSTANTS AT 25°C

5.1 IONIZATION CONSTANTS

MONOPROTIC ACIDS

acetic	$HC_2H_3O_2 \rightleftarrows H^+ + C_2H_3O_2^-$	1.8×10^{-5}
benzoic	$HC_7H_5O_2 \rightleftarrows H^+ + C_7H_5O_2^-$	6.0×10^{-5}
chlorous	$HClO_2 \rightleftarrows H^+ + ClO_2^-$	1.1×10^{-2}
cyanic	$HOCN \rightleftarrows H^+ + OCN^-$	1.2×10^{-4}
formic	$HCHO_2 \rightleftarrows H^+ + CHO_2^-$	1.8×10^{-4}
hydrazoic	$HN_3 \rightleftarrows H^+ + N_3^-$	1.9×10^{-5}
hydrocyanic	$HCN \rightleftarrows H^+ + CN^-$	4.0×10^{-10}
hydrofluoric	$HF \rightleftarrows H^+ + F^-$	6.7×10^{-4}
hypobromous	$HOBr \rightleftarrows H^+ + OBr^-$	2.1×10^{-9}
hypochlorous	$HOCl \rightleftarrows H^+ + OCl^-$	3.2×10^{-8}
nitrous	$HNO_2 \rightleftarrows H^+ + NO_2^-$	4.5×10^{-4}

POLYPROTIC ACIDS

arsenic	$H_3AsO_4 \rightleftarrows H^+ + H_2AsO_4^-$	$K_1 = 2.5 \times 10^{-4}$
	$H_2AsO_4^- \rightleftarrows H^+ + HAsO_4^{2-}$	$K_2 = 5.6 \times 10^{-8}$
	$HAsO_4^{2-} \rightleftarrows H^+ + AsO_4^{3-}$	$K_3 = 3 \times 10^{-11}$

FLUORIDES

BaF_2	2.4×10^{-5}
CaF_2	3.9×10^{-11}
PbF_2	4×10^{-8}
MgF_2	8×10^{-8}
SrF_2	1.9×10^{-10}

HYDROXIDPS

$Al(OH)_3$	5×10^{-33}
$Ba(OH)_2$	5.0×10^{-3}
$Cd(OH)_2$	2.0×10^{-14}
$Ca(OH)_2$	1.3 x.10-6
$Cr(OH)_3$	6.7×10^{-31}
$Co(OH)_2$	2.5×10^{-16}
$Co(OH)_3$	2.5×10^{-43}
$Cu(OH)_2$	1.6×10^{-19}
$Fe(OH)_2$	1.8×10^{-15}
$Fe(OH)_3$	6×10^{-38}
$Pb(OH)_2$	4.2×10^{-15}
$Mg(OH)_2$	$x.9 \times 10^{-12}$
$Mn(OH)_2$	2×10^{-13}
$Hg(OH)_2(HgO)$	3×10^{-26}
$Ni(OH)_2$	1.6×10^{-16}
$AgOH\ (Ag_2O)$	2.0×10^{-8}
$Sr(OH)_2$	$3\ 2 \times 10^{-4}$
$Sn(OH)_2$	3×10^{27}
$Zn(OH)_2$	4.5×10^{-17}

IODIDES

PbI_2	x.3 x IO-"
Hg_2I_2	4.5×10^{-29}
AgI	8.5×10^{-17}

OXALATES

BaC_2O_4	1.5×10^{-8}
CaC_2O_4	1.3×10^{-9}
PbC_2O_4	8.3 x IO-"
MgC_2O_4	$X.6 \times 10^{-5}$
$Ag_2C_2O_4$	1.1×10^{-11}
SrC_2O_4	5.6×10^{-8}

PHOSPHATES

$Ba_3(PO_4)_2$	6×10^{-39}
$Ca_3(PO_4)_2$	1.3×10^{-32}
$Pb_3(PO_4)_2$	1×10^{-54}
Ag_3PO_4	1.8×10^{-18}
$Sr_3(PO_4)_2$	1×10^{-31}

SULFATES

$BaSO_4$	1.5×10^{-9}
$CaSO_4$	2.4×10^{-5}
$PbSO_4$	1.3×10^{-8}
Ag_2SO_4	1.2×10^{-5}
$SrSO_4$	7.6×10^{-7}

SULFIDES

Bi_2S_3	1.6×10^{-72}
CdS	1.0×10^{-28}
cos	5×10^{-22}
CUS	8×10^{-37}
FeS	4×10^{-19}
PbS	7×10^{-29}
MnS	7×10^{-16}
HgS	1.6×10^{-54}
NiS	3×10^{-21}
Ag_2S	5.5×10^{-51}
SnS	1×10^{-26}
ZnS	2.5×10^{-22}

MISCELLANEOUS

$NaHCO_3$	1.2×10^{-3}
$KClO_3$	$x.9 \times 10^{-3}$
$K_2[PtCl_6]$	1.4×10^{-6}
$AgC_2H_3O_2$	2.3 x IO-"
AgCN	$1.6 \times$ IO-"
AgCNS	1.0×10^{-12}

POLYPROTIC ACIDS (Cont.)

carbonic	$CO_2 + H_2O \rightleftarrows H^+ + HCO_3^-$	$K_1 = 4.2 \times 10^{-7}$
	$HCO_3^- \rightleftarrows H^+ + CO_3^{2-}$	$K_2 = 4.8 \times 10^{-11}$
hydrosulfuric	$H_2S \rightleftarrows H^+ + HS^-$	$K_1 = 1.1 \times 10^{-7}$
	$HS^- \rightleftarrows H^+ + S^{2-}$	$K_2 = 1.0 \times 10^{-14}$
oxalic	$H_2C_2O_4 \rightleftarrows H^+ + HC_2O_4^-$	$K_1 = 5.9 \times 10^{-2}$
	$HC_2O_4^- \rightleftarrows H^+ + C_2O_4^{2-}$	$K_2 = 6.4 \times 10^{-5}$
phosphoric	$H_3PO_4 \rightleftarrows H^+ + H_2PO_4^-$	$K_1 = 7.5 \times 10^{-3}$
	$H_2PO_4^- \rightleftarrows H^+ + HPO_4^{2-}$	$K_2 = 6.2 \times 10^{-8}$
	$HPO_4^{2-} \rightleftarrows H^+ + PO_4^{3-}$	$K_3 = 1 \times 10^{-12}$
phosphorous (diprotic)	$H_3PO_3 \rightleftarrows H^+ + H_2PO_3^-$	$K_1 = 1.6 \times 10^{-2}$
	$H_2PO_3^- \rightleftarrows H^+ + HPO_3^{2-}$	$K_2 = 7 \times 10^{-7}$
sulfuric	$H_2SO_4 \rightarrow H^+ + HSO_4^-$	strong
	$HSO_4^- \rightleftarrows H^+ + SO_4^{2-}$	$K_2 = 1.3 \times 10^{-2}$
sulfurous	$SO_2 + H_2O \rightleftarrows H^+ + HSO_3^-$	$K_1 = 1.3 \times 10^{-2}$
	$HSO_3^- \rightleftarrows H^+ + SO_3^{2-}$	$K_2 = 5.6 \times 10^{-8}$

BASES

ammonia	$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$	1.8×10^{-5}
aniline	$C_6H_5NH_2 + H_2O \rightleftarrows C_6H_5NH_3^+ + OH^-$	4.6×10^{-10}
dimethylamine	$(CH_3)_2NH + H_2O \rightleftarrows (CH_3)_2NH_2^+ + OH^-$	7.4×10^{-4}
hydrazine	$N_2H_4 + H_2O \rightleftarrows N_2H_5^+ + OH^-$	9.8×10^{-7}
methylamine	$CH_3NH_2 + H_2O \rightleftarrows CH_3NH_3^+ + OH^-$	5.0×10^{-4}
pyridine	$C_5H_5N + H_2O \rightleftarrows C_5H_5NH^+ + OH^-$	1.5×10^{-9}
trimethylamine	$(CH_3)_3N + H_2O \rightleftarrows (CH_3)_3NH^+ + OH^-$	7.4×10^{-5}

5.2 SOLUBILITY PRODUCTS

BROMIDES

$PbBr_2$	4.6×10^{-6}
Hg_2Br_2	1.3×10^{-22}
$AgBr$	5.0×10^{-13}

CARBONATES

$BaCO_3$	1.6×10^{-9}
$CdCO_3$	5.2×10^{-12}
$CaCO_3$	4.1×10^{-9}
$CuCO_3$	2.5×10^{-10}
$FeCO_3$	2.1×10^{-11}
$PbCO_3$	1.5×10^{-15}
$MgCO_3$	1×10^{-15}
$MnCO_3$	8.8×10^{-11}
Hg_2CO_3	9.0×10^{-17}
$NiCO_3$	1.4×10^{-7}
Ag_2CO_3	8.2×10^{-12}

CARBONATES (Cont.)

$SrCO_3$	7×10^{-10}
$ZnCO_3$	2×10^{-10}

CHLORIDES

$PbCl_2$	1.6×10^{-5}
Hg_2Cl_2	1.1×10^{-18}
$AgCl$	1.7×10^{-10}

CHROMATES

$BaCrO_4$	8.5×10^{-11}
$PbCrO_4$	2×10^{-16}
Hg_2CrO_4	2×10^{-9}
Ag_2CrO_4	1.9×10^{-12}
$SrCrO_4$	3.6×10^{-5}

5.3 INSTABILITY CONSTANTS

AlF_6^{3-}	1.4×10^{-20}	$HgBr_4^{2-}$	2.3×10^{-22}
$Al(OH)_4^-$	1.3×10^{-33}	$HgCl_4^{2-}$	1.1×10^{-16}
$Al(OH)^{2+}$	7.1×10^{-10}	$Hg(CN)_4^{2-}$	4×10^{-42}
$Cd(NH_3)_4^{2+}$	7.5×10^{-8}	HgI_4^{2-}	5.3×10^{-31}
$Cd(CN)_4^{2-}$	1.4×10^{-19}	$Ni(NH_3)_4^{2+}$	1×10^{-8}
$Cr(OH)^{2+}$	5×10^{-11}	$Ni(NH_3)_6^{2+}$	1.8×10^{-9}
$Co(NH_3)_6^{2+}$	1.3×10^{-5}	$Ag(NH_3)_2^+$	6.0×10^{-8}
$Co(NH_3)_6^{3+}$	2.2×10^{-33}	$Ag(CN)_2^-$	1.8×10^{-19}
$Cu(NH_3)_2^+$	1.4×10^{-11}	$Ag(S_2O_3)_2^{3-}$	5×10^{-14}
$Cu(NH_3)_4^{2+}$	4.7×10^{-15}	$Ag(S_2O_3)_3^{5-}$	9.9×10^{-14}
$Cu(CN)_2^-$	1×10^{-33}	$Zn(NH_3)_4^{2+}$	3.4×10^{-10}
$Cu(OH)^+$	1×10^{-8}	$Zn(CN)_4^{2-}$	1.2×10^{-18}
$Fe(CN)_6^{4-}$	1×10^{-35}	$Zn(OH)_4^{2-}$	3.6×10^{-16}
$Fe(CN)_6^{3-}$	1×10^{-42}	$Zn(OH)^+$	4.1×10^{-5}
$Pb(OH)^+$	1.5×10^{-7}		

ภาคผนวก ๖

The atomic number and atomic weights of the elements (^{12}C = 12 amu, exactly)

Element	Symbol	Atomic number	Atomic weight*
Actinium	Ac	89	227.0218
Aluminum	Al	13	26.98154
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39948
Arsenic	As	33	74.9216
Astatine	At	85	(210)
Barium	Ba	56	137.33
Berkelium	Bk	91	(247)
Beryllium	Be	4	9.01218
Bismuth	Bi	83	208.9804
Boron	B	5	10.81
Bromine	Br	35	79.904
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Californium	Cf	98	(251)
Carbon	C	6	12.01 1
Cerium	Ce	58	140. 12
Cesium	Cs	55	t 32.9054
Chlorine	Cl	17	35.453
Chromium	Cr	24	5 1.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.546
Curium	Cm	96	(247)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(254)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Eermium	Fm	Ioo	(257)
Eluorine	F	9	18.99840
Erancium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.9665
Hafnium	Hf	72	178.49
Hahnium	Ha	105	(262)
Helium	He	2	4.00260
Holmium	Ho	67	164.9304
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.9045
Iridium	Ir	17	192.22
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.9055
Lawrencium	Lr	103	(260)
Lead	Ph	82	207.2
Lithium	Li	3	6.94 1
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.305
Manganese	Mn	25	54.9380
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20. 179
Neptunium	Np	93	237.0482
Nickel	Ni	28	58.70
Niobium	Nb	41	92.9064
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	0	8	15.9994
Palladium	Pd	46	106.4
Phosphorous	P	15	30.97376
Platinum	Pt	78	195.09
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.0983
Praseodymium	Pr	59	140.9077
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0359
Radium	Ra	88	226 0254
Radon	Rn	86	(222)
Rhenium	Re	75	186.207
Rhodium	Rh	45	102.9055
Rubidium	Rb	37	85 4678
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	44.9559
Selenium	Se	34	78.96
Silicon	Si	14	28.0855
Silver	Ag	47	107.868
Sodium	Na	11	22.98937
Strontium	Sr	38	87.62
Sulfur	S	Ib	32.06
Tantalum	Ta	73	180.9479
Technetium	Tc	43	(97)
Tellurium	Te	52	12: 60
Terbium	Tb	65	158.9254
Thallium	Tl	81	204.37
Thorium	Th	90	232.0381
Thulium	Tm	69	168 9342
Tin	Sn	50	118 69
Titanium	Ti	22	47.91)
Tungsten	W	74	183 85
Uranium	U	92	235 029
Vanadium	V	23	50.94 14
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.9059
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22
—	—	106	(263)

*A value in parentheses is the mass number of the longest-lived isotope of the element.

Table 2

ISOTOPES OF SOME ELEMENTS

(Naturally occurring nonradioactive isotopes are given in bold type. Naturally occurring radioactive Isotopes are bold-face italics in color. All other radioactive isotopes are in italics Naturally occurring isotopes are listed in order of their abundance All other Isotopes are listed in order of length of half-life.)

Elements	Mass Numbers of Isotopes
H	**1, 2,** *3*
He	**4, 3,** *6,* **7. 5**
Li	**7, 6,** *8, 9, 5*
Be	*9, 10, 7. 11, 8. 6*
B	**11, 10.8.** *13, 12, 9*
C	*12,* **13,** *14, 11, 10, 15, 16*
N	**14,** *15, 13. 16. 17, 12*
0	*16.* **18,** *17, 15, 14. 19, 20*
F	*19, 18, 17, 20. 21, 16*
Ne	**20, 22, 21, 24, 23,** *19, 18*
Na	**23,** *22. 24. 25, 21, 26. 20*
Mg	*24, 26. 25. 28, 27, 23*
Al	**27,** *26,* **28, 29, 25, 30. 24, 23**
Si	*28, 29, 30, 32, 31, 27, 26*
P	**31, 33, 32, 30, 34, 29, 28**
S	**32,** *34, 33, 36, 35, 38, 37, 31, 30*
Cl	*35. 37, 36, 39, 38, 40. 33, 34, 32*
Ar	**40, 36, 38,** *39, 42, 37, 41, 35*
K	*39.* **41,** *40, 43,* **42, 44, 45.** *38,* **37**
Ca	**40,** **44. 42,** *48* **43, 46.** *41, 45, 47, 49, 39, 38*
Cr	**52, 53, 50,** **54,** *51, 48, 49, 56, 55, 46. 47*
Fe	*56. 54, 57,* **58,** *60, 55, 59, 52, 53, 61*
Ni	**58, 60,** *62,* **61. 64,** *59,* **63, ti6. 57, 56. 6.5**
CU	**63, 65. 67, 64.** *61, 62. 66. 60, 59. 68. 58*
Zn	**64, 66, 68,** *67,* **70,** *65, 72, 62. 69, 63. 71, 60, 61*
Br	*79,* **81,** *77, 82, 83, 76. 7.5. 74, 84, 80. 78, 85. 88, 87, 89, 90*
Sr	**88, 87, 86, 84,** *90. 85. 89, 82, 83. 91, 92, 80. 81, 93, 94, 95*
Ag	**107, 109,** *105, 111, 113, 112. 104, 103, 106, 115. 102. 116, 108, 117, 110. 114*
Sn	**120, 118,** **116, 119, 117, 124, 122, 112, 114, 115,** *126, 113, 125, 121, 110, 127, 12.3 111, 109. 108, 129, 128, 1.30. 132*

ISOTOPES OF SOME ELEMENTS (cont'd)

Elements	Mass Numbers of Isotopes
I	127, 129, 125, 126. 131, 124, 133. 123, 130, 135. 132, 121, 120, 134, 128, 119, 118. 117, 122. 136, 137, 138, 139
Ba	138, 137, 136, 135; 134, 130, 132, 133, 140, 131, 128, 129, 126, 139, 141, 127, 142, 143
W	184, 186, 182, 183, 180,181. 185. 188. 178. 187, 177, 176. 179
Pt	195, 194, 196, 190,192, 190, 193, 188, 191, 197, 200, 189, 184, 186, 187, 199
Pb	208, 206, 207, 204,205, 202, 210, 203, 200, 212, 201, 209, 198, 199, 196. 211, 214, 195, 194
Bi	209, 208, 207, 205, 206, 210, 203, 204, 202, 201, 212, 213. 200, 199, 214, 215, 196, 211
Rn	222. 211,224, 210, 209, 221, 212, 208, 223, 207,206. 204. 215, 220.219. 218, 217. 216
Ra	226. 228. 225, 223, 224, 230. 227, 229, 222, 221, 220
U	238, 235, 234,236, 233, 232, 230, 237, 231, 229, 2.39, 228, 227
Np	237, 236,235, 234, 239, 238 240, 231, 233, 241. 232
Pu	244. 242, 239, 240, 238, 241, 236, 237, 246, 245, 2.34, 243, 232, 235, 233
Am	243. 241, 240. 242, 239, 244, 245, 238, 237, 246, 247
Cm	247, 248, 250. 245. 246, 243, 244, 242, 241. 240, 239, 238, 249
Bk	247, 248, 249, 245, 246, 243, 244, 250, 251
Cf	251, 249, 250. 252, 248, 254, 253, 246, 247, 245, 244. 243, 242
ES	254, 252, 255. 253, 251. 250, 249, 256, 248, 246, 247, 245
Fm	257, 253. 252, 255, 251. 254, 256, 250. 249, 248, 247, 245, 246, 244
Md	258, 257, 256, 255, 252
No	255, 253, 254, 257, 256, 252, 251
Lr	256, 257, 258, 259
104	2.57, 259, 260
105	260
106	263
107	261

COMMON ELEMENTS

Name	Symbol	Approx. at. wt.	Comm ox. nos.	Name	Symbol	Approx. at. wt.	Common ox. "OS.
aluminum	Al	27.0	+3	magnesium	Mg	24.3	+2
antimony	Sb	121.8	+3,+5	manganese	Mn	54.9	+2,+4,+7
arsenic	AS	74.9	+3,+5	mercury	Hg	200.6	+1,+2
barium	Ba	137 3	+2	nickel	Ni	58.7	+2
bismuth	Bi	209.0	+3	nitrogen	N	14.0	−3,+3,+5
bromine	Br	79.9	−1,+5	oxygen	0	16.0	-2
calcium	Ca	40.1	+2	phosphorus	P	31.0	+3,+5
carbon	C	12.0	+2,+4	platinum	Pl	195.1	+2,+4
chlorine	Cl	35.5	−1,+5,+7	potassium	K	39.1	+1
chromium	Cr	52 0	+2,+3,+6	silicon	Si	28.1	+4
cobalt	CO	58.9	+2,+3	silver	Ag	107.9	+1
copper	Cu	63.5	+1,+2	sodium	Na	23.0	+1
fluorine	F	19.0	-1	strontium	Sr	87.6	+2
gold	AU	197.0	+1,+3	sulfur	S	32.1	−2,+4,+6
hydrogen	H	1.o	−1,+1	tin	Sn	118.7	+2,+4
iodine	I	126.9	−1,+5	titanium	Ti	47.9	+3,+4
iron	Fe	55.8	+2,+3	tungsten	W	183.8	+6
lead	Pb	207.2	+2,+I	xinc	Zn	65.4	+2

COMMON IONS AND THEIR CHARGES

Name	Symbol	Charge	Name	iymbol	Charge
aluminum	Al^{+3}	+3	lead(II)	Pb^{++}	+2
amnonium	NH_4^+	+1	magnesium	Mg^{++}	+2
barium	Ba^{++}	+2	mercury(I)	Hg_2^{++}	+2
calcium	Ca^{++}	+2	mercury(II)	Hg^{++}	+2
chromium(III)	Cr^{+++}	+3	nickel(II)	Ni^{++}	+2
cobalt(II)	Co^{++}	+2	potassium	K^+	+1
copper(I)	Cu^+	+1	silver	Ag^+	+1
copper(II)	Cu^{++}	+2	sodium	Na^+	+1
hydronium	H_3O^+	+1	tin(II)	Sn^{++}	+2
iron(II)	Fe^{++}	+2	tin(IV)	Sn^{++++}	+4
iron(III)	Fe^{+++}	+3	xinc	Zn^{++}	+2
acetate	$C_2H_3O_2^-$	−1	hydrogen sulfate	HSO_4^-	−1
bromide	Br^-	- f	hydroxide	OH^-	−1
carbonate	CO_3^{--}	- 2	hypochlorite	ClO^-	−1
chlorate	ClO_3^-	−1	iodide	I^-	−1
chloride	Cl^-	−1	nitrate	NO_3^-	−1
chlorite	ClO_2^-	−1	nitrite	NO;	−1
chromate	CrO_4^{--}	- 2	oxide	O^{--}	- 2
cyanide	CN^-	−1	perchlorate	Cl&-	−1
dichromate	$Cr_2O_7^{--}$	- 2	permanganate	MO;	−1
fluoride	F^-	−1	peroxide	O_2^{--}	−2
hexacyanoferrate(II)	$Fe(CN)_6^{---}$	- 4	phosphate	PO_4^{---}	−3
hexacyanoferrate(III)	$Fe(CN)_6^{---}$	- 3	sulfate	SO_4^{--}	- 2
hydride	H	−1	sulfide	S^{--}	−2
hydrogen carbonate	HCO_3^-	- I	sulfite	SO_3^{--}	−2