$R_{\rm gas\text{-}law} = 0.0821 \frac{{\rm L} \cdot {\rm atm}}{{\rm mol} \cdot {\rm K}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} = 62.4 \frac{{\rm L} \cdot {\rm mmHg}}{{\rm mol} \cdot {\rm M}} =$ $L \cdot kPa \vee J$ = 8.314 $453.6 \; \mathrm{g} \quad 2.54 \; \mathrm{cm} \quad 0.946 \; \mathrm{L} \quad 6.022 \times 10^{23} \; \mathrm{units} \quad 22.4 \; \mathrm{L}$ 1 in 1 qt 1 lb P_{sea} 1 atm $=\frac{1 \text{ sea}}{101325 \text{ Pa}} = \frac{1 \text{ dem}}{760 \text{ mmHg}} = \frac{1 \text{ dem}}{14.7 \text{ psi}} = \frac{1 \text{ ked}}{4.184 \text{ kJ}}$ ${}^{\circ}\mathsf{C} = \frac{5}{9} ({}^{\circ}\mathsf{F} - 32) \text{ and } {}^{\circ}\mathsf{F} = \frac{9}{5} {}^{\circ}\mathsf{C} + 32$ $h = 6.626 \times 10^{-34} \text{Js} \vee \text{kgm}^2 \text{s}^{-1} \text{ and } c = 3.00 \times 10^8 \text{ ms}^{-1}$ $K_a=\frac{[{\rm H_3O^+}][{\rm A}^-]}{[{\rm HA}]}$ and $K_b=\frac{[{\rm HB}][{\rm OH}^-]}{[{\rm B}^-]}$, in water, ${\rm K_aK_b}=1.0$ $\triangle H_{\text{vap}} = 40.67 \text{kJ mol}^{-1}$ 1 IA $pH = -\log_{10}[H^+]$, $pOH = -\log_{10}[OH^-]$, $pK_a = -\log_{10}[OH^-]$

 $\begin{vmatrix} C_{\text{water}} = 4.184 \text{J (gK)}^{-1} v_{\text{rms}} = \sqrt{ \\ C_{\text{steam}} = 1.865 \text{J (gK)}^{-1} }$

 $E_n = -\frac{R_H}{n^2}$

 $E_{\rm photon} = hf = \frac{hc}{\lambda}$ and $\lambda = \frac{h}{mv}$

 $(K_b, K_f) = (0.512, 1.86)^{\circ} \text{C/m}$

 $\Pi = iMRT$ and $S_q = kP_q$

 $\triangle T_f = K_f mi$ and $\triangle T_b = K_b mi$

4 IVB

22 1.54

Ti

Titanium

47.87

40 1.33

Zr

Zirconium

91.22

72 1.3

Hf

Hafnium

178.49

104

Rutherfordium

(267)

La

Lanthanum

138.91

Ac

Actinium

(227)

 $R_{H_{\text{Rydberg}}} \stackrel{n}{=} 2.18 \times 10^{-18} \text{ J}$

 $\triangle E = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_i^2} \right)$

= Van't Hoff

3 IIIA

21 1.36

Sc

Scandium

44.96

Y

Yttrium

88.91

La-Lu

Lanthanide

Ac-Lr

Actinide

Sym

Name

mass

E.N.

57-71

89-103

1.22

39

2 IIA

Be

Beryllium

9.01

12 1.31

Mg

Magnesium

24.31

Ca

Calcium

40.08

Sr

Strontium

87.62

Ba

Barium

137.33

Ra

Radium

(226)

Alkali Metal

Metalloid

Non-metal

Noble Gas

 C_4H_{10} HCIO₄ EN, IE, EA, & \mathbb{Z}_{eff} increase $\rightarrow \uparrow$

Halogen

Metal

1.00

0.95

0.89

0.9

Alkaline-Earth **Z**

Lanthanide/Actinide

Radius & Metallic increase ←↓

20

38

56

88

1.57

2.20

0.98

0.93

0.82

 H_2

Hydrogen 1.01

Lithium

6.94

Na

Sodium 22.99

Potassium

39.10

Rb

Rubidium

85.47

Cs

Caesium

132.91

Fr

Francium

(223)

HI

HBr

HCI

 $C_3H_8 \mid HCIO_3$

HNO₃

H₂SO₄

Gas

CO

 CO_2

 CH_4

 C_2H_6

NO NO₂

N₂O NH₃

SO₃ SO₂ H₂S HCl

Super⁷

0.82

0.79

0.7

19

37

55

Periodic Table of Elements

mol	[D*] W	-2 1 (5 ,		Ion	Soluble with	Precipitat							
		$\frac{-2}{s} = kg (ms)^{-1}$	I .		NO ₃ Nitrate	Most cations	No commo	n cations						
cal	PV = nRT and	$\left P + \frac{an^2}{V^2}\right \left[V - \frac{an^2}{V^2}\right]$	nb] = nRT	. Ea	CIO_4^-	Most cations	No commo	n cations						
4 kJ │	$PV \propto 1$ and VT	$\stackrel{ iny \sim}{\propto} 1$ (Boyle and	Charle). $\begin{vmatrix} k = 1 \\ 1 \end{vmatrix}$	$=Ae^{-\frac{E_a}{RT}}$	CIO ₃	Most cations	No commo							
	$M = \frac{\text{moles solu}}{\text{L solution}}$	te and $m = \frac{mol}{mol}$	es solute A	$\begin{vmatrix} t = [A]_0 - kt \\ t = [A]_0 e^{-kt} \end{vmatrix}$	$C_2H_3O_2^-$	Most cations	Ag^+, F	Hg_2^{2+}						
	L solution	n kg	solvent $\begin{bmatrix} A \end{bmatrix}$	$ _{t} = [A]_{0}e^{-\pi t}$	F ⁻	Most cations	Cr ³							
	$X_{\text{mol fraction}} = \frac{\text{mod}}{1}$	ol component mol total		$t = \frac{1}{kt + \frac{1}{[A]_0}}$	CI ⁻	Most cations	(Ag, TI) ⁺ , Pb	$2^{+,4+},Hg_2^{2+}$						
						Most cations	(Ag, TI) ⁺ , Pb	$2+,4+$, Hg_2^{2+}						
$K_a =$	$K_a = rac{[{ m H_3O^+}][{ m A}^-]}{[{ m HA}]}$ and $K_b = rac{[{ m HB}][{ m OH}^-]}{[{ m B}^-]}$, in water, ${ m K_aK_b} = 1.0 imes 10^{-14}$					Most cations	(Ag, TI) ⁺ , Pb	$2^{+,4+}, Hg_2^{2+}$						18 VIIIA
	$pH = -\log_{10}[H^+], pOH = -\log_{10}[OH^-], pK_a = -\log_{10}[K_a]$					Most cations	Ag^+, Ba^2							10 1111/1
nH'-	pH + pOH = 14, and K _c = $\frac{[product]}{[reactant]}$, K _{eq} , K _{sp} \leftrightarrow K _p = K _c $(RT)^{\triangle n}$						$Pb^{2+,4+}, C$	a^{2+}, Hg_2^{2+}						2
	l					Most cations $Ba^{2+}, Sr^{2+}, Pb^{2+,4+},$			Li ⁺ , K ⁺ , Ba ²⁺ , Ca ²⁺ , Na ⁺ , Mg ²⁺ , Al ³⁺ , Mn ⁺² , Zn ²⁺ , Cr ^{3+,2+} , Fe ^{3+,2+} ,					He
K _a	$ m K_{a ext{-acetic}}=1.8 imes10^{-5}$, and in buffer pH $=$ pK $_{a}+\log_{10}\left(rac{[A^{-}]}{[HA]} ight)$.						$Ca^{2+},$	Hg_2^{2+}	Co ²⁺ , Ni ⁺ , S	n ²⁺ , Pb ²⁺ , 2H ⁺	, Cu ^{2+,+} , Ag ⁺ , F	Hg ²⁺ , Pt ²⁺ , Au ³⁺	+,+	Helium
	4					$Na^+, K^+, NH_4^+,$	Most othe		12 111 4	1.4.11.74	1 - 1 / / /	16 1/14	17 \ /	4.00
$\lambda = \frac{h}{mv}$		5.4.7				Li^+, Sr^{2+}			13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	
	$\triangle E = q + w = q - P \triangle V \text{ and } \triangle H = \triangle E + P \triangle V$					la^+, K^+, NH_4^+, Li^-	H, Most othe	r cations	5 2.04	6 2.55	7 3.14	8 3.44	9 3.98	10
J						Sr ²⁺ , Ba ²⁺ , Ca ²⁺				_		_		
	$k = 1.38 \times 10^{-23} \text{ JK}^{-1}$					$(Na, K, NH_4, Li)^+$	Most other cations		В	C	N_2	O_2	F_2	Ne
	$\triangle S = k \ln \left(rac{W_{ m final}}{W_{ m initial}} ight)$ and $\triangle S_{ m surr.} = -rac{\triangle H^{\circ}}{T}$				CO ₃ ²⁻ PO ₄ ³⁻	Na ⁺ , K ⁺ , NH ₄ ⁺	Most othe	r cations	Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
	$ T \wedge S - \wedge H T \wedge S $					No _{common} cations			10.81	12.01	14.01	16.00	19.00	20.18
s)°C/m	$-T\triangle S_{\text{universe}} = \triangle H_{\text{system}} - T\triangle S_{\text{system}}$					Most Anions	$(NH_4)_2$							
, ,						Nothing	Most a		13 1.61	14 1.90	15 2.19	16 2.38	17 3.16	18
kP_g	$\triangle G = \triangle G$	$G^{\circ} + RT \ln(Q)$,	so at eq., K_{eq} =	$=e^{-\triangle G^{\circ}/RT}$	As ³⁺	I ⁻	Most a		Αl	Si	Р	S	Cl_2	Ar
					Sb ³⁺	CI ⁻	Most a		Aluminium	Silicon	Phosphorus	Sulphur	Chlorine	Argon
/B	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	26.98	28.09	30.97	32.10	35.45	39.95
, 0	3 4 5		7 7110	O VIIID	3 VIIIB	10 VIIID		12 110						
1.54	23 1.63	24 1.66	25 1.55	26 1.83	27 1.88	28 1.91	29 1.90	30 1.65	31 1.81	32 2.01	33 2.18	34 2.55	35 2.96	36 3.00
ï	V	Cr*	Mn	Fe	Co	Ni	Cu★	Zn	Ga	Ge	As	Se	Br_2	Kr
ium	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel		Zinc ⁽²⁺⁾	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton
87	50.94	52.00	54.94	55.85	58.93	58.69	Copper 63.55	65.38	69.72	72.63	74.92	78.97	79.90	83.80
01	30.31	32.00	31.31	33.03	30.33	30.03	03.33	03.30	03.12	12.03	7 1.52	10.51	13.30	03.00
1.33	41 1.6	42 2.16	43 1.9	44 2.2	45 2.28	46 2.20	47 1.93	48 1.69	49 1.78	50 1.96	51 2.05	52 2.1	53 2.86	54 2.60
	_						_							
r	Nb*	Mo★	Tc	Ru*	Rh*	Pd**	Ag	Cd	In	Sn ★	Sb	Te	I ₂	Xe
nium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver ⁽¹⁺⁾	Cadmium	Indium	Tin	Antimony	Tellurium	lodine	Xenon
22	92.91	95.95	(98)	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
							70 0.54							
1.3	73 1.5	74 2.36	75 1.9	76 2.2	77 2.20	78 2.28	79 2.54	80 2.00	81 1.62	82 1.87	83 2.02	84 2.0	85 2.2	86 2.2
f	Ta	W	Re	Os	lr	Pt	Au★	Hg	TI	Pb	Bi	Po	At	Rn
ium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	(209)	(210)	(222)
4														
f	105	106	107	108	109	110	111	112	113	114	115	116	117	118
													117 T s	
fordium	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	FI	Mc	Lv		Og
	Db Dubnium	Sg Seaborgium	Bh Bohrium	Hs Hassium	Mt Meitnerium	Ds Darmstadtium	Rg Roentgenium	Cn Copernicium	Nh Nihonium	FI Flerovium	Mc Moscovium	L V Livermorium	Ts Tennessine	Og Ogannesson
fordium 7)	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	FI	Mc	Lv		Og
7)	Db Dubnium (268)	Sg Seaborgium (269)	Bh Bohrium (270)	Hs Hassium (277)	Mt Meitnerium (278)	Ds Darmstadtium (281)	Rg Roentgenium (282)	Cn Copernicium (285)	Nh Nihonium (286)	Flerovium (289)	Mc Moscovium (290)	Lv Livermorium (293)	Ts Tennessine (294)	Og Ogannesson (294)
7)	Dubnium (268) 58 1.12	Sg Seaborgium (269) 59 1.13	Bh Bohrium (270) 60 1.14	Hs Hassium (277) 61 1.13	Mt Meitnerium (278) 62 1.17	Ds Darmstadtium (281)	Rg Roentgenium (282)	Cn Copernicium (285)	Nh Nihonium (286) 66 1.22	Flerovium (289) 67 1.23	Mc Moscovium (290) 68 1.24	Lv Livermorium (293) 69 1.25	Tennessine (294) 70 1.1	Ogannesson (294) 71 1.27
7)	Db Dubnium (268) 58 1.12 Ce	Sg Seaborgium (269) 59 1.13 Pr	Bh Bohrium (270) 60 1.14 Nd	Hs Hassium (277) 61 1.13 Pm	Mt Meitnerium (278) 62 1.17 Sm	Ds Darmstadtium (281) 63 1.2 Eu	Rg Roentgenium (282) 64 1.2 Gd	Cn Copernicium (285) 65 1.1 Tb	Nh Nihonium (286) 66 1.22 Dy	Flerovium (289) 67 1.23 Ho	Mc Moscovium (290) 68 1.24 Er	Lv Livermorium (293) 69 1.25 Tm	75 Tennessine (294) 70 1.1 Yb	Og Ogannesson (294) 71 1.27 Lu
1.1 a	Db Dubnium (268) 58 1.12 Ce Cerium	Sg Seaborgium (269) 59 1.13 Pr Praseodymium	Bh Bohrium (270) 60 1.14 Nd Neodymium	Hs Hassium (277) 61 1.13 Pm Promethium	Mt Meitnerium (278) 62 1.17 Sm Samarium	Ds Darmstadtium (281) 63 1.2 Eu Europium	Rg Roentgenium (282) 64 1.2 Gd Gadolinium	Cn Copernicium (285) 65 1.1 Tb Terbium	Nh Nihonium (286) 66 1.22 Dy Dysprosium	Flerovium (289) 67 1.23 Ho Holmium	Mc Moscovium (290) 68 1.24 Er Erbium	Lv Livermorium (293) 69 1.25 Tm Thulium	Tennessine (294) 70 1.1 Yb Ytterbium	Og Ogannesson (294) 71 1.27 Lu Lutetium
1.1 a	Db Dubnium (268) 58 1.12 Ce	Sg Seaborgium (269) 59 1.13 Pr	Bh Bohrium (270) 60 1.14 Nd	Hs Hassium (277) 61 1.13 Pm	Mt Meitnerium (278) 62 1.17 Sm	Ds Darmstadtium (281) 63 1.2 Eu	Rg Roentgenium (282) 64 1.2 Gd	Cn Copernicium (285) 65 1.1 Tb	Nh Nihonium (286) 66 1.22 Dy	Flerovium (289) 67 1.23 Ho	Mc Moscovium (290) 68 1.24 Er	Lv Livermorium (293) 69 1.25 Tm	75 Tennessine (294) 70 1.1 Yb	Og Ogannesson (294) 71 1.27 Lu
1.1 a anum .91	Db Dubnium (268) 58 1.12 Ce Cerium 140.12	Sg Seaborgium (269) 59 1.13 Pr Praseodymium 140.91	Bh Bohrium (270) 60 1.14 Nd Neodymium 144.24	Hs Hassium (277) 61 1.13 Pm Promethium (145)	Meitnerium (278) 62 1.17 Sm Samarium 150.36	Ds Darmstadtium (281) 63 1.2 Eu Europium 151.96	Roentgenium (282) 64 1.2 Gd Gadolinium 157.25	Cn Copernicium (285) 65 1.1 Tb Terbium 158.93	Nh Nihonium (286) 66 1.22 Dy Dysprosium 162.50	Flerovium (289) 67 1.23 HO Holmium 164.93	Mc Moscovium (290) 68 1.24 Er Erbium 167.26	Lv Livermorium (293) 69 1.25 Tm Thulium 168.93	70 1.1 Yb Ytterbium 173.05	Og Ogannesson (294) 71 1.27 Lu Lutetium 174.97
7)	Db Dubnium (268) 58 1.12 Ce Cerium 140.12 90 1.3	\$\frac{\sqrt{g}}{\sqrt{seaborgium}}\$\text{(269)}\$ \$\frac{\sqrt{9}}{\sqrt{1.13}}\$\text{\text{Pr}}{\text{Praseodymium}}\$\text{140.91}\$ \$\frac{\sqrt{91}}{\sqrt{1.5}}\$	Bh Bohrium (270) 60 1.14 Nd Neodymium	Hs Hassium (277) 61 1.13 Pm Promethium (145) 93 1.36	Mt Meitnerium (278) 62 1.17 Sm Samarium 150.36 94 1.28	Ds Darmstadtium (281) 63 1.2 Eu Europium	Roentgenium (282) 64 1.2 Gd Gadolinium 157.25 96 1.28	Cn Copernicium (285) 65 1.1 Tb Terbium 158.93	Nh Nihonium (286) 66 1.22 Dy Dysprosium 162.50 98 1.3	Flerovium (289) 67 1.23 Ho Holmium 164.93	Mc Moscovium (290) 68 1.24 Er Erbium 167.26	Lv Livermorium (293) 69 1.25 Tm Thulium 168.93	Tennessine (294) 70 1.1 Yb Ytterbium 173.05 102 1.3	Og Ogannesson (294) 71 1.27 Lu Lutetium
1.1 a anum .91	Db Dubnium (268) 58 1.12 Ce Cerium 140.12 90 1.3	\$\frac{\sqrt{g}}{\sqrt{seaborgium}}\$\text{(269)}\$ \$\frac{\sqrt{9}}{\sqrt{1.13}}\$\text{\text{Pr}}{\text{Praseodymium}}\$\text{140.91}\$ \$\frac{\sqrt{91}}{\sqrt{1.5}}\$	Bh Bohrium (270) 60 1.14 Nd Neodymium 144.24 92 1.38	Hs Hassium (277) 61 1.13 Pm Promethium (145) 93 1.36	Meitnerium (278) 62 1.17 Sm Samarium 150.36	Ds Darmstadtium (281) 63 1.2 Eu Europium 151.96	Roentgenium (282) 64 1.2 Gd Gadolinium 157.25	Cn Copernicium (285) 65 1.1 Tb Terbium 158.93	Nh Nihonium (286) 66 1.22 Dy Dysprosium 162.50	Flerovium (289) 67 1.23 HO Holmium 164.93	Mc Moscovium (290) 68 1.24 Er Erbium 167.26	Lv Livermorium (293) 69 1.25 Tm Thulium 168.93	70 1.1 Yb Ytterbium 173.05	Og Ogannesson (294) 71 1.27 Lu Lutetium 174.97
1.1 a anum .91	Db Dubnium (268) 58 1.12 Ce Cerium 140.12 90 1.3 Th	Sg Seaborgium (269) 59 1.13 Pr Praseodymium 140.91 91 1.5 Pa	Bh Bohrium (270) 60 1.14 Nd Neodymium 144.24 92 1.38 U	Hs Hassium (277) 61 1.13 Pm Promethium (145)	Mt Meitnerium (278) 62 1.17 Sm Samarium 150.36 94 1.28	Ds Darmstadtium (281) 63 1.2 Eu Europium 151.96 95 1.13	Roentgenium (282) 64 1.2 Gd Gadolinium 157.25 96 1.28	Cn Copernicium (285) 65 1.1 Tb Terbium 158.93	Nh Nihonium (286) 66 1.22 Dy Dysprosium 162.50 98 1.3	Flerovium (289) 67 1.23 Ho Holmium 164.93	Mc Moscovium (290) 68 1.24 Er Erbium 167.26	Lv Livermorium (293) 69 1.25 Tm Thulium 168.93	Tennessine (294) 70 1.1 Yb Ytterbium 173.05 102 1.3	Ogannesson (294) 71 1.27 Lu Lutetium 174.97 103 1.3
1.1 a anum 91 1.1	Db Dubnium (268) 58 1.12 Ce Cerium 140.12 90 1.3	\$\frac{\sqrt{g}}{\sqrt{seaborgium}}\$\text{(269)}\$ \$\frac{\sqrt{9}}{\sqrt{1.13}}\$\text{\text{Pr}}{\text{Praseodymium}}\$\text{140.91}\$ \$\frac{\sqrt{91}}{\sqrt{1.5}}\$	Bh Bohrium (270) 60 1.14 Nd Neodymium 144.24 92 1.38	Hs Hassium (277) 61 1.13 Pm Promethium (145) 93 1.36 Np	Mt Meitnerium (278) 62 1.17 Sm Samarium 150.36 94 1.28 Pu	Ds Darmstadtium (281) 63 1.2 Eu Europium 151.96 95 1.13 Am	Rg Roentgenium (282) 64 1.2 Gd Gadolinium 157.25 96 1.28 Cm	Cn Copernicium (285) 65 1.1 Tb Terbium 158.93 97 1.3 Bk	Nh Nihonium (286) 66 1.22 Dy Dysprosium 162.50 98 1.3 Cf	Flerovium (289) 67 1.23 HO Holmium 164.93 99 1.3 Es	Mc Moscovium (290) 68 1.24 Er Erbium 167.26	Lv Livermorium (293) 69 1.25 Tm Thulium 168.93 101 1.3 Md	Tennessine (294) 70 1.1 Yb Ytterbium 173.05 102 1.3 No	Og Ogannesson (294) 71 1.27 Lu Lutetium 174.97 103 1.3 Lr