## $= 8.314 \frac{\overline{\text{L} \cdot \text{kPa} \vee \text{J}}}$ $R_{\rm gas\text{-}law} = 0.0821 \frac{{\sf L} \cdot {\sf atm}}{{\sf mol} \cdot {\sf K}} = 62.4 \frac{{\sf L} \cdot {\sf mmHg}}{{\sf mol} \cdot {\sf M}} = 62.4 \frac{{\sf L} \cdot {\sf mmHg}}{{\sf mol} \cdot {\sf M}} = 62.4 \frac{{\sf L} \cdot {\sf M}}{{\sf mol} \cdot {\sf M}} = 62.$ $453.6 \; \mathrm{g}$ $2.54 \; \mathrm{cm}$ $0.946 \; \mathrm{L}$ $6.022 \times 10^{23} \; \mathrm{units}$ $22.4 \; \mathrm{L}$ 1 in 1 qt 1 lb $P_{\mathsf{sea}}$ $\frac{1}{g_{\text{water}}} =$ $1 \mathsf{\ atm}$ $\frac{1}{1} \frac{1}{\text{mL}_{\text{water}}} = \frac{1}{101325} \frac{1}{\text{Pa}} = \frac{1}{760} \frac{1}{\text{mmHg}} = \frac{1}{14.7} \frac{1}{\text{psi}}$ $^{\circ}\mathsf{C} = \frac{5}{9}(^{\circ}\mathsf{F} - 32)$ and $^{\circ}\mathsf{F} = \frac{9}{5}{}^{\circ}\mathsf{C} + 32$

 $h = 6.626 \times 10^{-34} \text{Js} \vee \text{kgm}^2 \text{s}^{-1} \text{ and } c = 3.00 \times 10^8 \text{ ms}^{-1}$ 

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

 $C_4H_{10}$  HCIO $_4$  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

1 IA

 $H_2$ 

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

HNO<sub>3</sub>

H<sub>2</sub>SO<sub>4</sub>

 $C_3H_8 \mid HCIO_3$ 

Gas

CO

 $CO_2$ 

 $CH_4$ 

 $C_2H_6$ 

NO NO<sub>2</sub>

N<sub>2</sub>O NH<sub>3</sub>

 $SO_3 SO_2$ H<sub>2</sub>S HCl

Super<sup>7</sup>

0.82

0.79

0.7

19

37

55

2.20

0.98

0.93

0.82

1

 $\triangle H_{\text{vap}} = 40.67 \text{kJ mol}^{-1}$ 

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

 $E_{\rm photon} = hf = \frac{hc}{\lambda}$  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 Ruther-

fordium

Rf

(267)

La

Lanthanum

138.91

Ac

Actinium

(227)

1.1

57

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

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

= 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

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

## **Periodic Table of Elements**

$PV = nRT$ and $\left[P + \frac{an^2}{V^2}\right][V - nb] = nRT$	<u> </u>
$PV \propto 1$ and $VT \propto 1$ (Boyle and Charle).	
$M = \frac{\text{moles solute}}{\text{L solution}} \text{ and } m = \frac{\text{moles solute}}{\text{kg solvent}}$	H
L solution kg solvent	
$X_{\text{mol fraction}} = \frac{\text{mol component}}{\text{mol total}}.$	

		$k = Ae^{-\frac{E_a}{RT}}$ $[A]_t = [A]_0 - kt$ $[A]_t = [A]_0e^{-kt}$ $[A]_t = \frac{1}{kt + \frac{1}{ A _0}}$	
K	$K_a=rac{[{\sf H_3O^+}][{\sf A}^-]}{[{\sf HA}]}$ and $K_b=rac{[{\sf HB}][{\sf OH}^-]}{[{\sf B}^-]}$ , in water, ${\sf K_a}$	$K_{b} = 1.0 \times 10^{-14}$	

ol					Ion	Soluble with	Precipita								
		Γ2]			NO <sub>3</sub> Nitrate	Most cations	No commo								
		$\left[P + \frac{an^2}{V^2}\right] \left[V - \right]$		$=Ae^{-\frac{E_a}{RT}}$	CIO <sub>4</sub>	Most cations	No commo								
	$PV \propto 1$ and $VT$	$7 \propto 1$ (Boyle and	Charle). $\begin{vmatrix} \kappa = 1 \\ 0 \end{vmatrix}$	$= Ae^{-RT}$	CIO <sub>3</sub>	Most cations	No commo								
	$M = \frac{\text{moles solut}}{M}$	$\frac{\text{te}}{\text{n}}$ and $m = \frac{\text{mol}}{\text{kg}}$	es solute [A]	$t = [A]_0 - kt$ $t = [A]_0 e^{-kt}$	$C_2H_3O_2^-$	Most cations	$Ag^+,I$								
	L solution	n kg	solvent $\begin{bmatrix} \begin{bmatrix} 2 & 1 \end{bmatrix} \\ \begin{bmatrix} A \end{bmatrix}$	$t = \frac{1}{kt + \frac{1}{ A _0}}$	F <sup>-</sup>	Most cations	Cr <sup>3</sup>								
	$X_{\text{mol fraction}} = \frac{\text{mod}}{1}$	mol total ·	[1-1]	$t   kt + \frac{1}{[A]_0}$	CI <sup>-</sup>	Most cations	(Ag, TI) <sup>+</sup> , Pb	$Hg_{2}^{2+,4+},Hg_{2}^{2+}$							
7.7	[H <sub>2</sub> O <sup>+</sup> ][A <sup>-</sup> ]	7.2 [HB][OH <sup>-</sup> ]		1.0. 10-14	Br <sup>-</sup>	Most cations	(Ag, TI) <sup>+</sup> , Pb	$\frac{p^{2+,4+},Hg_2^{2+}}{p^{2+,4+},Hg_2^{2+}}$							
	L J	$K_b = \frac{[HB][OH^-]}{[B^-]},$		1 1	-  -	Most cations	(Ag, TI) <sup>+</sup> , Pb	$P^{2+,4+},Hg_2^{2+}$						18 VIIIA	
pl	$H = -\log_{10}[H^+]$	$-\log [-\log t]$	${ m g}_{10}[{\sf OH}^-]$ , ${\sf pK}_{\sf a}=$	$= -\log_{10}[K_a]$	$SO^{2-}_4$	Most cations	Ag <sup>+</sup> , Ba <sup>2</sup> Pb <sup>2+,4+</sup> , C	*+,Sr*+,						2	
pH ⊣	- $pOH = 14$ , and	$K_c = rac{[product]}{[reactant]}$ ,	$K_{eq}, K_{sp} \leftrightarrow K_{p}$	$= K_{c}(RT)^{\triangle n}   \underline{\hspace{0.2cm}}$	C 02-	N4	Pb <sup>2+</sup> , 1, C	$a^{2+}, Hg_2^{2+}$	5.2		. 21	12 - 21 - 21 21	2   2	2	
K <sub>a-</sub>	$_{\rm acetic} = 1.8 \times 10$	$0^{-5}$ , and <b>in buff</b>	$er pH = pK_a +$	$\log_{10}\left(\frac{[A^-]}{[HA]}\right)$ .	$CrO_4^{2-}$	Most cations	Ba <sup>2+</sup> , Sr <sup>2+</sup>		Li <sup>+</sup> , K <sup>+</sup> , Ba <sup>2</sup>	$^+$ , $\text{Ca}^{2+}$ , $\text{Na}^+$ , $\text{Na}^+$	$Mg^{2+}$ , $Al^{3+}$ , $Mn^{-1}$	$^{+2}$ , $Zn^{2+}$ , $Cr^{3+,2+}$	<sup>+</sup> , Fe <sup>3+,2+</sup> ,	He	
				-10 ([IIA])	S <sup>2-</sup>	$Na^+, K^+, NH_4^+,$	Ca <sup>2+</sup> ,		Co-1, NI1, S	on-', Pb-', 2H'	, Cu-''', Ag', I	agar, Ptar, Aus	1,1	Helium	
$=\frac{h}{mv}$					3	$Li^+, Sr^{2+}$	Most othe	er Cations	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	4.00	
$\overline{}$ $mv$		D A 1/		Z + DAIZ	1 <sup>-</sup> HO	$Na^+, K^+, NH_4^+, Li^-$	, Most other	ar cations	<b>5</b> 0.04		7 0.14	0 244	0 2.00	10	
I		$+ w = q - P \triangle V$ $\triangle S = \frac{q_{\text{if-reverse}}}{T}$ , o				$Sr^{2+}$ , $Ba^{2+}$ , $Ca^{2+}$		ci cations	5 2.04	<b>6</b> 2.55	<b>7</b> 3.14	8 3.44	9 3.98	10	
		1	$r S = \kappa m W $ (II	iicro-state)	CO <sub>3</sub> <sup>2-</sup>	$\frac{(Na, K, NH_4, Li)^+}{(Na, K, NH_4, Li)^+}$	Most othe	er cations	В	C	$N_2$	$O_2$	$F_2$	Ne	
		$\times 10^{-23}  \text{JK}^{-1}$			PO <sub>4</sub> <sup>3-</sup>	$Na^+, K^+, NH_4^+$	Most othe		Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon	
	$\triangle S = k \ln S$	$\ln\left(rac{W_{final}}{W_{initial}} ight)$ and $ riangle$	$\Delta S_{surr.} = -\frac{\Delta H^{\circ}}{T}$			No <sub>common</sub> cations			10.81	12.01	14.01	116.00	19.00	20.18	
C/m	$-T\triangle S_{\text{univ}}$	$_{\text{verse}} = \triangle H_{\text{system}}$	$-T\triangle S_{system}$		$(Na,K,NH_4)^+$	Most Anions	(NH <sub>4</sub> ) <sub>2</sub>		40 4 44		4	44	4= 0.40		
$=K_b\eta$	.	$T\triangle S_{universe} = \triangle$	-,		Bi <sup>3+</sup>	Nothing	Most a		<b>13</b> 1.61	14 1.90	<b>15</b> 2.19	<b>16</b> 2.38	<b>17</b> 3.16	18	
g		universe -			$As^{3+}$	I-	Most a	nions	Al	Si	Р	S	$Cl_2$	Ar	
					Sb <sup>3+</sup>	CI <sup>-</sup>	Most a	nions	Aluminium	Silicon	Phosphorus	Sulphur	Chlorine	Argon	
3	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	
	00 1.00	<b>24</b> 1.66	<b>05</b> 1.55	06 100	07 1.00	00 1.01	<b>29</b> 1.90	20 1.55	21 1.01	20 0.01	22 0.10	24 0.55	25 0.06	26 0.00	
1.54	<b>23</b> 1.63		<b>25</b> 1.55	<b>26</b> 1.83	27 1.88	<b>28</b> 1.91		<b>30</b> 1.65	<b>31</b> 1.81	<b>32</b> 2.01	<b>33</b> 2.18	<b>34</b> 2.55	<b>35</b> 2.96	<b>36</b> 3.00	
	V	Cr*	Mn	Fe	Co	Ni	Cu*	Zn	Ga	Ge	As	Se	$Br_2$	Kr	
ım	Vanadium	Chromium	Manganese	Iron	Cobalt	Nickel	Copper	Zinc <sup>(2+)</sup>	Gallium	Germanium	Arsenic	Selenium	Bromine	Krypton	
,	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.64	74.92	78.96	79.90	83.80	
	41 16	42 0.16	43 1.0	44 0.0	4E 2.20	46 2.20	47 4.00			<b>FO</b> 1.06					
1.33	41 1.6	<b>42</b> 2.16	<b>43</b> 1.9	44 2.2	<b>45</b> 2.28	<b>46</b> 2.20	<b>47</b> 1.93	48 1.69	<b>49</b> 1.78	<b>50</b> 1.96	<b>51</b> 2.05	<b>52</b> 2.1	<b>53</b> 2.86	<b>54</b> 2.60	
	Nb★	Mo*	Tc	Ru*	Rh <b>*</b>	Pd*	Ag	Cd	In	Sn*	Sb	Te	$I_2$	Xe	
um	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	$Silver^{(1+)}$	Cadmium	Indium	Tin	Antimony	Tellurium	lodine	Xenon	
2	92.91	95.94	(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							0.0	
1.3	<b>73</b> 1.5	<b>74</b> 2.36	<b>75</b> 1.9	<b>76</b> 2.2	<b>77</b> 2.20	<b>78</b> 2.28	<b>79</b> 2.54	<b>80</b> 2.00	<b>81</b> 1.62	<b>82</b> 1.87	<b>83</b> 2.02	<b>84</b> 2.0	<b>85</b> 2.2	<b>86</b> 2.2	
1	Ta	W	Re	Os	lr	Pt	Au★	Hg	TI	Pb	Bi	Po	At	Rn	
m	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon	
9	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)	
		106					444 5							110	
her-	105	106	107	108	109	<b>110</b> Darm-	111 Roent-	<b>112</b> Coper-	113	114	115	<b>116</b> Liver-	117	118	
m	Dubnium	Seaborgium	Bohrium	Hassium	Meitnerium	stadtium	genium	nicium	Nihonium	Flerovium	Moscovium	morium	Tennessine	Ogannesson	
	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	FI	Mc	Lv	Ts	Og	
)	(268)	(269)	(270)	(277)	(278)	(281)	(282)	(285)	(286)	(289)	(290)	(293)	(294)	(294)	
1.1	<b>58</b> 1.12	<b>59</b> 1.13	60 1.14	<b>61</b> 1.13	<b>62</b> 1.17	<b>63</b> 1.2	<b>64</b> 1.2	<b>65</b> 1.1	<b>66</b> 1.22	<b>67</b> 1.23	<b>68</b> 1.24	<b>69</b> 1.25	<b>70</b> 1.1	<b>71</b> 1.27	
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
um					Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	
1	Cerium	Praseodymium	Neodymium	Promethium	Samanum	Luiopiuiii							i tterbium		
T		Praseodymium 140.91	Neodymium 144.24	(145)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.05	174.97	
1	Cerium			(145)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.05	174.97	
1.1	Cerium			(145) <b>93</b> 1.36	150.36 <b>94</b> 1.28			158.93 <b>97</b> 1.3	162.50 <b>98</b> 1.3	164.93 <b>99</b> 1.3	167.26 100 1.3	168.93 <b>101</b> 1.3	173.05 <b>102</b> 1.3		
1.1	Cerium 140.12 90 1.3	140.91 <b>91</b> 1.5	144.24 <b>92</b> 1.38	(145) <b>93</b> 1.36	150.36 <b>94</b> 1.28	151.96 <b>95</b> 1.13	157.25 <b>96</b> 1.28	158.93 <b>97</b> 1.3	162.50	164.93	167.26 100 1.3	168.93 <b>101</b> 1.3	173.05	174.97	
1.1 m	Cerium 140.12	140.91	144.24	(145)	150.36	151.96	157.25	158.93	162.50 <b>98</b> 1.3	164.93 <b>99</b> 1.3	167.26	168.93	173.05 <b>102</b> 1.3	174.97 103 1.3	
	Cerium 140.12 90 1.3 Th	140.91 91 1.5 Pa	92 1.38 U	(145) 93 1.36 Np	150.36 94 1.28 Pu	151.96 95 1.13 Am	157.25 96 1.28 Cm	158.93 <b>97</b> 1.3 <b>Bk</b>	162.50 98 1.3 Cf	164.93 <b>99</b> 1.3	167.26  100 1.3  Fm	168.93  101 1.3  Md	173.05  102 1.3  No	174.97  103 1.3  Lr	