SCH4U: Chemistry, Grade 12, University Preparation

Periodic Table

1 IA												13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 **H** 1.01	2 IIA																2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.1	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.29
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac^** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
^	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Ions

Ion formula	Ion name	Ion formula	Ion name
NH_4^+	Ammonium		
$CH_3CO_2^-$	Acetate	PO_4^{3-}	Phosphate
CN^-	Cyanide	HPO_4^{2-}	Hydrogen phosphate
NO_2^-	Nitrite	$H_2PO_4^-$	Dihydrogen phosphate
NO_3^-	Nitrate	ClO^-	Hypochlorite
CO_3^{2-}	Carbonate	ClO_2^-	Chlorite
HCO_3^-	Hydrogen carbonate (or bicarbonate)	ClO_3^-	Chlorate
SO_3^{2-}	Sulfite	ClO_4^-	Perchlorate
SO_4^{2-}	Sulfate	CrO_4^{2-}	Chromate
HSO_4^-	Hydrogen sulfate (or bisulfate)	$Cr_2O_7^{2-}$	Dichromate
MnO_4^-	Permanganate	O_2^{2-}	Peroxide

Standard Reduction Potentials

	$E°_r$ (V)
$F_{2(g)} + 2e^- \rightleftharpoons 2F^-_{(aq)}$	+2.87
$PbO_{2(s)} + SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} + 2e^- \rightleftharpoons PbSO_{4(s)} + 2H_2O_{(l)}$	+1.69
$MnO_4^-{}_{(aq)} + 8H^+_{(aq)} + 5e^- \rightleftharpoons Mn^{2+}_{(aq)} + 4H_2O_{(l)}$	+1.51
$Au^{3+}_{(aq)} + 3e^- \rightleftharpoons Au_{(s)}$	+1.50
$ClO_4^-{}_{(aq)} + 8H^+_{(aq)} + 8e^- \rightleftharpoons Cl^-_{(aq)} + 4H_2O_{(l)}$	+1.39
$Cl_{2(g)} + 2e^- \rightleftharpoons 2Cl^-_{(aq)}$	+1.36
$2HNO_{2(aq)} + 4H^+_{(aq)} + 4e^- \rightleftharpoons N_2O_{(g)} + 3H_2O_{(l)}$	+1.30
$Cr_2O_7^{2-}{}_{(aq)} + 14H^+_{(aq)} + 6e^- \rightleftharpoons 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$	+1.23
$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightleftharpoons 2H_2O_{(l)}$	+1.23
$MnO_{2(s)} + 4H^+_{(aq)} + 2e^- \rightleftharpoons Mn^{2+}_{(aq)} + 2H_2O_{(l)}$	+1.22
$2IO_3^-{}_{(aq)} + 12H^+_{(aq)} + 10e^- \rightleftharpoons I_{2(s)} + 6H_2O_{(l)}$	+1.20
$Br_{2(l)} + 2e^- \rightleftharpoons 2Br^-_{(aq)}$	+1.07
$Hg^{2+}_{(aq)} + 2e^- \rightleftharpoons Hg_{(l)}$	+0.85
$ClO^-_{(aq)} + H_2O_{(l)} + 2e^- \rightleftharpoons Cl^-_{(aq)} + 2OH^-_{(aq)}$	+0.84
$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$	+0.80
$NO_3^-{}_{(aq)} + 2H^+_{(aq)} + e^- \rightleftharpoons NO_{2(g)} + H_2O_{(l)}$	+0.80
$Fe^{3+}_{(aq)} + e^- \rightleftharpoons Fe^{2+}_{(aq)}$	+0.77
$O_{2(g)} + 2H^+_{(aq)} + 2e^- \rightleftharpoons H_2O_{2(l)}$	+0.70
$MnO_4^-{}_{(aq)} + 2H_2O_{(l)} + 3e^- \rightleftharpoons MnO_{2(s)} + 4OH^-_{(aq)}$	+0.60
$I_{2(s)} + 2e^- \rightleftharpoons 2I^-_{(aq)}$	+0.54
$Cu^+_{(aq)} + e^- \rightleftharpoons Cu_{(s)}$	+0.52
$O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightleftharpoons 4OH^-_{(aq)}$	+0.40
$Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$	+0.34
$SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} + 2e^- \rightleftharpoons H_2SO_{3(aq)} + H_2O_{(l)}$	+0.17
$Sn^{4+}_{(aq)} + 2e^- \rightleftharpoons Sn^{2+}_{(aq)}$	+0.15
$Cu^{2+}_{(aq)} + e^- \rightleftharpoons Cu^+_{(aq)}$	+0.15
$S_{(s)} + 2H^+_{(aq)} + 2e^- \rightleftharpoons H_2S_{(aq)}$	+0.14
$AgBr_{(s)} + e^- \rightleftharpoons Ag_{(s)} + Br^-_{(aq)}$	+0.07
$2H^+_{(aq)} + 2e^- \rightleftharpoons H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2e^- \rightleftharpoons Pb_{(s)}$	−0.13
$Sn^{2+}_{(aq)} + 2e^- \rightleftharpoons Sn_{(s)}$	−0.14
$AgI_{(s)} + e^- \rightleftharpoons Ag_{(s)} + I^-_{(aq)}$	−0.15
$Ni^{2+}_{(aq)} + 2e^- \rightleftharpoons Ni_{(s)}$	−0.26
$Co^{2+}_{(aq)} + 2e^- \rightleftharpoons Co_{(s)}$	−0.28
$H_3PO_{4(aq)} + 2H^+_{(l)} + 2e^- \rightleftharpoons H_3PO_{3(aq)} + H_2O_{(l)}$	−0.28
$PbSO_{4(s)} + 2e^- \rightleftharpoons Pb_{(s)} + SO_4^{2-}{}_{(aq)}$	−0.36
$Se_{(s)} + 2H^+_{(aq)} + 2e^- \rightleftharpoons H_2Se_{(aq)}$	−0.40
$Cd^{2+}_{(aq)} + 2e^- \rightleftharpoons Cd_{(s)}$	−0.40
$Cr^{3+}_{(aq)} + e^- \rightleftharpoons Cr^{2+}_{(aq)}$	−0.41
$Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(s)}$	−0.44
$Ag_2S_{(s)} + 2e^- \rightleftharpoons 2Ag_{(s)} + S^{2-}_{(aq)}$	−0.69
$Zn^{2+}_{(aq)} + 2e^- \rightleftharpoons Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+_{(aq)} + 2e^- \rightleftharpoons H_2Te_{(aq)}$	−0.79
$2H_2O_{(l)} + 2e^- \rightleftharpoons H_{2(g)} + 2OH^-_{(aq)}$	−0.83
$Cr^{2+}_{(aq)} + 2e^- \rightleftharpoons Cr_{(s)}$	−0.91
$SO_4^{2-}{}_{(aq)} + H_2O_{(l)} + 2e^- \rightleftharpoons SO_3^{2-}{}_{(aq)} + 2OH^-_{(aq)}$	−0.93
$Al^{3+}_{(aq)} + 3e^- \rightleftharpoons Al_{(s)}$	−1.66
$Mg^{2+}_{(aq)} + 2e^- \rightleftharpoons Mg_{(s)}$	−2.37
$Na^+_{(aq)} + e^- \rightleftharpoons Na_{(s)}$	−2.71
$Ca^{2+}_{(aq)} + 2e^- \rightleftharpoons Ca_{(s)}$	−2.87
$Ba^{2+}_{(aq)} + 2e^- \rightleftharpoons Ba_{(s)}$	−2.91
$K^+_{(aq)} + e^- \rightleftharpoons K_{(s)}$	−2.93
$Li^+_{(aq)} + e^- \rightleftharpoons Li_{(s)}$	−3.04

Equations and Constants

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$P_A = P_{\text{total}} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{M}$$

$$\text{K} = {}^\circ\text{C} + 273$$

$$D = \frac{m}{V}$$

P = pressure
V = volume
T = temperature
n = number of moles
m = mass
M = molar mass
D = density

Gas constant, $R = 8.314 \text{ J mol}^{-1}\text{ K}^{-1}$
$= 0.08206 \text{ L atm mol}^{-1}\text{ K}^{-1}$
$= 62.36 \text{ L torr mol}^{-1}\text{ K}^{-1}$
1 atm = 760 mm Hg
= 760 torr
STP = 0.00 °C and 1.000 atm

EQUILIBRIUM

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}, \text{ where } a\text{ A} + b\text{ B} \rightleftarrows c\text{ C} + d\text{ D}$$

$$K_p = \frac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$
$$= K_a \times K_b$$

$$\text{pH} = -\log[H^+], \ \text{pOH} = -\log[OH^-]$$

$$14 = \text{pH} + \text{pOH}$$

$$\text{pH} = \text{p}K_a + \log\frac{[A^-]}{[HA]}$$

$$\text{p}K_a = -\log K_a, \ \text{p}K_b = -\log K_b$$

Equilibrium Constants

K_c (molar concentrations)
K_p (gas pressures)
K_a (weak acid)
K_b (weak base)
K_w (water)

THERMOCHEMISTRY/ ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

q = heat
m = mass
c = specific heat capacity
T = temperature
H° = standard enthalpy

First 10 Alkanes

Names of the first 10 alkanes

# of Carbon atoms	Name	Molecular Formula
1	methane	CH_4
2	ethane	C_2H_6
3	propane	C_3H_8
4	butane	C_4H_{10}
5	pentane	C_5H_{12}
6	hexane	C_6H_{14}
7	heptane	C_7H_{16}
8	octane	C_8H_{18}
9	nonane	C_9H_{20}
10	decane	$C_{10}H_{22}$

Standard Molar Entropies and Enthalpies of Formation

C6 Standard Molar Entropies and Enthalpies of Formation

Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))	Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))
acetone	$(CH_3)_2CO_{(l)}$	−248.1	198.8	carbon disulfide	$CS_{2(l)}$	+89.0	–
aluminum oxide	$Al_2O_{3(s)}$	−1675.7	50.92	carbon monoxide	$CO_{(g)}$	−110.5	197.66
ammonia	$NH_{3(g)}$	−45.9	192.78	chloroethene	$C_2H_3Cl_{(g)}$	+37.3	263.9
ammonium chloride	$NH_4Cl_{(s)}$	−314.4	94.6	chromium(III) oxide	$Cr_2O_{3(s)}$	−1139.7	81.2
ammonium chloride	$NH_4Cl_{(aq)}$	−299.7	169.9	copper(I) oxide	$Cu_2O_{(s)}$	−168.6	93.1
ammonium nitrate	$NH_4NO_{3(s)}$	−365.6	151.08	copper(II) oxide	$CuO_{(s)}$	−157.3	42.6
barium carbonate	$BaCO_{3(s)}$	−1216.3	112.1	copper(I) sulfide	$Cu_2S_{(s)}$	−79.5	120.9
barium hydroxide	$Ba(OH)_{2(s)}$	−944.7	107	copper(II) sulfide	$CuS_{(s)}$	−53.1	66.5
barium oxide	$BaO_{(s)}$	−553.5	72.07	cyclopropane	$C_3H_{6(g)}$	+17.8	–
barium sulfate	$BaSO_{4(s)}$	−1473.2	132.2	1,2-dichloroethane	$C_2H_4Cl_{2(l)}$	−126.9	–
benzene	$C_6H_{6(l)}$	+49.0	173.4	ethane	$C_2H_{6(g)}$	−83.8	229.1
bromine (vapour)	$Br_{2(g)}$	+30.9	245.47	1,2-ethanediol	$C_2H_4(OH)_{2(l)}$	−454.8	163.2
butane	$C_4H_{10(g)}$	−125.6	310.1	ethanoic (acetic) acid	$CH_3COOH_{(l)}$	−432.8	159.9
calcium carbonate	$CaCO_{3(s)}$	−1206.9	91.7	ethanol	$C_2H_5OH_{(l)}$	−235.2	161.0
calcium chloride	$CaCl_{2(s)}$	−795.8	104.6	ethanol	$C_2H_5OH_{(g)}$	−235.2	282.70
calcium hydroxide	$Ca(OH)_{2(s)}$	−986.1	83.4	ethene (ethylene)	$C_2H_{4(g)}$	+52.5	219.3
calcium oxide	$CaO_{(s)}$	−634.9	38.1	ethyne (acetylene)	$C_2H_{2(g)}$	+228.2	201.0
calcium sulphate	$CaSO_{4(s)}$	−1434.1	108.4	glucose	$C_6H_{12}O_{6(s)}$	−1273.1	212.1
carbon dioxide	$CO_{2(g)}$	−393.5	213.78				

Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))
hexane	$C_6H_{14(l)}$	−198.7	296.1
hydrazine	$N_2H_{4(g)}$	+95.4	237.11
hydrazine	$N_2H_{4(l)}$	50.6	121.2
hydrogen bromide	$HBr_{(g)}$	−36.3	198.70
hydrogen chloride	$HCl_{(g)}$	−92.3	186.90
hydrogen cyanide	$HCN_{(g)}$	+135.1	201.81
hydrogen iodide	$HI_{(g)}$	+26.5	206.59
hydrogen peroxide	$H_2O_{2(l)}$	−187.8	109.6
hydrogen sulfide	$H_2S_{(g)}$	−20.6	205.81
iodine (vapour)	$I_{2(g)}$	+62.4	180.79
iron(III) oxide	$Fe_2O_{3(s)}$	−824.2	87.40
iron(II, III) oxide	$Fe_3O_{4(s)}$	−1118.4	145.27
lead(II) oxide	$PbO_{(s)}$	−219.0	66.5
lead(IV) oxide	$PbO_{2(s)}$	−277.4	68.60
magnesium carbonate	$MgCO_{3(s)}$	−1095.8	65.7
magnesium chloride	$MgCl_{2(s)}$	−641.3	89.63
magnesium hydroxide	$Mg(OH)_{2(s)}$	−924.5	63.24
magnesium oxide	$MgO_{(s)}$	−601.6	26.95
manganese(II) oxide	$MnO_{(s)}$	−385.2	59.8
manganese(IV) oxide	$MnO_{2(s)}$	−520.0	53.1
mercury	$Hg_{(l)}$	0.0	75.90
mercury	$Hg_{(g)}$	61.4	174.97
mercury(II) oxide	$HgO_{(s)}$	−90.8	70.25
mercury(II) sulfide	$HgS_{(s)}$	−58.2	82.4
methanal (formaldehyde)	$CH_2O_{(g)}$	−108.6	218.8
methane	$CH_{4(g)}$	−74.4	186.3
methanoic (formic) acid	$HCOOH_{(l)}$	−425.1	129.0
methanol	$CH_3OH_{(l)}$	−239.1	126.8
methylpropane	$C_4H_{10(g)}$	−134.2	294.6
nickel(II) oxide	$NiO_{(s)}$	−239.7	38.00
nitric acid	$HNO_{3(l)}$	−174.1	155.60
nitrogen dioxide	$NO_{2(g)}$	+33.2	240.1
nitrogen monoxide	$NO_{(g)}$	+90.2	210.76
nitromethane	$CH_3NO_{2(l)}$	−113.1	171.8
octane	$C_8H_{18(l)}$	−250.1	—
ozone	$O_{3(g)}$	+142.7	163.2
pentane	$C_5H_{12(l)}$	−173.5	262.7
phenylethene (styrene)	$C_6H_5CHCH_{2(l)}$	+103.8	237.6
phosphorus pentachloride	$PCl_{5(g)}$	−443.5	364.6
phosphorus trichloride	$PCl_{3(l)}$	−319.7	217.2
phosphorus trichloride	$PCl_{3(g)}$	−287.0	311.8
potassium	$K_{(s)}$	0.0	75.90
potassium	$K_{(l)}$	2.3	71.46
potassium chlorate	$KClO_{3(s)}$	−397.7	143.1
potassium chloride	$KCl_{(s)}$	−436.7	82.55
potassium hydroxide	$KOH_{(s)}$	−424.8	78.9
propane	$C_3H_{8(g)}$	−104.7	270.2
silicon dioxide	$SiO_{2(s)}$	−910.7	41.46
silver bromide	$AgBr_{(s)}$	−100.4	107.11
silver chloride	$AgCl_{(s)}$	−127.0	96.25
silver iodide	$AgI_{(s)}$	−61.8	115.5
sodium bromide	$NaBr_{(s)}$	−361.1	86.82
sodium chloride	$NaCl_{(s)}$	−411.2	115.5
sodium hydroxide	$NaOH_{(s)}$	−425.6	64.4
sodium iodide	$NaI_{(s)}$	−287.8	98.50
sucrose	$C_{12}H_{22}O_{11(s)}$	−2225.5	360.2
sulfur dioxide	$SO_{2(g)}$	−296.8	248.22
sulfur trioxide (liquid)	$SO_{3(l)}$	−441.0	—
sulfur trioxide (vapour)	$SO_{3(g)}$	−395.7	256.77
sulfuric acid	$H_2SO_{4(l)}$	−814.0	156.90
tin(II) oxide	$SnO_{(s)}$	−280.7	57.17
tin(IV) oxide	$SnO_{2(s)}$	−577.6	49.04
2,2,4-trimethylpentane	$C_8H_{18(l)}$	−259.2	328.0
urea	$CO(NH_2)_{2(s)}$	−333.5	104.6
water (liquid)	$H_2O_{(l)}$	−285.8	69.95
water (vapour)	$H_2O_{(g)}$	−241.8	188.84
zinc oxide	$ZnO_{(s)}$	−350.5	43.65
zinc sulfide	$ZnS_{(s)}$	−206.0	57.7

- Standard molar enthalpies (heats) of formation are measured at SATP (25°C and 100 kPa). The values were obtained from *The CRC Handbook of Chemistry and Physics*, 71st Edition.
- The standard molar enthalpies of elements in their standard states are defined as zero.