Chemistry 2209 Formulas and Data Sheets

Chemical Reactions, Equations, and Stoichiometry

$R = 0.08206 \frac{L * atm}{mol * K} = 8.314 \frac{Pa * m^3}{mol * K}$	$\%\ Yield = \frac{actual}{theoretical} \times 100\%$
Theoretical Yield is based upon the limiting reagent. To find Limiting Reagent, use dimensional analysis to calculate the mass of required entity and see which of the two is lower. The lower mass is the Limiting Reagent which = theoretical yield.	
$\%\ by\ mass = \frac{mass\ of\ solute}{mass\ of\ solution} \times 100\%$	$Molarity\ (Concentration) = \frac{\#\ of\ moles}{volume\ of\ solution} = \left(\frac{mol}{L}\right)$
$V_1 M_1 = V_2 M_2$ **concentrated** **dilute**	**For Chem Kinetics:** $ln\left(\frac{k_2}{k_1}\right) = \frac{Ea}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

Ideal Gas Law, other Constants, and Electrolysis Equation

$\Delta S^\circ_{TOTAL} = \frac{\Delta G^\circ}{T} = \Delta S^\circ - \Delta S^\circ_{SURROUNDING}$	**STP:** $0^\circ C$ **and** 1 atm (101.325 kPa) **SATP:** $25^\circ C$ **and** 100 kPa
$grams\ of\ species = \frac{It}{nF} \times Molar\ Mass$	$0\ Kelvin = -273.15^\circ C$

Thermochemistry

For thermochemistry assume ideal gas behavior. Thermochemical data @ 298K	$\Delta E = Q + W$ **where** $Q = mc\Delta T$ **&** $W = -kT$	$Q_V = nC_V \Delta T$ **(heat transfer @ constant volume)**
$C_P - C_V = R = 8.314 \frac{J}{mol * K}$	$Q_P - Q_V = W$ **(work done)**	$Q_P = nC_P \Delta T$ **(heat transfer @ constant pressure)**
$\Delta H = \Delta E + \Delta nRT$ **(In a bomb calorimeter = constant volume)**	$Q_P = \Delta H$ **then** $\Delta E = \Delta H - \Delta nRT$ **(At constant Pressure)**	$E = \frac{c * \Delta T}{\#\ of\ moles}$
$Q_{rxn} = -Q_{calori} = -(mc\Delta T + kT)$	$W = -P\Delta V = -\Delta nRT$	$Q = mc\Delta T$
$W = Fd = k\Delta T = Q_P$	$\Delta H^0_{rxn} = \sum_{products}[n * \Delta H^0] - \sum_{reactants}[n * \Delta H^0]$	**Internal energy change → ΔE** **Enthalpy Change → ΔH**

The Chemical Bond & Oxidation – Reduction Reactions

LEO the lion says GER ... RAO/OAR

LEO = lose electrons oxidation | GER = gain electrons reduction
RAO = reducing agent undergo oxidation | OAR = oxidizing agent undergo reduction

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Chemical Equilibrium, Solubility & K_{SP}

$K = Ae^{-Ea\,/\,RT}$	$ln\left(\frac{K_2}{K_1}\right) = \left(\frac{\Delta H^\circ}{R}\right)\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
$K_P = K_C\,(RT)^{\Delta n}$	$\Delta H = C\,\Delta T = wt$ **Where *T* is Temperature (K) & *t* is Time (sec)**

Chemical Kinetics

	Zero Order	First Order	Second Order
Rate Law:	$-\frac{d[A]}{dt} = k\,[A]^0$	$-\frac{d[A]}{dt} = k\,[A]^1$	$-\frac{d[A]}{dt} = k\,[A]^2$
Integrated Rate Law:	$[A]_t = -kt + [A]_O$	$ln\left(\frac{[A]_O}{[A]_T}\right) = kt$	$\frac{1}{[A]_T} - \frac{1}{[A]_O} = kt$
Linear Plot needed:	$[A]$ **versus** t **Units:** $M * s^{-1}$	$ln\,[A]$ **versus** t **Units:** s^{-1}	$\frac{1}{[A]}$ **versus** t **Units:** $M^{-1} * s^{-1}$
Rate Constant:	Slope = $-k$ | $\frac{1}{s}$	Slope = $-k$ | $\frac{1}{s}$	Slope = $+k$ | $\frac{L}{mol*s}$
Half Life:	$t_{1/2} = \frac{[A]_O}{2k}$	$t_{1/2} = \frac{ln\,2}{k}$	$t_{1/2} = \frac{1}{k * [A]_O}$

Acids, Bases, & Equilibrium

$K_W = [H^+][OH^-] = 1.0 \times 10^{-14}$	$pH + pOH = 14$	$pH = -\log[H^+]$
$pKa = -\log(Ka)$	$pKb = -\log(Kb)$	$pOH = -\log[OH^-]$
$(Ka)(Kb) = Kw = 1.0 \times 10^{-14}$	$pKa + pKb = 14$	$pH = pKa + \log\left(\frac{conjugate\ base}{conjugate\ acid}\right)$
% Ionization = $\frac{[A^-]}{[HA]}$ x *initial moles of acid or base per liter* x 100%		

Electrochemistry

$Q = It$	$\Delta G = -nFE^0$	$E^0 = E^0_{OXIDATION} + E^0_{REDUCTION}$
$E = E^0 - \left(\frac{0.05916}{n}\right)(\log Q)$	$E^0_{CELL} = \left(\frac{0.05916}{n}\right)(\log K)$	1 Faraday = 96485 coulombs
Concentration Cell → $E_{CELL} = -\left(\frac{0.05916}{n}\right)\left(\log \frac{[\,]\ dilute}{[\,]\ concentrated}\right)$ ←← can be log(Q) or log(K)		

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Conversion Factors and Physical Constants

Length	**Volume**	**Mass**
1 inch = 2.54 cm 1 mile = 1.609 km 1 foot = 0.3048 m	1 L = 1000 cm^3 = 1000 mL 1 gal (CAN) = 4.546 L 1 gal (USA) = 3.785 L 1 m^3 = 1000 L	1 lb = 453.6 g 1 metric ton = 1000 kg 1 g = 6.0221 x 10^{23} amu 1 kg = 2.205 lb
Energy	**Other**	**Pressure**
1 cal = 4.184 J 1 L $*$ atm = 101.325 J 1 psi = 0.06805 atm 1 psi = 6.895 kPa	1 Faraday = 96485 Coulombs 1 Ampere = 1 C / s 1 Newton = 1 $\frac{kg*m}{s}$ 1 Watt = 1 J / s 1 Hour = 60 min = 3600 s	1 Pa = 1 N/m^2 = 1 $kg/m * s^2$ 1 bar = 10^5 Pa 1 atm = 101.325 kPa 1 atm = 760 torr = 760 mm Hg 1 atm = 1.01325 bar 1 mm Hg = 1 torr

1 J = 1 N $*$ m = 1 $\frac{kg*m^2}{s^2}$ = 1 V $*$ C = 1 kPa $*$ L = 1 Pa $*$ m^3	Avagadro's #: N_A = 6.0221 x 10^{23} Elementary Charge: e = 1.6022 x 10^{-19} C Temperature Change: 0^0C = 273.15 K
Plank's Constant: h = 6.6256 x 10^{-34} J $*$ s Speed of Light: c = 2.99792458 x 10^8 m / s Atomic Mass Unit: 6.022 x 10^{23} amu = 1 g	Electron Mass: 9.1095 x 10^{-28} g Proton Mass: 1.67252 x 10^{-24} g Neutron Mass: 1.67495 x 10^{-24} g

Prefixes Used with SI Units

Tera (T) 10^{12}	Kilo (k) 10^3	Deci (d) 10^{-1}	Micro (μ) 10^{-6}
Giga (G) 10^9	Hecto (h) 10^2	Centi (c) 10^{-2}	Nano (n) 10^{-9}
Mega (M) 10^6	Deca (da) 10^1	Milli (m) 10^{-3}	Pico (p) 10^{-12}

Bond Dissociation Energies (kJ / mol)

$$\Delta H_{rxn} = \sum(\Delta H \text{ bonds broken}) - \sum(\Delta H \text{ bonds formed})$$

Bond	Energy	Bond	Energy	Bond	Energy
H – H	436	H – N	393	H – O	463
H – S	368	H – P	326	H – F	568
H – Cl	432	H – Br	366	H – I	298
C – H	413	C – C	348	C = C	620
C ≡ C	812	C – N	276	C = N	615
C ≡ N	891	C – O	360	C = O	802
C – P	263	C – S	255	C = S	477
N – N	193	N = N	418	N ≡ N	941
N – O	176	N – P	209	O – O	142
O = O	498	O – P	502	O = S	469
P – P	197	P = P	489	S – S	268
S = S	352	F – F	157	Cl – Cl	243
Br – Br	194	I – I	153		

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Specific Heat Capacities at Constant Pressure $\left(\frac{J}{g*°C}\right)$

Aluminium	0.902	Antimony	0.205		
Cadmium	0.232	Cobalt	0.456	Vanadium	0.485
Copper	0.385	Gold	0.129	Zinc	0.388
Iron (Ferrus)	0.449	Lead	0.159	Titanium	0.523
Magnesium	1.016	Manganese	0.477	Tungsten	0.133
Mercury	0.140	Nickel	0.443	Water	4.184
Platinum	0.133	Silver	0.237	Ethanol	2.489
Sodium	1.228	Tin	0.213		

Ionization Constants at 25°C

Acid Name	Formula	pKa_1	pKa_2	pKa_3
Acetic Acid	CH_3COOH	4.75	---	---
Ascorbic Acid	$H_2C_6H_6O_6$	4.10	11.79	---
Benzenesulfonic Acid	$C_6H_5SO_3H$	0.70	---	---
Benzoic Acid	C_6H_5COOH	4.19	---	---
Boric Acid	$B(OH)_3$	9.14	---	---
Carbonic Acid	H_2CO_3	6.37	10.25	---
Chloroacetic Acid	$CH_2ClCOOH$	2.85	---	---
Chlorous Acid	$HClO_2$	2.00	---	---
Citric Acid	$H_3C_6H_5O_7$	3.13	4.77	6.39
Cyanic Acid	HCNO	3.66	---	---
Dichloroacetic Acid	CH_2COOH	1.48	---	---
Formic Acid	HCOOH	3.72	---	---
Hydrocyanic Acid	HCN	9.31	---	---
Hydrofluoric Acid	HF	3.46	---	---
Hydrosulfuric Acid	H_2S	6.88	14.15	---
Hypobromous Acid	HBrO	8.69	---	---
Hypochlorous Acid	HClO	7.53	---	---
Hypoiodous Acid	HIO	10.64	---	---
Iodic Acid	HIO_3	0.77	---	---
Lactic Acid	$CH_3CH(OH)COOH$	3.08	---	---
Nitrous Acid	HNO_2	3.37	---	---
Oxalic Acid	$(COOH)_2$	1.23	4.19	---
Phenol	C_6H_5OH	9.89	---	---
Phosphoric Acid	H_3PO_4	2.12	7.21	12.35
Phosphorous Acid	H_3PO_3	2.00	6.59	---
O–Phthalic Acid	$H_2C_6H_4O_4$	2.89	5.51	---
Sulfuric Acid	H_2SO_4	(Strong)	1.92	---
Sulfurous Acid	H_2SO_3	1.77	7.22	---
Tartaric Acid	$C_2H_4O_2(COOH)_2$	3.22	4.82	---
Trichloacetic Acid	CCl_3COOH	0.70	---	---

HCl , HBr , HI , HNO_3 , H_2SO_4 (Ka_1 only) , $HClO_3$, $HClO_4$ → → **ARE STRONG ACIDS**

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Base Name	Formula	pKb
Ammonia	NH_3	4.75
Aniline	$C_6H_5NH_2$	9.37
Dimethylamine	$(CH_3)_2NH$	3.27
Ethylamine	$C_2H_5NH_2$	3.19
Hydrazine	NH_2NH_2	5.77
Hydroxylamine	NH_2OH	7.97
Methylamine	CH_3NH_2	3.44
Morphine	$C_{17}H_{19}O_3N$	5.79
Nicotine	$C_{10}H_{11}N_2$	5.98
Pyridine	C_5H_5N	8.75
Triethylamine	$(C_2H_5)_3N$	2.99
Trimethylamine	$(CH_3)_3N$	4.19
Urea	$CO(NH_2)_2$	13.90
LiOH , NaOH , KOH , RbOH ➔➔ **VERY SOLUBLE STRONG BASES**		
$Mg(OH)_2$, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$ ➔➔ **STRONG BASES OF VERY LOW SOLUBILITY**		

Solubility Product Constants at 25°C

Compound	Formula	K_{SP}
Aluminum Hydroxide	$Al(OH)_3$	1.0×10^{-33}
Antimony Sulfide	Sb_2S_3	1.7×10^{-93}
Barium Carbonate	$BaCO_3$	8.1×10^{-9}
Barium Fluoride	BaF_2	1.7×10^{-6}
Barium Sulfate	$BaSO_4$	1.1×10^{-10}
Bismuth Sulfide	Bi_2S_3	1.0×10^{-97}
Calcium Carbonate	$CaCO_3$	8.7×10^{-9}
Calcium Chromate	$CaCrO_4$	7.1×10^{-4}
Calcium Fluoride	CaF_2	4.0×10^{-11}
Calcium Hydroxide	$Ca(OH)_2$	6.5×10^{-6}
Calcium Phosphate	$Ca_3(PO_4)_2$	1.0×10^{-31}
Calcium Sulfate	$CaSO_4$	2.4×10^{-5}
Copper (I) Bromide	$CuBr$	4.2×10^{-8}
Copper (I) Chloride	$CuCl$	1.0×10^{-6}
Copper (I) Iodide	CuI	5.1×10^{-12}
Copper (I) Sulfide	Cu_2S	2.0×10^{-47}
Copper (II) Iodate	$Cu(IO_3)_2$	1.4×10^{-7}
Copper (II) Oxalate	CuC_2O_4	2.9×10^{-8}
Copper (II) Sulfide	CuS	8.5×10^{-45}
Iron (II) Hydroxide	$Fe(OH)_2$	1.6×10^{-14}
Iron (II) Sulfide	FeS	6.3×10^{-18}
Iron (III) Hydroxide	$Fe(OH)_3$	2.0×10^{-39}
Iron (III) Sulfide	Fe_2S_3	1.4×10^{-28}
Lead (II) Bromide	$PbBr_2$	7.9×10^{-5}
Lead (II) Carbonate	$PbCO_3$	7.4×10^{-14}
Lead (II) Chloride	$PbCl_2$	1.6×10^{-5}
Lead (II) Fluoride	PbF_2	3.7×10^{-8}

Lead (II) Hydroxide	$Pb(OH)_2$	1.2×10^{-15}
Lead (II) Iodate	$Pb(IO_3)_2$	2.6×10^{-13}
Lead (II) Iodide	PbI_2	1.4×10^{-8}
Lead (II) Sulfate	$PbSO_4$	1.6×10^{-8}
Lead (II) Sulfide	PbS	3.4×10^{-28}
Lithium Carbonate	Li_2CO_3	1.7×10^{-3}
Magnesium Ammonium Phosphate	$MgNH_4PO_4$	2.5×10^{-13}
Magnesium Carbonate	$MgCO_3$	1.0×10^{-5}
Magnesium Fluoride	MgF_2	6.4×10^{-9}
Magnesium Hydroxide	$Mg(OH)_2$	1.1×10^{-11}
Mercury (I) Chloride	Hg_2Cl_2	1.3×10^{-18}
Mercury (I) Iodide	Hg_2I_2	1.2×10^{-28}
Mercury (II) Sulfide	HgS *(black)*	1.6×10^{-52}
Nickel (II) Hydroxide	$Ni(OH)_2$	6.5×10^{-18}
Silver Bromide	AgBr	7.7×10^{-13}
Silver Carbonate	Ag_2CO_3	6.2×10^{-12}
Silver Chloride	AgCl	1.6×10^{-10}
Sliver Chromate	Ag_2CrO_4	1.2×10^{-12}
Silver Hydroxide	AgOH	1.5×10^{-8}
Silver Iodide	AgI	1.5×10^{-16}
Silver Sulfate	Ag_2SO_4	1.4×10^{-5}
Silver Sulfide	Ag_2S	6.3×10^{-51}
Strontium Fluoride	SrF_2	7.9×10^{-10}
Strontium Sulfate	$SrSO_4$	3.2×10^{-7}
Zinc Hydroxide	$Zn(OH)_2$	4.5×10^{-17}
Zinc Sulfide	ZnS	1.6×10^{-24}

Standard Thermodynamic Data at 25°C and 1 atm

Compound	Formula	ΔH°f (kJ/mol)	ΔG°f (kJ/mol)	S° (J/K●mol)
Acetate ion	CH_3COO^- (aq)	−486.0	−369.2	+86.6
Acetic acid	CH_3COOH (aq)	−485.8	−396.5	+178.7
Ammonia	NH_3 (g) , NH_3 (aq)	−46.1 , −80.3	−16.5 , −26.5	+192 , +111
Ammonium chloride	NH_4Cl (S)	−314.4	−202.9	+94.6
Ammonium nitrate	NH_4NO_3 (S)	−365.6	−183.9	+151.1
Benzene	C_6H_6 (L)	+49.0	+124.4	+172.8
Calcium hydroxide	$Ca(OH)_2$ (S)	−986.1	−898.5	+83.4
Carbon (Graphite)	C	0	0	+5.7
Carbon (Diamond)	C	+1.9	+2.9	+2.4
Carbon dioxide	CO_2 (g)	−393.5	−394.4	+213.7
Carbon disulfide	CS_2 (L)	+89.7	+65.3	+151.3
Carbon monoxide	CO (g)	−110.5	−137.2	+197.7
Carbonate ion	CO_3^{2-} (aq)	−677.1	−527.8	−56.9
Chloride ion	Cl^- (aq)	−167.2	−131.2	+56.5
Copper (II) ion	Cu^{2+} (aq)	+64.8	+65.5	−99.6
Copper (II) chloride	$CuCl_2$ (S)	−220.1	−175.7	+108.1

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Copper (II) oxide	$CuO_{(S)}$	−157.3	−129.7	+42.6
Cyanide ion	$CN^-_{(aq)}$	+150.6	+172.4	+94.1
Cyclohexane	$C_6H_{12\,(L)}$	−156.4	+26.7	+204.4
Cyclopropane	$C_3H_{6\,(g)}$	+53.3	+104.4	+237.4
Dinitrogen oxide	$N_2O_{(g)}$	+82.1	+104.2	+219.9
Dinitrogen tetraoxide	$N_2O_{4\,(g)}$	+9.16	+97.9	+304.3
Ethane	$C_2H_{6\,(g)}$	−84.7	−32.8	+229.6
Ethanol	$C_2H_5OH_{(L)}$	−277.7	−174.8	+160.7
Ethylene	$C_2H_{4\,(g)}$	+52.3	+68.2	+219.6
Fluoride ion	$F^-_{(aq)}$	−332.6	−278.8	−13.8
Glucose	$C_6H_{12}O_{6\,(S)}$	−1274.5	−910.6	+212.1
Hydrazine	$N_2H_{4\,(g)}$	+95.4	+159.4	+238.5
Hydrogen chloride	$HCl_{(g)}$	−92.3	−95.3	+186.9
Hydrogen fluoride	$HF_{(g)}$	−271.1	−273.2	+173.8
Hydrogen peroxide	$H_2O_{2\,(aq)}$	−191.2	−134.0	+143.9
Hydrogen sulfide	$H_2S_{(g)}$	−20.6	−33.6	+205.8
Hydronium ion	$H_3O_{(aq)}$, $H^+_{(aq)}$	0	0	0
Hydroxide ion	$OH^-_{(aq)}$	−230.0	−157.2	−10.7
Iron (III) oxide	$Fe_2O_{3\,(S)}$	−824.2	−742.2	+87.4
Mercury *(gas)*	$Hg_{(g)}$	+61.3	+31.8	+174.9
Mercury *(liquid)*	$Hg_{(L)}$	0	0	+76.0
Mercury (I) chloride	$Hg_2Cl_{2\,(S)}$	−265.2	−210.7	+192.5
Mercury (II) chloride	$HgCl_{2\,(S)}$	−224.3	−178.6	+146.0
Methane	$CH_{4\,(g)}$	−74.8	−50.7	+186.3
Methanol	$CH_3OH_{(L)}$	−238.7	−166.3	+126.8
Nitrogen dioxide	$NO_{2\,(g)}$	+33.2	+51.3	+240.1
Nitrogen monoxide	$NO_{(g)}$	+90.2	+86.6	+210.8
Nitrate ion	$NO_3^-{}_{(aq)}$	−205.0	−108.7	+146.4
Octane	$C_8H_{18\,(L)}$	−250.0	+6.4	+358.0
Oxygen	$O_{2\,(g)}$	0	0	+205.1
Ozone	$O_{3\,(g)}$	+142.7	+163.2	+238.9
Potassium chlorate	$KClO_{3\,(S)}$	−397.7	−296.2	+143.1
Potassium chloride	$KCl_{(S)}$	−436.7	−409.1	+82.6
Propane	$C_3H_{8\,(g)}$	−103.9	−23.5	+270.2
Propene	$C_3H_{6\,(g)}$	+20.4	+62.8	+266.6
Silver ion	$Ag^+_{(aq)}$	−105.6	−77.1	+72.7
Silver chloride	$AgCl_{(S)}$	−127.1	−109.8	+96.2
Sucrose	$C_{12}H_{22}O_{11\,(S)}$	−2221.0	−1544.2	+360.2
Sulfur dioxide	$SO_{2\,(g)}$	−296.8	−300.2	+248.2
Sulfur trioxide	$SO_{3\,(g)}$	−395.7	−371.1	+256.8
Water	$H_2O_{(g)}$, $H_2O_{(L)}$	−241 , −285	−228 , −237	+188 , +69.9

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Formation Constant (K_F) of Complex Ions at 25°C

Ammonia Complexes:

$Ag(NH_3)_2^{2+}$	1.6×10^7
$Cd(NH_3)_4^{2+}$	1.0×10^7
$Cu(NH_3)_4^{2+}$	1.1×10^{13}
$Ni(NH_3)_6^{2+}$	5.5×10^8
$Zn(NH_3)_4^{2+}$	2.9×10^9

Hydroxide Complexes:

$Al(OH)_4^-$	7.7×10^{33}
$Zn(OH)_4^{2-}$	2.2×10^{16}

Halide Complexes:

$AgCl_2^-$	2.5×10^5
AlF_6^{3-}	6.7×10^{19}
$HgCl_4^{2-}$	1.2×10^{15}
HgI_4^{2-}	1.9×10^{30}

Cyanide Complexes:

$Ag(CN)_2^-$	1.0×10^{21}
$Au(CN)_2^-$	2.0×10^{38}
$Cd(CN)_4^{2-}$	1.2×10^{17}
$Cu(CN)_2^-$	1.0×10^{24}
$Cu(CN)_3^{2-}$	2.0×10^{27}
$Fe(CN)_6^{4-}$	1.0×10^{24}
$Fe(CN)_2^{3-}$	1.0×10^{31}
$Ni(CN)_4^{2-}$	1.0×10^{22}
$Hg(CN)_4^{2-}$	2.0×10^{41}
$Zn(CN)_4^{2-}$	6.0×10^{16}

Other Complexes:

$Ag(S_2O_3)_2^{3-}$	1.7×10^{13}
$Fe(C_2O_4)_3^{3-}$	3.0×10^{20}
$Fe(SCN)^{2-}$	1.2×10^2
$Zn(EDTA)^{2-}$	3.8×10^{16}

Calculating Entropy (Use the Equation below)

$$2d(O\text{–}H) + c(C\text{=}O) - a(n-1)(C\text{–}C) - a(2n+2)(C\text{–}H) - 2b(O\text{=}O) - d(44)$$

Standard Reduction Potentials Half-Reactions at 25°C, 1 $\frac{\text{mol}}{\text{L}}$, and 1 atm can be found on the next page ➔➔➔➔➔➔➔➔➔➔➔➔➔➔➔➔➔➔