



# Ember

EDUCATION

# Data Booklet

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H2 CHEMISTRY

WHATSAPP 88640447

[ember-education.com](https://ember-education.com)

# CHEM-IS-TRY *ing.* *Tiring.*

## But not at Ember.

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*An ember is the quiet, glowing piece of charcoal at a fireplace. Not yet a flame, but ready to catch fire. That is the vision of Ember Education for every student who walks through our doors.*

### **One class. One school. One pace.**

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Every JC follows the same H2 syllabus, but the order, pacing, and exam calendar at your school is nothing like the JC just a few MRT stops away. **Tuition centres that squeeze students from all JCs try to please everyone but end up syncing with no one.**

The advantage of Ember Education: **a class dedicated to your pace and your learning.**

### **Built around your school's calendar.**

When your school is three weeks out from a test, **the whole class is three weeks out.** We revise and drill the topics your school is testing, on the schedule your school is testing them. No more sitting through revision for content your school hasn't covered yet, or rushing past topics your school is still on.

### **Curated notes and questions.**

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Do you wish your notes went **straight to the point** more often? Our materials are handcrafted to **strip what's unnecessary**, leaving only what matters. Questions are curated to broaden exposure and **sharpen the instincts needed to score.** We build a strong foundation first, then layer upwards, without rushing. Students are also taught **the specific answering techniques markers look out for.**

### **Easy to reach, whenever you need us.**

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Currently located a short walk from **Jurong East MRT, Mayflower MRT, and Kovan MRT.** More classrooms opening up around Singapore. Contact us today.



*Come in for a free trial lesson, and see what learning at your school's pace feels like.*

# Fees & Referral

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## Fees

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Year 1	\$340 / month
Year 2	\$350 / month
Year 3	\$360 / month

First 50 sign-ups get 20% off their first month.

*Taking 2 or more subjects? \$50 off your second subject.*

## Referral Programme

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Know a friend who finds Chem tough too? Refer them.

1 <sup>st</sup> referral	\$88 cash
2 <sup>nd</sup> referral	\$108 cash
3 <sup>rd</sup> referral	\$138 cash
4 <sup>th</sup> referral	\$188 cash
5 <sup>th</sup> referral	\$288 cash

*Your referred friend also gets 20% off their first month (first 50 sign-ups only).*

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## 1 Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
the Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
rest mass of proton, ${}^1_1\text{H}$	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of neutron, ${}^1_0\text{n}$	$m_n = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron, ${}^0_{-1}\text{e}$	$m_e = 9.11 \times 10^{-31} \text{ kg}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.7 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. $V_m = 24 \text{ dm}^3 \text{ mol}^{-1}$ at r.t.p. (where s.t.p. is expressed as $10^5 \text{ Pa}$ [1 bar] and $273 \text{ K}$ [ $0^\circ \text{C}$ ], r.t.p. is expressed as $101\,325 \text{ Pa}$ [1 atm] and $293 \text{ K}$ [ $20^\circ \text{C}$ ])
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at $298 \text{ K}$ [ $25^\circ \text{C}$ ])
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ (= $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ )

## 2 Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements, in $\text{kJ mol}^{-1}$

	Proton Number	First	Second	Third	Fourth
H	1	1310	–	–	–
He	2	2370	5250	–	–
Li	3	519	7300	11800	–
Be	4	900	1760	14800	21000
B	5	799	2420	3660	25000
C	6	1090	2350	4610	6220
N	7	1400	2860	4590	7480
O	8	1310	3390	5320	7450
F	9	1680	3370	6040	8410
Ne	10	2080	3950	6150	9290
Na	11	494	4560	6940	9540
Mg	12	736	1450	7740	10500
Al	13	577	1820	2740	11600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
Cl	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4940	6480
Sc	21	632	1240	2390	7110
Ti	22	661	1310	2720	4170
V	23	648	1370	2870	4600
Cr	24	653	1590	2990	4770
Mn	25	716	1510	3250	5190
Fe	26	762	1560	2960	5400
Co	27	757	1640	3230	5100

	<b>Proton Number</b>	<b>First</b>	<b>Second</b>	<b>Third</b>	<b>Fourth</b>
Ni	28	736	1750	3390	5400
Cu	29	745	1960	3350	5690
Zn	30	908	1730	3828	5980
Ga	31	577	1980	2960	6190
Ge	32	762	1540	3300	4390
Br	35	1140	2080	3460	4850
Rb	37	403	2632	3900	5080
Sr	38	548	1060	4120	5440
Ag	47	731	2074	3361	–
Sn	50	707	1410	2940	3930
I	53	1010	1840	3200	4030
Cs	55	376	2420	3300	–
Ba	56	502	966	3390	–
Pb	82	716	1450	3080	4080

### 3 Bond energies

#### 3(a) Bond energies in diatomic molecules (*these are exact values*)

##### Homonuclear

Bond	Energy/kJ mol <sup>-1</sup>
H-H	436
D-D	442
N≡N	944
O=O	496
F-F	158
Cl-Cl	244
Br-Br	193
I-I	151

##### Heteronuclear

Bond	Energy/kJ mol <sup>-1</sup>
H-F	562
H-Cl	431
H-Br	366
H-I	299
C=O	1077

**3(b) Bond energies in polyatomic molecules** (*these are average values*)

**Homonuclear**

Bond	Energy/kJ mol <sup>-1</sup>
C–C	350
C=C	610
C≡C	840
C⋯C (benzene)	520
N–N	160
N=N	410
O–O	150
Si–Si	222
P–P	200
S–S	264

**Heteronuclear**

Bond	Energy/kJ mol <sup>-1</sup>
C–H	410
C–F	485
C–C/	340
C–Br	280
C–I	240
C–N	305
C=N	610
C≡N	890
C–O	360
C=O	740
C=O in CO <sub>2</sub>	805
N–H	390
N–C/	310
O–H	460
Si–C/	359
Si–H	320
Si–O (in SiO <sub>2</sub> (s))	460
Si=O (in SiO <sub>2</sub> (g))	640
P–H	320
P–C/	330
P–O	340
P=O	540
S–H	347
S–C/	250
S–O	360
S=O	500

## 4 Standard electrode potential and redox potentials, $E^\ominus$ at 298 K (25 °C)

For ease of reference, two tabulations are given:

- an extended list in alphabetical order;
- a shorter list in decreasing order of magnitude, i.e. a redox series.

### 4(a) $E^\ominus$ in alphabetical order

Electrode reaction	$E^\ominus / V$
$\text{Ag}^+ + e^- \rightleftharpoons \text{Ag}$	+0.80
$\text{Al}^{3+} + 3e^- \rightleftharpoons \text{Al}$	-1.66
$\text{Ba}^{2+} + 2e^- \rightleftharpoons \text{Ba}$	-2.90
$\text{Br}_2 + 2e^- \rightleftharpoons 2\text{Br}^-$	+1.07
$\text{Ca}^{2+} + 2e^- \rightleftharpoons \text{Ca}$	-2.87
$\text{Cl}_2 + 2e^- \rightleftharpoons 2\text{Cl}^-$	+1.36
$2\text{HOCl} + 2\text{H}^+ + 2e^- \rightleftharpoons \text{Cl}_2 + 2\text{H}_2\text{O}$	+1.64
$\text{ClO}^- + \text{H}_2\text{O} + 2e^- \rightleftharpoons \text{Cl}^- + 2\text{OH}^-$	+0.81
$\text{Co}^{2+} + 2e^- \rightleftharpoons \text{Co}$	-0.28
$\text{Co}^{3+} + e^- \rightleftharpoons \text{Co}^{2+}$	+1.89
$[\text{Co}(\text{NH}_3)_6]^{2+} + 2e^- \rightleftharpoons \text{Co} + 6\text{NH}_3$	-0.43
$\text{Cr}^{2+} + 2e^- \rightleftharpoons \text{Cr}$	-0.91
$\text{Cr}^{3+} + 3e^- \rightleftharpoons \text{Cr}$	-0.74
$\text{Cr}^{3+} + e^- \rightleftharpoons \text{Cr}^{2+}$	-0.41
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6e^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1.33
$\text{Cu}^+ + e^- \rightleftharpoons \text{Cu}$	+0.52
$\text{Cu}^{2+} + 2e^- \rightleftharpoons \text{Cu}$	+0.34
$\text{Cu}^{2+} + e^- \rightleftharpoons \text{Cu}^+$	+0.15
$[\text{Cu}(\text{NH}_3)_4]^{2+} + 2e^- \rightleftharpoons \text{Cu} + 4\text{NH}_3$	-0.05
$\text{F}_2 + 2e^- \rightleftharpoons 2\text{F}^-$	+2.87
$\text{Fe}^{2+} + 2e^- \rightleftharpoons \text{Fe}$	-0.44
$\text{Fe}^{3+} + 3e^- \rightleftharpoons \text{Fe}$	-0.04
$\text{Fe}^{3+} + e^- \rightleftharpoons \text{Fe}^{2+}$	+0.77
$[\text{Fe}(\text{CN})_6]^{3-} + e^- \rightleftharpoons [\text{Fe}(\text{CN})_6]^{4-}$	+0.36
$\text{Fe}(\text{OH})_3 + e^- \rightleftharpoons \text{Fe}(\text{OH})_2 + \text{OH}^-$	-0.56
$2\text{H}^+ + 2e^- \rightleftharpoons \text{H}_2$	0.00
$\text{I}_2 + 2e^- \rightleftharpoons 2\text{I}^-$	+0.54
$\text{K}^+ + e^- \rightleftharpoons \text{K}$	-2.92
$\text{Li}^+ + e^- \rightleftharpoons \text{Li}$	-3.04
$\text{Mg}^{2+} + 2e^- \rightleftharpoons \text{Mg}$	-2.38
$\text{Mn}^{2+} + 2e^- \rightleftharpoons \text{Mn}$	-1.18
$\text{Mn}^{3+} + e^- \rightleftharpoons \text{Mn}^{2+}$	+1.54
$\text{MnO}_2 + 4\text{H}^+ + 2e^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1.23
$\text{MnO}_4^- + e^- \rightleftharpoons \text{MnO}_4^{2-}$	+0.56
$\text{MnO}_4^- + 4\text{H}^+ + 3e^- \rightleftharpoons \text{MnO}_2 + 2\text{H}_2\text{O}$	+1.67

Electrode reaction	$E^\ominus / \text{V}$	
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.52	
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2 + \text{H}_2\text{O}$	+0.81	
$\text{NO}_3^- + 3\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{HNO}_2 + \text{H}_2\text{O}$	+0.94	
$\text{NO}_3^- + 10\text{H}^+ + 8\text{e}^- \rightleftharpoons \text{NH}_4^+ + 3\text{H}_2\text{O}$	+0.87	
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$	-2.71	
$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$	-0.25	
$[\text{Ni}(\text{NH}_3)_6]^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni} + 6\text{NH}_3$	-0.51	
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1.77	
$\text{HO}_2^- + \text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons 3\text{OH}^-$	+0.88	
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$	+1.23	← oxidation of water
$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$	+0.40	
$\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2$	+0.68	
$\text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{HO}_2^- + \text{OH}^-$	-0.08	
$2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2 + 2\text{OH}^-$	-0.83	← reduction of water
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$	-0.13	
$\text{Pb}^{4+} + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+}$	+1.69	
$\text{PbO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+} + 2\text{H}_2\text{O}$	+1.47	
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2 + 2\text{H}_2\text{O}$	+0.17	
$\text{S}_2\text{O}_8^{2-} + 2\text{e}^- \rightleftharpoons 2\text{SO}_4^{2-}$	+2.01	
$\text{S}_4\text{O}_6^{2-} + 2\text{e}^- \rightleftharpoons 2\text{S}_2\text{O}_3^{2-}$	+0.09	
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$	-0.14	
$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}$	+0.15	
$\text{V}^{2+} + 2\text{e}^- \rightleftharpoons \text{V}$	-1.20	
$\text{V}^{3+} + \text{e}^- \rightleftharpoons \text{V}^{2+}$	-0.26	
$\text{VO}^{2+} + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{V}^{3+} + \text{H}_2\text{O}$	+0.34	
$\text{VO}_2^+ + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{VO}^{2+} + \text{H}_2\text{O}$	+1.00	
$\text{VO}_3^- + 4\text{H}^+ + \text{e}^- \rightleftharpoons \text{VO}_2^+ + 2\text{H}_2\text{O}$	+1.00	
$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$	-0.76	

All ionic states refer to aqueous ions but other state symbols have been omitted.

**4(b)  $E^\ominus$  in decreasing order of oxidising power**

(a selection only — see also the extended alphabetical list on the previous pages)

Electrode reaction	$E^\ominus / V$
$F_2 + 2e^- \rightleftharpoons 2F^-$	+2.87
$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1.77
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1.52
$PbO_2 + 4H^+ + 2e^- \rightleftharpoons Pb^{2+} + 2H_2O$	+1.47
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.33
$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23
$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.07
$NO_3^- + 10H^+ + 8e^- \rightleftharpoons NH_4^+ + 3H_2O$	+0.87
$ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-$	+0.81
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$	+0.81
$Ag^+ + e^- \rightleftharpoons Ag$	+0.80
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0.77
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.34
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2 + 2H_2O$	+0.17
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+0.15
$S_4O_6^{2-} + 2e^- \rightleftharpoons 2S_2O_3^{2-}$	+0.09
$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	-0.13
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	-0.14
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	-0.44
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	-0.76
$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$	-0.83
$V^{2+} + 2e^- \rightleftharpoons V$	-1.20
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	-2.38
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	-2.87
$K^+ + e^- \rightleftharpoons K$	-2.92

## 5 Atomic and ionic radii

	atomic/nm		ionic/nm			
<b>(a) Period 1</b>						
single covalent	H	0.037			H <sup>-</sup>	0.208
van der Waals	He	0.140				
<b>(b) Period 2</b>						
metallic	Li	0.152	Li <sup>+</sup>	0.060		
	Be	0.112	Be <sup>2+</sup>	0.031		
single covalent	B	0.080	B <sup>3+</sup>	0.020		
	C	0.077	C <sup>4+</sup>	0.015	C <sup>4-</sup>	0.260
	N	0.074			N <sup>3-</sup>	0.171
	O	0.073			O <sup>2-</sup>	0.140
	F	0.072			F <sup>-</sup>	0.136
van der Waals	Ne	0.160				
<b>(c) Period 3</b>						
metallic	Na	0.186	Na <sup>+</sup>	0.095		
	Mg	0.160	Mg <sup>2+</sup>	0.065		
	Al	0.143	Al <sup>3+</sup>	0.050		
single covalent	Si	0.117	Si <sup>4+</sup>	0.041		
	P	0.110			P <sup>3-</sup>	0.212
	S	0.104			S <sup>2-</sup>	0.184
	Cl	0.099			Cl <sup>-</sup>	0.181
van der Waals	Ar	0.190				
<b>(d) Group 2</b>						
metallic	Be	0.112	Be <sup>2+</sup>	0.031		
	Mg	0.160	Mg <sup>2+</sup>	0.065		
	Ca	0.197	Ca <sup>2+</sup>	0.099		
	Sr	0.215	Sr <sup>2+</sup>	0.113		
	Ba	0.217	Ba <sup>2+</sup>	0.135		
	Ra	0.220	Ra <sup>2+</sup>	0.140		

	atomic/nm		ionic/nm	
<b>(e) Group 14</b>				
single covalent	C	0.077		
	Si	0.117	Si <sup>4+</sup>	0.041
	Ge	0.122	Ge <sup>2+</sup>	0.093
metallic	Sn	0.162	Sn <sup>2+</sup>	0.112
	Pb	0.175	Pb <sup>2+</sup>	0.120
<b>(f) Group 17</b>				
single covalent	F	0.072		F <sup>-</sup> 0.136
	Cl	0.099		Cl <sup>-</sup> 0.181
	Br	0.114		Br <sup>-</sup> 0.195
	I	0.133		I <sup>-</sup> 0.216
	At	0.140		
<b>(g) First row d block elements</b>				
metallic	Sc	0.164		Sc <sup>3+</sup> 0.075
	Ti	0.146	Ti <sup>2+</sup> 0.086	Ti <sup>3+</sup> 0.067
	V	0.135	V <sup>2+</sup> 0.079	V <sup>3+</sup> 0.064
	Cr	0.129	Cr <sup>2+</sup> 0.073	Cr <sup>3+</sup> 0.062
	Mn	0.132	Mn <sup>2+</sup> 0.083	Mn <sup>3+</sup> 0.058
	Fe	0.126	Fe <sup>2+</sup> 0.061	Fe <sup>3+</sup> 0.055
	Co	0.125	Co <sup>2+</sup> 0.065	Co <sup>3+</sup> 0.055
	Ni	0.124	Ni <sup>2+</sup> 0.069	Ni <sup>3+</sup> 0.056
	Cu	0.128	Cu <sup>2+</sup> 0.073	
	Zn	0.135	Zn <sup>2+</sup> 0.074	

## 6 Typical proton ( $^1\text{H}$ ) chemical shift values ( $\delta$ ) relative to TMS = 0

Type of proton	Environment of proton	Example structures	Chemical Shift range ( $\delta$ )
C–H	alkane	$-\text{CH}_3$ , $-\text{CH}_2-$ , $>\text{CH}-$	0.9–1.7
	alkyl next to C=O	$\text{CH}_3-\text{C}=\text{O}$ , $-\text{CH}_2-\text{C}=\text{O}$ , $>\text{CH}-\text{C}=\text{O}$	2.2–3.0
	alkyl next to aromatic ring	$\text{CH}_3-\text{Ar}$ , $-\text{CH}_2-\text{Ar}$ , $>\text{CH}-\text{Ar}$	2.3–3.0
	alkyl next to electronegative atom	$\text{CH}_3-\text{O}$ , $-\text{CH}_2-\text{O}$ , $-\text{CH}_2-\text{Cl}$ , $>\text{CH}-\text{Br}$	3.2–4.0
	attached to alkyne	$\equiv\text{C}-\text{H}$	1.8–3.1
	attached to alkene	$=\text{CH}_2$ , $=\text{CH}-$	4.5–6.0
	attached to aromatic ring	aryl–H	6.0–9.0
O–H (see note below)	aldehyde	$\text{R}-\text{CHO}$	9.3–10.5
	alcohol	$\text{RO}-\text{H}$	0.5–6.0
	phenol	aryl–OH	4.5–7.0
N–H (see note below)	carboxylic acid	$\text{R}-\text{CO}_2\text{H}$	9.0–13.0
	alkyl amine	$\text{R}-\text{NH}-$	1.0–5.0
	aryl amine	aryl– $\text{NH}_2$	3.0–6.0
	amide	$\text{R}-\text{C}(=\text{O})-\text{N}(\text{H})-$	5.0–12.0

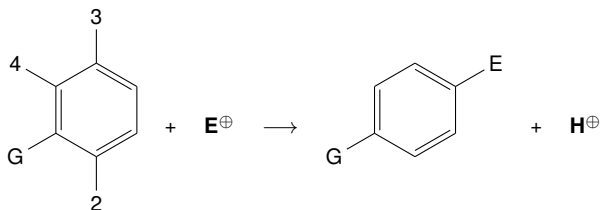
Note:  $\delta$  values for  $-\text{O}-\text{H}$  and  $-\text{N}-\text{H}$  protons can vary depending on solvent and concentration.

## 7 Characteristic infra-red absorption frequencies for some selected bonds

Bond	Functional groups containing the bond	Absorption range (in wavenumbers) / $\text{cm}^{-1}$	Appearance of peak (s = strong, w = weak)
C–C/	chloroalkanes	700–800	s
C–O	alcohol	970–1260	s
	ether	1000–1310	s
	ester	1050–1330	s
	carboxylic acids	1210–1440	s
C=C	aromatic	1475–1625	s
	alkenes	1635–1690	w
C=O	amides	1640–1690	s
	ketones and aldehydes	1670–1740	s
	carboxylic acids	1680–1730	s
	esters	1710–1750	s
C≡C	alkynes	2150–2250	w unless conjugated
C≡N	nitriles	2200–2250	w
C–H	alkanes, $\text{CH}_2\text{--H}$	2850–2950	s
	alkenes/arenes, $=\text{C--H}$	3000–3100	w
N–H	amines, amides	3300–3500	w
O–H	carboxylic acid, $\text{RCO}_2\text{--H}$	2500–3000	s and very broad
	H-bonded alcohol/phenol, $\text{RO--H}$	3200–3600	s
	free alcohol, $\text{RO--H}$	3580–3650	s and sharp

## 8 The orientating effect of groups in aromatic substitution reactions

The position of the incoming group, **E**, is determined by the nature of the group, **G**, already bonded to the ring, and not by the nature of the incoming group **E**.



<b>G</b>	-alkyl -OH or -OR -NH <sub>2</sub> , -NHR or -NR <sub>2</sub> -NHCOR	-Cl, -Br, -I	-CHO, -COR, -CO <sub>2</sub> H, -CO <sub>2</sub> R, -NH <sub>3</sub> <sup>+</sup> , -NO <sub>2</sub> , -CN
<b>Reactivity of ring (compared to benzene)</b>	Activated	Deactivated	Deactivated
<b>Position of E (relative to position of G)</b>	2- and/or 4-	2- and/or 4-	3-

## 9 Qualitative Analysis Notes

[ppt. = precipitate]

### 9(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH <sub>3</sub> (aq)
aluminium, Al <sup>3+</sup> (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH <sub>4</sub> <sup>+</sup> (aq)	ammonia produced on heating	–
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu <sup>2+</sup> (aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe <sup>2+</sup> (aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg <sup>2+</sup> (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn <sup>2+</sup> (aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess

**9(b) Reactions of anions**

<i>anion</i>	<i>reaction</i>
carbonate, $\text{CO}_3^{2-}$	$\text{CO}_2$ liberated by dilute acids
chloride, $\text{Cl}^-$ (aq)	gives white ppt. with $\text{Ag}^+$ (aq) (soluble in $\text{NH}_3$ (aq))
bromide, $\text{Br}^-$ (aq)	gives pale cream ppt. with $\text{Ag}^+$ (aq) (partially soluble in $\text{NH}_3$ (aq))
iodide, $\text{I}^-$ (aq)	gives yellow ppt. with $\text{Ag}^+$ (aq) (insoluble in $\text{NH}_3$ (aq))
nitrate, $\text{NO}_3^-$ (aq)	$\text{NH}_3$ liberated on heating with $\text{OH}^-$ (aq) and A/ foil
nitrite, $\text{NO}_2^-$ (aq)	$\text{NH}_3$ liberated on heating with $\text{OH}^-$ (aq) and A/ foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown $\text{NO}_2$ in air)
sulfate, $\text{SO}_4^{2-}$ (aq)	gives white ppt. with $\text{Ba}^{2+}$ (aq) (insoluble in excess dilute strong acids)
sulfite, $\text{SO}_3^{2-}$ (aq)	$\text{SO}_2$ liberated with dilute acids; gives white ppt. with $\text{Ba}^{2+}$ (aq) (soluble in dilute strong acids)

**9(c) Tests for gases**

<i>gas</i>	<i>test and test result</i>
ammonia, $\text{NH}_3$	turns damp red litmus paper blue
carbon dioxide, $\text{CO}_2$	gives a white ppt. with limewater (ppt. dissolves with excess $\text{CO}_2$ )
chlorine, $\text{Cl}_2$	bleaches damp litmus paper
hydrogen, $\text{H}_2$	"pops" with a lighted splint
oxygen, $\text{O}_2$	relights a glowing splint
sulfur dioxide, $\text{SO}_2$	turns aqueous acidified potassium manganate(VII) from purple to colourless

**9(d) Colour of halogens**

<i>halogen</i>	<i>colour of element</i>	<i>colour in aqueous solution</i>	<i>colour in hexane</i>
chlorine, $\text{Cl}_2$	greenish yellow gas	pale yellow	pale yellow
bromine, $\text{Br}_2$	reddish brown gas / liquid	orange	orange-red
iodine, $\text{I}_2$	black solid / purple gas	brown	purple

# 10 The Periodic Table of Elements

		Group															
1	2											13	14	15	16	17	18
ns <sup>1</sup>		np <sup>6</sup>															
3	4																
<b>Li</b> lithium	<b>Be</b> beryllium																
6.9	9.0																
11	12																
<b>Na</b> sodium	<b>Mg</b> magnesium																
23.0	24.3																
19	20																
<b>K</b> potassium	<b>Ca</b> calcium																
39.1	40.1																
37	38																
<b>Rb</b> rubidium	<b>Sr</b> strontium																
85.5	87.6																
55	56																
<b>Cs</b> caesium	<b>Ba</b> barium																
132.9	137.3																
87	88																
<b>Fr</b> francium	<b>Ra</b> radium																
(223)	(226)																
Key																	
atomic number																	
element symbol																	
element name																	
relative atomic mass																	
1	<b>H</b> hydrogen																
	1.0																
ns <sup>2</sup>																	
2	<b>He</b> helium																
	4.0																
np <sup>1</sup>																	
5	<b>B</b> boron	6	<b>C</b> carbon	7	<b>N</b> nitrogen	8	<b>O</b> oxygen	9	<b>F</b> fluorine	10	<b>Ne</b> neon						
10.8	12.0	14.0	14.0	14.0	14.0	16.0	16.0	19.0	19.0	20.2							
13	<b>Al</b> aluminium	14	<b>Si</b> silicon	15	<b>P</b> phosphorus	16	<b>S</b> sulfur	17	<b>Cl</b> chlorine	18	<b>Ar</b> argon						
27.0	28.1	31.0	31.0	31.0	31.0	32.1	32.1	35.5	35.5	39.9							
nd <sup>10</sup>																	
30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic	34	<b>Se</b> selenium	35	<b>Br</b> bromine						
65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0	79.0	83.8								
nd <sup>9</sup>																	
29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic	34	<b>Se</b> selenium	35	<b>Br</b> bromine				
63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0	79.0	83.8						
nd <sup>8</sup>																	
28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic	34	<b>Se</b> selenium	35	<b>Br</b> bromine		
58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0	79.0	83.8				
nd <sup>7</sup>																	
27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic	34	<b>Se</b> selenium	35	<b>Br</b> bromine
58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0	79.0	83.8		
nd <sup>6</sup>																	
26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic	34	<b>Se</b> selenium
55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0	79.0	83.8
nd <sup>5</sup>																	
25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium	33	<b>As</b> arsenic
54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9	74.9	79.0
nd <sup>4</sup>																	
24	<b>Cr</b> chromium	25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium	32	<b>Ge</b> germanium
52.0	52.0	54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6	72.6	74.9
nd <sup>3</sup>																	
23	<b>V</b> vanadium	24	<b>Cr</b> chromium	25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc	31	<b>Ga</b> gallium
50.9	50.9	52.0	52.0	54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4	69.7	72.6
nd <sup>2</sup>																	
22	<b>Ti</b> titanium	23	<b>V</b> vanadium	24	<b>Cr</b> chromium	25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper	30	<b>Zn</b> zinc
47.9	47.9	50.9	50.9	52.0	52.0	54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5	65.4	65.4
nd <sup>1</sup>																	
21	<b>Sc</b> scandium	22	<b>Ti</b> titanium	23	<b>V</b> vanadium	24	<b>Cr</b> chromium	25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt	28	<b>Ni</b> nickel	29	<b>Cu</b> copper
45.0	45.0	47.9	47.9	50.9	50.9	52.0	52.0	54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7	63.5	63.5
nd <sup>0</sup>																	
19	<b>K</b> potassium	20	<b>Ca</b> calcium	21	<b>Sc</b> scandium	22	<b>Ti</b> titanium	23	<b>V</b> vanadium	24	<b>Cr</b> chromium	25	<b>Mn</b> manganese	26	<b>Fe</b> iron	27	<b>Co</b> cobalt
39.1	40.1	45.0	45.0	47.9	47.9	50.9	50.9	52.0	52.0	54.9	54.9	55.8	55.8	58.9	58.9	58.7	58.7
nf <sup>7-14</sup>																	
57	<b>La</b> lanthanum	58	<b>Ce</b> cerium	59	<b>Pr</b> praseodymium	60	<b>Nd</b> neodymium	61	<b>Pm</b> promethium	62	<b>Sm</b> samarium	63	<b>Eu</b> europium	64	<b>Gd</b> gadolinium	65	<b>Tm</b> thulium
138.9	140.1	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9	140.9
nf <sup>14</sup>																	
89	<b>Ac</b> actinium	90	<b>Th</b> thorium	91	<b>Pa</b> protactinium	92	<b>U</b> uranium	93	<b>Np</b> neptunium	94	<b>Pu</b> plutonium	95	<b>Am</b> americium	96	<b>Cm</b> curium	97	<b>Bk</b> berkelium
227	232	231	232	231	232	231	232	231	232	231	232	231	232	231	232	231	232

\* Anomalous electronic configurations: Cr (Z = 24): [Ar]3d<sup>5</sup>4s<sup>1</sup>; Cu (Z = 29): [Ar]3d<sup>10</sup>4s<sup>1</sup>