



# Chemistry data booklet

First assessment 2016

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**Notes**

This booklet cannot be used for paper 1 of the examination (SLP1 and HLP1), but the periodic table given in section 6 will be available as part of these examination papers. Clean copies of this booklet must be made available to candidates for papers 2 and 3 (SLP2, HLP2, SLP3 and HLP3).

# 1. Some relevant equations

Topic	Equation	Topic	Equation
1.3	$PV = nR$	A.5	% Atom Economy = $\frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times 100\%$
2.2 and C.4	$c = v\lambda$	A.8	$n\lambda = 2d\sin\theta$
5.1	$q = mc\Delta T$	B.7	$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$
8.3	$pH = -\log_{10}[\text{H}_3\text{O}^+]$ or $pH = -\log_{10}[\text{H}^+]$	B.7	$\log_{10} \frac{I_0}{I} = \epsilon lc$
12.1	$E = hv$	C.1	Energy density = $\frac{\text{energy released from fuel}}{\text{volume of fuel consumed}}$
15.2	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	C.1	Specific energy = $\frac{\text{energy released from fuel}}{\text{mass of fuel consumed}}$
16.2	$k = Ae^{\frac{-E_a}{RT}}$	C.3	$N = N_0e^{-\lambda t}$
16.2	$\ln k = \frac{-E_a}{RT} + \ln A$	C.3 and D.8	$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$
16.2	$\ln \frac{k_1}{k_2} = \frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$	C.6	$E = E^0 - \left( \frac{RT}{nF} \right) \ln Q$
17.1	$\Delta G^\circ = -RT \ln K$	C.7	$\frac{\text{Rate}_1}{\text{Rate}_2} = \sqrt{\frac{M_2}{M_1}}$
19.1	$\Delta G^\circ = -nFE^\circ$	D.8	$N_t = N_0(0.5)^{t/k}$

## 2. Physical constants and unit conversions

Avogadro's constant ( $L$  or  $N_A$ ) =  $6.02 \times 10^{23} \text{ mol}^{-1}$

Gas constant ( $R$ ) =  $8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Molar volume of an ideal gas at STP =  $2.27 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$  (=  $22.7 \text{ dm}^3 \text{ mol}^{-1}$ )

$1 \text{ dm}^3 = 1 \text{ litre} = 1 \times 10^{-3} \text{ m}^3 = 1 \times 10^3 \text{ cm}^3$

STP conditions = 273 K and 100 kPa

SATP conditions = 298 K and 100 kPa

Speed of light =  $3.00 \times 10^8 \text{ ms}^{-1}$

Specific heat capacity of water =  $4.18 \text{ kJ kg}^{-1} \text{ K}^{-1} = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$

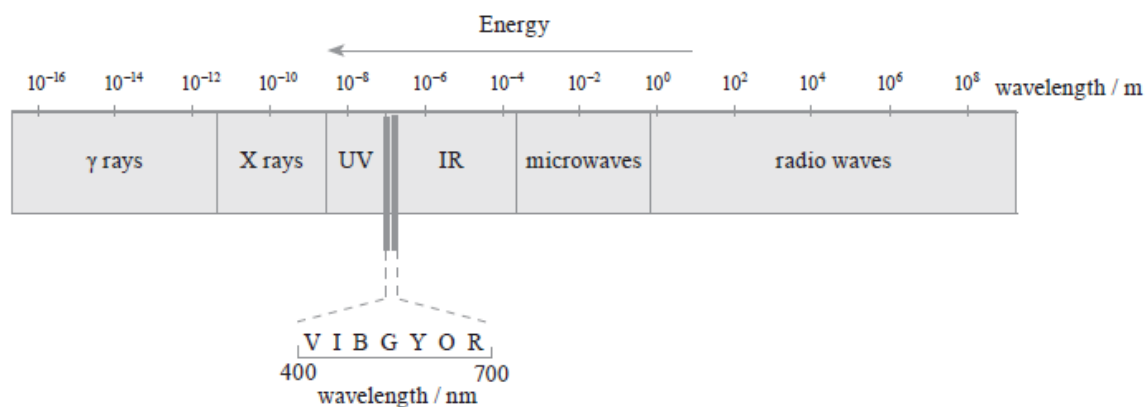
Planck's constant ( $h$ ) =  $6.63 \times 10^{-34} \text{ J s}$

Faraday's constant ( $F$ ) =  $96\,500 \text{ C mol}^{-1}$

Ionic product constant for water ( $K_w$ ) =  $1.00 \times 10^{-14}$  at 298 K

$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$

## 3. The electromagnetic spectrum



## 4. Fundamental particles

	Proton	Neutron	Electron
Mass (kg)	$1.672622 \times 10^{-27}$	$1.674927 \times 10^{-27}$	$9.109383 \times 10^{-31}$
Charge (C)	$1.602189 \times 10^{-19}$	0	$1.602189 \times 10^{-19}$

## 5. Names of the elements

Element	Symbol	Atomic number	Element	Symbol	Atomic number
actinium	Ac	89	mendelevium	Md	101
aluminium	Al	13	mercury	Hg	80
americium	Am	95	molybdenum	Mo	42
antimony	Sb	51	neodymium	Nd	60
argon	Ar	18	neon	Ne	10
arsenic	As	33	neptunium	Np	93
astatine	At	85	nickel	Ni	28
barium	Ba	56	niobium	Nb	41
berkelium	Bk	97	nitrogen	N	7
beryllium	Be	4	nobelium	No	102
bismuth	Bi	83	osmium	Os	76
bohrium	Bh	107	oxygen	O	8
boron	B	5	palladium	Pd	46
bromine	Br	35	phosphorus	P	15
cadmium	Cd	48	platinum	Pt	78
caesium	Cs	55	plutonium	Pu	94
calcium	Ca	20	polonium	Po	84
californium	Cf	98	potassium	K	19
carbon	C	6	praseodymium	Pr	59
cerium	Ce	58	promethium	Pm	61
chlorine	Cl	17	protactinium	Pa	91
chromium	Cr	24	radium	Ra	88
cobalt	Co	27	radon	Rn	86
copernicium	Cn	112	rhenium	Re	75
copper	Cu	29	rhodium	Rh	45
curium	Cm	96	roentgenium	Rg	111
darmstadtium	Ds	110	rubidium	Rb	37
dubnium	Db	105	ruthenium	Ru	44
dysprosium	Dy	66	rutherfordium	Rf	104
einsteinium	Es	99	samarium	Sm	62
erbium	Er	68	scandium	Sc	21
europium	Eu	63	seaborgium	Sg	106
fermium	Fm	100	selenium	Se	34
fluorine	F	9	silicon	Si	14
francium	Fr	87	silver	Ag	47

Element	Symbol	Atomic number	Element	Symbol	Atomic number
gadolinium	Gd	64	sodium	Na	11
gallium	Ga	31	strontium	Sr	38
germanium	Ge	32	sulfur	S	16
gold	Au	79	tantalum	Ta	73
hafnium	Hf	72	technetium	Tc	43
hassium	Hs	108	tellurium	Te	52
helium	He	2	terbium	Tb	65
holmium	Ho	67	thallium	Tl	81
hydrogen	H	1	thorium	Th	90
indium	In	49	thulium	Tm	69
iodine	I	53	tin	Sn	50
iridium	Ir	77	titanium	Ti	22
iron	Fe	26	tungsten	W	74
krypton	Kr	36	uranium	U	92
lanthanum	La	57	vanadium	V	23
lawrencium	Lr	103	xenon	Xe	54
lead	Pb	82	ytterbium	Yb	70
lithium	Li	3	yttrium	Y	39
lutetium	Lu	71	zinc	Zn	30
magnesium	Mg	12	zirconium	Zr	40
manganese	Mn	25			
meitnerium	Mt	109			

## 6. The periodic table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 <b>H</b> 1.01																	2 <b>He</b> 4.00
2	3 <b>Li</b> 6.94	4 <b>Be</b> 9.01											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18
3	11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31											13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.07	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95
4	19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.90
5	37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.96	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29
6	55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57 † <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.20	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
7	87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89 ‡ <b>Ac</b> (227)	104 <b>Rf</b> (267)	105 <b>Db</b> (268)	106 <b>Sg</b> (269)	107 <b>Bh</b> (270)	108 <b>Hs</b> (269)	109 <b>Mt</b> (278)	110 <b>Ds</b> (281)	111 <b>Rg</b> (281)	112 <b>Cn</b> (285)	113 <b>Uut</b> (286)	114 <b>Uuq</b> (289)	115 <b>Uup</b> (288)	116 <b>Uuh</b> (293)	117 <b>Uus</b> (294)	118 <b>Uuo</b> (294)

Atomic number
<b>Element</b>
Relative atomic mass

†	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.05	71 <b>Lu</b> 174.97
‡	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (262)



## 7. Melting points and boiling points of the elements (at 101.325 kPa)

-259.2																	He				
<b>H</b>																	-268.9				
-252.9																					
180.5	1287															2077	3500	-210.0	-218.8	-219.7	-248.6
<b>Li</b>	<b>Be</b>															<b>B</b>	<b>C</b>	<b>N</b>	<b>O</b>	<b>F</b>	<b>Ne</b>
1342	2468															4000	4827	-195.8	-183.0	-188.1	-246.0
97.8	650															660.3	1414	44.2	115.2	-101.5	-189.3
<b>Na</b>	<b>Mg</b>															<b>Al</b>	<b>Si</b>	<b>P</b>	<b>S</b>	<b>Cl</b>	<b>Ar</b>
882.9	1090															2519	3265	280.5	444.6	-34.0	-185.8
63.5	842	1541	1670	1910	1907	1246	1538	1495	1455	1084.6	419.5	29.8	938.2	817	220.8	-7.2	-157.4				
<b>K</b>	<b>Ca</b>	<b>Sc</b>	<b>Ti</b>	<b>V</b>	<b>Cr</b>	<b>Mn</b>	<b>Fe</b>	<b>Co</b>	<b>Ni</b>	<b>Cu</b>	<b>Zn</b>	<b>Ga</b>	<b>Ge</b>	<b>As</b>	<b>Se</b>	<b>Br</b>	<b>Kr</b>				
759	1484	2836	3287	3407	2671	2061	2861	2927	2913	2560	907	2229	2833	616	685	58.8	-153.4				
39.3	777	1522	1854	2477	2622	2157	2333	1963	1554.8	961.8	321.1	156.6	231.9	630.6	449.5	113.7	-111.8				
<b>Rb</b>	<b>Sr</b>	<b>Y</b>	<b>Zr</b>	<b>Nb</b>	<b>Mo</b>	<b>Tc</b>	<b>Ru</b>	<b>Rh</b>	<b>Pd</b>	<b>Ag</b>	<b>Cd</b>	<b>In</b>	<b>Sn</b>	<b>Sb</b>	<b>Te</b>	<b>I</b>	<b>Xe</b>				
688	1377	3345	4406	4741	4639	4262	4147	3695	2963	2162	767	2027	2586	1587	988	184.4	-108.1				
28.5	727	920	2233	3017	3414	3453	3033	2446	1768.2	1064.2	-38.8	304	327.5	271.4	254	302	-71				
<b>Cs</b>	<b>Ba</b>	<b>La</b>	<b>Hf</b>	<b>Ta</b>	<b>W</b>	<b>Re</b>	<b>Os</b>	<b>Ir</b>	<b>Pt</b>	<b>Au</b>	<b>Hg</b>	<b>Tl</b>	<b>Pb</b>	<b>Bi</b>	<b>Po</b>	<b>At</b>	<b>Rn</b>				
671	1845	3464	4600	5455	5555	5900	5008	4428	3825	2836	356.6	1473	1749	1564	962		-61.7				
21	696	1050																			
<b>Fr</b>	<b>Ra</b>	<b>Ac</b>																			
		3200																			

Melting point (°C)

**Element**

Boiling point (°C)

## 8. First ionization energy, electron affinity and electronegativity of the elements

1312 -73		First ionization energy (kJ mol <sup>-1</sup> )																2372																	
H		Electron affinity (kJ mol <sup>-1</sup> )																He																	
2.2		2 <sup>nd</sup> EA / kJ mol <sup>-1</sup>																																	
520 -60		Element																801 -27		1086 -122		1402		1314 -141 (+753)		1681 -328		2081							
Li		Electronegativity																B		C		N		O		F		Ne							
1.0																		2.0		2.6		3.0		3.4		4.0									
496 -53																		578 -42		787 -134		1012 -72		1000 -200 (+545)		1251 -349		1520							
Na																		Al		Si		P		S		Cl		Ar							
0.9																		1.6		1.9		2.2		2.6		3.2									
419 -48		590 -2		633 -18		659 -8		651 -51		653 -64		717		762 -15		760 -64		737 -112		745 -119		906		579 -41		762 -119		944 -78		941 -195		1140 -325		1351	
K		Ca		Sc		Ti		V		Cr		Mn		Fe		Co		Ni		Cu		Zn		Ga		Ge		As		Se		Br		Kr	
0.8		1.0		1.4		1.5		1.6		1.7		1.6		1.8		1.9		1.9		1.9		1.6		1.8		2.0		2.2		2.6		3.0			
403 -47		549 -5		600 -30		640 -41		652 -88		684 -72		702 -53		710 -101		720 -110		804 -54		731 -126		868		558 -29		709 -107		831 -101		869 -190		1008 -295		1170	
Rb		Sr		Y		Zr		Nb		Mo		Tc		Ru		Rh		Pd		Ag		Cd		In		Sn		Sb		Te		I		Xe	
0.8		1.0		1.2		1.3		1.6		2.2		2.1		2.2		2.3		2.2		1.9		1.7		1.8		2.0		2.0		2.1		2.7		2.6	
376 -46		503 -14		538 -45		659 -1		728 -31		759 -79		756 -14		814 -106		865 -151		864 -205		890 -223		1007		589 -36		716 -35		703 -91		812 -183		-270		1037	
Cs		Ba		La		Hf		Ta		W		Re		Os		Ir		Pt		Au		Hg		Tl		Pb		Bi		Po		At		Rn	
0.8		0.9		1.1		1.3		1.5		1.7		1.9		2.2		2.2		2.2		2.4		1.9		1.8		1.8		1.9		2.0		2.2			
393 -47		509 -10		499 -34																															
Fr		Ra		Ac																															
0.7		0.9		1.1																															

## 9. Atomic and ionic radii of the elements

32 <b>H</b>																37 <b>He</b>						
130 <b>Li</b> 76 (1+)	99 <b>Be</b> 45 (2+)																84 <b>B</b> 27 (3+)	75 <b>C</b> 16 (4+)	71 <b>N</b> 146 (3-)	64 <b>O</b> 140 (2-)	60 <b>F</b> 133 (1-)	62 <b>Ne</b>
160 <b>Na</b> 102 (1+)	140 <b>Mg</b> 72 (2+)																124 <b>Al</b> 54 (3+)	114 <b>Si</b> 40 (4+)	109 <b>P</b> 38 (5+)	104 <b>S</b> 184 (2-)	100 <b>Cl</b> 181 (1-)	101 <b>Ar</b>
200 <b>K</b> 138 (1+)	174 <b>Ca</b> 100 (2+)	159 <b>Sc</b> 75 (3+)	148 <b>Ti</b> 86 (2+) 61 (4+)	144 <b>V</b> 79 (2+) 54 (5+)	130 <b>Cr</b> 62 (3+) 44 (6+)	129 <b>Mn</b> 83 (2+) 53 (4+)	124 <b>Fe</b> 61 (2+) 55 (3+)	118 <b>Co</b> 65(+2) 55 (+3)	117 <b>Ni</b> 69 (2+)	122 <b>Cu</b> 77 (1+) 73 (2+)	120 <b>Zn</b> 74 (2+)	123 <b>Ga</b> 62(3+)	120 <b>Ge</b> 53 (4+) 272(4-)	120 <b>As</b> 58 (3+) 46 (5+)	118 <b>Se</b> 198 (2-)	117 <b>Br</b> 196 (1-)	116 <b>Kr</b>					
215 <b>Rb</b> 152 (1+)	190 <b>Sr</b> 118 (2+)	176 <b>Y</b> 90 (3+)	164 <b>Zr</b> 72 (4+)	156 <b>Nb</b> 72 (3+) 64 (5+)	146 <b>Mo</b> 65 (4+)	138 <b>Tc</b> 65(4+)	136 <b>Ru</b> 68(3+) 62 (4+)	134 <b>Rh</b> 67 (+3) 60 (+4)	130 <b>Pd</b> 86(2+) 62(4+)	136 <b>Ag</b> 115 (1+)	140 <b>Cd</b> 95 (2+)	142 <b>In</b> 80(3+)	140 <b>Sn</b> 118(2+) 69 (4+)	140 <b>Sb</b> 76 (3+)	137 <b>Te</b> 221 (2-)	136 <b>I</b> 220(1-)	136 <b>Xe</b>					
238 <b>Cs</b> 167 (1+)	206 <b>Ba</b> 135 (2+)	194 <b>La</b> 103 (3+)	164 <b>Hf</b> 71 (4+)	158 <b>Ta</b> 64 (5+)	150 <b>W</b> 66 (4+) 60(6+)	141 <b>Re</b> 63(4+) 53(7+)	136 <b>Os</b> 63 (4+) 55(6+)	132 <b>Ir</b> 68(+3) 63 (+4)	130 <b>Pt</b> 80(2+) 63(4+)	130 <b>Au</b> 137 (1+) 85 (3+)	132 <b>Hg</b> 119 (1+) 102 (2+)	144 <b>Tl</b> 150 (1+) 89 (3)	145 <b>Pb</b> 119 (2+) 78 (4+)	150 <b>Bi</b> 103 (3+) 76(5+)	142 <b>Po</b> 97(4+)	148 <b>At</b>	146 <b>Rn</b>					
242 <b>Fr</b>	211 <b>Ra</b>	201 <b>Ac</b>																				

Atomic radius ( $10^{-12}$ m)
<b>Element</b>
Ionic radius/ ( $10^{-12}$ m)

## 10. Covalent bond lengths

### Single bonds ( $10^{-12}$ m = pm)

	Br	C	Cl	F	H	I	N	O	P	S	Si
Br	228	194	214	176	141	247	214		220	227	216
C	194	154	177	138	108	214	147	143	184	182	185
Cl	214	177	199	163	128	232	197	170	203	199	202
F	176	138	163	142	92	257	136	142	154	158	156
H	141	108	128	92	74	160	101	97	142	134	148
I	247	214	232	257	160	267			247		243
N	214	147	197	136	101		146	136		175	174
O		143	170	142	97		136	148	154	161	163
P	220	184	203	154	142	247		154	221	210	
S	227	182	199	158	134		175	161	210	205	215
Si	216	185	202	156	148	243	174	163		215	232

### Multiple bonds ( $10^{-12}$ m = pm)

C=C	134	C≡N	116	N≡N	110
C≡C	120	C=O	122	N=O	114
C === C (in benzene)	140	C=S	156	O=O	121
C=N	130	N=N	125	S=S	189

# 11. Bond enthalpies and average bond enthalpies at 298 K

## Single bonds (kJ mol<sup>-1</sup>)

	Br	C	Cl	F	H	I	N	O	P	S	Si
Br	193	285	219	249	366	178		201	264	218	330
C	285	346	324	492	414	228	286	358	264	289	307
Cl	219	324	242	255	431	211	192	206	322	271	400
F	249	492	255	159	567	280	278	191	490	327	597
H	366	414	431	567	436	298	391	463	322	364	323
I	178	228	211	280	298	151		201	184		234
N		286	192	278	391		158	214			
O	201	358	206	191	463	201	214	144	363		466
P	264	264	322	490	322	184		363	198		
S	218	289	271	327	364					266	293
Si	330	307	400	597	323	234		466		293	226

## Multiple bonds (kJ mol<sup>-1</sup>)

C=C	614	C≡N	890	N≡N	945
C≡C	839	C=O	804	N=O	587
C ≡≡ C (in benzene)	507	C=S	536	O=O	498
C=N	615	N=N	470	S=S	429

## 12. Selected compounds—thermodynamic data

Substance	Formula	State	(kJ mol <sup>-1</sup> )	(kJ mol <sup>-1</sup> )	(J K <sup>-1</sup> mol <sup>-1</sup> )
methane	CH <sub>4</sub>	g	-74.0	-50.0	+186
ethane	C <sub>2</sub> H <sub>6</sub>	g	-84.0	-32.0	+230
propane	C <sub>3</sub> H <sub>8</sub>	g	-105	-24.0	+270
butane	C <sub>4</sub> H <sub>10</sub>	g	-126	-17.0	+310
pentane	C <sub>5</sub> H <sub>12</sub>	l	-173		
hexane	C <sub>6</sub> H <sub>14</sub>	l	-199		
ethene	C <sub>2</sub> H <sub>4</sub>	g	+52.0	+68.0	+220
propene	C <sub>3</sub> H <sub>6</sub>	g	+20.0	+62.0	+267
but-1-ene	C <sub>4</sub> H <sub>8</sub>	g	+0.10	+71.0	+306
<i>cis</i> -but-2-ene	C <sub>4</sub> H <sub>8</sub>	g	-7.0	+66.0	+301
<i>trans</i> -but-2-ene	C <sub>4</sub> H <sub>8</sub>	g	-11.0	+63.0	+297
ethyne	C <sub>2</sub> H <sub>2</sub>	g	+228	+211	+201
propyne	C <sub>3</sub> H <sub>4</sub>	g	+185	+194	+248
buta-1,3-diene	C <sub>4</sub> H <sub>6</sub>	g	+110	+151	+279
cyclohexane	C <sub>6</sub> H <sub>12</sub>	l	-156		
benzene	C <sub>6</sub> H <sub>6</sub>	l	+49.0	+125	+173
methylbenzene	C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub>	l	+12.0		
ethylbenzene	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> CH <sub>3</sub>	l	-12.0		
phenylethene	C <sub>6</sub> H <sub>5</sub> CHCH <sub>2</sub>	l	+104		
chloromethane	CH <sub>3</sub> Cl	g	-82.0	-58.0	+235
dichloromethane	CH <sub>2</sub> Cl <sub>2</sub>	l	-124		+178
trichloromethane	CHCl <sub>3</sub>	l	-134	-74.0	+202
bromomethane	CH <sub>3</sub> Br	g	-36.0	-26.0	+246
iodomethane	CH <sub>3</sub> I	l	-14.0		+163
chloroethane	C <sub>2</sub> H <sub>5</sub> Cl	g	-137	-53.0	
bromoethane	C <sub>2</sub> H <sub>5</sub> Br	l	-90.0	-26.0	+199
chlorobenzene	C <sub>6</sub> H <sub>5</sub> Cl	l	+11.0		
methanol	CH <sub>3</sub> OH	l	-239	-167	+127
ethanol	C <sub>2</sub> H <sub>5</sub> OH	l	-278	-175	+161
phenol	C <sub>6</sub> H <sub>5</sub> OH	s	-165		+144
methanal	HCHO	g	-109	-102	+219
ethanal	CH <sub>3</sub> CHO	g	-166	-133	+264
propanone	(CH <sub>3</sub> ) <sub>2</sub> CO	l	-248		+200
methanoic acid	HCOOH	l	-425	-361	+129
ethanoic acid	CH <sub>3</sub> COOH	l	-484	-390	+160
benzoic acid	C <sub>6</sub> H <sub>5</sub> COOH	s	-385		+168
methylamine	CH <sub>3</sub> NH <sub>2</sub>	g	-23	+32.0	+243
water	H <sub>2</sub> O	l	-285.8	-237.1	+70.0

Substance	Formula	State	(kJ mol <sup>-1</sup> )	(kJ mol <sup>-1</sup> )	(J K <sup>-1</sup> mol <sup>-1</sup> )
steam	H <sub>2</sub> O	g	-241.8	-228.6	+188.8
carbon monoxide	CO	g	-110.5	-137.2	+197.7
carbon dioxide	CO <sub>2</sub>	g	-393.5	-394.4	+213.8
hydrogen bromide	HBr	g	-36.3	-53.4	+198.7
hydrogen chloride	HCl	g	-92.3	-95.3	+186.9
hydrogen fluoride	HF	g	-273.3	-275.4	+173.8
hydrogen iodide	HI	g	+26.5	+1.7	+206.6

## 13. Enthalpies of combustion

The values of the molar enthalpy of combustion ( $\Delta H_c^\circ$ ) in the following table refer to a temperature of 298 K and a pressure of  $1.00 \times 10^5$  Pa.

Substance	Formula	State	$\Delta H_c^\circ$ (kJ mol <sup>-1</sup> )	Substance	Formula	State	$\Delta H_c^\circ$ (kJ mol <sup>-1</sup> )
hydrogen	H <sub>2</sub>	g	-286	propan-1-ol	C <sub>3</sub> H <sub>7</sub> OH	l	-2021
sulfur	S	s	-297	butan-1-ol	C <sub>4</sub> H <sub>9</sub> OH	l	-2676
carbon (graphite)	C	s	-394	cyclohexanol	C <sub>6</sub> H <sub>11</sub> OH	s	-3728
carbon monoxide	CO	g	-283	phenol	C <sub>6</sub> H <sub>5</sub> OH	s	-3053
methane	CH <sub>4</sub>	g	-891	ethoxyethane	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O	l	-2724
ethane	C <sub>2</sub> H <sub>6</sub>	g	-1561	methanal	HCHO	g	-571
propane	C <sub>3</sub> H <sub>8</sub>	g	-2219	ethanal	CH <sub>3</sub> CHO	g	-1167
butane	C <sub>4</sub> H <sub>10</sub>	g	-2878	benzaldehyde	C <sub>6</sub> H <sub>5</sub> CHO	l	-3525
pentane	C <sub>5</sub> H <sub>12</sub>	l	-3509	propanone	(CH <sub>3</sub> ) <sub>2</sub> CO	l	-1790
hexane	C <sub>6</sub> H <sub>14</sub>	l	-4163	pentan-3-one	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> CO	l	-3100
octane	C <sub>8</sub> H <sub>18</sub>	l	-5470	phenylethanone	CH <sub>3</sub> COC <sub>6</sub> H <sub>5</sub>	l	-4149
cyclohexane	C <sub>6</sub> H <sub>12</sub>	l	-3920	methanoic acid	HCOOH	l	-255
ethene	C <sub>2</sub> H <sub>4</sub>	g	-1411	ethanoic acid	CH <sub>3</sub> COOH	l	-874
buta-1,3-diene	C <sub>4</sub> H <sub>6</sub>	g	-2541	benzoic acid	C <sub>6</sub> H <sub>5</sub> COOH	s	-3228
ethyne	C <sub>2</sub> H <sub>2</sub>	g	-1301	ethanedioic acid	(COOH) <sub>2</sub>	s	-243
benzene	C <sub>6</sub> H <sub>6</sub>	l	-3268	ethyl ethanoate	CH <sub>3</sub> COOC <sub>2</sub> H <sub>5</sub>	l	-2238
methylbenzene	C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub>	l	-3910	ethanamide	CH <sub>3</sub> CONH <sub>2</sub>	s	-1186
naphthalene	C <sub>10</sub> H <sub>8</sub>	s	-5156	methylamine	CH <sub>3</sub> NH <sub>2</sub>	g	-1086
chloroethane	C <sub>2</sub> H <sub>5</sub> Cl	g	-1413	phenylamine	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	l	-3393
iodoethane	C <sub>2</sub> H <sub>5</sub> I	l	-1463	nitrobenzene	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	l	-3088
trichloromethane	CHCl <sub>3</sub>	l	-473	urea	CO(NH <sub>2</sub> ) <sub>2</sub>	s	-633
methanol	CH <sub>3</sub> OH	l	-726	glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	s	-2803
ethanol	C <sub>2</sub> H <sub>5</sub> OH	l	-1367	sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	s	-5640

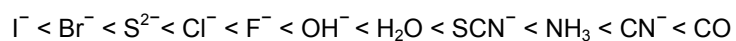


## 14. Common oxidation numbers of 3-D ions

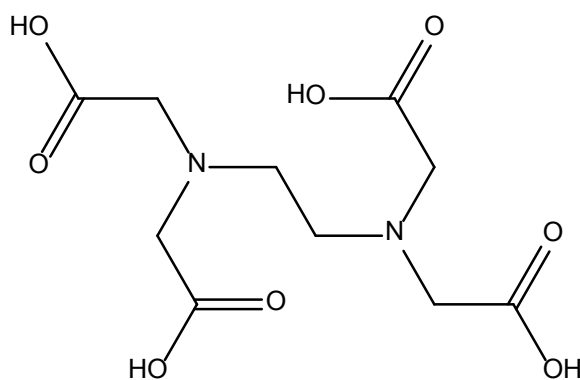
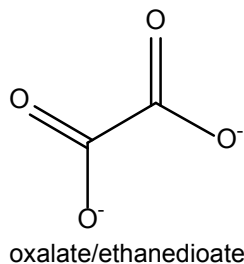
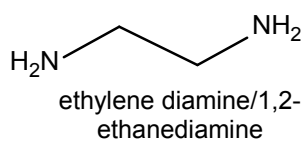
Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
								+1	
	+2	+2	+2	+2	+2	+2	+2	+2	+2
+3	+3	+3	+3	+3	+3	+3			
	+4	+4		+4					
		+5							
			+6	+6					
				+7					

## 15. Spectrochemical series

Ligands can be arranged in a spectrochemical series according to the energy difference they produce between the two sets of d-orbitals in an octahedral complex.

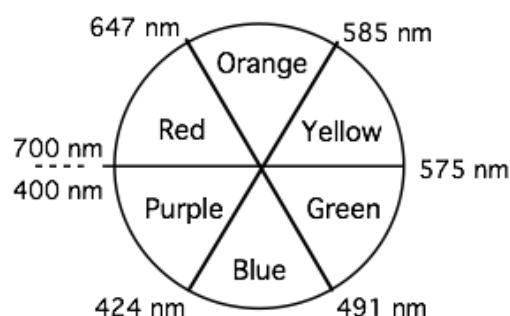


## 16. Ligands



EDTA

## 17. Colour wheel



## 18. Lattice enthalpies at 298 K (experimental values)

The lattice enthalpy values ( $\Delta H_{\text{lattice}}^\circ$ ) given relate to the endothermic process  $M_aX_b(s) \rightarrow a M^{b+}(g) + b X^{a-}(g)$  in which the gaseous ions of a crystal are separated to an infinite distance from each other.

### Experimental values

The data in this table are experimental values obtained by means of a suitable Born–Haber cycle.

Alkali metal halides	$\Delta H_{\text{lattice}}^\circ$ (kJ mol <sup>-1</sup> )			
	F	Cl	Br	I
Li	1049	864	820	764
Na	930	790	754	705
K	829	720	691	650
Rb	795	695	668	632
Cs	759	670	647	613
Other substances	$\Delta H_{\text{lattice}}^\circ$ (kJ mol <sup>-1</sup> )	Other substances	$\Delta H_{\text{lattice}}^\circ$ (kJ mol <sup>-1</sup> )	
CaF <sub>2</sub>	2651	CuCl <sub>2</sub>	2824	
BeCl <sub>2</sub>	3033	AgF	974	
MgCl <sub>2</sub>	2540	AgCl	918	
CaCl <sub>2</sub>	2271	AgBr	905	
SrCl <sub>2</sub>	2170	AgI	892	
BaCl <sub>2</sub>	2069			
MgO	3791			
CaO	3401			
SrO	3223			
BaO	3054			

## 19. Enthalpies of aqueous solutions

Solute	$\Delta H_{\text{sol}}^{\circ}$ (kJ mol <sup>-1</sup> )	Solute	$\Delta H_{\text{sol}}^{\circ}$ (kJ mol <sup>-1</sup> )
NH <sub>4</sub> Cl	+14.78	KCl	+17.22
NH <sub>4</sub> NO <sub>3</sub>	+25.69	KBr	+19.87
LiF	+4.73	KI	+20.33
LiCl	-37.03	RbF	-26.11
LiBr	-48.83	RbCl	+17.28
LiI	-63.30	RbBr	+21.88
NaF	+0.91	RbI	+25.10
NaCl	+3.88	CsF	-36.86
NaBr	-0.60	CsCl	+17.78
NaI	-7.53	CsBr	+25.98
KF	-17.73	CsI	+33.35

## 20. Enthalpies of hydration

Cations	$\Delta H_{\text{hyd}}^{\circ}$ (kJ mol <sup>-1</sup> )	Anions	$\Delta H_{\text{hyd}}^{\circ}$ (kJ mol <sup>-1</sup> )
Li <sup>+</sup>	-538	F <sup>-</sup>	-504
Na <sup>+</sup>	-424	Cl <sup>-</sup>	-359
K <sup>+</sup>	-340	Br <sup>-</sup>	-328
Rb <sup>+</sup>	-315	I <sup>-</sup>	-287
Cs <sup>+</sup>	-291	ClO <sub>3</sub> <sup>-</sup>	-331
Be <sup>2+</sup>	-2524	BrO <sub>3</sub> <sup>-</sup>	-358
Mg <sup>2+</sup>	-1963	IO <sub>3</sub> <sup>-</sup>	-446
Ca <sup>2+</sup>	-1616	ClO <sub>4</sub> <sup>-</sup>	-205
Sr <sup>2+</sup>	-1483	OH <sup>-</sup>	-519
Ba <sup>2+</sup>	-1346	CN <sup>-</sup>	-341
Ra <sup>2+</sup>	-1335	NO <sub>3</sub> <sup>-</sup>	-316
Al <sup>3+</sup>	-4741	HCO <sub>3</sub> <sup>-</sup>	-383
Ga <sup>3+</sup>	-4745	CO <sub>3</sub> <sup>2-</sup>	-1486
In <sup>3+</sup>	-4171	HSO <sub>4</sub> <sup>-</sup>	-362
Tl <sup>3+</sup>	-4163	SO <sub>4</sub> <sup>2-</sup>	-1099
Tl <sup>+</sup>	-346	PO <sub>4</sub> <sup>3-</sup>	-2921
Sn <sup>2+</sup>	-1587		
Pb <sup>2+</sup>	-1523		

## 21. Strengths of organic acids and bases

The acid strengths in the following tables are given in terms of  $pK_a$  values, where  $pK_a = -\log_{10} K_a$ .

The dissociation constant,  $K_a$ , values are for aqueous solutions at 298 K. Base strengths are given in terms of  $pK_b$  values.

### Carboxylic acids

Name	Formula	$pK_a$
methanoic	HCOOH	3.75
ethanoic	CH <sub>3</sub> COOH	4.76
propanoic	CH <sub>3</sub> CH <sub>2</sub> COOH	4.87
butanoic	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> COOH	4.83
2-methylpropanoic	(CH <sub>3</sub> ) <sub>2</sub> CHCOOH	4.84
pentanoic	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> COOH	4.83
2,2-dimethylpropanoic	(CH <sub>3</sub> ) <sub>3</sub> CCOOH	5.03
benzoic	C <sub>6</sub> H <sub>5</sub> COOH	4.20
phenylethanoic	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> COOH	4.31

### Halogenated carboxylic acids

Name	Formula	$pK_a$
chloroethanoic	CH <sub>2</sub> ClCOOH	2.87
dichloroethanoic	CHCl <sub>2</sub> COOH	1.35
trichloroethanoic	CCl <sub>3</sub> COOH	0.66
fluoroethanoic	CH <sub>2</sub> FCOOH	2.59
bromoethanoic	CH <sub>2</sub> BrCOOH	2.90
iodoethanoic	CH <sub>2</sub> ICOOH	3.18

### Phenols

Name	Formula	$pK_a$
phenol	C <sub>6</sub> H <sub>5</sub> OH	9.99
2-nitrophenol	O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub> OH	7.23
3-nitrophenol	O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub> OH	8.36
4-nitrophenol	O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub> OH	7.15
2,4-dinitrophenol	(O <sub>2</sub> N) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OH	4.07
2,4,6-trinitrophenol	(O <sub>2</sub> N) <sub>3</sub> C <sub>6</sub> H <sub>2</sub> OH	0.42

## Alcohols

Name	Formula	p <i>K</i> <sub>a</sub>
methanol	CH <sub>3</sub> OH	15.5
ethanol	C <sub>2</sub> H <sub>5</sub> OH	15.5

## Amines

Name	Formula	p <i>K</i> <sub>b</sub>
ammonia	NH <sub>3</sub>	4.75
methylamine	CH <sub>3</sub> NH <sub>2</sub>	3.34
ethylamine	CH <sub>3</sub> CH <sub>2</sub> NH <sub>2</sub>	3.35
dimethylamine	(CH <sub>3</sub> ) <sub>2</sub> NH	3.27
trimethylamine	(CH <sub>3</sub> ) <sub>3</sub> N	4.20
diethylamine	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> NH	3.16
triethylamine	(C <sub>2</sub> H <sub>5</sub> ) <sub>3</sub> N	3.25
phenylamine	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	9.13

## 22. Acid–base indicators

Indicator	p <i>K</i> <sub>a</sub>	pH range	Colour change	
			Acid	Alkali
methyl orange	3.7	3.1–4.4	red	yellow
bromophenol blue	4.2	3.0–4.6	yellow	blue
bromocresol green	4.7	3.8–5.4	yellow	blue
methyl red	5.1	4.4–6.2	red	yellow
bromothymol blue	7.0	6.0–7.6	yellow	blue
phenol red	7.9	6.8–8.4	yellow	red
phenolphthalein	9.6	8.3–10.0	colourless	pink

## 23. Ionization constant of water at varying temperatures

Temperature (°C)	$K_W$ value	Temperature (°C)	$K_W$ value
0	$0.113 \times 10^{-14}$	55	$7.24 \times 10^{-14}$
5	$0.185 \times 10^{-14}$	60	$9.55 \times 10^{-14}$
10	$0.292 \times 10^{-14}$	65	$12.4 \times 10^{-14}$
15	$0.453 \times 10^{-14}$	70	$15.9 \times 10^{-14}$
20	$0.684 \times 10^{-14}$	75	$20.1 \times 10^{-14}$
25	$1.00 \times 10^{-14}$	80	$25.2 \times 10^{-14}$
30	$1.47 \times 10^{-14}$	85	$31.3 \times 10^{-14}$
35	$2.09 \times 10^{-14}$	90	$38.3 \times 10^{-14}$
40	$2.92 \times 10^{-14}$	95	$46.6 \times 10^{-14}$
45	$4.02 \times 10^{-14}$	100	$56.0 \times 10^{-14}$
50	$5.43 \times 10^{-14}$		

## 24. Standard electrode potentials (298 K)

Oxidized species	$\rightleftharpoons$	Reduced species	$E^\circ$ (V)
$\text{Li}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Li}(\text{s})$	-3.04
$\text{K}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{K}(\text{s})$	-2.93
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Ca}(\text{s})$	-2.87
$\text{Na}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Na}(\text{s})$	-2.71
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Mg}(\text{s})$	-2.37
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^-$	$\rightleftharpoons$	$\text{Al}(\text{s})$	-1.66
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Mn}(\text{s})$	-1.18
$\text{H}_2\text{O}(\text{l}) + \text{e}^-$	$\rightleftharpoons$	$\frac{1}{2}\text{H}_2(\text{g}) + \text{OH}^-(\text{aq})$	-0.83
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Zn}(\text{s})$	-0.76
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Fe}(\text{s})$	-0.45
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Ni}(\text{s})$	-0.26
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Sn}(\text{s})$	-0.14
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Pb}(\text{s})$	-0.13
$\text{H}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\frac{1}{2}\text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Cu}^+(\text{aq})$	+0.15
$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.17
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{Cu}(\text{s})$	+0.34
$\frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^-$	$\rightleftharpoons$	$2\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Cu}(\text{s})$	+0.52
$\frac{1}{2}\text{I}_2(\text{s}) + \text{e}^-$	$\rightleftharpoons$	$\text{I}^-(\text{aq})$	+0.54
$\text{Fe}^{3+}(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^-$	$\rightleftharpoons$	$\text{Ag}(\text{s})$	+0.80
$\frac{1}{2}\text{Br}_2(\text{l}) + \text{e}^-$	$\rightleftharpoons$	$\text{Br}^-(\text{aq})$	+1.09
$\frac{1}{2}\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$	$\rightleftharpoons$	$\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^-$	$\rightleftharpoons$	$2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.36
$\frac{1}{2}\text{Cl}_2(\text{g}) + \text{e}^-$	$\rightleftharpoons$	$\text{Cl}^-(\text{aq})$	+1.36
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^-$	$\rightleftharpoons$	$\text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51
$\frac{1}{2}\text{F}_2(\text{g}) + \text{e}^-$	$\rightleftharpoons$	$\text{F}^-(\text{aq})$	+2.87

## 25. Activity series

**Li  
Cs  
Rb  
K  
Ba  
Sr  
Ca  
Na  
Mg  
Be  
Al**

**C**

**Zn  
Cr  
Fe  
Cd  
Co  
Ni  
Sn  
Pb**

**H**

**Sb  
As  
Bi  
Cu  
Ag  
Pd  
Hg  
Pt  
Au**



## 26. Infrared data

Characteristic ranges for infrared absorption due to stretching vibrations in organic molecules.

Bond	Organic molecules	Wavenumber ( $\text{cm}^{-1}$ )	Intensity
C-I	iodoalkanes	490–620	strong
C-Br	bromoalkanes	500–600	strong
C-Cl	chloroalkanes	600–800	strong
C-F	fluoroalkanes	1000–1400	strong
C-O	alcohols, esters, ethers	1050–1410	strong
C=C	alkenes	1620–1680	medium-weak; multiple bands
C=O	aldehydes, ketones, carboxylic acids and esters	1700–1750	strong
C≡C	alkynes	2100–2260	variable
O-H	hydrogen bonding in carboxylic acids	2500–3000	strong, very broad
C-H	alkanes, alkenes, arenes	2850–3090	strong
O-H	hydrogen bonding in alcohols and phenols	3200–3600	strong, broad
N-H	primary amines	3300–3500	medium, two bands

## 27. $^1\text{H}$ NMR data

Typical proton chemical shift values ( $\delta$ ) relative to tetramethylsilane (TMS) = 0.

R represents an alkyl group, and Hal represents F, Cl, Br, or I.

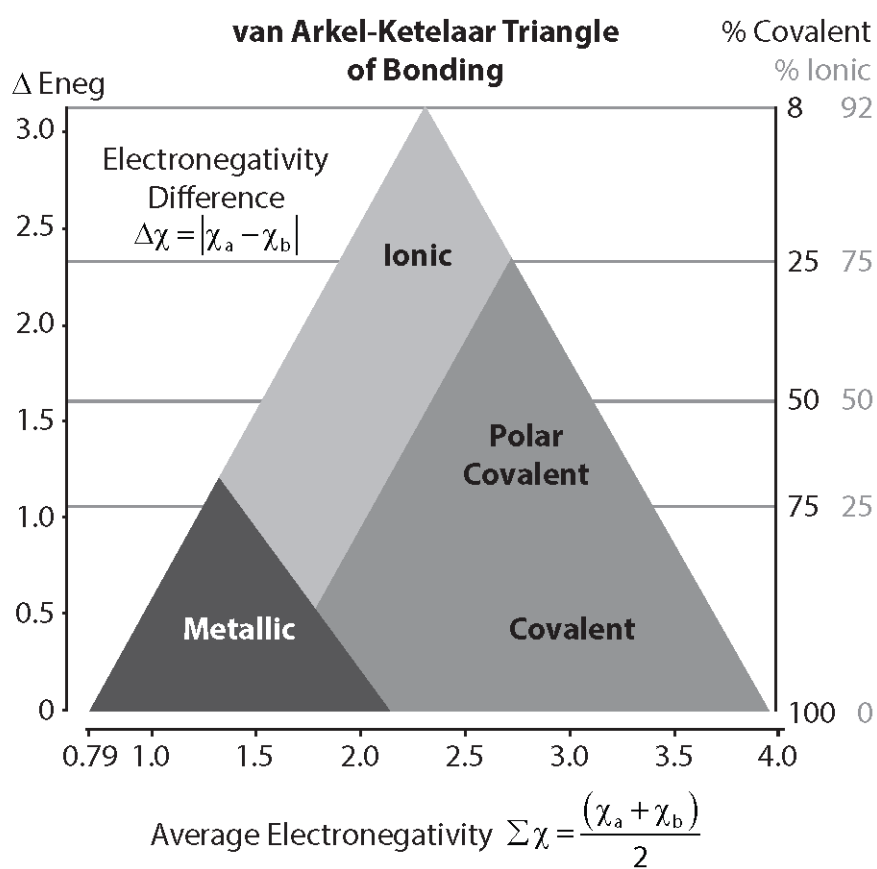
These values may vary in different solvents and conditions.

Type of proton	Chemical shift (ppm)
$\text{—CH}_3$	0.9–1.0
$\text{—CH}_2\text{—R}$	1.3–1.4
$\text{—R}_2\text{CH}$	1.5
	2.0–2.5
	2.2–2.7
	2.5–3.5
$\text{—C}\equiv\text{C—H}$	1.8–3.1
$\text{—CH}_2\text{—Hal}$	3.5–4.4
$\text{R—O—CH}_2\text{—}$	3.3–3.7
	3.7–4.8
	9.0–13.0
$\text{R—O—H}$	1.0–6.0
$\text{—HC}\equiv\text{CH}_2$	4.5–6.0
	4.0–12.0
	6.9–9.0
	9.4–10.0








## 28. Mass spectral fragments lost

Mass lost	Fragment lost	Mass lost	Fragment lost
15	CH <sub>3</sub> ·	29	CH <sub>3</sub> CH <sub>2</sub> ·, CHO·
17	OH·	31	CH <sub>3</sub> O·
18	H <sub>2</sub> O	45	COOH·
28	CH <sub>2</sub> =CH <sub>2</sub> , C=O·		

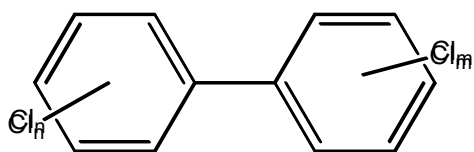
## 29. Triangular bonding diagram



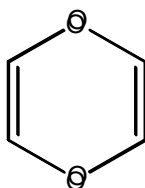
## 30. Resin identification codes

Resin Identification Code (RIC)	Plastic types	Resin Identification Code (RIC)	Plastic types
 PETE	polyethylene terephthalate	 PP	polypropylene
 HDPE	high-density polyethylene	 PS	polystyrene
 PVC	polyvinyl chloride	 OTHER	other
 LDPE	low-density polyethylene		

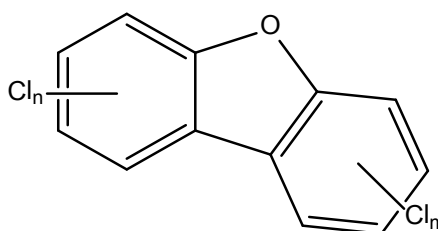
## 31. Representations of some materials molecules



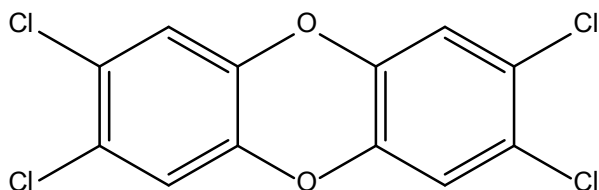
polychlorinated biphenyls



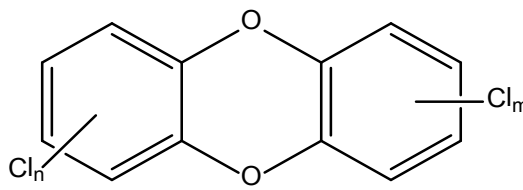
1,4-dioxin



polychlorinated dibenzofuran



2,3,7,8-tetrachlorodibenzodioxin



polychlorinated dibenzo-*p*-dioxin

## 32. Solubility product constants (at 298 K)

Compound	$K_{sp}$	Compound	$K_{sp}$
BaCO <sub>3</sub>	$2.58 \times 10^{-9}$	Hg <sub>2</sub> CO <sub>3</sub>	$3.6 \times 10^{-17}$
Ba(OH) <sub>2</sub> ·8H <sub>2</sub> O	$2.55 \times 10^{-4}$	Hg <sub>2</sub> SO <sub>4</sub>	$6.5 \times 10^{-7}$
BaSO <sub>4</sub>	$1.08 \times 10^{-10}$	NiCO <sub>3</sub>	$1.42 \times 10^{-7}$
CdCO <sub>3</sub>	$1.0 \times 10^{-12}$	Ni(OH) <sub>2</sub>	$5.48 \times 10^{-16}$
Cd(OH) <sub>2</sub>	$7.2 \times 10^{-15}$	Ag <sub>2</sub> CO <sub>3</sub>	$8.46 \times 10^{-12}$
PbCO <sub>3</sub>	$7.40 \times 10^{-14}$	Ag <sub>2</sub> SO <sub>4</sub>	$1.20 \times 10^{-5}$
Pb(OH) <sub>2</sub>	$1.43 \times 10^{-20}$	ZnCO <sub>3</sub>	$1.46 \times 10^{-10}$
PbSO <sub>4</sub>	$2.53 \times 10^{-8}$	Zn(OH) <sub>2</sub>	$3 \times 10^{-17}$

### 33. 2-amino acids

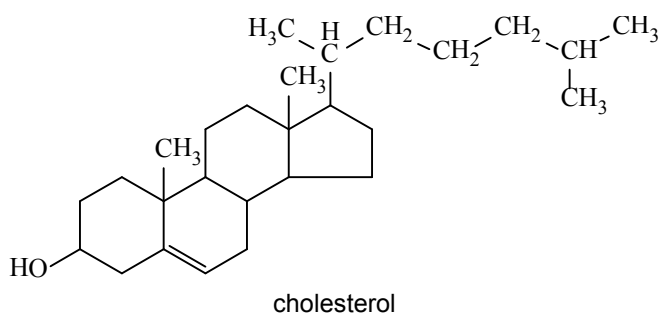
Common name	Symbol	Structural formula	pH of isoelectric point
alanine	Ala	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_3 \end{array}$	6.0
arginine	Arg	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}-\text{NH}_2 \\    \\ \text{NH} \end{array}$	10.8
asparagine	Asn	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{C}-\text{NH}_2 \\    \\ \text{O} \end{array}$	5.4
aspartic acid	Asp	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{COOH} \end{array}$	2.8
cysteine	Cys	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{SH} \end{array}$	5.1
glutamic acid	Glu	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{CH}_2-\text{COOH} \end{array}$	3.2
glutamine	Gln	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{CH}_2-\text{C}-\text{NH}_2 \\    \\ \text{O} \end{array}$	5.7
glycine	Gly	$\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$	6.0
histidine	His	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{N} \\ \diagup \quad \diagdown \\ \text{N} \quad \text{H} \end{array}$	7.6
isoleucine	Ile	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_2-\text{CH}_3 \end{array}$	6.0
leucine	Leu	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_3 \end{array}$	6.0
lysine	Lys	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}_2 \end{array}$	9.7
methionine	Met	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{CH}_2-\text{S}-\text{CH}_3 \end{array}$	5.7

Common name	Symbol	Structural formula	pH of isoelectric point
phenylalanine	Phe	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{C}_6\text{H}_5 \end{array}$	5.5
proline	Pro	$\begin{array}{c} \text{COOH} \\   \\ \text{HN} \\   \\ \text{C}_4\text{H}_7 \end{array}$	6.3
serine	Ser	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2-\text{OH} \end{array}$	5.7
threonine	Thr	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{H}_3\text{C}-\text{CH}-\text{OH} \end{array}$	5.6
tryptophan	Trp	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{C}_8\text{H}_6\text{N}_2 \end{array}$	5.9
tyrosine	Tyr	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{CH}_2 \\   \\ \text{C}_6\text{H}_4 \\   \\ \text{OH} \end{array}$	5.7
valine	Val	$\begin{array}{c} \text{H}_2\text{N}-\text{CH}-\text{COOH} \\   \\ \text{H}_3\text{C}-\text{CH}-\text{CH}_3 \end{array}$	6.0

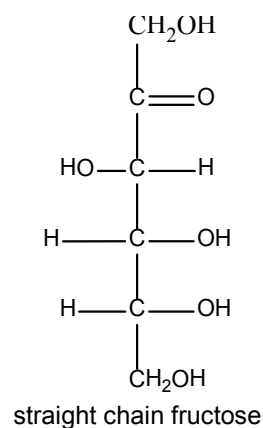
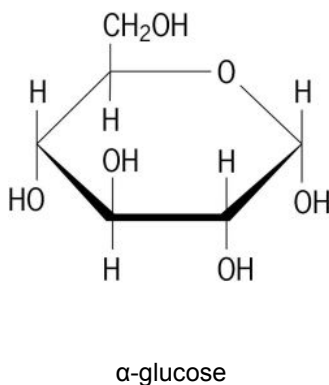
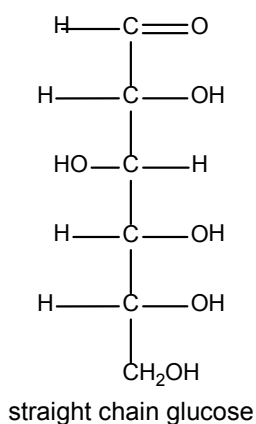
## 34. Lipids, carbohydrates and nucleotide components

### Lipids

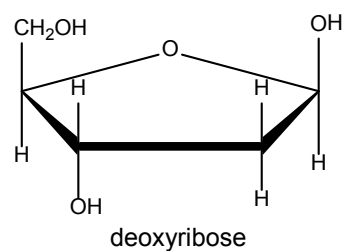
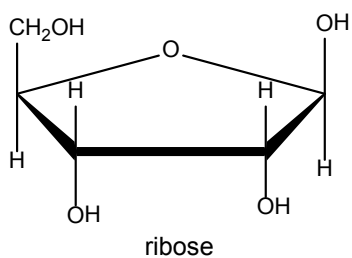
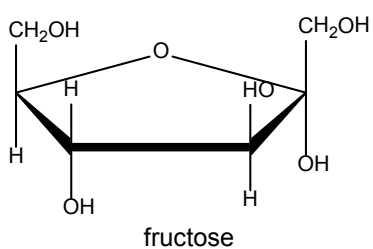
Octanoic acid	$\text{CH}_3(\text{CH}_2)_6\text{COOH}$
Lauric acid	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Palmitic acid	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Stearic acid	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Oleic acid	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Linoleic acid	$\text{CH}_3(\text{CH}_2)_4(\text{CH}=\text{CHCH}_2)_2(\text{CH}_2)_6\text{COOH}$
$\alpha$ -Linolenic acid	$\text{CH}_3\text{CH}_2(\text{CH}=\text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH}$



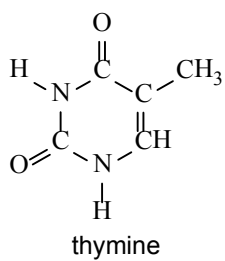
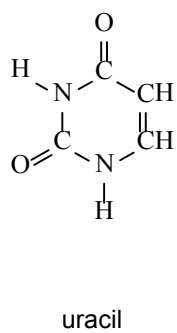
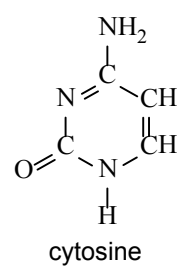
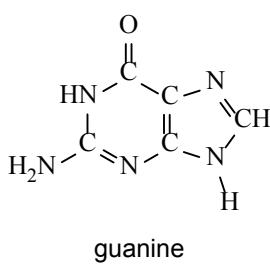
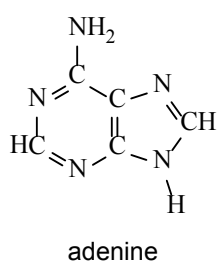
### Carbohydrates





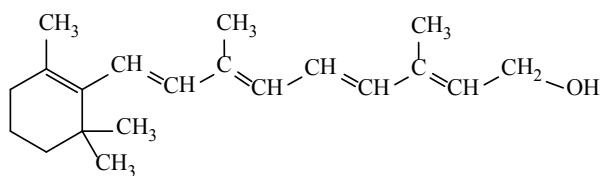


## Nitrogenous bases

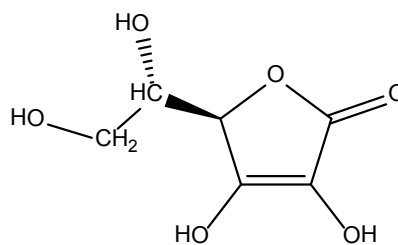


## 35. Vitamins and pigments

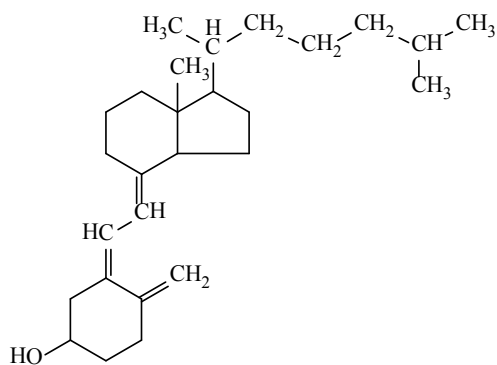
### Vitamins



retinol (vitamin A)

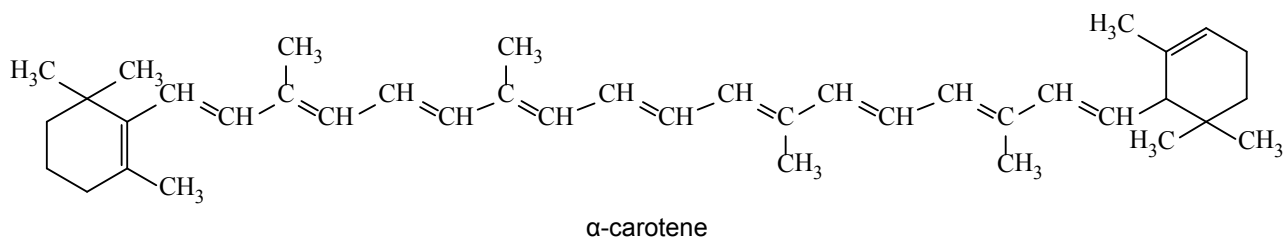
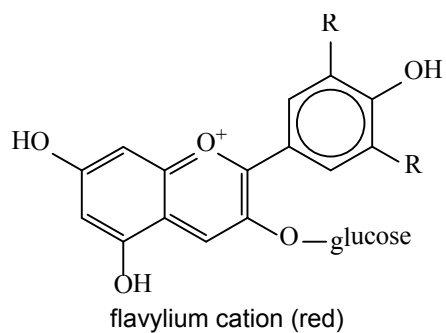
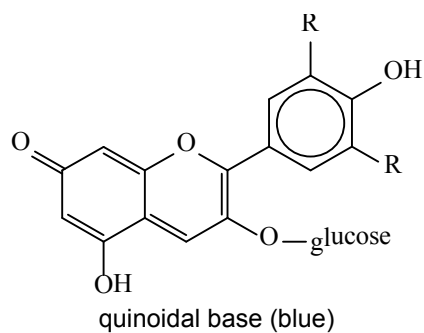
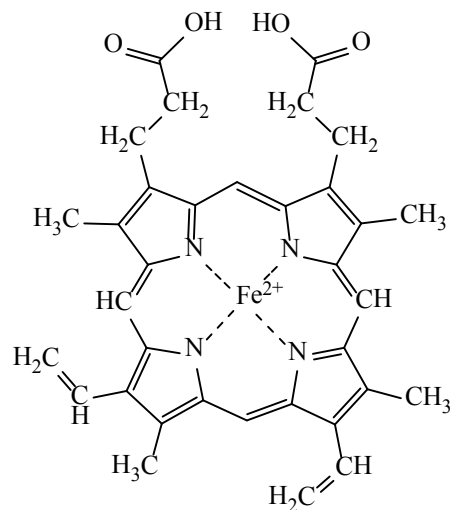
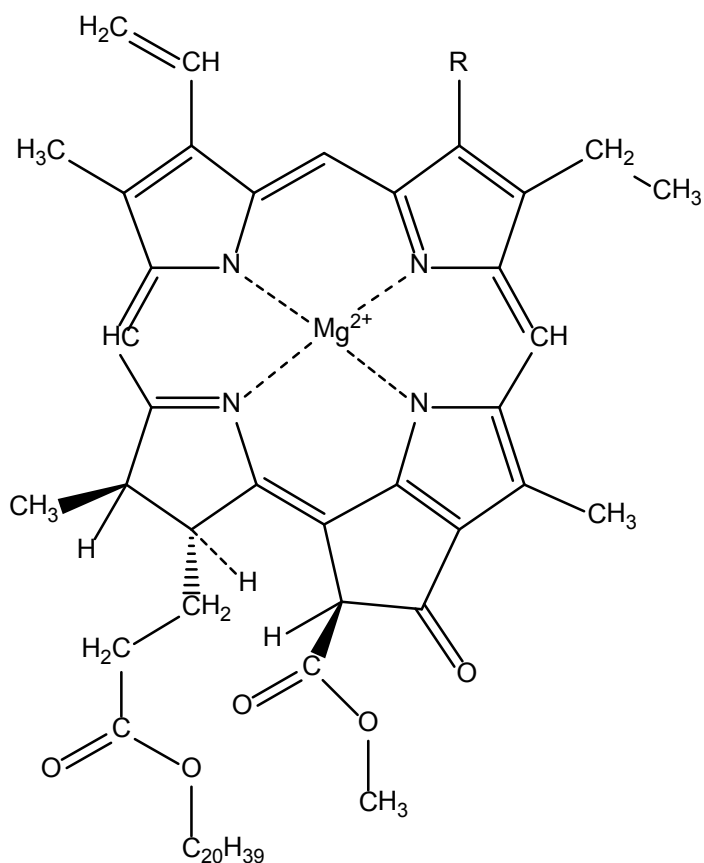


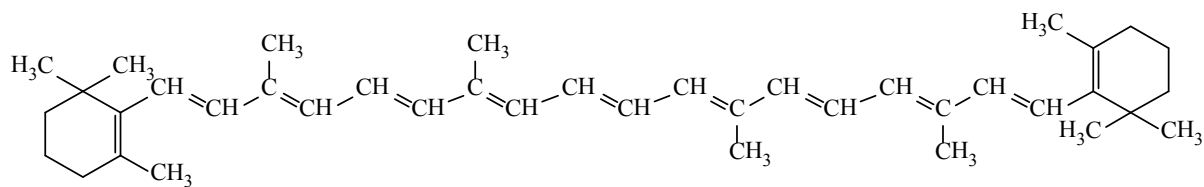
ascorbic acid (vitamin C)



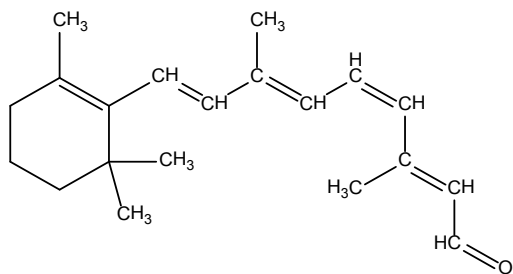
vitamin D (D<sub>3</sub>)

## Pigments

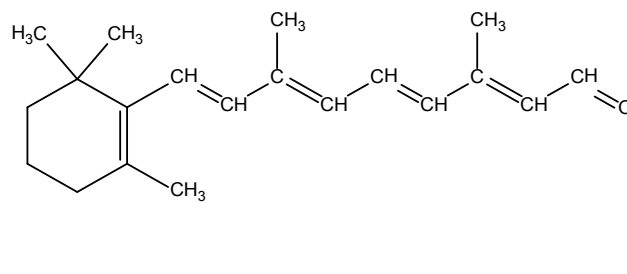




$\beta$ -carotene

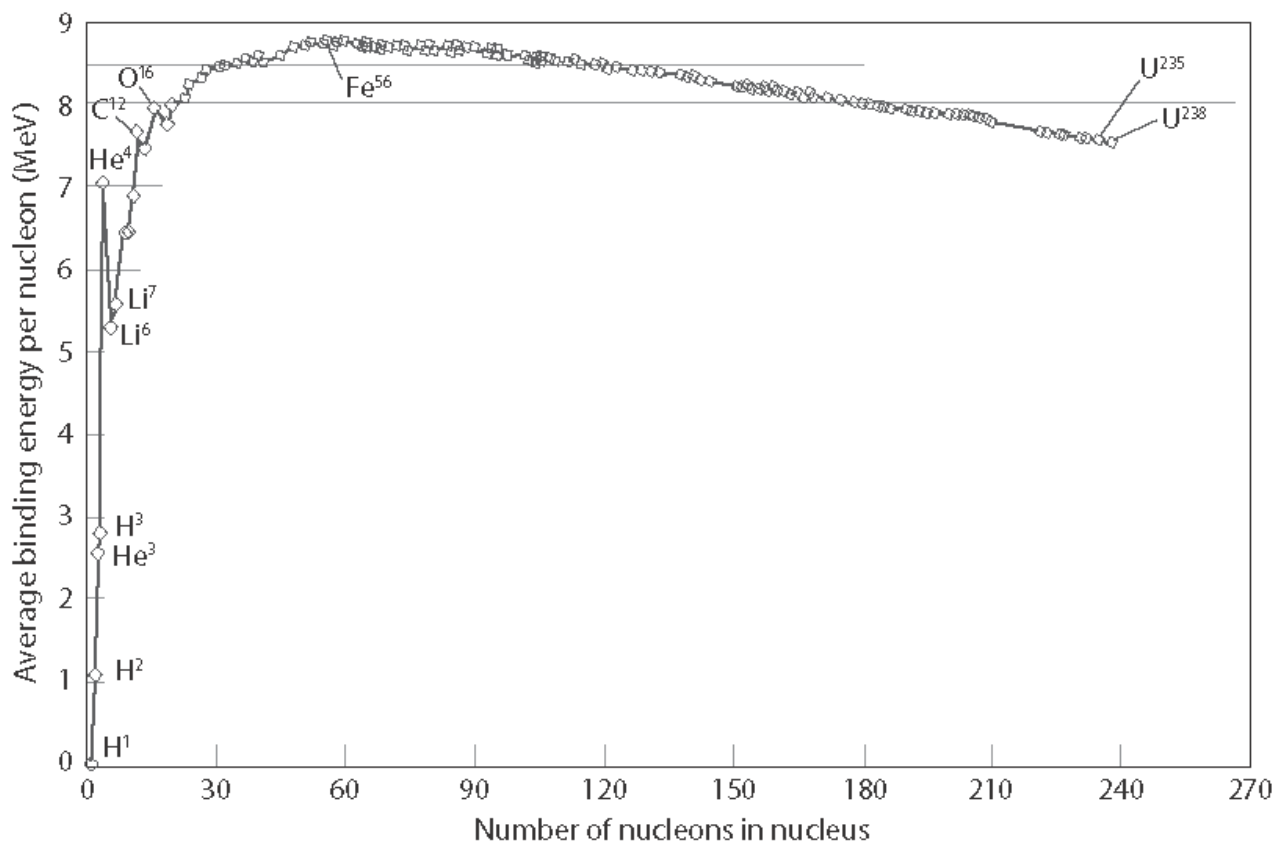


*11-cis-retinal*

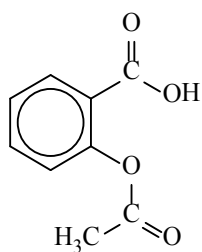


*all-trans-retinal*

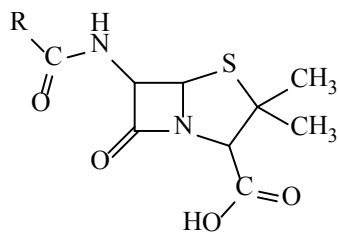
## 36. Binding energy curve



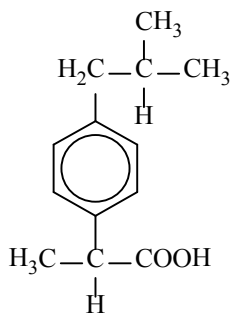
## 37. Representations of some medicinal molecules



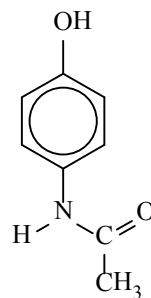
aspirin



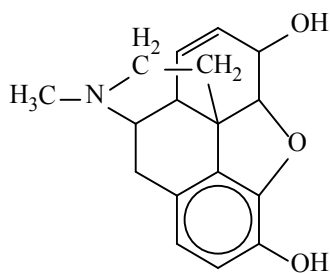
penicillin (general structure)



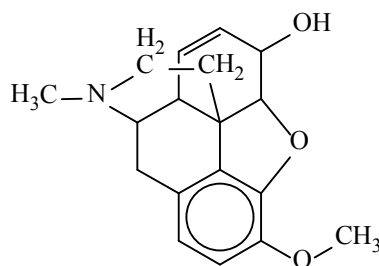
ibuprofen



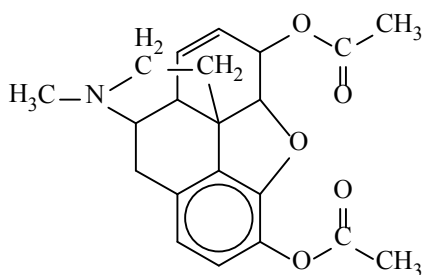
paracetamol (acetaminophen)



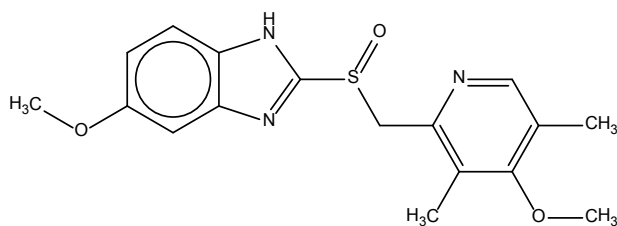
morphine



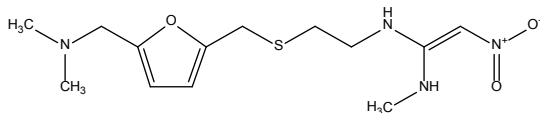
codeine



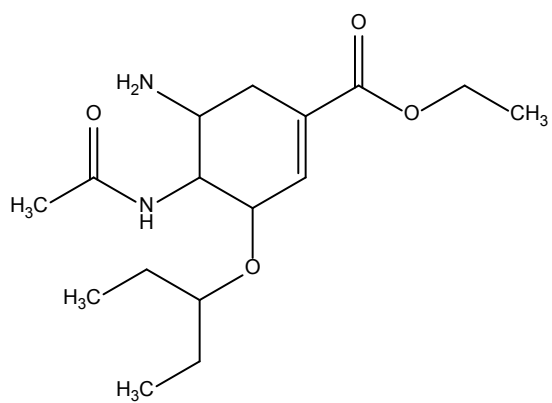
diamorphine (heroin)



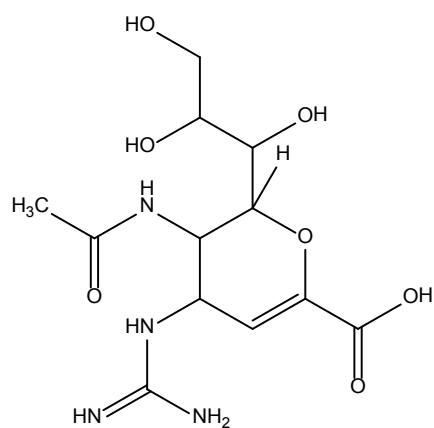
omeprazole



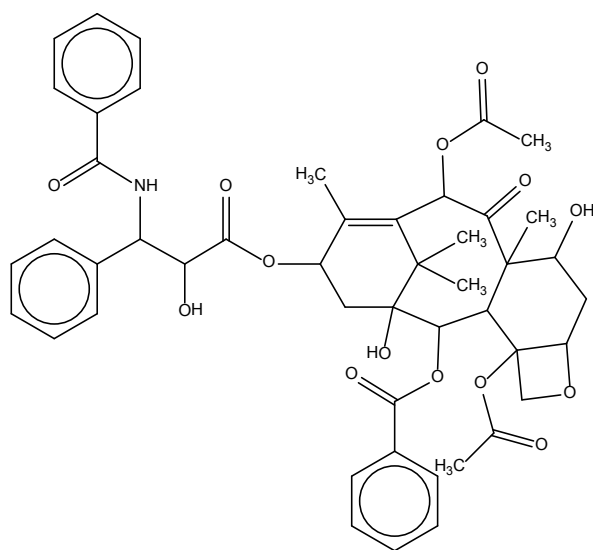
ranitidine



oseltamivir



zanamivir



taxol

## 38. References

**Data in sections 9, 10, 11, 12, 13, 22, 26 and 27 was taken fully or in part from:**

Aylward, G and Findlay, T. 2008. *SI chemical data*. (5th edition). Queensland, Australia. John Wiley & Sons.

**Data in section 20 reproduced** by permission of The Royal Society of Chemistry.

Barret, J. 2003. *Inorganic chemistry in aqueous solution*. London, UK. Royal Society of Chemistry.

**Data in section 13 was taken in part from:**

Burgess, DR. 2012. "Thermochemical Data". *NIST Chemistry WebBook, NIST Standard Reference Database*. Number 69. <http://webbook.nist.gov>.

**Data in sections 7, 8, 9, 12, 13, 18, 19, 21, 23, 24, 28, 32, 33 was taken fully or in part from:**

Haynes, WM, (ed). 2012. *CRC Handbook of chemistry and physics*. (93rd edition). Boca Raton, US. CRC Press.

**Data in section 29 can be found in the following source:**

Leach, MR. 2013. *Timeline of structural theory*. 04 January 2013. [http://www.meta-synthesis.com/webbook/30\\_timeline/timeline.html](http://www.meta-synthesis.com/webbook/30_timeline/timeline.html).