VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2012

CHEMISTRY

Written examination

Day Date 2012

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (1 hour 30 minutes)**

DATA BOOK

Directions to students

- A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

Table of contents

INCREASING CORE CHARGE

CATION SIZE DECREASES

ANION SIZE DECREASES

INCREASING ATOMIC + IONIC RADIUS

INCREASING SHIELDING

1. Periodic table of the elements

highest melting point

Most electronegative elements

atomic number
79 **Au** 197.0 Gold
symbol of element
relative atomic mass
name of element

1 **H** 1.0 Hydrogen																	**2** **He** 4.0 Helium
3 **Li** 6.9 Lithium	**4** **Be** 9.0 Beryllium											**5** **B** 10.8 Boron	**6** **C** 12.0 Carbon	**7** **N** 14.0 Nitrogen	**8** **O** 16.0 Oxygen	**9** **F** 19.0 Fluorine	**10** **Ne** 20.2 Neon
11 **Na** 23.0 Sodium	**12** **Mg** 24.3 Magnesium											**13** **Al** 27.0 Aluminium	**14** **Si** 28.1 Silicon	**15** **P** 31.0 Phosphorus	**16** **S** 32.1 Sulfur	**17** **Cl** 35.5 Chlorine	**18** **Ar** 39.9 Argon
19 **K** 39.1 Potassium	**20** **Ca** 40.1 Calcium	**21** **Sc** 45.0 Scandium	**22** **Ti** 47.9 Titanium	**23** **V** 50.9 Vanadium	**24** **Cr** 52.0 Chromium	**25** **Mn** 54.9 Manganese	**26** **Fe** 55.8 Iron	**27** **Co** 58.9 Cobalt	**28** **Ni** 58.7 Nickel	**29** **Cu** 63.5 Copper	**30** **Zn** 65.4 Zinc	**31** **Ga** 69.7 Gallium	**32** **Ge** 72.6 Germanium	**33** **As** 74.9 Arsenic	**34** **Se** 79.0 Selenium	**35** **Br** 79.9 Bromine	**36** **Kr** 83.8 Krypton
37 **Rb** 85.5 Rubidium	**38** **Sr** 87.6 Strontium	**39** **Y** 88.9 Yttrium	**40** **Zr** 91.2 Zirconium	**41** **Nb** 92.9 Niobium	**42** **Mo** 96.0 Molybdenum	**43** **Tc** (98) Technetium	**44** **Ru** 101.1 Ruthenium	**45** **Rh** 102.9 Rhodium	**46** **Pd** 106.4 Palladium	**47** **Ag** 107.9 Silver	**48** **Cd** 112.4 Cadmium	**49** **In** 114.8 Indium	**50** **Sn** 118.7 Tin	**51** **Sb** 121.8 Antimony	**52** **Te** 127.6 Tellurium	**53** **I** 126.9 Iodine	**54** **Xe** 131.3 Xenon
55 **Cs** 132.9 Caesium	**56** **Ba** 137.3 Barium	**57** **La** 138.9 Lanthanum	**72** **Hf** 178.5 Hafnium	**73** **Ta** 180.9 Tantalum	**74** **W** 183.8 Tungsten	**75** **Re** 186.2 Rhenium	**76** **Os** 190.2 Osmium	**77** **Ir** 192.2 Iridium	**78** **Pt** 195.1 Platinum	**79** **Au** 197.0 Gold	**80** **Hg** 200.6 Mercury	**81** **Tl** 204.4 Thallium	**82** **Pb** 207.2 Lead	**83** **Bi** 209.0 Bismuth	**84** **Po** (210) Polonium	**85** **At** (210) Astatine	**86** **Rn** (222) Radon
87 **Fr** (223) Francium	**88** **Ra** (226) Radium	**89** **Ac** (227) Actinium	**104** **Rf** (261) Rutherfordium	**105** **Db** (262) Dubnium	**106** **Sg** (266) Seaborgium	**107** **Bh** (264) Bohrium	**108** **Hs** (267) Hassium	**109** **Mt** (268) Meitnerium	**110** **Ds** (271) Darmstadtium	**111** **Rg** (272) Roentgenium	**112** **Cn** (285) Copernicium	**113** **Uut** (284)	**114** **Uuq** (289)	**115** **Uup** (288)	**116** **Uuh** (293)	**117** **Uus** (294)	**118** **Uuo** (294)

ELECTRONEGATIVITY INCREASES

1ST IONISATION ENERGY INCREASES

Highest boiling points (highest is W)

LANTHANIDES →	**58** **Ce** 140.1 Cerium	**59** **Pr** 140.9 Praseodymium	**60** **Nd** 144.2 Neodymium	**61** **Pm** (145) Promethium	**62** **Sm** 150.4 Samarium	**63** **Eu** 152.0 Europium	**64** **Gd** 157.3 Gadolinium	**65** **Tb** 158.9 Terbium	**66** **Dy** 162.5 Dysprosium	**67** **Ho** 164.9 Holmium	**68** **Er** 167.3 Erbium	**69** **Tm** 168.9 Thulium	**70** **Yb** 173.1 Ytterbium	**71** **Lu** 175.0 Lutetium
ACTINIDES →	**90** **Th** 232.0 Thorium	**91** **Pa** 231.0 Protactinium	**92** **U** 238.0 Uranium	**93** **Np** (237) Neptunium	**94** **Pu** (244) Plutonium	**95** **Am** (243) Americium	**96** **Cm** (247) Curium	**97** **Bk** (247) Berkelium	**98** **Cf** (251) Californium	**99** **Es** (252) Einsteinium	**100** **Fm** (257) Fermium	**101** **Md** (258) Mendelevium	**102** **No** (259) Nobelium	**103** **Lr** (262) Lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

TURN OVER

AN OIL RIG CAT

→ all these are REDUCTION HALF-EQUATIONS

2. The electrochemical series

OXIDANTS + e^- ⇌ REDUCTANTS	E° in volt
STRONGEST OXIDANT → $F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	−0.23
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	−0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	−0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.03
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	−1.67
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.34
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	−2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$ ← STRONGEST REDUCANT	−3.02

INCREASING OXIDANT STRENGTH ↑

INCREASING REDUCTANT STRENGTH ↓

E° = "electrode potential" "at standard conditions": 1 atm, 1 mol L^{-1}, 25 °C

At non-standard conditions, the E° values will change slightly, and the sequence may change, too.
Eg. At 2M, 1 atm, 25°C, these two SWAP PLACES.

STANDARD HYDROGEN ELECTRODE } all the other values are relative to this.

Strong oxidants react spontaneously with strong reductants.

↓

For a spontaneous reaction to occur, the oxidant must have a higher E° than the reductant.

Reverse any of these half-equations to make an OXIDATION HALF-EQUATION.

3. Physical constants

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

Charge on one electron $= -1.60 \times 10^{-19}$ C

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

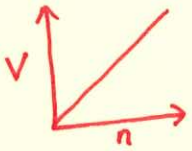
Gas constant (R) $= 8.31$ J K^{-1}mol^{-1}

Ionic product for water (K_w) $= 1.00 \times 10^{-14}$ mol^2 L^{-2} at 298 K
(Self ionisation constant)

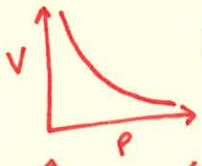
Molar volume (V_m) of an ideal gas at 273 K, 101.3 kPa (STP) $= 22.4$ L mol^{-1}
Molar volume (V_m) of an ideal gas at 298 K, 101.3 kPa (SLC) $= 24.5$ L mol^{-1}

Specific heat capacity (c) of water $= 4.18$ J g^{-1} K^{-1}
Density (d) of water at 25°C $= 1.00$ g mL^{-1}

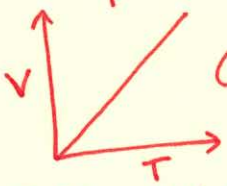
1 atm $= 101.3$ kPa $= 760$ mm Hg
0°C $= 273$ K



Avogadro's Law



Boyle's Law



Charles' Law

Sum of partial pressures = total pressure (Dalton's Law)

$n = \frac{m}{M}$ $N = n \times N_A$ $n = C \times V$

$C_1V_1 = C_2V_2$ $C_1V_1 + C_2V_2 = C_3V_3$

$PV = nRT$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$E = V \times I \times t$ $E = m \times c \times \Delta T$

$C_f = \frac{E}{\Delta T} = \frac{VIt}{\Delta T}$ $Q = I \times t$

$\rho = \frac{m}{V}$ (ρ ↑ Density) $n(e^-) = \frac{Q}{F} = \frac{I \times t}{F}$ (F → 96500, a constant)

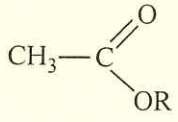
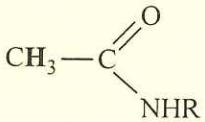
4. SI prefixes, their symbols and values

SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

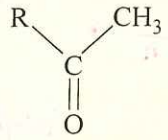
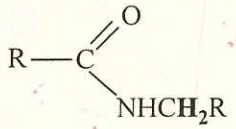
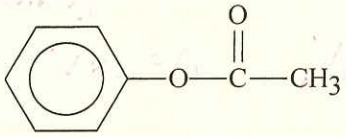
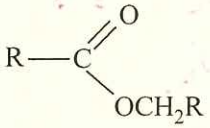
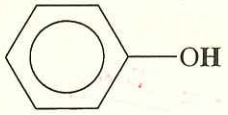
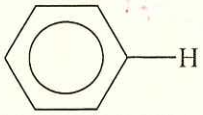
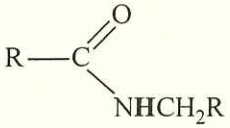
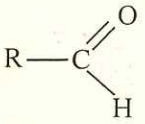
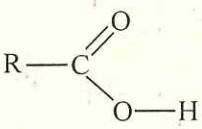
Type of proton	Chemical shift (ppm)
R–CH_3 alkanes	0.8–1.0
R–CH_2–R alkanes	1.2–1.4
RCH = CH–$\mathbf{CH_3}$ alkenes	1.6–1.9
R_3–CH	1.4–1.7
 or  esters / amide group	2.0

$pH = -\log_{10}[H_3O^+]$

$[H_3O^+] = 10^{-pH}$

$[OH^-] = \frac{10^{-14}}{[H_3O^+]}$ ★ ONLY WORKS AT 25°C

$[H_3O^+] = \frac{10^{-14}}{[OH^-]}$

Type of proton	Chemical shift (ppm)
	2.1–2.7
R–CH_2–X (X = F, Cl, Br or I) halogens	3.0–4.5
R–C**H**$_2$–OH, R_2–C**H**–OH	3.3–4.5
 amide group	3.2
R—O—CH_3 or R—O—CH_2R	3.3
 methyl benzoate	2.3
 esters	4.1
R–O–H alkanols	1–6 (varies considerably under different conditions)
R–NH_2 amides	1–5
RHC=C**H**$_2$ alkenes	4.6–6.0
 phenol	7.0
 benzene	7.3
 amide group	8.1
 aldehydes	9–10
 carboxylic acids	9–13

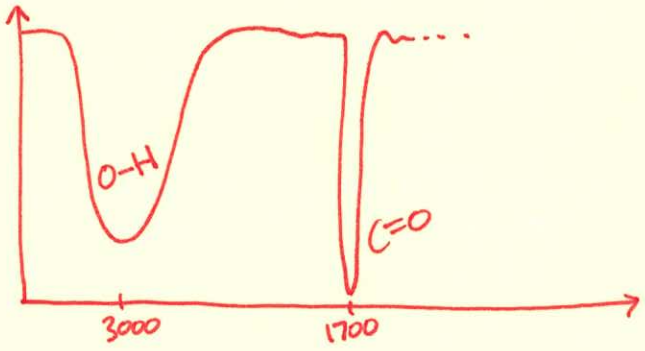
6. ^{13}C NMR data

Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$ haloalkanes	15–80
$R_3C–NH_2$ amides	35–70
$R–CH_2–OH$ alkanols	50–90
$RC{\equiv}CR$ alkynes	75–95
$R_2C{=}CR_2$ alkenes	110–150
RCOOH carboxylic acids	160–185

7. Infrared absorption data

Characteristic range for infrared absorption

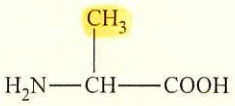
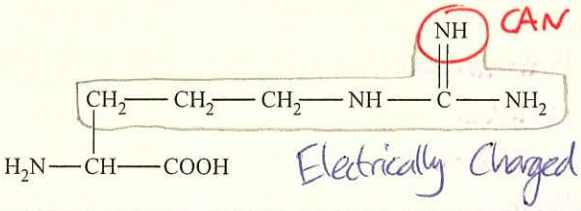
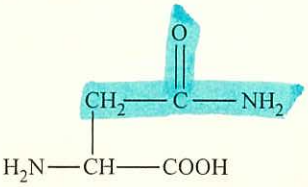
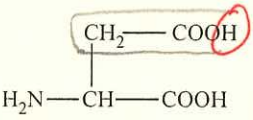
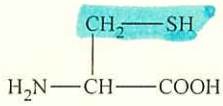
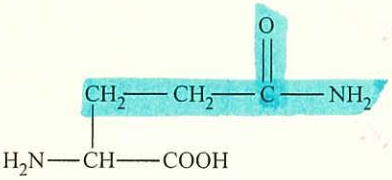
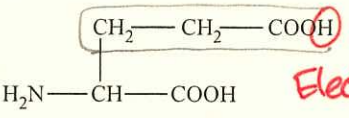
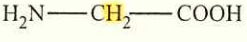
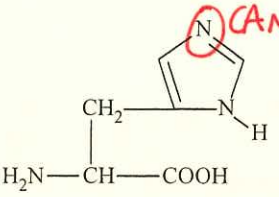
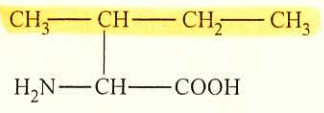
Bond	Wave number (cm^{-1})
C–Cl	700–800
C–C	750–1100
C–O	1000–1300
C=C	1610–1680
C=O narrow, deep peak	1670–1750
O–H (acids) broad peak	2500–3300
C–H	2850–3300
O–H (alcohols) broad peak	3200–3550
N–H (primary amines)	3350–3500

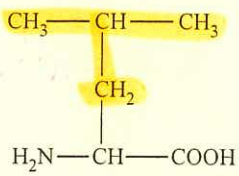
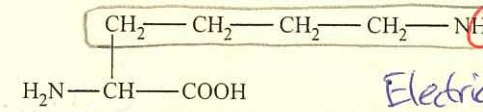
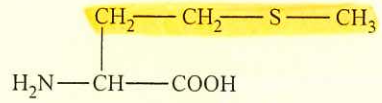
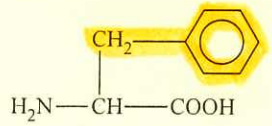
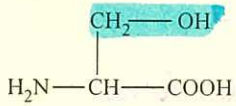
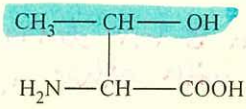
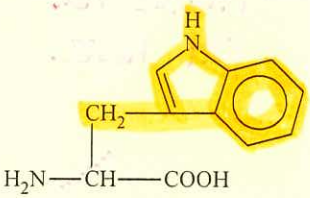
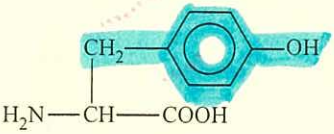
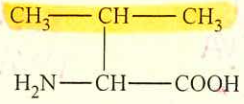


R-groups are highlighted: POLAR / NON-POLAR

8. 2-amino acids (α-amino acids)

ELECTRICALLY CHARGED (ACIDIC / BASIC)

Name	Symbol	Structure
alanine	Ala	
arginine	Arg	 CAN ACCEPT H+ Electrically Charged: Basic
asparagine	Asn	
aspartic acid	Asp	 CAN DONATE H+ Electrically Charged: Acidic
cysteine	Cys	 Disulphide bridges form between cysteine residues (tertiary structure)
glutamine	Gln	
glutamic acid	Glu	 CAN DONATE H+ Electrically charged: Acidic
glycine	Gly	
histidine	His	 CAN ACCEPT H+ Electrically Charged: Basic
isoleucine	Ile	

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	 CAN ACCEPT H+ Electrically Charged: Basic
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

Triglycerides can be named after the GLYCERYL fatty acids that formed them: eg. tristearate, trilinoleate. (GLYCERYL)

9. Formulas of some fatty acids

Name	Formula
Lauric	$C_{11}H_{23}COOH$
Myristic	$C_{13}H_{27}COOH$
Palmitic	$C_{15}H_{31}COOH$
Palmitoleic	$C_{15}H_{29}COOH$
Stearic	$C_{17}H_{35}COOH$
Oleic	$C_{17}H_{33}COOH$
Linoleic	$C_{17}H_{31}COOH$
Linolenic	$C_{17}H_{29}COOH$
Arachidic	$C_{19}H_{39}COOH$
Arachidonic	$C_{19}H_{31}COOH$

C=C

C=C

C=C

C=C

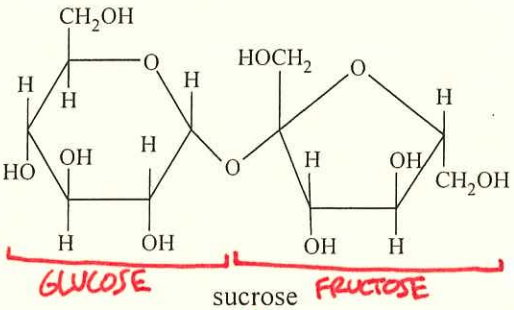
$C_nH_{2n+1}COOH$ is SATURATED

$C_nH_{2n-1}COOH$ has one C=C (MONO-UNSATURATED)

$C_nH_{2n-3}COOH$ has two C=C (DI-UNSATURATED)

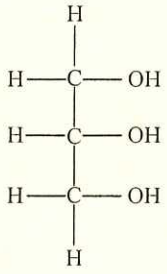
≥2 C=C are called "POLYUNSATURATED"

10. Structural formulas of some important biomolecules



sucrose

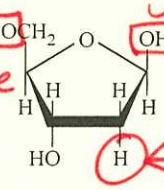
→ a disaccharide formed by a condensation reaction.



glycerol

+ 3 Fatty Acids → 1 triglyceride + $3H_2O$

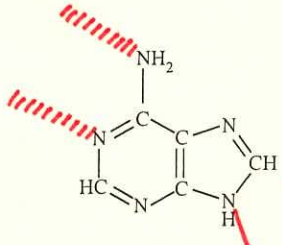
this OH is lost during condensation reaction with phosphate



this OH is lost during condensation reaction with either A, T, G or C.

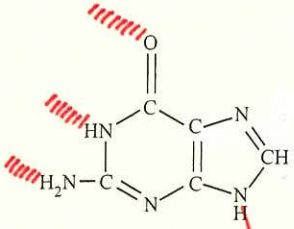
deoxyribose

ribose has OH here.



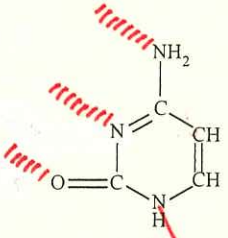
adenine

bonds to DNA chain (to the sugar)



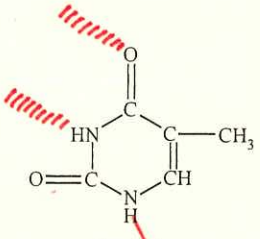
guanine

bonds to DNA chain (to the sugar)



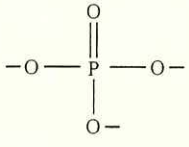
cytosine

bonds to DNA chain (to the sugar)



thymine

bonds to DNA chain (to the sugar)



phosphate

A=T C≡G

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
Thymol blue	1.2–2.8	red	yellow	2×10^{-2}
Methyl orange	3.1–4.4	red	yellow	2×10^{-4}
Bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
Methyl red	4.2–6.3	red	yellow	8×10^{-6}
Bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
Phenol red	6.8–8.4	yellow	red BRIGHT PINK	1×10^{-8}
Phenolphthalein	8.3–10.0	colourless	red DARK PINK	5×10^{-10}

12. Acidity constants, K_a, of some weak acids at 25 °C

Name	Formula	K_a
Ammonium ion	NH_4^+	5.6×10^{-10}
Benzoic	C_6H_5COOH	6.4×10^{-5}
Boric	H_3BO_3	5.8×10^{-10}
Ethanoic	CH_3COOH	1.7×10^{-5}
Hydrocyanic	HCN	6.3×10^{-10} WEAKEST ACID IN THIS LIST
Hydrofluoric	HF	7.6×10^{-4} STRONGEST ACID IN THIS LIST
Hypobromous	HOBr	2.4×10^{-9}
Hypochlorous	HOCl	2.9×10^{-8}
Lactic	$HC_3H_5O_3$	1.4×10^{-4}
Methanoic	HCOOH	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	C_2H_5COOH	1.3×10^{-5}

13. Values of molar enthalpy of combustion of some common fuels at 298 K and 101.3 kPa

Substance	Formula	State	ΔH_c (kJ mol^{-1})
hydrogen	H_2	g	–286
carbon (graphite)	C	s	–394
methane	CH_4	g	–889
ethane	C_2H_6	g	–1557
propane	C_3H_8	g	–2217
butane	C_4H_{10}	g	–2874
pentane	C_5H_{12}	l	–3509
hexane	C_6H_{14}	l	–4158
octane	C_8H_{18}	l	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	l	–725
ethanol	C_2H_5OH	l	–1364
1-propanol	$CH_3CH_2CH_2OH$	l	–2016
2-propanol	$CH_3CHOHCH_3$	l	–2003
glucose	$C_6H_{12}O_6$	s	–2816

Always use these states when writing combustion equations. (IF THEY'RE AT 298 K & 101.3 kPa).

END OF DATA BOOK

All ethanoates (CH_3COO^-) are soluble.
All nitrates (NO_3^-) are soluble.
All chlorides (Cl^-) are soluble except for Silver, Lead and Mercury.
" iodides (I^-) " " " " " " " " .
" bromides (Br^-) " " " " " " " " .

All sulphates/sulfates (SO_4^{2-}) are soluble except for Barium, Calcium, Lead, Silver and Tin

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All hydroxides (OH^-) are INSOLUBLE except for $LiOH$, $NaOH$, KOH, $RbOH$, NH_4OH, $Sr(OH)_2$, $Ba(OH)_2$.
All carbonates (CO_3^{2-}) are INSOLUBLE except for Li_2CO_3, Na_2CO_3, K_2CO_3, Rb_2CO_3, $(NH_4)_2CO_3$
All phosphates (PO_4^{3-}) " " " " Li_3PO_4, Na_3PO_4, K_3PO_4, Rb_3PO_4, $(NH_4)_3PO_4$.
All sulphites/sulfates (SO_3^{2-}) " " " " Li_2SO_3, Na_2SO_3, K_2SO_3, Rb_2SO_3, $(NH_4)SO_3$.