Pearson

# Pearson Edexcel Level 3 Advanced Level GCE in Chemistry (9CH0)

# Data Booklet

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This Data Booklet is available on our Chemistry 2015 webpage. Centres will be sent copies of the Data Booklet for the first examination series.

Centres can make additional fresh copies by printing the Data Booklet from our website. Candidates must use an unmarked copy of the Data Booklet in examinations.

**Acknowledgement of source**
The data used in the Data Booklet is derived from the *Nuffield Advanced Science, Revised Book of Data* (ISBN 058235448X), Nuffield Foundation.

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# Introduction

This Data Booklet is for use with the Pearson Edexcel Level 3 Advanced Level GCE in Chemistry (9CH0) assessments for papers 1, 2 and 3.

Students will be provided with a clean copy of this Data Booklet for these assessments, which should be kept under the same conditions as the assessment papers.

Students may have a copy of this Data Booklet for their personal use in lessons and for homework, to allow them to become familiar with how to use it.

## Physical constants

| | |
|---|---|
| Avogadro constant ($L$) | $6.02 \times 10^{23}$ mol$^{-1}$ |
| Elementary charge ($e$) | $1.60 \times 10^{-19}$ C |
| Gas constant ($R$) | 8.31 J mol$^{-1}$ K$^{-1}$ |
| Molar volume of a gas at room temperature and pressure (r.t.p.): | 24 dm$^3$ mol$^{-1}$ |
| Ionic product of water ($K_w$) | $1.00 \times 10^{-14}$ mol$^2$ dm$^{-6}$ |

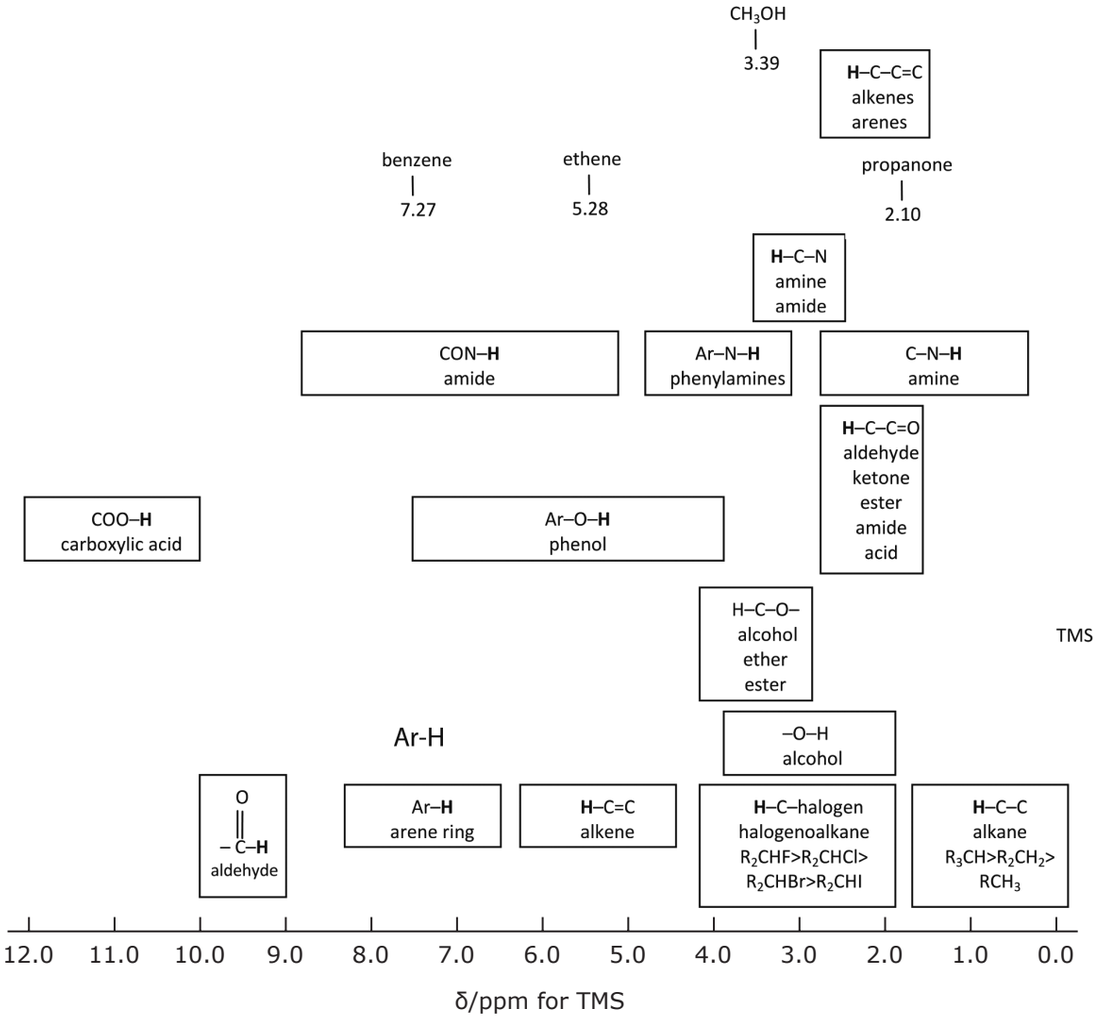
1 dm$^3$ = 1000 cm$^3$ = 0.001 m$^3$

## Infrared spectroscopy

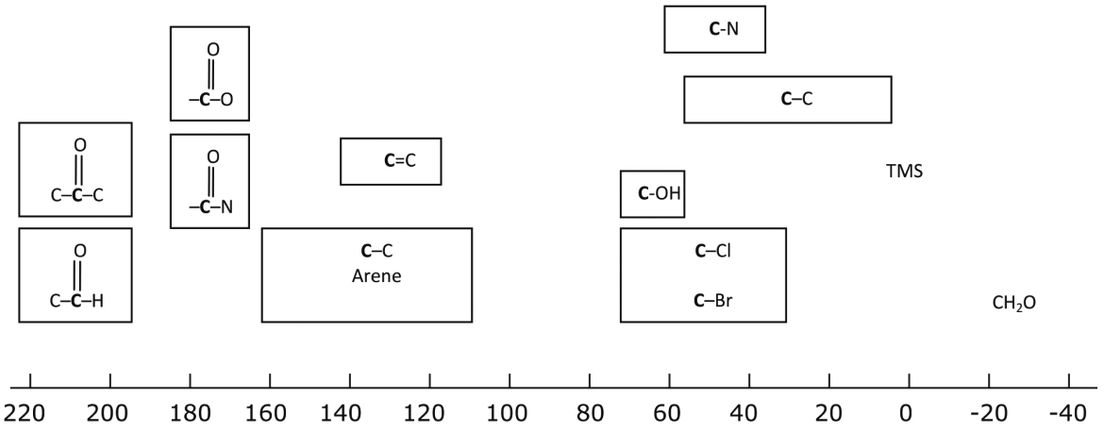
### Correlation of infrared absorption wavenumbers with molecular structure

| Group | Wavenumber range/cm$^{-1}$ |
|---|---|
| **C-H stretching vibrations** | |
| Alkane | 2962-2853 |
| Alkene | 3095-3010 |
| Alkyne | 3300 |
| Arene | 3030 |
| Aldehyde | 2900-2820 and 2775-2700 |
| | |
| **C-H bending vibrations** | |
| Alkane | 1485-1365 |
| Arene 5 adjacent hydrogen atoms | 750 and 700 |
| 4 adjacent hydrogen atoms | 750 |
| 3 adjacent hydrogen atoms | 780 |
| 2 adjacent hydrogen atoms | 830 |
| 1 isolated hydrogen atom | 880 |
| | |
| **N-H stretching vibrations** | |
| Amine | 3500-3300 |
| Amide | 3500-3140 |
| | |
| **O-H stretching vibrations** | |
| Alcohols and phenols | 3750-3200 |
| Carboxylic acids | 3300-2500 |
| | |
| **C=C stretching vibrations** | |
| Isolated alkene | 1669-1645 |
| Arene | 1600, 1580, 1500, 1450 |
| | |
| **C=O stretching vibrations** | |
| Aldehydes, saturated alkyl | 1740-1720 |
| Ketones, alkyl | 1720-1700 |
| Ketones, aryl | 1700-1680 |
| Carboxylic acids, alkyl | 1725-1700 |
| Carboxylic acids, aryl | 1700-1680 |
| Carboxylic acid, anhydrides | 1850-1800 and 1790-1740 |
| Acyl halides, chlorides | 1795 |
| Acyl halides, bromides | 1810 |
| Esters, saturated | 1750-1735 |
| Amides | 1700-1630 |
| | |
| **Triple bond stretching vibrations** | |
| C≡N | 2260-2215 |
| C≡C | 2260-2100 |

## $^{1}$H nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)




## $^{13}$C nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)



## Pauling electronegativities

### Pauling electronegativity index

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | H | | | | | | | | | | He |
| | | | | | | | 2·1 | | | | | | | | | | |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| 1·0 | 1·5 | | | | | | | | | | | 2·0 | 2·5 | 3·0 | 3·5 | 4·0 | |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| 0·9 | 1·2 | | | | | | | | | | | 1·5 | 1·9 | 2·1 | 2·5 | 3·0 | |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| 0·8 | 1·0 | 1·3 | 1·5 | 1·6 | 1·6 | 1·5 | 1·8 | 1·8 | 1·8 | 1·9 | 1·6 | 1·6 | 2·0 | 2·0 | 2·4 | 2·8 | |
| 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 | 2·1 | 1·9 | 2·2 | 2·2 | 2·2 | 1·9 | 1·6 | 1·7 | 1·9 | 1·9 | 2·1 | 2·5 | |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |
| 0·7 | 0·9 | 1·1 | 1·3 | 1·5 | 2·3 | 1·9 | 2·2 | 2·2 | 2·2 | 2·5 | 2·0 | 1·6 | 1·8 | 1·9 | 2·0 | 2·2 | |

## Indicators

| | | **p*K*in (at 298 K)** | ***acid*** | **pH range** | ***alkaline*** |
|---|---|---|---|---|---|
| 1 | Thymol blue (acid) | 1.7 | red | 1.2–2.8 | yellow |
| 2 | Screened methyl orange | 3.7 | purple | 3.2–4.2 | green |
| 3 | Methyl orange | 3.7 | red | 3.2–4.4 | yellow |
| 4 | Bromophenol blue | 4.0 | yellow | 2.8–4.6 | blue |
| 5 | Bromocresol green | 4.7 | yellow | 3.8–5.4 | blue |
| | | | | | |
| 6 | Methyl red | 5.1 | red | 4.2–6.3 | yellow |
| 7 | Litmus | | red | 5.0–8.0 | blue |
| 8 | Bromothymol blue | 7.0 | yellow | 6.0–7.6 | blue |
| 9 | Phenol red | 7.9 | yellow | 6.8–8.4 | red |
| 10 | Phenolphthalein (in ethanol) | 9.3 | colourless | 8.2–10.0 | red |

## Standard electrode potentials

$E^{\ominus}$ Standard electrode potential of aqueous system at 298 K, that is, standard emf of electrochemical cell in the hydrogen half-cell forms the left-hand side electrode system.

| | Right-hand electrode system | $E^{\ominus}$/V |
|---|---|---|
| 1 | $Na^+ + e^- \rightleftharpoons Na$ | −2.71 |
| 2 | $Mg^{2+} + 2e^- \rightleftharpoons Mg$ | −2.37 |
| 3 | $Al^{3+} + 3e^- \rightleftharpoons Al$ | −1.66 |
| 4 | $V^{2+} + 2e^- \rightleftharpoons V$ | −1.18 |
| 5 | $Zn^{2+} + 2e^- \rightleftharpoons Zn$ | −0.76 |
| 6 | $Cr^{3+} + 3e^- \rightleftharpoons Cr$ | −0.74 |
| 7 | $Fe^{2+} + 2e^- \rightleftharpoons Fe$ | −0.44 |
| 8 | $Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$ | −0.41 |
| 9 | $V^{3+} + e^- \rightleftharpoons V^{2+}$ | −0.26 |
| 10 | $Ni^{2+} + 2e^- \rightleftharpoons Ni$ | −0.25 |
| 11 | $H^+ + e^- \rightleftharpoons ½H_2$ | 0.00 |
| 12 | $S_4O_6^{2-} + 2e^- \rightleftharpoons 2S_2O_3^{2-}$ | +0.09 |
| 13 | $Cu^{2+} + e^- \rightleftharpoons Cu^+$ | +0.15 |
| 14 | $Cu^{2+} + 2e^- \rightleftharpoons Cu$ | +0.34 |
| 15 | $VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$ | +0.34 |
| 16 | $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ | +0.40 |
| 17 | $S_2O_3^{2-} + 6H^+ + 4e^- \rightleftharpoons 2S + 3H_2O$ | +0.47 |
| 18 | $Cu^+ + e^- \rightleftharpoons Cu$ | +0.52 |
| 19 | $I_2 + 2e^- \rightleftharpoons 2I^-$ | +0.54 |
| 20 | $O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O_2$ | +0.68 |
| 21 | $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ | +0.77 |
| 22 | $Ag^+ + e^- \rightleftharpoons Ag$ | +0.80 |
| 23 | $NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$ | +0.80 |
| 24 | $ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-$ | +0.89 |
| 25 | $VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$ | +1.00 |
| 26 | $Br_2 + 2e^- \rightleftharpoons 2Br^-$ | +1.09 |
| 27 | $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ | +1.23 |
| 28 | $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ | +1.33 |
| 29 | $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ | +1.36 |
| 30 | $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ | +1.51 |
| 31 | $H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$ | +1.77 |

# The Periodic Table of Elements

| 1 | 2 | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 0 (8) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1.0 H hydrogen 1 | | | | | | | | | | (18) 4.0 He helium 2 |
| (1) | (2) | | Key | | | | | | | | | (13) | (14) | (15) | (16) | (17) | |
| 6.9 Li lithium 3 | 9.0 Be beryllium 4 | | relative atomic mass<br>**atomic symbol**<br>name<br>atomic (proton) number | | | | | | | | | 10.8 B boron 5 | 12.0 C carbon 6 | 14.0 N nitrogen 7 | 16.0 O oxygen 8 | 19.0 F fluorine 9 | 20.2 Ne neon 10 |
| 23.0 Na sodium 11 | 24.3 Mg magnesium 12 | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | 27.0 Al aluminium 13 | 28.1 Si silicon 14 | 31.0 P phosphorus 15 | 32.1 S sulfur 16 | 35.5 Cl chlorine 17 | 39.9 Ar argon 18 |
| 39.1 K potassium 19 | 40.1 Ca calcium 20 | 45.0 Sc scandium 21 | 47.9 Ti titanium 22 | 50.9 V vanadium 23 | 52.0 Cr chromium 24 | 54.9 Mn manganese 25 | 55.8 Fe iron 26 | 58.9 Co cobalt 27 | 58.7 Ni nickel 28 | 63.5 Cu copper 29 | 65.4 Zn zinc 30 | 69.7 Ga gallium 31 | 72.6 Ge germanium 32 | 74.9 As arsenic 33 | 79.0 Se selenium 34 | 79.9 Br bromine 35 | 83.8 Kr krypton 36 |
| 85.5 Rb rubidium 37 | 87.6 Sr strontium 38 | 88.9 Y yttrium 39 | 91.2 Zr zirconium 40 | 92.9 Nb niobium 41 | 95.9 Mo molybdenum 42 | [98] Tc technetium 43 | 101.1 Ru ruthenium 44 | 102.9 Rh rhodium 45 | 106.4 Pd palladium 46 | 107.9 Ag silver 47 | 112.4 Cd cadmium 48 | 114.8 In indium 49 | 118.7 Sn tin 50 | 121.8 Sb antimony 51 | 127.6 Te tellurium 52 | 126.9 I iodine 53 | 131.3 Xe xenon 54 |
| 132.9 Cs caesium 55 | 137.3 Ba barium 56 | 138.9 La* lanthanum 57 | 178.5 Hf hafnium 72 | 180.9 Ta tantalum 73 | 183.8 W tungsten 74 | 186.2 Re rhenium 75 | 190.2 Os osmium 76 | 192.2 Ir iridium 77 | 195.1 Pt platinum 78 | 197.0 Au gold 79 | 200.6 Hg mercury 80 | 204.4 Tl thallium 81 | 207.2 Pb lead 82 | 209.0 Bi bismuth 83 | [209] Po polonium 84 | [210] At astatine 85 | [222] Rn radon 86 |
| [223] Fr francium 87 | [226] Ra radium 88 | [227] Ac* actinium 89 | [261] Rf rutherfordium 104 | [262] Db dubnium 105 | [266] Sg seaborgium 106 | [264] Bh bohrium 107 | [277] Hs hassium 108 | [268] Mt meitnerium 109 | [271] Ds darmstadtium 110 | [272] Rg roentgenium 111 | | | | | | | |

Elements with atomic numbers 112-116 have been reported but not fully authenticated

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Lanthanide series | 140 Ce cerium 58 | 141 Pr praseodymium 59 | 144 Nd neodymium 60 | [147] Pm promethium 61 | 150 Sm samarium 62 | 152 Eu europium 63 | 157 Gd gadolinium 64 | 159 Tb terbium 65 | 163 Dy dysprosium 66 | 165 Ho holmium 67 | 167 Er erbium 68 | 169 Tm thulium 69 | 173 Yb ytterbium 70 | 175 Lu lutetium 71 |
| * Actinide series | 232 Th thorium 90 | [231] Pa protactinium 91 | 238 U uranium 92 | [237] Np neptunium 93 | [242] Pu plutonium 94 | [243] Am americium 95 | [247] Cm curium 96 | [245] Bk berkelium 97 | [251] Cf californium 98 | [254] Es einsteinium 99 | [253] Fm fermium 100 | [256] Md mendelevium 101 | [254] No nobelium 102 | [257] Lr lawrencium 103 |

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