Physical constants

Avogadro constant (L) $6.02 \times 10^{23} \text{ mol}^{-1}$

Elementary charge (e) 1.60×10^{-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 dm³ mol⁻¹

Ionic product of water (K_W) 1.00 x 10⁻¹⁴ mol² dm⁻⁶

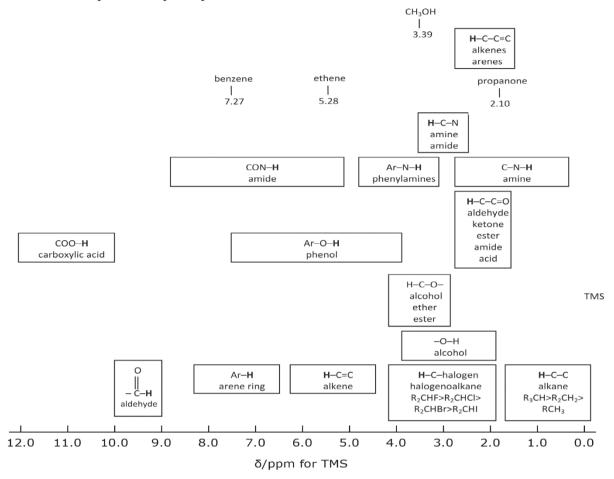
 $1 \text{ dm}^3 = 1000 \text{ cm}^3 = 0.001 \text{ m}^3$

Infrared spectroscopy

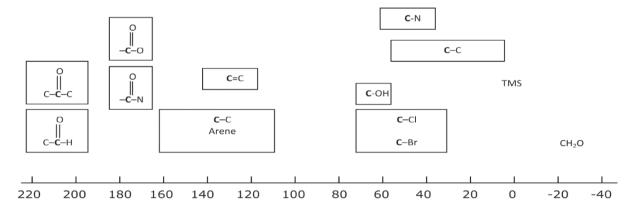
Correlation of infrared absorption wavenumbers with molecular structure

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

¹H nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)



¹³C nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)



Pauling electronegativities

Pauling electronegativity index

| | | | | | | | Н | | | | | | | | | | Не |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| | | | | | | | 2.1 | | | | | | | | | | |
| Li | Be | | | | | | | | | | | В | C | Ν | 0 | F | Ne |
| 1.0 | 1.5 | | | | | | | | | | | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | |
| Na | Mg | | | | | | | | | | | Αl | Si | Р | 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 | Υ | Zr | Nb | Мо | 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 | Τl | 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 <i>K</i> in (at 298 K) | acid | pH range | alkaline |
|------------------------|--------------------------------------------------------------------------------------------|---------------------------------|----------------------------------------------|------------------------------------------------------|-------------------------------------------|
| 1 2 3 4 5 | Thymol blue (acid) Screened methyl orange Methyl orange Bromophenol blue Bromocresol green | 1.7 3.7 3.7 4.0 4.7 | red purple red yellow yellow | 1.2-2.8 3.2-4.2 3.2-4.4 2.8-4.6 3.8-5.4 | yellow green yellow blue blue |
| 6 7 8 9 10 | Methyl red Litmus Bromothymol blue Phenol red Phenolphthalein (in ethanol) | 5.1 7.0 7.9 9.3 | red red yellow yellow colourless | 4.2-6.3 5.0-8.0 6.0-7.6 6.8-8.4 8.2-10.0 | yellow blue blue red red |

Standard electrode potentials

E 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 [⊕] /V |
|----|--------------------------------------------------------------------|-------------------|
| 1 | Na ⁺ + e ⁻ ⇌ Na | -2.71 |
| 2 | $Mg^{2+} + 2e^{-} \rightleftharpoons Mg$ | -2.37 |
| 3 | $AI^{3+} + 3e^- \rightleftharpoons AI$ | -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 | $H^+ + e^- \rightleftharpoons \frac{1}{2}H_2$ | 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 ⁻ ⇌ Cu | +0.34 |
| 15 | $VO^{2+} + 2H^{+} + e^{-} \rightleftharpoons V^{3+} + H_{2}O$ | +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 ⁻ ⇌ 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 | $CIO^- + H_2O + 2e^- \rightleftharpoons CI^- + 2OH^-$ | +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

| | | | | | | | | | | | | | | | | | | _ | | | | | | |
|-------|----------------------------------|----------------------|---------------|--------------------------------|------|-----|------------------|------|----|-----------------|-------|----|-----------------------|----|-------|----------|-----------------|-------|---------------------------------------------------------|-----------------------------|---|-------|---------------------|------------------------------------------------------------------------------------------|
| 0 (8) | 4.0 He helium | 20.2 | Re | neon 10 | 39.9 | Ar | argon 18 | 83.8 | 추 | krypton 36 | 131.3 | Xe | xenon | 74 | [222] | 唇 | radon 86 | | ted | | | | | |
| 7 | Ę | 19.0 | ட | fluorine 9 | 35.5 | ರ | chlorine 17 | 79.9 | 늄 | bromine 35 | 126.9 | П | iodine | 3 | [210] | ¥ | astatine 85 | | een repor | | | 175 | 3 | lutetium |
| 9 | (7) | 16.0 | 0 | oxygen 8 | 32.1 | S | sulfur 16 | 79.0 | Š | selenium 34 | 127.6 | Þ | tellurium | 7C | [509] | 8 | polonium 84 | | 116 have b | iticated | | 173 | ዿ | ytterbium lutetium |
| 2 | (35) | 14.0 | z | nitrogen 7 | 31.0 | _ | phosphorus 15 | 74.9 | As | arsenic 33 | 121.8 | S | antimony E4 | 5 | 209.0 | 运 | bismuth 83 | | nbers 112- | but not fully authenticated | | 169 | Ē | thulium |
| 4 | Ş | 12.0 | ပ | carbon 6 | 28.1 | Si | silicon 14 | 72.6 | હ | germanium 32 | 118.7 | Sn | i Ei | 2 | 207.2 | ይ | lead 82 | | Elements with atomic numbers 112-116 have been reported | but not f | | 167 | ㅁ | erbium |
| ю | 43 | 10.8 | B | boron 5 | 27.0 | ¥ | aluminium 13 | 2.69 | ල | gallium 31 | 114.8 | П | mulpui | 44 | 204.4 | F | thallium 81 | | nents with | | | 165 | 운 | holmium |
| | | | | | | | (12) | 65.4 | Zu | zinc 30 | 112.4 | 8 | cadmium | 40 | 200.6 | 훗 | mercury 80 | | Elen | | | 163 | δ | prascodmium neodymium promethium samarium europium gadolinium terbium dysprosium holmium |
| | | | | | | | (11) | 63.5 | 3 | copper 29 | 107.9 | Ag | silver | 4/ | 197.0 | Ρſ | gold 79 | [272] | æ | roentgenium 111 | | 159 | ൧ | terbium |
| | | | (10) | | | | | | | nickel 28 | 106.4 | Ь | palladium | 40 | 195.1 | 폾 | platinum 78 | [271] | മ് | damstadtium 110 | | 157 | B | gadolinium |
| | | | | | | | (6) | 58.9 | ප | cobalt 27 | 102.9 | 듄 | rhodium | 40 | 192.2 | <u>,</u> | iridium 77 | [568] | ₩ | meitnerium 109 | | 152 | 品 | europium |
| | 1.0 H hydrogen 1 | | | | | (8) | | | 굡 | iron 26 | 101.1 | æ | 2 | 44 | 190.2 | õ | osmium 76 | [277] | Ұ | hassium 108 | 2 | 150 | Sm | samarium |
| | | | | | | | (7) | 54.9 | W | manganese 75 | [86] | ည | molybdenum technetium | 43 | 186.2 | Re | rhenium 75 | [264] | 뮵 | bohrium 107 | | [147] | Pm | promethium |
| | | mass | l la | number |] | | (9) | 52.0 | ъ | chromium 24 | 95.9 | Wo | molybdenum | 74 | 183.8 | ≥ | tungsten 74 | [596] | Şg | n seaborgium bo | | 144 | PR | neodymium |
| | Kov | relative atomic mass | atomic symbol | name atomic (proton) number | | | (2) | 50.9 | > | vanadium 23 | 92.9 | ą | niobium | 4 | 180.9 | Тa | tantalum 73 | [292] | | dubnium 105 | | 141 | P | praseodymium |
| | | relat | ato | atomic | | | (4) | 47.9 | j۳ | titanium 22 | | | zir | 4 | _ | | hafnium 72 | [261] | ∡ | nutherfordium 104 | Ш | 140 | e e | cerium |
| | | _ | | | | | (3) | 45.0 | ß | scandium 71 | 88.9 | > | yttrium | ۶۶ | 138.9 | Ľa* | lanthanum 57 | [227] | ¥¢ | actinium 89 | | | es | |
| 7 | ć | 9.0 | Be | beryllium 4 | 24.3 | W S | magnesium 12 | 40.1 | ౮ | calcium 20 | 87.6 | Sr | strontium | န | 137.3 | Ba | barium 56 | [326] | æ | radium 88 | | | * Lanthanide series | * Actinide series |
| - | ξ | 6.9 | == | lithium 3 | 23.0 | R | sodium 11 | 39.1 | ¥ | potassium 19 | 85.5 | & | rubidium 37 | તે | 132.9 | ర | caesium 55 | [223] | Ŀ | francium 87 | | | * Lanti | * Actin |
| | | | | | | | | | | | | | | | | | | | | | | | | |

^{*} Lanthanide series

Er erbium 68

4

Pa 6

4 29

62

8

23

berkelium

^{*} Actinide series