Neap

Trial Examination 2022

Question and Response Booklet

QCE Chemistry Units 3&4

Paper 2

Student's Name: _____

Teacher's Name: _____

Time allowed

- Perusal time – 10 minutes
- Working time – 90 minutes

General instructions

- Answer all questions in this question and response booklet.
- Write using black or blue pen.
- QCAA-approved calculator permitted.
- Formula and data booklet provided.
- Planning paper will not be marked.

Section 1 (65 marks)

- 8 short response questions

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2022 QCE Chemistry Units 3&4 Written Examination.

SECTION 1

Instructions

- If you need more space for a response, use the additional pages at the back of this booklet.
  - On the additional pages, write the question number you are responding to.
  - Cancel any incorrect response by ruling a single diagonal line through your work.
  - Write the page number of your alternative/additional response, i.e. See page …
  - If you do not do this, your original response will be marked.

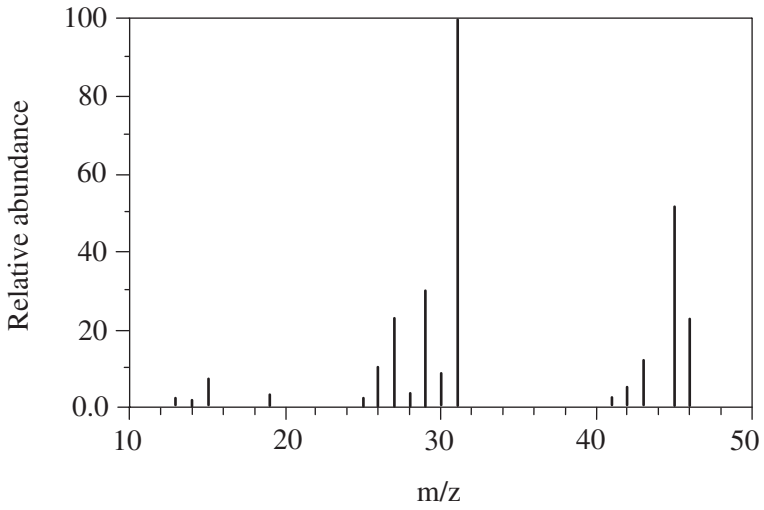
DO NOT WRITE ON THIS PAGE

THIS PAGE WILL NOT BE MARKED

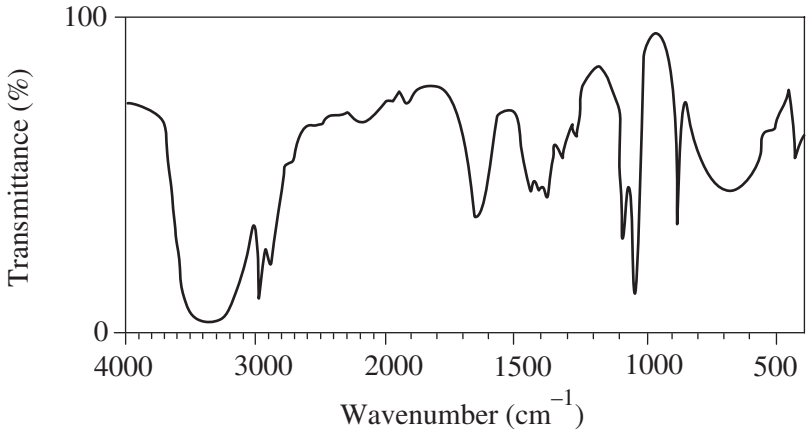
QUESTION 1 (8 marks)

The mass and infrared spectra for an alcohol are shown.

Mass spectrum

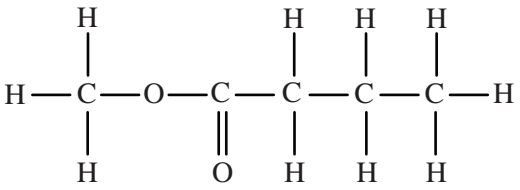


Infrared spectrum



a) Analyse both spectra to deduce the structural formula of the alcohol. Explain your reasoning. *[6 marks]*

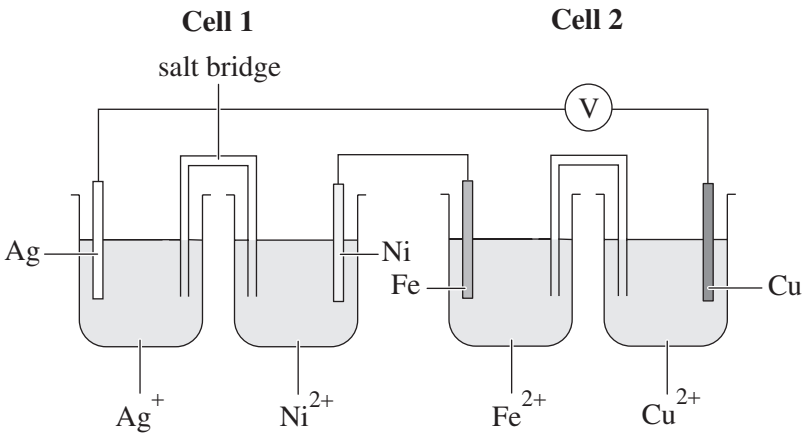
b) The diagram shows an ester that was synthesised.



Determine whether the alcohol deduced in 1a) was or was not used to synthesise the ester. Explain your reasoning. *[2 marks]*

QUESTION 2 (8 marks)

The diagram shows two electrochemical cells. The concentrations of Ag^+, Ni^{2+}, Fe^{2+} and Cu^{2+} are all 1 M.



a) Refer to the standard electrode potentials to deduce the direction of flow of electrons between the cells. Explain your reasoning. *[6 marks]*

b) Calculate the overall emf of the cells. Show your working. *[2 marks]*

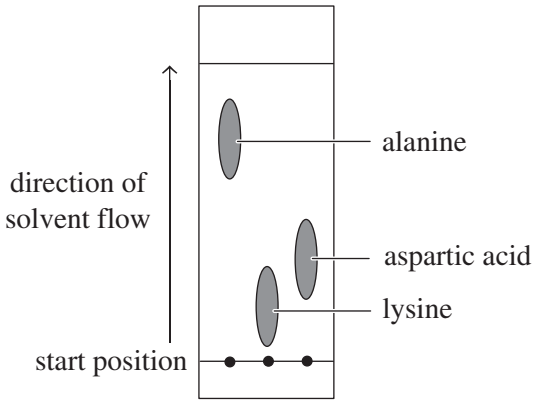
emf = _____ V

QUESTION 3 (8 marks)

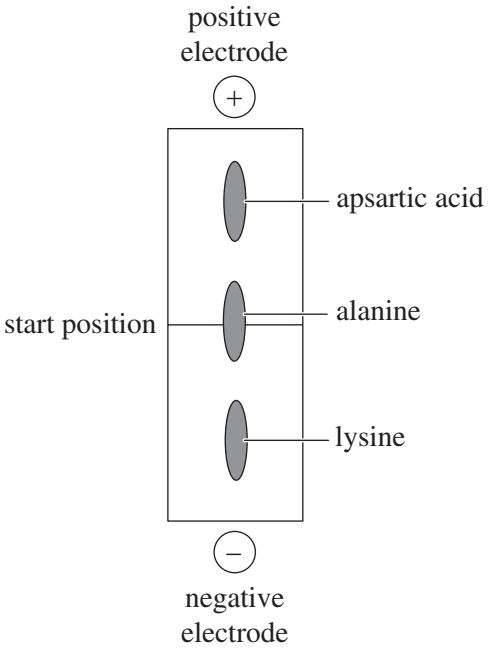
A scientist wished to separate the amino acids alanine, aspartic acid and lysine.

The diagrams show a paper chromatogram of a mixture of the amino acids and the result of an electrophoresis experiment using the same mixture in a buffer with a pH of 6.1.

Paper chromatogram



Electrophoresis



a) In the paper chromatogram, alanine is separated from the other amino acids by a large distance and there is poor separation between lysine and aspartic acid.

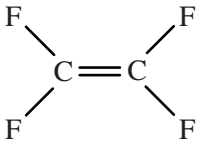
Explain why this occurs. *[3 marks]*

b) Explain why there is good separation between lysine and aspartic acid in the electrophoresis experiment. Include diagrams in your response. *[3 marks]*

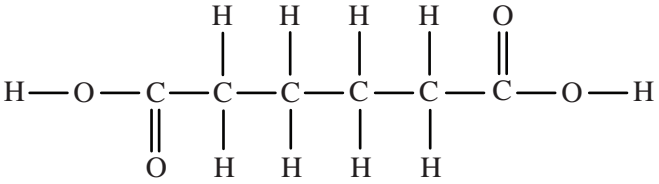
c) Explain why alanine hardly moved in the electrophoresis experiment. Include a diagram in your response. *[2 marks]*

QUESTION 4 (9 marks)

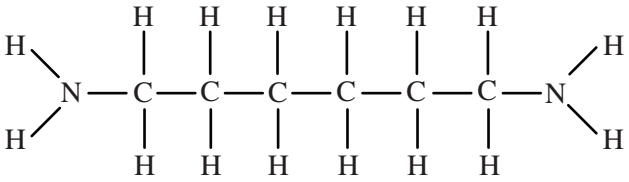
Polymers are usually formed by joining smaller units (monomers) together. Three monomers are shown.



tetrafluoroethylene



adipic acid



hexamethylene diamine

a) Draw and name the polymer formed by joining many tetrafluoroethylene units together. *[2 marks]*

IUPAC name _____

When adipic acid and hexamethylene diamine are joined, they form the polymer nylon 6,6.

b) Draw the polymer formed by joining many adipic acid and hexamethylene diamine units together. *[1 mark]*

c) Complete the table below to compare the polymers from 4a) and 4b). *[4 marks]*

Monomer(s)	Type of reaction to form polymer	Does the polymer formed have alternating units?
tetrafluoroethylene		
adipic acid and hexamethylene diamine		

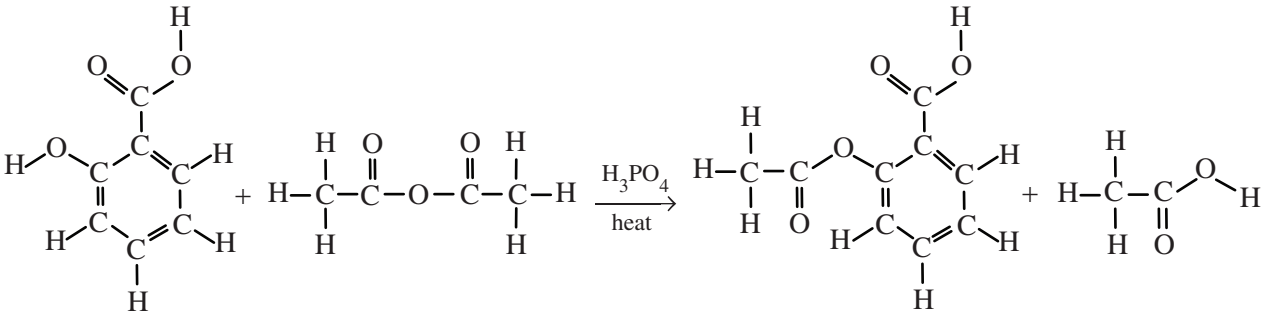
d) i) What does '6,6' in the name nylon 6,6 indicate? *[1 mark]*

ii) Propose why nylon 6,6 forms strong fibres. Refer to intermolecular forces in your response. *[1 mark]*

QUESTION 5 (7 marks)

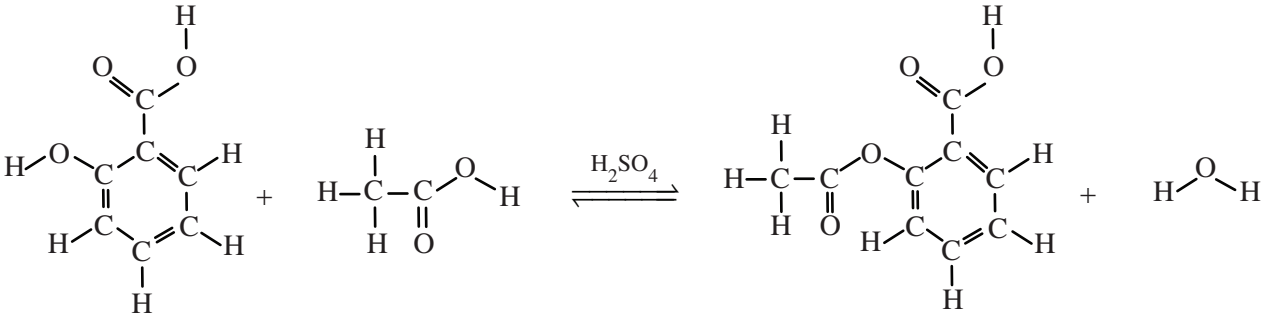
Aspirin (acetylsalicylic acid, $C_9H_8O_4$) can be prepared through two different reactions. The reactions are shown.

Reaction 1



salicylic acid	ethanoic anhydride	acetylsalicylic acid	ethanoic acid
$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
$M = 138.13$	$M = 102.1$	$M = 180.17$	$M = 60.06$

Reaction 2



salicylic acid	ethanoic acid	acetylsalicylic acid	water
$C_7H_6O_3$	$C_2H_4O_2$	$C_9H_8O_4$	H_2O
$M = 138.13$	$M = 60.06$	$M = 180.17$	$M = 18.02$

a) A researcher wants to use 100 g of salicylic acid to produce aspirin. He is trying to decide which reaction is better to use. He has 50 g each of ethanoic anhydride and ethanoic acid.

Calculate the mass of aspirin that each reaction would produce and state the limiting reagent for each reaction. Show your working. *[6 marks]*

mass of aspirin produced by reaction 1 = _____ g (to two decimal places)

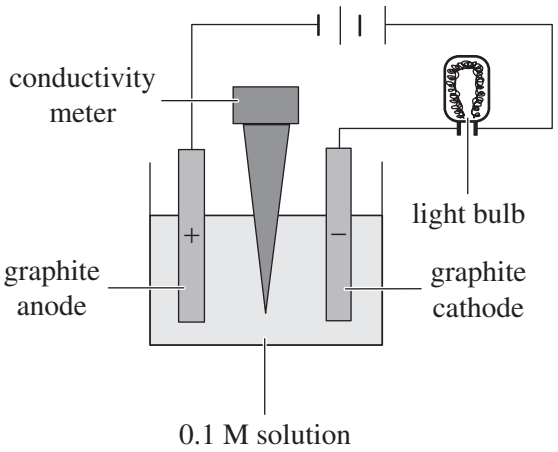
mass of aspirin produced by reaction 2 = _____ g (to two decimal places)

b) Reaction 1 is usually used to produce aspirin despite having a lower atom economy than reaction 2.

Identify why this is. *[1 mark]*

QUESTION 6 (11 marks)

The diagram shows an experiment set-up that was used to investigate the relative strengths of acids and bases in aqueous solution. The power supply was connected to two graphite electrodes.



The brightness of the light bulb and relative electrical conductance for each solution are recorded in the table.

Solution (0.1 M)	Light bulb brightness	Relative electrical conductance	pK_a	pK_b
ethanoic acid (CH_3COOH)	dim	4.2	4.74	–
hydrochloric acid (HCl)	very bright	11.7	–5.90	–
nitric acid (HNO_3)	bright	6.8	–1.37	–
sulfuric acid (H_2SO_4)	bright	8.8	–2.00	–
hydroiodic acid (HI)			–9.30	–
sodium hydroxide (NaOH)	very bright	10.6	–	–0.56
methylamine (CH_3NH_2)		3.1	–	3.34
ammonia (NH_3)		4.2	–	4.75

a) Complete the table above by indicating the brightness of the bulbs and estimating the relative electrical conductance of HI. *[4 marks]*

b) i) Identify which acid has the lowest pH. Explain your reasoning. *[2 marks]*

ii) Determine the strongest base in terms of degree of ionisation at equilibrium in aqueous solution. Explain your reasoning. *[2 marks]*

c) Describe the relationship between the concentration of hydrogen ions (H^+), electrical conductivity and light bulb brightness. *[1 mark]*

d) An unknown solution, which was thought to be an acid, was tested. The relative electrical conductance of the solution was recorded as 5.2.

Deduce the nature of the acid. Explain your reasoning. *[2 marks]*

QUESTION 7 (7 marks)

a) The dissociation constant, K_a, of hypochlorous acid (HOCl) is 3.0×10^{-8}. The conjugate base of HOCl is the hypochlorite ion (OCl^-).

Show that the dissociation constant, K_b, of OCl^- is 3.3×10^{-7}. Assume that the temperature is 25°C. *[2 marks]*

b) The K_b of OCl^- as stated in 7a) is the equilibrium constant (K_c) for the following equation.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

Calculate the pH of a 0.20 M solution of HOCl. Assume that the temperature is 25°C.
Show your working and state any assumptions made. *[5 marks]*

pH = _____ (to two decimal places)

QUESTION 8 (7 marks)

Fehling's solution is a deep blue alkaline solution containing a complex of the Cu^{2+} ion. It can be used as a test to detect the presence of glucose in urine, differentiating between the presence of aldehydes and ketones in carbohydrates according to the following equation.

$$RCHO(aq) + 2Cu^{2+}(aq) + 5OH^{-} \rightarrow RCOO^{-}(aq) + Cu_2O(s) + 3H_2O(l)$$

When a reducing sugar is present, the reaction produces a brick-red coloured precipitate of the Cu^{+}(I) oxide.

The following experiment was set up to test four solutions. Fehling's solution was added to each solution and the solutions were then heated. The observations are recorded in the table.

Solution tested	Observation
glucose	The solution darkened slightly, changing to a brown colour.
sucrose	The solution remained blue.
sucrose and citric acid	The solution changed to a very dark blue with a precipitate starting to form.
starch	The solution remained blue.

a) i) State why the glucose solution reacted with Fehling's solution. *[1 mark]*

ii) State why the sucrose solution did not react with Fehling's solution. *[1 mark]*

iii) State why the starch solution did not react with Fehling's solution. *[1 mark]*

b) Explain why glucose is sometimes referred to as a reducing sugar. In your response, refer to the reaction between the glucose solution and Fehling's solution. *[2 marks]*

c) If the sucrose solution had been hydrolysed before the Fehling's solution was added to it, predict whether a change would have been observed. *[1 mark]*

d) Infer why a change was observed in the reaction that used the sucrose and citric acid solution. *[1 mark}*

END OF PAPER

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

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Write the question number you are responding to.

Neap

Trial Examination 2022

Formula and Data Booklet

QCE Chemistry Units 3&4

FORMULAS

Processing of data
Absolute uncertainty of the mean $\Delta\overline{x} = \pm\dfrac{\left(x_{\max} - x_{\min}\right)}{2}$
Percentage uncertainty (%) $= \dfrac{\text{absolute uncertainty}}{\text{measurement}} \times \dfrac{100}{1}$
Percentrage error (%) $= \left\lvert\dfrac{\text{measured value} - \text{true value}}{\text{true value}}\right\rvert \times 100$

Chemical reactions – reactants, products and energy change
$\Delta H = H_{(\text{products})} - H_{(\text{reactants})}$
$\Delta H = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$
$Q = mc\Delta T$
Percentage yield (%) $= \dfrac{\text{experimental yield}}{\text{theoretical yield}} \times \dfrac{100}{1}$

Aqueous solutions and acidity
Molarity $= \dfrac{\text{moles of solute } (n)}{\text{volume of solution } (V)}$

Chemical equilibrium systems
$K_c = \dfrac{[C]^c}{[A]^a}\dfrac{[D]^d}{[B]^b}$ for the reaction: aA + bB $\rightleftharpoons$ cC + dD
$K_w = [H^+][OH^-]$
$pH = -\log_{10}[H^+]$
$pOH = -\log_{10}[OH^-]$
$K_w = K_a \times K_b$
$K_a = \dfrac{[H_3O^+][A^-]}{[HA]}$
$K_b = \dfrac{[BH^+][OH^-]}{[B]}$

PHYSICAL CONSTANTS AND UNIT CONVERSIONS

Physical constants and unit conversions	
Absolute zero	$0\ \text{K} = -273°\text{C}$
Atomic mass unit	$1\ \text{amu} = 1.66 \times 10^{-27}\ \text{kg}$
Avogadro's constant	$N_\text{A} = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Ideal gas constant	$R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Ionic product constant for water (at 298 K)	$K_\text{w} = 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$
Molar volume of an ideal gas (at STP)	$2.27 \times 10^{-2}\ \text{m}^3\ \text{mol}^{-1} = 22.7\ \text{dm}^3\ \text{mol}^{-1}$
Specific heat capacity of water (at 298 K)	$c_\text{w} = 4.18\ \text{J g}^{-1}\ \text{K}^{-1}$
Standard temperature and pressure (STP)	273 K and 100 kPa
Volume and capacity conversions	$1\ \text{dm}^3 = 1 \times 10^{-3}\ \text{m}^3 = 1 \times 10^3\ \text{cm}^3 = 1\ \text{L}$

LIST OF ELEMENTS

Name	Atomic no.	Symbol
Hydrogen	1	H
Helium	2	He
Lithium	3	Li
Beryllium	4	Be
Boron	5	B
Carbon	6	C
Nitrogen	7	N
Oxygen	8	O
Fluorine	9	F
Neon	10	Ne
Sodium	11	Na
Magnesium	12	Mg
Aluminium	13	Al
Silicon	14	Si
Phosphorus	15	P
Sulfur	16	S
Chlorine	17	Cl
Argon	18	Ar
Potassium	19	K
Calcium	20	Ca
Scandium	21	Sc
Titanium	22	Ti
Vanadium	23	V
Chromium	24	Cr
Manganese	25	Mn
Iron	26	Fe
Cobalt	27	Co
Nickel	28	Ni
Copper	29	Cu
Zinc	30	Zn
Gallium	31	Ga
Germanium	32	Ge
Arsenic	33	As
Selenium	34	Se
Bromine	35	Br

Name	Atomic no.	Symbol
Krypton	36	Kr
Rubidium	37	Rb
Strontium	38	Sr
Yttrium	39	Y
Zirconium	40	Zr
Niobium	41	Nb
Molybdenum	42	Mo
Technetium	43	Tc
Ruthenium	44	Ru
Rhodium	45	Rh
Palladium	46	Pd
Silver	47	Ag
Cadmium	48	Cd
Indium	49	In
Tin	50	Sn
Antimony	51	Sb
Tellerium	52	Te
Iodine	53	I
Xenon	54	Xe
Cesium	55	Cs
Barium	56	Ba
Lanthanum	57	La
Cerium	58	Ce
Praseodymium	59	Pr
Neodymium	60	Nd
Promethium	61	Pm
Samarium	62	Sm
Europium	63	Eu
Gadolinium	64	Gd
Terbium	65	Tb
Dysprosium	66	Dy
Holmium	67	Ho
Erbium	68	Er
Thulium	69	Tm
Ytterbium	70	Yb

LIST OF ELEMENTS (CONTINUED)

Name	Atomic no.	Symbol
Lutetium	71	Lu
Hafnium	72	Hf
Tantalum	73	Ta
Tungsten	74	W
Rhenium	75	Re
Osmium	76	Os
Iridium	77	Ir
Platinum	78	Pt
Gold	79	Au
Mercury	80	Hg
Thallium	81	Tl
Lead	82	Pb
Bismuth	83	Bi
Polonium	84	Po
Astatine	85	At
Radon	86	Rn
Francium	87	Fr
Radium	88	Ra
Actinium	89	Ac
Thorium	90	Th
Protactinium	91	Pa
Uranium	92	U
Neptunium	93	Np
Plutonium	94	Pu

Name	Atomic no.	Symbol
Americium	95	Am
Curium	96	Cm
Berkelium	97	Bk
Californium	98	Cf
Einsteinium	99	Es
Fermium	100	Fm
Mendelevium	101	Md
Nobelium	102	No
Lawrencium	103	Lr
Rutherfordium	104	Rf
Dubnium	105	Db
Seaborgium	106	Sg
Bohrium	107	Bh
Hassium	108	Hs
Meitnerium	109	Mt
Darmstadtium	110	Ds
Roentgenium	111	Rg
Copernicium	112	Cn
Nihonium	113	Nh
Flerovium	114	Fl
Moscovium	115	Mc
Livermorium	116	Lv
Tennessine	117	Ts
Oganesson	118	Og

PERIODIC TABLE OF THE ELEMENTS

KEY

1 H 1.01 — atomic number; symbol; relative atomic mass*

1																	18
1 H 1.01	2											13	14	15	16	17	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (98.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57–71 Lanthanoids	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (210.0)	85 At (210.0)	86 Rn (222.0)
87 Fr (223.0)	88 Ra (226.1)	89–103 Actinoids	104 Rf (261.1)	105 Db (262.1)	106 Sg (263.1)	107 Bh (264.1)	108 Hs (265.1)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (293)	117 Ts (294)	118 Og (294)

Lanthanoids

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (146.9)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97

Actinoids

89 Ac (227.0)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237.0)	94 Pu (239.1)	95 Am (241.1)	96 Cm (244.1)	97 Bk (249.1)	98 Cf (252.1)	99 Es (252.1)	100 Fm (252.1)	101 Md (258.1)	102 No (259.1)	103 Lr (262.1)

Groups are numbered according to IUPAC convention 1–18.

*Values in brackets are for the isotope with the longest half-life.

ATOMIC AND IONIC RADII OF SELECTED ELEMENTS

KEY

Li 3
130
76 (1+)

atomic number
symbol
atomic radius (10^{-12} m)
charge of ion

ionic radius (10^{-12} m)

1																	18
H 1 32 208 (1–)	2											13	14	15	16	17	**He** 2 37
Li 3 130 76 (1+)	**Be** 4 99 45 (2+)											**B** 5 84 27 (3+)	**C** 6 75 16 (4+)	**N** 7 71 146 (3–)	**O** 8 64 140 (2–)	**F** 9 60 133 (1–)	**Ne** 10 62
Na 11 160 102 (1+)	**Mg** 12 140 72 (2+)	3	4	5	6	7	8	9	10	11	12	**Al** 13 124 53 (3+)	**Si** 14 114 40 (4+)	**P** 15 109 38 (5+)	**S** 16 104 184 (2–)	**Cl** 17 100 181 (1–)	**Ar** 18 101
K 19 200 138 (1+)	**Ca** 20 174 100 (2+)	**Sc** 21 159 75 (3+)	**Ti** 22 148 86 (2+) 61 (4+)	**V** 23 144 79 (2+) 54 (5+)	**Cr** 24 130 62 (3+) 44 (6+)	**Mn** 25 129 83 (2+) 64 (3+)	**Fe** 26 124 78 (2+) 64 (3+)	**Co** 27 118 74 (2+) 61 (3+)	**Ni** 28 117 69 (2+) 60 (3+)	**Cu** 29 122 77 (1+) 73 (2+)	**Zn** 30 120 74 (2+)	**Ga** 31 123 62 (3+)	**Ge** 32 120 53 (4+) 272 (4–)	**As** 33 120 58 (3+) 46 (5+)	**Se** 34 118 198 (2–)	**Br** 35 117 196 (1–)	**Kr** 36 116
Rb 37 215 152 (1+)	**Sr** 38 190 118 (2+)	**Y** 39 176 90 (3+)	**Zr** 40 164 72 (4+)	**Nb** 41 156 64 (5+)	**Mo** 42 148 65 (4+)	**Tc** 43 138 65 (4+)	**Ru** 44 136 62 (4+)	**Rh** 45 134 67 (3+)	**Pd** 46 130 86 (2+)	**Ag** 47 136 115 (1+)	**Cd** 48 140 95 (2+)	**In** 49 142 80 (3+)	**Sn** 50 140 69 (4+)	**Sb** 51 140 76 (3+)	**Te** 52 137 221 (2–)	**I** 53 136 220 (1–)	**Xe** 54 136
Cs 55 238 167 (1+)	**Ba** 56 206 135 (2+)																

Groups are numbered according to IUPAC convention 1–18.

ELECTRONEGATIVITIES AND FIRST IONISATION ENERGIES OF SELECTED ELEMENTS

KEY

H 1 2.2 1318	atomic number symbol electronegativity first ionisation enthalpies (kJ mol^{-1})

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1 2.2 1318																	He 2 2379
Li 3 1.0 526	Be 4 1.6 906											B 5 2.0 807	C 6 2.6 1093	N 7 3.0 1407	O 8 3.4 1320	F 9 4.0 1687	Ne 10 2087
Na 11 0.9 502	Mg 12 1.3 744											Al 13 1.6 584	Si 14 1.9 793	P 15 2.2 1018	S 16 2.6 1006	Cl 17 3.2 1257	Ar 18 1527
K 19 0.8 425	Ca 20 1.0 596	Sc 21 1.4 637	Ti 22 1.5 664	V 23 1.6 656	Cr 24 1.7 659	Mn 25 1.6 724	Fe 26 1.8 766	Co 27 1.9 765	Ni 28 1.9 743	Cu 29 1.9 752	Zn 30 1.7 913	Ga 31 1.8 585	Ge 32 2.0 768	As 33 2.2 953	Se 34 2.6 947	Br 35 3.0 1146	Kr 36 2.9 1357
Rb 37 0.8 409	Sr 38 1.0 556	Y 39 1.2 606	Zr 40 1.3 666	Nb 41 1.6 670	Mo 42 2.2 691	Tc 43 1.9 708	Ru 44 2.2 717	Rh 45 2.3 726	Pd 46 2.2 811	Ag 47 1.9 737	Cd 48 1.7 874	In 49 1.8 565	Sn 50 2.0 715	Sb 51 2.1 840	Te 52 2.1 876	I 53 2.7 1015	Xe 54 2.6 1177
Cs 55 0.8 382	Ba 56 0.9 509																

Groups are numbered according to IUPAC convention 1–18.

SOLUBILITY OF SELECTED COMPOUNDS AT 298 K

	bromide	carbonate	chloride	hydroxide	iodide	nitrate	oxide	phosphate	sulfate
aluminium	s	–	s	i	s	s	i	i	s
ammonium	s	s	s	s	s	s	–	s	s
barium	s	i	s	s	s	s	s	i	i
calcium	s	i	s	p	s	s	p	i	p
cobalt(II)	s	i	s	i	s	s	i	i	s
copper(II)	s	–	s	i	i	s	i	i	s
iron(II)	s	i	s	i	s	s	i	i	s
iron(III)	s	–	s	i	s	s	i	i	s
lead(II)	p	i	s	i	i	s	i	i	i
lithium	s	s	s	s	s	s	s	–	s
magnesium	s	i	s	i	s	s	i	p	s
manganese(II)	s	i	s	i	s	s	i	p	s
potassium	s	s	s	s	s	s	s	s	s
silver	i	i	i	i	i	s	i	i	p
sodium	s	s	s	s	s	s	s	s	s
zinc	s	i	s	i	s	s	i	i	s

Key

Abbreviation	Explanation
s	soluble in water (solubility greater than 10 g L^{-1})
p	partially soluble in water (solubility between 1 and 10 g L^{-1})
i	insoluble in water (solubility less than 1 g L^{-1})
–	no data

AVERAGE BOND ENTHALPIES AT 298 K

Single bonds

	ΔH (kJ mol^{-1})								
	H	**C**	**N**	**O**	**F**	**S**	**Cl**	**Br**	**I**
H	436								
C	414	346							
N	391	286	158						
O	463	358	214	144					
F	567	492	278	191	159				
S	364	289			327	266			
Cl	431	324	192	206	255	271	242		
Br	366	285		201	249	218	219	193	
I	298	228		201	280		211	178	151

Multiple bonds

Bond	ΔH (kJ mol^{-1})
C=C	614
C≡C	839
C=N	615
C≡N	890
C=O	804
N=N	470
N≡N	945
O=O	498

REACTIVITY SERIES OF METALS

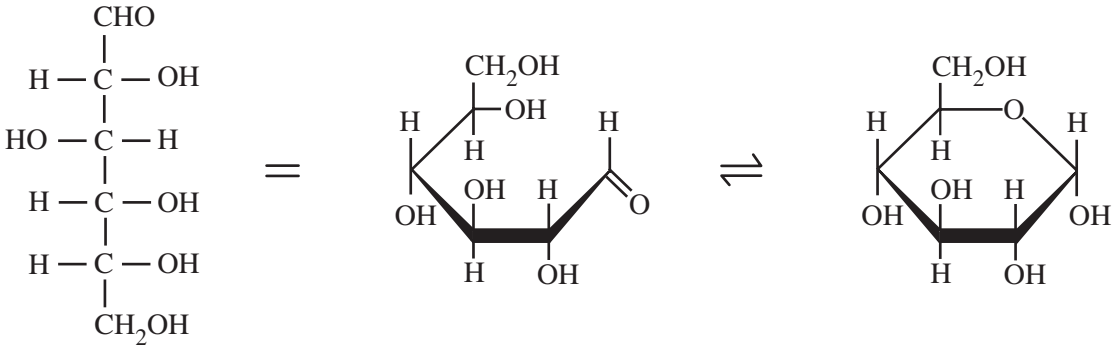
Element	Reactivity
K	most reactive ↑
Na	
Li	
Ba	
Sr	
Ca	
Mg	
Al	
C*	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	
Ni	
Sn	
Pb	
H_2*	
Sb	
Bi	
Cu	
Hg	
Ag	
Au	
Pt	least reactive

* Carbon (C) and hydrogen gas (H_2) added for comparison

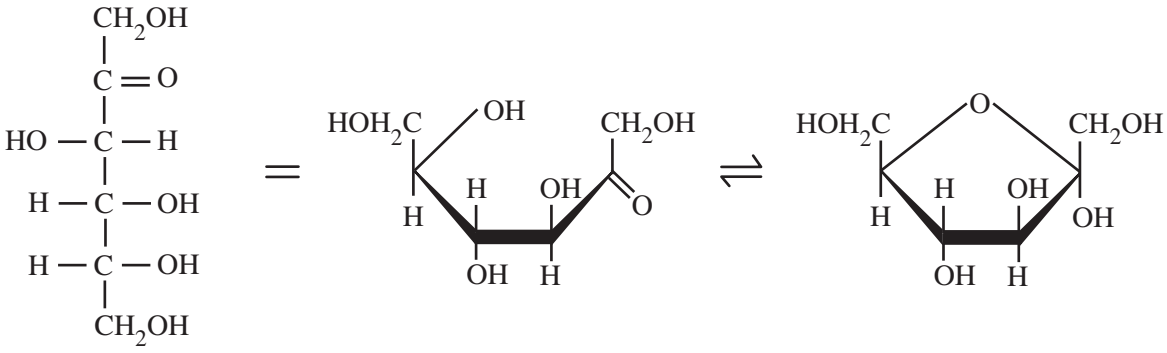
STANDARD ELECTRODE POTENTIALS AT 298 K

Oxidised species ⇌ Reduced species	E° (V)
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.04
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.94
$Ba^{2+}(aq) + 2e^- \rightleftharpoons Ba(s)$	–2.91
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.36
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.68
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.18
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.24
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$	+0.16
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons SO_2(aq) + 2H_2O(l)$	+0.16
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^+(aq) + e^- \rightleftharpoons Cu(s)$	+0.52
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.08
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.89

GLUCOSE AND FRUCTOSE: STRAIGHT CHAIN AND α-RING FORMS

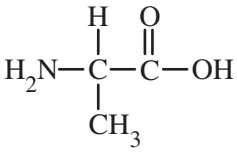
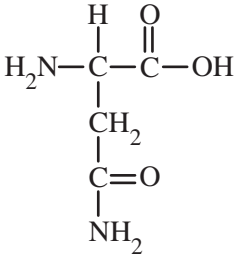
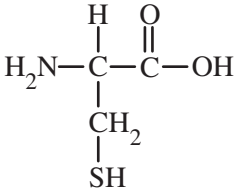
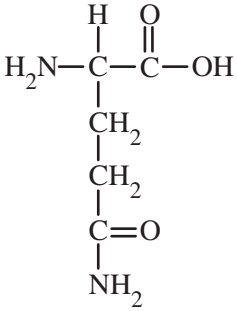


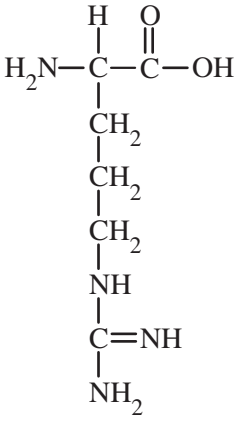
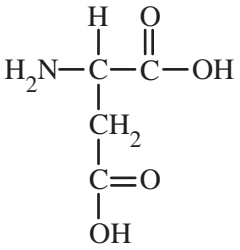
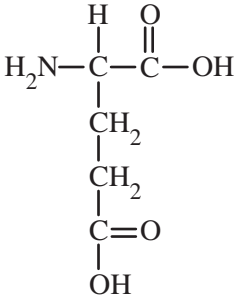
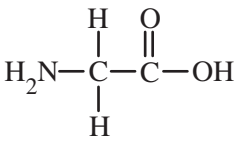
straight chain D-glucose α-D-glucose



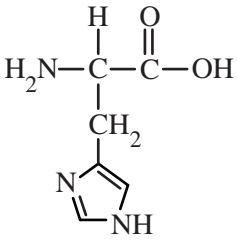
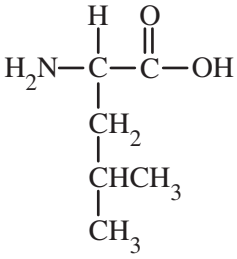
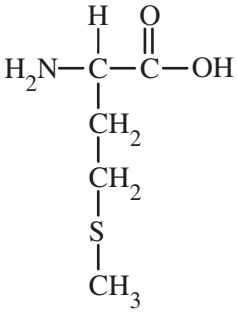
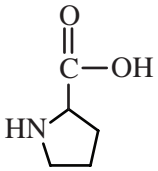
straight chain D-fructose α-D-fructose

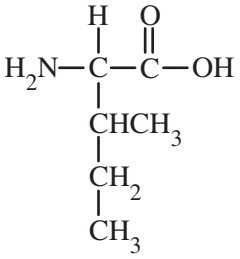
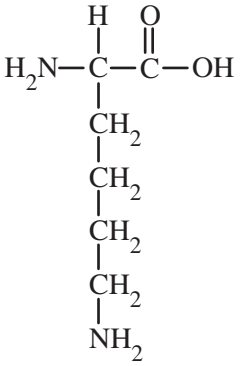
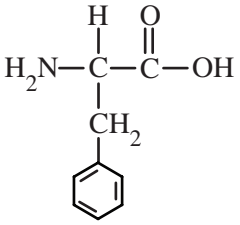
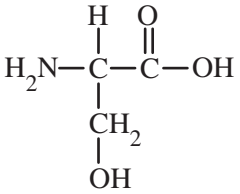
COMMON AMINO ACIDS

Common name (symbol)	Structural formula	pH of isoelectric point
Alanine (Ala)		6.1
Asparagine (Asn)		5.4
Cysteine (Cys)		5.1
Glutamine (Gln)		5.7

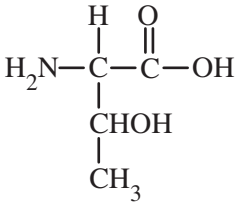
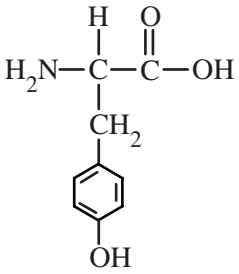
Common name (symbol)	Structural formula	pH of isoelectric point
Arginine (Arg)		10.7
Aspartic acid (Asp)		3.0
Glutamic acid (Glu)		3.2
Glycine (Gly)		6.1

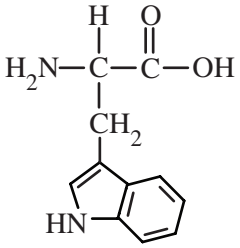
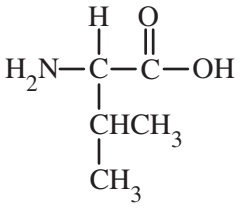
COMMON AMINO ACIDS (continued)

Common name (symbol)	Structural formula	pH of isoelectric point
Histidine (His)		7.6
Leucine (Leu)		6.0
Methionine (Met)		5.7
Proline (Pro)		6.3

Common name (symbol)	Structural formula	pH of isoelectric point
Isoleucine (Ile)		6.0
Lysine (Lys)		9.7
Phenylalanine (Phe)		5.7
Serine (Ser)		5.7

COMMON AMINO ACIDS (continued)

Common name (symbol)	Structural formula	pH of isoelectric point
Threonine (Thr)		5.6
Tyrosine (Tyr)		5.7

Common name (symbol)	Structural formula	pH of isoelectric point
Tryptophan (Trp)		5.9
Valine (Val)		6.0

ACID–BASE INDICATORS

Name	pKa	pH range of colour change	Colour change (acidic to basic)
Methyl orange	3.7	3.1–4.4	red to yellow
Bromophenol blue	4.2	3.0–4.6	yellow to blue
Bromocresol green	4.7	3.8–5.4	yellow to blue
Methyl red	5.1	4.4–6.2	pink to yellow
Bromothymol blue	7.0	6.0–7.6	yellow to blue
Phenol red	7.9	6.8–8.4	yellow to red
Phenolphthalein	9.6	8.3–10.0	colourless to pink

INFRARED DATA

The table below shows the characteristic range of infrared absorption due to stretching in organic molecules.

Bond	Organic molecules	Wavelength (cm^{-1})
C–I	iodoalkanes	490–620
C–Br	bromoalkanes	500–600
C–Cl	chloroalkanes	600–800
C–F	fluoroalkanes	1000–1400
C–O	alcohol, ester	1050–1410
C=C	alkenes	1620–1680
C=O	aldehydes, carboxylic acid, ester, ketones	1700–1750
C≡C	alkynes	2100–2260
O–H	carboxylic acids (hydrogen-bonded)	2500–3000
C–H	alkanes, alkenes, alkynes, aldehydes, amides	2720–3100
O–H	alcohol (hydrogen-bonded)	3200–3600
N–H	amines	3300–3500

FORMULAS AND CHARGES FOR COMMON POLYATOMIC IONS

Anions	
acetate (ethanoate)	CH_3COO^- or $C_2H_3O_2^-$
carbonate	CO_3^{2-}
chlorate	ClO_3^-
chlorite	ClO_2^-
chromate	CrO_4^{2-}
citrate	$C_6H_5O_7^{3-}$
cyanide	CN^-
dichromate	$Cr_2O_7^{2-}$
dihydrogen phosphate	$H_2PO_4^-$
hypochlorite	ClO^-
hydrogen carbonate	HCO_3^-
hydrogen sulfate	HSO_4^-
hydrogen phosphate	HPO_4^{2-}
hydroxide	OH^-
nitrate	NO_3^-
nitrite	NO_2^-
perchlorate	ClO_4^-
permanganate	MnO_4^-
peroxide	O_2^{2-}
phosphate	PO_4^{3-}
sulfate	SO_4^{2-}
sulfite	SO_3^{2-}
thiosulfate	$S_2O_3^{2-}$

Cations	
ammonium	NH_4^+
hydronium	H_3O^+

REFERENCES

Aylward, G and Findlay, T 2008, *SI Chemical Data*, 5th ed, John Wiley & Sons, Brisbane.

Haynes, WM (ed) 2016, *CRC Handbook of Chemistry and Physics*, 97th ed, CRC Press, Boca Raton, US.