Neap

Trial Examination 2020

Question and response booklet

QCE Chemistry Units 3&4

Paper 1

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.
- QCAA-approved calculator permitted.
- QCAA formula and data booklet provided.
- Planning paper will not be marked.

Section 1 (25 marks)

- 25 multiple choice questions

Section 2 (35 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 2020 QCE Chemistry examination.

SECTION 1

Instructions

- Choose the best answer for Questions 1–25.
- This section has 25 questions and is worth 25 marks.
- Use a 2B pencil to fill in the A, B, C or D answer bubble completely.
- If you change your mind or make a mistake, use an eraser to remove your response and fill in the new answer bubble completely.

	A	B	C	D
Example:	●	○	○	○

	A	B	C	D
1.	○	○	○	○
2.	○	○	○	○
3.	○	○	○	○
4.	○	○	○	○
5.	○	○	○	○
6.	○	○	○	○
7.	○	○	○	○
8.	○	○	○	○
9.	○	○	○	○
10.	○	○	○	○
11.	○	○	○	○
12.	○	○	○	○
13.	○	○	○	○
14.	○	○	○	○
15.	○	○	○	○
16.	○	○	○	○
17.	○	○	○	○
18.	○	○	○	○
19.	○	○	○	○
20.	○	○	○	○
21.	○	○	○	○
22.	○	○	○	○
23.	○	○	○	○
24.	○	○	○	○
25.	○	○	○	○

SECTION 2

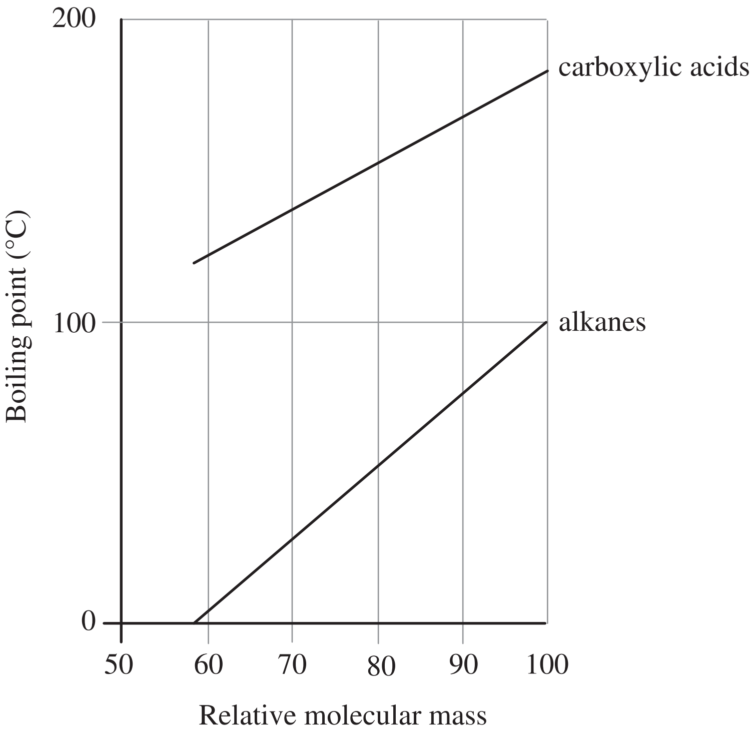
Instructions

- Write using black or blue pen.
- 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.
- This section has eight questions and is worth 35 marks.

DO NOT WRITE ON THIS PAGE
THIS PAGE WILL NOT BE MARKED

QUESTION 26 (3 marks)

The graph below shows the variation in boiling points for two homologous series with relative molecular masses.



In terms of intermolecular forces, explain the trend for both homologous series and account for the lower boiling points of the alkanes.

QUESTION 27 (5 marks)

a) The hydroxide ion (OH^-) concentration in an aqueous solution at 25ºC is 6.25×10^{-4} mol L^{-1}.

Determine the pH of the solution. Show your working. *[2 marks]*

pH = ______________

b) A student repeats titrations of 20.00 mL of 0.1135 M potassium hydroxide (KOH) with sulfuric acid (H_2SO_4) and finds that the average volume required to reach the endpoint is 19.35 mL.

Calculate the concentration of the sulfuric acid. Show your working. *[3 marks]*

Concentration = ______________ M

QUESTION 28 (6 marks)

The percentage of ionisation of three different monoprotic acids of concentration 0.10 M are shown in the table below.

Acid	methanoic	ethanoic	nitric
Percentage of ionisation	4.3	1.3	100

a) The acids are clear liquids that have the same appearance. Two methods are used to try to distinguish between the acids:

- measuring the electrical conductivity of each liquid
- determining the volume of a 0.10 M sodium hydroxide (NaOH) solution needed to neutralise 50 mL of each liquid.

Using chemical principles, explain whether each method would be successful or not. *[4 marks]*

b) Explain which one of the three acids would have the highest pK_a value. *[2 marks]*

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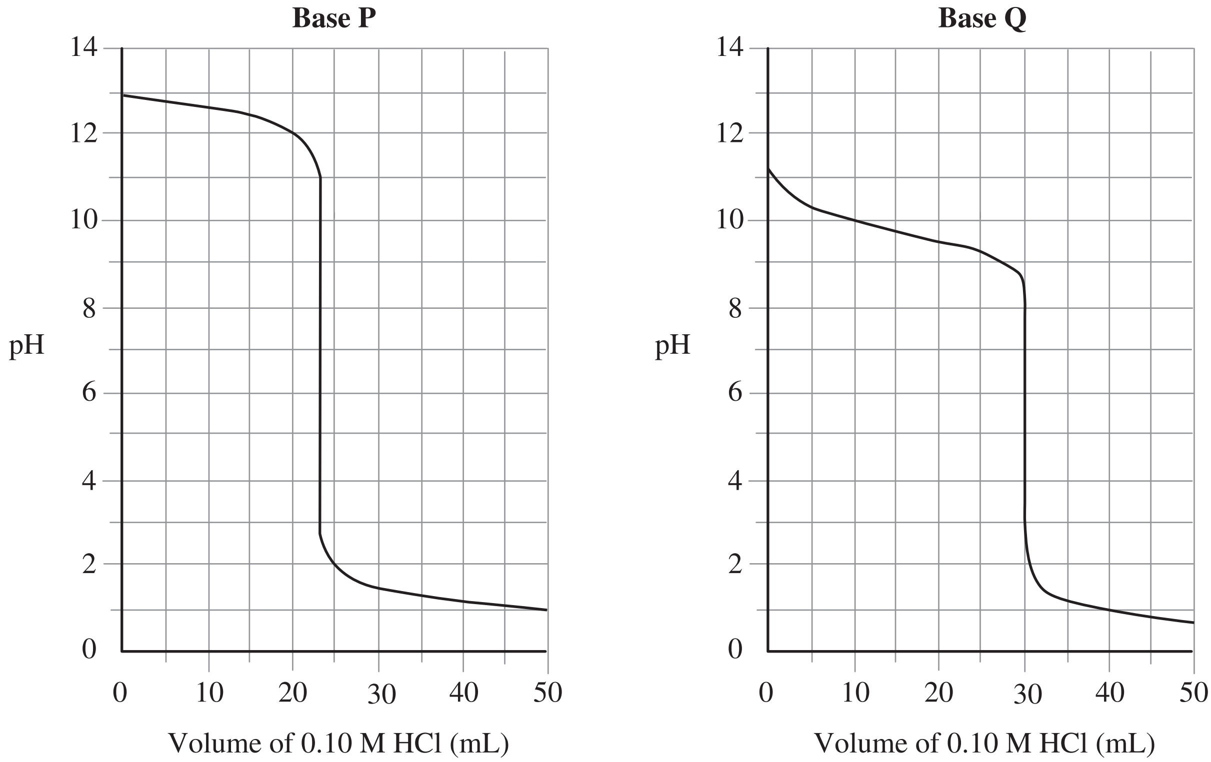
QUESTION 29 (5 marks)

Identical volumes of two bases, P and Q, were titrated with 0.10 M hydrochloric acid (HCl). The titration curves are shown below.



a) Justify two conclusions that can be made about the bases from the results of the titrations. *[4 marks]*

Conclusion 1:____

Conclusion 2:____

b) Name one indicator that could be used for both titrations. *[1 mark]*

QUESTION 30 (4 marks)

Hydrogen gas is used as a fuel and can be synthesised using different methods. One method involves the reaction of methane with steam according to the following equation.

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$$

a) In a laboratory experiment using this method, 12.4 g of methane is used to produce 3.71 g of hydrogen gas. Calculate the percentage yield of this reaction. Show your working. *[2 marks]*

____

____

____

____

____

____

Percentage yield of H_2 = ___________ %

b) Hydrogen gas is used as the energy source in a hydrogen fuel cell. The overall cell reaction is shown by the following equation.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

Write the half-equations for the reactions that occur at the electrodes in a hydrogen fuel cell that uses an acidic electrolyte. Include state symbols. *[2 marks]*

Cathode: ____

Anode: ____

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QUESTION 31 (5 marks)

The chemical reaction of an indicator (represented by HIn) can be shown by the following chemical equation.

$$HIn(aq) + H_2O(l) \rightleftharpoons In^-(aq) + H_3O^+(aq)$$

a) Using information from the equation, write an expression for the acid dissociation constant (K_a) of the indicator. *[1 mark]*

K_a =

b) Explain how the indicator performs its function in a titration where an acidic solution is titrated with a basic solution. *[3 marks]*

c) What occurs in the buffer zone region of an acid–base titration? *[1 mark]*

QUESTION 32 (5 marks)

Ammonia is prepared industrially from hydrogen and nitrogen using a suitable catalyst according to the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The table below shows the equilibrium yield of ammonia at different temperatures and pressures.

Total pressure (atmospheres)	**Temperature (ºC)**		
	300	**400**	**500**
200	61	38	18
600	84	69	40
1000	92	80	56

(Note: 1 atmosphere = approximately 100 kPa)

a) Explain how it can be deduced from the data that the formation of ammonia is exothermic. *[2 marks]*

b) The usual conditions for the industrial production of ammonia are moderate pressure (100–250 atmospheres) and moderate temperature (350–550ºC). In terms of yield and rate of reaction, explain why these conditions are used for the production of ammonia. *[3 marks]*

TEQCHEM_QA_P1_20.FM

QUESTION 33 (2 marks)

Explain the difference between the structures of the *cis* and *trans* isomers of pent-2-ene. You may include diagrams to support your response.

END OF PAPER

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

Neap

Trial Examination 2020

Formula and data booklet

QCE Chemistry Units 3&4

FORMULAS

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

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

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

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

PHYSICAL CONSTANTS AND UNIT CONVERSIONS

Physical constants and unit conversions	
Absolute zero	0 K = –273°C
Atomic mass unit	1 amu = 1.66×10^{-27} kg
Avogadro's constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
Ideal gas constant	$R = 8.31$ J mol^{-1} K^{-1}
Ionic product constant for water (at 298 K)	$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}
Molar volume of an ideal gas (at STP)	2.27×10^{-2} m^3 mol^{-1} = 22.7 dm^3 mol^{-1}
Specific heat capacity of water (at 298 K)	$c_w = 4.18$ J g^{-1} K^{-1}
Standard temperature and pressure (STP)	273 K and 100 kPa
Volume and capacity conversions	1 dm^3 = 1×10^{-3} m^3 = 1×10^3 cm^3 = 1 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	atomic number
H	symbol
1.01	relative atomic mass*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	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											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) ionic radius (10^{-12} m) charge of ion

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1 32 208 (1–)																	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+)											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

1	atomic number
H	symbol
2.2	electronegativity
1318	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.

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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

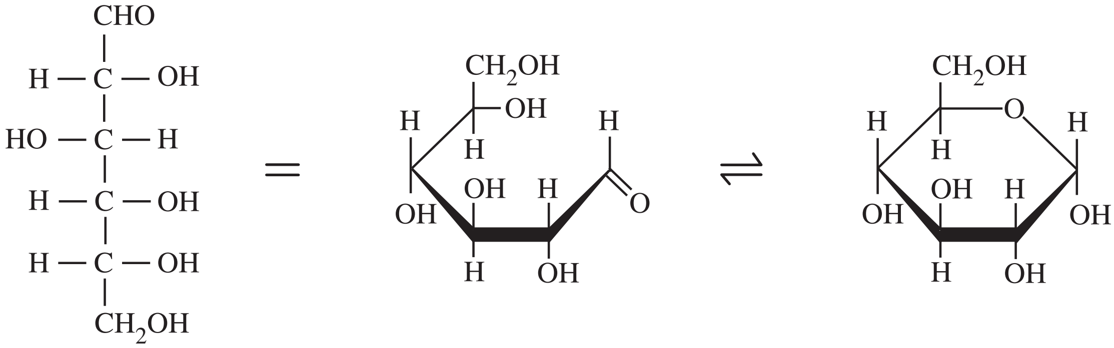
Element	Reactivity
K	most reactive ↑
Na	
Li	
Ba	
Sr	
Ca	
Mg	
Al	
C*	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	
Ni	
Sn	
Pb	
H_2*	
Sb	
Bi	
Cu	
Hg	
Ag	
Au	
Pt	least reactive

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

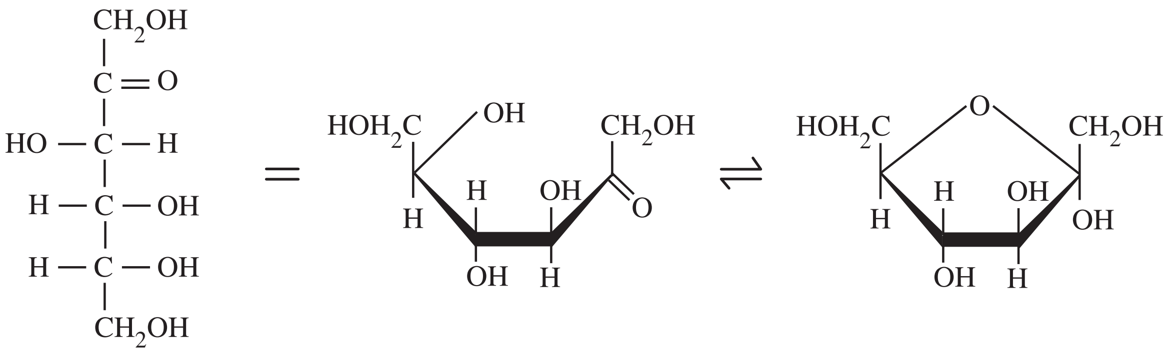
STANDARD ELECTRODE POTENTIALS AT 298 K

Oxidised species $\rightleftharpoons$ 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

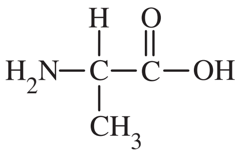
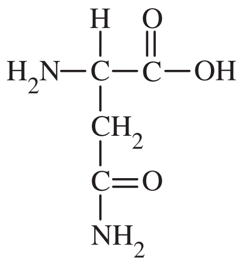
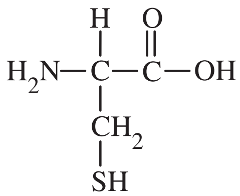
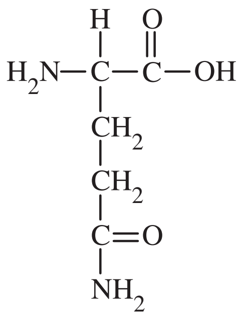


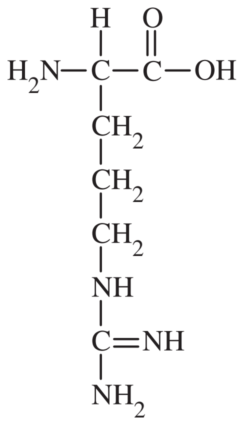
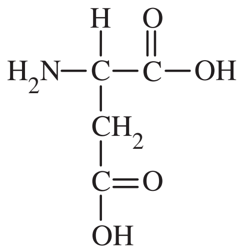
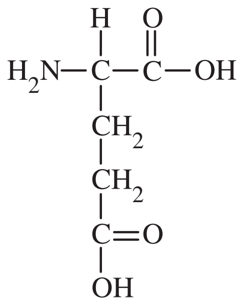
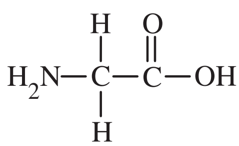
straight chain D-glucose α-D-glucose



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

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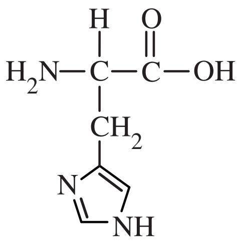
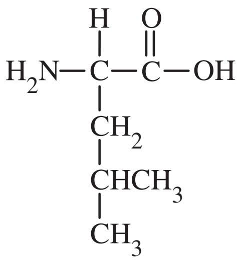
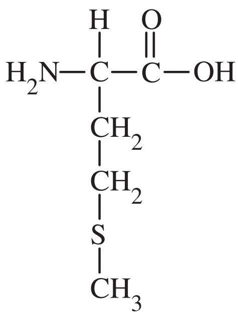
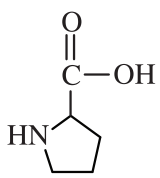
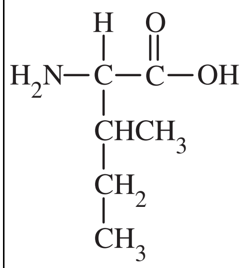
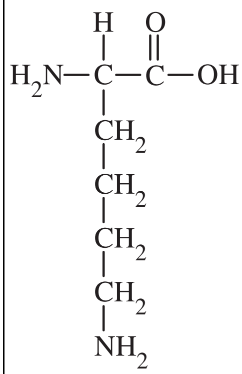
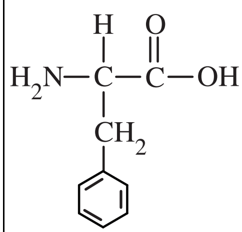
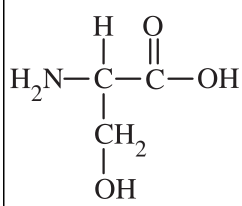
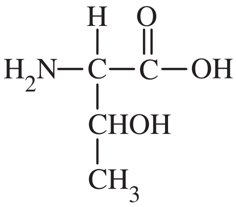
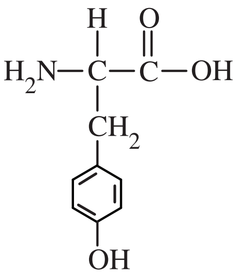
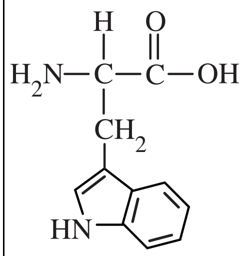
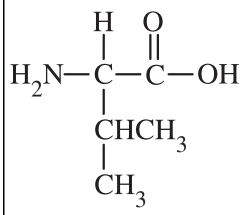
COMMON AMINO ACIDS (continued)

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
Tryptophan (Trp)		5.9
Valine (Val)		6.0

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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, Gordon & Findlay, Tristan (2008) *SI Chemical Data*, 6th ed, John Wiley & Sons, Brisbane.

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