		Centre Number	Candidate Number
Surname			
First name(s)			2

GCE AS

B410U20-1

Z22-B410U20-1

Part of WJEC

FRIDAY, 27 MAY 2022 – AFTERNOON

CHEMISTRY – AS component 2

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 7.**	**10**	
Section B	**8.**	**13**	
	9.	**15**	
	10.	**13**	
	11.	**19**	
	12.	**10**	
	Total	**80**	

B410U201 01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:

- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid. You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.
Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.10**(a).

SECTION A

Answer **all** questions.

1. Name the compound $(CH_3)_4C$. [1]

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2. State the meaning of the term ‘heterolytic bond fission’. [1]

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3. Explain why propanoic acid is soluble in water but propane is not. [2]

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4. Propanoic acid reacts with magnesium to form magnesium propanoate and hydrogen.

Write an equation for this reaction. [1]

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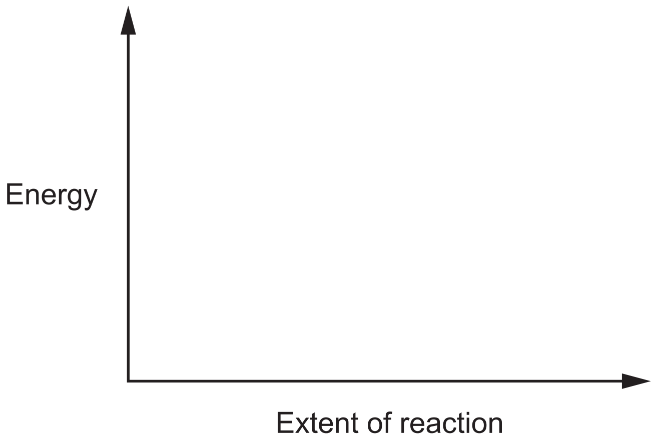
5. The enthalpy change for a reversible reaction is $-98\,\text{kJ mol}^{-1}$.

(a) On the axes below draw the energy profile for this reaction.

Label the enthalpy change. [1]



(b) The activation energy for the backward reaction is $234\,\text{kJ mol}^{-1}$.

Calculate the activation energy for the forward reaction. [1]

Activation energy = ... kJ mol^{-1}

6. A gas cylinder for a barbecue contains 9.0 kg of propane.

Calculate the number of propane molecules in the cylinder. [2]

Molecules of propane = ...

7. State how many isomers are represented by the formula C_5H_{12}. [1]

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10

SECTION B

Answer **all** questions.

8. Propane and propene are typical examples of hydrocarbons.

(a) Describe the nature of the bonding in propene and explain how this governs its chemical behaviour.

A diagram may be used in support of your answer. [4]

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(b) Propene can undergo polymerisation to form poly(propene).

Draw the repeating unit in poly(propene). [1]

(c) Although propane is generally unreactive it can react with chlorine in sunlight to form 1-chloropropane as one of the organic products.

(i) Name the type of reaction mechanism which occurs in this case. [1]

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(ii) Write the mechanism for the reaction to form 1-chloropropane.

Include one termination step. [4]

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(d) A hydrocarbon has a relative molecular mass of 136. The percentage composition, by mass, is C 88.1%; H 11.9%.

Calculate both the empirical and molecular formulae of the compound.

You **must** show your working. [3]

Empirical formula ....

Molecular formula ....

13

9. (a) Ethanol can be produced industrially by the hydration of ethene.

$$CH_2{=}CH_2(g) \quad + \quad H_2O(g) \quad \rightleftharpoons \quad CH_3CH_2OH(g) \qquad \Delta H = -46\ \text{kJ mol}^{-1}$$

(i) Name the catalyst used in this production. [1]

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(ii) Calculate the average bond enthalpy for the C — C bond using the enthalpy change of reaction above and the average bond enthalpy values given in the table. [3]

Bond	Average bond enthalpy / kJ mol^{-1}
C ═ C	612
C — H	413
C — O	360
O — H	463

Average bond enthalpy of C — C = ... kJ mol^{-1}

(b) (i) State the meaning of the term 'standard enthalpy change of combustion', $\Delta_c H^\theta$. [2]

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(ii) The enthalpy change of combustion of ethanol is $-1370\,kJ\,mol^{-1}$.

The density of ethanol is $0.789\,g\,cm^{-3}$.

Calculate the heat energy released, in kJ, when $0.350\,dm^3$ of ethanol is burned.

Give your answer to an **appropriate** number of significant figures. [3]

Heat energy released = ... kJ

Turn over.

(c) Ethanol can be heated under reflux with propanoic acid in the presence of concentrated sulfuric acid to form an ester.

(i) Draw a labelled diagram of the apparatus you could use for heating under reflux. [3]

(ii) Explain how this apparatus prevents escape of vapour and give a reason why the escape of vapour should be prevented. [2]

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(iii) Draw the structure of the ester that forms. [1]

15

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10. (a) Halogenoalkanes can be hydrolysed to give alcohols.

Devise an experiment to compare the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

Include the expected results and use these to state the trend in the rates of reaction. Explain this trend. [6 QER]

(b) 1-Chlorobutane can be converted into 2-iodobutane in a two-stage synthesis.

$$CH_3CH_2CH_2CH_2Cl \longrightarrow CH_3CH_2CH{=}CH_2 \longrightarrow CH_3CH_2CHICH_3$$

Stage 1 has a 25% yield and stage 2 has a 92% yield.

Calculate the mass of 2-iodobutane made from 37.6 g of 1-chlorobutane. [3]

Mass of 2-iodobutane = ... g

(c) Chlorofluorocarbons, CFCs, were used for a variety of purposes but have now been replaced by hydrofluorocarbons, HFCs.

Explain why HFCs have replaced CFCs. [4]

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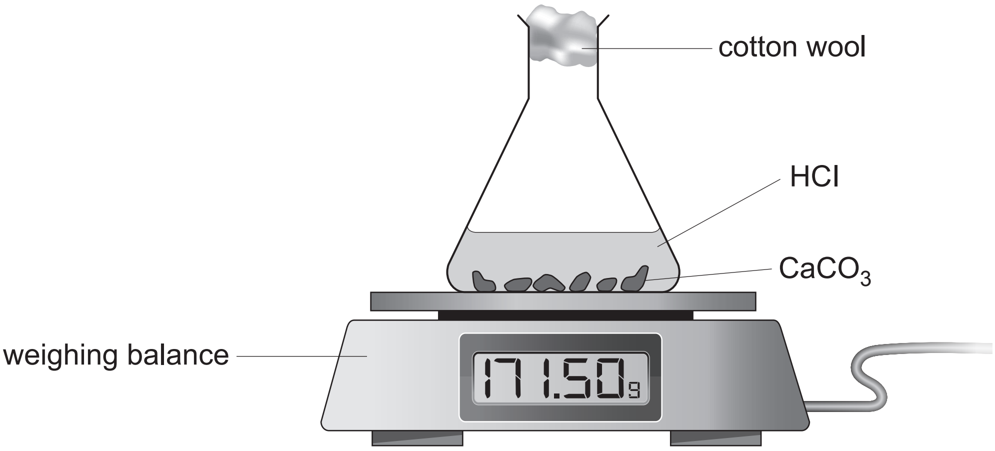
13

11. (a) A student carried out an experiment to study the rate of the reaction between calcium carbonate and hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

He used the following apparatus to measure the total mass of the reagents and the flask every 30 s for 6 minutes.



The solution remained at room temperature and the reaction was still in progress when the final measurement was taken.

His results are shown below.

Time / min	Mass of reagents + flask / g
0	171.50
0.5	171.37
1.0	171.29
1.5	171.23
2.0	171.19
2.5	171.12
3.0	171.07
3.5	171.02
4.0	170.98
4.5	170.94
5.0	170.91
5.5	170.89
6.0	170.87

(i) Suggest why cotton wool was placed in the neck of the flask. [1]

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(ii) Briefly describe a different experimental method, other than loss of mass, that would allow the rate of this reaction to be determined. [2]

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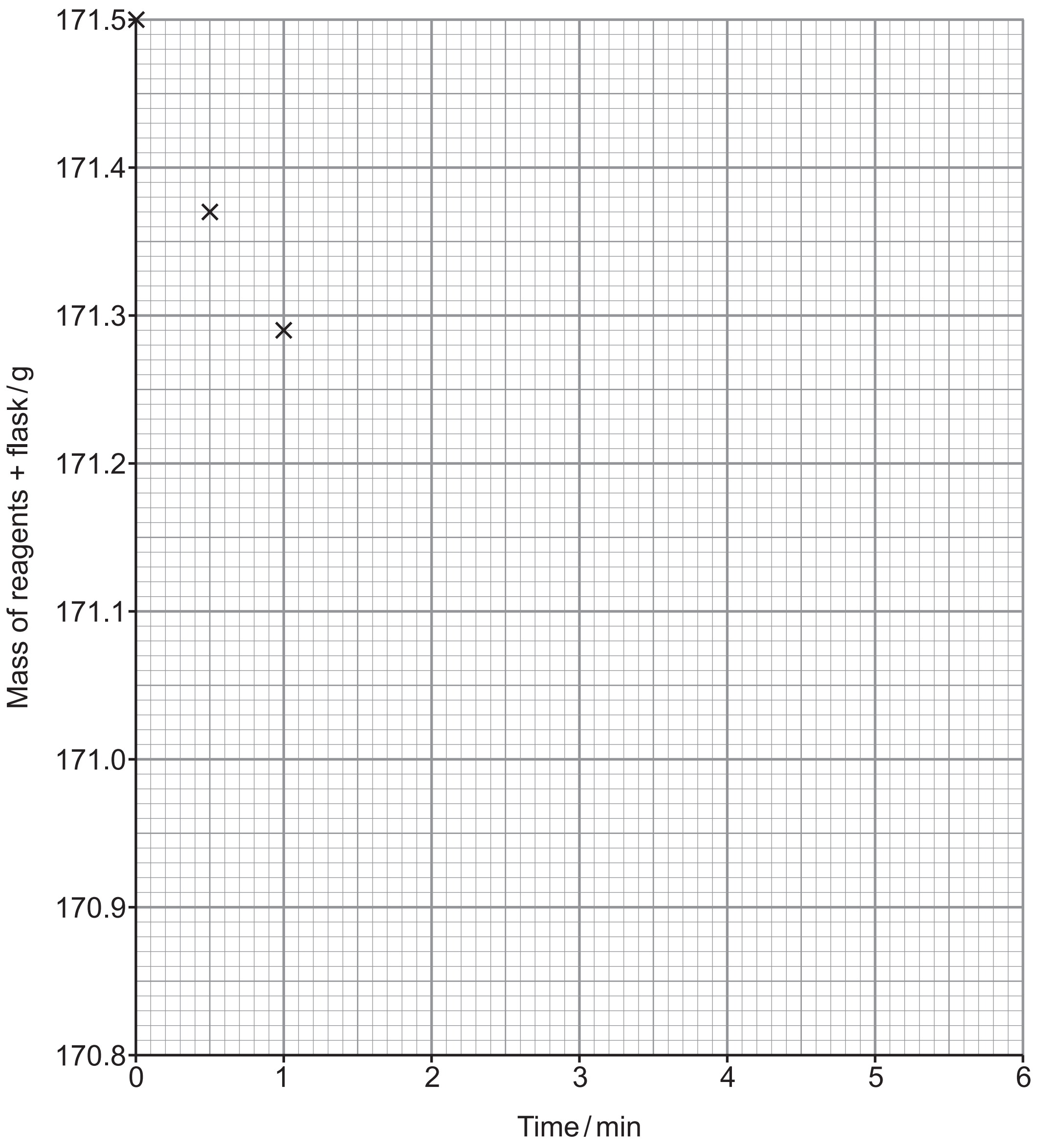
(iii) Complete the plot for the results of the experiment and draw a line of best fit. [3]



(iv) Use the graph to calculate the rate of reaction, in grams per minute, at 1 minute. [2]

Rate = ... g min^{-1}

(v) He used 1.50 g of calcium carbonate and 40.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid.

Calcium carbonate is the limiting reactant. Calculate the mass of carbon dioxide that would have been lost if the reaction had been allowed to go to completion. [2]

Mass of carbon dioxide = ... g

(vi) He then repeated the experiment using 1.50 g of powdered calcium carbonate.

Sketch on the graph in part (iii) the curve he would expect to obtain. Explain any differences in the curves. [3]

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(b) Another student carried out an experiment to study the enthalpy change for the reaction between calcium carbonate and hydrochloric acid.

She reacted 2.50 g of the carbonate with 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid in a polystyrene cup. The acid was in excess.

She used a thermometer that was accurate to ±0.1 °C and the temperature rose from 19.2 °C to 21.3 °C.

(i) Calculate the molar enthalpy change for this reaction, in kJ mol^{-1}. [3]

ΔH^{θ} = ... kJ mol^{-1}

(ii) Calculate the percentage error in the temperature rise recorded. [1]

Percentage error = ... %

(iii) She repeated the experiment but used 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid.

Predict the temperature change in this reaction. Give a reason for your answer. [1]

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(iv) She repeated the experiment again but used 50.0 cm^3 of 1.00 mol dm^{-3} nitric acid.

Predict the temperature change in this reaction. Give a reason for your answer. [1]

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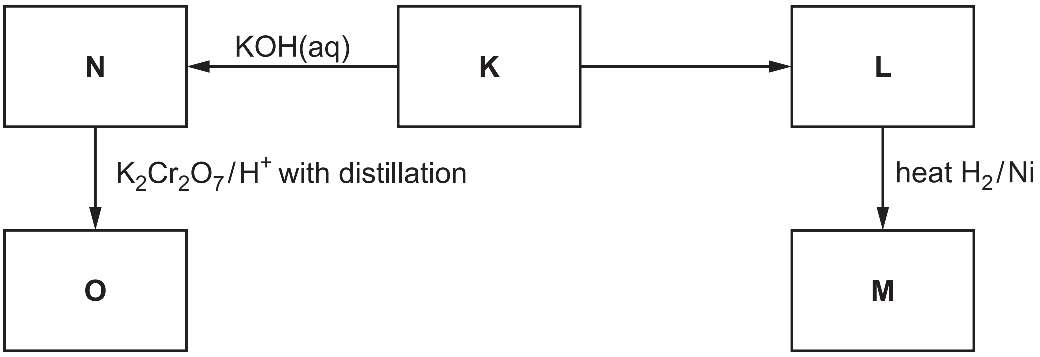
19

12. Study the reaction scheme shown below and the other information that follows.



Compound **L** is a hydrocarbon. It does not show *E-Z* isomerism and its mass spectrum shows a molecular ion peak at m/z 56.

The ^1H NMR spectrum for compound **K** shows 3 peaks and the ratio of the peak areas is 6:1:2.

The ^{13}C NMR spectrum for compound **N** shows 3 peaks.

Compound **O** does not react with sodium carbonate.

(a) Identify compounds **K**, **L**, **M** and **N**. Give your reasoning. [8]

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(b) Name the homologous series to which compound **O** belongs. [1]

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(c) State the reagent(s) and conditions needed for the conversion of compound **K** to compound **L**. [1]

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10

END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

Examiner only

Question number	**Additional page, if required. Write the question number(s) in the left-hand margin.**

Examiner only

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GCE AS

B410U20-1A

Z22-B410U20-1A

FRIDAY, 27 MAY 2022 – AFTERNOON

CHEMISTRY – AS component 2
Data Booklet

Avogadro constant $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant $R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
molar gas volume at 273 K and 1 atm $V_m = 22.4\ \text{dm}^3\ \text{mol}^{-1}$
molar gas volume at 298 K and 1 atm $V_m = 24.5\ \text{dm}^3\ \text{mol}^{-1}$
Planck constant $h = 6.63 \times 10^{-34}\ \text{J s}$
speed of light $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
density of water $d = 1.00\ \text{g cm}^{-3}$
specific heat capacity of water $c = 4.18\ \text{J g}^{-1}\ \text{K}^{-1}$
ionic product of water at 298 K $K_w = 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$
fundamental electronic charge $e = 1.60 \times 10^{-19}\ \text{C}$

temperature (K) = temperature (°C) + 273

$1\ \text{dm}^3 = 1000\ \text{cm}^3$
$1\ \text{m}^3 = 1000\ \text{dm}^3$
1 tonne = 1000 kg
$1\ \text{atm} = 1.01 \times 10^5\ \text{Pa}$

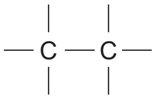
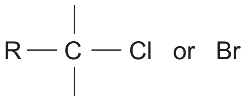
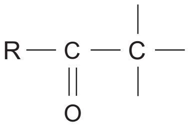
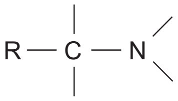
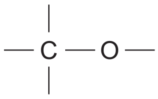
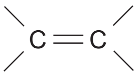
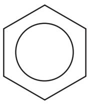
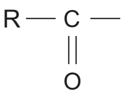
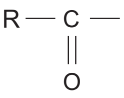
Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

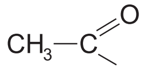
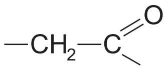
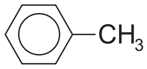
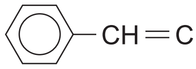
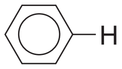
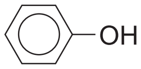
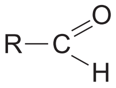
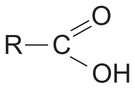
Infrared absorption values

Bond	Wavenumber / cm^{-1}
C — Br	500 to 600
C — Cl	650 to 800
C — O	1000 to 1300
C = C	1620 to 1670
C = O	1650 to 1750
C ≡ N	2100 to 2250
C — H	2800 to 3100
O — H (carboxylic acid)	2500 to 3200 (very broad)
O — H (alcohol / phenol)	3200 to 3550 (broad)
N — H	3300 to 3500

^{13}C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
 $-\overset{\vert}{\underset{\vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$	5 to 40
 $R-\overset{\vert}{\underset{\vert}{C}}-Cl$ or Br	10 to 70
 $R-\underset{O}{\underset{\Vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$	20 to 50
 $R-\overset{\vert}{\underset{\vert}{C}}-N<$	25 to 60
 $-\overset{\vert}{\underset{\vert}{C}}-O-$	50 to 90
	90 to 150
R — C ≡ N	110 to 125
	110 to 160
 $R-\underset{O}{\underset{\Vert}{C}}-$ (carboxylic acid / ester)	160 to 185
 $R-\underset{O}{\underset{\Vert}{C}}-$ (aldehyde / ketone)	190 to 220

^{1}H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
	2.0 to 2.5
	2.0 to 3.0
	2.2 to 2.3
$HC-Cl$ or $HC-Br$	3.1 to 4.3
$HC-O$	3.3 to 4.3
$R-OH$	4.5 *
$-C=CH$	4.5 to 6.3
$-C=CH-CO$	5.8 to 6.5
	6.5 to 7.5
	6.5 to 8.0
	7.0 *
	9.8 *
	11.0 *

*variable figure dependent on concentration and solvent

THE PERIODIC TABLE

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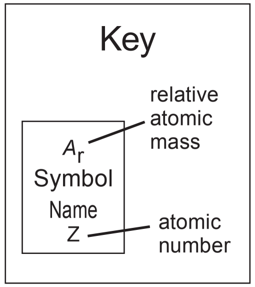

s block | d block | p block

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 Be Beryllium 4											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
3	23.0 Na Sodium 11	24.3 Mg Magnesium 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	40.0 Ar Argon 18
4	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
5	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	98.9 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 La ▸ Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(210) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) Ac ▸▸ Actinium 89															

f block

▸ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) 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
▸▸ Actinoid elements	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