

Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel
Level 3 GCE**

Centre Number

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Candidate Number

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Time 1 hour 45 minutes

Paper
reference

9CH0/02

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

**Candidates must have: Scientific calculator
Data Booklet
Ruler**

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- Show all your working in calculations and include units where appropriate.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- For the question marked with an asterisk (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Good luck with your examination.

Turn over ►

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Pearson

Answer ALL questions.

Some questions must be answered with a cross .
If you change your mind about an answer, put a line through the box
and then mark your new answer with a cross .

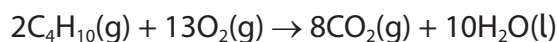
1 What is the total number of **ions** in 26.4 g of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$?

[Molar mass of $(\text{NH}_4)_2\text{SO}_4 = 132 \text{ g mol}^{-1}$ Avogadro constant = $6.0 \times 10^{23} \text{ mol}^{-1}$]

- A 4.0×10^{22}
 B 1.2×10^{23}
 C 2.4×10^{23}
 D 3.6×10^{23}

(Total for Question 1 = 1 mark)

2 The equation for the complete combustion of butane is



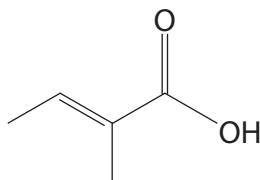
What is the minimum volume of oxygen, at room temperature and pressure (r.t.p.),
needed for the complete combustion of 0.200 mol of butane?

[Molar volume of a gas at r.t.p. = $24.0 \text{ dm}^3 \text{ mol}^{-1}$]

- A 4.8 dm^3
 B 9.6 dm^3
 C 31.2 dm^3
 D 62.4 dm^3

(Total for Question 2 = 1 mark)

3 What is the systematic name for tiglic acid?



tiglic acid

- A *E*-2-methylbut-2-enoic acid
 B *Z*-2-methylbut-2-enoic acid
 C *E*-3-methylbut-2-enoic acid
 D *Z*-3-methylbut-2-enoic acid

(Total for Question 3 = 1 mark)



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4 This question is about alkenes with the molecular formula C_5H_{10} .

(a) Draw the **skeletal** formulae of three **branched** chain alkenes with the molecular formula C_5H_{10} .

(3)



(b) Which of these compounds would form pent-2-ene **only**, when reacted with concentrated phosphoric acid, H_3PO_4 ?

(1)

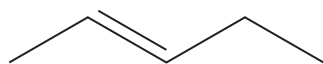
- A $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2$
- B $\text{CH}_2(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- C $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
- D $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$

(c) Pent-2-ene reacts with hydrogen bromide, HBr , to form two bromoalkanes.

Complete the diagram to show the mechanism for the formation of 2-bromopentane in this reaction.

Include curly arrows, and relevant lone pairs and dipoles.

(4)



- (d) A sample of pent-1-ene, with a mass of 1.33 g, is warmed to 60 °C in a sealed container. The volume of the container is 500 cm³.

Calculate the pressure inside the container.

Include units and give your answer to an appropriate number of significant figures.

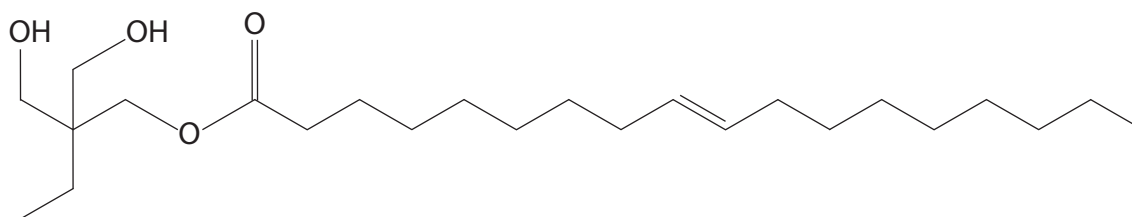
[Gas constant (R) = 8.31 J mol⁻¹ K⁻¹]

(4)

(Total for Question 4 = 12 marks)



- 5 Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

- (a) Name the **three** functional groups present in compound **X**.

(2)

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- (b) The effectiveness of this synthetic oil is much reduced if it is contaminated with water.

Give, in terms of a chemical reaction, a possible reason for this.

(1)

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(c) An alternative to synthetic oil is known as mineral oil and consists solely of hydrocarbons separated from crude oil.

(i) What is the name of the process used to separate different hydrocarbons from crude oil?

(1)

- A cracking
- B reforming
- C fractional distillation
- D heating under reflux

(ii) Explain why compound **X** is likely to have a higher boiling temperature than hydrocarbons of a similar molecular mass and shape.

A detailed description of how the intermolecular forces arise is not required.

(2)

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(Total for Question 5 = 6 marks)



6 This question is about carbon monoxide, CO, which is a toxic and colourless gas used widely in the chemical industry.

(a) Draw a dot-and-cross diagram of a molecule of carbon monoxide.

Use dots (•) for the carbon electrons and crosses (×) for the oxygen electrons.

(2)

(b) Carbon monoxide can be made by the thermal decomposition of sodium ethanedioate.



Calculate the atom economy, by mass, for the production of carbon monoxide in this reaction.

(2)

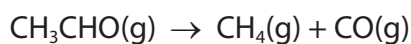
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- (c) Carbon monoxide can also be made by the thermal decomposition of ethanal, CH₃CHO, in the gas phase.



This reaction was carried out at two different temperatures, and all other variables were kept constant.

Temperature / K	Rate / mol dm ⁻³ s ⁻¹	1/Temperature (1/T) / K ⁻¹	ln rate
700	0.0108	1.43 × 10 ⁻³	
850	4.90		1.59

- (i) Complete the data in the table. (1)
- (ii) Calculate the activation energy, E_a , for the reaction without plotting a graph. Include a sign and units in your answer.

The Arrhenius equation may be written as

$$\ln \text{rate} = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \quad [R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}] \quad (3)$$



(d) Haemoglobin (Hb) found in red blood cells reacts almost irreversibly with carbon monoxide.

Initial rate experiments were carried out to investigate the effect of the concentrations of Hb and CO on the rate of this reaction.

Experiment	[Hb] / mol dm ⁻³	[CO] / mol dm ⁻³	Rate / mol dm ⁻³ s ⁻¹
1	2.09×10^{-6}	1.40×10^{-6}	8.20×10^{-7}
2	4.18×10^{-6}	1.40×10^{-6}	1.64×10^{-6}
3	3.26×10^{-6}	2.80×10^{-6}	2.56×10^{-6}

(i) Deduce the order of reaction with respect to haemoglobin. (1)

(ii) Determine the order with respect to carbon monoxide using your answer to (d)(i) and the data in the table. Justify your answer. (2)

(iii) Write the rate equation for this reaction using your answers to (d)(i) and (d)(ii). (1)



(iv) Calculate the rate constant, k , for the reaction, using the data from Experiment 1 and the rate equation from (d)(iii).
Include units in your answer.

(3)

(Total for Question 6 = 15 marks)

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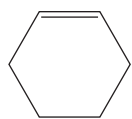
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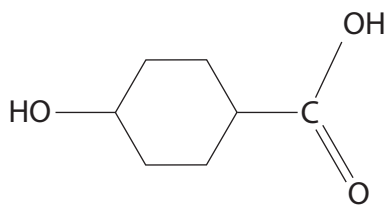


*7 This question is about polymers.

(a) Compare and contrast how each of these monomers forms a polymer.



cyclohexene



4-hydroxycyclohexanecarboxylic acid

Include equations, showing the formation of a single repeat unit for each polymer.

(6)

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Handwriting practice area with 20 sets of horizontal dotted lines.



(b) Give three ways in which waste polymers can be utilised to improve their sustainability.

(3)

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(Total for Question 7 = 9 marks)

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8 This question is about a dicarboxylic acid **Y** which is present in some citrus fruits. **Y** contains only the elements carbon, hydrogen and oxygen.

- (a) A sample of **Y** with a mass of 1.98 g was burned completely in excess oxygen. The reaction formed 2.51 g of carbon dioxide, CO_2 , and 0.69 g of water, H_2O .

Use these data to calculate the empirical formula of **Y**.

(4)



P 6 5 4 6 4 A 0 1 5 2 8

(b) A solution was prepared using 4.34 g of the dicarboxylic acid **Y** made up to a volume of 250 cm³ with distilled water.

A 25.0 cm³ sample of this solution was then titrated using sodium hydroxide solution, NaOH(aq), of concentration 0.320 mol dm⁻³.

The mean titre of sodium hydroxide solution was 26.10 cm³.

Calculate the molar mass of **Y** using the titration data, and hence deduce its structure. You must show your working.

(5)

(c) Which of these is used to convert a dicarboxylic acid into a diol?

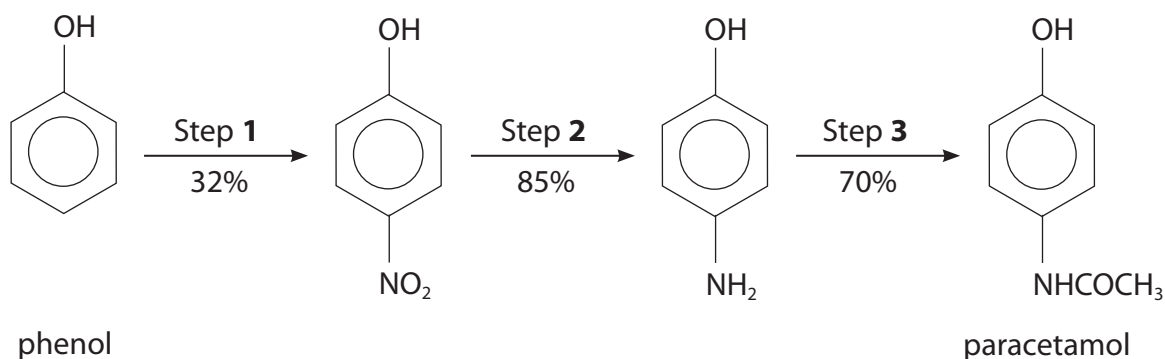
(1)

- A** LiAlH₄ and ether
- B** KMnO₄ and H₂SO₄
- C** Sn and HCl
- D** Na₂Cr₂O₇ and H₂SO₄

(Total for Question 8 = 10 marks)



- 9 The painkiller paracetamol can be synthesised from phenol in three steps. The percentage yield for each step is shown.



- (a) In Step 1 another product also forms. The two products can be distinguished using their ^{13}C NMR spectra.

Complete the table to show the number of peaks in each ^{13}C NMR spectrum.

(2)

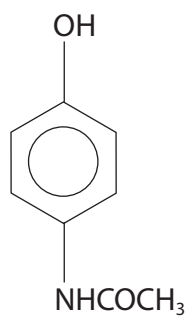
Product		
Number of peaks in the ^{13}C NMR spectrum		

- (b) Calculate the minimum mass of phenol needed to synthesise 1.00 kg of paracetamol. [M_r values: paracetamol = 151.0 phenol = 94.0]

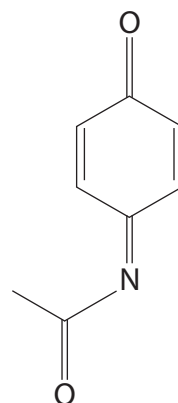
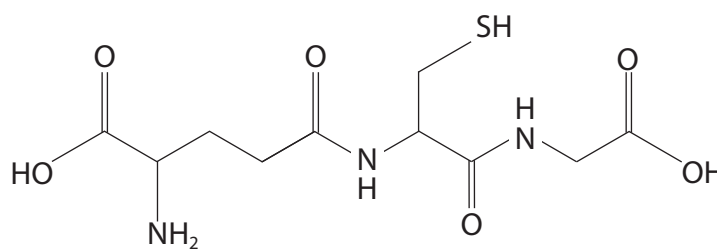
(3)



- (c) When metabolised in the body, paracetamol forms a toxic compound **Z**.
This is then removed in the liver by a reaction with the tripeptide glutathione.



paracetamol

compound **Z**

glutathione

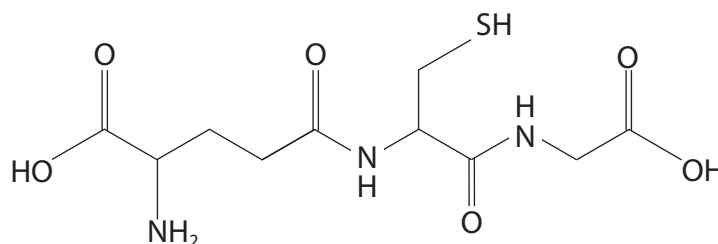
- (i) The conversion of paracetamol to compound **Z** is

(1)

- A** addition
 B hydrolysis
 C oxidation
 D reduction

- (ii) Draw a circle around each of the chiral carbon atoms in glutathione.

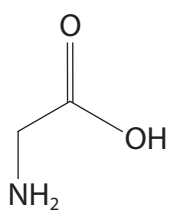
(1)



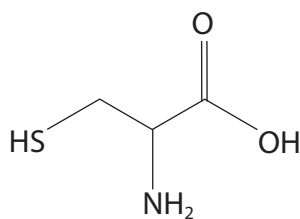
(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

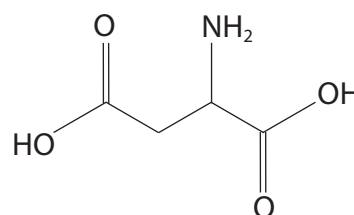
(1)



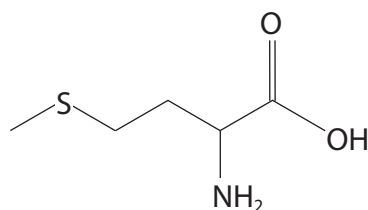
glycine



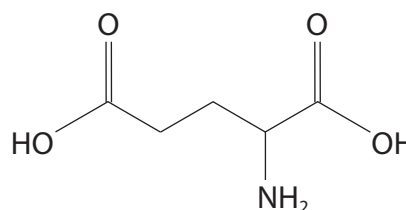
cysteine



aspartic acid



methionine



glutamic acid

- A aspartic acid and cysteine
- B glutamic acid and cysteine
- C glutamic acid and methionine
- D aspartic acid and methionine

(d) Explain why amino acids such as glycine are crystalline solids at room temperature.

(2)

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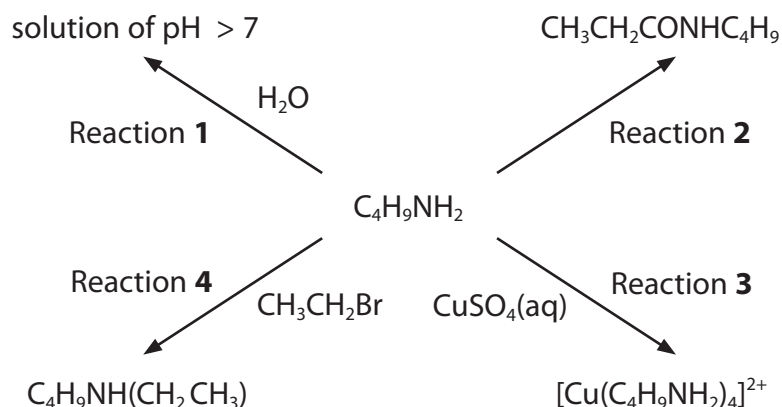
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(Total for Question 9 = 10 marks)



10 This question is about the amines butylamine, $C_4H_9NH_2$, and phenylamine, $C_6H_5NH_2$.

The reaction scheme shows some reactions of butylamine, a primary amine.



(a) (i) Write the equation for Reaction 1 to show why the pH of the solution is greater than 7. State symbols are not required.

(1)

(ii) Explain why phenylamine is a weaker base than butylamine.

(3)

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(b) Give the name and structural formula of the compound needed to react with butylamine in Reaction 2.

(2)

Name

Structural formula



(c) What is seen when excess butylamine is used in Reaction 3?

(1)

- A blue solution
- B blue precipitate
- C yellow solution
- D yellow precipitate

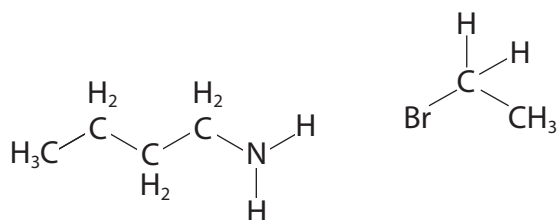
(d) (i) What is the type and mechanism of the reaction in Reaction 4?

(1)

- A electrophilic addition
- B electrophilic substitution
- C nucleophilic addition
- D nucleophilic substitution

(ii) Complete the diagram to show the mechanism for Reaction 4.
Include curly arrows, and relevant lone pairs and dipoles.

(4)



(Total for Question 10 = 12 marks)



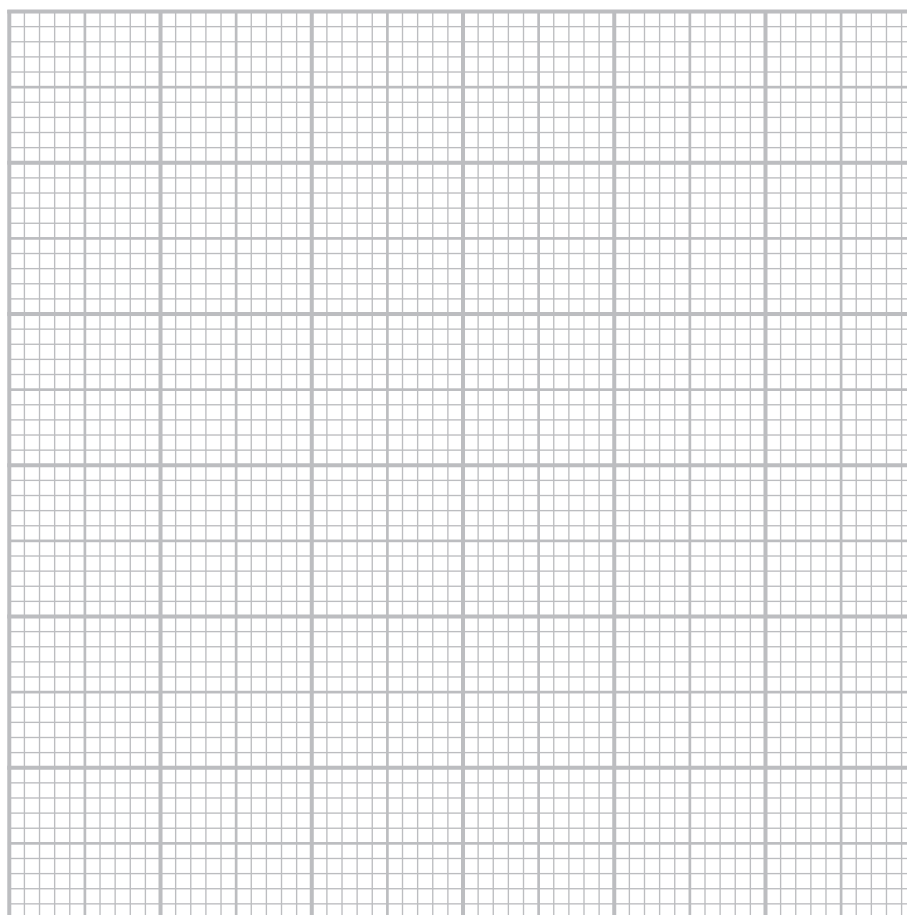
- 11 A series of experiments was carried out to determine the kinetics of the reaction between a chloroalkane, RCl , and potassium hydroxide in aqueous solution. A large excess of the chloroalkane was used.

The data obtained are shown.

$[\text{OH}^-] / \text{mol dm}^{-3}$	Time / s
0.00100	39
0.00200	31
0.00300	23
0.00400	16
0.00500	8

- (a) Plot a graph of the concentration of the hydroxide ions against time.

(2)



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(b) State the order with respect to hydroxide ions.
Justify your answer by reference to your graph in (a).

(2)

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(c) Deduce the type of mechanism occurring.
Justify your answer.

(2)

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(d) Give the classification of the chloroalkane in this reaction.

(1)

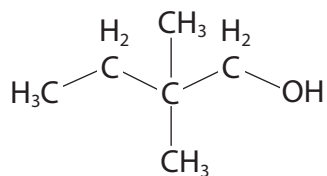
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(Total for Question 11 = 7 marks)



12 The alcohol 2,2-dimethylbutan-1-ol has the structure



Devise a reaction scheme for a synthesis of this alcohol starting from 2-bromo-2-methylbutane.

Include in your answer all reagents and conditions and the structures of any intermediate compounds.

(6)

(Total for Question 12 = 6 marks)

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1 2 3 4 5 6 7 0 (8)
(18)

1.0
H
hydrogen
1

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

(1) (2)

6.9
Li
lithium
3

9.0
Be
beryllium
4

24.3
Mg
magnesium
12

(13)

10.8
B
boron
5

12.0
C
carbon
6

14.0
N
nitrogen
7

16.0
O
oxygen
8

17.0
F
fluorine
9

19.0
Ne
neon
10

(14)

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

(15)

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

(16)

112.4
Cd
cadmium
48

121.8
Sb
antimony
51

127.6
Te
tellurium
52

127.6
Po
polonium
84

131.3
Xe
xenon
54

(17)

204.4
Tl
thallium
81

207.2
Pb
lead
82

209.0
Bi
bismuth
83

210
At
astatine
85

[222]
Rn
radon
86

(18)

4.0
He
helium
2

(9)

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

(10)

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

(11)

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

(12)

[98]
Tc
technetium
43

186.2
Re
rhenium
75

183.8
W
tungsten
74

187.2
Ir
iridium
77

192.2
Rh
rhodium
45

(13)

91.2
Zr
zirconium
40

91.2
Hf
hafnium
72

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

192.2
Ir
iridium
77

(14)

88.9
Y
yttrium
39

138.9
La*
lanthanum
57

137.3
Ba
barium
56

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

(15)

92.9
Nb
niobium
41

95.9
Mo
molybdenum
42

101.1
Ru
ruthenium
44

102.9
Rh
rhodium
45

106.4
Pd
palladium
46

(16)

50.9
V
vanadium
23

52.0
Cr
chromium
24

54.9
Mn
manganese
25

58.9
Co
cobalt
27

58.7
Ni
nickel
28

(17)

47.9
Ti
titanium
22

47.9
Zr
zirconium
40

91.2
Hf
hafnium
72

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

(18)

45.0
Sc
scandium
21

88.9
Y
yttrium
39

138.9
La*
lanthanum
57

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

(19)

50.9
V
vanadium
23

52.0
Cr
chromium
24

54.9
Mn
manganese
25

58.9
Co
cobalt
27

58.7
Ni
nickel
28

(20)

47.9
Ti
titanium
22

47.9
Zr
zirconium
40

91.2
Hf
hafnium
72

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

(21)

45.0
Sc
scandium
21

88.9
Y
yttrium
39

138.9
La*
lanthanum
57

178.5
Hf
hafnium
72

187.2
Re
rhenium
75

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

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

* Lanthanide series

* Actinide series

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