Write your name here

| Surname | Other names |
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**Pearson Edexcel Level 3 GCE**

Centre Number | | | | | |

Candidate Number | | | | |

# Chemistry

## Advanced

## Paper 2: Advanced Organic and Physical Chemistry

Monday 19 June 2017 – Morning
**Time: 1 hour 45 minutes**

Paper Reference
**9CH0/02**

**You must have:**
Data Booklet
Scientific calculator, 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.*

### 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.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

*Turn over* ▶

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P 4 8 0 5 9 A 0 1 2 4

Pearson

**Answer ALL questions.**

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

**1** This is a question about alkanes.

(a) What is the reaction mechanism when ethane and chlorine react in UV light?

**(1)**

☒ **A** electrophilic addition

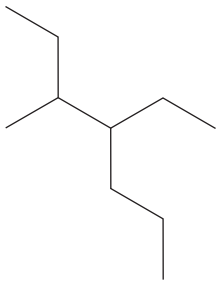
☒ **B** electrophilic substitution

☒ **C** free radical addition

☒ **D** free radical substitution

(b) What is the name of this alkane?

**(1)**



☒ **A** 2-ethyl-3-propylpentane

☒ **B** 4-ethyl-3-methylheptane

☒ **C** 3-methyl-4-propylhexane

☒ **D** 4-methyl-3-propylhexane

(c) Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation.

**(2)**

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(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

**(1)**

$C_8H_{18}$ → ..... + .....

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

**(1)**

**(Total for Question 1 = 6 marks)**

DO NOT WRITE IN THIS AREA

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**2** Diamond, graphene and graphite are different forms of carbon.

(a) The structural feature that graphene and graphite have in common is that the carbon atoms are arranged in

**(1)**

☒ **A** layers with each atom bonded to four others

☒ **B** hexagonal and pentagonal rings within a layer

☒ **C** hexagonal rings within a layer

☒ **D** a three-dimensional structure

(b) The bond angles within a layer of graphene and a layer of graphite are

**(1)**

☒ **A** 90° and 109.5°

☒ **B** all 109.5°

☒ **C** 109.5° and 120°

☒ **D** all 120°

(c) One way in which diamond differs from graphene and graphite is that only diamond has

**(1)**

☒ **A** a high melting temperature

☒ **B** a precise molecular formula

☒ **C** poor electrical conductivity

☒ **D** a giant structure

**(Total for Question 2 = 3 marks)**

**3** This is a question about halogenoalkanes and related compounds.

(a) Explain the trend in reactivity of the **primary** chloro-, bromo- and iodoalkanes with aqueous hydroxide ions.

**(2)**

(b) In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

(i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

**(4)**

(ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

**(2)**

(c) The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

**(3)**

(d) Explain why ethene has a boiling temperature of −104 °C, whereas ethanol has a boiling temperature of 78 °C.

**(3)**

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**(Total for Question 3 = 14 marks)**

**4** Traditionally, high-flying aircraft and Formula 1 racing cars have had their tyres inflated with nitrogen gas instead of air. Recently, this practice has been extended to some other cars.

(a) A car tyre is filled with nitrogen gas to a volume of 8.98 $dm^3$ and a pressure of 207 kPa at 20 °C.

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

**(3)**

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

**(1)**

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(b) One reason for the use of nitrogen gas in car tyres is that less gas is lost from the tyres during use because nitrogen molecules are larger than oxygen molecules. A suggested explanation for this is that nitrogen atoms are larger than oxygen atoms.

Explain why a nitrogen atom is larger than an oxygen atom.

**(2)**

.....

.....

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.....

**(Total for Question 4 = 6 marks)**

**5** This is a question about catalytic converters in car exhaust systems.

(a) When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

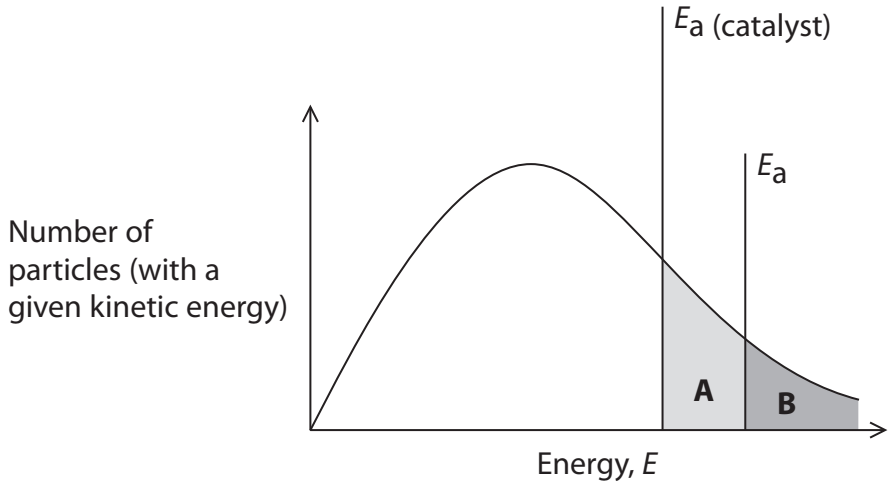
(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

**(1)**

(ii) Describe the stages by which the reaction in (a)(i) occurs in a catalytic converter.

**(3)**

(b) Which area in the Maxwell-Boltzmann distribution diagram represents the **increase** in the number of particles with sufficient energy to react in the presence of a catalyst?




**(1)**

☒ **A** area A

☒ **B** area B

☒ **C** area A – area B

☒ **D** area A + area B

(c) In the UK, the exhaust emissions of a petrol-fuelled vehicle must be less than 1.00 g of carbon monoxide per kilometre.

What is the maximum number of carbon monoxide molecules that can be emitted per kilometre for a vehicle to meet this regulation?

**(1)**

☒ **A** $1.37 \times 10^{22}$

☒ **B** $2.15 \times 10^{22}$

☒ **C** $6.02 \times 10^{23}$

☒ **D** $1.69 \times 10^{25}$

**(Total for Question 5 = 6 marks)**

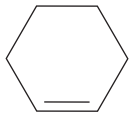
**6** This is a question about polymerisation.

(a) But-1-ene and cyclohexene both form addition polymers.

Draw a section of each polymer, showing **two** repeat units.

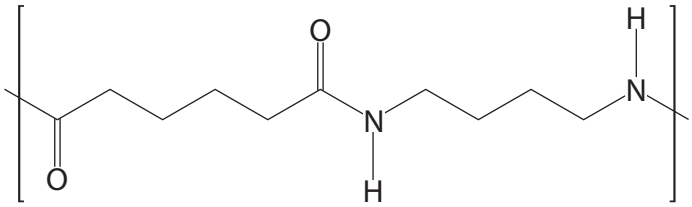
**(2)**

$CH_2{=}CHCH_2CH_3$ →

 →

(b) Deduce the two monomers needed to produce the polyamide shown.

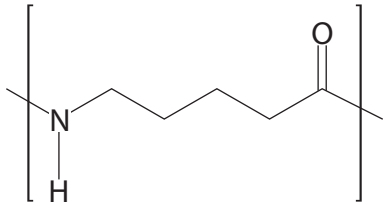
**(2)**




and

(c) Deduce the single monomer that could be used to produce the polyamide shown.

**(1)**




(d) PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

**(2)**

(ii) State how separate samples of these two enantiomers could be distinguished in a laboratory.

**(1)**

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(iii) Biodegradable polyesters break down naturally.

State why this is an advantage.

**(1)**

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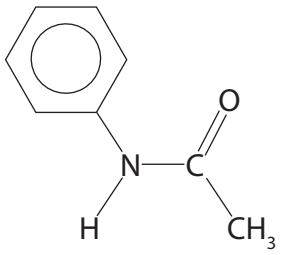
**(Total for Question 6 = 9 marks)**

**7** Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.




Antifebrin

(a) Some of the following reagents can be used to produce Antifebrin from benzene.

- Aluminium chloride
- Ammonia, concentrated
- Benzene
- Ethanal
- Ethanoic acid
- Ethanol
- Ethanoyl chloride
- Hydrochloric acid, concentrated
- Hydrochloric acid, dilute
- Iron
- Nitric acid, concentrated
- Nitric acid, dilute
- Propanone
- Sodium chloride
- Sulfuric acid, concentrated
- Tin

Selecting from only these reagents, devise a **three-step** synthetic pathway to convert benzene into Antifebrin. You should include the structures of the two intermediate compounds and the reaction conditions.

**(5)**

(b) What is the number of peaks in a C-13 NMR spectrum of Antifebrin?

**(1)**

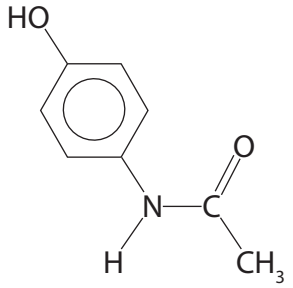
☒ **A** 5

☒ **B** 6

☒ **C** 7

☒ **D** 8

(c) Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.




The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

**(2)**

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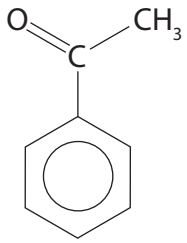
(d) A tablet with a total mass of 500 mg contained $3.10 \times 10^{-3}$ mol of paracetamol.

Calculate the percentage by mass of paracetamol in the tablet, quoting your answer to an appropriate number of significant figures.

**(2)**

**(Total for Question 7 = 10 marks)**

**8** Phenylethanone is an ingredient in many types of chewing gum.



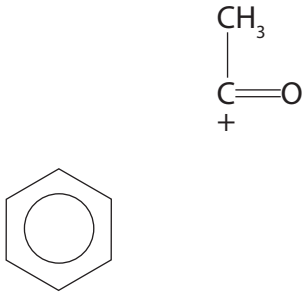
One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, $CH_3COCl$.

(a) (i) Write the equation for the formation of the electrophile, $CH_3CO^+$, from ethanoyl chloride using the catalyst aluminium chloride.

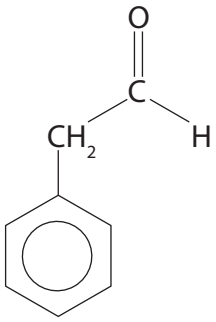
**(1)**

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

**(4)**



(b) Phenylethanone can be distinguished from its structural isomer, phenylethanal, in a number of different ways.




(i) Which would react with phenylethanone but **not** with phenylethanal?

**(1)**

☒ **A** acidified sodium dichromate(VI)

☒ **B** alkaline iodine solution

☒ **C** Fehling's solution

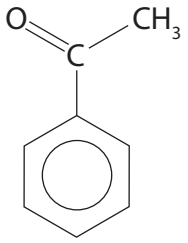
☒ **D** Tollens' reagent

(ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

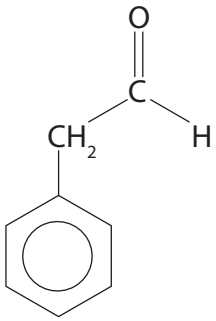
**(4)**

*(iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.



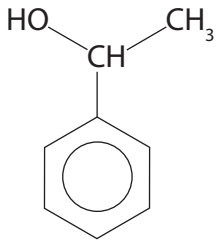

Phenylethanone




Phenylethanal

**(6)**

(c) The compound 1-phenylethanol can be formed from phenylethanone.




Give the reagent and conditions that would be used to form 1-phenylethanol.

**(2)**

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**(Total for Question 8 = 18 marks)**

**9** This question is about reaction kinetics.

(a) Compound **A** decomposes in a first order reaction.

Calculate the time it takes for the mass of **A** to decrease from 600 g to 37.5 g if the decomposition has a constant half-life of 14 minutes.

**(1)**

(b) The 'initial rates' method was used to investigate the orders of reaction with respect to reactants **X**, **Y** and **Z**. The table shows the results obtained.

| Run | Initial concentration / mol $dm^{-3}$ | | | Initial rate / mol $dm^{-3}$ $s^{-1}$ |
|---|---|---|---|---|
| | **X** | **Y** | **Z** | |
| 1 | 0.00100 | 0.00300 | 0.00600 | $2.17 \times 10^{-6}$ |
| 2 | 0.00100 | 0.00600 | 0.00600 | $8.68 \times 10^{-6}$ |
| 3 | 0.00050 | 0.00600 | 0.00600 | $4.34 \times 10^{-6}$ |
| 4 | 0.00300 | 0.00300 | 0.00300 | $6.51 \times 10^{-6}$ |

(i) Calculate the orders with respect to **X**, **Y** and **Z**.

**(3)**

**X** .....

**Y** .....

**Z** .....

(ii) Give the rate equation for the reaction and hence calculate the rate constant, *k*, to an appropriate number of significant figures. Include units in your answer.

**(4)**

(c) The kinetics of the 'bromine clock' were investigated and the rate equation was found to be

$$\text{Rate} = k[BrO_3^-][Br^-][H^+]^2$$

(i) What is the overall reaction order?

**(1)**

- ☒ **A** First
- ☒ **B** Second
- ☒ **C** Third
- ☒ **D** Fourth

(ii) Calculate the concentration of bromide ions required to produce a reaction rate of $4.08 \times 10^{-3}$ mol dm$^{-3}$ s$^{-1}$ at 298 K given that

$k = 8.00$ dm$^9$ mol$^{-3}$ s$^{-1}$

$[BrO_3^-] = 0.200$ mol dm$^{-3}$

$[H^+] = 0.100$ mol dm$^{-3}$

**(2)**

(d) The rate constant for the reaction between bromoethane and aqueous hydroxide ions was determined at five different temperatures.

The results are given in the table.

| Temperature (T) / K | 1 / Temperature (1 / T) / $K^{-1}$ | Rate constant, $k$ / $dm^3\ mol^{-1}\ s^{-1}$ | ln $k$ |
|---|---|---|---|
| 293 | $3.41 \times 10^{-3}$ | $5.83 \times 10^{-5}$ | −9.75 |
| 303 | | $1.67 \times 10^{-4}$ | |
| 313 | | $5.26 \times 10^{-4}$ | |
| 323 | | $1.36 \times 10^{-3}$ | |
| 333 | $3.00 \times 10^{-3}$ | $3.77 \times 10^{-3}$ | −5.58 |

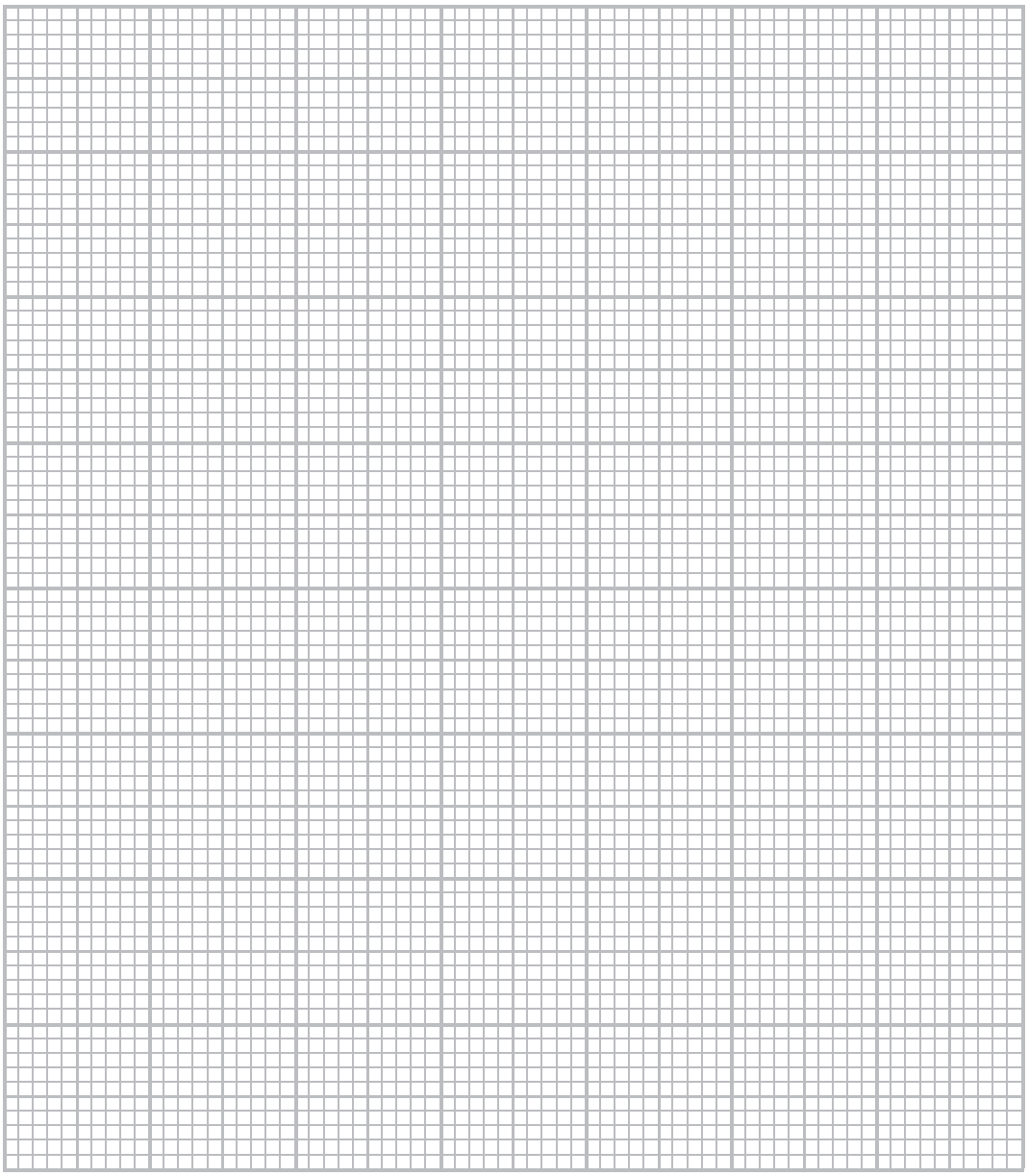
Complete the data in the table and use them to plot a graph of ln $k$ against 1 / T and hence determine the activation energy, $E_a$, in kJ $mol^{-1}$.

You should include the value and units of the gradient of the line.

The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

**(7)**



**(Total for Question 9 = 18 marks)**

**TOTAL FOR PAPER = 90 MARKS**

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# The Periodic Table of Elements

| 1 | 2 | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 0 (8) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1.0 H hydrogen 1 | | | | | | | | | | (18) 4.0 He helium 2 |
| (1) | (2) | | Key | | | | | | | | | (13) | (14) | (15) | (16) | (17) | |
| 6.9 Li lithium 3 | 9.0 Be beryllium 4 | | relative atomic mass<br>atomic symbol<br>name<br>atomic (proton) number | | | | | | | | | 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 |
| 23.0 Na sodium 11 | 24.3 Mg magnesium 12 | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (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 | 39.9 Ar argon 18 |
| 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 |
| 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] Tc technetium 43 | 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 | 114.8 In indium 49 | 118.7 Sn tin 50 | 121.8 Sb antimony 51 | 127.6 Te tellurium 52 | 126.9 I iodine 53 | 131.3 Xe xenon 54 |
| 132.9 Cs caesium 55 | 137.3 Ba barium 56 | 138.9 La* lanthanum 57 | 178.5 Hf hafnium 72 | 180.9 Ta tantalum 73 | 183.8 W tungsten 74 | 186.2 Re rhenium 75 | 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 | 204.4 Tl thallium 81 | 207.2 Pb lead 82 | 209.0 Bi bismuth 83 | [209] Po polonium 84 | [210] At astatine 85 | [222] Rn radon 86 |
| [223] Fr francium 87 | [226] Ra radium 88 | [227] Ac* actinium 89 | [261] Rf rutherfordium 104 | [262] Db dubnium 105 | [266] Sg seaborgium 106 | [264] Bh bohrium 107 | [277] Hs hassium 108 | [268] Mt meitnerium 109 | [271] Ds damstadtium 110 | [272] Rg roentgenium 111 | | | | | | | |

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

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Lanthanide series | 140 Ce cerium 58 | 141 Pr praseodymium 59 | 144 Nd neodymium 60 | [147] Pm promethium 61 | 150 Sm samarium 62 | 152 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 |
| * Actinide series | 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 |