**cea**
*Rewarding Learning*

**ADVANCED**
**General Certificate of Education**
**2019**

Centre Number

Candidate Number

# Chemistry

**Assessment Unit A2 1**
*assessing*
Further Physical and
Organic Chemistry

**[ACH12]**

*ACH12*

**TUESDAY 4 JUNE, AFTERNOON**

### TIME

2 hours.

### INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all twenty-one** questions.
Answer **all ten** questions in **Section A**. Record your answers by marking the appropriate letter on the answer sheet provided. Use only the spaces numbered 1 to 10. Keep in sequence when answering.
Answer **all eleven** questions in **Section B**.
**You must answer the questions in the spaces provided.**
**Do not write outside the boxed area on each page or on blank pages.**
Complete in black ink only. **Do not write with a gel pen.**

### INFORMATION FOR CANDIDATES

The total mark for this paper is 110.
Quality of written communication will be assessed in Questions **12(a)(ii)** and **20(a)(ii)**.
In Section A all questions carry equal marks, i.e. **one** mark for each question.
In Section B the figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements, containing some data, is included with this question paper.

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*28ACH1201*

## Section A

For each of the following questions only **one** of the lettered responses (A–D) is correct.

**Select the correct response in each case and mark its code letter by connecting the dots as illustrated on the answer sheet.**

**1**   How many sigma bonds are there in benzene?

   A   3

   B   6

   C   12

   D   24

**2**   Which compound has the highest boiling point?

   A   Methanal

   B   Methanol

   C   Methanoic acid

   D   Methyl methanoate

**3**   Which reagent will distinguish between the molecules $C_6H_5CHO$ and $C_6H_5COCH_3$?

   A   Aqueous bromine

   B   Aqueous diammine silver(I) ions

   C   Lithium tetrahydridoaluminate(III)

   D   Sodium

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**4** The following reaction is an intermediate stage in the manufacture of the polymer perspex.

$$CH_3COCH_3 \quad + \quad HCN \quad \rightarrow \quad CH_3C(OH)(CN)CH_3$$
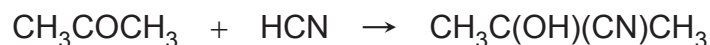
What type of reaction is this?

A Electrophilic addition

B Nucleophilic addition

C Nucleophilic substitution

D Radical substitution

**5** For which compound is it possible to construct a Born–Haber cycle?

A Boron trichloride

B Hydrogen chloride

C Lead(II) chloride

D Phosphorus(III) chloride

**6** What is the name of the $NO_2^+$ ion?

A Nitrate cation

B Nitrite cation

C Nitronium ion

D Nitrosonium ion

**[Turn over**

12201

**7** What is the percentage of carbon in dimethylbenzene?

A 88.9 %

B 89.7 %

C 90.3 %

D 90.6 %

**8** Vegetable oils are hardened to

A convert to unsaturated fats.

B increase the melting temperature.

C prevent oxidation.

D reduce viscosity.

**9** What is the conjugate base of the acid $HCO_3^-$?

A $CO_3^-$

B $CO_3^{2-}$

C $H_2CO_3$

D $OH^-$

**10** Which pair of reactants would produce the ester $C_3H_7CO_2C_2H_5$?

A $C_2H_5Cl$ and $C_3H_7CO_2H$

B $C_3H_7OH$ and $C_2H_5COCl$

C $C_2H_5OH$ and $C_3H_7COCl$

D $C_3H_7Cl$ and $C_2H_5CO_2H$

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**(Questions continue overleaf)**

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## Section B

Answer **all eleven** questions in this section

**11** The splitting of water into hydrogen and oxygen becomes feasible at 5440 K.

$$H_2O(g) \longrightarrow H_2(g) + \frac{1}{2}O_2(g)$$
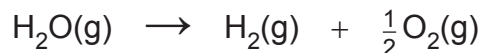
| molecule | $H_2O(g)$ | $H_2(g)$ | $O_2(g)$ |
|---|---|---|---|
| **S /J K$^{-1}$ mol$^{-1}$** | 189 | 131 | 205 |

**(a)** Define the term **entropy**.

_____

_____ [1]

**(b)** Using the data in the table, calculate the molar entropy change for this reaction.

_____

_____

_____ [1]

**(c)** Suggest, and explain, the effect upon the entropy change if liquid water was split instead of gaseous water.

_____

_____

_____ [2]

12201

**(d)** Define the term **feasible**.

_____

_____ [1]

**(e)** Calculate the value for the molar enthalpy change for the splitting of gaseous water at 5440 K.

_____

_____ [2]

*28ACH1207*

**12** In 1931 Moelwyn-Hughes and Hinshelwood monitored the decarboxylation of the strong acid **A**:



**A**
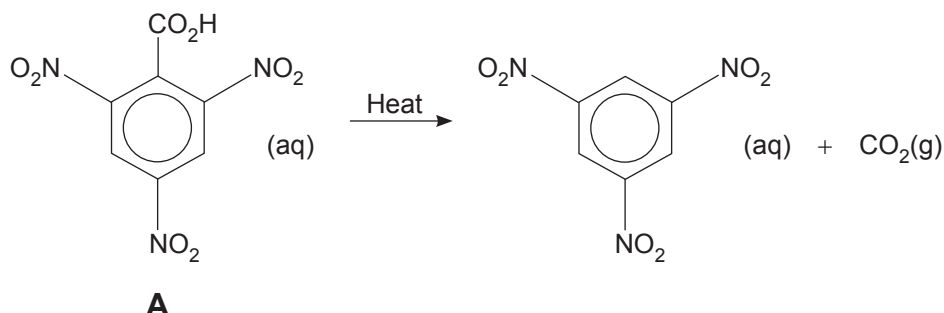
**(a) (i)** Suggest an IUPAC name for the organic product.

_____ [1]

**(ii)** Moelwyn-Hughes and Hinshelwood followed the kinetics of the reaction by titration. Explain how they could have determined the rate of reaction. Include in your answer the names of an alkali and an indicator which could be used. Indicate what steps and graphs would be needed to determine the order of reaction with respect to **A**.

**In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.**

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ [6]

**(b)** Moelwyn-Hughes and Hinshelwood obtained the following data from their experiments.

| experiment | $[A] \times 10^{-4}$/ mol dm$^{-3}$ | initial rate $\times 10^{-6}$/ mol dm$^{-3}$min$^{-1}$ |
|---|---|---|
| 1 | 2.50 | 2.40 |
| 2 | 1.67 | 1.64 |
| 3 | 1.04 | 1.02 |

**(i)** State the order of the reaction.

_____ [1]

**(ii)** Using the results from experiment 1 calculate the rate constant, stating its units.

_____

_____ [2]

**(iii)** Explain why the rate constant would increase if the experiment was repeated at a higher temperature.

_____

_____ [1]

**[Turn over**

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**13** Thalidomide was first marketed in 1957 as a sedative to reduce morning sickness during pregnancy. It contains a chiral centre and exists as two optical isomers.
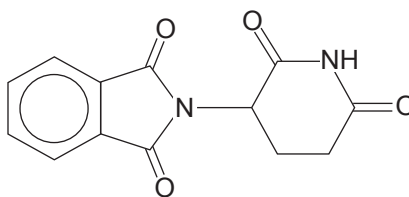


thalidomide

**(a)** Circle the chiral centre in the structure above. [1]

**(b)** Define the term **optical isomers**.

_____

_____ [1]

**(c)** The original use of thalidomide led to babies being born with deformed limbs. It was found that one optical isomer of thalidomide caused these birth defects. Suggest how the drug action may be determined by the stereochemistry of the drug.

_____

_____ [1]

**(d)** Thalidomide, in the sedative, was used as a racemic mixture. Define the term **racemic mixture** and explain why a racemic mixture would be optically inactive.

_____

_____

_____ [2]

12201

14 The titration curve for a strong acid with a strong alkali can be determined by measuring pH using specialised pH paper or a pH meter.

**(a)** Suggest an advantage and a disadvantage of using the pH meter compared to pH paper.

_____

_____

_____

_____ [2]

**(b)** Explain, using your knowledge of titration curves, why both methyl orange and phenolphthalein are suitable indicators for this titration.

_____

_____ [1]

**(c)** Explain whether the salt solution formed from the reaction between sulfuric acid and sodium hydroxide is neutral or not.

_____

_____ [1]

**[Turn over**

**15** The ester tripalmitin can be used to make biodiesel using transesterification. Tripalmitin is formed when glycerol reacts with palmitic acid.

$$CH_2OCOC_{15}H_{31}$$
$$|$$
$$CHOCOC_{15}H_{31}$$
$$|$$
$$CH_2OCOC_{15}H_{31}$$
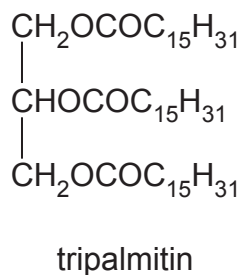
tripalmitin

**(a)** Write an equation for the formation of tripalmitin from glycerol and palmitic acid.

[2]

**(b)** Use the structure of tripalmitin to explain whether tripalmitin is a saturated or unsaturated fat.

[2]

**(c)** Explain the term **transesterification**.

[2]

12201

*28ACH1212*

**(d)** Write the equation for the reaction between tripalmitin and methanol forming molecules, some of which are used in biodiesel.

[1]

**(e)** From the equation written in **(d)**, write the formula of the product that could be used as biodiesel.

[1]

**[Turn over**

12201

*28ACH1213*

**16** Benzene is used to synthesise the analgesic, ibuprofen. This occurs using a multi-step reaction involving both Friedel–Crafts acylation and alkylation.
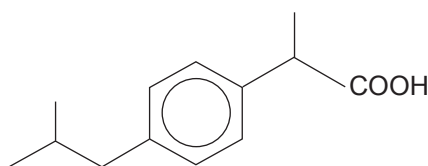
ibuprofen

**(a)** The first step in this reaction is the acylation of benzene with 2-methylpropanoyl chloride. The structure of 2-methylpropanoyl chloride is shown below.
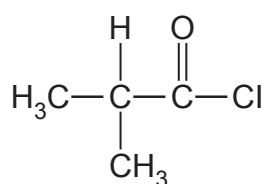
2-methylpropanoyl chloride

Show the mechanism for the catalysed reaction between 2-methylpropanoyl chloride and benzene, using aluminium chloride as a catalyst.

[5]

**(b)** Draw a dot and cross diagram for the aluminium-containing intermediate species formed by the catalyst during this reaction.

[1]

**(c)** A later step in the synthesis is shown below.
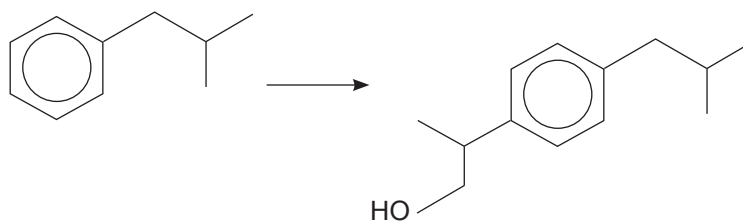


Suggest the structure of the organic reagent used for the step shown.

[1]

**(d)** The acylation and alkylation reactions of benzene are substitution reactions. Explain why benzene undergoes substitution reactions rather than addition reactions.

_____

_____ [1]

**[Turn over**

12201

**17** The dissociation of water is an endothermic process. At 60 °C the ionic product of water, $K_w$, has a value of $9.3 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$.

$$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$
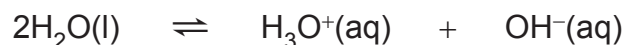
**(a) (i)** Write the expression for $K_w$.

_____ [1]

**(ii)** Explain why the expression for $K_w$ does not include the concentration of water.

_____

_____ [1]

**(b) (i)** Calculate the pH of water at 60 °C. Give your answer to two decimal places.

_____

_____

_____ [2]

**(ii)** Explain whether water at 60 °C is neutral, acidic or alkaline.

_____

_____ [2]

*28ACH1216*

**(iii)** Calculate the pH of a solution containing 256.5 g of barium hydroxide dissolved in 500 cm$^3$ of water at 60 °C. Give your answer to two decimal places.

_____

_____

_____

_____

_____ [4]

**(c) (i)** An acidic buffer is formed when 10.0 cm$^3$ of 0.12 mol dm$^{-3}$ aqueous sodium hydroxide is added to 25.0 cm$^3$ of 0.18 mol dm$^{-3}$ ethanoic acid. Calculate the pH of this buffer. The pK$_a$ of ethanoic acid is 4.76. Give your answer to two decimal places.

_____

_____

_____

_____

_____

_____

_____ [4]

**(ii)** Explain, using an equation, the effect of adding small amounts of acid to the buffer.

_____

_____ [2]

**[Turn over**

12201

*28ACH1217*

**18** Sulfur dioxide is reacted with oxygen to form sulfur trioxide in the manufacture of sulfuric acid in the Contact Process.

$$2SO_2(g) \quad + \quad O_2(g) \quad \rightleftharpoons \quad 2SO_3(g) \quad -197\,kJ$$

**(a)** State the pressure and catalyst used in this reaction.

_____

_____ **[2]**

**(b)** Explain why the temperature chosen for this reaction, 450 °C, can be described as a compromise temperature.

_____

_____

_____

_____ **[2]**

**(c)** Write an expression for $K_c$ for the above reaction.

**[1]**

12201

**(d)** Sulfur dioxide, oxygen and sulfur trioxide were mixed and allowed to reach equilibrium in a 20 dm$^3$ container. At equilibrium, 8.0 moles of sulfur dioxide and 10.0 moles of sulfur trioxide were present. Calculate the number of moles of oxygen present if the numerical value of K$_c$ is 27.9 mol$^{-1}$ dm$^3$.

_____

_____

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_____

_____ [4]

**[Turn over**

12201

**19** The lattice enthalpy of magnesium chloride is 2493 kJ mol$^{-1}$ and that of calcium chloride is 2237 kJ mol$^{-1}$.

**(a) (i)** Write an equation, including state symbols, for the lattice enthalpy of calcium chloride.

_____ [2]

**(ii)** Explain why the lattice enthalpy of magnesium chloride is greater than that of calcium chloride.

_____

_____ [1]

**(b) (i)** The enthalpy of solution of magnesium chloride is $-155$ kJ mol$^{-1}$. Complete the following enthalpy diagram for dissolving magnesium chloride.



MgCl$_2$(s)

[2]
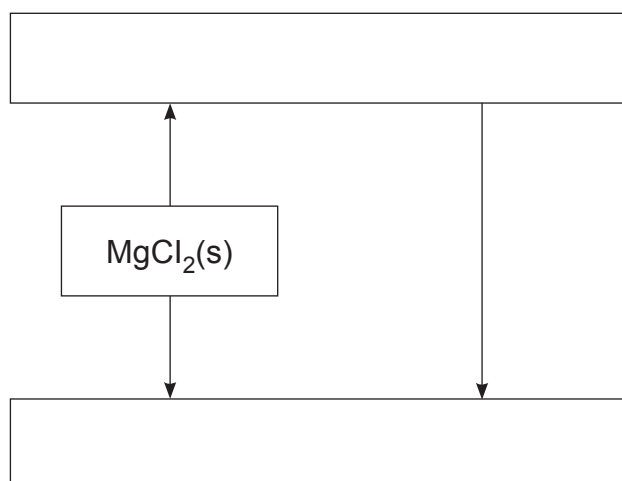
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*28ACH1220*

**(ii)** Calculate the enthalpy of hydration of magnesium ions. The enthalpy of hydration of chloride ions is $-364\,kJ\,mol^{-1}$.

_____

_____

_____ [2]

**20** Cinnamaldehyde is a pale yellow liquid that can be obtained from the bark of cinnamon trees.

$$H_5C_6 \diagdown \underset{H}{C} = \underset{CHO}{C} \diagup H$$
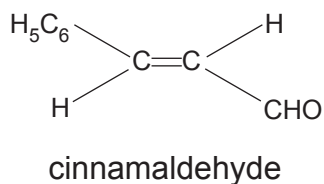
cinnamaldehyde

**(a) (i)** Cinnamaldehyde is a geometric isomer. State and explain which geometric isomer cinnamaldehyde is.

_____

_____ [2]

**(ii)** Explain how a pale yellow oil suspected as being cinnamaldehyde, could be identified using 2,4-dinitrophenylhydrazine. Include in your answer experimental details of the preparation of cinnamaldehyde-2,4-dinitrophenylhydrazone.

**In this question you will be assessed on using your written communication skills including the use of specialist scientific terms.**

_____

_____

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_____

12201

_____

_____

_____ [6]

**(b)** Write an equation for the reduction of cinnamaldehyde with lithal using [H] to represent the reducing agent.

_____ [1]

**(c)** Oxidation of cinnamaldehyde produces cinnamic acid which is a solid at room temperature with a melting point of 132–133 °C. Explain why cinnamic acid has a higher melting point than cinnamaldehyde.

_____

_____

_____

_____ [3]

**[Turn over**

12201

*28ACH1223*

**21** Ethanoyl chloride can be used in the preparation of esters. It reacts readily with moisture in the air.

**(a)** Write an equation for the reaction of ethanoyl chloride with water.

_____ [1]

**(b)** Describe a chemical test for the inorganic product of the reaction, indicating a positive result for this test.

_____

_____ [2]

**(c) (i)** Write an equation for the reaction of excess ethanoyl chloride with ethane-1,2-diol to produce an ester.

[2]

**(ii)** Calculate the percentage yield if 31 g of ethane-1,2-diol produces 49 g of the ester.

_____

_____

_____ [3]

12201

**(d)** State **three** advantages of using ethanoyl chloride instead of ethanoic acid in esterification reactions.

_____

_____

_____ [3]

**(e)** Give the formula and the IUPAC name of a reagent that could convert ethanoic acid into ethanoyl chloride.

_____ [2]

## THIS IS THE END OF THE QUESTION PAPER

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*28ACH1228*

## General Information

1 tonne = $10^6$ g

1 metre = $10^9$ nm

One mole of any gas at 293 K and a pressure of 1 atmosphere ($10^5$ Pa) occupies a volume of 24 dm³

Avogadro Constant = $6.02 \times 10^{23}$ mol⁻¹

Planck Constant = $6.63 \times 10^{-34}$ J s

Specific Heat Capacity of water = 4.2 J g⁻¹ K⁻¹

Speed of Light = $3 \times 10^8$ m s⁻¹

## Characteristic absorptions in IR spectroscopy

| Wavenumber/cm⁻¹ | Bond | Compound |
|---|---|---|
| 550–850 | C–X (X = Cl, Br, I) | Haloalkanes |
| 750–1100 | C–C | Alkanes, alkyl groups |
| 1000–1300 | C–O | Alcohols, esters, carboxylic acids |
| 1450–1650 | C=C | Arenes |
| 1600–1700 | C=C | Alkenes |
| 1650–1800 | C=O | Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides |
| 2200–2300 | C≡N | Nitriles |
| 2500–3200 | O–H | Carboxylic acids |
| 2750–2850 | C–H | Aldehydes |
| 2850–3000 | C–H | Alkanes, alkyl groups, alkenes, arenes |
| 3200–3600 | O–H | Alcohols |
| 3300–3500 | N–H | Amines, amides |

## Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

| Chemical Shift | Structure | |
|---|---|---|
| 0.5–2.0 | –C**H** | Saturated alkanes |
| 0.5–5.5 | –O**H** | Alcohols |
| 1.0–3.0 | –N**H** | Amines |
| 2.0–3.0 | –CO–C**H** | Ketones |
| | –N–C**H** | Amines |
| | $C_6H_5$–C**H** | Arene (aliphatic on ring) |
| 2.0–4.0 | X–C**H** | X = Cl or Br (3.0–4.0) |
| | | X = I (2.0–3.0) |
| 4.5–6.0 | –C=C**H** | Alkenes |
| 5.5–8.5 | RCON**H** | Amides |
| 6.0–8.0 | –C₆**H**₅ | Arenes (on ring) |
| 9.0–10.0 | –C**H**O | Aldehydes |
| 10.0–12.0 | –COO**H** | Carboxylic acids |

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

# Data Leaflet
## Including the Periodic Table of the Elements

For the use of candidates taking Advanced Subsidiary and Advanced Level Examinations

**Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations**

# gce a/as examinations
# chemistry

For first teaching from September 2016
For first award of AS Level in Summer 2017
For first award of A Level in Summer 2018
Subject Code: 1110

Rewarding Learning

# THE PERIODIC TABLE OF ELEMENTS
## Group

| I | II | | | | | | | | | | | III | IV | V | VI | VII | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1 **H** Hydrogen 1 | | | | | | | | | | | | | | | | | 4 **He** Helium 2 |
| 7 **Li** Lithium 3 | 9 **Be** Beryllium 4 | | | | | | | | | | | 11 **B** Boron 5 | 12 **C** Carbon 6 | 14 **N** Nitrogen 7 | 16 **O** Oxygen 8 | 19 **F** Fluorine 9 | 20 **Ne** Neon 10 |
| 23 **Na** Sodium 11 | 24 **Mg** Magnesium 12 | | | | | | | | | | | 27 **Al** Aluminium 13 | 28 **Si** Silicon 14 | 31 **P** Phosphorus 15 | 32 **S** Sulfur 16 | 35.5 **Cl** Chlorine 17 | 40 **Ar** Argon 18 |
| 39 **K** Potassium 19 | 40 **Ca** Calcium 20 | 45 **Sc** Scandium 21 | 48 **Ti** Titanium 22 | 51 **V** Vanadium 23 | 52 **Cr** Chromium 24 | 55 **Mn** Manganese 25 | 56 **Fe** Iron 26 | 59 **Co** Cobalt 27 | 59 **Ni** Nickel 28 | 64 **Cu** Copper 29 | 65 **Zn** Zinc 30 | 70 **Ga** Gallium 31 | 73 **Ge** Germanium 32 | 75 **As** Arsenic 33 | 79 **Se** Selenium 34 | 80 **Br** Bromine 35 | 84 **Kr** Krypton 36 |
| 85 **Rb** Rubidium 37 | 88 **Sr** Strontium 38 | 89 **Y** Yttrium 39 | 91 **Zr** Zirconium 40 | 93 **Nb** Niobium 41 | 96 **Mo** Molybdenum 42 | 98 **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 |
| 133 **Cs** Caesium 55 | 137 **Ba** Barium 56 | 139 **La*** Lanthanum 57 | 178 **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 |
| 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** Darmstadtium 110 | 272 **Rg** Roentgenium 111 | 285 **Cn** Copernicium 112 | | | | | | |

| 140 **Ce** Cerium 58 | 141 **Pr** Praseodymium 59 | 144 **Nd** Neodymium 60 | 145 **Pm** Promethium 61 | 150 **Sm** Samarium 62 | 152 **Eu** Europium 63 | 157 **Gd** Gadolinium 64 | 159 **Tb** Terbium 65 | 162 **Dy** Dysprosium 66 | 165 **Ho** Holmium 67 | 167 **Er** Erbium 68 | 169 **Tm** Thulium 69 | 173 **Yb** Ytterbium 70 | 175 **Lu** Lutetium 71 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

\* 58 – 71   Lanthanum series
† 90 – 103  Actinium series

**a** = relative atomic mass (approx)
**x** = atomic symbol
**b** = atomic number