Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Monday 19 June 2023

Afternoon (Time: 1 hour 45 minutes)

Paper reference **9CH0/02**

Chemistry

Advanced
PAPER 2: Advanced Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over

Pearson

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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 question is about some organic compounds.

(a) Draw the **skeletal** formula of 1,3-dimethylcyclohexane.

(1)

(b) What is the general formula for a **cycloalkene**?

(1)

☐ **A** C_nH_{2n-2}

☐ **B** C_nH_{2n}

☐ **C** C_nH_{2n+1}

☐ **D** C_nH_{2n+2}

(c) A student is asked to devise a laboratory synthesis of 1,2-dichloroethane. The student suggests reacting ethane with chlorine in the presence of ultraviolet radiation.

Give **two** reasons why this is not a good method to prepare 1,2-dichloroethane.

(2)

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(Total for Question 1 = 4 marks)

2 This question is about alcohols.

(a) Ethanol is a fuel and can be made by either the fermentation of carbohydrates or the hydration of ethene.

How is the ethanol formed by the fermentation of carbohydrates classified?

(1)

☒ **A** a biofuel and non-renewable

☒ **B** a biofuel and renewable

☒ **C** a fossil fuel and non-renewable

☒ **D** a fossil fuel and renewable

(b) Write the equation for the complete combustion of methanol.
State symbols are not required.

(1)

(c) Identify, by name or formula, the reagent(s) needed to convert propan-1-ol into 1-iodopropane.

(1)

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(d) A sample of pure propan-2-ol is analysed using infrared and ^{13}C NMR spectroscopy.

(i) Which of these sets of wavenumber ranges, in cm^{-1}, will be seen in the infrared spectrum of propan-2-ol?

(1)

☒ **A** 1485 – 1365, 2962 – 2853 and 3300 – 2500

☒ **B** 1485 – 1365, 2962 – 2853 and 3750 – 3200

☒ **C** 1669 – 1645, 2962 – 2853 and 3750 – 3200

☒ **D** 1740 – 1720, 3300 – 2500 and 3750 – 3200

(ii) State the number of peaks in the ^{13}C NMR spectrum of propan-2-ol.

(1)

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(e) The equation for the oxidation of ethanol by acidified dichromate(VI) ions is shown.

$$3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

Deduce the half-equation for the oxidation of ethanol to ethanoic acid.
State symbols are not required.

(1)

(Total for Question 2 = 6 marks)

3 This question is about the molar masses of three organic compounds, **X**, **Y** and **Z**.

(a) The accurate relative atomic masses, A_r, of four of the elements that could be present in an organic compound are shown.

Element	A_r
hydrogen, H	1.0078
carbon, C	12.0000
nitrogen, N	14.0031
oxygen, O	15.9949

The mass spectrum of organic compound **X** gives a molecular ion peak at $m/z = 60.0323$

What is compound **X**?

(1)

☒ **A** ethanamide, CH_3CONH_2

☒ **B** ethanoic acid, CH_3COOH

☒ **C** trimethylamine, $(CH_3)_3N$

☒ **D** urea, $CO(NH_2)_2$

(b) 9.90 g of a gaseous organic compound, **Y**, occupies a volume of 5.40 dm^3 at room temperature and pressure (r.t.p.).

Calculate the molar mass of the compound **Y**.

[molar gas volume at r.t.p. = 24.0 $dm^3 mol^{-1}$]

(2)

(c) A quantity of a volatile organic liquid, **Z**, is placed in a 60.0 cm^3 flask and heated to 95.0°C. When all the liquid has vaporised, the flask is sealed.

Mass of vapour = 0.170 g

Pressure = 100.6 kPa

Gas constant (*R*) = 8.31 J mol^{-1} K^{-1}

Calculate the molar mass of compound **Z**, giving your answer to an appropriate number of significant figures.
Assume there was no air left in the flask once the liquid **Z** had vaporised.

(4)

(Total for Question 3 = 7 marks)

4 This question is about some hydrocarbons.

(a) A 2.50 g sample of a hydrocarbon gave 7.59 g of carbon dioxide on complete oxidation.

Calculate the empirical formula of the hydrocarbon.

(4)

(b) Benzene and ethene react with bromine under different conditions but both reactions involve an electrophile.

(i) An electrophile is a substance that

(1)

☒ **A** accepts a pair of electrons

☒ **B** accepts an unpaired electron

☒ **C** donates a pair of electrons

☒ **D** donates an unpaired electron

(ii) Explain why benzene is resistant to bromination but ethene reacts readily with bromine at room temperature.

(4)

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(Total for Question 4 = 9 marks)

5 Nitrogen monoxide reacts with oxygen to form nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The rate is proportional to the concentration of oxygen and to the square of the concentration of nitrogen monoxide.

(a) The rate of this reaction can be determined by measuring the change in the total gas pressure.

(i) Give a reason why this method can be used in this reaction.

(1)

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(ii) State **two** factors, other than initial amounts of reactants, that must be kept constant for this method to work.

(1)

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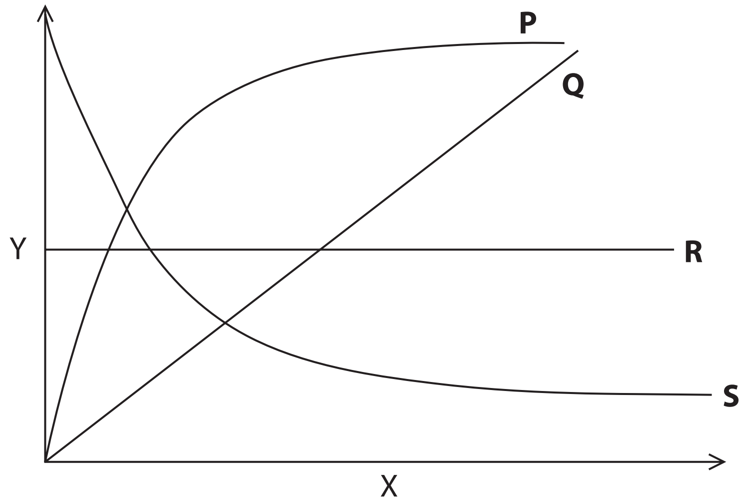
(b) The graph shows four lines of a quantity Y plotted against a quantity X.



(i) Which line shows the relationship between the concentration of nitrogen monoxide (Y) and time (X)?

(1)

☒ **A** line **P**

☒ **B** line **Q**

☒ **C** line **R**

☒ **D** line **S**

(ii) Which line shows the relationship between rate (Y) and concentration of oxygen (X)?

(1)

☒ **A** line **P**

☒ **B** line **Q**

☒ **C** line **R**

☒ **D** line **S**

(c) The rate of this reaction is z mol dm^{-3} s^{-1} under certain conditions.

The concentration of nitrogen monoxide is doubled and the concentration of oxygen is halved. All other conditions remain the same.

What will be the new rate of reaction in mol dm^{-3} s^{-1}?

(1)

☒ **A** $z/2$

☒ **B** z

☒ **C** $2z$

☒ **D** $4z$

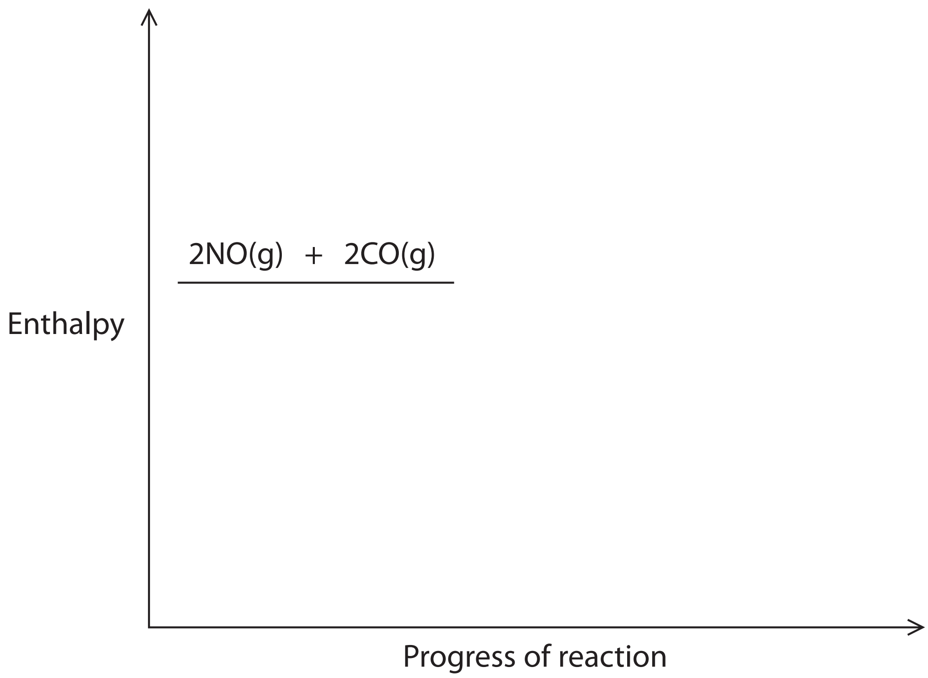
(d) Nitrogen monoxide is formed in car engines. It is removed by the catalytic converter in the car exhaust.

$$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g)$$

The reaction is exothermic and the most active catalyst is platinum.

(i) Complete the labelled reaction profile for the **catalysed** reaction.

(3)



(ii) Catalysts, such as platinum, are very expensive.

Explain an economic benefit of using a catalyst in an industrial process.

(2)

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(Total for Question 5 = 10 marks)

6 Iodine reacts with propanone in acidic conditions.

$$I_2(aq) + CH_3COCH_3(aq) \xrightarrow{H^+(aq)} CH_3COCH_2I(aq) + H^+(aq) + I^-(aq)$$

A student was asked to investigate the kinetics of this reaction.
The student predicted that the rate equation for the reaction would be

$$\text{rate} = k[I_2(aq)][CH_3COCH_3(aq)][H^+(aq)]^0$$

because the balanced equation shows that one molecule of iodine reacts with one molecule of propanone and the acid is a catalyst.

(a) The student first determined the order of reaction with respect to iodine by keeping the concentrations of propanone and acid constant.
The student used the outline procedure shown.

- mix 25 cm^3 of aqueous propanone with 25 cm^3 of dilute sulfuric acid in a conical flask
- add 25 cm^3 of aqueous iodine, immediately start a stopwatch and swirl the mixture in the conical flask
- use a pipette to remove a 10.0 cm^3 sample of the solution and place it in a clean conical flask
- add a spatula measure of sodium hydrogencarbonate and note the exact time it is added
- take four more 10.0 cm^3 samples of the mixture and add sodium hydrogencarbonate to each of them at regular time intervals
- titrate the unreacted iodine in the samples with sodium thiosulfate solution using starch indicator.

(i) State how the student could ensure that the concentrations of propanone and acid are effectively constant throughout the experiment.

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(ii) Explain why sodium hydrogencarbonate is added.

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(b) The student obtained these results.

Time / min	5	10	15	20	25
Volume of thiosulfate / cm^3	15.0	13.8	12.6	11.4	10.2

(i) Give a reason why it is not necessary to calculate the concentration of iodine at each time to work out the order of reaction with respect to iodine.
(1)

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(ii) Plot a graph to show that the order of reaction with respect to iodine is zero.
(2)

(iii) Give a reason why the graph shows that the order of reaction with respect to iodine is zero.
(1)

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(c) Further experiments showed that the correct overall rate equation is

$$rate = k[CH_3COCH_3(aq)][H^+(aq)][I_2(aq)]^0$$

(i) Deduce a possible rate determining step in the mechanism of this reaction. Curly arrows are not required.

(2)

(ii) Data from two experiments carried out at the same temperature are shown.

Experiment	$[CH_3COCH_3(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	$[I_2(aq)]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	3.0	0.4	0.02	3.36×10^{-5}
2	4.0	0.2	0.04	

What is the rate, in mol dm^{-3} s^{-1}, in Experiment 2?

(1)

☒ **A** 2.24×10^{-5}

☒ **B** 3.36×10^{-5}

☒ **C** 4.48×10^{-5}

☒ **D** 8.96×10^{-5}

(iii) The experiment in (a) is repeated but using aqueous bromine instead of aqueous iodine. All other conditions are kept the same.

Explain how you would expect the rate of reaction of bromination of propanone to compare with the rate of iodination of propanone.

Assume that the reaction between bromine and propanone in acidic conditions has the same rate equation as that between iodine and propanone in acidic conditions.

(2)

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(Total for Question 6 = 12 marks)

7 This question is about carbonyl compounds.

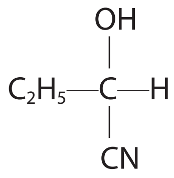
(a) Ethanal, CH_3CHO, and ethanoic acid, CH_3COOH, are both soluble in water but ethanoic acid has a much higher boiling temperature than ethanal.

Explain these physical properties of ethanal and ethanoic acid in terms of intermolecular forces.

Include a labelled diagram to show why ethanal is soluble in water.

(4)

(b) Propanal reacts with hydrogen cyanide in the presence of potassium cyanide to form 2-hydroxybutanenitrile.



(i) Draw the mechanism for this reaction.
Include curly arrows and any relevant lone pairs and dipoles.

(4)

(ii) Explain whether or not the 2-hydroxybutanenitrile formed will be a racemic mixture.

(3)

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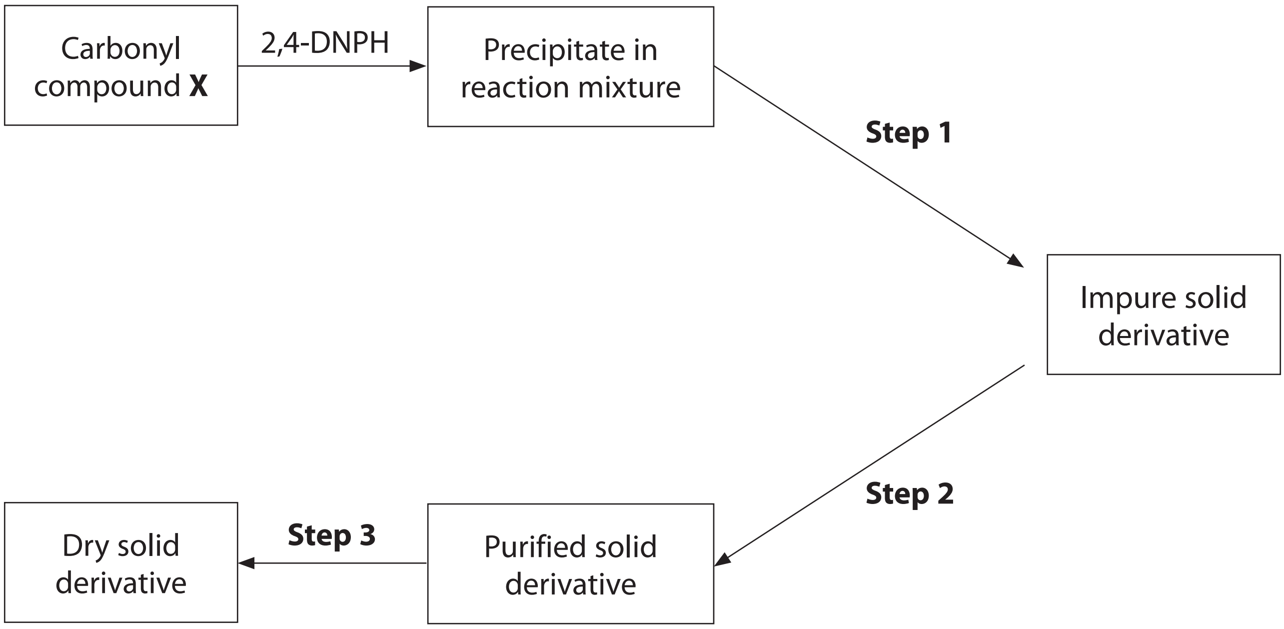
(c) Carbonyl compounds can be identified by reacting them with 2,4-dinitrophenylhydrazine (2,4-DNPH) to form a solid derivative. These derivatives have characteristic melting temperatures.

(i) Identify the steps required to prepare a sample of a pure, dry derivative of a carbonyl compound **X**.

(3)



Step 1

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Step 2

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Step 3

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(ii) The melting temperature ranges of the derivatives of some carbonyl compounds that could be **X** are shown in the table.

Carbonyl compound	Melting temperature range of derivative / °C
ethanal	165 – 168
propanal	154 – 156
propanone	127 – 129
cyclohexanone	158 – 160

The melting temperature of the derivative of carbonyl compound **X** is 156–158 °C and **X** has an absorption at 1717 cm^{-1} in its infrared spectrum.

Deduce the identity of **X**. Justify your answer.

(2)

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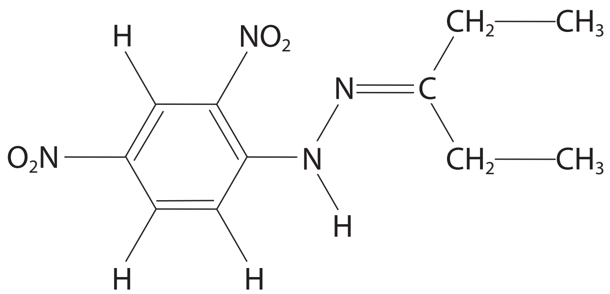
(iii) These carbonyl compounds may also be identified using modern methods such as proton NMR spectroscopy.
The structure of the pentan-3-one derivative formed with 2,4-DNPH is shown.



Label the different proton environments that would give rise to the peaks in the low resolution proton NMR spectrum.

(2)

(Total for Question 7 = 18 marks)

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8 This question is about isomerism in organic compounds.

(a) How many structural isomers are there with the formula C_5H_{12}?

(1)

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

(b) Propene reacts with bromine to form 1,2-dibromopropane as the only product.

Draw the mechanism for the reaction between propene and bromine.
Include curly arrows and any relevant lone pairs and dipoles.

(3)

(c) When propene reacts with a mixture of bromine and sodium chloride, it forms 1,2-dibromopropane, 1-bromo-2-chloropropane and 2-bromo-1-chloropropane but no 1,2-dichloropropane.

(i) Explain, by reference to your mechanism in (b), why no 1,2-dichloropropane forms.

(2)

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(ii) Explain why far more 1-bromo-2-chloropropane forms than 2-bromo-1-chloropropane.

(2)

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*(d) Discuss the different types of stereoisomerism that occur in organic compounds. Use only molecules **A** and **B** as examples.

$CHCl{=}C(CH_3)Br$ **A** $CH_3CH(OH)COOH$ **B**

Include in your answer:

- how the different types of isomerism arise
- the naming of alkenes with the formula **A**
- the properties of isomers with the formula **B**
- diagrams of the different isomers.

(6)

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(Total for Question 8 = 14 marks)

9 This question is about the analysis of some organic compounds.

(a) A compound **A** (C_3H_7Cl) reacts with dilute aqueous sodium hydroxide to produce **B** (C_3H_8O). **B** can be oxidised to **C** (C_3H_6O), which cannot be oxidised any further.

A reacts with magnesium in dry ether to give **D** (C_3H_7MgCl). When carbon dioxide is passed through the solution of **D**, followed by acidification, **E** ($C_4H_8O_2$) is formed.

Identify the structures of **A** to **E**.

(5)

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(b) An organic compound, **Q**, contains carbon, hydrogen and nitrogen only.

When a 1.19 g sample of the compound was heated with sodium hydroxide solution, all of the nitrogen was converted into ammonia. The ammonia was passed into 100.0 cm^3 of 0.225 $mol\,dm^{-3}$ hydrochloric acid.

$$NH_3(g) + HCl(aq) \rightarrow NH_4Cl(aq)$$

25.0 cm^3 portions of the resulting solution containing unreacted hydrochloric acid required a mean titre of 15.5 cm^3 of 0.100 $mol\,dm^{-3}$ sodium hydroxide for neutralisation.

Calculate the percentage of nitrogen in **Q**.

(5)

(Total for Question 9 = 10 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)											(13)	(14)	(15)	(16)	(17)	
6.9 **Li** lithium 3	9.0 **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
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** darmstadtium 110	[272] **Rg** roentgenium 111							

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

Key:

relative atomic mass **atomic symbol** name atomic (proton) number

* 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