Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Monday 8 June 2020

Afternoon (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.*

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 ▶

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P 6 2 6 6 9 A 0 1 3 2

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 question is about methanol, CH_3OH.

(a) Draw a dot-and-cross diagram to show the bonding in a molecule of methanol.
Show outer shell electrons only.

(2)

(b) Predict which bond has the shortest bond length in a molecule of methanol.

(1)

.....

(c) Methanol is soluble in water.

(i) State the strongest type of intermolecular force that occurs between molecules of methanol and water.

(1)

.....

(ii) Draw a labelled diagram to show the interaction named in (c)(i) between one molecule of methanol and one molecule of water.
Include any relevant lone pairs and dipoles in your diagram.

(3)

(Total for Question 1 = 7 marks)

2 This question is about alkenes.

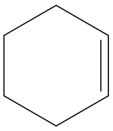
(a) Which of these has the molecular formula C_6H_{10}?

(1)

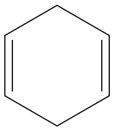
☒ **A**

☒ **B**

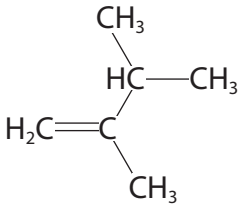
☒ **C**



☒ **D**



(b) What is the systematic name of this alkene?



(1)

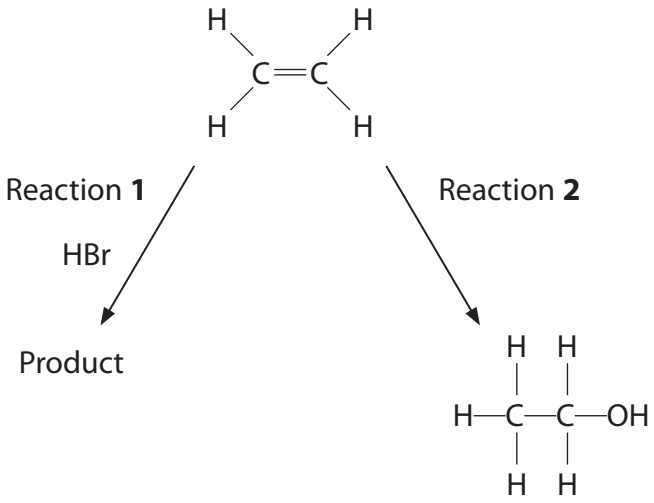
☒ **A** 2-methylpent-1-ene

☒ **B** 3-methylpent-1-ene

☒ **C** 2,3-dimethylbut-1-ene

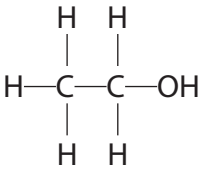
☒ **D** 2,3-dimethylbut-3-ene

(c) Two reactions of ethene are shown.

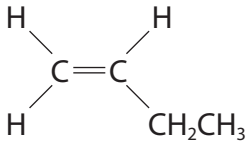


Complete the table.

(3)

Reaction	Reagent and condition	Product
1	HBr at room temperature	
2		

(d) But-1-ene has the structure



(i) Draw the structure of the polymer formed when but-1-ene polymerises.
Include **two** repeat units.

(1)

(ii) Calculate the number of molecules in 70.0 g of but-1-ene.
[Avogadro constant = 6.02×10^{23} mol^{-1}]

(2)

(Total for Question 2 = 8 marks)

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3 This question is about the compound potassium bromate, $KBrO_3$.

(a) These bromate ions react with bromide ions in acidic solution.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

(i) Explain, in terms of oxidation numbers, whether or not this is a disproportionation reaction.

(2)

(ii) What is the overall order of this reaction?

(1)

☒ **A** 3

☒ **B** 6

☒ **C** 12

☒ **D** cannot tell from this information

(b) Potassium bromate decomposes on heating.

$$2KBrO_3 \rightarrow 2KBr + 3O_2$$

Calculate the maximum volume of oxygen, in dm^3, measured at room temperature and pressure (r.t.p.), that could be produced from the complete decomposition of 5.20 g of potassium bromate.

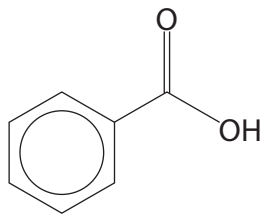
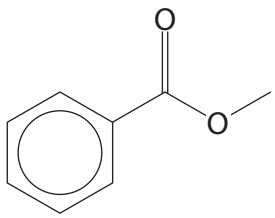
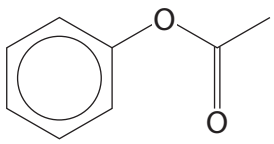
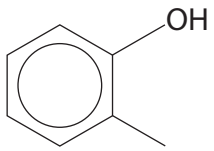
[Molar volume of gas at r.t.p. = 24.0 dm^3 mol^{-1}]

(3)

(Total for Question 3 = 6 marks)

4 This question is about the identification of some organic compounds.

(a) The skeletal formulae of four organic compounds are shown.

Compound **P** 	Compound **Q** 
Compound **R** 	Compound **S** 

(i) Which of these compounds can be hydrolysed to form methanol as one of the products?

(1)

☒ **A** Compound **P**

☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(ii) Which of these compounds produces carbon dioxide when it reacts with aqueous sodium hydrogencarbonate?

(1)

☒ **A** Compound **P**

☒ **B** Compound **Q**

☒ **C** Compound **R**

☒ **D** Compound **S**

(b) Compound **T**, $C_4H_{10}O$, is oxidised by acidified potassium dichromate(VI) to form compound **U**, C_4H_8O.

U gives an orange precipitate with 2,4-dinitrophenylhydrazine (Brady's reagent) but does **not** give a red precipitate when heated with Fehling's solution.

T reacts with ethanoyl chloride to form compound **V**, $C_6H_{12}O_2$.

Deduce the structures of compounds **T**, **U** and **V**. Justify your answers.

(6)

(Total for Question 4 = 8 marks)

5 This question is about hydrocarbons.

(a) Which of these molecular formulae represents a non-cyclic, saturated hydrocarbon?

(1)

☒ **A** C_6H_6

☒ **B** C_6H_{10}

☒ **C** C_6H_{12}

☒ **D** C_6H_{14}

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

(1)

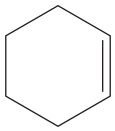
☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

(c) How many σ bonds and π bonds are there in one molecule of cyclohexene?



(1)

	σ bonds	π bonds
☒ **A**	5	2
☒ **B**	6	1
☒ **C**	15	2
☒ **D**	16	1

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(d) When hydrocarbons undergo complete combustion, there is a change in the total volume of gases.

(i) Ethane burns in excess oxygen.

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$$

All gas volumes are measured at the same temperature and pressure when water is a gas.

What is the **increase** in the total volume when 100 cm^3 of ethane is burned in excess oxygen?

(1)

☒ **A** 50 cm^3

☒ **B** 100 cm^3

☒ **C** 200 cm^3

☒ **D** 500 cm^3

(ii) A combustion experiment was carried out using conditions under which water was a liquid.

A cyclic hydrocarbon, C_xH_y, was mixed with excess oxygen and ignited. Under the conditions of the experiment, this hydrocarbon was gaseous and had a volume of 25 cm^3.

The equation for the complete combustion of C_xH_y is

$$C_xH_y(g) + (x + \frac{y}{4})O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

The total gas volume **decreased** by 75 cm^3.
The remaining gases were shaken with aqueous sodium hydroxide and the total gas volume **decreased** by a further 125 cm^3.

All gas volumes were measured at the same temperature and pressure.

Suggest the identity of the cyclic hydrocarbon by calculating the molecular formula of C_xH_y.
Include the **skeletal formula** of the cyclic hydrocarbon.

(3)

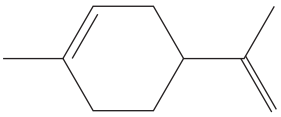
(e) Propene reacts with iodine monochloride, ICl, by an electrophilic addition mechanism.

Draw the mechanism for the reaction between propene and iodine monochloride to form the **major** product.

Include the dipole on the ICl molecule, curly arrows and any relevant lone pairs of electrons.

(4)

(f) Limonene is obtained from the oil in lemon peel and it is the only alkene present.



0.500 g of the oil reacted with exactly 30.6 cm^3 of a solution of bromine dissolved in cyclohexane with a concentration of 0.200 mol dm^{-3}.

Calculate the percentage by mass of limonene in the oil.
Give your answer to an appropriate number of significant figures.

Assume that there is nothing else in the oil that reacts with bromine.

(4)

(Total for Question 5 = 15 marks)

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6 A bromoalkane, RBr, reacts with aqueous hydroxide ions in a nucleophilic substitution reaction.

$$RBr + OH^- \rightarrow R{-}OH + Br^-$$

This reaction is first order with respect to the bromoalkane and the rate equation is

$$\text{rate} = k[RBr]^1[OH^-]^x$$

where x is the order of the reaction with respect to hydroxide ions.

In an experiment, a sample of the bromoalkane was added to a large excess of aqueous sodium hydroxide and the concentration of the bromoalkane was determined at regular time intervals.

Results

Time / s	[RBr] / mol dm^{-3}
0	0.100
30	0.065
60	0.042
90	0.028
120	0.019
150	0.014

(a) This experiment is carried out using the bromoalkane dissolved in ethanol and the hydroxide ions dissolved in water.

Give a reason why a solution of hydroxide ions dissolved in pure ethanol should **not** be used.

(1)

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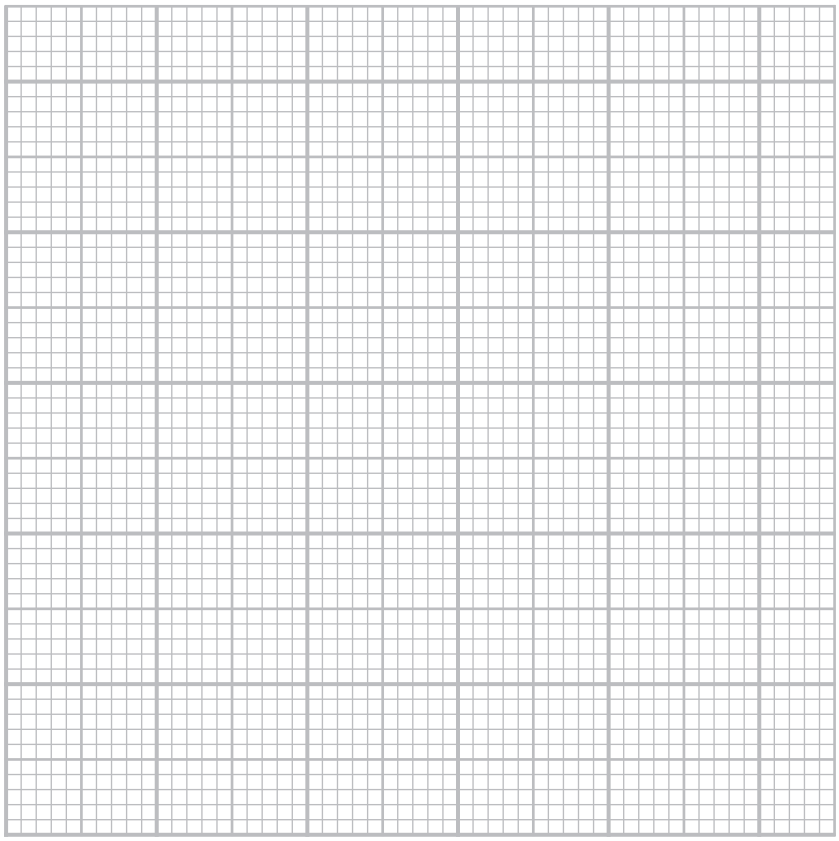
(b) Plot a graph of [RBr] against time.

(3)



(c) Explain how the graph shows that the reaction is first order with respect to RBr. Include the values of two consecutive half-lives.

You **must** show your working for the half-lives on the graph.

(2)

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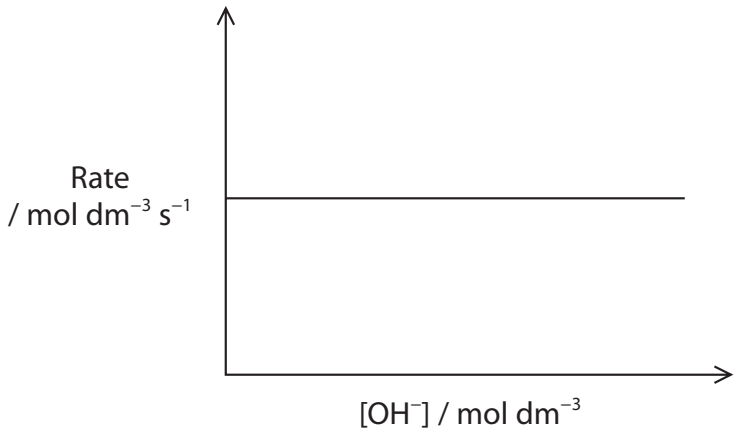
(d) The experiment was repeated using equal concentrations of RBr and varying the concentration of hydroxide ions.

A graph was plotted of the results.



(i) Deduce the value of x in the rate equation.

$$\text{rate} = k[\text{RBr}]^1[\text{OH}^-]^x$$

(1)

.....

(ii) Give the mechanism for the reaction that is consistent with the orders of reaction with respect to R—Br and hydroxide ions.
Include curly arrows and relevant lone pairs.

(3)

(e) 2-bromobutane can react with aqueous hydroxide ions by an S_N1 mechanism.

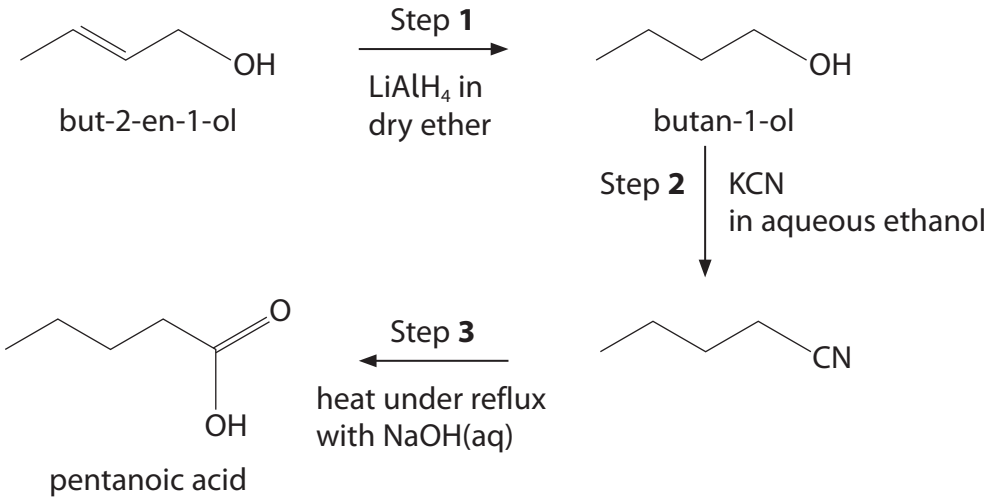
Explain why the butan-2-ol produced from a single optical isomer of 2-bromobutane, using this mechanism, is **not** optically active.

(3)

(Total for Question 6 = 13 marks)

7 This question is about the synthesis of organic compounds.

(a) A student suggested the following plan for the synthesis of pentanoic acid from but-2-en-1-ol.



(i) $LiAlH_4$ is a source of hydride ions, H^-.

Give a possible reason why $LiAlH_4$ cannot be used to reduce alkenes.

(1)

(ii) Give a suitable reagent and condition for Step **1**.

(2)

(iii) Step **2** is incorrect because alcohols can only be converted to nitriles via an intermediate compound.
Identify a suitable intermediate compound by name or formula.

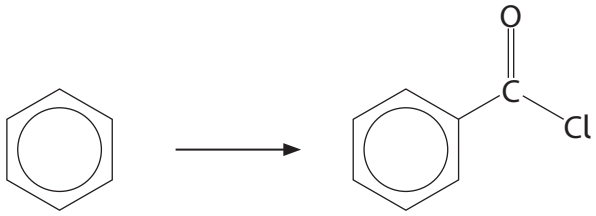
(1)

(iv) Step **3** involves the hydrolysis of a nitrile.

Give the additional reagent that should be added after heating under reflux with aqueous sodium hydroxide, to produce pentanoic acid.

(1)

(b) Devise a four-step synthesis, involving the use of a Grignard reagent, to convert benzene into benzoyl chloride.



Include the reagents and conditions for each step in the synthesis and the structures of the intermediates.

(7)

(Total for Question 7 = 12 marks)

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8 This question is about the analysis of organic compounds.

(a) **X** is an organic compound.

(i) The accurate relative atomic masses, A_r, of the four elements that could make up **X** are shown in the table.

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

X gives a molecular ion peak at $m/z = 100.0522$ on its mass spectrum.

Which is the molecular formula of **X**?

(1)

☒ **A** C_7H_{16}

☒ **B** $C_6H_{12}O$

☒ **C** $C_6H_{14}N$

☒ **D** $C_5H_8O_2$

(ii) The infrared spectrum of **X** contains major absorption wavenumber ranges at 3300–2500 cm^{-1}, 1725–1700 cm^{-1} and 1669–1645 cm^{-1}.

Identify the two functional groups in **X**.

(2)

.....

.....

(iii) **X** has an unbranched carbon chain and does **not** exhibit geometric isomerism.

Draw the **skeletal formula** of **X**.

(1)

*(b) There are similarities and differences in the ^{13}C NMR spectra and the high resolution ^{1}H NMR spectra of isomeric organic compounds.

Compare the NMR spectra of propan-1-ol with those of propan-2-ol.

Include the number of peaks, relative peak areas and splitting patterns, where appropriate.

Chemical shift values are **not** required.

(6)

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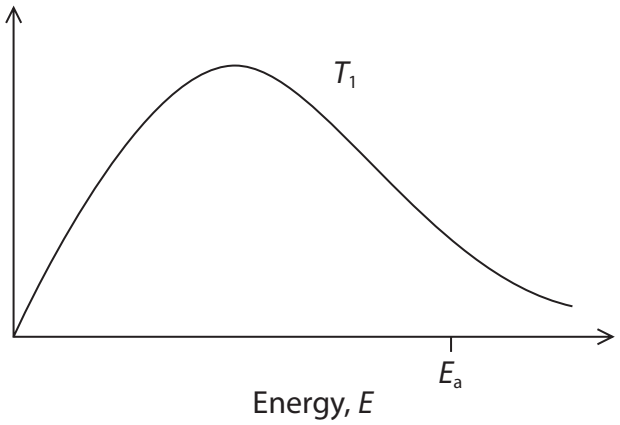
(Total for Question 8 = 10 marks)

9 This question is about the effect of temperature on the rate of decomposition of nitrogen(V) oxide.

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

(a) The diagram shows the Maxwell-Boltzmann distribution of molecular energies for nitrogen(V) oxide at a temperature T_1.

E_a is the activation energy of this reaction.



(i) Give the label for the vertical axis.

(1)

.....

(ii) Draw a second curve on the same set of axes for the same gas at a **lower** temperature, T_2.

(2)

(iii) Explain, in terms of collisions and energy, why lowering the temperature decreases the rate of reaction.

(2)

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.....

.....

(iv) A catalyst is added to the gas.

Label the diagram above with the symbol E_{cat} to show a possible activation energy for the reaction in the presence of a catalyst.

(1)

(b) The rate constant for the decomposition of nitrogen(V) oxide was determined at two temperatures.

Temperature / K	Rate constant / s^{-1}
328	1.50×10^{-3}
338	4.87×10^{-3}

Calculate the activation energy for this reaction.

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

You should **not** attempt to use any graphical method to answer this question.

The Arrhenius equation relating two rate constants, k_1 and k_2, at two different temperatures, T_1 and T_2, can be expressed as

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

(5)

(Total for Question 9 = 11 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										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 atomic symbol name 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)	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

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
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

* Lanthanide series

* Actinide series