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Candidate surname		Other names	
<b>Pearson Edexcel</b> <b>Level 3 GCE</b>		Centre Number	Candidate Number
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<b>Tuesday 11 June 2019</b>			
Afternoon (Time: 1 hour 45 minutes)		Paper Reference <b>9CH0/02</b>	
<b>Chemistry</b> <b>Advanced</b> <b>Paper 2: Advanced Organic and Physical Chemistry</b>			
<b>Candidates must have: Scientific calculator</b> <b>Data Booklet</b> <b>Ruler</b>			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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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 This question is about some reactions of alcohols.

(a) (i) Which alcohol **cannot** be oxidised by acidified potassium dichromate(VI)?

(1)

- ☐ A hexan-2-ol
- ☐ B 2-methylpentan-2-ol
- ☐ C hexan-3-ol
- ☐ D 2-methylpentan-3-ol

(ii) Which alcohol reacts with iodine in the presence of alkali to form a yellow solid?

(1)

- ☐ A hexan-2-ol
- ☐ B 2-methylpentan-2-ol
- ☐ C hexan-3-ol
- ☐ D 2-methylpentan-3-ol

(b) Which reagent is used with iodine to prepare iodoalkanes from alcohols?

(1)

- ☐ A red phosphorus
- ☐ B concentrated phosphoric acid
- ☐ C sulfur
- ☐ D concentrated sulfuric acid

(Total for Question 1 = 3 marks)

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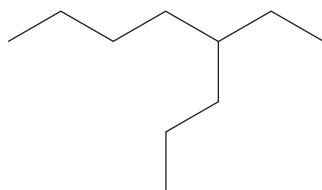
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2 This question is about alkanes and their reactions.

(a) What is the IUPAC name for this alkane?



(1)

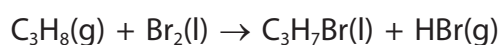
- ☐ A 4-ethyloctane
- ☐ B 5-ethyloctane
- ☐ C 3-propylheptane
- ☐ D 5-propylheptane

(b) What is the name of the process that could be used to produce propane,  $C_3H_8$ , from decane,  $C_{10}H_{22}$ ?

(1)

- ☐ A substitution
- ☐ B reforming
- ☐ C fractional distillation
- ☐ D cracking

(c) A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.



(i) The first step of the reaction involves

(1)

- ☐ A heterolytic bond fission to form free radicals
- ☐ B heterolytic bond fission to form ions
- ☐ C homolytic bond fission to form free radicals
- ☐ D homolytic bond fission to form ions

- (ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (c).

(2)

- (iii) A source from the internet gave the percentage yield for this reaction as 31.0%. The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

- ☐ **A** bromine is very unreactive
- ☐ **B** a gaseous reactant always gives a low yield
- ☐ **C** the reaction is very slow
- ☐ **D** the reaction produces a mixture of organic products

- (iv) Calculate the volume of propane, in  $\text{dm}^3$ , measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.

Give your answer to an appropriate number of significant figures.

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

(3)

(Total for Question 2 = 9 marks)

**3** This question is about compounds of Group 5 elements.

(a) Phosphorus forms two chlorides with the formulae  $\text{PCl}_3$  and  $\text{PCl}_5$ .

(i) Explain the shape of the  $\text{PCl}_3$  molecule. The bond angle is not required.

(3)

(ii) Draw a diagram to show the three-dimensional shape of the  $\text{PCl}_5$  molecule in the gas phase.

Include bond angles and the name of the shape.

(3)

(iii) Explain why phosphorus forms  $\text{PCl}_5$  but nitrogen does not form  $\text{NCl}_5$ .

(2)

- (b) Nitrogen trichloride,  $\text{NCl}_3$ , has a boiling temperature of 344 K, and nitrogen trifluoride,  $\text{NF}_3$ , has a boiling temperature of 144 K.

Explain this difference in boiling temperatures, by referring to all the intermolecular forces present.

(5)

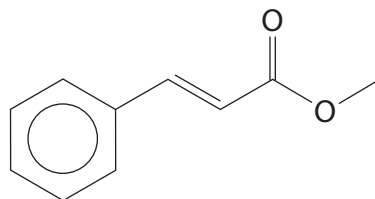
- (c) Which of these compounds produces hydrogen chloride when it reacts with  $\text{PCl}_5$ ?

(1)

- ☐ A propanal
- ☐ B propan-1-ol
- ☐ C propanone
- ☐ D propyl propanoate

(Total for Question 3 = 14 marks)

4 Methyl cinnamate,  $C_{10}H_{10}O_2$ , is a white crystalline solid used in the perfume industry.

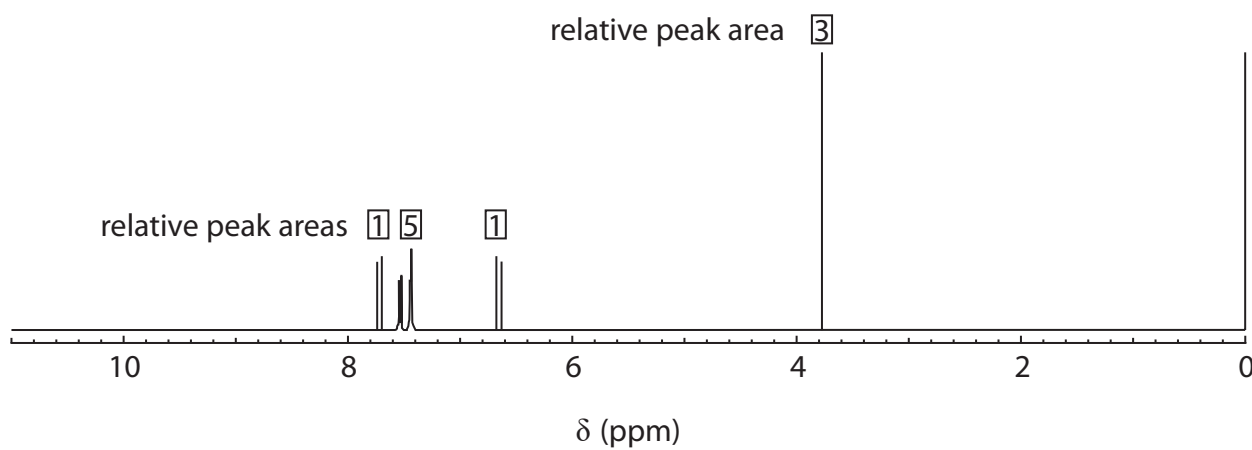


methyl cinnamate

(a) Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

(b) A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy. A simplified spectrum is shown.



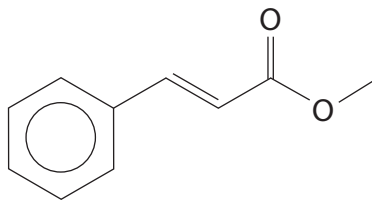
(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

(2)



- (ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on the diagram shown. Fully justify your answer.

(3)



- (c) Methyl cinnamate undergoes an addition reaction in the dark with bromine.

- (i) Draw the mechanism for the reaction between methyl cinnamate and bromine,  $\text{Br}_2$ .  
Include curly arrows, and relevant lone pairs and dipoles.

(4)

(ii) Deduce the number of optical isomers of the addition product that can exist.

(1)

- ☐ **A** 2
- ☐ **B** 3
- ☐ **C** 4
- ☐ **D** 8

(iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

(1)

- ☐ **A** diffracted
- ☐ **B** reflected
- ☐ **C** refracted
- ☐ **D** rotated

(Total for Question 4 = 13 marks)

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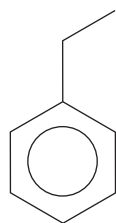
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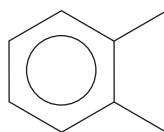
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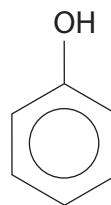
- 5 This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene



phenol

- (a) Ethylbenzene can be formed by the reaction of a chloroalkane with benzene, catalysed by aluminium chloride,  $\text{AlCl}_3$ .
- (i) Draw the **displayed** formula of the chloroalkane required for this reaction. (1)
- (ii) Draw the mechanism for this reaction.  
Include equations showing the role of the catalyst and how it is regenerated. (5)

(iii) Explain whether phenol is likely to be less or more reactive than benzene with the chloroalkane from (a)(i).

(3)

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(b) A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165°C and a pressure of 118 kPa, this sample had a volume of 70.5 cm<sup>3</sup>.

Use the Ideal Gas Equation to calculate the molar mass, in g mol<sup>-1</sup>, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

(4)

- (c) The time taken for a compound to pass through the column in gas chromatography is called the retention time.

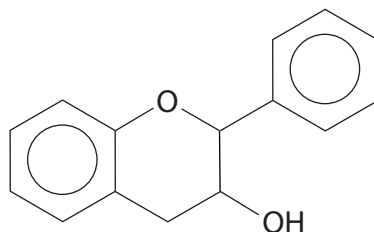
Explain why different compounds will have different retention times in the same column, under the same conditions.

(2)

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**(Total for Question 5 = 15 marks)**

- 6 The compound flavan-3-ol is found in tea, fruit and wine.



- (a) Clearly label all the chiral carbon atoms in flavan-3-ol. (1)
- (b) Give the molecular formula for flavan-3-ol. (1)
- \*(c) A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.
- Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell. (6)



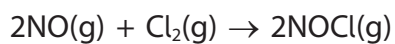
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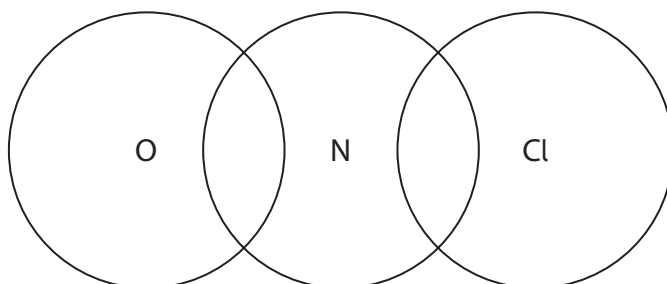
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(Total for Question 6 = 8 marks)

7 Nitrogen monoxide and chlorine react together to form nitrosyl chloride.



(a) Draw a dot-and-cross diagram for nitrosyl chloride, showing only the outer shell electrons.



(2)

(b) The rate equation for the formation of nitrosyl chloride is

$$\text{Rate} = k[\text{NO}]^2[\text{Cl}_2]$$

(i) Complete the table by adding the missing values.

Experiment	$[\text{NO}] / \text{mol dm}^{-3}$	$[\text{Cl}_2] / \text{mol dm}^{-3}$	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$
1	0.122	0.241	$1.09 \times 10^{-2}$
2		0.482	$8.72 \times 10^{-2}$
3	0.366		$4.91 \times 10^{-2}$

(2)

- (ii) Calculate the rate constant,  $k$ , using data from Experiment 1.  
Include units with your answer.

(3)

- (iii) Explain how using a catalyst increases the rate constant,  $k$ .

(2)

- (iv) The heterogeneous catalyst palladium was suggested for use in this reaction. Explain how impurities in the gaseous reactants could make the catalyst less effective.

(3)

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(Total for Question 7 = 12 marks)

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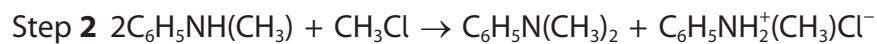
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- 8 Gentian violet is a purple crystalline solid used as an antifungal treatment.

It can be synthesised from dimethylphenylamine,  $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$ .

- (a) The dimethylphenylamine used in the synthesis can be made by the stepwise reaction of phenylamine with chloromethane.



The reaction mechanism for Step 1 between phenylamine and chloromethane is the same as that in the reaction between ammonia and chloromethane.

- (i) What is the reaction type and mechanism in Step 1?

(1)

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

- (ii) Draw the mechanism for the reaction in Step 1.  
Include curly arrows, and relevant lone pairs and dipoles.

(4)

- (iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.

Specific details of the solvent used are not required.

(4)

- (b) The rate constant for the reaction between a solution of gentian violet and aqueous sodium hydroxide was determined at different temperatures.

Temperature ( $T$ ) / K	1 / Temperature ( $1/T$ ) / K <sup>-1</sup>	Rate constant, $k$ / dm <sup>3</sup> mol <sup>-1</sup> s <sup>-1</sup>	ln $k$
283.5	$3.53 \times 10^{-3}$	$2.71 \times 10^{-3}$	-5.91
287.5	$3.48 \times 10^{-3}$	$3.55 \times 10^{-3}$	
291.5		$4.75 \times 10^{-3}$	-5.35
295.0	$3.39 \times 10^{-3}$	$6.10 \times 10^{-3}$	-5.10
298.5	$3.35 \times 10^{-3}$	$7.60 \times 10^{-3}$	-4.88

- (i) Complete the data in the table.

(1)

- (ii) Plot a graph and use it to determine the activation energy for the reaction in kJ mol<sup>-1</sup>.

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

The Arrhenius equation can be shown as

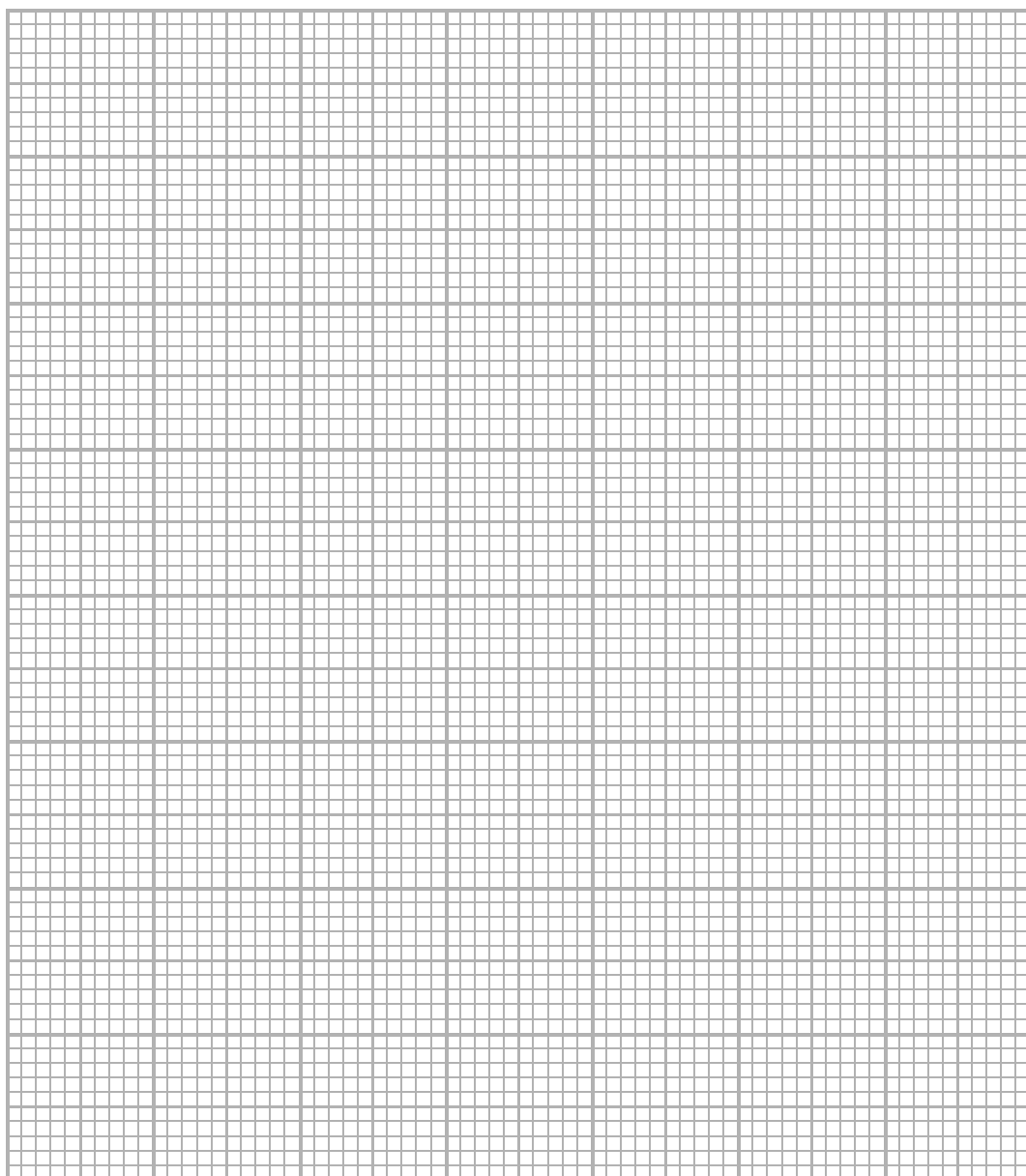
$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(6)

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Gradient

Activation energy

(Total for Question 8 = 16 marks)

**TOTAL FOR PAPER = 90 MARKS**

1

2

3

4

5

6

7

0 (8)

1.0

H

hydrogen

1

(1)

(2)

6.9

Li

lithium

3

9.0

Be

beryllium

4

23.0

Na

sodium

11

24.3

Mg

magnesium

12

relative atomic mass

atomic symbol

name

atomic (proton) number

(13)

(14)

(15)

(16)

(17)

0 (8)

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

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

\* Lanthanide series

\* Actinide 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

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

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Md

mendelevium

101

[254]

No

nobelium

102

[257]

Lr

lawrencium

103