Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initial	
Question	Mark
1	
2	
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10	
11	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2009

Chemistry CHEM2

Unit 2 Chemistry In Action

Thursday 11 June 2009 1.30 pm to 3.15 pm

For this paper you must have:
- Periodic Table/Data Sheet provided as an insert (enclosed).
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. **Answers written in margins or on blank pages will not be marked.**
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- The Periodic Table/Data Sheet is provided as an insert.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  - – use good English
  - – organise information clearly
  - – use specialist vocabulary where appropriate.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

Section A

Answer **all** the questions in the spaces provided.

1 Sodium thiosulfate solution ($Na_2S_2O_3$) reacts slowly with dilute hydrochloric acid to form a precipitate. The rate of this reaction can be studied by measuring the time (*t*) that it takes for a small fixed amount of precipitate to form under different conditions. The fixed amount of precipitate is taken as the amount needed to obscure a cross on paper.

The equation for this reaction is shown below.

$$Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + S + SO_2 + H_2O$$

1 (a) Identify the insoluble product of this reaction which forms the precipitate.

....

(1 mark)

1 (b) When this reaction takes place, the collision between the reacting particles requires an activation energy. State what is meant by the term *activation energy*.

....

....

(2 marks)

1 (c) In terms of particles, explain why, at a fixed temperature, you might expect the rate of this reaction to double when the concentration of sodium thiosulfate is doubled and the concentration of hydrochloric acid remains the same.

....

....

....

....

(2 marks)

1 (d) (i) State what is meant by the term *rate of reaction*.

....

....

(1 mark)

1 (d) (ii) Consider the description of the way in which this experiment is carried out.
Use your understanding of the term *rate of reaction* to explain why it is possible to use a simplified formula $\frac{1}{t}$ as a measure of the rate of **this** reaction.

....

....

(1 mark)

7

Turn over for the next question

2 Barium can be extracted from barium oxide (BaO) in a process using aluminium. A mixture of powdered barium oxide and powdered aluminium is heated strongly. The equation for this extraction process is shown below.

$$3BaO(s) + 2Al(s) \longrightarrow 3Ba(s) + Al_2O_3(s)$$

Some standard enthalpies of formation are given in the table below.

Substance	BaO(s)	$Al_2O_3(s)$
$\Delta H_f^\ominus / kJ\,mol^{-1}$	–558	–1669

2 (a) (i) State what is meant by the term *standard enthalpy of formation*.

....

....

....

....

....

(3 marks)

2 (a) (ii) State why the standard enthalpy of formation of barium and that of aluminium are both zero.

....

(1 mark)

2 (a) (iii) Use the data to calculate the standard enthalpy change for the reaction shown by the equation above.

....

....

....

....

....

(3 marks)

2 (b) (i) Suggest the major reason why this method of extracting barium is expensive.

....

(1 mark)

2 (b) (ii) Using barium oxide and aluminium powders increases the surface area of the reactants. Suggest **one** reason why this increases the rate of reaction.

....

(1 mark)

2 (c) (i) Write an equation for the reaction of barium with water.

....

(1 mark)

2 (c) (ii) A solution containing barium ions can be used to test for the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction which occurs and state what is observed.

Simplest ionic equation

....

Observation ....

(2 marks)

2 (c) (iii) State how barium sulfate can be used in medicine. Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use ....

Explanation ....

....

(2 marks)

14

Turn over ▶

3 A group of students devised an experiment which they believed would enable them to investigate the strength of the intermolecular forces between ethyl ethanoate molecules ($CH_3COOCH_2CH_3$) and trichloromethane molecules ($CHCl_3$).

They mixed exactly 0.10 mol of each of the two liquids in a copper calorimeter and recorded the following results. The starting temperature of both liquids was the same.

Mass of 0.10 mol of ethyl ethanoate / g	8.80
Mass of 0.10 mol of trichloromethane / g	11.95
Increase in temperature (ΔT) on mixing / K	9.5

3 (a) (i) Write an expression for the heat change (q) which relates mass (m), specific heat capacity (c) and change in temperature (ΔT).

....

(1 mark)

3 (a) (ii) Calculate the amount of heat required to increase the temperature of 8.80 g of ethyl ethanoate by 9.5 K during the mixing process. (You should assume that c for ethyl ethanoate = 1.92 J $g^{-1}K^{-1}$)

....

(1 mark)

3 (a) (iii) Calculate the amount of heat required to increase the temperature of 11.95 g of trichloromethane by 9.5 K during the mixing process. (You should assume that c for trichloromethane = 0.96 J $g^{-1}K^{-1}$)

....

(1 mark)

3 (a) (iv) Using the values from parts (a) (ii) and (a) (iii), calculate the molar enthalpy change in kJ mol^{-1} for the mixing process.

....

....

(2 marks)

3 (b) The students deduced that the heat change was due only to the formation of intermolecular forces between ethyl ethanoate molecules and trichloromethane molecules.

Ignoring all experimental errors, give **one** reason why the students may have made an incorrect deduction.

....

....

(1 mark)

6

Turn over for the next question

4 Carbon monoxide and hydrogen are used in the manufacture of methanol. An equilibrium is established according to the following equation.

$$CO(g) + 2H_2(g) \overset{\text{Cu catalyst}}{\rightleftharpoons} CH_3OH(g) \qquad \Delta H = -9l \text{ kJ mol}^{-1}$$

4 (a) Give **two** features of a reaction at equilibrium.

Feature 1 ....

....

Feature 2 ....

....

(2 marks)

4 (b) Explain why an increase in temperature causes a decrease in the equilibrium yield of methanol.

....

....

....

(2 marks)

4 (c) (i) State what is meant by the term *catalyst*.

....

....

(1 mark)

4 (c) (ii) State the effect, if any, of the copper catalyst on the position of this equilibrium at a fixed temperature.

....

(1 mark)

4 (d) Two methods are used to produce carbon monoxide from natural gas. Equations for these two methods are shown below.

Method 1 $CH_4 + H_2O \longrightarrow CO + 3H_2$

Method 2 $CH_4 + CO_2 \longrightarrow 2CO + 2H_2$

The manufacture of methanol from these sources of carbon monoxide has been described as carbon neutral.

4 (d) (i) State what is meant by the term *carbon neutral*.

....

....

....

(1 mark)

4 (d) (ii) Show how combining the equations from these two methods can lead to the 1:2 mol ratio of carbon monoxide to hydrogen required for this synthesis of methanol.

....

....

....

(1 mark)

8

Turn over for the next question

5 This question is about the extraction of metals.

5 (a) Coke is mainly carbon and is a raw material used in the extraction of iron from iron(III) oxide.

5 (a) (i) Write an equation for the formation of carbon monoxide from carbon.

....

(1 mark)

5 (a) (ii) Write an equation for the reduction of iron(III) oxide to iron by carbon monoxide.

....

(1 mark)

5 (a) (iii) The Earth's resources of iron(III) oxide are very large and commercial ores have a high iron content. Give **one** economic and **one** environmental reason for recycling scrap iron and steel.

Economic reason ....

....

Environmental reason ....

....

(2 marks)

5 (b) Pure titanium is extracted by the reduction of titanium(IV) chloride, but not by the direct reduction of titanium(IV) oxide using carbon.

5 (b) (i) Write an equation for the conversion of titanium(IV) oxide into titanium(IV) chloride.

....

(2 marks)

5 (b) (ii) Write an equation for the extraction of titanium from titanium(IV) chloride.

....

(2 marks)

5 (b) (iii) State why titanium is not extracted directly from titanium(IV) oxide using carbon.

....

(1 mark)

5 (c) Aluminium is extracted by the electrolysis of a molten mixture containing aluminium oxide.

5 (c) (i) State why the electrolysis needs to be of a *molten* mixture.

....

(1 mark)

5 (c) (ii) Write an equation for the reaction of oxide ions at the positive electrode during the electrolysis.

....

(1 mark)

5 (c) (iii) State why the positive electrodes need frequent replacement.

....

(1 mark)

5 (c) (iv) Give the major reason why it is less expensive to recycle aluminium than to extract it from aluminium oxide by electrolysis.

....

(1 mark)

13

Turn over for the next question

6 Acidified silver nitrate solution can be used to identify and distinguish between halide ions in solution.

6 (a) Explain why hydrochloric acid should **not** be used to acidify the silver nitrate.

....

....

(1 mark)

6 (b) State and explain what would be observed when acidified silver nitrate solution is added to a solution of sodium fluoride.

Observation ....

Explanation ....

(2 marks)

6 (c) State what would be observed when acidified silver nitrate solution is added to a solution containing iodide ions. Write the **simplest ionic** equation for the reaction that occurs.

Observation ....

Equation ....

(2 marks)

5

7 The reaction of bromine with an alkene is used in a test to show that the alkene is unsaturated.

7 (a) State what is meant by the term *unsaturated* as applied to an alkene.

....

(1 mark)

7 (b) Name and outline a mechanism for the reaction of bromine with but-2-ene.

Name of mechanism ....

Mechanism

(5 marks)

7 (c) But-2-ene can exist as a pair of stereoisomers.

7 (c) (i) State what is meant by the term *stereoisomers*.

....

....

....

(2 marks)

7 (c) (ii) Draw the structure of (*E*)-but-2-ene.

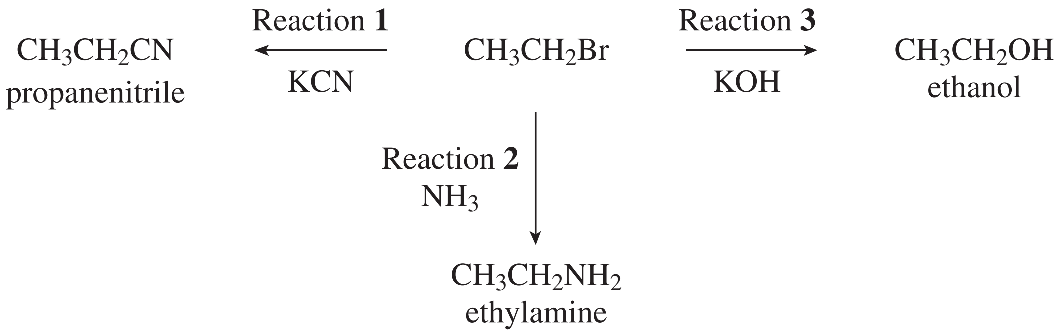
....

(1 mark)

9

Turn over ▶

8 Nucleophiles react with bromoethane in substitution reactions. This type of reaction is illustrated in the following scheme.



8 (a) State what is meant by the term *nucleophile*.

....

(1 mark)

8 (b) Outline a mechanism for the reaction of potassium cyanide with bromoethane (Reaction **1**).

(2 marks)

8 (c) Explain why an excess of ammonia is needed in Reaction **2** to produce a high yield of ethylamine.

....

....

(1 mark)

8 (d) When potassium hydroxide reacts with bromoethane, ethene can also be formed. Name and outline a mechanism for this reaction.

Name of mechanism ....

Mechanism

(4 marks)

8

Turn over for the next question

Turn over ▶

9 Butan-2-ol can be oxidised by acidified potassium dichromate(VI) to form butanone as shown by the following equation.

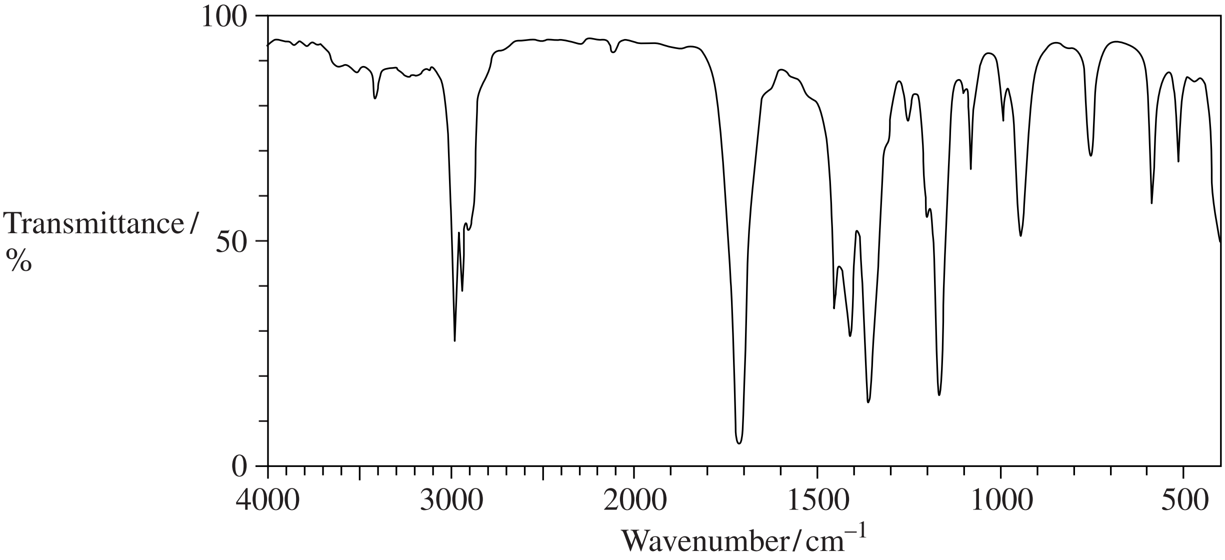
$$CH_3CH_2CH(OH)CH_3 + [O] \longrightarrow CH_3CH_2COCH_3 + H_2O$$

9 (a) State the class of alcohol to which butan-2-ol belongs.

....

(1 mark)

9 (b) The infrared spectrum shown below is either that of butan-2-ol or that of butanone.



Identify the compound to which this infrared spectrum refers.

Explain your answer.

You may find it helpful to refer to the table of infrared absorption data on the back of the Periodic Table (**Table 1**).

Identity of the compound ....

Explanation ....

....

....

(3 marks)

9 (c) Draw the displayed formula of the alcohol C_4H_9OH which is resistant to oxidation by acidified potassium dichromate(VI).

....

(1 mark)

5

Turn over for the next question

Section B

Answer **both** questions in the spaces provided.

10 In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$$2KBr + MnO_2 + 2H_2SO_4 \longrightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

10 (a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

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(3 marks)

10 (b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**. Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

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(5 marks)

Question 10 continues on the next page

Turn over ▶

10 (c) Bromine has been used for more than 70 years to treat the water in swimming pools. The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

....

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(4 marks)

12

11 One of the first substances used as an anaesthetic in medicine was chloroform (trichloromethane, $CHCl_3$). By 1950, *halothane* was in common use but by 1990 this had been replaced by more acceptable anaesthetics such as *desflurane*.

$CF_3CHBrCl$	$CF_3CHFOCHF_2$
halothane	*desflurane*

One reason for replacing *halothane* was that it is an organic compound that contains chlorine. Chlorine-containing organic compounds are thought to cause damage to the ozone layer in the upper atmosphere.

11 (a) Name and outline a mechanism for the reaction of chlorine with methane to form chloromethane (CH_3Cl).

Write an overall equation for the reaction of chlorine with methane to form trichloromethane ($CHCl_3$).

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(5 marks)

Question 11 continues on the next page

Turn over ▶

11 (b) Explain how chlorine atoms are formed from chlorine-containing organic compounds in the upper atmosphere.

Explain, with the aid of equations, how chlorine atoms act as a catalyst in the decomposition of ozone into oxygen.

....

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(6 marks)

11 (c) Use the formulae of the two anaesthetics, *halothane* and *desflurane*, to help to explain why *desflurane* is considered to be a more **environmentally** acceptable anaesthetic than *halothane*.

....

....

....

....

(2 marks)

13

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

GCE Chemistry Data Sheet

Table 1
Infrared absorption data

Bond	Wavenumber /cm^{-1}
N − H (amines)	3300 − 3500
O − H (alcohols)	3230 − 3550
C − H	2850 − 3300
O − H (acids)	2500 − 3000
$C\equiv N$	2220 − 2260
C = O	1680 − 1750
C = C	1620 − 1680
C − O	1000 − 1300
C − C	750 − 1100

Table 2
^{1}H n.m.r. chemical shift data

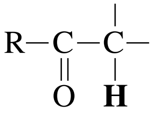
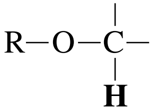
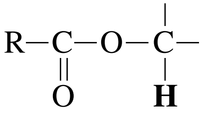
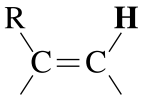
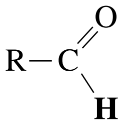
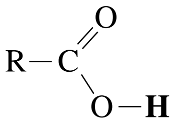
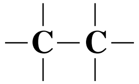
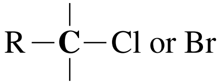
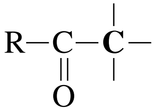
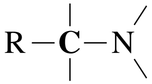
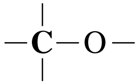
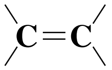
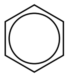
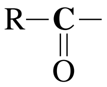
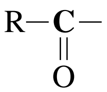
Type of proton	δ/ppm
RO**H**	0.5 − 5.0
RCH_3 (**H**)	0.7 − 1.2
RNH_2 (**H**)	1.0 − 4.5
R_2CH_2 (**H**)	1.2 − 1.4
R_3CH (**H**)	1.4 − 1.6
 $R-\underset{\|\atop O}{C}-\overset{\|}{\underset{\|\atop \mathbf{H}}{C}}-$	2.1 − 2.6
 $R-O-\overset{\|}{\underset{\|\atop \mathbf{H}}{C}}-$	3.1 − 3.9
RCH_2Cl or Br (**H**)	3.1 − 4.2
 $R-\underset{\|\atop O}{C}-O-\overset{\|}{\underset{\|\atop \mathbf{H}}{C}}-$	3.7 − 4.1
	4.5 − 6.0
	9.0 − 10.0
	10.0 − 12.0

Table 3
^{13}C n.m.r. chemical shift data

Type of carbon		δ/ppm
 $-\overset{\|}{\underset{\|}{\mathbf{C}}}-\overset{\|}{\underset{\|}{\mathbf{C}}}-$		5 − 40
 $R-\overset{\|}{\underset{\|}{\mathbf{C}}}-Cl$ or Br		10 − 70
 $R-\underset{\|\atop O}{C}-\overset{\|}{\underset{\|}{\mathbf{C}}}-$		20 − 50
		25 − 60
 $-\overset{\|}{\underset{\|}{\mathbf{C}}}-O-$	alcohols, ethers or esters	50 − 90
		90 − 150
$R-\mathbf{C}\equiv N$		110 − 125
		110 − 160
 $R-\underset{\|\atop O}{\mathbf{C}}-$	esters or acids	160 − 185
 $R-\underset{\|\atop O}{\mathbf{C}}-$	aldehydes or ketones	190 − 220

The Periodic Table of the Elements

Key

relative atomic mass
symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							1.0 **H** hydrogen 1										4.0 **He** helium 2
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											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	96.0 **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	[267] **Rf** rutherfordium 104	[268] **Db** dubnium 105	[271] **Sg** seaborgium 106	[272] **Bh** bohrium 107	[270] **Hs** hassium 108	[276] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[280] **Rg** roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

* **58 – 71** Lanthanides	140.1 **Ce** cerium 58	140.9 **Pr** praseodymium 59	144.2 **Nd** neodymium 60	[145] **Pm** promethium 61	150.4 **Sm** samarium 62	152.0 **Eu** europium 63	157.3 **Gd** gadolinium 64	158.9 **Tb** terbium 65	162.5 **Dy** dysprosium 66	164.9 **Ho** holmium 67	167.3 **Er** erbium 68	168.9 **Tm** thulium 69	173.1 **Yb** ytterbium 70	175.0 **Lu** lutetium 71
† **90 – 103** Actinides	232.0 **Th** thorium 90	231.0 **Pa** protactinium 91	238.0 **U** uranium 92	[237] **Np** neptunium 93	[244] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[247] **Bk** berkelium 97	[251] **Cf** californium 98	[252] **Es** einsteinium 99	[257] **Fm** fermium 100	[258] **Md** mendelevium 101	[259] **No** nobelium 102	[262] **Lr** lawrencium 103