Candidate Name	Centre Number	Candidate Number
		2

GCE A level

1095/01

CHEMISTRY CH5

A.M. MONDAY, 28 June 2010

1¾ hours

FOR EXAMINER'S USE ONLY		
Section	Question	Mark
A	1	
	2	
	3	
B	4	
	5	
TOTAL MARK		

1095 01 01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need:
- a calculator;
- a copy of the **Periodic Table** supplied by WJEC. Refer to it for any **relative atomic masses** you require.

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.
Section B Answer **both** questions in **Section B** in a separate answer book which should then be placed inside this question-and-answer book.

Candidates are advised to allocate their time appropriately between **Section A (40 marks)** and **Section B (40 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

You are reminded that marking will take into account the Quality of Written Communication in all written answers.

Examiner only

SECTION A

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

1. *(a)* Magnesium carbonate decomposes on heating.

$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

(i) Given the enthalpy change of formation, $\Delta H_f^{\ominus}$, values below, calculate the enthalpy change, $\Delta H^{\ominus}$, for the decomposition of magnesium carbonate. [1]

Species	Enthalpy change of formation $\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	–393.5
$MgCO_3(s)$	–1095.8
$MgO(s)$	–601.7

....

....

....

(ii) The entropy change, $\Delta S^{\ominus}$, for the decomposition is 174.8 J mol^{-1}K^{-1}. Explain why there is an increase in entropy for this reaction. [1]

....

....

(iii) Convert the value of $\Delta S^{\ominus}$ into units of kJ mol^{-1}K^{-1}. [1]

....

....

(iv) Using your answers to *(a)*(i) and (iii), determine, in degrees K, the temperature above which magnesium carbonate would decompose spontaneously. [3]

....

....

....

Examiner only

(b) The solution of ionic compounds such as magnesium carbonate or sodium carbonate in water at 20 °C (room temperature) can be represented by the equations

$$MgCO_3(s) \rightleftharpoons Mg^{2+}(aq) + CO_3^{2-}(aq)$$

$$Na_2CO_3(s) \rightleftharpoons 2Na^{+}(aq) + CO_3^{2-}(aq)$$

Use the free energy change, ΔG, values in the table to comment on the solubilities of magnesium carbonate and sodium carbonate in water. [2]

Solution	Free Energy Change ΔG / kJ mol^{-1}
$MgCO_3(s) \rightleftharpoons Mg^{2+}(aq) + CO_3^{2-}(aq)$	+28.2
$Na_2CO_3(s) \rightleftharpoons 2Na^{+}(aq) + CO_3^{2-}(aq)$	–4.3

....

....

....

1095 01 03

Examiner only

(c) As solids do not affect the position of equilibrium, for the solution equilibrium

$$MgCO_3(s) \rightleftharpoons Mg^{2+}(aq) + CO_3^{2-}(aq)$$

the simplest expression for the equilibrium constant, K_c, can be written

$$K_c = [Mg^{2+}(aq)][CO_3^{2-}(aq)]$$

(i) Given that the solubility of $MgCO_3$ at 20 °C is 3.16×10^{-3} mol dm^{-3}, state the molar concentrations of magnesium ions, Mg^{2+}(aq), and carbonate ions, CO_3^{2-}(aq), in a saturated $MgCO_3$ solution. [1]

....

....

(ii) Hence calculate the value of K_c at 20 °C. [1]

....

....

(iii) Giving your reasons, state whether the value of K_c is consistent with the value of the free energy change, ΔG, given for this reaction in *(b)*. [1]

....

....

(iv) By applying Le Chatelier's Principle to the chemical equation above, and giving your reasons, state the effect on the solubility of magnesium carbonate of adding sodium carbonate to the solution. [1]

....

....

Total [12]

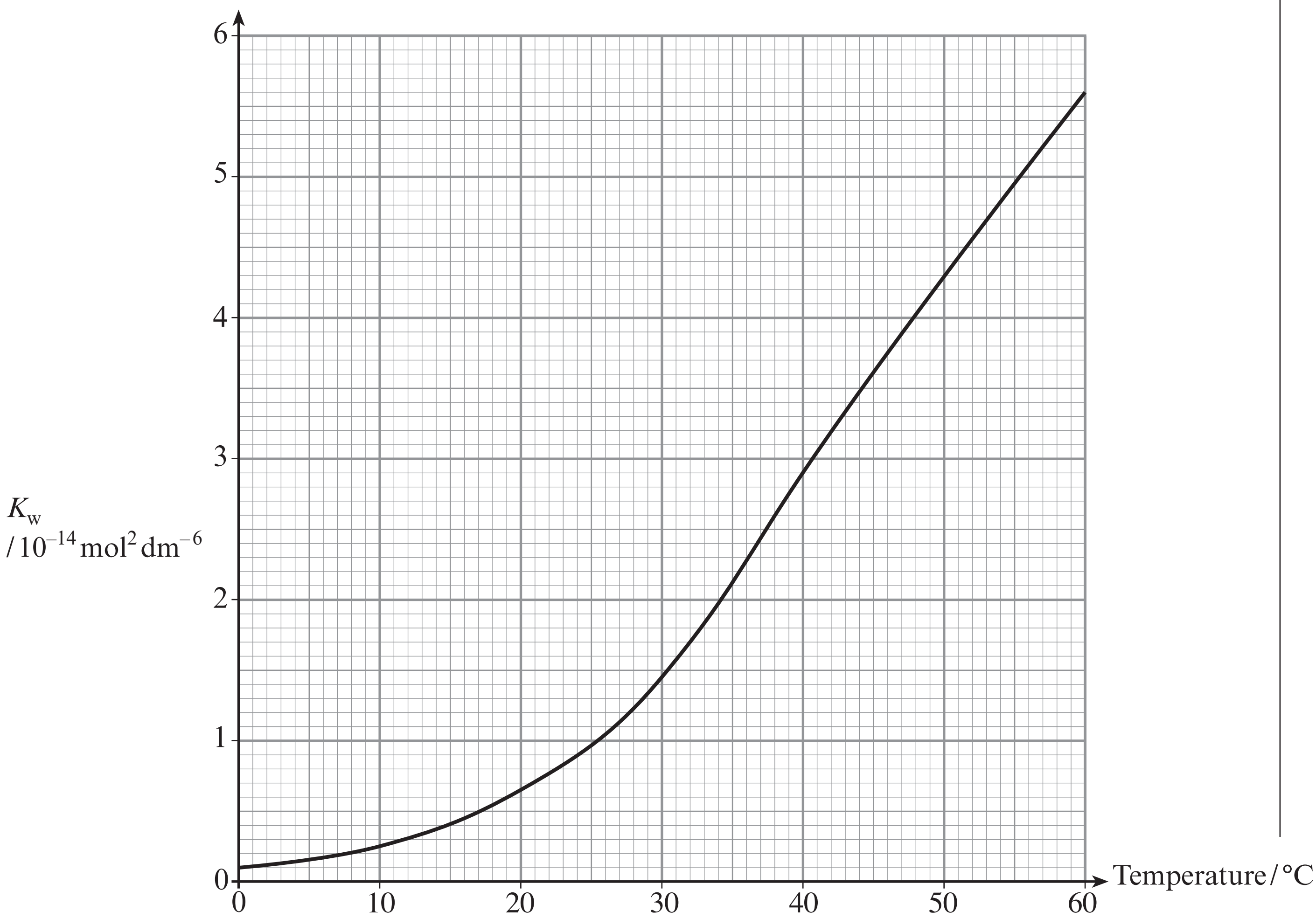
1095 01 05

BLANK PAGE

Turn over.

Examiner only

2. *(a)* The diagram shows the variation of the ionic product of water, K_w, with temperature.



(i) Give the expression for the ionic product of water, K_w. [1]

(ii) By reference to the diagram, and giving your reasoning, state whether the ionisation of water is an exothermic or an endothermic process. [1]

....

....

(iii) Use the diagram to determine the value ($mol^2 dm^{-6}$) of K_w at 50 °C. [1]

....

....

(iv) Hence calculate $[H^+]$ and the pH of pure water at 50 °C. [2]

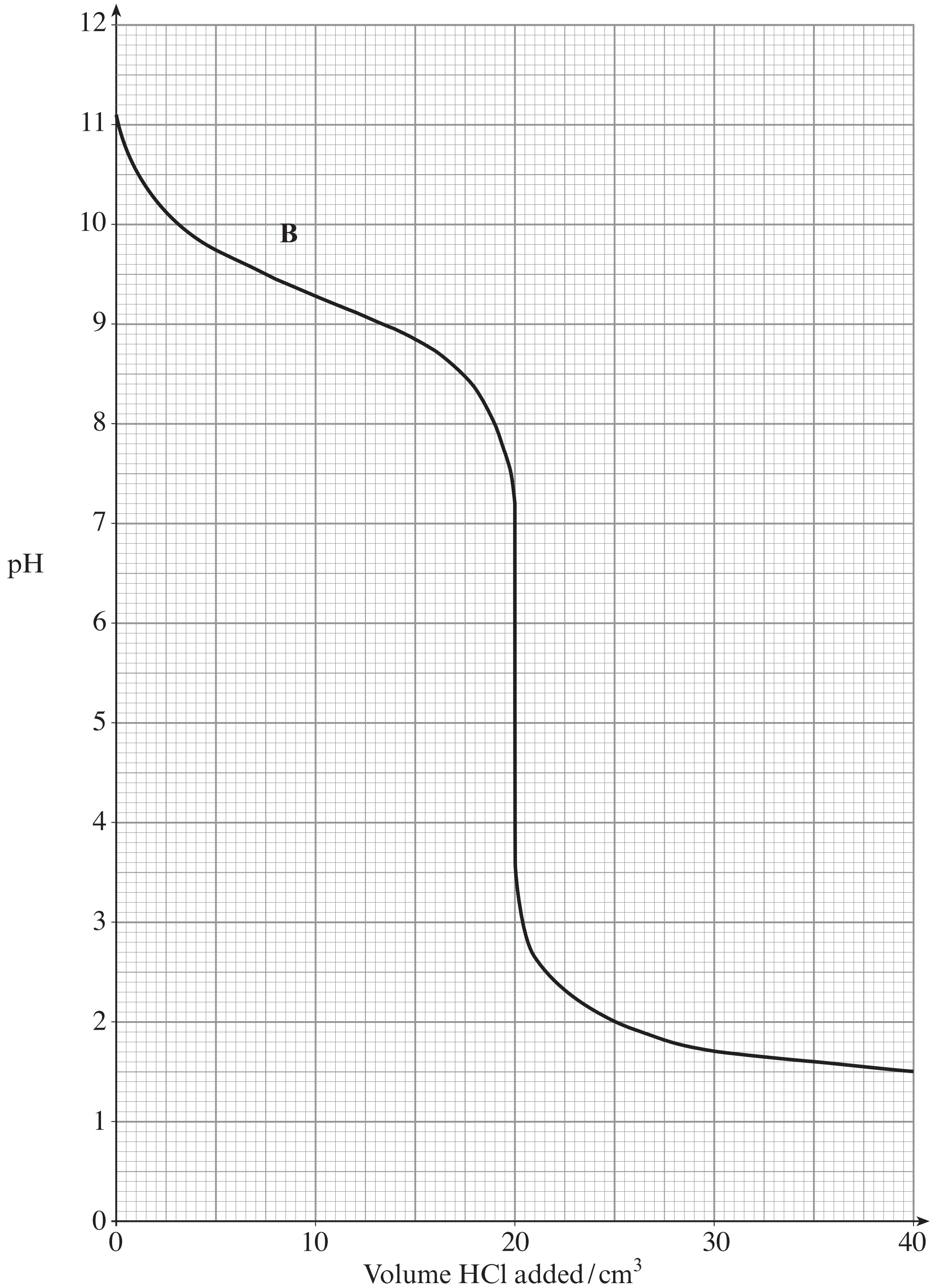
....

....

Examiner only

(b) The diagram below shows how pH changes during the course of a titration when hydrochloric acid of concentration 0.100 mol dm^{-3} is added from a burette to 25.0 cm^3 of aqueous ammonia.

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



(i) Calculate, to **two** significant figures, the concentration of the aqueous ammonia solution. [3]

....

....

....

Turn over.

Examiner only

(ii) Explain why a buffering effect occurs in the region of the curve marked with the letter **B**, where a mixture of NH_3(aq) and NH_4Cl(aq) is present. [3]

....

....

....

....

....

(iii) Giving your reasoning, state which of the following indicators would be suitable for the titration of ammonia against hydrochloric acid. [2]

Indicator	pH range
Bromothymol blue	6.0 - 7.6
Methyl red	4.2 - 6.3
Methyl yellow	2.9 - 4.0
Phenolphthalein	8.2 - 10.0

....

....

....

Total [13]

Examiner only

3. *Read the passage below and then answer questions (a) to (d) in the spaces provided.*

Hydrogen Fuel Cells

Although fuel cells have been around since 1839, it took another 120 years until NASA demonstrated some of their potential applications when providing power during space flights.

A fuel cell works like an electrochemical cell (battery) but does not run down or need recharging. It will produce electricity and heat as long as fuel (hydrogen) is supplied. A fuel cell consists of two electrodes—an anode where oxidation occurs and a cathode for reduction—sandwiched around an electrolyte. Replacing the salt bridge of conventional electrochemical cells, several electrolyte systems have been tried such as phosphoric acid or a solid electrolyte based on polymeric fluorocarbons. The relevant electrode potentials are

$$2H^+ + 2e^- \rightleftharpoons H_2 \qquad E^\ominus = 0\,V$$

$$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O \qquad E^\ominus = 1.23\,V$$

Hydrogen is fed to the anode, and oxygen (air) to the cathode. Activated by a catalyst, usually involving a layer of platinum and carbon a few nanometres thick, hydrogen atoms separate into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte. Fuel cells can be used to power vehicles or to provide electricity and heat to buildings.

A significant barrier to using fuel cells in vehicles is hydrogen storage. Most fuel-cell vehicles powered by hydrogen store the hydrogen as a compressed gas in pressurized tanks. Due to the low energy density of hydrogen, it is difficult to store enough hydrogen onboard to allow vehicles to travel the same distance as petrol-powered vehicles.

A potentially energy-dense water-based fuel is based on sodium tetrahydridoborate(III) (30% by mass $NaBH_4$ in water). A catalyst induces rapid hydrogen production

$$NaBH_4 + 2H_2O \rightarrow 4H_2 + NaBO_2 \qquad \Delta H^\ominus = -300\,kJ\,mol^{-1}$$

and pure humidified H_2 is delivered to the engine or fuel cell. The exothermic reaction requires no heat input and sodium borate, $NaBO_2$, can be recycled into $NaBH_4$.

– End of passage –

Turn over.

Examiner only

(a) State the function performed by both the salt bridge in an electrochemical cell and the electrolyte in a fuel cell. *(lines 6-7)* [2]

....

....

(b) (i) Explain why the $2H^+ + 2e^- \rightleftharpoons H_2$ electrode has an electrode potential of zero. *(line 10)* [1]

....

....

(ii) Calculate the EMF of the hydrogen fuel cell. *(lines 10-11)* [1]

....

....

(iii) Give **one** reason why the EMF calculated in *(b)*(ii) is not attained in practice, with 0.7 V being a typical value for a fuel cell. [1]

....

....

(iv) Write a balanced equation for the overall reaction which occurs in the cell. *(lines 10-11)* [1]

....

....

(v) Given that $\Delta H_f^{\ominus}$ $H_2O(l) = -285.8\ kJ\ mol^{-1}$, calculate the enthalpy change, $\Delta H^{\ominus}$, for the equation in *(b)*(iv). [1]

....

....

Examiner only

(c) (i) State **one** disadvantage, mentioned in the passage, of using hydrogen fuel cells to power vehicles. *(lines 18-21)* [1]

....

....

(ii) Give a second disadvantage, not mentioned in the passage, of using hydrogen as a fuel in vehicles. [1]

....

....

(iii) State **one** advantage of using a hydrogen fuel cell compared to the combustion of petrol. [1]

....

....

(d) When 1 kg of the water-based fuel (30% $NaBH_4$ by mass) is reacted to produce hydrogen, calculate *(lines 22-26)*

(i) the mass, and hence the number of moles, of $NaBH_4$ in 1 kg of the water-based fuel, [2]

....

....

(ii) the energy given out (kJ) by 1 kg of the water-based fuel, [1]

....

....

(iii) the volume of hydrogen gas produced. [2]

[Assume 1 mol H_2 gas occupies a volume of 24 dm^3]

....

....

....

....

Total [15]

SECTION B

Answer **both** *questions in the separate answer book provided.*

4. *(a)* Bromine, Br_2, reacts with propanone, CH_3COCH_3, in aqueous solution.

$$Br_2(aq) + CH_3COCH_3(aq) \rightarrow HBr(aq) + CH_3COCH_2Br(aq)$$

(i) If the initial bromine concentration, $[Br_2(aq)]$, was 0.0020 mol dm^{-3} and the Br_2 was completely used up in 17 min 30 seconds, calculate the rate of the reaction (including units). [2]

(ii) Outline one method which could be used to determine the rate for this reaction. [2]

(iii) The following results were obtained when propanone and bromine were reacted in acid solution.

Rate of reaction / mol dm^{-3} min^{-1}	$[Br_2(aq)]$ / mol dm^{-3}	$[CH_3COCH_3(aq)]$ / mol dm^{-3}
6.80×10^{-5}	0.10	0.40
1.36×10^{-4}	0.10	0.80
1.36×10^{-4}	0.20	0.80

Determine the orders of reaction with respect to $Br_2(aq)$ and with respect to $CH_3COCH_3(aq)$. [2]

(iv) A separate experiment was carried out to determine the effect of pH on the rate of reaction.

Rate of reaction / mol dm^{-3} min^{-1}	$[Br_2(aq)]$ / mol dm^{-3}	$[CH_3COCH_3(aq)]$ / mol dm^{-3}	pH
1.36×10^{-3}	0.10	0.80	0
1.36×10^{-4}	0.10	0.80	1
1.36×10^{-5}	0.10	0.80	2

I State how the rate of reaction varies with change in pH. [1]

II Using the table, show that the reaction is first order with respect to H^+ ions. [1]

III State the role of H^+ ions in the reaction. [1]

IV Write the full rate equation for the reaction, giving the units for the rate constant. [2]

(QWC) [1]

(b) Both boron nitride, BN, and carbon, C, form hexagonal graphite-type structures. Explain why

- BN and C can both adopt the same hexagonal structure;
- both BN and C exhibit lubricating properties;
- C is an electrical conductor but BN is an insulator at room temperature. [6]

(QWC) [2]

Total [20]

5. *(a)* *Bordeaux Mixture* is one of the earliest fungicides, first used about 1885. It can be prepared by mixing copper sulfate solution with excess limewater (calcium hydroxide solution).

(i) State what you would observe when copper sulfate solution is mixed with limewater. [2]

(ii) Write an equation for the reaction that occurs. [1]

(b) A sample of *Bordeaux Mixture* was analysed to determine its copper content. Firstly, it was reacted with excess potassium iodide

$$2Cu^{2+} + 4I^{-} \rightarrow 2CuI + I_2$$

and the iodine produced was then titrated against sodium thiosulfate solution.

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

(i) Name the indicator used for the titration and state the colour change at the end-point. [2]

(ii) If a 31.2 g sample of *Bordeaux Mixture* required 12.25 cm^3 of sodium thiosulfate solution with concentration 0.100 mol dm^{-3} $Na_2S_2O_3$ to react with the liberated iodine, calculate the mass of copper in the sample and hence the % Cu by mass in *Bordeaux Mixture*. Your answers should be given to **three** significant figures. [3]

(c) Copper can exist as Cu^{2+} or Cu^{+} compounds.

(i) Write the full electron configurations for Cu^{2+} ions **and** Cu^{+} ions. [2]

(ii) Explain why most Cu^{2+} compounds are coloured blue in the presence of water. [4]

(iii) Briefly explain why most Cu^{+} compounds are colourless or white. [1]

(d) (i) State what would be observed, and give equations for any reactions, when tetrachloromethane, CCl_4, and silicon(IV) chloride, $SiCl_4$, are separately added to water. [3]

(ii) Explain why lead forms a solid chloride $PbCl_2$, but the corresponding CCl_2 and $SiCl_2$ are too unstable to exist. [2]

Total [20]

GCE A level

1095/01-A

CHEMISTRY CH5
DATA SHEET

A.M. MONDAY, 28 June 2010

THE PERIODIC TABLE

Group

Key: A_r = relative atomic mass; Symbol; Name; Z = atomic number

s Block (Groups 1–2); d Block; p Block (Groups 3–0); f Block

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 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
3	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	40.0 Ar Argon 18
4	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
5	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	98.9 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
6	133 Cs Caesium 55	137 Ba Barium 56	139 ▶ La Lanthanum 57	179 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
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) ▶▶ Ac Actinium 89															

f Block

▶ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) 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
▶▶ Actinoid elements	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