Write your name here

Surname	Other names

Centre Number	Candidate Number

Edexcel GCE

Chemistry

Advanced

Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Tuesday 19 June 2012 – Afternoon
Time: 1 hour 40 minutes

Paper Reference
6CH05/01

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

Instructions

- Use **black** ink or 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.*
- Questions labelled with an **asterisk** (*****) are ones where the quality of your written communication will be assessed – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

PEARSON

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ~~☒~~ and then mark your new answer with a cross ☒.

1 The acid used in a standard hydrogen electrode to provide a 1 mol dm^{-3} solution of hydrogen ions is

☒ **A** ethanoic acid.

☒ **B** phosphoric(V) acid.

☒ **C** sulfuric acid.

☒ **D** hydrochloric acid.

(Total for Question 1 = 1 mark)

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2 To measure the standard electrode potential for the $Ag^+(aq)|Ag(s)$ electrode, the most suitable chemical for the solution in a salt bridge to connect the two half cells is

☒ **A** potassium chloride.

☒ **B** potassium iodide.

☒ **C** potassium nitrate.

☒ **D** potassium sulfate.

(Total for Question 2 = 1 mark)

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3 For any reversible reaction, ln K is proportional to

☒ **A** both ΔS_{total} and E_{cell}.

☒ **B** ΔS_{total} but not E_{cell}.

☒ **C** E_{cell} but not ΔS_{total}.

☒ **D** neither E_{cell} nor ΔS_{total}.

(Total for Question 3 = 1 mark)

4 This question is about a titration to determine the iron content of a tablet. The iron(II) ions in the tablet are oxidized to iron(III) ions by acidified manganate(VII) ions which are reduced to manganese(II) ions.

(a) The mole ratio of iron(II) to manganate(VII) ions in the reaction is

(1)

	Fe^{2+}	MnO_4^-
☒ **A**	1	5
☒ **B**	2	5
☒ **C**	5	2
☒ **D**	5	1

(b) A 0.200 g tablet is dissolved to make exactly 100 cm³ of solution. 10 cm³ of this solution is found to contain 5.38×10^{-5} mol of iron(II) ions.

The percentage by mass of iron ($A_r = 55.8$) in the tablet is

(1)

☒ **A** $\dfrac{5.38 \times 10^{-5} \times 55.8}{0.200} \times \dfrac{100}{10} \times 100\%$

☒ **B** $\dfrac{5.38 \times 10^{-5}}{55.8 \times 0.200} \times \dfrac{100}{10} \times 100\%$

☒ **C** $\dfrac{5.38 \times 10^{-5} \times 55.8}{0.200} \times \dfrac{10}{100} \times 100\%$

☒ **D** $\dfrac{5.38 \times 10^{-5} \times 0.200}{55.8} \times \dfrac{10}{100} \times 100\%$

(Total for Question 4 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

5 Some fuel cells are used to produce energy from the combination of hydrogen and oxygen. The half-equations for a hydrogen-oxygen fuel cell in alkaline solution are

$$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq) \qquad E^\ominus = -0.83\ V$$

$$\tfrac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightleftharpoons 2OH^-(aq) \qquad E^\ominus = +0.40\ V$$

(a) The equation for the cell reaction is

(1)

☒ **A** $3H_2O(l) + \tfrac{1}{2}O_2(g) \rightarrow H_2(g) + 4OH^-(aq)$

☒ **B** $H_2(g) + 4OH^-(aq) \rightarrow 3H_2O(l) + \tfrac{1}{2}O_2(g)$

☒ **C** $H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)$

☒ **D** $H_2O(l) \rightarrow H_2(g) + \tfrac{1}{2}O_2(g)$

(b) From the data above, E_{cell} for the reaction in the hydrogen-oxygen fuel cell is

(1)

☒ **A** –0.43 V

☒ **B** +0.43 V

☒ **C** –1.23 V

☒ **D** +1.23 V

(c) An advantage of operating a hydrogen fuel cell over a conventional jet engine for powering an aeroplane is

(1)

☒ **A** it is 100% efficient.

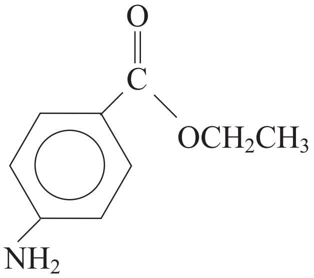
☒ **B** it does not produce greenhouse gas emissions.

☒ **C** it does not produce emissions which damage the ozone layer.

☒ **D** hydrogen is easier to transport.

(Total for Question 5 = 3 marks)

6 Benzocaine is used as a local anaesthetic.



Separate samples of a solution of benzocaine are added to 2,4-dinitrophenylhydrazine, hot aqueous sodium hydroxide, and dilute hydrochloric acid.

Which chemicals react with benzocaine?

☒ **A** All three

☒ **B** Only sodium hydroxide and hydrochloric acid

☒ **C** Only hydrochloric acid

☒ **D** Only sodium hydroxide

(Total for Question 6 = 1 mark)

7 In the first commonly used breathalyser, acidified potassium dichromate(VI) was used which was reduced to chromium(III) by alcohol.

The colour change seen when alcohol was present in a motorist's breath is from

☒ **A** orange to green.

☒ **B** orange to yellow.

☒ **C** yellow to green.

☒ **D** yellow to orange.

(Total for Question 7 = 1 mark)

8 For which of the following are both tests acceptable evidence for a driver to be successfully prosecuted for excess alcohol in the blood in many countries?

☒ **A** A dichromate(VI) breath analyser and a blood test.

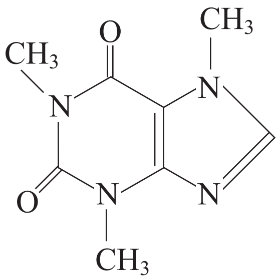
☒ **B** A dichromate(VI) breath analyser and a fuel cell breath analyser.

☒ **C** A dichromate(VI) breath analyser and an infrared breath analyser.

☒ **D** An infrared breath analyser and a blood test.

(Total for Question 8 = 1 mark)

9 The structural formula of caffeine, $C_8H_{10}O_2N_4$, is shown below.



(a) How many main peaks would you expect in the proton nuclear magnetic resonance spectrum of caffeine?

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) At which of the following wavenumbers is an absorption peak **not** present in the infrared spectrum of caffeine?

(1)

☒ **A** 3600 cm^{-1}

☒ **B** 2925 cm^{-1}

☒ **C** 1690 cm^{-1}

☒ **D** 1660 cm^{-1}

(c) The parent ion peak of caffeine in the mass spectrum of caffeine would be at m/e ratio

(1)

☒ **A** 101

☒ **B** 102

☒ **C** 193

☒ **D** 194

(d) Intermolecular forces between caffeine molecules would include

(1)

☒ **A** London forces only.

☒ **B** London forces and hydrogen bonds.

☒ **C** London forces and permanent dipole forces.

☒ **D** London forces, permanent dipole forces, and hydrogen bonds.

(Total for Question 9 = 4 marks)

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10 (a) The principal advantage of combinatorial chemistry over traditional methods for developing pharmaceuticals is that

(1)

☒ **A** very small amounts of compounds are used.

☒ **B** many more compounds can be made in a given time.

☒ **C** compounds formed are more powerful drugs.

☒ **D** compounds formed have fewer side effects.

(b) A refinement of combinatorial chemistry involves initially attaching compounds firmly to polymer beads. The type of attachment is most likely to be by

(1)

☒ **A** metallic bonds.

☒ **B** covalent bonds.

☒ **C** London forces.

☒ **D** permanent dipole forces.

(Total for Question 10 = 2 marks)

11 Four reactions involving the transition elements copper and chromium are given below.

1 $Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$

2 $[Cu(H_2O)_4(OH)_2](s) + 4NH_3(aq) \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+}(aq) + 2OH^{-}(aq) + 2H_2O(l)$

3 $[Cr(H_2O)_3(OH)_3](s) + 3OH^{-}(aq) \rightarrow [Cr(OH)_6]^{3-}(aq) + 3H_2O(l)$

4 $[Cr(H_2O)_3(OH)_3](s) + 3H^{+}(aq) \rightarrow [Cr(H_2O)_6]^{3+}(aq)$

(a) Which reaction produces a dark blue solution?

(1)

☒ **A** **1**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(b) Which two reactions show the amphoteric behaviour of a metal hydroxide?

(1)

☒ **A** **1** and **2**

☒ **B** **2** and **3**

☒ **C** **2** and **4**

☒ **D** **3** and **4**

(c) Predict, without calculation, which reaction has the most negative value for ΔS_{system}.

(1)

☒ **A** **1**

☒ **B** **2**

☒ **C** **3**

☒ **D** **4**

(Total for Question 11 = 3 marks)

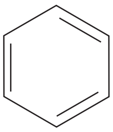
TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

12 This question is about benzene and its compounds.

(a) A Kekulé structure of benzene suggests the molecule consists of alternate double and single carbon to carbon bonds.



The standard enthalpy change of hydrogenation of a carbon to carbon double bond is –120 kJ mol^{-1}.

(i) Calculate the standard enthalpy change of hydrogenation of benzene for the Kekulé structure.

(1)

....

*(ii) The actual standard enthalpy change of hydrogenation of benzene is –208 kJ mol^{-1}.

Use this information and your answer to (i), to calculate the difference in stability of benzene and the Kekulé structure.

What does this tell us about the bonding in benzene?

Explain how this influences the type of chemical reactions that benzene undergoes.

(4)

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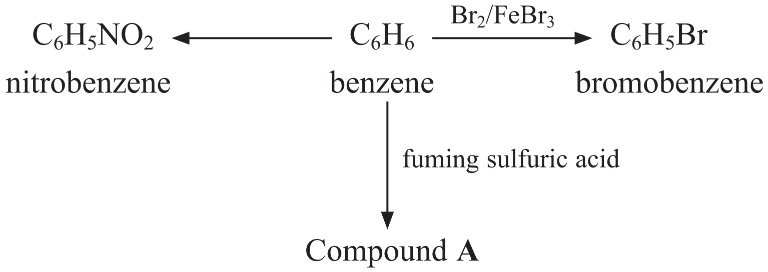
(b) The flow chart shows some typical reactions of benzene.



(i) Identify the two chemicals needed to make nitrobenzene from benzene.

(2)

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....

(ii) Classify the type of reagent required in all three reactions.

(1)

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(iii) Show, with appropriate diagrams, the mechanism for the reaction of benzene with bromine, in the presence of iron(III) bromide, to form bromobenzene. Include the formation of the ion attacking the benzene molecule.

(4)

(iv) Give the structural formula and the name for compound **A**.

(2)

Name ....

(c) (i) Explain why phenol, C_6H_5OH, and methoxybenzene, $C_6H_5OCH_3$, are much more reactive than benzene with bromine.

(3)

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(ii) Write the equation for the reaction between phenol and bromine water. State symbols are **not** required.

(2)

(d) Diphenylmethane, $(C_6H_5)_2CH_2$, is often added to soap to create the pleasant smell of geraniums. It can be made from benzene and one other reagent, using a suitable catalyst.

Identify the other starting material and the catalyst by name or formula.

(2)

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....

(Total for Question 12 = 21 marks)

13 This question is about 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$.

(a) Write an equation for the reaction between 1,2-diaminoethane and **excess** dilute hydrochloric acid.

(2)

(b) When an aqueous solution of nickel(II) ions is added to 1,2-diaminoethane, a complex ion forms.

$$3H_2NCH_2CH_2NH_2 + Ni(H_2O)_6^{2+} \rightarrow Ni(H_2NCH_2CH_2NH_2)_3^{2+} + 6H_2O$$

(i) Suggest the colour of this complex.

(1)

....

(ii) Without using the data booklet, suggest why the complex formed is more stable than $Ni(H_2O)_6^{2+}$ by considering the appropriate entropy change.

(2)

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....

(iii) This complex can exist as two structures, which are non-superimposable mirror images.

Suggest the physical property that would enable you to distinguish between these two structures.

(1)

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....

(c) 1,2-diaminoethane reacts with butane-1,2-dioyl dichloride, $ClOCCH_2CH_2COCl$, to form a polymer.

(i) Draw a displayed formula for this polymer showing one repeat unit.

(2)

(ii) Give, and explain, the name for this type of polymerization reaction.

(2)

*(iii) State and explain the intermolecular forces between two of these polymer chains.

(5)

(Total for Question 13 = 15 marks)

14 An organic compound **X** contains carbon, hydrogen, oxygen and nitrogen.

0.132 g of **X** is burned completely in oxygen to produce 0.072 g of water, 0.176 g of carbon dioxide and 24.0 cm^3 of nitrogen.

[Molar volume of nitrogen under the conditions of the experiment = 24 000 cm^3 mol^{-1}]

(a) Calculate the empirical formula of compound **X**.

(5)

(b) The molar mass of **X** is 132 g mol^{-1}. Deduce the molecular formula for **X**. Show how you arrived at your answer.

(1)

(c) When **X** is refluxed with concentrated hydrochloric acid for several hours, cooled and neutralized, there is only one organic product, **Y**, which has the molecular formula $C_2H_5O_2N$.

One mole of **Y** will react with either one mole of hydrochloric acid or one mole of sodium hydroxide solution.

When **Y** is sprayed with a solution of ninhydrin and heated, a purple colour is observed.

(i) Use **all** the information above to deduce the functional groups present in **Y** and to classify the type of compound it is. Justify your answer.

(3)

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....

(ii) Deduce the displayed formula for **Y** and give its name.

(2)

Name of **Y** ....

(iii) Hence give the structural formula for **X**.

(1)

(Total for Question 14 = 12 marks)

TOTAL FOR SECTION B = 48 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

15

Some unusual oxidation states

You will probably have seen manganese in its common oxidation states during your study of chemistry. Manganese(II) sulfate occurs as very pale pink crystals in the hydrated form. Manganese(IV) oxide is a black powder which is often used as a catalyst. Potassium manganate(VII) occurs as very dark purple crystals and forms a purple aqueous solution, which is a powerful oxidizing agent.

You are less likely to have seen compounds containing the other oxidation states of manganese, which are manganese(VI), manganese(V), manganese(III) and manganese(I). However, compounds containing each of these four oxidation states can be prepared.

Manganese(VI)

Manganese(VI), in MnO_4^{2-}, can be prepared in a reverse disproportionation reaction, by reacting manganate(VII) ions with manganese(IV) oxide in alkali.

Equation 1

$$2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq) \rightarrow 3MnO_4^{2-}(aq) + 2H_2O(l) \quad E^{\ominus}_{cell} = -0.03V$$

The reaction is not thermodynamically favourable under standard conditions. However, the E_{cell} value can be made positive by increasing the concentration of hydroxide ions so that green manganate(VI) ions form.

Manganese(V)

Manganese(V) can be formed by adding a little potassium manganate(VII) to very concentrated (12 mol dm^{-3}) aqueous sodium hydroxide. The solution slowly becomes blue as manganate(V) ions, $MnO_3^-(aq)$, form. The ionic half-equations are:

Equation 2

$$MnO_4^-(aq) + H_2O(l) + 2e^- \rightarrow MnO_3^-(aq) + 2OH^-(aq)$$

Equation 3

$$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$$

Manganese(III)

A deep red solution containing manganese(III) ions is formed by the oxidation of manganese(II) hydroxide by potassium manganate(VII) in acid solution. The ionic equation for the reaction is:

Equation 4

$$MnO_4^-(aq) + 4Mn(OH)_2(s) + 16H^+(aq) \rightarrow 5Mn^{3+}(aq) + 12H_2O(l)$$

Manganese(I)

Manganese(I) ions are not stable in aqueous solution, but do form stable complex ions. They can be made by reducing hexacyanomanganate(II) ions, $Mn(CN)_6^{4-}$, to hexacyanomanganate(I) ions, $Mn(CN)_6^{5-}$.

(a) (i) Give the formula of manganese(IV) oxide.

(1)

....

(ii) How do catalysts speed up reactions?

(2)

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....

....

....

(iii) Explain how transition metal ions can act as homogeneous catalysts.

(2)

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....

(b) (i) Suggest why the preparation of manganate(VI) ions, MnO_4^{2-}, in **equation 1**, may be described as a reverse disproportionation reaction by considering the relevant oxidation states.

(2)

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....

(ii) The two half-equations which are combined to form **equation 1** are

$$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq) \qquad E^\ominus = +0.56\ V$$

$$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq) \qquad E^\ominus = +0.59\ V$$

Explain, by reference to these half-equations, why increasing the concentration of hydroxide ions alters the electrode potential to make the preparation of manganate(VI) ions more likely.

(3)

(c) Use equations **2** and **3** to answer the following questions.

(i) Identify the gas formed in the preparation of manganate(V) ions.

(1)

(ii) By appropriately combining these two equations, write the ionic equation for the formation of manganate(V) ions from manganate(VII) ions.

(2)

(iii) Identify the main hazard and state how you would minimize the associated risk in this preparation of manganate(V) ions.

(2)

(d) Identify the reagents you would use to make manganese(II) hydroxide for the preparation of manganese(III) ions.

(2)

....

....

(e) (i) Draw a dot and cross diagram to show the electron arrangement in the cyanide ion, CN^-.

(2)

(ii) Explain how the cyanide ion acts as a ligand.

(2)

....

....

....

....

(iii) Suggest the name of the shape of the hexacyanomanganate(I) ion.

(1)

....

(Total for Question 15 = 22 marks)

TOTAL FOR SECTION C = 22 MARKS
TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (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	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	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