



Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2024

Centre Number

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Candidate Number

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Chemistry

Assessment Unit AS 2

assessing

Further Physical and Inorganic
Chemistry and an Introduction to
Organic Chemistry



[SCH24]

SCH24

TUESDAY 21 MAY, MORNING

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

Answer **all sixteen** questions in **Sections A and B**.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.

Quality of written communication will be assessed in Question **13(b)**.

The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

A Periodic Table of Elements, containing some data, is included with this question paper.



Section A

For each of the following questions, only **one** of the lettered responses (A–D) is correct.

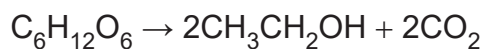
Select the correct response for each question and write the appropriate letter in the space provided.

1 Which one of the following exhibits E–Z isomerism?

- A $\text{H}_2\text{C}=\text{CHCl}$
- B $(\text{CH}_3)_2\text{C}=\text{CH}_2$
- C $\text{H}_2\text{C}=\text{CHCH}_3$
- D $\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{C}_2\text{H}_5$

Answer _____ [1]

2 Which one of the following is the atom economy for the production of ethanol by fermentation?

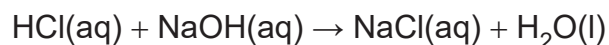


- A 25.6%
- B 34.3%
- C 51.1%
- D 67.6%

Answer _____ [1]



- 3 When 10 cm³ of 2.0 mol dm⁻³ hydrochloric acid is reacted with 10 cm³ of 2.0 mol dm⁻³ sodium hydroxide solution, the temperature change is ΔT .

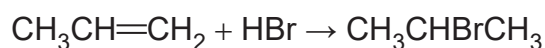


Which one of the following is the temperature change when the reaction is repeated with 50 cm³ of each solution?

- A $\frac{1}{5} \times \Delta T$
- B ΔT
- C $5 \times \Delta T$
- D $10 \times 2 \times \Delta T$

Answer _____ [1]

- 4 The equation for the reaction of propene with hydrogen bromide is shown below.



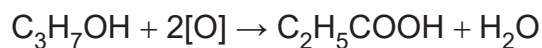
Which one of the following describes the mechanism for this reaction?

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

Answer _____ [1]



- 5 Which one of the following is the percentage yield of propanoic acid if 81.5 g are formed by the complete oxidation of 90.0 g of propan-1-ol?



- A 73.4%
- B 88.6%
- C 89.5%
- D 90.6%

Answer _____ [1]

- 6 Which one of the following is the catalyst used in the hydrogenation of alkenes?

- A iron
- B manganese(IV) oxide
- C nickel
- D vanadium(V) oxide

Answer _____ [1]

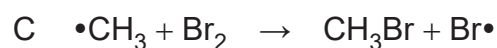
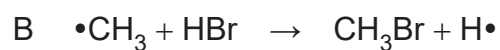
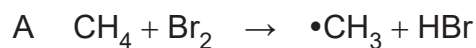
- 7 Which one of the following reacts with ethanol to produce steamy fumes?

- A ammonia
- B hydrogen chloride
- C phosphorus(V) chloride
- D sodium

Answer _____ [1]



8 Which one of the following equations correctly shows a propagation step in the photochemical radical substitution reaction of methane with bromine?



Answer _____ [1]

9 Which one of the following shows the products for the reaction of magnesium with steam?

A magnesium hydroxide and hydrogen

B magnesium hydroxide and oxygen

C magnesium oxide and hydrogen

D magnesium oxide and oxygen

Answer _____ [1]

10 Which one of the following is the major product in the reaction between but-1-ene and hydrogen bromide?

A 1-bromobutane

B 2-bromobutane

C 1,1-dibromobutane

D 1,2-dibromobutane

Answer _____ [1]

[Turn over

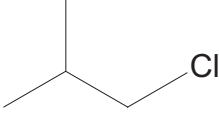
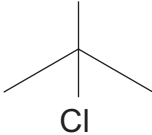


Section B

Answer **all six** questions in this section

11 Halogenoalkanes are reactive organic molecules.

(a) There are four structural isomers with the formula C_4H_9Cl . Complete the table below to give information about these isomers.

IUPAC name	Skeletal formula	Classification
1-chlorobutane		Primary
		Primary
		Secondary
2-chloro-2-methylpropane		

[5]



(b) 2-chloro-2-methylpropane reacts with aqueous potassium hydroxide.

(i) State the IUPAC name of the organic product of this reaction.

_____ [1]

(ii) Draw the mechanism for the reaction of 2-chloro-2-methylpropane with aqueous potassium hydroxide.

[4]

[Turn over

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(c) The progress of the reaction between 2-chloro-2-methylpropane and aqueous potassium hydroxide can be monitored using infrared spectroscopy.

(i) Explain why organic molecules absorb infrared radiation.

_____ [1]

(ii) Describe how the infrared spectrum of 2-chloro-2-methylpropane is different from that of the purified product of the reaction in part (b).

_____ [1]



(d) Complete the following table, outlining reactions of 1-chlorobutane with different reagents.

Reagent	Conditions	Reaction type	Structure of organic product
Potassium hydroxide	Reflux in ethanolic solution		
Ammonia	Ammonia in ethanol, heat in sealed tube		$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
Potassium cyanide	Reflux in ethanolic solution	Substitution	

[4]



12 Enthalpy changes may be determined using average bond enthalpy values and by Hess's Law.

(a) Define the following terms:

(i) **Average bond enthalpy**

[2]

(ii) **Hess's Law**

[2]

(b) The equation for the thermal decomposition of barium nitrate is given below.



The table below shows some enthalpy changes which are involved in the determination of the enthalpy of decomposition of barium nitrate.

Enthalpy change	Equation	$\Delta H / \text{kJ mol}^{-1}$
Enthalpy of formation of barium nitrate	$\text{Ba}(\text{s}) + \text{N}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow \text{Ba}(\text{NO}_3)_2(\text{s})$	-988.0
Enthalpy of formation of barium oxide	$\text{Ba}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{BaO}(\text{s})$	-558.1
Enthalpy of formation of nitrogen dioxide		+33.2

(i) Write an equation for the enthalpy of formation of nitrogen dioxide.

[2]



(ii) Using Hess's Law, calculate a value for the enthalpy change for the thermal decomposition of barium nitrate per mole of barium nitrate. Give your answer to 3 significant figures.

Answer _____ kJ mol⁻¹ [4]

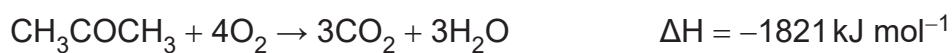
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(c) The complete combustion of propanone is represented by the equation below:



Calculate the average bond enthalpy of the C=O bond.

Bond	Average bond enthalpy /kJ mol ⁻¹
C—H	412
C—C	348
O—H	463
O=O	496

Answer _____ kJ mol⁻¹ [4]





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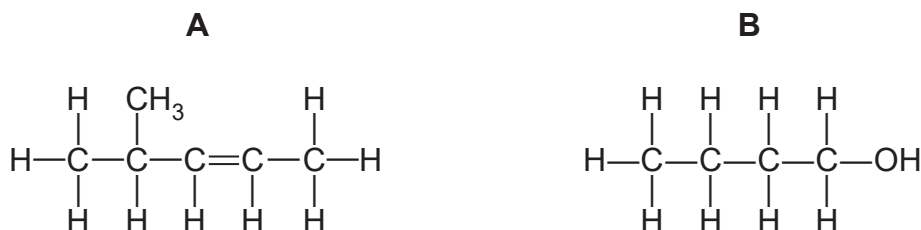
13 Organic compounds undergo a wide range of reactions.

(a) But-1-ene can undergo addition polymerisation. Draw the structure of the polymer formed from but-1-ene, showing three repeating units.

[1]



- (c) The structures of two organic compounds, labelled **A** and **B**, are shown below. Compound **A** reacts with hydrogen and compound **B** reacts with acidified potassium dichromate(VI) solution.



- (i) Write the empirical formula of compound **A**.

_____ [1]

- (ii) State the IUPAC names of compounds **A** and **B**.

A _____

B _____ [2]

- (iii) State the IUPAC name of the compound formed when **A** reacts with hydrogen.

_____ [1]

- (iv) State the type of reaction which occurs when compound **B** reacts with acidified potassium dichromate(VI) solution.

_____ [1]



(v) Draw the structural formula of another alcohol, which is an isomer of compound **B**, that would **not** react with acidified potassium dichromate(VI) solution. Explain your answer.

[2]

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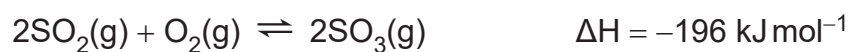
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14 Sulfuric acid is manufactured by the Contact process.

One reaction in this process involves the conversion of sulfur dioxide to sulfur trioxide according to the following equation:



(a) This reaction can reach dynamic equilibrium. Define the term **dynamic equilibrium**.

[2]

(b) Write an expression for K_c for the above reaction and state its units.

Units: _____ [2]

(c) State and explain the effect of increasing the pressure on the equilibrium yield of sulfur trioxide.

[3]



(d) On the axes below, draw an enthalpy level diagram for this reaction. Label the axes and the enthalpy change (ΔH).



[3]

(e) The sulfur trioxide produced in the Contact process is absorbed into 98% sulfuric acid to produce oleum ($\text{H}_2\text{S}_2\text{O}_7$). The oleum is then diluted by dissolving it in water to produce sulfuric acid.

Write an equation for the reaction between oleum and water to produce sulfuric acid.

_____ [1]



- 15 (a) Catalytic converters convert unreacted hydrocarbons, such as ethane, to less harmful products.

Calculate the total volume, in dm^3 , of gaseous products formed when 11.85 kg of ethane were reacted with excess nitrogen(IV) oxide in a catalytic converter.

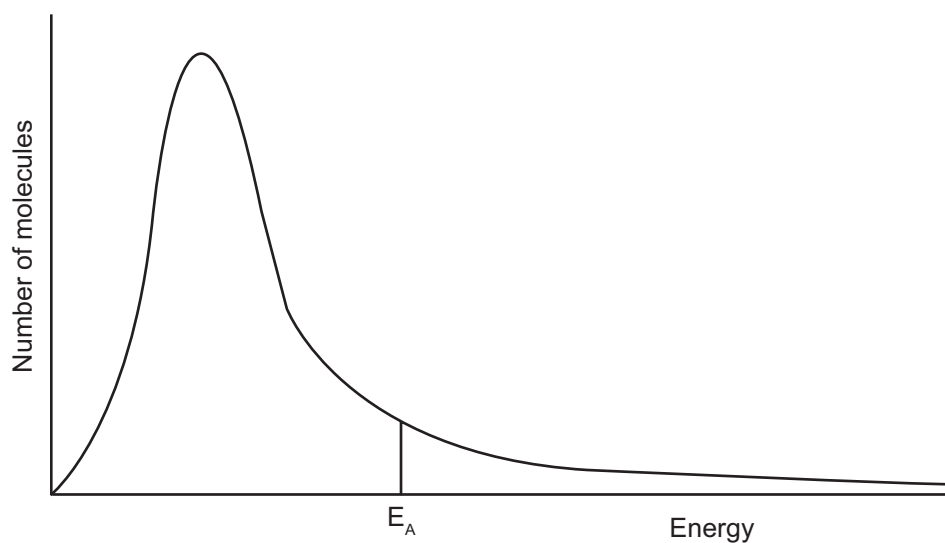
The molar gas volume is 24 dm^3 .



Answer _____ dm^3 [3]



(b) The Maxwell–Boltzmann distribution of molecular energies for a mixture of ethane and nitrogen(IV) oxide at 300 K is shown below.



(i) With reference to the graph, explain how the catalyst increases the rate of this chemical reaction.

[3]

(ii) Sketch on the graph the distribution of molecular energies you would expect to obtain at 500 K. [2]

[Turn over



(c) Alkanes can be replaced as fuels by hydrogen or by alcohols, such as ethanol.

The table below compares the use of hydrogen and ethanol as fuels.

Fuel	Enthalpy of combustion /kJ mol ⁻¹	Energy evolved per gram /kJ	Energy evolved per cm ³ /kJ	State at room temperature and pressure
Hydrogen	-286	143	0.012	gas
Ethanol	-1367			liquid

(i) Write an equation for the complete combustion of one mole of ethanol.

_____ [2]

(ii) Calculate the molar mass of ethanol.

Answer _____ g mol⁻¹ [1]

(iii) Calculate the energy evolved per gram for ethanol.

Answer _____ kJ [1]



(iv) Calculate the energy evolved per cm^3 for ethanol. The density of ethanol is 0.79 g cm^{-3} .

Answer _____ kJ [2]

(v) Suggest one environmental advantage of using hydrogen as a fuel rather than ethanol.

[1]

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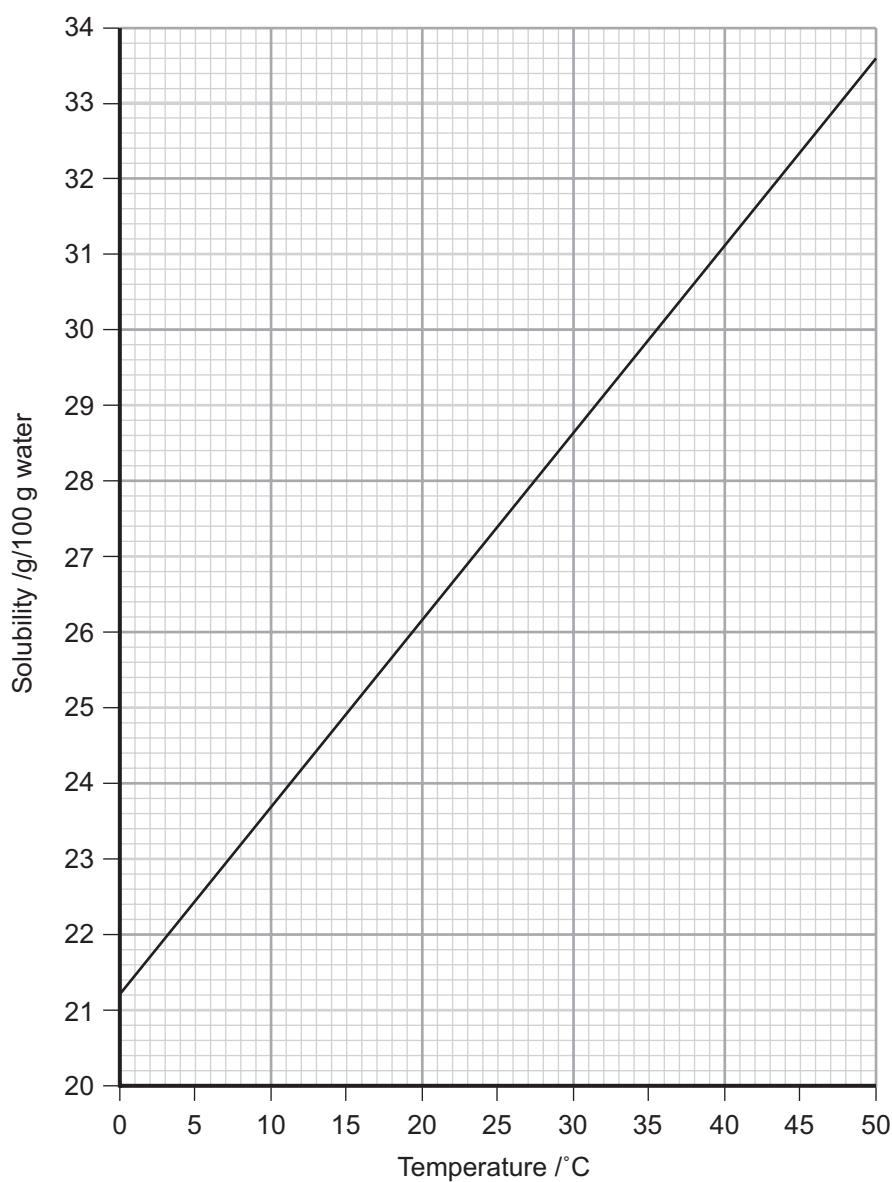


16 The solubility of Group II compounds in water varies greatly.

(a) Explain what is meant by the term **solubility**.

[1]

(b) The graph below shows the solubility of magnesium sulfate at different temperatures.



- (i) Calculate the mass of solid that would crystallise when a saturated solution of magnesium sulfate in 2 kg of water is cooled from 30 °C to 20 °C.

Answer _____ g [2]

- (ii) Magnesium sulfate is formed when magnesium reacts with sulfuric acid. Write an equation for this reaction.

_____ [1]

- (c) Group II metals react with water to form metal hydroxides.

- (i) Write an equation for the reaction of calcium with water.

_____ [1]

- (ii) State the trend in solubility of the Group II hydroxides.

_____ [1]

[Turn over



(d) The table below shows the decomposition temperatures of the Group II carbonates.

Group II carbonate	Decomposition temperature /°C
magnesium carbonate	540
calcium carbonate	900
strontium carbonate	1290
barium carbonate	1360

(i) Write an equation for the decomposition of strontium carbonate.

_____ [1]

(ii) State and explain the trend in the thermal stability of the Group II carbonates.

_____ [3]

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General Information

1 tonne = 10^6 g

1 metre = 10^9 nm

One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

Specific Heat Capacity of water = $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light = $3 \times 10^8 \text{ ms}^{-1}$



Characteristic absorptions in IR spectroscopy

Wavenumber/cm ⁻¹	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C ₆ H ₅ –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C ₆ H ₅	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations chemistry

THE PERIODIC TABLE OF ELEMENTS

Group

I II III IV V VI VII 0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1 H Hydrogen 1																			4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10		
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18		
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36		
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 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		
133 Cs Caesium 55	137 Ba Barium 56	139 La [*] Lanthanum 57	178 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		
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	285 Cn Copernicium 112								

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series



a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 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