

**2011-AL
CHEM**

PAPER 2

BEACON COLLEGE

MOCK EXAMINATION - 2011

CHEMISTRY A-LEVEL PAPER 2

3 hours

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1. There are **TWO** sections in this paper, Section A and Section B
2. Section A carries 60 marks
Section B carries 40 marks
3. Answer **ALL** questions from both Sections A and B
4. Answer to questions from Section A and B are to be written in the **AL(C)** and **AL(E)** Answer Books respectively.
5. Some constants, characteristic infra-red absorption wavenumber ranges, standard reduction potentials and a Periodic Table can be found on page 11, 12 and 13 of this Question Book.

Section A

Answer **ALL** questions, using the **AL(C)** Answer Book.

1. (a) Bromate(V) ion (BrO_3^-) slowly oxidizes bromide ion to form bromine and water. In order to determine the activation energy of the reaction, certain amount of potassium bromate(V), potassium bromide, dilute sulphuric acid, phenol and methyl orange were mixed. The time (t) for the disappearance of red color was recorded. The reaction was repeated at different temperature (T) using the same amount of each component. The experimental results are shown below:

T/ K	304	311	315	320
t/ s	113	70	54	39

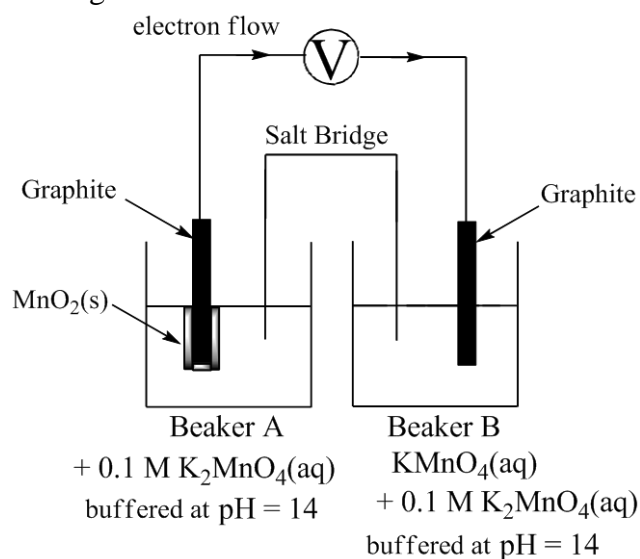
- (i) Write the chemical equation between bromate(V) ions and bromide ion.
- (ii) Write the chemical equation between phenol and bromine.
(Hint: 1 mole of phenol reacts with 3 moles of bromine)
- (iii) Explain the function of methyl orange in the experiment.
- (iv) A student tries to follow the reaction by the following chemical method.
Add a certain amount potassium iodide, thiosulphate and starch indicator to the reaction mixture. Record the time for the appearance of blue color.
Do you agree with the student? Explain your answer.
- (iv) By plotting a suitable graph, determine the activation energy of the reaction.
- (v) Write a physical method that can be used to monitor the above reaction.

[10 marks]

1. (b) Given the following standard reduction potentials:

	Potential
The reduction of $\text{MnO}_4^-(\text{aq})$ to $\text{MnO}_4^{2-}(\text{aq})$ in alkaline medium	0.56 V
The reduction of $\text{MnO}_4^{2-}(\text{aq})$ to $\text{MnO}_2(\text{s})$ in alkaline medium	0.59 V
The reduction of $\text{MnO}_4^-(\text{aq})$ to $\text{MnO}_4^{2-}(\text{aq})$ in acidic medium	0.56 V
The reduction of $\text{MnO}_4^{2-}(\text{aq})$ to $\text{MnO}_2(\text{s})$ in acidic medium	2.26 V

Consider the following chemical cell:



- (i) Write the overall ionic equation of the redox reaction. State the observable changes in Beaker A and Beaker B.
 - (ii) The potential measured by voltmeter is + 0.0763 V. Calculate the concentration of permanganate ion in Beaker B.
 - (iii) If a few drops of water are added to Beaker A, explain how the potential measured will be affected.
 - (iv) After a certain period of time, the solution in Beaker A was poured into dilute sulphuric acid. Brown precipitate was observed. Write the ionic equation involved.
- (c) FeO_4^{2-} is a very strong oxidizing agent, which is only stable in alkaline condition. It can oxidize ethanol to carbon dioxide and it is reduced to iron (III) hydroxide.
- (i) Write the ionic equation involved in the reaction
 - (ii) In an experiment, when alkaline $\text{FeO}_4^{2-}(\text{aq})$ was added to ethanol, no colorless bubble was observed. Account for this phenomenon.

[10 marks]

- 2 (a) NH_4HS undergoes decomposition to form ammonia and hydrogen sulphide. The chemical equation is shown below:



At 310 K, the K_p for the above decomposition is 81 kPa^2 .

- (i) In an experiment, 5 mol of $\text{NH}_4\text{HS(s)}$, 0.15 mol of ammonia and 0.13 mol hydrogen sulphide are introduced into an evacuated vessel of 25.0 dm^3 kept at 310K. Calculate the equilibrium partial pressure of NH_3 and H_2S .
- (ii) If 0.05 mol ammonia was added to the reaction mixture in (i), calculate the equilibrium partial pressure of NH_3 and H_2S .
- (iii) It was found that the K_p becomes triple at 131.3 K, calculate the standard enthalpy change for the dissociation of NH_4HS . Hence comment on the relative stability between NH_4HS and its decomposition products.

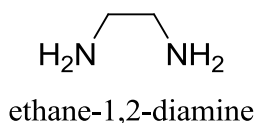
[10 marks]

- (b) Explain how the following stresses affect the equilibrium position of the reaction and the total pressure of the system at equilibrium in (a).

- (i) Injection of 3 moles of helium gas at constant volume
- (ii) Compressing the vessel at constant temperature

[3 marks]

- 2 (c) Ethane-1,2-diamine, abbreviated as “en”, is a bidentate ligand. Its structure is shown below:



Ethane-1,2-diamine can react with zinc ion to form a complex Zn(en)_y^{2+} . The following experiment was conducted in order to determine the value of y (y is a positive integer):

Excess en was added to 50 cm^3 of 0.3 M zinc nitrate solution. The solution was diluted with H_2O to 150 cm^3 . An organic solvent J was added to the mixture. After shaking the reaction mixture, 25 cm^3 of each layers were transferred to conical flasks. It was found that the 25 cm^3 organic layer required 100 cm^3 of 2.6 M hydrochloric acid for complete neutralization while 25 cm^3 of the aqueous layer required 100 cm^3 of 0.3 M hydrochloric acid for complete neutralization.

- (i) What is the definition of partition law ?
- (ii) Given that the partition coefficient (K_d) of en between organic solvent J and water is 13(en is more soluble in organic solvent J). Calculate the value of y .
- (iii) Draw the structure of Zn(en)_y^{2+} .
- (iv) Do you think Zn(en)_y^{2+} can rotate plane-polarized light? Explain your answer.

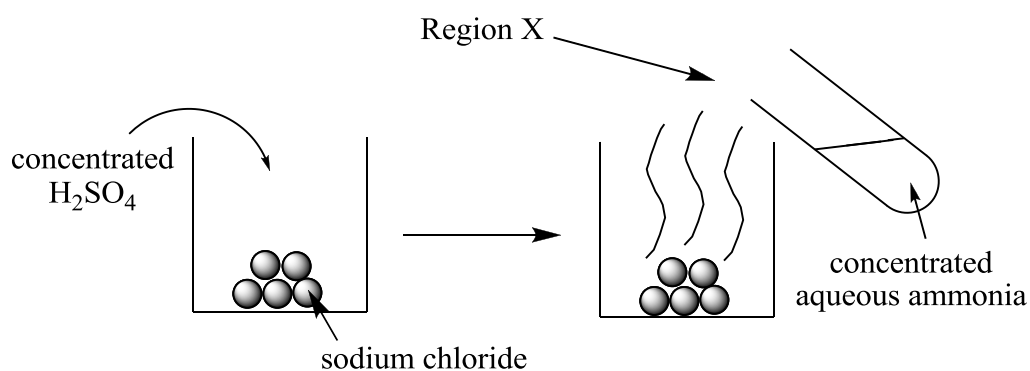
[7 marks]

3 (a) Explain whether the following statements are correct.

- (i) The rate of reaction with higher activation energy is more sensitive to the changes in temperature.
- (ii) Ionic compound with more negative lattice enthalpies is more stable.
- (iii) For group(V) and group(VI) elements in the second period of the periodic table, they exist in elemental forms by forming multiple bonds. While for those in the third period, they exist in elemental forms by forming single bonds.
- (iv) The salts of group (II) metals are generally less soluble than those of group (I) metals.

[8 marks]

(b) Consider the following experiments:



In the above experiment, 3 cm^3 of concentrated sulphuric acid is added to 10.53 g of sodium chloride salt.

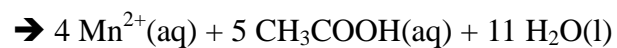
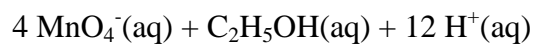
- (i) Given that the percentage of mass and density of the concentrated sulphuric acid is 98% and 1.84 g cm^{-3} respectively, calculate the volume of the gaseous product, measured at room temperature and pressure that can be obtained. (You are required to write the chemical equation, with physical state, involved in the calculations)
[Relative atomic masses: H = 1.0; O = 16.0; Na = 23.0; S = 32.1; Cl = 35.5. Molar volume of gas at RTP = 24.0 dm^3]
- (ii) State the observable change in Region X and write the chemical equation involved. (you are required to show the physical states of each substances)

[8 marks]

3 (c) Briefly outline the experimental procedures required for the followings:

(i) Determination of concentration of potassium iodate(V) solution.
(You are required to write the ionic equations involved. Steps involving calculations are not required)

(ii) Monitoring the rate of the following reaction by colorimetric measurement:



(You are required to explain the principle behind)

[6 marks]

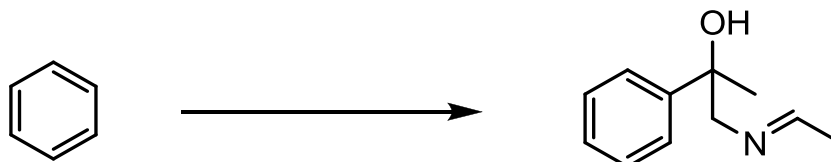
END OF SECTION A

Section B

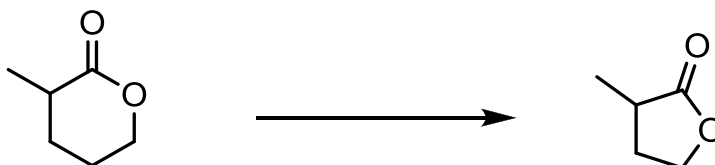
Answer **ALL** questions, using the **AL(E)** Answer Book.

- 4.. (a) Outline a synthetic route, with no more than six steps, to accomplish each of the following transformations. For each step, give the reagent(s), conditions and the structure of the organic product.

(i)



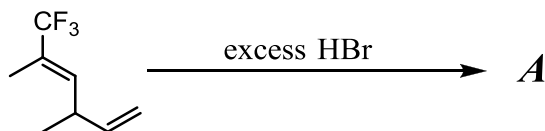
(ii)



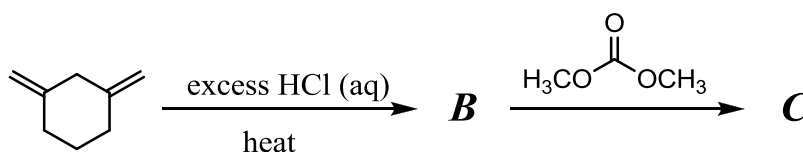
(9 marks)

- (b) Give the reagent(s) **D**, **E**, **F**, and the structure of the product **A**, **B**, **C**.

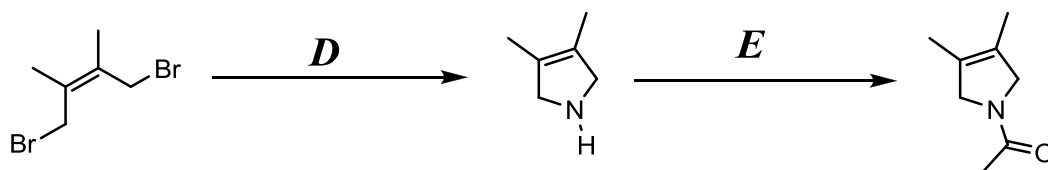
(i)



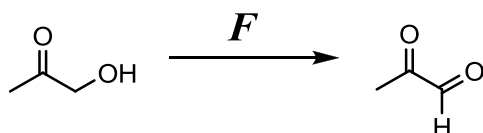
(ii)



(iii)

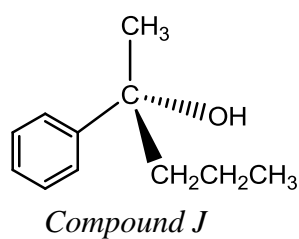


(b) (iv)

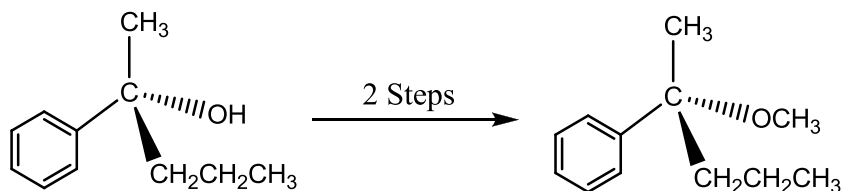


(5 marks)

4. (c) *Compound J* is an optically active compound, its structure is shown below:



- (i) When *Compound J* is treated with dilute sulphuric acid at room temperature. It lost its optical activity. Write a mechanism to account for this phenomenon.
- (ii) Suggest a synthetic route for the following conversion.



5. (a) *Compound W* has 2 chiral centers. Experimental data of *W* are shown below.
- I. Elemental analysis shows that *W* contains 66.7% carbon, 8.0% hydrogen and 25.3% oxygen by mass.
 - II. Upon vaporization, 3 g *W* occupies 200 dm³ at 177 °C under 445.8 Pa
 - III. *W* shows strong absorption at 1610 cm⁻¹, 1720 cm⁻¹ and no absorption at 3400 cm⁻¹ in the infra-red spectrum
 - IV. When *W* was treated with dilute sulphuric acid and heated for 10 minutes, methanol was isolated from the reaction mixture.
 - V. *W* shows peaks with the mass to charge ratio 126, 95 and 67 in the mass spectrum.

Using the given experimental data,

- (i) deduce the molecular formula of *W*.
- (ii) deduce the structure of *W*
(you are required to account for all experimental data given)

[8 marks]

- (b) 5 g *W* reacts was treated with lithium aluminum hydride. Upon acidification of the reaction mixture, 1.8 g of compound *X* was formed. Draw the structure of *X* and calculate the percentage yield of the reaction.

[3 marks]

5. (c) Polythene is a very common thermoplastic which is widely used in making plastic bags. It can be prepared by the free radical polymerization of ethene using benzoyl peroxide as the initiator.
- (i) Write a mechanism for the polymerization.
 - (ii) The polymer chain of low density polythene contains branched chains. Write a mechanism to account for this phenomenon.
 - (iii) Explain why low density polythene has a low melting point.
 - (iv) Styrene can also undergo free radical polymerization using benzoyl peroxide as the initiator. However, the polymer chain of polystyrene has no branched chains. Give an explanation for this.

[9 marks]

END OF PAPER

Constants

Gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 3 \times 10^8 \text{ m s}^{-1}$

Ionic product of water at 298 K, $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

Specific heat capacity of water = $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

Bond	Compound type	Wavenumber range / cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acid and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O-H	Acids (Hydrogen –bonded)	2500 to 3300
C-H	Alkanes, alkenes, arenes	2840 to 3095
O-H	Alcohols, phenols (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

Standard Reduction Potentials at 298 K

	E^\ominus / V
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.04
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.92
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.38
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.66
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.19
$\text{V}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{V}(\text{s})$	-1.18
$\text{Cr}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cr}(\text{s})$	-0.91
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Cr}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cr}^{2+}(\text{aq})$	-0.41
$\text{V}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{2+}(\text{aq})$	-0.26
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}^+(\text{aq})$	+0.15
$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	+0.17
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.34
$[\text{Fe}(\text{CN})_6]^{3-}(\text{aq}) + \text{e}^- \rightleftharpoons [\text{Fe}(\text{CN})_6]^{4-}(\text{aq})$	+0.36
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.52
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{MnO}_4^-(\text{aq}) + \text{e}^- \rightleftharpoons \text{MnO}_4^{2-}(\text{aq})$	+0.56
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{VO}^{2+} + \text{H}_2\text{O}(\text{l})$	+1.00
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	+1.07
$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+1.47
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51
$\text{MnO}_4^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l})$	+1.70
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{S}_2\text{O}_8^{2-}(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{SO}_4^{2-}(\text{aq})$	+2.01

PERIODIC TABLE

<table border="1" style="border-collapse: collapse; width: 100px; height: 50px;"> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">H</td> <td style="text-align: center;">1.01</td> </tr> </table>		1	H	1.01	<table border="1" style="border-collapse: collapse; width: 100px; height: 50px;"> <tr> <td style="text-align: center;">Atomic number</td> <td style="text-align: center;">Symbol</td> <td style="text-align: center;">Atomic weight (rounded value)</td> </tr> </table>		Atomic number	Symbol	Atomic weight (rounded value)																		
1	H	1.01																									
Atomic number	Symbol	Atomic weight (rounded value)																									
IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA												
1 H 1.01	3 Li 6.94	11 Na 23.0	19 K 39.1	27 Co 58.9	35 Br 79.9	43 Tc 98.9	51 Sb 121.8	59 Au 197.0	67 Ho 164.9	75 C 12.0	83 Bi 208.0	91 P 31.0	99 At (210)	107 I 126.9	115 Xe 131.3												
20 Ca 40.1	28 Fe 55.8	36 Kr 83.8	44 Ru 101.1	52 Te 127.6	60 Zn 65.4	68 Er 167.3	76 Os 192.2	84 Po (210)	92 U 238.0	100 Fm (257)	108 Hs (269)	116 Lv (293)	124 Og (294)														
37 Rb 85.5	45 Rh 102.9	53 I 126.9	61 Pm (145)	69 Tm 168.9	77 Ir 192.2	85 At (210)	93 Np (237)	101 Md (258)	109 Mt (269)	117 Ts (294)	125 Og (294)																
54 Xe 131.3	62 Sm 150.4	70 Yb 173.0	78 Pt 195.1	86 Rn (222)	94 Pu (244)	102 No (259)	110 Ds (285)	118 Og (294)																			
87 Fr (223)	95 Am (243)	103 Lr (260)	103 Lr (260)	111 Rg (288)	119 Uue (298)	127 Uuq (304)	135 Uub (310)	143 Uut (316)	151 Uuq (322)	159 Uuh (328)	167 Uuo (334)	175 Uuq (340)	183 Uuq (346)	191 Uuq (352)	199 Uuq (358)	207 Uuq (364)	215 Uuq (370)	223 Uuq (376)									