LAST NAME: ______________________________

FIRST NAME: ______________________________

Student Number: ______________________________

CHM 1311 B
Midterm #1
Fall 2013

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 10 pages in this test. A periodic table and data sheets are provided at the end. You may rip these pages off of the exam and use them to cover your work during the test. Any scratch work should be done on the back of these pages.

Please show all work to receive partial credit.

You have 75 minutes to complete the test.

Question	**Points Possible**	**Points Earned**	**TA Initial**
1	**12**		
2	**12**		
3	**16**		
4	**10**		
TOTAL	**50**		

#1. (12 points) Short Answer Questions

a) Name the following compounds:

NaClO ________________**sodium hypochlorite**________________

$HBrO_3$ _____________________**bromic acid**_________________

b) What is the molecular formula of aluminium hydroxide?

$Al(OH)_3$ **-0.5 if formula stoichiometry wrong**

c) Circle the gas that would have the lowest density at standard temperature and pressure.

A) SF_6 **B) CF_2Cl_2** **C) CO_2** [✓ **D) N_2**] **E) Kr**

d) For the list of gases shown above, name the gas with the highest average speed at standard temperature and pressure.

N_2

e) At standard temperature and pressure, what type of interaction is dominant in a real gas that has a volume that is larger than the volume predicted by the ideal gas law?

Repulsive interactions

f) A system absorbs 623 J of heat while doing 457 J of work. What is the value of ΔU?

$\Delta U = 623\text{ J} - 457\text{ J} = 166\text{ J}$ **-0.5 if sign for one of the energies is wrong**

g) Write the appropriate symbol for the species containing 45 neutrons, 35 protons, and 36 electrons. **(2 marks)**

$$^{80}_{35}\mathrm{Br}^{-}$$

h) Name the subatomic particle that is produced in a cathode ray tube.

The electron

i) How many millilitres of a liquid would fit into a cylinder with a radius of 3.0 m and height of 69 cm? (Volume of a cylinder = $\pi r^2 h$) **-0.5 very wrong sig figs, -0.5 if diff units in final answer**

$$V = \pi r^2 h = \pi (3.0\text{ m})^2 \left(\frac{10^4\text{ cm}^2}{1\text{ m}^2}\right)(69\text{ cm}) = 2.0\times10^7\text{ cm}^3 = 2.0\times10^7\text{ mL}$$

(2 marks)

#2. (12 points) The combustion of 0.246 g of an organic compound gives 0.656 g CO_2, 0.134 g H_2O, and 1.86 × 10^{-3} mol N_2 gas.

a) Does this organic compound contain any oxygen? Use a calculation to support your answer. (6 marks)

Use law of mass conservation to find number of moles of oxygen used in reaction.

$$m_{\text{reactants}} = m_{\text{products}} = m_{\text{H}_2\text{O}} + m_{\text{CO}_2} + m_{\text{N}_2} = m_{\text{Compound}} + m_{\text{O}_2}$$

$$\begin{aligned} m_{\text{O}_2} &= m_{\text{H}_2\text{O}} + m_{\text{CO}_2} + n_{\text{N}_2} M_{\text{N}_2} - m_{\text{Compound}} \\ &= 0.134 \text{ g} + 0.656 \text{ g} + \left(1.86\text{x}10^{-3} \text{ mol}\right)\left(2 \times 14.01 \text{ g/mol}\right) - 0.246 \text{ g} \\ &= 0.5961 \text{ g} \end{aligned}$$

Now we convert this to number of moles of oxygen, and compare to the number of moles of oxygen in the products:

$$n_{\text{O,Reactants}} = \frac{m_{\text{O}_2}}{M_{\text{O}_2}} = \frac{0.5961 \text{ g}}{2 \times 16.00 \text{ g/mol}} \times \frac{2 \text{ mol O}}{1 \text{ mol O}_2} = 3.725 \times 10^{-2} \text{ mol}$$

$$\begin{aligned} n_{\text{O,Products}} &= \frac{m_{\text{CO}_2}}{M_{\text{CO}_2}} \times \frac{2 \text{ mol O}_2}{1 \text{ mol CO}_2} + \frac{m_{\text{H}_2\text{O}}}{M_{\text{H}_2\text{O}}} \\ &= \frac{0.656 \text{ g}}{(12.01 + 16.00 \times 2) \text{ g/mol}} \times \frac{2 \text{ mol O}}{1 \text{ mol CO}_2} + \frac{0.134 \text{ g}}{\left(1.008 \times 2 + 16.00\right) \text{ g/mol}} \\ &= 0.01491 \text{ mol} \times \frac{2 \text{ mol O}}{1 \text{ mol CO}_2} + 0.007438 \text{ mol} = 3.725 \times 10^{-2} \text{ mol} \end{aligned}$$

Since number of moles in products equals the number of moles of oxygen in the reactant, there can be no oxygen in the organic compound. (Otherwise we would have had less O_2 being used in the combustion reaction.)

b) What is the empirical formula of this organic compound? (2 marks)

$$n_C = n_{\text{CO}_2} = \frac{m_{\text{CO}_2}}{M_{\text{CO}_2}} = 1.491 \times 10^{-2} \text{ mol}$$

c) $n_{\text{H}} = n_{\text{H}_2\text{O}} \times \dfrac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = 2 \times 0.007438 \text{ mol} = 1.491 \times 10^{-2} \text{ mol}$

d) $n_{\text{N}} = n_{\text{N}_2} \times \dfrac{2 \text{ mol N}}{1 \text{ mol N}_2} = 2 \times 1.86 \times 10^{-3} \text{ mol} = 3.72 \times 10^{-3} \text{ mol}$

$$\text{C}_{\frac{1.491\text{x}10^{-2}}{3.72\text{x}10^{-3}}} \text{H}_{\frac{1.489\text{x}10^{-2}}{3.72\text{x}10^{-3}}} \text{N}_{\frac{3.72\text{x}10^{-3}}{3.72\text{x}10^{-3}}} = \text{C}_4\text{H}_4\text{N}$$

Answer: ____________ **C_4H_4N** ______________________

e) **Given that $H_2(g)$ has an effusion rate that is approximately 8-times faster than the effusion rate of this compound, what is the molecular formula of this organic compound? (4 marks)**

$$\frac{\text{Rate H}_2}{\text{Rate compound}} = 8 = \sqrt{\frac{M_{\text{Compound}}}{M_{\text{H}_2}}}$$

$$M_{\text{Compound}} = 8^2 M_{\text{H}_2} = 129.024 \text{ g/mol}$$

$$M_{\text{C}_4\text{H}_4\text{N}} = (12.01\times4+1.008\times4+14.01\times4) \text{ g/mol} = 66.082 \text{ g/mol}$$

f) $$\text{Whole number multiple} = \frac{M_{\text{Compound}}}{M_{\text{C}_4\text{H}_4\text{N}}} = \frac{129.024 \text{ g/mol}}{66.082 \text{ g/mol}} = 2$$

g) **The molecular formula is:** $C_{4\times2}H_{4\times2}N_{1\times2}$

Answer: ________________ **$C_8H_8N_2$**__________________

#3. In the following reaction:

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

O_2 was collected over water at 25.2°C. When the tube collecting the gas was lowered such that the level of water inside the tube matched the level outside the tube, the volume was 674 mL. A barometer in the lab showed a pressure reading of 765.0 mmHg on the day of the experiment, while the vapour pressure for water at this temperature is 23.8 mmHg.

a) **What is the mole fraction of O_2 in the gas collected over water? (3 marks)**

Pressure of the atmosphere = 765.0 mmHg = total pressure of gas trapped in tube
Pressure of the water vapour = 23.8 mmHg
Pressure of the trapped gas = (765.0 – 23.8) mmHg = 741.2 mmHg

$$p_{\text{O}_2} = X_{\text{O}_2} p_T$$

$$X_{\text{O}_2} = \frac{p_{\text{O}_2}}{p_T} = \frac{741.2 \text{ mmHg}}{761.1 \text{ mmHg}} = 0.9739$$

-0.5 if only number of moles of gas calculated

Answer: _____________**0.9739**______________________

b) Calculate the percent yield of the reaction, given that the reaction was performed with 14.0 g of $KClO_3$. (6 marks)

$$n_{O_2} = n_{KClO_3} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} = \frac{m_{KClO_3}}{M_{KClO_3}} \times \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} = \frac{14.0 \text{ g}}{(39.10 + 35.45 + 16.00 \times 3) \text{ g/mol}} \times \frac{3}{2} = 0.1714 \text{ mol}$$

$$m_{O_2} = n_{O_2} M_{O_2} = 0.1714 \text{ mol } \times \left(16.00 \text{ g/mol } \times 2\right) = 5.483 \text{ g}$$

Actual yield:

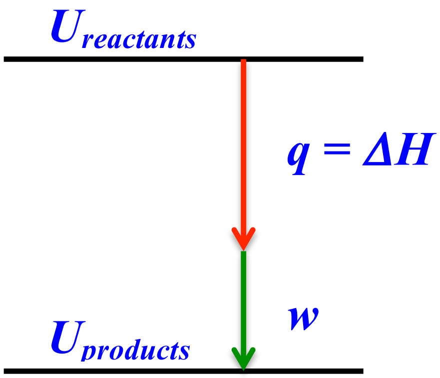
$$m_{O_2} = n_{O_2} M_{O_2} = \frac{p_{O_2} V_{O_2} M_{O_2}}{RT} = \frac{(741.2 \text{ mmHg})\left(\frac{1 \text{ atm}}{760 \text{ mmHg}}\right)(0.674 \text{ L})(2 \times 16.00 \text{ g/mol})}{(0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1})(273.15 + 25.2)\text{K}} = 0.8592 \text{ g}$$

Percent yield:

c) $$\% \text{ yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100\% = \frac{0.8592 \text{ g}}{5.483 \text{ g}} \times 100\% = 15.7\%$$

Answer: 15.7%

d) **Draw an energy level diagram, given that this is an exothermic reaction. Include labels for $U_{\text{reactants}}$, U_{products} and indicate the type(s) of energy transfer and the direction of the transfer in this diagram. (4 marks)**



Since gas is being produced in the reaction, it must do work to expand against 1 atm of pressure.
$\Delta V > 0$, $w < 0$
Therefore some of the energy must be released by the system as work. The remainder is released as heat

e) **Based on your diagram in c), will the absolute value of ΔH be greater than, less than or equal to the absolute value of ΔU for this reaction? Show ΔH in the energy level diagram drawn in c). (2 marks)**

Since enthalpy is the heat of a constant pressure process, ΔH = q in the diagram above. As drawn in this diagram, $|\Delta U| > |\Delta H|$.

f) **If exactly the same reaction was performed in a rigid-walled container, would ΔH be greater than, less than or equal to the ΔH shown in part d)? Justify your answer with one sentence. (1 mark)**

Since we start with the same reactants and finish with the same products in the two reactions, any state function will be the same for the constant volume versus constant pressure conditions. Since enthalpy is as state function it is the same for the two scenarios.

#4. For the following reaction in aqueous solution:

$$MnO_4^- + H_2C_2O_4 \rightarrow Mn^{2+} + CO_2 + H_2O$$

+7 -2 +1 +3 -2 +2 +4 -2 +1 -2

a) **Write the oxidation numbers below each element in the reaction above (2 marks)**

b) **Based on your answer in a), what is the oxidizing agent in this reaction? (1 mark)**

MnO_4^- is being reduced, so it is the oxidizing agent.

c) **Balance this equation in acidic solution (7 marks).**

Balance half reactions:

$$8H^+ + MnO_4^- + 5\ e^- \rightarrow Mn^{2+} + 4H_2O$$

$$H_2C_2O_4 \rightarrow 2\ CO_2 + 2H^+ + 2\ e^-$$

Balance electrons:

$$16H^+ + 2MnO_4^- + 10\ e^- \rightarrow 2Mn^{2+} + 8H_2O$$

$$5\ H_2C_2O_4 \rightarrow 10\ CO_2 + 10H^+ + 10\ e^-$$

Add reactions: $16H^+ + 2MnO_4^- + 5\ H_2C_2O_4 \rightarrow 2Mn^{2+} + 8H_2O + 10\ CO_2 + 10H^+$

Cancel out excess: $6H^+ + 2MnO_4^- + 5\ H_2C_2O_4 \rightarrow 2Mn^{2+} + 8H_2O + 10\ CO_2$

Final balanced chemical equation:

$$6H^+ + 2MnO_4^- + 5\ H_2C_2O_4 \rightarrow 2Mn^{2+} + 8H_2O + 10\ CO_2$$

Constants and Conversion Factors

1 mmHg = 1 torr 760 mmHg = 1 atm 1 atm = 101.325 kPa 1 atm = 1.013125 bar
$1\ \text{cm}^3 = 1$ mL $1\ \text{dm}^3 =$ 1000 mL = 1 L $1\ \text{m}^3 = 1000$ L
1 cal = 4.184 J

Avogadro's Number	N	$6.022\text{x}10^{23}\ \text{mol}^{-1}$
Atomic mass unit	u	$1.66054\text{x}10^{-27}$ kg
Gas constant	R	$8.31451\ \text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.08206\ \text{atm}\cdot\text{L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$8.31451\ \text{m}^3\ \text{Pa}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.0831451\ \text{bar L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$

Equations

$$T(\text{in K}) = T(\text{in }^\circ\text{C}) + 273.15\text{ K}$$

$$n = \frac{m}{M}$$

$$\%\text{ Yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$c(\text{mol / L}) = \frac{n}{V}$$

$$c_1V_1 = c_2V_2$$

$$pV = nRT$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$p_T = p_1 + p_2 + p_3 + \ldots$$

$$p_A = X_A \times p_T$$

$$d = \frac{m}{V} = \frac{p \cdot MM}{RT}$$

$$E_K = \frac{1}{2}m\text{v}^2$$

$$u_{rms} = \sqrt{\frac{3RT}{M}}$$

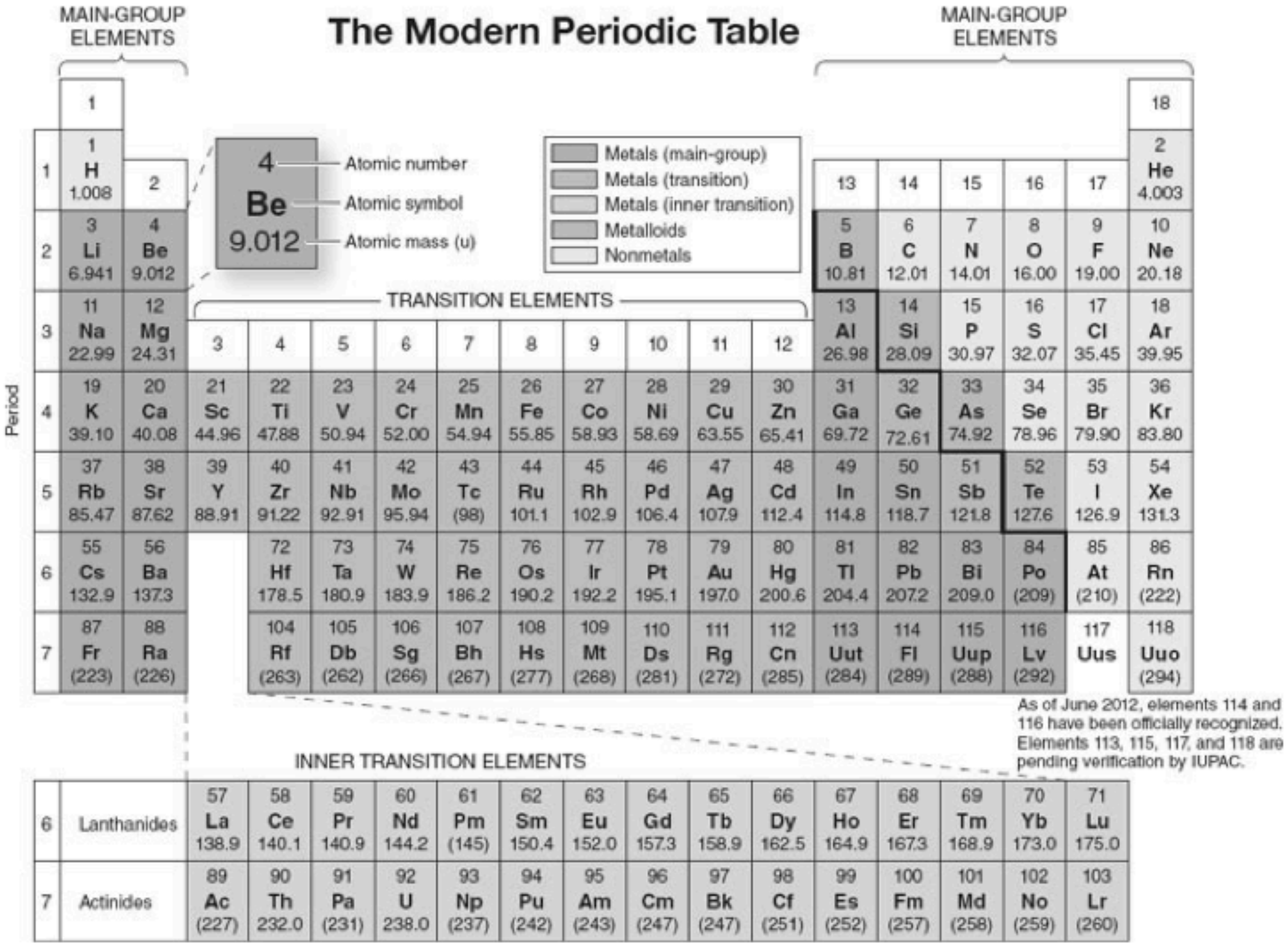
$$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{M_B}{M_A}}$$

$$\left(p + \frac{n^2a}{V^2}\right)\left(V - nb\right) = nRT$$

$$w = -p\Delta V$$

$$\Delta U = U_{final} - U_{initial} = q + w$$

$$\Delta H = \Delta U + p\Delta V$$



The Modern Periodic Table

MAIN-GROUP ELEMENTS

MAIN-GROUP ELEMENTS

TRANSITION ELEMENTS

4 — Atomic number
Be — Atomic symbol
9.012 — Atomic mass (u)

- ▨ Metals (main-group)
- ▨ Metals (transition)
- ▨ Metals (inner transition)
- ▨ Metalloids
- ☐ Nonmetals

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3		72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)		104 Rf (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (292)	117 Uus	118 Uuo (294)

As of June 2012, elements 114 and 116 have been officially recognized. Elements 113, 115, 117, and 118 are pending verification by IUPAC.

INNER TRANSITION ELEMENTS

6	Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
7	Actinides	89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)