

NAME: \_\_\_\_\_

Student Number: \_\_\_\_\_

Fall 2012

**Chemistry 1000 Practice Midterm #1B**

\_\_\_\_\_/ 55 marks

- INSTRUCTIONS:
- 1) Please read over the test carefully before beginning. You should have 7 pages of questions and a formula/periodic table sheet.
  - 2) If your work is not legible, it will be given a mark of zero.
  - 3) Marks will be deducted for incorrect information added to an otherwise correct answer.
  - 4) Marks will be deducted for improper use of significant figures and for missing or incorrect units.
  - 5) Show your work for all calculations. Answers without supporting calculations will not be given full credit.
  - 6) You may use a calculator.
  - 7) You have 90 minutes to complete this test.

**Confidentiality Agreement:**

I agree not to discuss (or in any other way divulge) the contents of this exam until after 8:30pm Mountain Time on Monday, October 15<sup>th</sup>, 2012. I understand that breaking this agreement would constitute academic misconduct, a serious offense with serious consequences. The minimum punishment would be a mark of 0/55 on this exam and removal of the “overwrite midterm mark with final exam mark” option for my grade in this course; the maximum punishment would include expulsion from this university.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_


Course: CHEM 1000 (General Chemistry I)

Semester: Fall 2012

The University of Lethbridge

Spelling matters!

Fluorine = F                  Fluorene = C<sub>13</sub>H<sub>10</sub>

Flourine = 

**Question Breakdown**

<b>Q1</b>	/ 2
<b>Q2</b>	/ 3
<b>Q3</b>	/ 6
<b>Q4</b>	/ 3
<b>Q5</b>	/ 3
<b>Q6</b>	/ 5
<b>Q7</b>	/ 8
<b>Q8</b>	/ 2
<b>Q9</b>	/ 5
<b>Q10</b>	/ 2
<b>Q11</b>	/ 6
<b>Q12</b>	/ 5
<b>Q13</b>	/ 5

<b>Total</b>	/ 55
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1. What does the term “equivalent dose” mean? Why is this concept useful? [2 marks]

The “equivalent dose” is a measure of the biological damage done by a radioactive sample.

“Equivalent dose” is a useful concept because different types of radiation ( $\alpha$  vs.  $\beta$  vs.  $\gamma$ ) interact differently with biological tissue. Even if two sources of radiation deliver the same amount of energy to the same mass of tissue, they won't necessarily result in the same amount of tissue damage.

2. Balance the following nuclear reactions. [3 marks]  
*Note that you will need to infer some products.*

- (a)  $^{64}\text{Ga}$  emits a positron.



- (b)  $^{239}\text{U}$  decays to  $^{239}\text{Np}$ .



- (c)  $^{232}\text{Am}$  undergoes spontaneous fission, producing  $^{85}\text{Kr}$ , two neutrons and another nucleus.



3. Complete the following table: [6 marks]

Symbol	Z	N	Stable? (yes/no)	Predicted Type of Decay*
${}_{45}^{103}\text{Rh}$	45	58	yes	
${}_{35}^{88}\text{Br}$	35	53	no	$\beta^-$ decay (above band of stability, so N/Z must decrease)
${}_{18}^{32}\text{Ar}$	18	14	no	$\beta^+$ emission or electron capture (below band of stability, so N/Z must increase)

\*If you have indicated that an isotope is stable, do not fill in the box for its “predicted type of decay”.

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4. For each of the following species, write the ground state electron configuration. Use the noble gas abbreviation. [3 marks]

(a) Zr

(b)  $\text{Fe}^{3+}$ 

(Fe is  $[\text{Ar}] 4s^2 3d^6$ ; remove the two 4s electrons then one 3d electron)

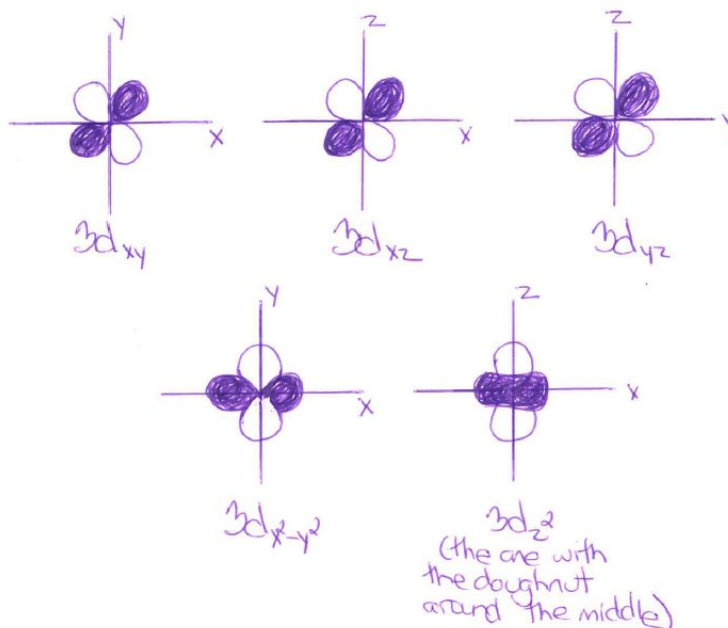
(c)  $\text{S}^{2-}$ 

(S is  $[\text{Ne}] 3s^2 3p^4$ ; add two more electrons into 3p; electron configurations should show all valence electrons so don't write [Ar])

5. Complete the following statements by filling in the blanks. [3 marks]

(a) Zr has 36 core electrons and 4 valence electrons.(b)  $\text{Fe}^{3+}$  has 18 core electrons and 5 valence electrons.(c)  $\text{S}^{2-}$  has 10 core electrons and 8 valence electrons.

6. Draw and label a complete set of 3d orbitals. [5 marks]  
Each orbital must be drawn on a labeled set of axes and must show relative phase.



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7. Protactinium (Pa) has a ground-state electron configuration of  $[\text{Rn}] 7s^2 6d^1 5f^2$ . **[8 marks]**(a) What is unusual about this ground-state electron configuration? [1 mark]

This electron configuration has two incomplete subshells (6d and 5f).

(b) Provide a valid set of quantum numbers for each of the valence electrons in an atom of Pa by completing the table below. [4 marks]

electron	$n$	$l$	$m_l$	$m_s$
7s	7	0	0	$+\frac{1}{2}$
7s	7	0	0	$-\frac{1}{2}$
6d	6	2	*	$+\frac{1}{2}$
5f	5	3	**	$+\frac{1}{2}$
5f	5	3	**	$+\frac{1}{2}$

\* Any single value between -2 and +2

\*\* Any two different values between -3 and +3

(c) Explain the difference between the terms “diamagnetic” and “paramagnetic”. [2 marks]

A diamagnetic substance has no net spin since all of the electrons are spin-paired.

A paramagnetic substance has a net spin since it has at least one electron that is not spin-paired.

(d) Is a neutral atom of Pa diamagnetic or paramagnetic? [1 mark]

paramagnetic

8. For each of the charges below, give an example of an element whose most stable ion has that charge. You may give the name or symbol for the element. **[2 marks]**

\_\_\_\_\_ makes a dication (+2 charge). *any element in group 2*

*(also, Sn, Pb and some transition metals)*

\_\_\_\_\_ makes a monoanion (-1 charge). *any element in group 17*

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9. Answer the following questions concerning the Bohr model of the atom. **[5 marks]**

- (a) It is only possible to calculate the energy of electrons in atoms of one neutral element using the Bohr model of the atom. What is this element? What is the relevant difference between this element and every other element? *[2 marks]*

Hydrogen is the only neutral element for which the energy of its electron can be calculated using the Bohr model.

Hydrogen is unique in that it only has one electron.

- (b) Briefly explain how the observation of line spectra was used as experimental evidence against the Rutherford model of the atom, requiring development of a new atomic model (the Bohr model). *[3 marks]*

The Rutherford model of the atom suggested that the electrons in an atom existed in a cloud and could have any energy. As such, it would be expected that they could absorb any energy of light to be excited into a higher energy state and therefore emit any energy of light when falling back down into a ground state (or, at least, into a less excited state).

This was inconsistent with the observation that pure samples of an element would only emit light with specific wavelengths, and that those wavelengths were characteristic for each element. Since each wavelength of light corresponds to a specific energy-per-photon, if each element only emitted specific wavelengths when relaxing after excitation, then each element was only emitting specific energies of light.

This implied that the electrons in an atom were only able to have specific (quantized) energies, and required development of a new atomic model.

10. A sample of boron is analyzed by mass spectrometry and found to have the following composition:

Isotope	Mass	Abundance
$^{10}\text{B}$	10.012 937 u	19.8%
$^{11}\text{B}$	11.009 305 u	80.2%

Calculate the molar mass of this sample of boron to the correct number of significant figures. **[2 marks]**

$$M_B = \left(\frac{19.8\%}{100\%}\right)(10.012\ 937\ \text{u}) + \left(\frac{80.2\%}{100\%}\right)(11.009\ 305\ \text{u})$$

$$M_B = 1.98\ \text{u} + 8.83\ \text{u}$$

$$M_B = 10.81\ \text{u}$$

$$M_B = 10.81\ \frac{\text{g}}{\text{mol}}$$

*Recall that sig. fig. rules are different for multiplication/division (fewest sig. fig) than for addition/subtraction (fewest decimal places), so each type of operation should have its sig. fig. worked out separately. Do not round until the end of the calculation, though!*

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11. Copper metal has a threshold energy of  $7.5 \times 10^{-19}$  J. A sample of copper is struck with a photon and an electron is ejected with a kinetic energy of  $1.30 \times 10^{-18}$  J. **[6 marks]**

(a) Calculate the maximum possible wavelength of the photon. **[4 marks]**  
Express your answer using an appropriate SI prefix so that the value is between 0.1 and 1000.

Step 1: Calculate the energy of the photon

$$E_{\text{photon}} = E_{\text{threshold}} + E_{\text{kinetic}}$$

$$E_{\text{photon}} = (7.5 \times 10^{-19} \text{ J}) + (1.30 \times 10^{-18} \text{ J}) \quad \text{This is the same as } 0.75 \times 10^{-18} \text{ J} + 1.30 \times 10^{-18} \text{ J}$$

$$E_{\text{photon}} = 2.05 \times 10^{-18} \text{ J}$$

Step 2: Calculate the wavelength of the photon

$$E_{\text{photon}} = h\nu \quad \text{and} \quad c = \lambda\nu \quad \text{therefore} \quad E_{\text{photon}} = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E_{\text{photon}}} = \frac{(6.626070 \times 10^{-34} \frac{\text{J}}{\text{Hz}})(2.997925 \times 10^8 \frac{\text{m}}{\text{s}})}{2.05 \times 10^{-18} \text{ J}} = 9.69 \times 10^{-8} \text{ m}$$

$$\lambda = 9.69 \times 10^{-8} \text{ m} \times \frac{10^9 \text{ nm}}{1 \text{ m}} = 96.9 \text{ nm}$$

(b) What kind of electromagnetic radiation is this? **[1 mark]**  
ultraviolet

(c) This question describes an example of what phenomenon? **[1 mark]**  
photoelectric effect

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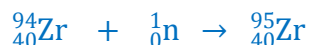
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12. Heavy nuclei are made by very high-energy processes in supernovae, but also by slower neutron capture processes (accompanied by some number of beta decays) in very old and large stars (red giants), where a number of nuclear reactions occur that produce neutrons.

For example,  $^{95}\text{Zr}$  is made in red giants when  $^{94}\text{Zr}$  captures a neutron. **[5 marks]**

- (a) Calculate the energy change per mole for this process. **[4 marks]**

Step 1: Write a balanced chemical equation for the reaction



Step 2: Calculate the change in mass for the reaction

$$\Delta m = m_{\text{products}} - m_{\text{reactants}}$$

$$\Delta m = m_{\text{Zr-95}} - (m_{\text{Zr-94}} + m_{\text{n}})$$

$$\Delta m = 94.908\,042\,u - (93.906\,314\,u + 1.008\,664\,916\,u) = -0.006\,937\,u$$

Step 3: Since you are calculating energy-per-mole, convert atomic mass into molar mass.

$$\Delta m = -0.006\,937\,u = -0.006\,937\,\frac{\text{g}}{\text{mol}}$$

$$\Delta m = -0.006\,937\,\frac{\text{g}}{\text{mol}} \times \frac{1\text{kg}}{1000\text{g}} = -6.937 \times 10^{-6}\,\frac{\text{kg}}{\text{mol}}$$

Step 4: Calculate the change in energy for the reaction

$$\Delta E = \Delta mc^2$$

$$\Delta E = \left(-6.937 \times 10^{-6}\,\frac{\text{kg}}{\text{mol}}\right) \left(2.997\,925 \times 10^8\,\frac{\text{m}}{\text{s}}\right)^2$$

$$\Delta E = -6.235 \times 10^{11}\,\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2\cdot\text{mol}} \times \frac{1\text{J}}{1\,\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}}$$

$$\Delta E = -6.235 \times 10^{11}\,\frac{\text{J}}{\text{mol}}$$

*Alternately, you could have converted the mass in 'u' into a mass in 'kg', used that to calculate the energy per decay (in J) the used Avogadro's number to find J/mol from J.*

- (b) Is this process energetically favorable? **[1 mark]**

Yes.  $\Delta E$  is negative.

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13. Most smoke detectors contain approximately 37 kBq of americium-241 ( $^{241}\text{Am}$ ).  $^{241}\text{Am}$  is an alpha emitter with a half-life of 432 years. The alpha radiation ionizes the air entering the detection chamber, which allows a small current to flow. Ions tend to stick to smoke particles, which reduces the current. If a current drop is detected, the alarm sounds. **[5 marks]**

(a) A typical smoke detector will remain in service for 8 to 10 years. What will the activity of the  $^{241}\text{Am}$  source be after 10 years? **[4 marks]**

Step 1: Establish what we know

$$A = kN \quad \text{therefore} \quad N = A/k \quad \text{and}$$

$$\ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1) \quad \text{therefore} \quad \ln\left(\frac{\left(\frac{A_2}{k}\right)}{\left(\frac{A_1}{k}\right)}\right) = -k(t_2 - t_1) \quad \text{therefore} \quad \ln\left(\frac{A_2}{A_1}\right) = -k(t_2 - t_1)$$

We know neither  $t_1$  nor  $t_2$  but we know that the elapsed time is 10 years so  $t_2 - t_1 = 10$  years

Step 2: Calculate  $k$  from half-life

$$\ln(2) = -kt_{1/2} \quad \text{therefore} \quad k = \frac{\ln(2)}{t_{1/2}}$$

$$k = \frac{\ln(2)}{432 \text{ y}} = 0.00160 \text{ y}^{-1}$$

Step 3: Calculate  $A_2$  from  $A_1$  and  $k$

$$\ln\left(\frac{A_2}{A_1}\right) = -k(t_2 - t_1)$$

$$\ln\left(\frac{A_2}{A_1}\right) = -(0.00160 \text{ y}^{-1})(10 \text{ y})$$

$$\ln\left(\frac{A_2}{A_1}\right) = -0.016$$

$$\left(\frac{A_2}{A_1}\right) = e^{-0.016}$$

$$A_2 = A_1(e^{-0.016})$$

$$A_2 = 37 \text{ kBq}(e^{-0.016})$$

$$A_2 = 36 \text{ kBq}$$

(b) Based on your answer to part (a), do you think that the 10 year recommended lifespan is due to loss of radioactivity or to other factors (aging of electronics, etc.)? **[1 mark]**

This is a very small loss of radioactivity, so it is likely that there are other factors contributing to the 10 year recommended lifespan of the smoke detector.



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## Some Useful Constants and Formulae

### Fundamental Constants and Conversion Factors

Atomic mass unit (u)	$1.660\,539 \times 10^{-27}$ kg	Planck's constant	$6.626\,070 \times 10^{-34}$ J·Hz <sup>-1</sup>
Avogadro's number	$6.022\,141 \times 10^{23}$ mol <sup>-1</sup>	Proton mass	1.007 277 u
Bohr radius (a <sub>0</sub> )	$5.291\,772 \times 10^{-11}$ m	Neutron mass	1.008 665 u
Electron charge (e)	$1.602\,177 \times 10^{-19}$ C	Rydberg Constant (R <sub>H</sub> )	$2.179\,872 \times 10^{-18}$ J
Electron mass	$5.485\,799 \times 10^{-4}$ u	Speed of light in vacuum	$2.997\,925 \times 10^8$ m·s <sup>-1</sup>

### Formulae

$$c = v\lambda \qquad E = h\nu \qquad p = mv \qquad \lambda = \frac{h}{p} \qquad \Delta x \cdot \Delta p > \frac{h}{4\pi}$$

$$r_n = a_0 \frac{n^2}{Z} \qquad E_n = -R_H \frac{Z^2}{n^2} \qquad E_k = \frac{1}{2}mv^2$$

$$\Delta E = \Delta mc^2 \qquad A = -\frac{\Delta N}{\Delta t} \qquad A = kN \qquad \ln\left(\frac{N_2}{N_1}\right) = -k(t_2 - t_1) \qquad \ln(2) = k \cdot t_{1/2}$$

### Some Useful Masses

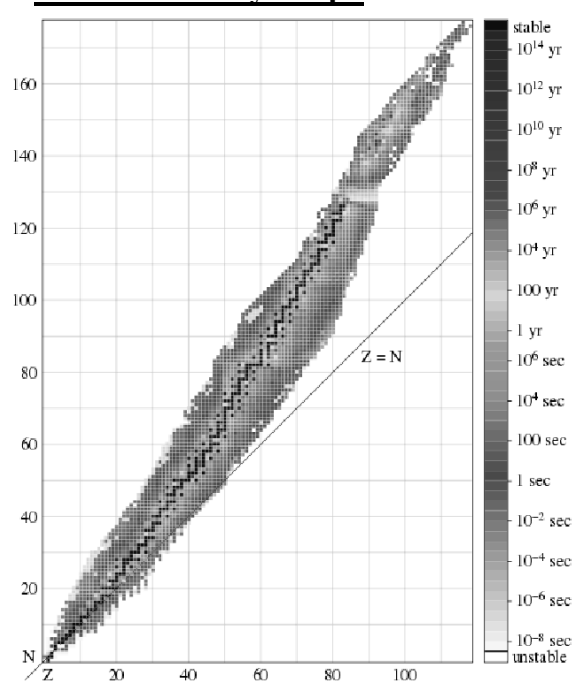
${}^{95}_{40}\text{Zr}$	94.908 042 u
${}^{94}_{40}\text{Zr}$	93.906 314 u
${}^4_2\alpha$	4.001 506 179 u
${}^1_1p$	1.007 276 467 u
${}^1_0n$	1.008 664 916 u

The graph at the right shows the band of stability. Stable isotopes are in black. Isotopes that exist but are not stable are shown in varying shades of gray with the shades of gray corresponding to different half-lives.

The original version of the graph used a rainbow colour scale.

[http://commons.wikimedia.org/wiki/File:Isotopes\\_and\\_half-life\\_eo.svg](http://commons.wikimedia.org/wiki/File:Isotopes_and_half-life_eo.svg)

### Band of Stability Graph



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**CHEM 1000 Periodic Table**

<b>1</b>	<b>CHEM 1000 Periodic Table</b>																<b>18</b>	
1.0079 <b>H</b> 1												<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	4.0026 <b>He</b> 2	
6.941 <b>Li</b> 3	9.0122 <b>Be</b> 4												10.811 <b>B</b> 5	12.011 <b>C</b> 6	14.0067 <b>N</b> 7	15.9994 <b>O</b> 8	18.9984 <b>F</b> 9	20.1797 <b>Ne</b> 10
22.9898 <b>Na</b> 11	24.3050 <b>Mg</b> 12	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>	26.9815 <b>Al</b> 13	28.0855 <b>Si</b> 14	30.9738 <b>P</b> 15	32.066 <b>S</b> 16	35.4527 <b>Cl</b> 17	39.948 <b>Ar</b> 18	
39.0983 <b>K</b> 19	40.078 <b>Ca</b> 20	44.9559 <b>Sc</b> 21	47.88 <b>Ti</b> 22	50.9415 <b>V</b> 23	51.9961 <b>Cr</b> 24	54.9380 <b>Mn</b> 25	55.847 <b>Fe</b> 26	58.9332 <b>Co</b> 27	58.693 <b>Ni</b> 28	63.546 <b>Cu</b> 29	65.39 <b>Zn</b> 30	69.723 <b>Ga</b> 31	72.61 <b>Ge</b> 32	74.9216 <b>As</b> 33	78.96 <b>Se</b> 34	79.904 <b>Br</b> 35	83.80 <b>Kr</b> 36	
85.4678 <b>Rb</b> 37	87.62 <b>Sr</b> 38	88.9059 <b>Y</b> 39	91.224 <b>Zr</b> 40	92.9064 <b>Nb</b> 41	95.94 <b>Mo</b> 42	(98) <b>Tc</b> 43	101.07 <b>Ru</b> 44	102.906 <b>Rh</b> 45	106.42 <b>Pd</b> 46	107.868 <b>Ag</b> 47	112.411 <b>Cd</b> 48	114.82 <b>In</b> 49	118.710 <b>Sn</b> 50	121.757 <b>Sb</b> 51	127.60 <b>Te</b> 52	126.905 <b>I</b> 53	131.29 <b>Xe</b> 54	
132.905 <b>Cs</b> 55	137.327 <b>Ba</b> 56	<b>La-Lu</b>	178.49 <b>Hf</b> 72	180.948 <b>Ta</b> 73	183.85 <b>W</b> 74	186.207 <b>Re</b> 75	190.2 <b>Os</b> 76	192.22 <b>Ir</b> 77	195.08 <b>Pt</b> 78	196.967 <b>Au</b> 79	200.59 <b>Hg</b> 80	204.383 <b>Tl</b> 81	207.19 <b>Pb</b> 82	208.980 <b>Bi</b> 83	(210) <b>Po</b> 84	(210) <b>At</b> 85	(222) <b>Rn</b> 86	
(223) <b>Fr</b> 87	226.025 <b>Ra</b> 88	<b>Ac-Lr</b>	(261) <b>Rf</b> 104	(262) <b>Db</b> 105	(263) <b>Sg</b> 106	(262) <b>Bh</b> 107	(265) <b>Hs</b> 108	(266) <b>Mt</b> 109	(281) <b>Dt</b> 110	(283) <b>Rg</b> 111								
138.906 <b>La</b> 57	140.115 <b>Ce</b> 58	140.908 <b>Pr</b> 59	144.24 <b>Nd</b> 60	(145) <b>Pm</b> 61	150.36 <b>Sm</b> 62	151.965 <b>Eu</b> 63	157.25 <b>Gd</b> 64	158.925 <b>Tb</b> 65	162.50 <b>Dy</b> 66	164.930 <b>Ho</b> 67	167.26 <b>Er</b> 68	168.934 <b>Tm</b> 69	173.04 <b>Yb</b> 70	174.967 <b>Lu</b> 71				
227.028 <b>Ac</b> 89	232.038 <b>Th</b> 90	231.036 <b>Pa</b> 91	238.029 <b>U</b> 92	237.048 <b>Np</b> 93	(240) <b>Pu</b> 94	(243) <b>Am</b> 95	(247) <b>Cm</b> 96	(247) <b>Bk</b> 97	(251) <b>Cf</b> 98	(252) <b>Es</b> 99	(257) <b>Fm</b> 100	(258) <b>Md</b> 101	(259) <b>No</b> 102	(260) <b>Lr</b> 103				

Developed by Prof. R. T. Boeré