Topics in the November 2008 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2008-N-2:

- Nuclear and Radiation Chemistry

2008-N-3:

- Band Theory - MO in Solids

2008-N-4:

2008-N-5:

- Periodic Table and the Periodic Trends
- Shape of Atomic Orbitals and Quantum Numbers

2008-N-6:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Filling Energy Levels in Atoms Larger than Hydrogen

2008-N-7:

- Lewis Structures
- VSEPR

2008-N-8:

- Bonding - MO theory (larger molecules)

2008-N-9:

- Chemical Equilibrium

2008-N-10:

- Thermochemistry
- First and Second Law of Thermodynamics

2008-N-11:

- Gas Laws
- Chemical Equilibrium

2008-N-12:

- Equilibrium and Thermochemistry in Industrial Processes
- Electrochemistry

2008-N-13:

- Nitrogen in the Atmosphere

2008-N-14:

- Electrolytic Cells

2008-N-15:

- Electrochemistry

22/07(a) **The University of Sydney**

CHEMISTRY 1A - CHEM1101

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 2008 **TIME ALLOWED: THREE HOURS**

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		**SID NUMBER**	
OTHER NAMES		**TABLE NUMBER**	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 23 pages of examinable material.
- Complete the written section of the examination paper in INK.
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new short answer question begins with a •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheets.
- Pages 19, 21, 25 and 28 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-10	33	

Short answer section

Page	Marks Max	Gained		Marker
11	6			
12	3			
13	4			
14	4			
15	5			
16	6			
17	6			
18	4			
20	6			
22	5			
23	3			
24	3			
26	6			
27	6			
Total	67			

Marks
6

- Write down an equation representing the decay mechanism of ^{14}C.

The half-life of ^{14}C is 5730 years. What is the activity of precisely 1 g of this isotope, given that each atom weighs 14.00 amu? Give your answer in Bq.

Answer:

Carbon-14 is used as a radioactive tracer in the urea breath test, a diagnostic test for *Helicobacter pylori*. Name an instrument which can be used to detect radioactive carbon dioxide in the breath of a patient.

A patient ingests 1.00 g of urea with a total activity of 1.00 μCi. What is the percentage, by weight, of carbon-14 in this sample?

Answer:

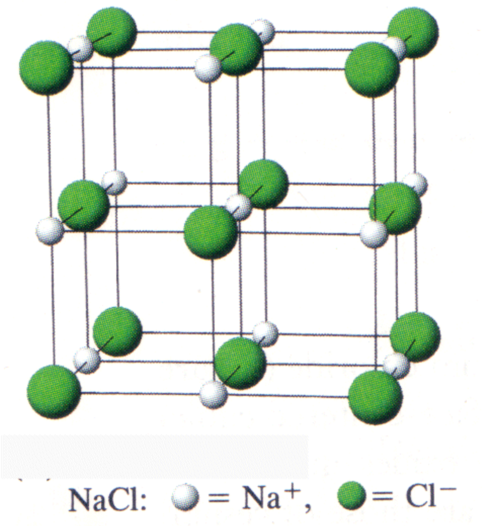
Marks
3

- Pure silicon is an insulator. Explain how incorporation of a small amount of nearby elements can bring about 'p-type' semiconduction. Explain your choice of dopant and use diagrams as required.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
4

- A cartoon representation of the structure of *halite* (NaCl) is shown below. The structure arises from the closest possible packing of anions stabilized by cations in the interstices. From a density of 2.16 g cm^{-3}, a nearest neighbour distance of 282 pm was calculated.



Crystal structure	Madelung constant (*A*)
ZnS (wurtzite)	1.641
NaCl	1.748
CsCl	1.763

What is the molar lattice energy of *halite*?

Answer:

What would be the Madelung constant of lithium chloride given that it does not adopt the wurtzite structure? Explain your answer.

Marks
4

- Explain why, in general, there is a decrease in atomic radius from left to right across the second row of the periodic table (lithium to neon), but an abrupt increase in radius on going to the next row.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

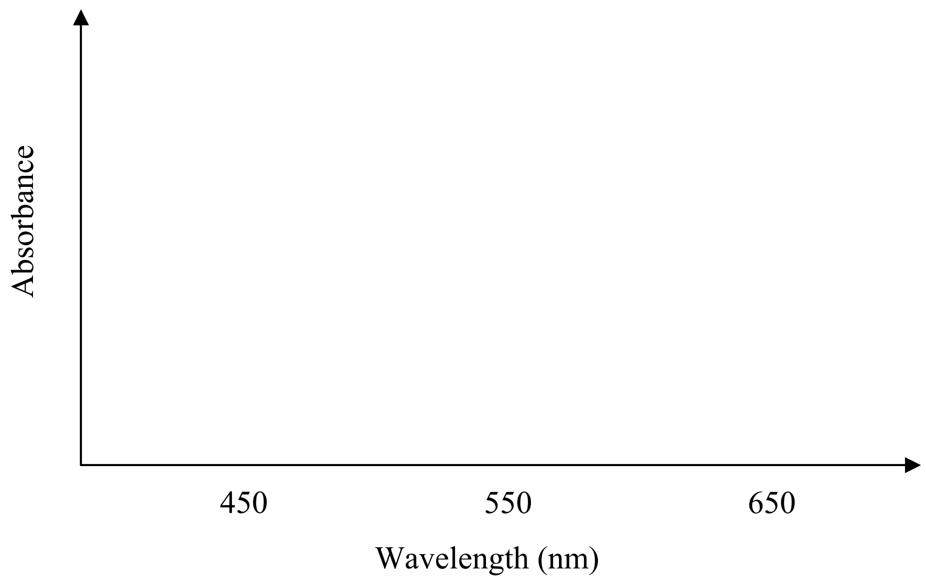
- Moseley discovered experimentally in 1913 that the atomic number, *Z*, of an element is inversely proportional to the square root of the wavelength, λ, of fluorescent X-rays emitted when an electron drops from the *n* = 2 to the *n* = 1 shell. **3**

$$i.e. \quad \frac{1}{\sqrt{\lambda}} = kZ$$

What element would emit such X-rays with a wavelength one-quarter that of zirconium?

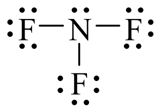
Answer:

- Many plants are green due to their high chlorophyll content. Draw on the diagram below the absorption spectrum of a green pigment such as chlorophyll. **2**



Marks

- Complete the following table showing the number of valence electrons, a Lewis structure and the predicted shape of each of the following species. **4**

Formula	Number of valence electrons	Lewis structure	Name of molecular shape
e.g. NF_3	26		trigonal pyramidal
BeF_2			
BH_4^-			

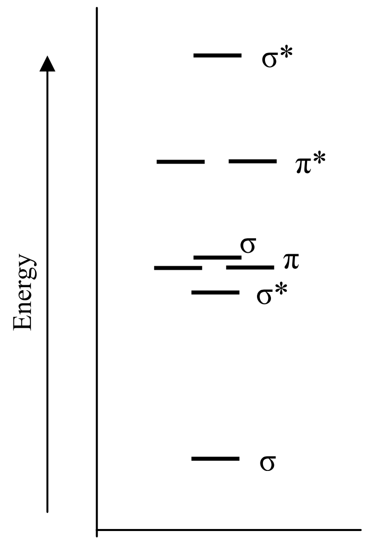
Draw the major resonance contributors of the nitrite ion, NO_2^-. **2**

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks 6

- Carbon and oxygen can combine to form carbon monoxide, the second most abundant molecule in the universe.

The molecular orbital energy level diagram provided shows the energies of the orbitals for the valence electrons in CO. Indicate on this diagram the ground state electronic configuration of CO using the arrow notation for electron spins.



What homonuclear diatomic molecule has the same electronic structure as CO? Comment on the bond orders of these two species.

How would adding an electron to CO to form CO^- affect the strength of the bond between the two atoms? Explain your answer.

Are the atomic orbital energies of oxygen lower or higher than carbon? Explain your answer and comment on how this may affect the electron density in bonding orbitals of the CO molecule.

Marks
4

- Consider the following reaction.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

An experiment was conducted in which 0.1000 mol of $N_2O_4(g)$ was introduced into a 1.000 L flask. After equilibrium had been established at a particular temperature, the concentration of $N_2O_4(g)$ was found to be 0.0491 M. Calculate the equilibrium constant, K_c, for the reaction as written at that temperature.

Answer:

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Marks
6

- A 50.0 mL solution contained 10.00 g of NaOH in water at 25.00 °C. When it was added to a 250.0 mL solution of 0.200 M HCl at 25.00 °C in a “coffee cup” calorimeter, the temperature of the solution rose to 27.24 °C.

  Is the process an endothermic or exothermic reaction?

  Assuming the specific heat of the solution is 4.18 J K^{-1} g^{-1}, that the calorimeter absorbs a negligible amount of heat, and that the density of the solution is 1.00 g mL^{-1}, calculate $\Delta_r H$ (in kJ mol^{-1}) for the following reaction.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Answer:

When the experiment was repeated using 12.00 g of NaOH in water, the temperature increase was the same. Explain.

Marks

- Hydrogen cyanide, $HCN(g)$, is prepared commercially by the reaction of methane, $CH_4(g)$, ammonia, $NH_3(g)$, and oxygen, $O_2(g)$, at high temperature. The other product is gaseous water. Write a chemical equation for the reaction. **2**

What volume of $HCN(g)$ can be obtained from 20.0 L of $CH_4(g)$, 20.0 L of $NH_3(g)$ and 20.0 L of $O_2(g)$? The volumes of all gases are measured at the same temperature and pressure.

Answer:

- The reaction of carbon disulfide with chlorine is as follows. **3**

$$CS_2(g) + 3Cl_2(g) \rightleftharpoons CCl_4(g) + S_2Cl_2(g) \qquad \Delta H°_{298} = -238 \text{ kJ mol}^{-1}$$

In which direction will the reaction move when the following changes are made to the system initially at equilibrium?

(a) The pressure on the system is doubled by halving the volume.

(b) CCl_4 is removed.

(c) The system is heated.

Marks
3

- In the chlor-alkali process, three useful products are formed, including two of the "top ten" chemicals. Write the overall reaction, identify the two "top ten" chemicals, and propose why the third useful product is not usually harnessed in this process.

Explain why the Na^{+}(aq) is not reduced to Na(s) in this process.

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Marks
3

- The heat of formation of nitric oxide, NO(g), is +90. kJ mol^{-1}. Why does nitric oxide form in a car engine when it does not form to any appreciable extent at room temperature? Make sure you include the appropriate chemical reactions in your answer.

What happens to the NO(g) once emitted from the tailpipe? Again, include any appropriate chemical reactions.

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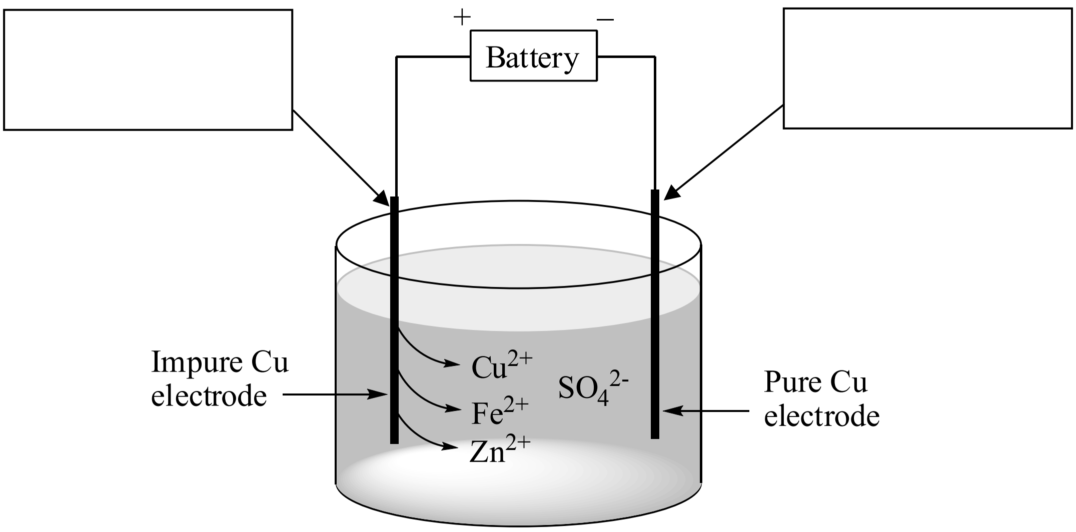
Marks
6

- In the refining of copper, impure copper electrodes are electrolysed in a manner such as described in the following figure. The impure Cu electrode contains varying amounts of metals such as zinc and iron as well as noble metals like gold, silver and platinum. Indicate in the boxes on the figure, which electrode is the anode and which is the cathode.



Why are noble metals left as a mud on the bottom of the reaction cell?

Explain why Zn^{2+} and Fe^{2+} are not deposited from solution during this reaction.

What mass of pure copper (in kg) will be obtained when the electrolytic cell is operated for 24.0 hours at a constant current of 100.0 A?

Answer:

Marks
6

- The standard dry cell (battery) has the following shorthand notation:

$$Zn(s) \mid Zn^{2+}(aq) \parallel MnO_2(s), Mn_2O_3(s) \mid graphite(s)$$

Which component of the battery is the anode?

Give the balanced half equation that takes place at the anode.

Which component of the battery is the cathode?

Give the balanced half equation that takes place at the cathode.

What is the role of the salt bridge in a voltaic cell and how is this accomplished?

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CHEM1101 - CHEMISTRY 1A

DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23}$ mol^{-1}

Faraday constant, $F = 96485$ C mol^{-1}

Planck constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light in vacuum, $c = 2.998 \times 10^{8}$ m s^{-1}

Rydberg constant, $E_R = 2.18 \times 10^{-18}$ J

Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J K^{-1}

Permittivity of a vacuum, $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 J^{-1} m^{-1}

Gas constant, $R = 8.314$ J K^{-1} mol^{-1}

= 0.08206 L atm K^{-1} mol^{-1}

Charge of electron, $e = 1.602 \times 10^{-19}$ C

Mass of electron, $m_e = 9.1094 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.6726 \times 10^{-27}$ kg

Mass of neutron, $m_n = 1.6749 \times 10^{-27}$ kg

Properties of matter

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L

Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L

Density of water at 298 K = 0.997 g cm^{-3}

Conversion factors

1 atm = 760 mmHg = 101.3 kPa

0 °C = 273 K

1 L = 10^{-3} m^3

1 Å = 10^{-10} m

1 eV = 1.602×10^{-19} J

1 Ci = 3.70×10^{10} Bq

1 Hz = 1 s^{-1}

1 tonne = 10^3 kg

1 W = 1 J s^{-1}

Decimal fractions

Fraction	Prefix	Symbol
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Decimal multiples

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

CHEM1101 - CHEMISTRY 1A

Standard Reduction Potentials, *E*°

Reaction	*E*° / V
$S_2O_8^{2-}$ + $2e^-$ → $2SO_4^{2-}$	+2.01
$Co^{3+}(aq)$ + e^- → $Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq)$ + e^- → $Ce^{3+}(aq)$	+1.72
$Au^{3+}(aq)$ + $3e^-$ → $Au(s)$	+1.50
Cl_2 + $2e^-$ → $2Cl^-(aq)$	+1.36
O_2 + $4H^+(aq)$ + $4e^-$ → $2H_2O$	+1.23
Br_2 + $2e^-$ → $2Br^-(aq)$	+1.10
$MnO_2(s)$ + $4H^+(aq)$ + e^- → Mn^{3+} + $2H_2O$	+0.96
$Pd^{2+}(aq)$ + $2e^-$ → $Pd(s)$	+0.92
$Ag^+(aq)$ + e^- → $Ag(s)$	+0.80
$Fe^{3+}(aq)$ + e^- → $Fe^{2+}(aq)$	+0.77
$Cu^+(aq)$ + e^- → $Cu(s)$	+0.53
$Cu^{2+}(aq)$ + $2e^-$ → $Cu(s)$	+0.34
$Sn^{4+}(aq)$ + $2e^-$ → $Sn^{2+}(aq)$	+0.15
$2H^+(aq)$ + $2e^-$ → $H_2(g)$	0 (by definition)
$Fe^{3+}(aq)$ + $3e^-$ → $Fe(s)$	–0.04
$Pb^{2+}(aq)$ + $2e^-$ → $Pb(s)$	–0.13
$Sn^{2+}(aq)$ + $2e^-$ → $Sn(s)$	–0.14
$Ni^{2+}(aq)$ + $2e^-$ → $Ni(s)$	–0.24
$Co^{2+}(aq)$ + $2e^-$ → $Co(s)$	–0.28
$Fe^{2+}(aq)$ + $2e^-$ → $Fe(s)$	–0.44
$Cr^{3+}(aq)$ + $3e^-$ → $Cr(s)$	–0.74
$Zn^{2+}(aq)$ + $2e^-$ → $Zn(s)$	–0.76
$2H_2O$ + $2e^-$ → $H_2(g)$ + $2OH^-(aq)$	–0.83
$Cr^{2+}(aq)$ + $2e^-$ → $Cr(s)$	–0.89
$Al^{3+}(aq)$ + $3e^-$ → $Al(s)$	–1.68
$Mg^{2+}(aq)$ + $2e^-$ → $Mg(s)$	–2.36
$Na^+(aq)$ + e^- → $Na(s)$	–2.71
$Ca^{2+}(aq)$ + $2e^-$ → $Ca(s)$	–2.87
$Li^+(aq)$ + e^- → $Li(s)$	–3.04

CHEM1101 - CHEMISTRY 1A

Useful formulas

Thermodynamics & Equilibrium $\Delta U = q + w = q - p\Delta V$ $\Delta_{universe}S = \Delta_{sys}S - \frac{\Delta_{sys}H}{T_{sys}}$ $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times 2.303 \log Q$ $= E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Colligative properties $\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Quantum Chemistry** $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = -Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$
Acids and Bases $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
Radioactivity $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = $8033 \ln(A_0/A_t)$	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Miscellaneous $A = -\log_{10}\frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A\frac{e^2}{4\pi\varepsilon_0 r}N_A$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

22/07(b)

CHEM1101 – CHEMISTRY 1A

November 2008

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 HYDROGEN **H** 1.008																	2 HELIUM **He** 4.003
3 LITHIUM **Li** 6.941	4 BERYLLIUM **Be** 9.012											5 BORON **B** 10.81	6 CARBON **C** 12.01	7 NITROGEN **N** 14.01	8 OXYGEN **O** 16.00	9 FLUORINE **F** 19.00	10 NEON **Ne** 20.18
11 SODIUM **Na** 22.99	12 MAGNESIUM **Mg** 24.31											13 ALUMINIUM **Al** 26.98	14 SILICON **Si** 28.09	15 PHOSPHORUS **P** 30.97	16 SULFUR **S** 32.07	17 CHLORINE **Cl** 35.45	18 ARGON **Ar** 39.95
19 POTASSIUM **K** 39.10	20 CALCIUM **Ca** 40.08	21 SCANDIUM **Sc** 44.96	22 TITANIUM **Ti** 47.88	23 VANADIUM **V** 50.94	24 CHROMIUM **Cr** 52.00	25 MANGANESE **Mn** 54.94	26 IRON **Fe** 55.85	27 COBALT **Co** 58.93	28 NICKEL **Ni** 58.69	29 COPPER **Cu** 63.55	30 ZINC **Zn** 65.39	31 GALLIUM **Ga** 69.72	32 GERMANIUM **Ge** 72.59	33 ARSENIC **As** 74.92	34 SELENIUM **Se** 78.96	35 BROMINE **Br** 79.90	36 KRYPTON **Kr** 83.80
37 RUBIDIUM **Rb** 85.47	38 STRONTIUM **Sr** 87.62	39 YTTRIUM **Y** 88.91	40 ZIRCONIUM **Zr** 91.22	41 NIOBIUM **Nb** 92.91	42 MOLYBDENUM **Mo** 95.94	43 TECHNETIUM **Tc** [98.91]	44 RUTHENIUM **Ru** 101.07	45 RHODIUM **Rh** 102.91	46 PALLADIUM **Pd** 106.4	47 SILVER **Ag** 107.87	48 CADMIUM **Cd** 112.40	49 INDIUM **In** 114.82	50 TIN **Sn** 118.69	51 ANTIMONY **Sb** 121.75	52 TELLURIUM **Te** 127.60	53 IODINE **I** 126.90	54 XENON **Xe** 131.30
55 CAESIUM **Cs** 132.91	56 BARIUM **Ba** 137.34	57-71	72 HAFNIUM **Hf** 178.49	73 TANTALUM **Ta** 180.95	74 TUNGSTEN **W** 183.85	75 RHENIUM **Re** 186.2	76 OSMIUM **Os** 190.2	77 IRIDIUM **Ir** 192.22	78 PLATINUM **Pt** 195.09	79 GOLD **Au** 196.97	80 MERCURY **Hg** 200.59	81 THALLIUM **Tl** 204.37	82 LEAD **Pb** 207.2	83 BISMUTH **Bi** 208.98	84 POLONIUM **Po** [210.0]	85 ASTATINE **At** [210.0]	86 RADON **Rn** [222.0]
87 FRANCIUM **Fr** [223.0]	88 RADIUM **Ra** [226.0]	89-103	104 RUTHERFORDIUM **Rf** [261]	105 DUBNIUM **Db** [262]	106 SEABORGIUM **Sg** [266]	107 BOHRIUM **Bh** [262]	108 HASSIUM **Hs** [265]	109 MEITNERIUM **Mt** [266]	110 DARMSTADTIUM **Ds** [271]	111 ROENTGENIUM **Rg** [272]							

LANTHANOIDS	57 LANTHANUM **La** 138.91	58 CERIUM **Ce** 140.12	59 PRASEODYMIUM **Pr** 140.91	60 NEODYMIUM **Nd** 144.24	61 PROMETHIUM **Pm** [144.9]	62 SAMARIUM **Sm** 150.4	63 EUROPIUM **Eu** 151.96	64 GADOLINIUM **Gd** 157.25	65 TERBIUM **Tb** 158.93	66 DYSPROSIUM **Dy** 162.50	67 HOLMIUM **Ho** 164.93	68 ERBIUM **Er** 167.26	69 THULIUM **Tm** 168.93	70 YTTERBIUM **Yb** 173.04	71 LUTETIUM **Lu** 174.97
ACTINOIDS	89 ACTINIUM **Ac** [227.0]	90 THORIUM **Th** 232.04	91 PROTACTINIUM **Pa** [231.0]	92 URANIUM **U** 238.03	93 NEPTUNIUM **Np** [237.0]	94 PLUTONIUM **Pu** [239.1]	95 AMERICIUM **Am** [243.1]	96 CURIUM **Cm** [247.1]	97 BERKELLIUM **Bk** [247.1]	98 CALIFORNIUM **Cf** [252.1]	99 EINSTEINIUM **Es** [252.1]	100 FERMIUM **Fm** [257.1]	101 MENDELEVIUM **Md** [256.1]	102 NOBELIUM **No** [259.1]	103 LAWRENCIUM **Lr** [260.1]