Topics in the June 2009 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2009-J-2:

- Nuclear and Radiation Chemistry

2009-J-3:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Liquid Crystals

2009-J-4:

- Shape of Atomic Orbitals and Quantum Numbers

2009-J-5:

- Periodic Table and the Periodic Trends
- Filling Energy Levels in Atoms Larger than Hydrogen
- Bonding - MO theory (polar bonds)

2009-J-6:

- Bonding - MO theory (larger molecules)

2009-J-7:

- Band Theory - MO in Solids

2009-J-8:

- Lewis Structures
- VSEPR

2009-J-9:

- Chemical Equilibrium
- Equilibrium and Thermochemistry in Industrial Processes

2009-J-10:

- Chemical Equilibrium

2009-J-11:

- Gas Laws
- Thermochemistry
- First and Second Law of Thermodynamics

2009-J-12:

- Gas Laws
- Thermochemistry

2009-J-13:

- Chemical Equilibrium

2009-J-14:

- Types of Intermolecular Forces

2009-J-15:

- Electrochemistry

22/05(a)

The University of Sydney

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2009 **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 24 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, 22 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-11	34	

Short answer section

	Marks			
Page	Max	Gained		Marker
12	4			
13	4			
14	5			
15	5			
16	6			
17	4			
18	7			
20	4			
21	3			
23	5			
24	5			
25	2			
26	6			
27	6			
Total	66			
Check total				

Marks

- Scholars think that a parchment scroll recently found in the Middle East could have originated from the same group responsible for the Dead Sea Scrolls. If a modern piece of parchment has an activity of 4.0×10^{-4} Ci g^{-1}, calculate the expected activity of the recently discovered scroll if it originated 2100 years ago. **2**

Answer:

- ^{11}C is an unstable isotope of carbon. Which force within the ^{11}C nucleus is responsible for its instability? Explain. **2**

Which force is responsible for the greater stability of the ^{12}C isotope compared to the ^{11}C isotope? Explain.

	Marks
• In an electron microscope, to what minimum velocity must the electrons in the beam be accelerated in order to achieve a better spatial resolution (*i.e.*, have a shorter wavelength) than a visible light microscope? Assume an average wavelength of visible light of 500 nm.	**2**

Answer:

	Marks
• Sketch the arrangement of molecules in a nematic phase and a smectic phase of a liquid crystal.	**2**

nematic phase	smectic phase

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
5

- Sketch the following wavefunctions using lobe representations. Clearly mark all nodal surfaces, nuclear positions and the relative sign (+ or –) of the wavefunction within the lobes.

a 2*s* atomic orbital	a 3*p* atomic orbital

Explain the significance of (a) the lobes, (b) the nodes and (c) the sign of the wavefunction, in terms of the probability of finding an electron at a given point in space relative to the nucleus.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks

- Explain the trends in electron affinities for the first 5 elements of the second row of the periodic table, in terms of their electronic configurations.
  i.e. Discuss the trend in ΔH for the following reaction: $A(g) + e^- \rightarrow A^-(g)$

3

Element	Li	Be	B	C	N
ΔH (in kJ mol^{-1})	–60	+241	–27	–122	+8

- Briefly explain the following concepts and their electronic origins.

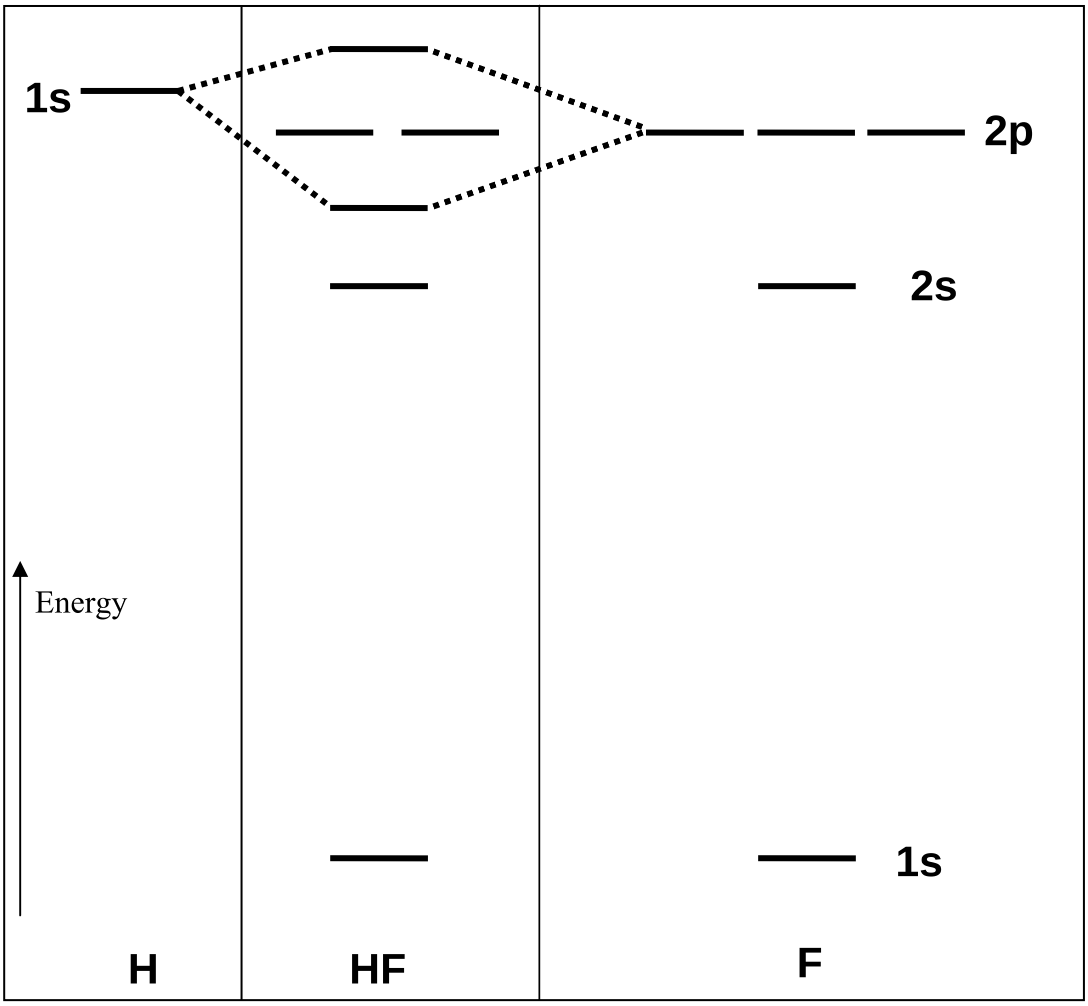
2

(a) paramagnetism

(b) polar bond

Marks 6

- The following diagram shows the energy level diagram for the molecular orbitals in the HF molecule (centre), in comparison to the atomic energy levels of hydrogen (left) and fluorine (right).



Add the ground state electron configuration to the diagrams for all three species using the arrow notation for electron spin.

Label the orbitals of HF according to whether they are bonding, non-bonding, or anti-bonding.

Sketch the σ-bonding orbital showing the position of the atomic nuclei.

Marks
4

- Explain what is meant by the term "band gap".

The band gap of the semiconductor gallium(II) sulfide is 2.53 eV. What range of wavelengths (in nm) would you expect this material to absorb?

For reference, the relationship between colours and wavelengths is as follows:

violet	blue	green	yellow	orange	red
400–450	450–490	490–560	560–590	590–630	630–700 nm

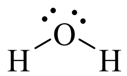
Predict the colour of a single crystal of GaS according to a human observer when it is illuminated with white light. Explain your answer.

Marks

- Draw the major resonance contributors of nitryl chloride, $ClNO_2$. **2**

What is the bond order of the N–O bonds?

- Complete the following table showing the number of valence electrons, a Lewis structure and the predicted shape of each of the following species. **5**

Molecule name	Chemical formula	Number of valence electrons	Lewis structure	Geometry of species
e.g. water	H_2O	8		bent
carbonate ion				
chlorine trifluoride				

Marks

- Consider the following reaction at equilibrium. **2**

$$CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g) \quad K_c = 1.30 \times 10^{-2}$$

What is the concentration of CO(g) when $[CH_3OH(g)] = 3.49 \times 10^{-1}$ M and $[H_2(g)] = 1.76 \times 10^{-1}$ M?

Answer:

- Explain briefly the chemical principles behind a) froth flotation, **or** b) electrorefining. **2**

Marks
3

- Solid NH_4HS in placed in an evacuated container at 25 ºC and the following equilibrium is established.

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g) \qquad \Delta H^{\circ} = +93 \text{ kJ mol}^{-1}$$

At equilibrium, some solid NH_4HS remains in the container. Predict and explain each of the following.

(a) The effect on the equilibrium partial pressure of NH_3 gas when additional solid NH_4HS is introduced into the container.

(b) The effect on the amount of solid NH_4HS present when the volume of the container is decreased.

(c) The effect on the amount of solid NH_4HS present when the temperature is increased.

Marks
5

- A gaseous hydrocarbon is found to contain 85.6 % carbon and 17.4 % hydrogen by mass. A 10.0 L sample of this gas has a mass of 23.78 g at 1.00 atm and 298 K. Show that the hydrocarbon is butane, C_4H_{10}.

Using the data below, calculate the heat generated when this quantity of butane is burnt in air.

$\Delta_f H°$: $C_4H_{10}(g)$ –126 kJ mol^{-1}, $CO_2(g)$ –394 kJ mol^{-1}, $H_2O(l)$ = –286 kJ mol^{-1}

Answer:

Marks
5

- A radiator generates 150 J to heat up air inside a sealed container with volume of 2.00 L and initially at 25 °C and atmospheric pressure. What will be the pressure inside the container after heating?

  Assume that air is composed of 80 % nitrogen and 20 % oxygen by volume.

  Specific heat capacities: N_2 29.14 J K^{-1} mol^{-1} and O_2 29.38 J K^{-1} mol^{-1}

Pressure:

If this heated air is injected into a balloon, it will rise. Use the ideal gas equation to explain why this happens.

Marks
2

- Fe_2O_3 can be reduced by carbon monoxide according to the following equation.

$$Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g) \qquad K_p = 19.9 \text{ at } 1000 \text{ K}$$

At 1000 K, what are the equilibrium partial pressures of CO and CO_2 if the only gas initially present is CO at a partial pressure of 0.978 atm?

p(CO) =	$p(CO_2)$ =

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Marks
6

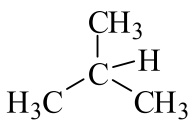
- Explain the trend in the following table in terms of the type and size of intermolecular forces.

Substance	Boiling point (°C)
CH_3CH_3	–89
$CH_3CH_2CH_2CH_3$	–1
$CH_3CH_2–O–CH_2CH_3$	35
CH_3CH_2OH	78
H_2O	100

There are two isomers with the molecular formula C_4H_{10}.

$CH_3–CH_2–CH_2–CH_3$

butane



2-methylpropane

Discuss which isomer will have the greater intermolecular forces.

Marks
6

- Consider the galvanic cell Zn(s)| Zn^{2+}(aq)|| Ag^{+}(aq)| Ag(s) with initial concentrations of [Zn^{2+}] = 1.00 M and [Ag^{+}] = 0.50 M. Draw the cell and clearly label which electrode is the anode and which electrode is the cathode.

Write the equation for the reaction.

Calculate the cell potential at 298 K.

Answer:

Is this a spontaneous voltaic cell? Give a reason for your answer.

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

CHEM1101 - CHEMISTRY 1A

Standard Reduction Potentials, E°

Reaction	$E°$ / V
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$	+1.72
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	+1.18
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+0.96
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O$	+0.96
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.53
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–0.40
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	–0.74
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.89
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.68
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.36
$Na^+(aq) + e^- \rightarrow Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	–2.87
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

CHEM1101 - CHEMISTRY 1A

Useful formulas

Quantum Chemistry	**Electrochemistry**
$E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2 E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6$ K nm	$\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times 2.303 \log Q$ $= E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Acids and Bases	**Gas Laws**
$pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	$PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
Radioactivity	**Kinetics**
$t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = 8033 $\ln(A_0/A_t)$ years	$t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Colligative properties	**Thermodynamics & Equilibrium**
$\Pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	$\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $\Delta_{univ} S° = R \ln K$ $K_p = K_c (RT)^{\Delta n}$
Miscellaneous	**Mathematics**
$A = -\log\frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A\frac{e^2}{4\pi\varepsilon_0 r}N_A$	If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$ Area of circle = πr^2 Surface area of sphere = $4\pi r^2$

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]