Topics in the June 2013 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2013-J-2:

- Ionic Bonding

2013-J-3:

- Types of Intermolecular Forces
- First and Second Law of Thermodynamics

2013-J-4:

- Filling Energy Levels in Atoms Larger than Hydrogen
- Nuclear and Radiation Chemistry

2013-J-5:

- Periodic Table and the Periodic Trends
- Wave Theory of Electrons and Resulting Atomic Energy Levels

2013-J-6:

- Bonding - MO theory (larger molecules)

2013-J-7:

- Lewis Structures
- VSEPR

2013-J-8:

- Thermochemistry
- Nitrogen Chemistry and Compounds
- Nitrogen in the Atmosphere

2013-J-9:

- Chemical Equilibrium

2013-J-10:

- First and Second Law of Thermodynamics
- Gas Laws
- Nitrogen Chemistry and Compounds

2013-J-11:

- Equilibrium and Thermochemistry in Industrial Processes

2013-J-12:

- Electrolytic Cells
- Electrochemistry
- Batteries and Corrosion

2013-J-13:

- Electrochemistry
- Batteries and Corrosion

2205(a)

THE UNIVERSITY OF SYDNEY

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2013 **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 21 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 •.
- Only non-programmable, University-approved calculators may be used.
- Students are warned 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 17 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-10	30	

Short answer section

Page	Marks: Max	Marks: Gained		Marker
11	6			
12	5			
13	8			
14	5			
15	8			
16	6			
18	5			
19	4			
20	5			
21	4			
22	7			
23	7			
Total	70			
Check total				

Marks
6

- What is an ionic bond?

Why does ionic bonding favour the formation of macroscopic crystals rather than molecules?

What information do you need to estimate the relative lattice energies of two chemically different salts?

Marks

- Intermolecular forces are responsible for the physical properties of many compounds. What are dispersion forces? 3

The boiling points of F_2, Cl_2 and Br_2 are 85, 239 and 338 K, respectively. Where would you expect the boiling point of I_2? Give reasons.

- The Second Law states that all observable processes must involve a net increase in entropy. When liquid water freezes into ice at 0 °C, the entropy of the water decreases. Explain how this is consistent with the Second Law. 2

Marks

- Write down the ground state electron configurations for the following species. Na is given as an example. **4**

Na	[Ne] $3s^1$
K	
As	
Sr	
C^+	

Name the elements described by the following configurations.

[Kr] $5s^2\ 4d^6$
[Xe] $6s^2\ 5d^1\ 4f^{11}$

- Radioactivity may have damaging effects on humans but can also be used for medical imaging to potentially save lives. Which of alpha and gamma radiation is better suited for medical imaging? Give reasons. **4**

Given nuclides with half-lives of minutes, hours or years, which would be best used for medical imaging? Explain.

Marks
5

- The Periodic Table as arranged by Mendeleev allows us to make predictions about the behaviours of elements based on those around them. Briefly describe why the Periodic Table works.

Silicon and tin have the same structure as diamond. Use the information in the following table to predict the density of tin.

Element	Atomic Mass	Density (g cm^{-3})	Bond length (pm)
Si	28	2.329	233
Sn	118		280

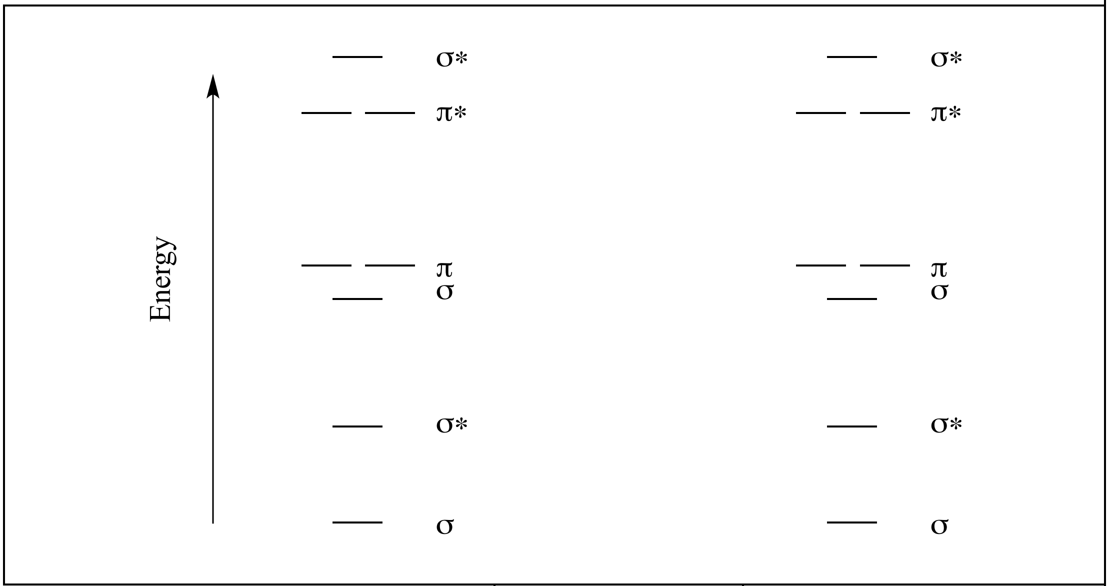
Answer:

Marks
8

- Oxygen exists in the troposphere as a diatomic molecule.

  How many valence electrons in the O_2 molecule?

  The molecular orbital energy levels for O_2 are shown below. On the left-hand diagram, fill in the **valence** electrons for oxygen, O_2, in the ground state.



(a) What is the bond order for O_2?

(b) Clearly label a bonding orbital and an anti-bonding orbital on the left-hand diagram.

(c) Clearly label the HOMO of O_2 on the left-hand diagram.

(d) On the right-hand diagram, indicate the lowest energy electronic configuration for O_2 which has no unpaired electrons.

The blue colour of liquid O_2 arises from an electronic transition whereby one 635 nm photon excites two molecules to the state indicated by the configuration in (d) *at the same time*. What wavelength photon would be emitted by one molecule returning from this state to the ground state?

Answer:

Suggest a heteronuclear diatomic species, isoelectronic with O_2, that might be expected to have similar spectroscopic behaviour.

Marks
6

- Complete the following table for the molecules SF_6 and SF_4.

Molecule	Total number of valence electrons	Lewis structure	Shape of molecule
SF_6			
SF_4			

Sulfur hexafluoride (SF_6) is quite inert, whilst sulfur tetrafluoride (SF_4) is highly reactive. Suggest a reason for the difference in reactivity between SF_6 and SF_4.

Marks

- 1.00 L of water is heated to 95 °C and then solid copper, initially at 25 °C, is immersed in it. What mass of copper was added if the final temperature of the water was 84 °C? Show all working. **3**

  Data: Specific heat capacity of Cu(s) is 0.39 J g^{-1} K^{-1}.
  Specific heat capacity of $H_2O(l)$ is 4.184 J g^{-1} K^{-1}.
  The density of water is 1.0 g mL^{-1}.

Answer:

- Atmospheric nitrogen is converted into ammonia or various oxides by both natural processes and those associated with human activity. Identify one process (either natural or due to human activity) that results in the conversion of N_2 to either NH_3 or an oxide of nitrogen and identify the nitrogen compound produced in that process. **2**

Marks
4

- Consider the following reaction.

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

An equilibrium mixture in a 1.00 L container is found to contain $[N_2O_4]$ = 1.00 M and $[NO_2]$ = 0.46 M. The vessel is then compressed to half its original volume while the temperature is kept constant. Calculate the concentration $[N_2O_4]$ when the compressed system has come to equilibrium. Show all working.

Answer:

Marks

- Use the standard heats of formation provided to calculate the molar heat of combustion of liquid methanol, CH_3OH, in oxygen to produce CO_2 and water. Your answer must include a balanced chemical equation for this reaction. Show all working. **2**

Data:

Compound	$H_2O(l)$	$CH_3OH(l)$	$CO_2(g)$
$\Delta_f H^o$ / kJ mol^{-1}	–285.9	–238.6	–393.5

Answer:

- Calculate the volume change when 10.0 g of solid trinitrotoluene $C_7H_5N_3O_6(s)$ explosively decomposes via the following process at 2000. °C and 1.0 atm. **3**

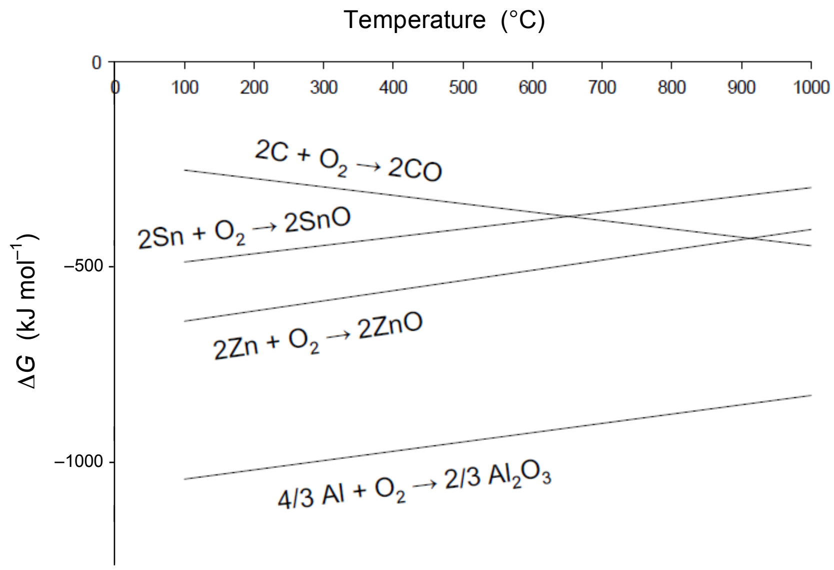
$$2C_7H_5N_3O_6(s) \rightarrow 12CO(g) + 5H_2(g) + 3N_2(g) + 2C(s)$$

Assume all gases behave as ideal gases and neglect the volume of any solid phases. Show all working.

Answer:

Marks
4

- The diagram below represents the Gibbs free energy change associated with the formation of four different oxides.



Using the free energy data above, write down the equation and indicate with an arrow the direction of the expected spontaneous reaction under the following conditions. If no reaction occurs, write "no reaction".

CO and Sn are mixed at 400 °C
Al and ZnO are mixed at 400 °C
CO and Sn are mixed at 900 °C

Which oxide has the smallest (least negative) enthalpy of formation?

Marks

- How many hours does it take to form 10.0 L of O_2 measured at 99.8 kPa and 28 °C from water if a current of 1.3 A passes through the electrolysis cell? **3**

Answer:

- In concentration cells no net chemical conversion occurs, however a measurable voltage is present between the two half-cells. Explain how the voltage is produced. **2**

- Is H_2 a stronger reducing agent under acidic or basic conditions? Give reasons for your answer. **2**

Marks
7

- A galvanic cell utilises the following redox reaction.

$$NH_4^+(aq) + 8Ce^{4+}(aq) + 3H_2O(l) \rightarrow NO_3^-(aq) + 8Ce^{3+}(aq) + 10H^+(aq)$$

What species is the reducing agent in this reaction?

How many electrons are transferred in the redox reaction?

Calculate the standard cell potential, $E°_{cell}$, for this electrochemical cell.

Answer:

Calculate $\Delta G°$ for the redox reaction at 25 °C.

Answer:

What is the effect on the E_{cell} of decreasing the concentration of $NO_3^-(aq)$ in the anode compartment?

Calculate the cell potential, E_{cell}, when $[NH_4^+] = 0.35$ M, $[Ce^{4+}] = 0.25$ M, $[NO_3^-] = 5.0 \times 10^{-2}$ M, $[Ce^{3+}] = 6.0 \times 10^{-2}$ M, and the pH is 2.0.

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 = 1.013 bar
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
$Co^{3+}(aq) + e^{-} \rightarrow Co^{2+}(aq)$	+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
$NO_3^{-}(aq) + 10H^{+}(aq) + 8e^{-} \rightarrow NH_4^{+}(aq) + 3H_2O$	+0.88
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$	+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
$BiO^{+}(aq) + 2H^{+}(aq) + 3e^{-} \rightarrow Bi(s) + H_2O$	+0.32
$Sn^{4+}(aq) + 2e^{-} \rightarrow Sn^{2+}(aq)$	+0.15
$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^{-} \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^{-} \rightarrow Pb(s)$	–0.126
$Sn^{2+}(aq) + 2e^{-} \rightarrow Sn(s)$	–0.136
$Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$	–0.24
$Co^{2+}(aq) + 2e^{-} \rightarrow Co(s)$	–0.28
$Cd^{2+}(aq) + 2e^{-} \rightarrow Cd(s)$	–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
$Sc^{3+}(aq) + 3e^{-} \rightarrow Sc(s)$	–2.09
$Mg^{2+}(aq) + 2e^{-} \rightarrow Mg(s)$	–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 $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6$ K nm	**Electrochemistry** $\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n}\log Q$ (at 25 °C)
Acids and Bases $pH = -\log[H^+]$ $pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	**Gas Laws** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = \frac{1}{2}mv^2$
Radioactivity $t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age = 8033 $\ln(A_0/A_t)$ years	**Kinetics** $t_{½} = \ln 2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Colligative Properties & Solutions $\Pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	**Thermodynamics & Equilibrium** $\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT\ln Q$ $\Delta G° = -RT\ln K$ $\Delta_{univ}S° = R\ln K$ $K_p = K_c\left(\frac{RT}{100}\right)^{\Delta n}$
Miscellaneous $A = -\log\frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A\frac{e^2}{4\pi\varepsilon_0 r}N_A$	**Mathematics** If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$ 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** [263]	105 DUBNIUM **Db** [268]	106 SEABORGIUM **Sg** [271]	107 BOHRIUM **Bh** [274]	108 HASSIUM **Hs** [270]	109 MEITNERIUM **Mt** [278]	110 DARMSTADTIUM **Ds** [281]	111 ROENTGENIUM **Rg** [281]	112 COPERNICIUM **Cn** [285]		114 FLEROVIUM **Fl** [289]		116 LIVERMORIUM **Lv** [293]		

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]