Topics in the June 2012 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2012-J-2:

- Nuclear and Radiation Chemistry

2012-J-3:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Lewis Structures
- VSEPR

2012-J-4:

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

2012-J-5:

- Band Theory - MO in Solids

2012-J-6:

- Bonding - MO theory (H_2)
- Bonding - MO theory (larger molecules)

2012-J-7:

- Lewis Structures
- VSEPR

2012-J-8:

- First and Second Law of Thermodynamics
- Gas Laws

2012-J-9:

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

2012-J-10:

- Chemical Equilibrium

2012-J-11:

- Thermochemistry
- First and Second Law of Thermodynamics

2012-J-12:

- Thermochemistry
- First and Second Law of Thermodynamics
- Chemical Equilibrium
- Equilibrium and Thermochemistry in Industrial Processes

2012-J-13:

- Electrochemistry

2012-J-14:

- Electrochemistry
- Batteries and Corrosion

2012-J-15:

- Types of Intermolecular Forces

2205(a)

THE UNIVERSITY OF SYDNEY

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2012 **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 •.
- 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 18, 22, 25 and 28 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-10	31	

Short answer section

Page	Marks Max	Gained		Marker
11	6			
12	6			
13	4			
14	5			
15	6			
16	6			
17	5			
19	4			
20	4			
21	4			
23	4			
24	5			
26	6			
27	4			
Total	69			
Check total				

Marks
6

- On the 6th of April 2011, after the earthquake and tsunami in Japan, levels of ^{131}I in seawater were recorded at 7.5×10^6 times the legal limit. The half-life of ^{131}I is 8.02 days. How long will it take for the radioactivity of the initially sampled seawater to fall back to the legal limit?

Answer:

Why is the ^{131}I nucleus unstable?

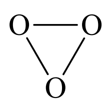
Write a balanced equation for a likely decay mechanism of ^{131}I.

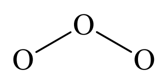
Another significant seawater contaminant detected after the tsunami was ^{137}Cs, which has a half-life of 30 years. If you were exposed to equal concentrations of both isotopes for 1 hour, which isotope, ^{137}Cs or ^{131}I, would do more damage? Explain your reasoning.

Marks

- Explain the physical significance of the square of the wavefunction, ψ^2. **2**

- The σ-bonding in two plausible structures of ozone, O_3, is shown below. Complete each structure by adding electrons and/or π-bonds as appropriate. **4**





Predict the geometry of ozone? Give reasons for your answer.

Marks
4

- The "Paschen" series of emission lines corresponds to emission from higher lying energy states to the $n = 3$ state in hydrogen-like atoms. Calculate the wavelength (in nm) of the lowest energy "Paschen" emission line in Li^{2+}.

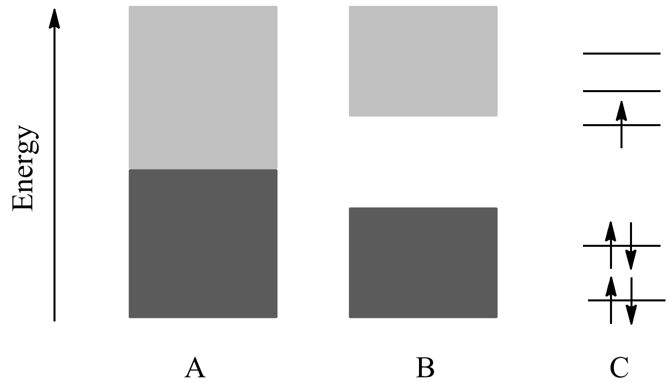
Answer:

What are the possible l states for the $n = 4$ level of Li^{2+}?

Sketch the atomic orbital with $n = 3$ and the lowest value of l.

Marks
5

- The diagram below shows the band structure of two solid elements, A and B. Dark grey denotes filled electron energy levels, light grey denotes unfilled levels. Also shown are the atomic energy levels (valence electron orbitals only) of another element, C.



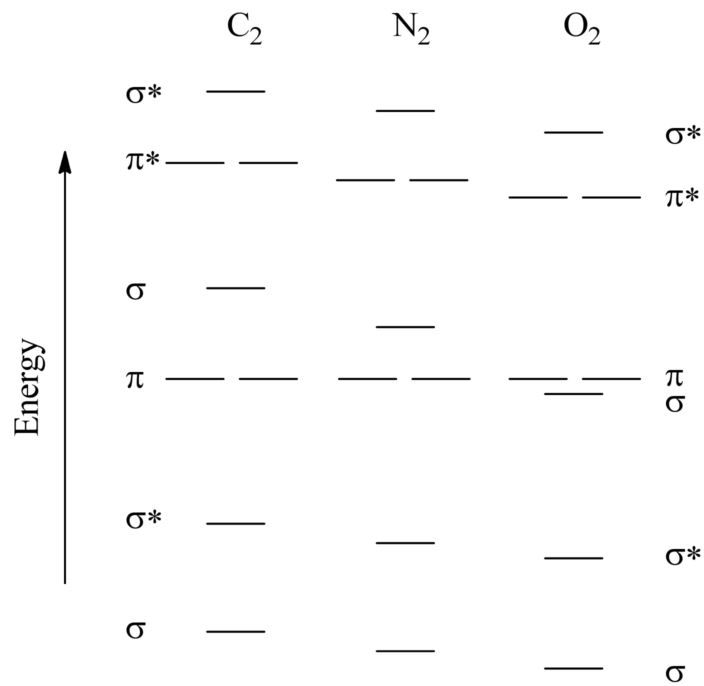
Describe the electrical properties of elements A and B, explaining your reasoning.

If a small amount of element C is deliberately added to each of A and B, describe what effect this will have on the electrical properties of each. Give reasons.

Marks 6

- The following diagram shows the molecular orbital energy level diagrams for the valence electrons in the homonuclear diatomic molecules C_2, N_2 and O_2.

  Complete the diagram by filling in the remaining *valence* electrons for each molecule and determining its bond order.



Bond order:			

Explain why the energy of the lowest energy σ orbital shown above gets lower from left to right across the periodic table.

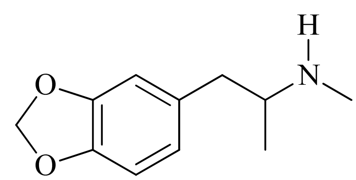
Clearly label the HOMO and LUMO of O_2 on the diagram above.

Marks

- The stick representation of 3,4-methylenedioxy-*N*-methylamphetamine ("ecstasy") is shown in the box below. **3**

  (a) Identify clearly with asterisks (*) ALL the carbon atoms that have a tetrahedral geometry.

  (b) Circle all the CH_3 groups.



Name the N-containing functional group in ecstasy.

- Complete the following table. The central atom is underlined. Carbon dioxide is given as an example. **3**

Molecule	Lewis structure	Shape of molecule
<u>C</u>O_2	$:\ddot{O}=C=\ddot{O}:$	linear
<u>P</u>Br_3		
<u>S</u>O_2		

Marks

- Explain why quartz, $SiO_2(s)$, does not spontaneously decompose into silicon and oxygen at 25 °C, even though the standard entropy change of the reaction is large and positive. **2**

$$SiO_2(s) \rightarrow Si(s) + O_2(g) \qquad \Delta S° = 164 \text{ J K}^{-1} \text{ mol}^{-1}$$

- The equation for the detonation of nitroglycerine, $C_3H_5N_3O_9(l)$, is given below. **3**

$$4C_3H_5N_3O_9(l) \rightarrow 6N_2(g) + 12CO_2(g) + 10H_2O(g) + O_2(g)$$

What mass of nitroglycerine is required to produce 1000 L of product gases at 2000 °C and 1.00 atm? Assume all gases behave as ideal gases. Show all working.

Answer:

Marks

- A 2.5 kg block of aluminium is heated to 80.0 °C and then placed into a thermally insulated water bath consisting of 10.0 L of water at 25.0 °C. Calculate the final temperature of the water once equilibrium has been reached. Show all working. **3**

  Data: Specific heat capacity of Al(s) is 0.900 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 g mL^{-1}.

Answer:

- Provide a brief explanation of the term "nitrogen fixation". **1**

Page Total:

Marks 4

- Consider the following reaction.

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$$

An equilibrium mixture in a 1.00 L vessel was found to contain $[SO_2(g)]$ = 0.800 M, $[NO_2(g)]$ = 0.100 M, $[SO_3(g)]$ = 0.600 M and $[NO(g)]$ = 0.400 M. If the volume and temperature are kept constant, what amount of NO(g) needs to be added to the reaction vessel to give an equilibrium concentration of $NO_2(g)$ of 0.300 M?

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
4

- In a process called pyrolysis, a hydrocarbon fuel is partially dehydrogenated to produce hydrogen gas, which can then be combined with oxygen to produce water. Using ethane C_2H_6 as the fuel, the overall process is described by the following balanced equation:

$$2C_2H_6(g) + O_2(g) \rightarrow 2C_2H_4(g) + 2H_2O(l)$$

Data:

Compound	$H_2O(l)$	$C_2H_6(g)$	$C_2H_4(g)$	$CO_2(g)$	$CO(g)$
$\Delta_f H^\circ$ / kJ mol^{-1}	–285.9	–84.67	52.28	–393.5	–110.5

Using heats of formation, calculate the heat of reaction per mole of ethane consumed in the reaction described above.

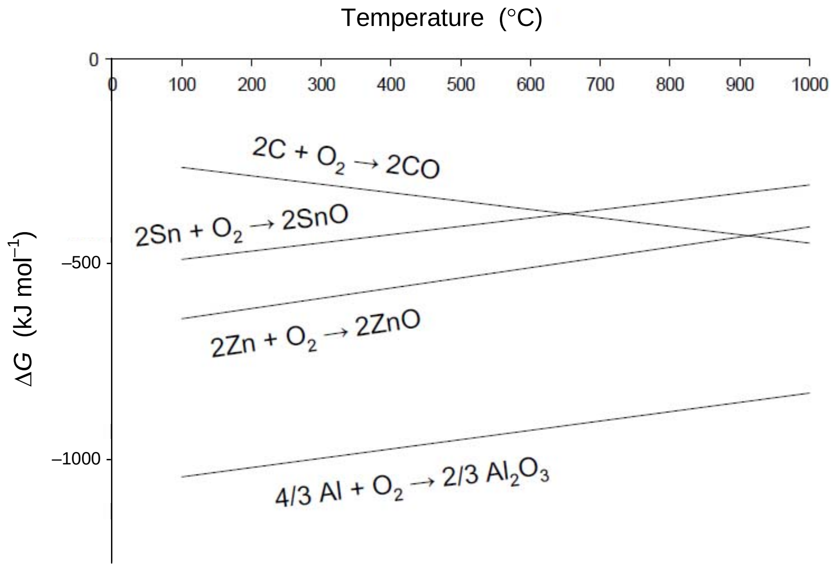
Answer:

Simply burning ethane in oxygen to produce carbon dioxide and water releases 1560 kJ per mole of ethane consumed. Provide a brief explanation of the difference between the heats of combustion and the pyrolysis-based process described above.

Briefly describe one environmental benefit of using the pyrolysis-based process for energy production.

Marks
4

- The diagram below represents the Gibbs Free energy change associated with the formation of 4 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 you think no reaction would occur, write "no reaction".

a) C and SnO are mixed at 400 °C

b) C and SnO are mixed at 900 °C

c) SnO, Sn, Zn and ZnO are mixed at 900 °C

Of the 4 oxide formation reactions, write down one for which the entropy change is negative. Provide a brief explanation for your choice.

Marks

- Consider a voltaic cell in which oxidation of Cr to Cr^{3+} by O_2 in the presence of acid occurs. Write the half-reaction that occurs at each electrode and the overall balanced redox reaction. **3**

Reaction at anode	
Reaction at cathode	
Overall balanced reaction	

- Is O_2 a stronger oxidizing agent under acidic or basic conditions? Give reasons for your answer. **2**

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
6

- A voltaic cell utilises the following redox reaction.

$$Bi(s) + 3Fe^{3+}(aq) + H_2O(l) \rightarrow 3Fe^{2+}(aq) + BiO^{+}(aq) + 2H^{+}(aq)$$

What species is the oxidising 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 the equilibrium constant for the redox reaction at 25 °C.

Answer:

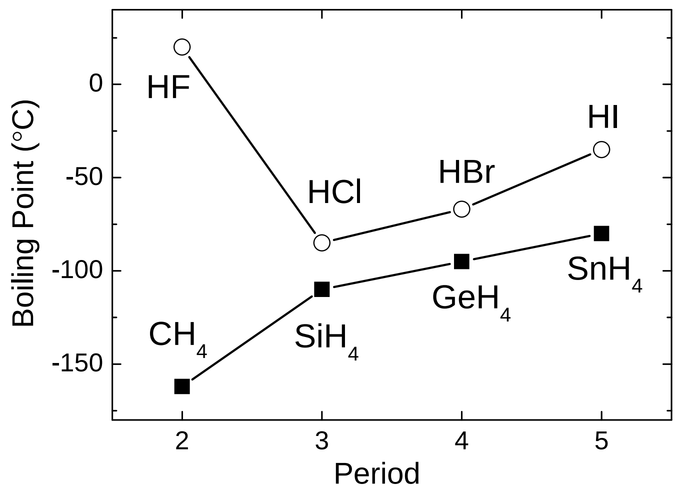
What is the effect on the E_{cell} of decreasing the concentration of $BiO^{+}(aq)$ in the anode compartment?

Calculate the cell potential, E_{cell}, when $[Fe^{3+}] = 8.2 \times 10^{-2}$ M, $[Fe^{2+}] = 0.45$ M, $[BiO^{+}] = 0.85$ M, and the pH is 2.15.

Answer:

Marks
4

- The figure below shows the boiling points of Group 14 and Group 17 hydrides as a function of the period (row) of the periodic table.



It is apparent from this figure that:
- the tetrahydrides have lower boiling points than the monohydrides,
- the boiling points increase with period, with the exception of HF.

Explain these features.

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
$BiO^+(aq) + 2H^+(aq) + 3e^- \rightarrow Bi(s) + H_2O$	+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
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–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
$Sc^{3+}(aq) + 3e^- \rightarrow Sc(s)$	–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** $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = ½mv^2$
Radioactivity $t_{½} = \ln2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age $= 8033 \ln(A_0/A_t)$ years	**Kinetics** $t_{½} = \ln2/k$ $k = Ae^{-Ea/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln\frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
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 $= \pi r^2$ 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** [263]	107 BOHRIUM **Bh** [264]	108 HASSIUM **Hs** [265]	109 MEITNERIUM **Mt** [268]	110 DARMSTADTIUM **Ds** [281]	111 ROENTGENIUM **Rg** [272]	112 COPERNICIUM **Cn** [285]						

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]