Topics in the June 2007 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2007-J-2:

- Nuclear and Radiation Chemistry

2007-J-3:

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

2007-J-4:

- Lewis Structures
- VSEPR

2007-J-5:

2007-J-6:

- Thermochemistry
- First and Second Law of Thermodynamics

2007-J-7:

- Thermochemistry
- First and Second Law of Thermodynamics

2007-J-8:

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

2007-J-9:

- Gas Laws
- Chemical Equilibrium

2007-J-10:

- Chemical Equilibrium

2007-J-11:

- Electrochemistry

2007-J-12:

- Electrolytic Cells

22/05(a) # The University of Sydney

CHEMISTRY 1A - CHEM1101

CONFIDENTIAL

FIRST SEMESTER EXAMINATION

JUNE 2007 **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 •.
- 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 15 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

	Marks	
Pages	Max	Gained
2-11	33	

Short answer section

Page	Marks: Max	Gained		Marker
12	8			
13	10			
14	9			
16	4			
17	5			
18	3			
19	5			
20	5			
21	6			
22	5			
23	7			
Total	67			
Check total				

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{55}_{26}\mathrm{Fe} + {}^{0}_{-1}\mathrm{e} \rightarrow \boxed{}$$

$$^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow 2\,{}^{1}_{1}\mathrm{p} + \boxed{}$$

$$^{15}_{7}\mathrm{N} + {}^{1}_{1}\mathrm{p} \rightarrow {}^{15}_{8}\mathrm{O} + \boxed{}$$

- Calculate the atomic mass of lead from the isotope information provided. **2**

Isotope	Mass of isotope (a.m.u.)	Relative abundance
^{204}Pb	203.97304	1.40%
^{206}Pb	205.97446	24.10%
^{207}Pb	206.97589	22.10%
^{208}Pb	207.97664	52.40%

Answer:

- Calculate the molar activity of ^{11}C (in curie), given its half-life of 20.3 minutes. **3**

Answer:

Marks

- Provide a brief explanation of each of the following terms. (You may include an equation or a diagram where appropriate). **4**

(a) Pauli exclusion principle

(b) the Bohr model of the atom

- Write down the ground state electron configurations for the following elements. The configuration of lithium is given as an example. **2**

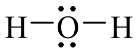
Li	$1s^2$ $2s^1$
Ne	
Br	

- Sketch the following wave functions as lobe representations. Clearly mark all nodal surfaces and nuclear positions. **4**

(a) a 2*p* orbital	(b) a π molecular orbital

Marks

- Complete the following table. Water is given as an example. **6**

Name	Lewis structure	Number of valence electron pairs on central atom	Geometric arrangement of valence electron pairs on central atom	Molecular shape
water		4	tetrahedral	bent
sulfur hexafluoride				
iodine trichloride				
xenon tetrafluoride				

- A typical surface (skin) temperature of an adult human is 33.0 °C. Calculate the wavelength at which the most intense electromagnetic radiation is emitted from the human body. **3**

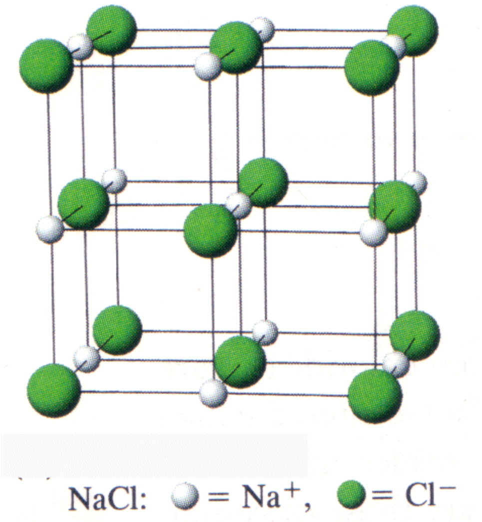
Answer:

Calculate the energy of a single photon of this radiation.

Answer:

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
5

- The current "petrochemical economy" is based on the combustion of fossil fuels, of which octane is a typical example.

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$$

Calculate the heat of combustion of octane using the supplied heat of formation data.

Data: $C_8H_{18}(l)$: –249.9 kJ mol^{-1}; $CO_2(g)$: –393.5 kJ mol^{-1}; $H_2O(l)$: –285.8 kJ mol^{-1}

Answer:

How much energy is released when 1.00 L of octane is burned?
Data: Density of octane is 0.67 kg L^{-1}

Answer:

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
3

- The so-called "hydrogen economy" is based on $H_2(g)$ produced from water by solar energy. The gas is then burned as fuel:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H_r = -571.6 \text{ kJ mol}^{-1}$$

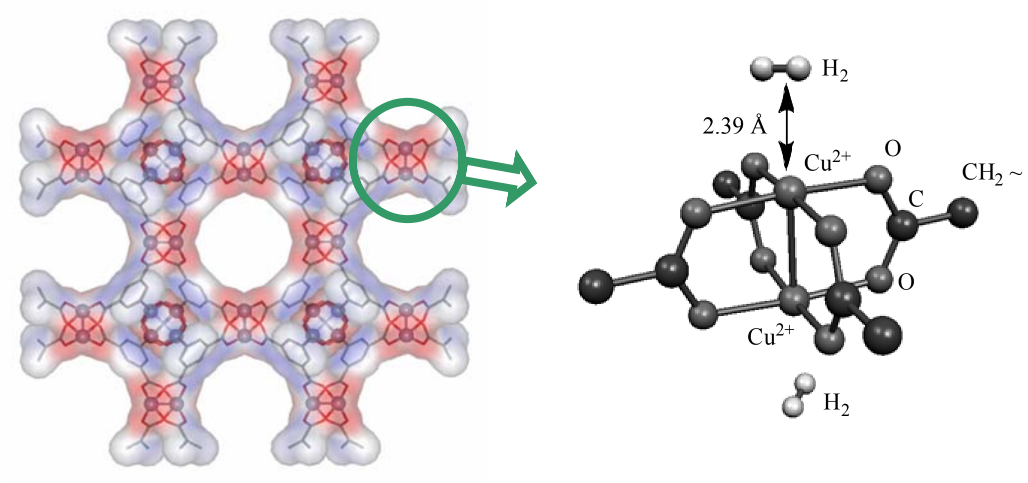
Calculate the volume of H_2 gas at 25 °C and 1 atm required to produce 1.0×10^4 kJ of heat.

Answer:

THIS QUESTION CONTINUES ON THE NEXT PAGE.
THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
5

A major disadvantage of hydrogen as a fuel is that it is a gas, and therefore hard to store. There is an enormous world-wide effort, including research performed in the University of Sydney, to develop novel chemical structures in which H_2 can be stored much more efficiently. One of the structures being tested in the School of Chemistry is shown below.



What type of intermolecular force (or forces) are responsible for the binding between the Cu^{2+} and the H_2?

In order that such a material be useful for fuel storage, the binding of the H_2 must be reversible:

$$\text{cage(s)} + H_2\text{(g)} \rightleftharpoons \text{cage}\cdot H_2\text{(s)}$$

One simple way to reverse the binding is to increase the temperature, so that at low temperature the equilibrium lies to the right and at high temperature to the left. Use this information, plus any chemical knowledge or intuition to infer the sign of ΔG, ΔH and ΔS at "low" and "high" temperatures. (You may assume that ΔH and ΔS do not change greatly with temperature.)

Marks
5

- N_2(g) and O_2(g) react with each other to a small extent if a catalyst is present to form nitric oxide, NO(g), according to the following equation.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

The equilibrium constant, K_p, for this reaction is 4.35×10^{-35} at 298 K and 2.75×10^{-20} at 500 K. Is the reaction exothermic or endothermic? Give reasons for your answer.

The partial pressures of O_2(g) and N_2(g) in air are 0.210 atm and 0.780 atm respectively. If air at atmospheric pressure is sealed in a 1.00 L container containing the catalyst at 298 K, what will be the partial pressure of NO(g) and the total pressure inside the container at equilibrium?

Pressure of NO(g):	Total pressure:

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Marks
6

Oxidation of NO(g) to produce the pollutant NO_2(g) is favoured at higher temperatures, such as those in a car exhaust:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

The equilibrium constant, K_p, for this reaction is 1.3×10^4 at 500 K. What is the value of K_c at 500 K?

K_c =

Using this value and the equilibrium constant for the formation of NO(g) from the previous page, calculate the value of K_c for the formation of NO_2(g) from N_2(g) and O_2(g) at 500 K according to the following equation.

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$$

K_c =

Marks

- Give balanced ionic equations for the reactions that occur in each of the following cases. **3**

Potassium metal is added to excess water.
Solutions of zinc nitrate and sodium phosphate are mixed.
Solid strontium carbonate is dissolved in dilute nitric acid.

- Explain why the voltage of the lead acid battery ($E°$ = 2.05 V) decreases when it discharges, whereas the zinc/silver button battery ($E°$ = 1.6 V) does not. **2**

$$Pb(s), PbSO_4(s) \mid H^+(aq), HSO_4^-(aq) \parallel H^+(aq), HSO_4^-(aq) \mid PbO_2(s), PbSO_4(s)$$

$$Zn(s), ZnO(s) \mid OH^-(aq) \parallel OH^-(aq) \mid Ag_2O(s), Ag(s)$$

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Marks

- If 1.00 tonne (10^3 kg) of aluminium metal is produced by the electrolysis of molten Al_2O_3, how many tonnes of carbon dioxide are emitted by oxidation of the carbon electrodes? **3**

Answer:

- The electrolysis of aqueous sodium chloride produces $H_2(g)$ and $Cl_2(g)$. Circle the choice that correctly finishes each of the following statements about this process. **4**

The $Cl_2(g)$ is produced at the …………………..	anode	cathode
In the aqueous salt solution, the sodium ions migrate towards the electrode that produces…...	$Cl_2(g)$	$H_2(g)$
As the electrolysis proceeds the pH of the aqueous salt solution……………………………	increases	decreases
If the process were being run with a battery, the positive electrode of the battery would be connected to the electrode that produces ………	$Cl_2(g)$	$H_2(g)$

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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

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

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]							

LANTHANIDES	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
ACTINIDES	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]