

2211(a)

THE UNIVERSITY OF SYDNEY

CHEM1109 - CHEMISTRY 1B LIFE SCIENCES

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 2010

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 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.
- Page 24 is for rough work only.

OFFICIAL USE ONLY

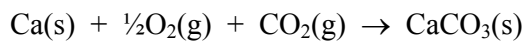
~~Multiple choice section~~

| | | | |
|-------|-----|--------|--|
| | | Marks | |
| Pages | Max | Gained | |
| 2-10 | 28 | | |

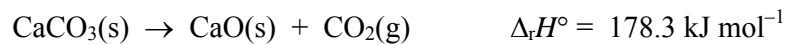
Short answer section

| Page | Marks | | Marker |
|-------------|-------|--------|--------|
| | Max | Gained | |
| 11 | 5 | | |
| 12 | 4 | | |
| 13 | 6 | | |
| 14 | 6 | | |
| 15 | 8 | | |
| 16 | 2 | | |
| 17 | 6 | | |
| 18 | 8 | | |
| 19 | 5 | | |
| 20 | 8 | | |
| 21 | 7 | | |
| 23 | 7 | | |
| Total | 72 | | |
| Check Total | | | |

- Calculate $\Delta_r H^\circ$ for the reaction



given the following heats of reaction:

**Marks****2**

Answer:

- Explain how the definition of the Gibbs free energy change

$$\Delta G = \Delta H - T\Delta S$$

expresses the Second Law of Thermodynamics.

3

- Calculate the density (in g L^{-1}) of $\text{CO}_2(\text{g})$ at 298 K and $1.013 \times 10^5 \text{ Pa}$ (1 atm).

Marks
4

Answer:

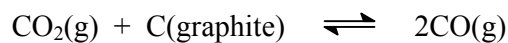
How does the density change with an increase in temperature at constant pressure?

How does the density change with an increase in temperature at constant volume?

Is there any temperature at which the density of $\text{CO}_2(\text{g})$ is less than that of air?
Explain your answer.

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- At high temperatures (1100 K), $\text{CO}_2(\text{g})$ can be reduced to $\text{CO}(\text{g})$ by elemental carbon (graphite):



A vessel at 1100 K containing powdered graphite was filled with $\text{CO}_2(\text{g})$ to a pressure of 0.458 atm. After equilibration was established, the final pressure was 0.757 atm. With reference to a standard state of 1 atm, calculate K_p for the reaction.

Marks
6

$K_p =$

What do you expect to be the signs of ΔG and ΔS for this reaction? Explain the reasons for your predictions.

What experiment could be run in order to determine the sign of ΔH for this reaction?

- Explain why the addition of salt to water raises the boiling point temperature of the solution but lowers the freezing point temperature.

Marks
3

- An aqueous solution with a volume of 10.0 mL contains 0.025 g of a purified protein of unknown molecular weight. The osmotic pressure of the solution was measured in an osmometer to be 0.0036 atm at 20.0 °C. Assuming ideal behaviour and no dissociation of the protein, estimate its molar mass.

3

Answer:

-
- Sketch the titration curve (pH against mL of added base) when 25.0 mL of 0.10 M hydrofluoric acid (HF) with a pK_a of 3.17 is titrated with 0.10 M NaOH. Calculate the pH at the following four points:
 - (i) before any NaOH is added;
 - (ii) when half of the HF has been neutralised;
 - (iii) at the equivalence point; and
 - (iv) 50% beyond the equivalence point, *i.e.* when 1.5 times the equivalence volume has been added.
-

Marks
8

-
- Explain why iron storage proteins are necessary for the transport of iron both intracellularly and extracellularly within the bloodstream at a pH of 7.4.

Marks
2

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- At present levels of $\text{CO}_2(\text{g})$ in the atmosphere, water in contact with air becomes acidic ($\text{pH} = 5.60$) through the hydrolysis of H_2CO_3 (*i.e.* $\text{CO}_2(\text{aq})$).



What is the concentration of H_2CO_3 in such natural waters?

Marks**6**

Answer:

What is the total concentration of dissolved CO_2 ?

Answer:

If the atmospheric level of $\text{CO}_2(\text{g})$ were to double, what would be the new pH of natural waters in equilibrium with the atmosphere?

Answer:

- ^{18}Ne is an unstable isotope of neon. Which force within the nucleus is responsible for its instability? Explain.

Marks
8

Write two possible mechanisms for the radioactive decay of ^{18}Ne to ^{18}F .

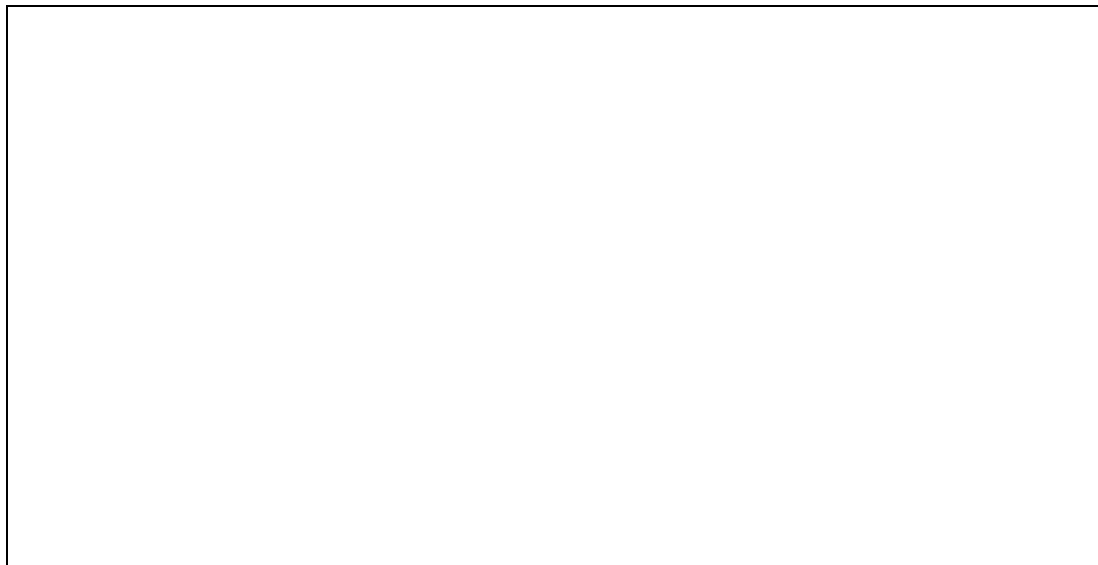
The molar mass of ^{18}Ne is $18.006 \text{ g mol}^{-1}$. The activity of an isotopically pure 1.000 g sample of ^{18}Ne is measured as $1.392 \times 10^{22} \text{ Bq}$. Calculate the half-life of ^{18}Ne .

Answer:

How long will it take for the activity of this pure 1.000 g sample of ^{18}Ne to drop to $1.000 \times 10^{10} \text{ Bq}$?

Answer:

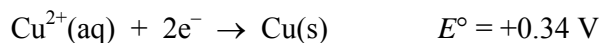
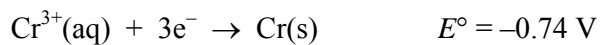
- Explain, with the aid of a diagram labelling all the key components, how sodium stearate ($C_{17}H_{35}COONa$) can stabilise long-chain non-polar hydrocarbons (“grease”) in water.

Marks**3**

- Explain what is meant by a “non-oxidising acid” in aqueous solution.

2**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

- Write the overall chemical reaction that takes place in a galvanic cell based on the following half-cell reactions:

**Marks**
8

Write the same reaction in shorthand voltaic cell notation.

Which metal electrode is acting as the cathode in this reaction?

Calculate the potential of a battery based on this cell in which the concentration of $\text{Cu}^{2+}(\text{aq})$ is 0.0355 M, the concentration of $\text{Cr}^{3+}(\text{aq})$ is 1.6650 M and the temperature is 25 °C..

Answer:

How much free energy will be released as the battery described in the previous question runs down completely?

Answer:

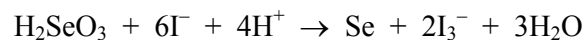
- Write out the full name in standard notation of $[\text{Co}(\text{NH}_3)_4(\text{SCN})_2]\text{Cl}$ and draw all the possible isomers of the complex ion.

Marks**7**

Describe and contrast the nature of the chemical bonds:

- (a) between N and H in NH_3 ;
- (b) between Co and NH_3 ; and
- (c) between $[\text{Co}(\text{NH}_3)_4(\text{SCN})_2]$ and Cl in this compound.

- The following reaction is run from 4 different starting positions.

**Marks****7**

| Experiment Number | Initial $[\text{H}_2\text{SeO}_3]$ (mol L ⁻¹) | Initial $[\text{I}^-]$ (mol L ⁻¹) | Initial $[\text{H}^+]$ (mol L ⁻¹) | Initial rate of increase of $[\text{I}_3^-]$ (mol L ⁻¹ s ⁻¹) |
|-------------------|---|---|---|---|
| 1 | 0.100 | 0.100 | 0.100 | 1.000 |
| 2 | 0.100 | 0.075 | 0.100 | 0.422 |
| 3 | 0.075 | 0.100 | 0.100 | 0.750 |
| 4 | 0.100 | 0.075 | 0.075 | 0.237 |

Determine the rate law for the reaction.

Rate law:

Calculate the value of the rate constant.

Answer:

Suggest an appropriate technique for measuring the rate of increase of $[\text{I}_3^-]$ in the above experiments.

CHEM1109 - CHEMISTRY 1B LIFE SCIENCES**DATA SHEET***Physical constants*Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$ Faraday constant, $F = 96485 \text{ C mol}^{-1}$ Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$ Speed of light in vacuum, $c = 2.998 \times 10^8 \text{ m s}^{-1}$ Rydberg constant, $E_R = 2.18 \times 10^{-18} \text{ J}$ Boltzmann constant, $k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$ Permittivity of a vacuum, $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$ Gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$ Charge of electron, $e = 1.602 \times 10^{-19} \text{ C}$ Mass of electron, $m_e = 9.1094 \times 10^{-31} \text{ kg}$ Mass of proton, $m_p = 1.6726 \times 10^{-27} \text{ kg}$ Mass of neutron, $m_n = 1.6749 \times 10^{-27} \text{ kg}$ *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 Ci = 3.70 × 10¹⁰ Bq

0 °C = 273 K

1 Hz = 1 s⁻¹1 L = 10⁻³ m³1 tonne = 10³ kg1 Å = 10⁻¹⁰ m1 W = 1 J s⁻¹1 eV = 1.602 × 10⁻¹⁹ J*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 |

CHEM1109 - CHEMISTRY 1B LIFE SCIENCES*Standard Reduction Potentials, E°*

| Reaction | E° / V |
|---|----------------------|
| $\text{Co}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Co}^{2+}(\text{aq})$ | +1.82 |
| $\text{Ce}^{4+}(\text{aq}) + \text{e}^- \rightarrow \text{Ce}^{3+}(\text{aq})$ | +1.72 |
| $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}$ | +1.51 |
| $\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Au}(\text{s})$ | +1.50 |
| $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightarrow 2\text{Cr}^{3+}(\text{g}) + 7\text{H}_2\text{O}$ | +1.36 |
| $\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$ | +1.36 |
| $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$ | +1.23 |
| $\text{Pt}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pt}(\text{s})$ | +1.18 |
| $\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{Mn}^{3+} + 2\text{H}_2\text{O}$ | +0.96 |
| $\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \rightarrow \text{NO}(\text{g}) + 2\text{H}_2\text{O}$ | +0.96 |
| $\text{Pd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pd}(\text{s})$ | +0.92 |
| $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$ | +0.80 |
| $\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$ | +0.77 |
| $\text{Cu}^+(\text{aq}) + \text{e}^- \rightarrow \text{Cu}(\text{s})$ | +0.53 |
| $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ | +0.34 |
| $\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$ | +0.15 |
| $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ | 0 (by definition) |
| $\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Fe}(\text{s})$ | -0.04 |
| $\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$ | -0.13 |
| $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$ | -0.14 |
| $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$ | -0.24 |
| $\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s})$ | -0.40 |
| $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$ | -0.44 |
| $\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$ | -0.74 |
| $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$ | -0.76 |
| $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ | -0.83 |
| $\text{Cr}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cr}(\text{s})$ | -0.89 |
| $\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$ | -1.68 |
| $\text{Sc}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Sc}(\text{s})$ | -2.09 |
| $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$ | -2.36 |
| $\text{Na}^+(\text{aq}) + \text{e}^- \rightarrow \text{Na}(\text{s})$ | -2.71 |
| $\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ca}(\text{s})$ | -2.87 |
| $\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$ | -3.04 |

CHEM1109 - CHEMISTRY 1B LIFE SCIENCES

Useful formulas

| | |
|---|--|
| <p>Quantum Chemistry</p> $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $E = -Z^2 E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$ $T\lambda = 2.898 \times 10^6 \text{ K nm}$ | <p>Electrochemistry</p> $\Delta G^\circ = -nFE^\circ$ <p>Moles of $e^- = It/F$</p> $E = E^\circ - (RT/nF) \times 2.303 \log Q$ $= E^\circ - (RT/nF) \times \ln Q$ $E^\circ = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E^\circ - \frac{0.0592}{n} \log Q \text{ (at } 25^\circ \text{C)}$ |
| <p>Acids and Bases</p> $pK_w = \text{pH} + \text{pOH} = 14.00$ $pK_w = \text{p}K_a + \text{p}K_b = 14.00$ $\text{pH} = \text{p}K_a + \log\{[A^-] / [HA]\}$ | <p>Gas Laws</p> $PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$ $E_k = \frac{1}{2}mv^2$ |
| <p>Radioactivity</p> $t_{1/2} = \ln 2 / \lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ $^{14}\text{C age} = 8033 \ln(A_0/A_t) \text{ years}$ | <p>Kinetics</p> $t_{1/2} = \ln 2 / k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_0 - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$ |
| <p>Colligative Properties & Solutions</p> $\Pi = cRT$ $P_{\text{solution}} = X_{\text{solvent}} \times P^\circ_{\text{solvent}}$ $c = kp$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$ | <p>Thermodynamics & Equilibrium</p> $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G = \Delta G^\circ + RT \ln Q$ $\Delta G^\circ = -RT \ln K$ $\Delta_{\text{univ}} S^\circ = R \ln K$ $\ln \frac{K_2}{K_1} = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$ |
| <p>Miscellaneous</p> $A = -\log \frac{I}{I_0}$ $A = \epsilon cl$ $E = -A \frac{e^2}{4\pi\epsilon_0 r} N_A$ | <p>Mathematics</p> <p>If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$</p> $\ln x = 2.303 \log x$ <p>Area of circle = πr^2</p> <p>Surface area of sphere = $4\pi r^2$</p> |

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 YTRIUM 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 DARMSTADIUM Ds [271] | 111 ROENTGENIUM Rg [272] | 112 COPERNICIUM Cn [283] | | | | | | |

| | | | | | | | | | | | | | | | |
|-----------------|--|--|---|--|--|---|---|---|--------------------------------------|---|---|---|--|--|---|
| LANTHANOID S | 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 BERKELIUM 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] |