

Topics in the June 2012 Exam Paper for CHEM1903

Click on the links for resources on each topic.

2012-J-2:

- [Bonding in H₂ - MO theory](#)
- [Bonding in O₂, N₂, C₂H₂, C₂H₄ and CH₂O](#)

2012-J-3:

- [Atomic Electronic Spectroscopy](#)
- [Bonding in O₂, N₂, C₂H₂, C₂H₄ and CH₂O](#)

2012-J-4:

- [Nuclear and Radiation Chemistry](#)

2012-J-5:

- [Nuclear and Radiation Chemistry](#)

2012-J-6:

- [Lewis Structures](#)
- [VSEPR](#)

2012-J-7:

- [Thermochemistry](#)

2012-J-8:

- [First and Second Law of Thermodynamics](#)

2012-J-9:

- [Polar Bonds](#)
- [Ionic Bonding](#)

2012-J-10:

- [Chemical Equilibrium](#)

2012-J-11:

- [Electrochemistry](#)
- [Batteries and Corrosion](#)

2221(a)

THE UNIVERSITY OF SYDNEY

CHEMISTRY 1A (ADVANCED) - CHEM1901

CHEMISTRY 1A (SPECIAL STUDIES PROGRAM) - CHEM1903

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 20 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, 20 and 24 are for rough working only.

OFFICIAL USE ONLY

Multiple choice section

| Marks | | |
|-------|-----|--------|
| Pages | Max | Gained |
| 2-10 | 31 | |

Short answer section

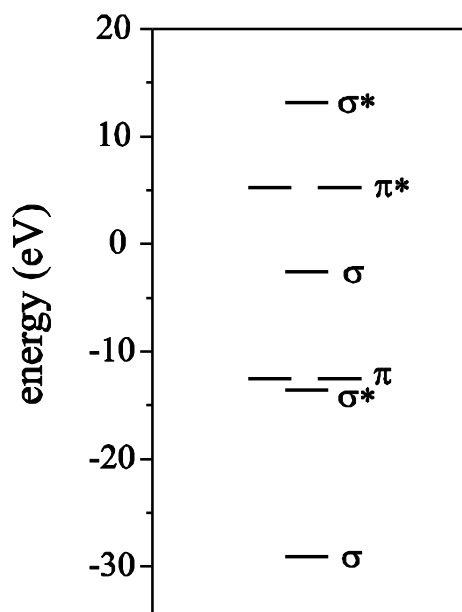
| Page | Marks | | Marker |
|-------------|-------|--------|--------|
| | Max | Gained | |
| 11 | 5 | | |
| 12 | 6 | | |
| 13 | 4 | | |
| 14 | 8 | | |
| 15 | 8 | | |
| 16 | 6 | | |
| 18 | 4 | | |
| 19 | 6 | | |
| 21 | 9 | | |
| 22 | 6 | | |
| 23 | 7 | | |
| Total | 69 | | |
| Check Total | | | |

- C_2 is a reaction intermediate observed in flames, comets, circumstellar shells and the interstellar medium. In 2011, a new state of C_2 was observed with 4 parallel spins.

Marks
5

How many *valence* electrons are there in C_2 ?

Complete the calculated MO diagram for the lowest energy state of C_2 with 4 parallel spins by inserting the appropriate number of electrons into the appropriate orbitals.



What is the bond order of this state of C_2 ?

Is this state paramagnetic? Give reasoning.

What is the bond order of the ground state of C_2 ?

- An “excimer laser” is a type of ultraviolet laser used for lithography, micromachining and eye surgery. In one type of laser, an electrical discharge through HCl and Xe in a helium buffer gas yields metastable XeCl molecules, described like an ion pair. These then emit 308 nm light and dissociate into Xe and Cl atoms.

Marks
6

| element | Ionisation energy / kJ mol^{-1} | Electron affinity / kJ mol^{-1} |
|---------|---|---|
| Xe | 1170.4 | – |
| Cl | 1251.1 | –349 |

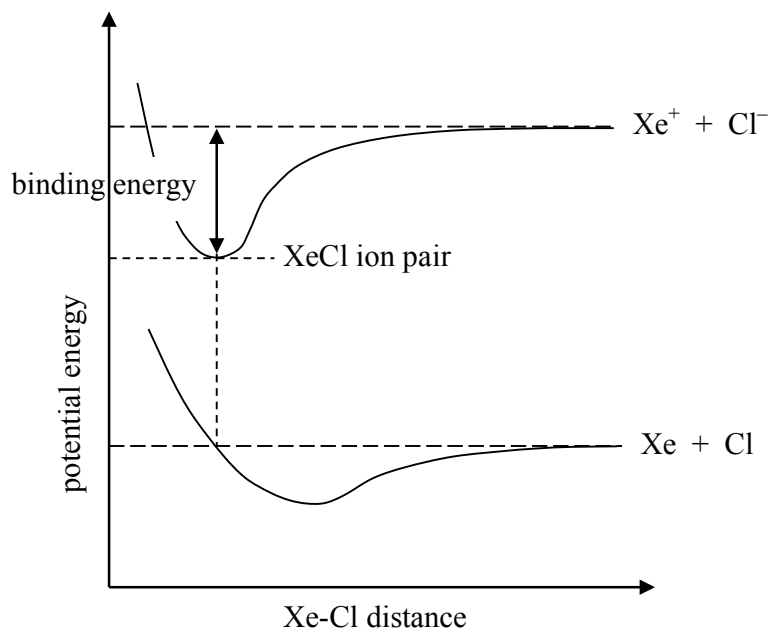
What energy, in eV, is required to convert a pair of Xe and Cl atoms into Xe^+ and Cl^- ions?

Answer:

What energy (in eV) is released when the XeCl molecules emit ultraviolet light?

Answer:

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Marks
4

What is the binding energy (in J) of the XeCl ion pair?

Answer:

If the binding is electrostatic, what is the approximate equilibrium bond length of XeCl if the binding energy is given by the Coulomb formula: $E = \frac{q_1 q_2}{4\pi\epsilon_0 r}$?

Answer:

- The generation of energy in a nuclear reactor is largely based on the fission of either ^{235}U or ^{239}Pu . The fission products include every element from zinc through to the f -block. Explain why most of the radioactive fission products are β -emitters.

Marks
8

Much of the fission yield is concentrated in two peaks, one in the second transition row and the other later in the periodic table. Identify the missing “sister” products of the following daughter nuclides of ^{235}U by writing balanced nuclear equations. The fission reactions are triggered by the absorption of one neutron, and release three neutrons upon disintegration of the short-lived ^{236}U nucleus.

| | |
|-------------------|--|
| ^{141}Ba | |
| ^{95}Sr | |

Many of the fission products are short lived, and spent fuel rods are eventually contaminated by longer-lived species. The radioactivity of spent fuel can be modelled simply by the exponential decay of the ^{137}Cs and ^{90}Sr . The % yields and half lives of these nuclides are given in the table.

| nuclide | %Yield <i>per fission event</i> | Half-life (years) |
|-------------------|---------------------------------|-------------------|
| ^{90}Sr | 4.505 | 28.9 |
| ^{137}Cs | 6.337 | 30.23 |

After use, nuclear fuel rods are stored in ponds of cooling water, awaiting safe disposal. If 3 % of the mass of used fuel rods consists of fission products of ^{235}U and ^{239}Pu , what percentage of the mass is made up by each of these nuclides?

| | |
|--------------------|---------------------|
| ^{90}Sr : | ^{137}Cs : |
|--------------------|---------------------|

THIS QUESTION CONTINUES ON THE NEXT PAGE.

| | |
|--|--------------------------|
| What are the specific activities of ^{90}Sr and ^{137}Cs in Bq g^{-1} ? | Marks 8 |
| | |
| ^{90}Sr : | ^{137}Cs : |
| Assuming the majority of the activity of a spent fuel rod to be due to these nuclides, what will be the activity of a 1 tonne fuel rod 100 years after placing it in the pond? | |
| | |
| Answer: | |

- Complete the table below showing the Lewis structures and the predicted shapes of the following species.

Marks
6

| Formula | Lewis Structure | Approximate F-X-F bond angle(s) | Name of molecular shape |
|-------------------------------|-----------------|---------------------------------|-------------------------|
| NF ₃ | | | |
| XeF ₃ ⁺ | | | |
| XeF ₄ | | | |
| XeOF ₄ | | | |

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

- When 20.0 mL of 0.250 M Ba(OH)₂ at 47.5 °C is added to a constant pressure (“coffee cup”) calorimeter containing 200.0 mL of 0.500 M H₂SO₄ also at 47.5 °C, a white precipitate is formed. The final temperature of the solution is 46.4 °C. Given that the enthalpy of neutralisation of H⁺(aq) and OH⁻(aq) is -56.5 kJ mol⁻¹, and assuming that the specific heat capacity and density of all solutions involved are the same as that of pure water (c = 4.184 J K⁻¹ g⁻¹ and ρ = 1.000 g mL⁻¹), calculate the enthalpy of solution of BaSO₄ in kJ mol⁻¹.

Marks
4

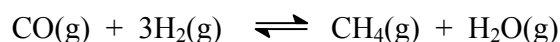
Answer:

| | |
|---|--------------------------|
| <ul style="list-style-type: none">• Explain the following phenomena. (a) When O_2 dissolves in water at room temperature, the total entropy of the system decreases. | Marks 6 |
| | |
| <p>(b) When $MgSO_4$ is dissolved in water, there is a very small but measurable decrease in volume.</p> | |
| | |
| <p>(c) A crystal (<i>e.g.</i> of $NaCl$) in its lowest energy configuration (thermodynamic ground state) will always contain defects at finite temperatures.</p> | |
| | |

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

| | |
|---|--------------------------|
| <ul style="list-style-type: none">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 |
| | |
| <ul style="list-style-type: none">Consider the complex $K_4[Mn(CN)_6]$. Describe and contrast the origin, strength and directionality of the chemical bonds in this compound (a) between C and N; (b) between the manganese and cyanide ions; and (c) between the complex and the potassium counterions. | 6 |
| | |

- Equal volumes of carbon monoxide and hydrogen gas are introduced into a sealed 4.5 L flask at 1200 K and the following reaction occurs.



Sometime later, total pressure in the flask is 46.4 atm. Calculate the total amount of gas (in mol) in the flask at this later time.

Marks
6

Answer:

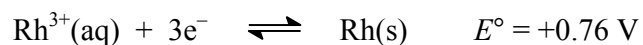
When the total pressure in the flask is 46.4 atm, the flask contains 0.22 mol of CH₄. Calculate the amount of H₂(g) (in mol) that was initially introduced into the flask.

Answer:

In a separate experiment, it is determined that the reaction is in equilibrium when the same 4.5 L flask contains 0.18 mol of CH₄, 0.24 mol of H₂O, 0.82 mol of CO and 0.65 mol of H₂ at 1200 K. Was the reaction at equilibrium in the previous part of this question? Show all working.

Answer: YES / NO

- A voltaic cell is set up at 298 K based on the following half-cell reactions.



Write the overall chemical reaction that takes place in this cell.

Write the same reaction in shorthand voltaic cell notation.

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

Calculate the potential of this cell at 298 K, in which the concentration of $\text{Pt}^{2+}(\text{aq})$ is $0.0544 \text{ mmol L}^{-1}$ and the concentration of $\text{Rh}^{3+}(\text{aq})$ is $0.0393 \text{ mmol L}^{-1}$.

Answer:

Marks
7

CHEM1901 - CHEMISTRY 1A (ADVANCED)
CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

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 = 3.70×10^{10} Bq

0 °C = 273 K

1 Hz = 1 s⁻¹

1 L = 10⁻³ m³

1 tonne = 10³ kg

1 Å = 10⁻¹⁰ m

1 W = 1 J s⁻¹

1 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 |

CHEM1901 - CHEMISTRY 1A (ADVANCED)
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Standard Reduction Potentials, E°

| Reaction | <i>E° / V</i> |
|--|-------------------|
| $\text{Co}^{3+}(\text{aq}) + \text{e}^{-} \rightarrow \text{Co}^{2+}(\text{aq})$ | +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 |
| $\text{Cl}_2 + 2\text{e}^{-} \rightarrow 2\text{Cl}^{-}(\text{aq})$ | +1.36 |
| $\text{O}_2 + 4\text{H}^{+}(\text{aq}) + 4\text{e}^{-} \rightarrow 2\text{H}_2\text{O}$ | +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 |
| $\text{BiO}^{+}(\text{aq}) + 2\text{H}^{+}(\text{aq}) + 3\text{e}^{-} \rightarrow \text{Bi}(\text{s}) + \text{H}_2\text{O}$ | +0.32 |
| $\text{Sn}^{4+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Sn}^{2+}(\text{aq})$ | +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 |

CHEM1901 - CHEMISTRY 1A (ADVANCED)
CHEM1903 - CHEMISTRY 1A (SPECIAL STUDIES PROGRAM)

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> $E = E^\circ - (RT/nF) \times \ln Q$ $E^\circ = (RT/nF) \times \ln K$ $E = E^\circ - \frac{0.0592}{n} \log Q \text{ (at 25 }^\circ\text{C)}$ |
| <p>Acids and Bases</p> $\text{pH} = -\log[\text{H}^+]$ $\text{p}K_w = \text{pH} + \text{pOH} = 14.00$ $\text{p}K_w = \text{p}K_a + \text{p}K_b = 14.00$ $\text{pH} = \text{p}K_a + \log\{[\text{A}^-] / [\text{HA}]\}$ | <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> $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G = \Delta G^\circ + RT \ln Q$ $\Delta G^\circ = -RT \ln K$ $\Delta_{\text{univ}} S^\circ = R \ln K$ $K_p = K_c \left(\frac{RT}{100} \right)^{\Delta n}$ |
| <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 | 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 | 2 HELIUM He 4.003 |
| 3 LITHIUM Li 6.941 | | | | | | | | | | | | 13 ALUMINUM Al 26.98 | 14 SILICON Si 28.09 | 15 PHOSPHORUS P 30.97 | 16 SULFUR S 32.07 | 17 CHLORINE Cl 35.45 | 10 NEON Ne 20.18 |
| 11 SODIUM Na 22.99 | 12 MAGNESIUM Mg 24.31 | | | | | | | | | | | 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 |
| 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 | 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 |
| 37 RUBIDIUM Rb 85.47 | 38 STRONTIUM Sr 87.62 | 39 YTRBIUM 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 | 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] |
| 55 CAESIUM Cs 132.91 | 56 BARIUM Ba 137.34 | 57-71 LANTHANOIDES | 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 | | | | | | |
| 87 FRANCIUM Fr [223.0] | 88 RADIUM Ra [226.0] | 89-103 ACTINOIDES | 104 RIFTERBORIUM 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 ROENTGIUM Rg [272] | 112 COPIERNICIUM Cn [285] | | | | | | |

| | | | | | | | | | | | | | | |
|--|--------------------------------------|--|-------------------------------------|---|---|---|--------------------------------------|---|---|---|--|---|---|---|
| 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
| LANTHANUM La 138.91 | CERIUM Ce 140.12 | PRASEODYMIUM Pr 140.91 | NEODYMIUM Nd 144.24 | PROMETHIUM Pm [144.9] | SAMARIUM Sm 150.4 | EUROPIUM Eu 151.96 | GADOLINIUM Gd 157.25 | TERBIUM Tb 158.93 | DYSPROSIUM Dy 162.50 | HOLMIUM Ho 164.93 | ERBIUM Er 167.26 | THULIUM Tm 168.93 | YTERBIUM Yb 173.04 | LUTETIUM Lu 174.97 |
| 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 MEYERBERGIUM Md [256.1] | 102 NOBELIUM No [259.1] | 103 LAWRENCIUM Lr [260.1] |