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CHM 1301
CHM 1311 B

GENERAL CHEMISTRY: QUIZ 2

STUDENT NAME____

STUDENT ID. No.____

CIRCLE ONE: CHM 1301 CHM 1311B

CONSTANTS

R = 8.314 J/molK = 0.08206 L atm/molK=0.08314 bar L/molK

1 atm = 760 Torr = 760 mm Hg = 101.325 kPa = 1.01325 x 10^5 Pa = 1.01325 bar

N_A = 6.022 x 10^{23} mol^{-1}

d_{water} = 1.00 g/cm^3 ; g = 9.81 m/s^2

There are 8 pages in this quiz including the cover page, equations and the periodic table.

Check and ensure you have answered each question before handing in the quiz.

PLEASE use a pen!! Box, underline or highlight your FINAL answer.

The quiz is out of 25 points with a maximum of 28 points possible

CLEARLY explain your thinking…

USE UNITS!

(6) 1.00 mol each of CO and Cl_2 are introduced into an evacuated 1.75 L flask, and the following equilibrium is established at 668 K: for the reaction

$$CO\,(g) + Cl_2\,(g) \rightleftharpoons COCl_2\,(g) \qquad K = 22.5$$

$P_{CO} = P_{Cl_2} = \frac{nRT}{V} = \frac{(1.00\ mol)(0.08314\ \frac{bar\,L}{mol\,K})(668\ K)}{1.75\ L} = 31.7\ bar$

a) Determine the equilibrium partial pressures of all the gases.

	$CO(g)$	$+\ Cl_2(g)$	$\rightleftharpoons COCl_2(g)$
I	31.7 bar	31.7 bar	–
C	$-x$	$-x$	x
E	$31.7-x$	$31.7-x$	x

$$K = \frac{P_{COCl_2}}{P_{CO}P_{Cl_2}} = \frac{x}{(31.7-x)^2} = 22.5$$

$$x = 22.5(1.01\times10^3 - 63.5x + x^2)$$

$$22.5x^2 - 1.43\times10^3 x + 2.27\times10^4 = 0$$

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{1.43\times10^3 \pm \sqrt{(-1.43\times10^3)^2 - 4(22.5)(2.27\times10^4)}}{2(22.5)}$$

use ⊖ root $= 30.1$ bar

$\therefore P_{COCl_2} = 30.1$ bar $\quad P_{CO} = P_{Cl_2} = 1.6$ bar

b) What is the total pressure at equilibrium?

$P_{TOT} = P_{CO} + P_{Cl_2} + P_{COCl_2} = ((1.6\times2) + 30.1)$ bar $= 33.2$ bar

c) Once the reaction reaches equilibrium, if the pressure is gradually increased, which way will the reaction shift? Explain your answer.

To the RIGHT (towards products)

1 mol of gas as product ; 2 mol reactants

higher P means rxn shifts to form fewer moles

(8) 20.0 mL of 0.275 mol/L NH_3, ($K_b = 1.8 \times 10^{-5}$), are titrated with 0.325 mol/L HI solution. Calculate:

a) The pH of the solution before titration.

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

	NH_3	NH_4^+	OH^-
I	0.275 mol/L	—	—
C	−x	x	x
E	0.275−x	x	x

$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{x^2}{0.275-x} = 1.8\times10^{-5}$

assume $x \ll 0.275$ ∴ $0.275 - x \approx 0.275$ ok

$\frac{x^2}{0.275} = 1.8\times10^{-5}$ ∴ $x = [OH^-] = 2.2\times10^{-3}$ mol/L

∴ pOH = $-\log(2.2\times10^{-3}) = 2.65$

∴ pH = 14.00 − 2.65 = **11.35**

b) The volume of acid required to reach the equivalence point.

$c_A V_A = c_B V_B$

$(0.325 \frac{mol}{L}) V_A = (0.275 \frac{mol}{L})(20.0\ mL)$

$V_A =$ **16.9 mL**

c) The pH at the midpoint of the titration.

$NH_3(aq) + HI(aq) \rightarrow NH_4^+(aq) + I^-(aq)$

$0.275 \frac{mol}{L}\left(\frac{20.0}{28.5}\right)$; $0.325\left(\frac{8.5}{28.5}\right)$

	NH_3	HI	NH_4^+	I^-
I	0.193	9.65×10^{-2}	—	—
C	-9.65×10^{-2}	-9.65×10^{-2}	9.65×10^{-2}	—
F	9.65×10^{-2}	0	9.65×10^{-2}	

pH = $-\log\left(\frac{1.0\times10^{-14}}{1.8\times10^{-5}}\right) + \log\left(\frac{9.65\times10^{-2}}{9.65\times10^{-2}}\right)$ (→ 0)

= **9.26**

d) The pH at the equivalence point.

$NH_3(aq) + HI(aq) \rightarrow NH_4^+(aq) + I^-(aq)$

$0.275 \frac{mol}{L}\left(\frac{20.0}{36.9}\right)$; $0.325 \frac{mol}{L}\left(\frac{16.9}{36.9}\right)$

	NH_3	HI	NH_4^+	I^-
I	0.149 mol/L	0.149 mol/L	—	—
C	−0.149	−0.149	+0.149	
F	0	0	0.149	

$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

	NH_4^+	NH_3	H_3O^+
I	0.149 mol/L	—	—
C	−x	x	x
E	0.149 − x	x	x

$K_a = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} = \frac{[NH_3][H_3O^+]}{[NH_4^+]} = \frac{x^2}{0.149-x}$

assume $x \ll 0.149$ ∴ $0.149 - x \approx 0.149$ ok!

$\frac{x^2}{0.149} = 5.6\times10^{-10}$; $x = 9.1\times10^{-6} \frac{mol}{L} = [H^+]$

∴ pH = $-\log(9.1\times10^{-6})$ = **5.04**

(6) Zinc phosphate is a very slightly soluble salt having a K_{sp} of 9.0×10^{-33} at 25°C .

a) Write the equation for the solubility equilibrium of zinc phosphate.

$$Zn_3(PO_4)_2(s) \rightleftharpoons 3Zn^{2+}(aq) + 2PO_4^{3-}(aq)$$

b) Calculate the molar solubility of zinc phosphate in pure water at this temperature.

$$Zn_3(PO_4)_2(s) \rightleftharpoons 3Zn^{2+}(aq) + 2PO_4^{3-}(aq)$$

	$Zn_3(PO_4)_2$	Zn^{2+}	PO_4^{3-}
I	some	–	–
C	$-s$	$3s$	$2s$
E	some	$3s$	$2s$

$$K_{sp} = [Zn^{2+}]^3[PO_4^{3-}]^2 = (3s)^3(2s)^2 = 9.0\times10^{-33}$$

$$(27s^3)(4s^2) = 108s^5 = 9.0\times10^{-33}$$

$$s = 1.5\times10^{-7}\ \frac{mol}{L}$$

c) Calculate the molar solubility of zinc phosphate in a solution of 0.100 mol/L zinc nitrate.

$$Zn_3(PO_4)_2(s) \rightleftharpoons 3Zn^{2+}(aq) + 2PO_4^{3-}(aq)$$

	$Zn_3(PO_4)_2$	Zn^{2+}	PO_4^{3-}
I	some	$0.100\ \frac{mol}{L}$	–
C	$-s$	$3s$	$2s$
E	some	$0.100+3s$	$2s$

$$K_{sp} = [Zn^{2+}]^3[PO_4^{3-}]^2 = (0.100+3s)^3(2s)^2 = 9.0\times10^{-33}$$

assume $3s \ll 0.100 \therefore 0.100+3s \approx 0.100$

$$(0.100)^3(4s^2) = 9.0\times10^{-33}$$

$$s = 1.5\times10^{-15}\ \frac{mol}{L}$$

(5) The initial rate of the reaction:

$$A + B \rightarrow C + D$$

Is determined for different initial conditions. The rate data obtained at 25°C are listed in the table below:

$Rate = k[A]^m[B]^n$

Experiment	$[A]_o$ (mol/L)	$[B]_o$ (mol/L)	Initial Rate (mol/Ls)
1	0.185	0.133	3.35×10^{-4}
2	0.185	0.266	1.35×10^{-3}
3	0.370	0.133	6.75×10^{-4}
4	0.370	0.266	2.70×10^{-3}

a) What is the rate law for the reaction?

$$\frac{Rate\,2}{Rate\,1} = \frac{k(0.185)^m(0.266)^n}{k(0.185)^m(0.133)^n} = 2^n = \frac{1.35\times10^{-3}}{3.35\times10^{-4}} = 4$$

$$2^n = 2^2 \qquad \boxed{n = 2}$$

$$\frac{Rate\,3}{Rate\,1} = \frac{k(0.370)^m(0.133)^n}{k(0.185)^m(0.133)^n} = 2^m = \frac{6.75\times10^{-4}}{3.35\times10^{-4}} = 2$$

$$2^m = 2^1 \qquad \boxed{m = 1}$$

$$\boxed{Rate = k[A][B]^2}$$

b) What is the value WITH THE PROPER UNITS for the rate constant?

$$Rate = k[A][B]^2$$

$$3.35\times10^{-4}\,\frac{mol}{Ls} = k\left(0.185\,\frac{mol}{L}\right)\left(0.133\,\frac{mol}{L}\right)^2$$

$$\boxed{k = 0.102\,\frac{L^2}{mol^2 s}}$$

c)

BONUS QUESTION: To be answered ONLY if ALL previous questions have been answered!

$NH_4Cl(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$

(3) You are asked to bring the pH of 0.500 L of 0.500 mol/L NH_4Cl to 7.00. What volume, in drops, (1 drop = 0.05 mL) of which of the following solutions would you use: 10.0 mol/L HCl or 10.0 mol/L NH_3?

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

	NH_4^+	NH_3	H_3O^+
I	$0.500 \frac{mol}{L}$	–	–
C	$-x$	x	x
E	$0.500 - x$	x	x

$$K_a = \frac{K_w}{K_b} = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} = 5.6\times10^{-10} = \frac{[NH_3][H_3O^+]}{[NH_4^+]} = \frac{x^2}{0.500 - x}$$

assume $x \ll 0.500$ $\therefore 0.500 - x \approx 0.500$

$$\frac{x^2}{0.500} = 5.6\times10^{-10} \qquad x = 1.7\times10^{-5} \frac{mol}{L} = [H_3O^+]$$

$$pH = -\log[H_3O^+] = -\log(1.7\times10^{-5}) = \boxed{4.78} \quad \therefore \text{acidic}$$

ADD 10.0 $\frac{mol}{L}$ NH_3 to bring pH to 7.00

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$7.00 = -\log(5.6\times10^{-10}) + \log\frac{[A^-]}{[HA]}$$

$$\log\frac{[A^-]}{[HA]} = -2.26$$

$$\frac{[A^-]}{[HA]} = 5.6\times10^{-3}$$

$NH_4^+(aq) + H_2O \rightleftharpoons NH_3(aq) + H_3O^+$

$0.500\left(\frac{500}{500+V}\right) \qquad 10.0\left(\frac{V}{500+V}\right)$

$$\frac{\frac{10.0V}{500+V}}{\frac{250}{500+V}} = 5.6\times10^{-3}$$

$$\frac{10.0V}{250.} = 5.6\times10^{-3}$$

$$V = 0.14\ mL = \frac{0.14\ mL}{0.05\ \frac{mL}{drop}} = \boxed{3\ drops}$$

Equations and Constants

Gas Laws

$pV = nRT$

$p_{Total} = p_1 + p_2 + p_3 + \ldots$

$d = \frac{m}{V} = \frac{p(MM)}{RT}$

$KE = (1/2)mv_{av}^2$

$u_{rms} = \sqrt{\frac{3RT}{M}}$

$\frac{RateA}{RateB} = \sqrt{\frac{M_b}{M_a}}$

$p + \frac{n^2 a}{V^2}(V - nb) = nRT$

1 atm = 760 Torr = 760 mm Hg = 1.01325×10^5 Pa = 1.01325 bar = 101.325 kPa

Equilibrium

$K_p = K(RT)^{\Delta n}$

$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$

$K_{sp} = [C]^c[D]^d$

Acid/Base

$pOH = -\log[OH^-]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \bullet K_b = K_w$

$pH = pKa + \log\frac{[A^-]}{[HA]}$

$pH = \frac{pK_{a1} + pK_{a2}}{2}$

$C_1V_1 = C_2V_2$

Electrochemistry

$\Delta G^o = -nFE^o$

$E = E^o - \frac{RT}{nF}\ln(Q)$

Or $E = E^o - \frac{0.059}{n}\log(Q)$ at 25^oC

$Q = I \cdot t$

Quantum Mechanics

$\lambda \cdot \nu = c$

$E = h \cdot \nu$

$m = \frac{h}{\lambda c}$

$E = \frac{1}{2} m u^2$

$\lambda = h/mu$

Energy of state = -2.178×10^{-18} J / n^2

$\Delta x \cdot \Delta p \geq h / 4\pi$

$E = -C(1/n^2)$

Liquids and Colligative Properties

$\ln(p_1/p_2) = \Delta H^o/R\,(1/T_2 - 1/T_1)$

$p_{solution} = X_{solvent} \bullet p^o_{solvent}$

$\Delta T_{BP} = K_{BP} \bullet m$

$\Delta T_{FP} = K_{FP} \bullet m$

$\Delta T = K \bullet m \bullet i$

$\Pi = cRT$

molality = mol solute/mass solvent (kg)

General

$n = \frac{m}{MM}$ $d = \frac{m}{V}$ $c = \frac{n}{V}$

Thermodynamics	
$\Delta U = q$	$\ln\left(\frac{K_1}{K_2}\right) = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
$w_{system} = -p\Delta V$	**Kinetics**
$\Delta E = q + w$	Rate = $k[A]^x[B]^y[C]^z$
$\Delta H = \Delta E + p\Delta V$	Rate = k
$q_P = \Delta E + p\Delta V$	Rate = k[A]
$\Delta E = nC_v\Delta T$	Rate = $k[A]^2$
$\Delta H = q_p = m\, C_p\, \Delta T$	$[A] = -kt + [A]_0$
$C_p = C_v + R$	$\ln[A] = -kt + \ln[A]_0$
$\Delta_r H^\circ = \Sigma\ \nu_p \Delta_f H_p^\circ - \Sigma\ \nu_r \Delta_f H_r^\circ$	$1/[A] = kt + 1/[A]_0$
$\Delta H^o = \frac{q}{n}$	$t = [A]_0 / 2k$
$q_{rev} = -w_{max} = nRT \ln(V_2/V_1)$	ln 2 = kt
$\Delta S = q_{rev} / T$	$k = Ae^{-Ea/RT}$
$\Delta S_{T1-T2} = nC_p \ln(T_2/T_1)$	$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$
$\Delta S_{T1-T2} = nC_V \ln(T_2/T_1)$	**Bonding**
$\Delta S^0_{surroundings} = \frac{q_{surroundings}}{T} = \frac{-\Delta H_{sys}}{T}$	DE = $k(Q_1Q_2 / r)$
$\Delta G^o = \Delta H^o - T\Delta S^o$	$DH_{rxn} = Sn_pD$(reactants) - Sn_rD(products)
$\Delta G = \Delta G^o + RT\ln(Q)$	Formal Charge = #valence e^- in free atom - #lone pair e^- - 1/2(# bonding e^-)
$\Delta G^o = -RT\ln(K)$	

Data For Water and Other Constants

Density d = 1.00 g/mL (25°C) C = 4.184 J g^{-1} °C^{-1} (liquid)

Avogadro's Number	*N*	6.022×10^{23}	mol^{-1}
Boltzmann's constant	*k*	1.30866×10^{-23}	$J \cdot K^{-1}$
Faraday's constant	*F*	96,485	$C \cdot mol^{-1}$
Gas constant	*R*	8.31451	$J \cdot K^{-1} \cdot mol^{-1}$
	R	0.08206	$L \cdot atm \cdot K^{-1} \cdot mol^{-1}$
Mass of Electron	m_e	$9.10938188 \times 10^{-31}$	kg
Planck's constant	*h*	6.62608×10^{-34}	$J \cdot s$
Speed of Light	*c*	2.99792458×10^{8}	$m \cdot s^{-1}$

$K_w = 1.00 \times 10^{-14}$ General Information: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

PERIODIC TABLE OF THE ELEMENTS

Key (Carbon):
- 14 ⟸ Group IUPAC
- IVA ⟸ Group CAS
- Atomic Number ⟹ 6
- Symbol ⟹ C
- Selected Oxidation States: -4 +2 +4
- Name ⟹ Carbon
- Atomic Mass: 12.011
- Electron Configuration ⟹ 2-4

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H Hydrogen 1.0079 +1 -1 1																	2 He Helium 4.0026 0 2
2	3 Li Lithium 6.941 +1 2-1	4 Be Beryllium 9.0122 +2 2-2											5 B Boron 10.811 +3 2-3	6 C Carbon 12.011 -4 +2 +4 2-4	7 N Nitrogen 14.007 -3 -2 -1 +1 +2 +3 +4 +5 2-5	8 O Oxygen 15.999 -2 2-6	9 F Fluorine 18.998 -1 2-7	10 Ne Neon 20.179 0 2-8
3	11 Na Sodium 22.990 +1 2-8-1	12 Mg Magnesium 24.305 +2 2-8-2											13 Al Aluminium 26.982 +3 2-8-3	14 Si Silicon 28.086 -4 +2 +4 2-8-4	15 P Phosphorus 30.974 -3 +3 +5 2-8-5	16 S Sulphur 32.065 -2 +4 +6 2-8-6	17 Cl Chlorine 35.453 -1 +1 +3 +5 +7 2-8-7	18 Ar Argon 39.948 0 2-8-8
4	19 K Potassium 39.098 +1 2-8-8-1	20 Ca Calcium 40.078 +2 2-8-8-2	21 Sc Scandium 44.956 +3 2-8-9-2	22 Ti Titanium 47.867 +2 +3 +4 2-8-10-2	23 V Vanadium 50.942 +2 +3 +4 +5 2-8-11-2	24 Cr Chromium 51.996 +2 +3 +6 2-8-13-1	25 Mn Manganese 54.938 +2 +3 +4 +7 2-8-13-2	26 Fe Iron 55.845 +2 +3 2-8-14-2	27 Co Cobalt 58.933 +2 +3 2-8-15-2	28 Ni Nickel 58.693 +2 +3 2-8-16-2	29 Cu Copper 63.546 +1 +2 2-8-18-1	30 Zn Zinc 65.39 +2 2-8-18-2	31 Ga Gallium 69.723 +3 2-8-18-3	32 Ge Germanium 72.64 -4 +2 +4 2-8-18-4	33 As Arsenic 74.922 -3 +3 +5 2-8-18-5	34 Se Selenium 78.96 -2 +2 +6 2-8-18-6	35 Br Bromine 79.904 -1 +1 +5 2-8-18-7	36 Kr Krypton 83.80 0 +2 2-8-18-8
5	37 Rb Rubidium 85.468 +1 2-8-18-8-1	38 Sr Strontium 87.62 +2 2-8-18-8-2	39 Y Yttrium 88.906 +3 2-8-18-9-2	40 Zr Zirconium 91.224 +4 2-8-18-10-2	41 Nb Niobium 92.906 +3 +5 2-8-18-12-1	42 Mo Molybdenum 95.94 +3 +6 2-8-18-13-1	43 Tc Technetium (98) +4 +6 +7 2-8-18-14-1	44 Ru Ruthenium 101.07 +3 2-8-18-15-1	45 Rh Rhodium 102.91 +3 2-8-18-16-1	46 Pd Palladium 106.42 +2 +4 2-8-18-18	47 Ag Silver 107.87 +1 2-8-18-18-1	48 Cd Cadmium 112.41 +2 2-8-18-18-2	49 In Indium 114.82 +3 2-8-18-18-3	50 Sn Tin 118.71 +2 +4 2-8-18-18-4	51 Sb Antimony 121.76 -3 +3 +5 2-8-18-18-5	52 Te Tellurium 127.60 -2 +4 +6 2-8-18-18-6	53 I Iodine 126.90 -1 +1 +5 +7 2-8-18-18-7	54 Xe Xenon 131.29 0 +2 +4 +6 2-8-18-18-8
6	55 Cs Cesium 132.91 +1 2-8-18-18-8-1	56 Ba Barium 137.33 +2 2-8-18-18-8-2	57-71 La Lanthanide	72 Hf Hafnium 178.49 +4 2-8-18-32-10-2	73 Ta Tantalum 180.95 +5 2-8-18-32-11-2	74 W Tungsten 183.84 +6 2-8-18-32-12-2	75 Re Rhenium 186.21 +4 +6 +7 2-8-18-32-13-2	76 Os Osmium 190.23 +3 +4 2-8-18-32-14-2	77 Ir Iridium 192.22 +3 +4 2-8-18-32-15-2	78 Pt Platinum 195.08 +2 +4 2-8-18-32-17-1	79 Au Gold 196.97 +1 +3 2-8-18-32-18-1	80 Hg Mercury 200.59 +1 +2 2-8-18-32-18-2	81 Tl Thallium 204.38 +1 +3 2-8-18-32-18-3	82 Pb Lead 207.2 +2 +4 2-8-18-32-18-4	83 Bi Bismuth 208.98 +3 +5 2-8-18-32-18-5	84 Po Polonium (209) +2 +4 2-8-18-32-18-6	85 At Astatine (210) 2-8-18-32-18-7	86 Rn Radon (222) 0 2-8-18-32-18-8
7	87 Fr Francium (223) +1 -18-32-18-8-1	88 Ra Radium (226) +2 -18-32-18-8-2	89-103 Ac Actinide	104 Rf Rutherfordium (261) -18-32-32-10-2	105 Db Dubnium (262) -18-32-32-11-2	106 Sg Seaborgium (266) -18-32-32-12-2	107 Bh Bohrium (264) -18-32-32-13-2	108 Hs Hassium (277) -18-32-32-14-2	109 Mt Meitnerium (268) -18-32-32-15-2	110 Uun Ununnilium (281) +2 +4 -18-32-32-17-1	111 Uuu Unununium (272) -18-32-32-18-1	112 Uub Ununbium (285) -18-32-32-18-2	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (291)	117 Uus Ununseptium	118 Uuo Ununoctium (294)

Electron Shells

			S	P	D	F
1	K	2	2			
2	L	8	2	6		
3	M	18	2	6	10	
4	N	32	2	6	10	14
5	O	32	2	6	10	14
6	P	18	2	6	10	
7	Q	8	2	6		
8	R	2	2			

Lanthanide

57 La Lanthanium 138.91 +3 2-8-18-18-9-2	58 Ce Cerium 140.12 +3 +4 2-8-18-20-8-2	59 Pr Praseodymium 140.91 +3 2-8-18-21-8-2	60 Nd Neodymium 144.24 +3 2-8-18-22-8-2	61 Pm Promethium (145) +3 2-8-18-23-8-2	62 Sm Samarium 150.36 +2 +3 2-8-18-24-8-2	63 Eu Europium 151.96 +2 +3 2-8-18-25-8-2	64 Gd Gadolinium 157.25 +3 2-8-18-25-9-2	65 Tb Terbium 158.93 +3 2-8-18-27-8-2	66 Dy Dysprosium 162.50 +3 2-8-18-28-8-2	67 Ho Holmium 164.93 +3 2-8-18-29-8-2	68 Er Erbium 167.26 +3 2-8-18-30-8-2	69 Tm Thulium 168.93 +3 2-8-18-31-8-2	70 Yb Ytterbium 173.04 +2 +3 2-8-18-32-8-2	71 Lu Lutetium 174.97 +3 2-8-18-32-9-2

Actinide

89 Ac Actinium (227) +3 -18-32-18-9-2	90 Th Thorium 232.04 +4 -18-32-18-10-2	91 Pa Protactinium 231.04 +4 +5 -18-32-20-9-2	92 U Uranium 238.03 +3 +4 +5 +6 -18-32-21-9-2	93 Np Neptunium (237) +3 +4 +5 +6 -18-32-23-8-2	94 Pu Plutonium (244) +3 +4 +5 +6 -18-32-24-8-2	95 Am Americium (243) +3 +4 +5 +6 -18-32-25-8-2	96 Cm Curium (247) +3 -18-32-25-9-2	97 Bk Berkelium (247) +3 +4 -18-32-27-8-2	98 Cf Californium (251) +3 -18-32-28-8-2	99 Es Einsteinium (252) -18-32-29-8-2	100 Fm Fermium (257) -18-32-30-8-2	101 Md Mendelevium (258) -18-32-31-8-2	102 No Nobelium (259) -18-32-32-8-2	103 Lr Lawrencium (262) -18-32-32-9-2