# *leyChemistry 1A, Spring 2011*

Midterm 3
April 11, 2011
(90 min, closed book)

Name:_____

SID:_____

TA Name:_____

- There are 40 multiple choice questions worth 3 points each.
- There is only one correct answer for each question unless otherwise specified.
- Only answers on the Scantron form will be graded.
- Scantron must be properly filled in and cannot contain any smudges or other marks. Scantrons will not be rescanned!
- You can tear off the equation sheet and the periodic table for your convenience.
- You can use the page margin or the back of the pages as scratch paper.
- You can take the exam booklet with you after the exam.

## Quantum:

$E = h\nu$

$\lambda\nu = c$

$\lambda_{deBroglie} = h / p = h / mv$

$E_{kin}$ (e-) = $h\nu - \Phi = h\nu - h\nu_0$

$$E_n = -\frac{Z^2}{n^2} R_\infty$$

$\Delta x \, \Delta p \sim h$

$p = mv$

$E_n = h^2n^2/8mL^2$ ; n = 1, 2, 3...

$E_v = (v + ½)\, hA/2\pi$; $A = (k/m)^{½}$

$E_n = n(n + 1)\, hB$; $B = h/8\pi^2I$; $I = 2mr^2$

$m = m_A m_B/(m_A + m_B)$

## Ideal Gas:

$PV = nRT$

$$E_{kin} = \frac{3}{2} RT$$

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

## Constants:

$N_0 = 6.02214 \times 10^{23}$ mol$^{-1}$

$R_\infty = 2.179874 \times 10^{-18}$ J

$R_\infty = 3.28984 \times 10^{15}$ Hz

$k = 1.38066 \times 10^{-23}$ J K$^{-1}$

$h = 6.62608 \times 10^{-34}$ J s

$m_e = 9.101939 \times 10^{-31}$ kg

$c = 2.99792 \times 10^{8}$ m s$^{-1}$

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C

*Gas Constant:*

R = 8.31451 J K$^{-1}$ mol$^{-1}$

R = 8.20578 x 10$^{-2}$ L atm K$^{-1}$ mol$^{-1}$

1 nm = 10$^{-9}$ m

1 kJ = 1000 J

1 atm = 760 mm Hg = 760 torr ≈ 1 bar

1 L atm ≈ 100 J

## Thermodynamics:

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \Sigma\, \Delta H°_f$ (products) - $\Sigma\, \Delta H°_f$ (reactants)

$\Delta S° = \Sigma\, S°$ (products) - $\Sigma\, S°$ (reactants)

$\Delta G° = \Sigma\, \Delta G°_f$ (products) - $\Sigma\, \Delta G°_f$ (reactants)

$S = k_B \ln W$

$\Delta S = q_{rev}/T$

$\Delta E = q + w$

$w = - P_{ext}\Delta V$

for $aA + bB \rightleftarrows cC + dD$

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

$\Delta G = \Delta G° + RT \ln Q$

$G = G° + RT\ln(a)$; a = activity = $\gamma P/P°$ or $\gamma[A]/[A]°$

$\Delta G° = - RT \ln K$

$\Delta G° = - nF\Delta Є°$

$\Delta Є = \Delta Є° - (RT/nF) \ln Q$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta T = i k_{b,f}\, m$

$\Pi = iMRT$

$P_{total} = P_A + P_B = X_A P_A° + X_B P_B°$

$q = cm(T_2 - T_1)$

## Kinetics:

$[A]_t = [A]_0 e^{-kt}$

$\ln[A]_t = \ln[A]_0 - kt$

$t_{1/2} = \ln 2/k$

$1/[A]_t = 1/[A]_0 + kt$

$k = A\, e^{(-Ea/RT)}$

$\ln(k_1/k_2) = E_a/R\, (1/T_2 - 1/T_1)$

$t_{1/2} = 1/[A]_0 k$

$t_{1/2} = [A]_0/kt$

1. One of the underlying assumptions of the kinetic theory of gases is
A. Gas molecules move randomly at fixed velocities.
B. Gas molecules only exert forces when they move close to one another.
C. Energy is lost only during collisions with the container.
D. All of these are assumptions of the kinetic theory of gases.
E. None of these is an assumption of the kinetic theory of gases.
ANS: E

2. At 25°C we have the following root-mean-square speeds (in m/s): Xe - 238, Ar - 431, He - 1360. Thus sulfur dioxide gas molecules at 25°C should have a root-mean-square speed
A. < 238 m/s.
B. > 238 m/s but < 431 m/s.
C. > 431 m/s but < 1360 m/s.
D. > 1360 m/s.
E. This cannot be predicted.
ANS: B

3. At a certain absolute temperature the average speed of $H_2$ molecules is 1780 m/s. Thus at an absolute temperature twice as great, the average speed of He atoms would be
A. 890 m/s
B. 1260 m/s
C. 1780 m/s
D. 3560 m/s
E. none of these
ANS: C

4. What happens to bicycle tires on hot days versus cold days?
A. The tires expand because an increase in temperature corresponds to an increase in molecular speed which causes an increase in the force of gas collisions on the inside of the tire.
B. The tires shrink because an increase in temperature corresponds to a decrease in molecular speed which causes a decrease in the force of gas collisions on the inside of the tire.
C. The tires expand because an increase in temperature causes the gas molecules to be less attracted to each other and therefore they take up more space.
D. The tires shrink because an increase in temperature causes the gas molecules to be more attracted to each other and therefore they take up less space.
E. The tires stay the same volume because the amount of gas contained within the tire does not change.

ANS: A

5. Which of the following conditions should minimize deviations from ideal gas behavior in a real gas?
A. high *T* and high *P*
B. low *T* and low *P*
C. low *T* and high *P*
D. high *T* and low *P*
E. This requires specific knowledge of the gas to predict.
ANS: D

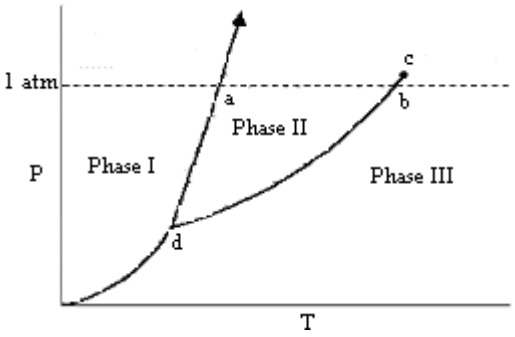
6. What is the pressure of 2.50 mol of $CO_2$ in a 1.00-L flask at 298K when calculated using the van der Waals equation? For $CO_2$, the values of the van der Waals constants are a = 3.59 $L^2$-atm/$mol^2$ and b = 0.0427 L/mol. The van der Waal's equation is given below.

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

A. 5.74
B. 46.0
C. 59.5
D. 61.1
E. 68.5

ANS: B

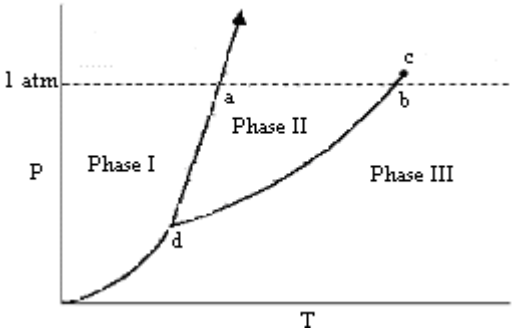
7. The temperature at point *a* is the




A. critical point.
B. triple point.
C. absolute freezing point.
D. normal freezing point.
E. normal boiling point.

ANS: D

8. The transition from Phase I to Phase II is called




A. melting.
B. freezing.
C. sublimation.
D. evaporation.
E. condensation.

ANS: A

9. For a balloon expanding against atmospheric pressure, the work *w* done on the balloon is
A. positive
B. negative
C. of indeterminate sign
D. zero
E. This cannot be answered without additional information.
ANS: B

10 . A gas is compressed from 39.92 L to 12.97 L at a constant pressure of 5.00 atm. In the course of this compression 9.82 kJ of energy is released as heat. The heat *q* for this process is
A. 135 kJ
B. -135 kJ
C. -9.82 kJ
D. 9.82 kJ
E. This cannot be determined without additional information.
ANS: C

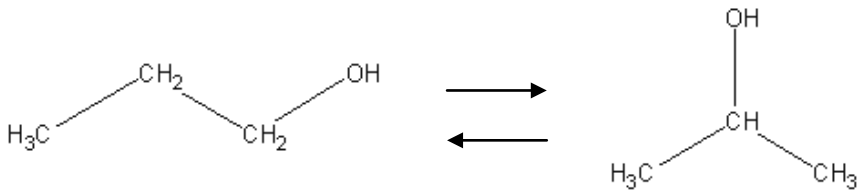
11. Which of the following processes is expected to be endothermic?

A. combustion of a hydrocarbon
B. dilution of concentrated sulfuric acid with water
C. freezing of liquid $N_2$ at its normal melting point (53 K)
D. vaporization of zinc at its normal boiling point (1179 K)
E. All of these are endothermic.
ANS: D

12. The First Law of Thermodynamics is the law of

A. conservation of energy
B. conservation of matter
C. conservation of enthalpy
D. All of these are involved.
E. none of these
ANS: A

13. Propanol (pro) burns cooler than isopropanol (iso). What can you conclude about the isomerization of propanol to isopropanol?




propanol isopropanol

A. $\Delta H°_{rxn} < 0$
B. $\Delta H°_{rxn} > 0$
C. $\Delta H°_{rxn} = 0$
D. $\Delta H°_f$ (propanol) = $\Delta H°_f$ (isopropanol)
E. none of these

B

14. Gaseous methane ($CH_4$) burns completely in air with a heat of combustion of -890 kJ $mol^{-1}$. Calculate the heat liberated by burning 4.00 L of $CH_4(g)$ measured at 101°C and 723 torr. Assume methane is an ideal gas at this condition.
A. 110 kJ
B. 159 kJ
C. 409 kJ
D. 890 kJ
E. none of these
ANS: A

15. Determine the heat of reaction for the process

$Fe_2O_{3(s)} + FeO_{(s)} \rightarrow Fe_3O_{4(s)}$

using the information given below:

$2Fe_{(s)} + O_{2(g)} \rightarrow 2FeO_{(s)}$ $\Delta H° = -544.0$ kJ
$4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$ $\Delta H° = -1648.8$ kJ
$3Fe_{(s)} + 2O_{2(g)} \rightarrow Fe_3O_{4(s)}$ $\Delta H° = -1118.4$ kJ

A. -1074.0 kJ

B. -22.0 kJ
C. 22.2 kJ
D. 249.8 kJ
E. 1074.0 kJ

ANS: B

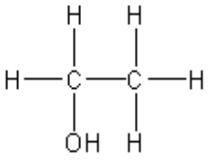
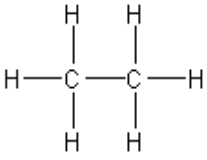
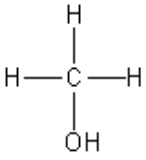
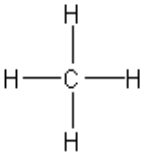
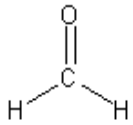
16. Which of the following is <u>not</u> a state function?
A. *q*
B. *E*
C. *H*
D. *PV*
E. All of these are state functions.
ANS: A

17. A 43.9-g piece of copper ($c_s$ = 0.385 J $g^{-1}$ $K^{-1}$) at 135.0°C is plunged into 254 g of water at 39.0°C. Assuming that no heat is lost to the surroundings, what will the final temperature of the system be? The heat capacity of water is 4.184 J $g^{-1}$ $K^{-1}$.
A. 100.0°C
B. 87.0°C
C. 53.1°C
D. 40.5°C
E. none of these
ANS: D

18. The following process of bond-breaking → bond formation corresponds to the combustion of which compound?

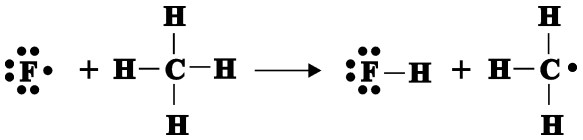
$$3\ \text{C-H} + \text{O-H} + \text{C-O} + 3/2\ \text{O=O} \rightarrow 2\ \text{C=O} + 4\ \text{O-H}$$

A.Ethanol B.Ethane C.Methanol D.Methane E.Formaldehyde

C

19. Methane can react with a fluorine atom to produce a methyl radical and hydrogen fluoride.



$\Delta H°_{rxn}$ = -153 kJ/mol

Based on the $\Delta H°_{rxn}$ , which of the following is true?

A. Breaking chemical bonds releases energy.
B. All reactions involving bond-breaking and bond formation are exothermic.
C. The H-F bond is stronger than the C-H bond.
D. The H-F bond is weaker than the C-H bond.
E. The heat of the reactants is absorbed by the products.
C

20. The decomposition:

$H_2O_2 \rightarrow H_2O + 1/2\ O_2$

is exothermic. What is the molecular structure of $H_2O_2$?

ANS: A

21. As a demonstration, three balloons were filled with the following mixtures. Which balloons produces the most heat when the contents undergo combustion reactions?

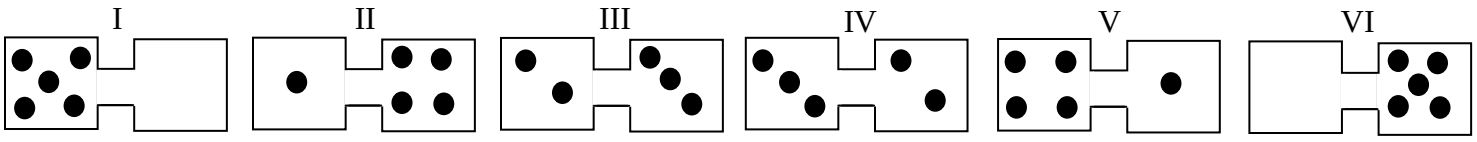
A. 2 moles $C_8H_{18}$

B. 3 moles $C_8H_{18}$

C. 2 moles $C_8H_{18}$ and 2 moles $O_2$

B

22. Which process is accompanied by the largest increase in entropy?




A. I → II

B. I → III

C. II → III

D. III → IV

E. V → VI

B

23. Which of the following processes should show the greatest increase in entropy?

A. $C_6H_6(l) + \frac{15}{2}O_2(g) \rightarrow 6CO_2(g) + 3H_2O(g)$

B. $2NO_2(g) \rightarrow N_2O_4(g)$

C. $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

D. $BaS(s) + 2NaNO_3(s) \rightarrow Ba(NO_3)_2(s) + Na_2S(s)$

E. This cannot be predicted without additional information.

ANS: A

24. Calculate the value of ΔS° for the reaction shown:

$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$

At 25°C the values of entropy in J $K^{-1}$ $mol^{-1}$ are nitrogen, 191.61: hydrogen, 130.68 ; and ammonia, 192.77.

A. -198.11 J/K

B. -259.03 J/K

C. -390.88 J/K

D. -393.20 J/K

E. -969.19 J/K

ANS: A

25. Consider the process whereby 1.00 mol of $H_2O(s)$ is melted to $H_2O(l)$ at the normal melting point of ice, 273.15 K. Which of the following is true for this process?

A. $\Delta H > 0$

B. $\Delta G = 0$

C. $\Delta H = T\Delta S$

D. All of these are true.

E. None of these is true.

ANS: D

26. Calculate $\Delta G_{rxn}$ (kJ) at 298 K under the conditions shown below for the following reaction.

$Fe_2O_3(s) + 3CO\ (g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta G^0 = -28.0$ kJ at 298K

$P(CO) = 1.4$ atm, $P(CO_2) = 2.1$ atm

A. 31.0 kJ

B. 2.99 kJ

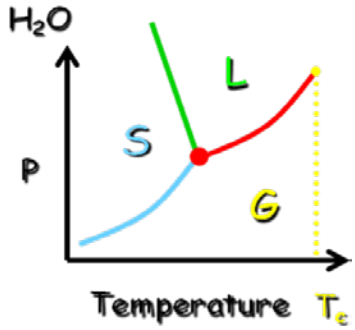
C. -30.7 kJ

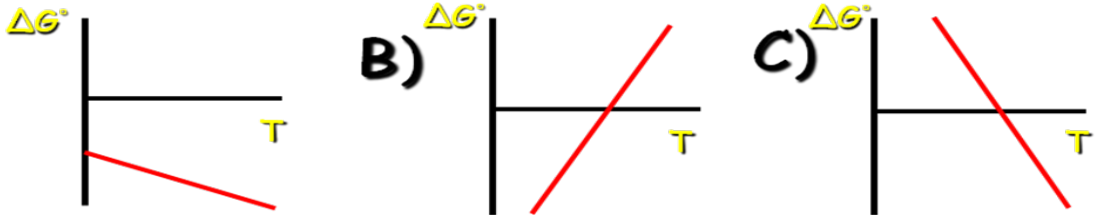
D. 17.5 kJ

E. -25.0 kJ

ANS: E

27. Which is the correct plot of $\Delta G^\circ$ vs. T for the reaction $H_2O$ (l) ↔ $H_2O$ (g)?




ANS: C

28. For the reaction, X + Y → A + B, $\Delta G_{rxn}$ is -1324 kJ $mol^{-1}$. Which one of the following statements CANNOT be concluded concerning this reaction?

A. The reaction is thermodynamically favorable.
B. The reaction is spontaneous as written.
C. The products are more stable than the reactants.
D. The reaction will proceed rapidly from left to right.
E. All of these are valid.

ANS: D

29. Which is true for the following reaction under standard conditions?

$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$
$\Delta H^\circ$ is 137 kJ and $\Delta S^\circ$ is 120 J/K.

A. spontaneous at all temperatures
B. spontaneous only at high temperature
C. spontaneous only at low temperature
D. not spontaneous at all temperatures
E. cannot be determined

ANS: B

30. If a catalyst is added to a chemical reaction, the equilibrium yield of a product will be _____, and the time taken to come to equilibrium will be _____ than before.

A. higher; less
B. lower; the same
C. higher; the same

D. the same; less
E. lower; less
ANS: D

31. Consider the **endothermic** reaction
$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$
If such a system at equilibrium is heated, equilibrium will _____,because _____.
A. be unchanged; temperature has no effect on equilibrium
B. shift to the left; increased temperature favors an exothermic reaction
C. shift to the right; increased temperature favors an exothermic reaction
D. shift to the right; increased temperature favors an endothermic reaction
E. shift to the left; increased temperature favors an endothermic reaction

ANS: D

32. Consider the reaction

$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$.
If the pressure is decreased on an equilibrium mixture of these three substances, equilibrium will _____,because _____.
A. shift to the right; lower pressure favors fewer moles of gas
B. shift to the right; lower pressure favors more moles of gas
C. shift to the left; lower pressure favors fewer moles of gas
D. shift to the left; lower pressure favors more moles of gas
E. be unchanged; solid $NH_4Cl$ does not appear in the equilibrium constant expression.

ANS: B

33. Consider the equilibrium system
$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$.
If more C(s) is added, the equilibrium will ____; if CO is removed the equilibrium will ____.
A. shift to the left; shift to the left
B. shift to the right; shift to the right
C. shift to the right; shift to the left
D. be unchanged; shift to the left
E. be unchanged; shift to the right

ANS: E

34. Which set of conditions describes a reaction that is most likely to proceed?
A. endothermic, decreasing entropy, high activation energy
B. exothermic, decreasing entropy, high activation energy
C. exothermic, increasing entropy, high activation energy
D. exothermic, increasing entropy, low activation energy
E. endothermic, decreasing entropy, low activation energy
ANS: D

35. What is the value of the equilibrium constant at 25°C for a reaction, if the value of $\Delta G°_{rxn}$ is -47.8 kJ at 25°C?
A. 1.70
B. 6.88
C. $2.30 \times 10^2$
D. $2.74 \times 10^5$
E. $2.37 \times 10^8$
ANS: E

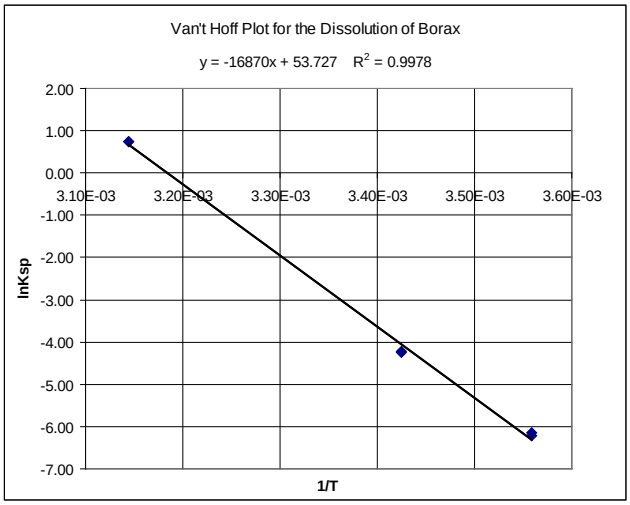
36. If the equilibrium constants for the two reactions
$2\ HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$
and
$I_2(g) + Cl_2(g) \rightleftharpoons 2\ ICl(g)$
are denoted $K_1$ and $K_2$ respectively, then the equilibrium constant for the reaction
$2\ HCl(g) + I_2(g) \rightleftharpoons 2\ ICl(g) + H_2(g)$ equals
A. $(K_1/K_2)^2$.
B. $(K_1K_2)^2$.
C. $K_1K_2$.
D. $K_1+K_2$.
E. $K_1K_2/2$.
ANS: C

37. Consider the equilibrium reaction
$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$.
A sample of pure $NO_2(g)$ at 0.140 atm is allowed to come to equilibrium. It is then found that 57.0 % of the $NO_2(g)$ has reacted to form $N_2O_4(g)$. What is the value of K?
A. 0.211
B. 0.377
C. 0.754
D. 4.73
E. 11.0

ANS: E

38. In the experiment "How Hot is that Flame", A bomb calorimeter is calibrated with benzoic acid, for which the specific heat of combustion is -26.41 kJ/g. The combustion of 1.327 g of benzoic acid causes the temperature of the calorimeter to rise from 25.998°C to 27.918°C. Calculate the calorimeter constant $K_{cal}$.
A. 10.37 kJ $K^{-1}$
B. 18.25 kJ $K^{-1}$
C. 38.21 kJ $K^{-1}$
D. 67.29 kJ $K^{-1}$
E. none of these
ANS: B

39. A student explored the thermodynamic properties of the dissolution of borax using titrations at different temperatures. The following plot was obtained. What is $\Delta S^o$ in J/mol•K for the dissolution of borax?




F. 53.727
G. -16780
H. 446.69
I. 140.26
J. -140.26
C

40. A student has a solution of potassium chromate ($K_2CrO_4$) in a test tube. The solution is yellow. To this test tube, several drops of a solution of sulfuric acid are added. Given the reactions below, predict what changes will occur after the addition of acid and why the changes occur.

$$K_2CrO_4(s) \rightleftharpoons 2\,K^+(aq) + CrO_4^{-2}(aq)$$
(yellow)

$$H_2SO_4\,(aq) \rightleftharpoons H^+(aq) + HSO_4^-(aq)$$

$$2\,H^+(aq) + 2\,CrO_4^{-2}(aq) \rightleftharpoons Cr_2O_7^{-2}(aq) + H_2O(l)$$
(yellow) (orange)

A. The solution remains yellow because sulfuric acid is colorless
B. The solution remains yellow because no additional reactions take place
C. The solution turns a lighter yellow because it is more dilute after adding acid
D. The solution turns orange because the acid reacts with the chromate to convert it to dichromate which is orange.
D

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hydrogen 1 **H** 1.0079 | | | | | | | | | | | | | | | | | helium 2 **He** 4.0026 |
| lithium 3 **Li** 6.941 | beryllium 4 **Be** 9.0122 | | | | | | | | | | | boron 5 **B** 10.811 | carbon 6 **C** 12.011 | nitrogen 7 **N** 14.007 | oxygen 8 **O** 15.999 | fluorine 9 **F** 18.998 | neon 10 **Ne** 20.180 |
| sodium 11 **Na** 22.990 | magnesium 12 **Mg** 24.305 | | | | | | | | | | | aluminium 13 **Al** 26.982 | silicon 14 **Si** 28.086 | phosphorus 15 **P** 30.974 | sulfur 16 **S** 32.065 | chlorine 17 **Cl** 35.453 | argon 18 **Ar** 39.948 |
| potassium 19 **K** 39.098 | calcium 20 **Ca** 40.078 | | scandium 21 **Sc** 44.956 | titanium 22 **Ti** 47.867 | vanadium 23 **V** 50.942 | chromium 24 **Cr** 51.996 | manganese 25 **Mn** 54.938 | iron 26 **Fe** 55.845 | cobalt 27 **Co** 58.933 | nickel 28 **Ni** 58.693 | copper 29 **Cu** 63.546 | zinc 30 **Zn** 65.39 | gallium 31 **Ga** 69.723 | germanium 32 **Ge** 72.61 | arsenic 33 **As** 74.922 | selenium 34 **Se** 78.96 | bromine 35 **Br** 79.904 | krypton 36 **Kr** 83.80 |
| rubidium 37 **Rb** 85.468 | strontium 38 **Sr** 87.62 | | yttrium 39 **Y** 88.906 | zirconium 40 **Zr** 91.224 | niobium 41 **Nb** 92.906 | molybdenum 42 **Mo** 95.94 | technetium 43 **Tc** [98] | ruthenium 44 **Ru** 101.07 | rhodium 45 **Rh** 102.91 | palladium 46 **Pd** 106.42 | silver 47 **Ag** 107.87 | cadmium 48 **Cd** 112.41 | indium 49 **In** 114.82 | tin 50 **Sn** 118.71 | antimony 51 **Sb** 121.76 | tellurium 52 **Te** 127.60 | iodine 53 **I** 126.90 | xenon 54 **Xe** 131.29 |
| caesium 55 **Cs** 132.91 | barium 56 **Ba** 137.33 | 57-70 ✶ | lutetium 71 **Lu** 174.97 | hafnium 72 **Hf** 178.49 | tantalum 73 **Ta** 180.95 | tungsten 74 **W** 183.84 | rhenium 75 **Re** 186.21 | osmium 76 **Os** 190.23 | iridium 77 **Ir** 192.22 | platinum 78 **Pt** 195.08 | gold 79 **Au** 196.97 | mercury 80 **Hg** 200.59 | thallium 81 **Tl** 204.38 | lead 82 **Pb** 207.2 | bismuth 83 **Bi** 208.98 | polonium 84 **Po** [209] | astatine 85 **At** [210] | radon 86 **Rn** [222] |
| francium 87 **Fr** [223] | radium 88 **Ra** [226] | 89-102 ✶ ✶ | lawrencium 103 **Lr** [262] | rutherfordium 104 **Rf** [261] | dubnium 105 **Db** [262] | seaborgium 106 **Sg** [266] | bohrium 107 **Bh** [264] | hassium 108 **Hs** [269] | meitnerium 109 **Mt** [268] | ununnilium 110 **Uun** [271] | ununnunium 111 **Uuu** [272] | ununbium 112 **Uub** [277] | | ununquadium 114 **Uuq** [289] | | | | |

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| *Lanthanide series | lanthanum 57 **La** 138.91 | cerium 58 **Ce** 140.12 | praseodymium 59 **Pr** 140.91 | neodymium 60 **Nd** 144.24 | promethium 61 **Pm** [145] | samarium 62 **Sm** 150.36 | europium 63 **Eu** 151.96 | gadolinium 64 **Gd** 157.25 | terbium 65 **Tb** 158.93 | dysprosium 66 **Dy** 162.50 | holmium 67 **Ho** 164.93 | erbium 68 **Er** 167.26 | thulium 69 **Tm** 168.93 | ytterbium 70 **Yb** 173.04 |
| **Actinide series | actinium 89 **Ac** [227] | thorium 90 **Th** 232.04 | protactinium 91 **Pa** 231.04 | uranium 92 **U** 238.03 | neptunium 93 **Np** [237] | plutonium 94 **Pu** [244] | americium 95 **Am** [243] | curium 96 **Cm** [247] | berkelium 97 **Bk** [247] | californium 98 **Cf** [251] | einsteinium 99 **Es** [252] | fermium 100 **Fm** [257] | mendelevium 101 **Md** [258] | nobelium 102 **No** [259] |