Periodic Table of the Elements

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atomic number → 14
atomic weight → 28.09
Si ← symbol: **black** solid
blue liquid
red gas
white synthetically prepared *most stable isotope*
grey synthetically prepared; later found in trace amounts in nature
Silicon ← name

- ▨ alkali metals
- ▨ alkaline earth metals
- ▨ transition metals
- ▨ other metals
- ▨ metalloids
- ▨ noble gases
- ▨ halogens
- ▨ other non-metals
- ▨ unknown chemical properties
- ▨ discovery claimed

Glenn T Seaborg

1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.18 Ne Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminum	14 28.09 Si Silicon	15 30.97 P Phosphorus	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.69 Ni Nickel	29 63.55 Cu Copper	30 65.41 Zn Zinc	31 69.72 Ga Gallium	32 72.64 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc*** Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.42 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.71 Sn Tin	51 121.76 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.29 Xe Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La ▸ Lanthanum	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.84 W Tungsten	75 186.21 Re Rhenium	76 190.23 Os Osmium	77 192.22 Ir Iridium	78 195.08 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.38 Tl Thallium	82 207.2 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At* Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03 Ac ▸ Actinium	104 (261) Rf* Rutherfordium	105 (262) Db* Dubnium	106 (266) Sg* Seaborgium	107 (264) Bh Bohrium	108 (277) Hs Hassium	109 (268) Mt Meitnerium	110 (281) Ds Darmstadtium	111 (272) Rg Roentgenium	112 (285) Cn Copernicium	113 — Uut Ununtrium	114 (298.19) Fl Flerovium	115 — Uup Ununpentium	116 (293) Lv Livermorium	117 — Uus Ununseptium	118 — Uuo Ununoctium

Lanthanide series ▸	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.36 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
Actinide series ▸	90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np* Neptunium	94 (244) Pu* Plutonium	95 (243) Am** Americium	96 (247) Cm* Curium	97 (247) Bk* Berkelium	98 (251) Cf* Californium	99 (252) Es* Einsteinium	100 (257) Fm* Fermium	101 (258) Md* Mendelevium	102 (259) No* Nobelium	103 (262) Lr* Lawrencium

* Discovered at Lawrence Berkeley National Laboratory
** Discovered in Chicago by Berkeley team
*** Discovered in Italy using a sample from Berkeley cyclotron bombardment

CSO26949

Physical Constants

Standard Acceleration of terrestrial gravity	$g = 9.80665$ m s^{-2} (exactly)
Avogadro's number	$N_0 = 6.022137 \times 10^{23}$
Bohr radius	$a_0 = 0.52917725$ Å $= 5.2917725 \times 10^{-11}$ m
Boltzmann's constant	$k_B = 1.38066 \times 10^{-23}$ J K^{-1}
Electron Charge	$e = 1.6021773 \times 10^{-19}$ C
Faraday constant	$\mathcal{F} = 96{,}485.31$ C mol^{-1}
Masses of fundamental particles:	
Electron	$m_e = 9.109390 \times 10^{-31}$ kg
Proton	$m_p = 1.672623 \times 10^{-27}$ kg
Neutron	$m_n = 1.674929 \times 10^{-27}$ kg
Ratio of proton mass to electron mass	$m_p/m_e = 1836.15270$
Permittivity of vacuum	$\epsilon_0 = 8.8541878 \times 10^{-12}$ C^2 J^{-1} m^{-1}
Planck's constant	$h = 6.626076 \times 10^{-34}$ J s
Speed of light in vacuum	$c = 2.99792458 \times 10^{8}$ m s^{-1} (exactly)
Universal gas Constant	$R = 8.31451$ J mol^{-1} K^{-1} $= 0.0820578$ L atm mol^{-1} K^{-1}
Rydberg Constant	$R_\infty = e^4 m_e/(8\epsilon_0^2 h^2)$

Conversion Factors

Standard Atmosphere	1 atm = 1.01325×10^5 Pa = 1.01325×10^5 kg m^{-1} s^{-2} (exactly)
Atomic mass unit	1 u = 1.660540×10^{-27} kg
	1 u = 1.492419×10^{-10} J = 931.4942 MeV (energy equivalent from E = mc2)
Calorie	1 cal = 4.184 J (exactly)
Electron volt	1 eV = $1.6021773 \times 10^{-10}$ J = 96.48531 kJ mol^{-1}
Foot	1 ft = 12 in = 0.3048 m (exactly)
Gallon (U.S.)	1 gallon = 4 quarts = 3.78541 L (exactly)
Liter-atmosphere	1 L atm = 101.325 J (exactly)
Metric ton	1 metric ton = 1000 kg (exactly)
Pound	1 lb = 16 oz = 0.45359237 kg (exactly)

$\frac{n^2h^2}{8mL^2}$ $E = -\frac{Z^2}{n^2} R_\infty$

Question 1 **(15 + 5 points)**

A) What mass (g) of H_2O is made when 5.0 L of a stoichiometric mixture of propane (C_3H_8) and oxygen at 10 atm, 300 K is combusted?

4 6

$$C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2$$

$$PV = nRT \quad n_{total} = \frac{P \cdot V}{RT} \quad n_{C_3H_8} = n_{total} \times \frac{1}{1+5} = \frac{10 atm \times 5 L}{0.08206\ atm\ mol^{-1}\ K^{-1} \times 300K} \times \frac{1}{6} = 2.031 mol$$

$$2.031 mol\ C_3H_8 \times \frac{4 mol\ H_2O}{1 mol\ C_3H_8} \times \frac{18.016 g\ H_2O}{1 mol\ H_2O} = 146 g = 1.5 \times 10^2 g$$

B) Three trials yield the following results for the mass of H_2O produced in the above reaction:

1.532 g 1.467 g 1.581 g

Calculate the *standard deviation of the mean* for these results.

$$mean = \frac{1.532 g + 1.467 g + 1.581 g}{3} = 1.527 g$$

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{(1.532-1.527)^2 + (1.467-1.527)^2 + (1.581-1.527)^2}{3}}$$

$$= 0.0467 g$$

$$= 0.047 g$$

Question 2 **(10 points each)**

A) For Li^{2+}, determine the wavelength of the photon emitted by transition from the 4d → 2s orbitals.

$n=4 \rightarrow n=2.$

$$E_4 = -\frac{Z^2}{n^2} R_\infty = -\frac{3^2}{4^2} \cdot R_\infty \text{ J}$$

$$= -\frac{9}{16} R_\infty \text{ J}$$

$$E_2 = -\frac{3^2}{2^2} \cdot R_\infty = 4E_4 = -\frac{9}{4} R_\infty \text{ J}$$

$$\Delta E = E_4 - E_2 = -\frac{9}{16} R_\infty + \frac{9}{4} R_\infty = \frac{27}{16} R_\infty \text{ J}$$

$$E = h \cdot \frac{c}{\lambda}$$

$$\lambda = \frac{h \cdot c}{E} = \frac{6.626\times10^{-34} \text{ Js} \cdot 3\times10^{8} \text{ m/s}}{\frac{27}{16} R_\infty \text{ J}} = 1.18\times10^{-25} \cdot \frac{1}{R_\infty} \text{ m}$$

B) The equation for the De Broglie wavelength works for photons as well. Calculate the momentum of this photon and, assuming that we are 99% certain of this momentum, what is the most certain we can be of this photon's position?

$$p = mv \quad \cancel{v = \frac{1}{2}} \quad KE = \frac{1}{2} mv^2 \quad v = \sqrt{\frac{\cancel{0}E}{\frac{1}{2}m}} = \sqrt{\frac{1.18\times10^{-25} \cdot \frac{1}{R_\infty}}{\frac{1}{2}\times 9.11\times10^{-31} \text{ kg}}}$$

$$p = 9.11\times10^{-34} \text{ kg} \times \sqrt{\frac{1.18\times10^{-25} \frac{1}{R_\infty}}{\frac{1}{2}\times 9.11\times10^{-31} \text{ kg}}}$$

$$\Delta p = 0.99 \times p = \cancel{0.1}0.99 \times 9.11\times10^{-34} \text{ kg} \sqrt{\frac{1.18\times10^{-25} \cdot \frac{1}{R_\infty}}{\frac{1}{2}\times 9.11\times10^{-31} \text{ kg}}}$$

$$\Delta x \cdot \Delta p \leq \frac{h}{4\pi}$$

$$\Delta x \leq \frac{h}{4\pi} \times \frac{1}{\Delta p}$$

$$\Delta x \leq \frac{h}{4\pi} \times \frac{1}{0.99\times10^{-34}\times 9.11 \times \sqrt{\frac{1.18\times10^{-25} \frac{1}{R_\infty}}{\frac{1}{2}\times 9.11\times10^{-31} \text{ kg}}}}$$

$$\Delta x \leq$$

Question 3 **(5 points)**

Deuterium, also known as "heavy hydrogen" because its mass is about twice that of hydrogen, has a nucleus consisting of one proton and one neutron. If a deuterium atom has one electron, how do the shapes and sizes (radial extent) of its orbitals (i.e. 1s, 2s, 2p) compare to a hydrogen atom's?

H → 2 amu 1p^+ 1 neu

(H only has proton)

Shape = since Deuterium has one 1e^-, so the one e- will be in 1S orbital

the shape ~~of~~ 1S is will same of H's 1S orbital

Size: the ~~[illegible]~~ added neutron in the neuclen don't affect the charge of the nuclei, Zeff doesn't change, so according to Colomb's Law,

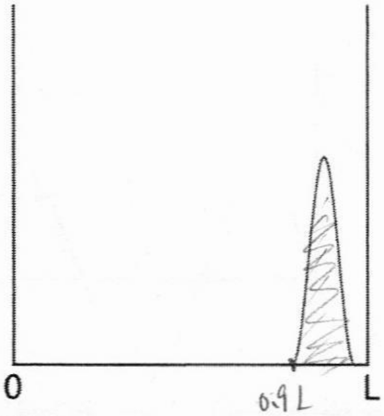
$F = k_e \frac{|q_1||q_2|}{r^2}$, $|q_1||q_2|$ dosn't change, so r^2 should be held as constant too.

Thus both shape and size will be same as H.

Question 4 **(20 points, 10 points each)**

A) We can model an electron in a linear molecule as a particle in a 1-dimensional box. If the wave function of that electron is:

H-C-CX



$E = \frac{n^2h^2}{8mL^2}$

and the molecule being modeled is HCCX (where X is at 0.9L), what column (or name the group) is element "X" most likely in and why?

H≡C=C−X.

CH

$\int_0^{0.9L} |\psi(x)|^2 dx = 1$

$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$ $\int_{0.9L}^{L} \frac{2}{L} \sin^2\left(\frac{n\pi x}{L}\right) dx = 1$

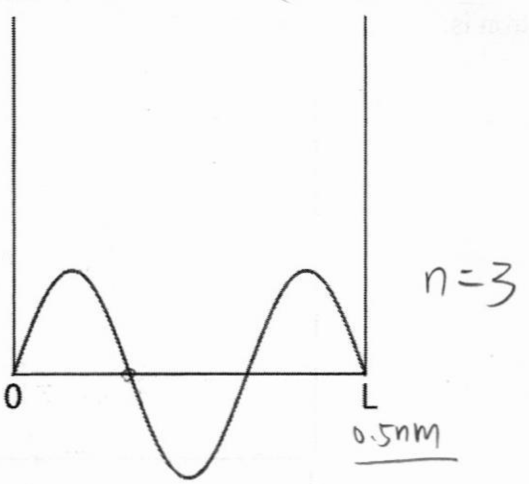
want $\underline{\underline{n}}$ sin

$n =$

will be in group VII

X is in $\boxed{\text{halogen}}$

B) If the total length of the molecule above is 0.5 nanometers, and we treat it as a particle in a box, calculate the energy of the following wave function for the electron:



n=3 (3 chunk)

$$E = \frac{n^2h^2}{8mL^2} = \frac{3^2 \cdot h^2}{8 \cdot 9.11\times10^{-31}\,kg \times (0.5\times10^{-9})^2} = 2.38\times10^{12}\,J$$

$$= 2.4\times10^{12}\,J$$

Question 5 **(5 Points each)**

Arrange the following substances in order and explain your choice of order

15p+

A) P^{2-}, Kr, Sr^{2+}, Cl in order of increasing radius

17e- ①

elements in period4 has large radius for one more shell of electrons.

both Sr^{2+} ~~has~~ and Kr have 36e- and in ~~ed~~ period4, but Sr^{2+} has more Zeff. so less radius.

$Cl < P^{2-} < Sr^{2+} < Kr$

both Cl and P^{2-} are in period 3, and 17e-z but Cl has more protons, which means more Zeff, so radius of Cl should be smaller than P^{2-}.

B) Br^{-} Kr, Rb^{+}, Se in order of increasing ionization energy

$Se < Br^{-} < Kr < Rb^{+}$

not in an octet. easiest to remove

all full octet, but Rb^{+} has the most p+, which mean the most Zeff than Kr and Br^{-}, so it's hardest to remove a e-

C) H, Ca, C, Br in order of increasing electronegativity

$Ca < Br < C < H$

form H bond with othe element.

metal tend to lose election

C has one less shell of election more ~~the~~ effective charges.

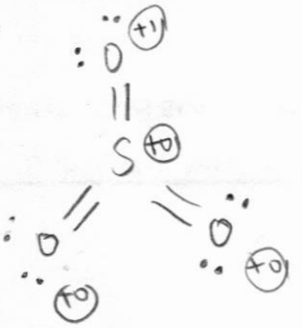
Question 6 **(10 Points each)**

For the following compounds:

A. Draw the Lewis Structure, explicitly showing the formal charges and molecular geometry
B. Indicate the Electron Pair Geometry
C. Indicate the Molecular Geometry

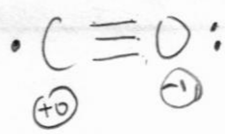
24.

I. Sulfur Trioxide (SO_3)

A.  	B. SN=3 trignal planar	C. trignal planar

4 +6 -1 9

II. CO^+ ion

A.  	B. linear	C. linear