

Question 1 1.5-point multiple choice, **select 1 answer only**. Do *all* questions (1.5 points each, 6 total)

- (i) What is the missing particle in this balanced nuclear reaction?



(e)  $\alpha$ -particle

- (ii) David Price won the Cy Young Award in 2012. His fastball pitch averages 95 mph. Assuming a baseball weighs 0.145 kg and the speed converts to 42.5 m/s, what is the wavelength of Price's fastball?

(c)  $1.08 \times 10^{-34} \text{ m}$

- (iii) The half-life of  ${}^{232}\text{Pu}$  is 34.1 minutes. Calculate how long it would take 99% of a sample of  ${}^{232}\text{Pu}$  to decay.

(a) 227 min

- (iv) One of these sets of quantum numbers is valid. Choose the valid set.

(a)  $n = 3, l = 2, m_l = 2$

Question 2 1-point multiple choice, **select 1 answer only**. Do *all* questions (1 point each, 3 total; there is no penalty for a wrong guess):

- (i) Based on the geometry (trigonal planar), what is the hybridization of the C in formaldehyde,  $\text{H}_2\text{C}=\text{O}$ ?

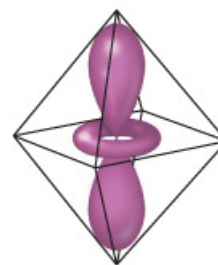
(c)  $sp^2$

- (ii) Based on the geometry (trigonal bipyramidal), what is the hybridization of the P in formaldehyde,  $\text{PCl}_5$ ?

(e)  $sp^3d$

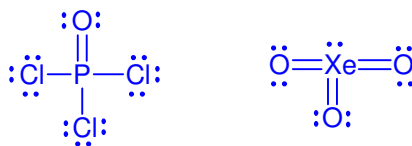
- (iii) What is this orbital?

(c)  $3d_{z^2}$

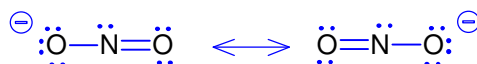
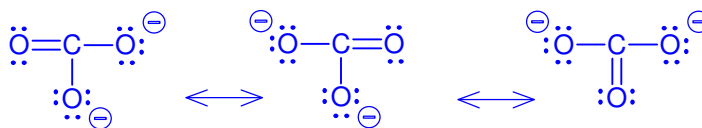


Question 3

- (a) Draw the Lewis structure for **1 of the following 2**. Note that the central atom will not obey the octet rule. (2 points)



- (b) Draw the Lewis structure of **either**  $\text{CO}_3^{2-}$  **or**  $\text{NO}_2^-$ . Include all lone pairs, resonance structures, and formal charges. (3 points)



- (c) Pick any *2 of the 4 molecules* in (a) or (b) and say what its VSEPR shape is? Choose from: linear, bent, trigonal pyramidal, trigonal bipyramidal, square-based pyramidal, trigonal planar, square planar, see-saw, T-shaped, tetrahedral, or octahedral. (2 points)

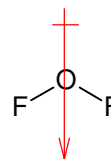
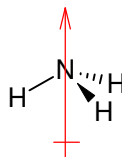
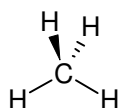
$\text{POCl}_3$  = tetrahedral

$\text{XeO}_3$  = trigonal pyramidal

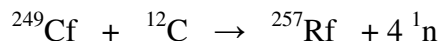
$\text{CO}_3^{2-}$  = trigonal planar

$\text{NO}_2^-$  = bent

- (d) Show the **overall** dipole moment (or state that it is 0) for **2 of the following 3** molecules. (2 points)



Question 4 (3 points) The synthesis of rutherfordium (Rf) occurs by the following (balanced) nuclear reaction. Calculate the energy required (in J/mol) to force this reaction to take place. The exact masses (in g/mol) are  $^{249}\text{Cf} = 249.07485$ ,  $^{12}\text{C} = 12$  (exactly),  $^{257}\text{Rf} = 257.1032$ , and  $^1_0\text{n} = 1.00866$ .



$\Delta m = \text{products} - \text{reactants}$

$$= 257.1032 + 4 \times 1.00866 - 12 - 249.07485 = 0.06299 \text{ g/mol} = 6.299 \times 10^{-5} \text{ kg/mol}$$

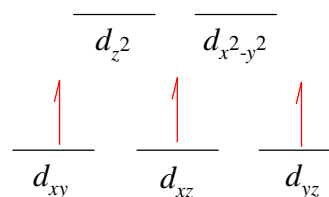
$$E = mc^2 = (6.299 \times 10^{-5} \text{ kg/mol})(3.00 \times 10^8 \text{ m/s})^2 = 5.67 \times 10^{12} \text{ J/mol}$$

Question 5 Arrange the following elements based on their periodic trends (2 points)

Atomic radius (smallest to largest): Sr, Te, Ru Te < Ru < Sr

Ionization energy (smallest to largest): Al, Ca, Rb Rb < Ca < Al

Question 6 Determine the number of  $d$ -electrons, then arrange them in the  $d$ -orbitals, for the octahedral complex ion  $[\text{V}(\text{H}_2\text{O})_6]^{2+}$ . (2 points)



## Appendix 1: Formula Sheet

$PV = nRT$ $P_{\text{total}} = P_1 + P_2 + \dots$ $\left(P + \frac{n^2 a}{V^2}\right) \cdot (V - nb) = nRT$ $\bar{u} = \sqrt{\frac{3RT}{M_m}}$ $\frac{\text{rate}_A}{\text{rate}_B} = \frac{\bar{u}_A}{\bar{u}_B} = \frac{\sqrt{M_{mB}}}{\sqrt{M_{mA}}}$	$\ln \frac{N_t}{N_0} = -kt$ $t_{1/2} = \frac{\ln 2}{k}$ $E = mc^2$ $c = \lambda \nu (= \lambda f)$ $E = h\nu (= hf)$ $\bar{E}_k = \frac{1}{2} m \bar{u}^2$ $\Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2} \right)$ $\lambda = \frac{h}{mv}$ $A = \epsilon bc$ $(\Delta x)(\Delta(mv)) \geq \hbar/4\pi$
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### Constants:

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$c = 2.9979 \times 10^8 \text{ m/s}$$

$$\text{joules} = \text{kg m}^2 \text{ s}^{-2}$$

$$0^\circ\text{C} = 273.15 \text{ K}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 8.314 \text{ L Pa mol}^{-1} \text{ K}^{-1} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$\text{STP} = 1 \text{ atm}, 0^\circ\text{C}$$

$$1 \text{ atm} = 101.325 \text{ kPa} = 760.00 \text{ Torr}$$

$$\text{mass of an electron: } 0.000549 \text{ amu (g/mol)}$$

$$\text{mass of a proton: } 1.00728 \text{ amu}$$

$$\text{mass of a neutron: } 1.008665 \text{ amu}$$

$$\text{elementary charge (e)} = 1.60218 \times 10^{-19} \text{ C}$$

$$\text{kilo} = 10^3 \quad \text{centi} = 10^{-2} \quad \text{milli} = 10^{-3} \quad \text{micro} = 10^{-6} \quad \text{nano} = 10^{-9} \quad \text{pico} = 10^{-12}$$

# The Periodic Table of the Elements (with Electronegativities)

1

Hydrogen 1 <b>H</b> 1.01 2.1	2	
Lithium 3 <b>Li</b> 6.94 1.0	Beryllium 4 <b>Be</b> 9.01 1.5	
Sodium 11 <b>Na</b> 22.99 0.9	Magnesium 12 <b>Mg</b> 24.31 1.2	
Potassium 19 <b>K</b> 39.10 0.8	Calcium 20 <b>Ca</b> 40.08 1.0	
Rubidium 37 <b>Rb</b> 85.47 0.8	Strontium 38 <b>Sr</b> 87.62 1.0	
Cesium 55 <b>Cs</b> 132.91 0.7	Barium 56 <b>Ba</b> 137.33 0.9	
Francium 87 <b>Fr</b> (223) 0.7	Radium 88 <b>Ra</b> (226) 0.9	

Alkali metals	Alkaline earth metals	Transition metals	Lanthanides	Actinides	Other metals	Metalloids (semi-metal)	Nonmetals	Halogens	Noble gases
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Element name	Mercury
Symbol	<b>Hg</b>
Atomic #	80
Avg. Mass	200.59
Electronegativity	1.9

18

Element name → Mercury											
80 ←											
Symbol → <b>Hg</b>											
200.59 ← Avg. Mass											
Electronegativity → 1.9											
Atomic #											
13 14 15 16 17											
Helium 2 He 4.00											
Neon 10 Ne 20.18											
Fluorine 9 F 19.00											
Oxygen 8 O 16.00											
Nitrogen 7 N 14.01											
Carbon 6 C 12.01											
Boron 5 B 10.81											
Aluminum 13 Al 26.98											
Silicon 14 Si 28.09											
Phosphorus 15 P 30.97											
Sulfur 16 S 32.07											
Chlorine 17 Cl 35.45											
Argon 18 Ar 39.95											
Krypton 36 Kr 83.80											
Bromine 35 Br 79.90											
Selenium 34 Se 78.96											
Arsenic 33 As 74.92											
Germanium 32 Ge 72.61											
Tin 50 Sn 118.71											
Indium 49 In 114.82											
Cadmium 48 Cd 112.41											
Silver 47 Ag 107.87											
Palladium 46 Pd 106.42											
Nickel 28 Ni 58.69											
Copper 29 Cu 63.55											
Zinc 30 Zn 65.39											
Gallium 31 Ga 69.72											
Selenium 34 Se 78.96											
Bromine 35 Br 79.90											
Krypton 36 Kr 83.80											
Xenon 54 Xe 131.29											
Antimony 51 Sb 121.76											
Tellurium 52 Te 127.60											
Iodine 53 I 126.90											
Astatine 85 At (210)											
Polonium 84 Po (209)											
Bismuth 83 Bi 208.98											
Ununseptium 115 Uus (294?)											
Ununhexium 116 Uuh (293)											
Ununquadium 114 Uuq (289)											
Ununtrium 113 Uut (284)											
Ununbium 112 Uub (285)											
Rutherfordium 104 Rf (267)											
Dubnium 105 Db (268)											
Seaborgium 106 Sg (271)											
Berkelium 107 Bk (272)											
Californium 108 Cf (270)											
Einsteinium 109 Es (271)											
Fermium 100 Fm (257)											
Mendelevium 101 Md (258)											
Nobelium 102 No (259)											
Lawrencium 103 Lr (262)											
Radium 86 Ra (226)											
Francium 87 Fr (223)											
Radium 86 Ra (226)											
Actinium 87 Ac (227)											
Thorium 90 Th (232)											
Protactinium 91 Pa (231)											
Uranium 92 U (238)											
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)											
Lawrencium 103 Lr (262)											