

1 Cognitive reasoning in the chemical sciences 3.9

Some of the following questions are similar to questions which have been asked before. Others are exactly the same as previous questions. Some you may find brand new. Please do all of these problems without referring to any prior work or class notes.

1. We have two balloons both at STP. The one contains 4.0 grams of H_2 while the other contains 64.0 g of O_2 . Does the hydrogen balloon look bigger, the oxygen balloon look bigger or do the two balloons look the same size?
2. Please draw the nodes of the following orbitals. Assuming that the orbital belongs to a Li^{2+} ion, find the energies of the two orbitals.
 - (a) $3p_x$
 - (b) $5d_{x^2-y^2}$
3. A metal M forms an oxide X. X has the empirical formula MO_2 and is 13.38 mass percent oxygen. When heated, X gives off oxygen and converts to Y, which is 9.334 mass percent oxygen. (a) What is the identity of metal M? (b) What is the empirical formula of the compound Y?
4. CrO_4^{2-} can be used to titrate for metals which have not yet reached their highest regular oxidation state. For example, CrO_4^{2-} oxidizes Co^{2+} to Co^{3+} and Ti^{2+} to Ti^{4+} . In this oxidation-reduction process the Cr atoms are reduced to Cr^{3+} . A 34.83 g sample of a mixed TiO and CoO ore is titrated with exactly 53.41 mL of 4.173 M BaCrO_4 solution. What is the molar ratio of the Ti to Co in the original sample?
5. The French scientist La Cheville-Tordue is studying real gases. She has determined the a and b parameters for carbon dioxide (CO_2), ammonia (NH_3), carbon disulfide (CS_2), dodecane ($\text{C}_{20}\text{H}_{42}$), and neon (Ne) for the van der Waals equation:

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

At 1 atm, ammonia and carbon dioxide are both gases, ammonia having the higher boiling point. At 1 atm, carbon disulfide and dodecane boil at respectively 46 and 216°C

Compound	a ($\text{L}^2\text{atm}/\text{mol}^2$)	b (L/mol)
X	3.610	0.0427
Y	4.250	—
Z	11.10	0.0726
W	—	0.3758
Q	0.214	0.0171

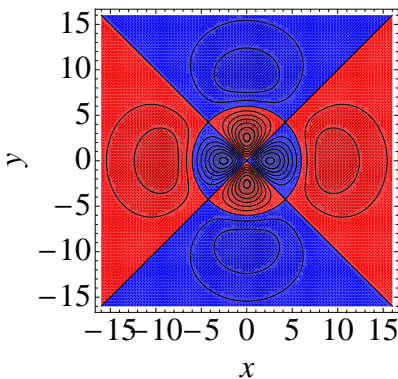
Unfortunately La Cheville Tordue has also forgotten to record two pieces of data in her table. Please, nonetheless, deduce which of the five compounds goes with which line of data.

6. An unusual atomic orbitals is:

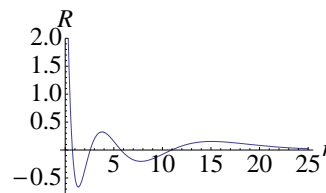
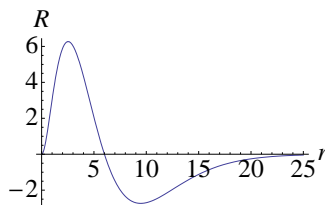
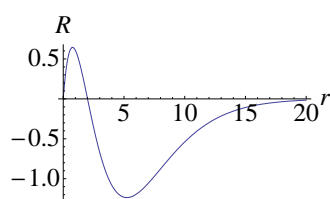
$$\psi = r^3 e^{-\frac{r}{2}} (x^2 - 2xy + y^2)$$

Please draw a rough contour map on the xy plane for this orbital.

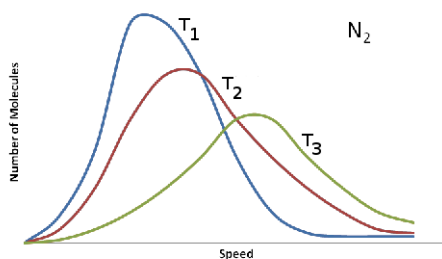
7. Given below is the contour map of an atomic orbital. *Dark grey* is positive and *light grey* is negative. Identify the orbital. (For example $3p_x$ is the full name of an orbital.)



Please identify which of the three radial functions given below corresponds with the contour map given in the diagram above. For credit, very briefly explain the reasoning behind your choice.



8. The three temperatures in the graph below correspond to 100 K, 300 K and 700 K. Which one is which?



9. An industrial solid catalyst under an oxygen atmosphere converts ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, into acetic acid, CH_3COOH . A 100.0 g solution of ethanol in water is converted into a 114.2 g pure solution of acetic acid in water. What is the mole percent (moles of ethanol to total moles of molecules) in the original ethanol solution?