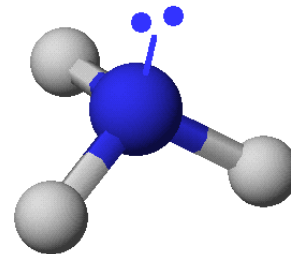


Ammonia, NH_3 , and its salt are important biochemically and industrially. This exam will explore the chemistry of ammonia and its derivatives in a number of questions.



1. (6 points) Nickel is a (metal)(metalloid)(nonmetal) _____ with a symbol of _____ and an atomic number of _____. The element has _____ protons in the nucleus. A nickel(II) cation has _____ electrons outside of the nucleus. If nickel-59 is the most abundant isotope of the element, an atom of this isotope has _____ neutrons in the nucleus.

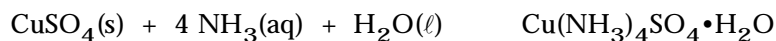
2. (6 points) Give the name or formula of each compound below, as appropriate.

Formula	Name
(a) $\text{Ba}(\text{OH})_2$	_____
(b) NH_4Cl	_____
(c) $\text{Ca}(\text{CH}_3\text{CO}_2)_2$	_____
(d) _____	nickel(II) sulfide
(e) _____	iron(III) carbonate
(f) _____	nitrogen dioxide

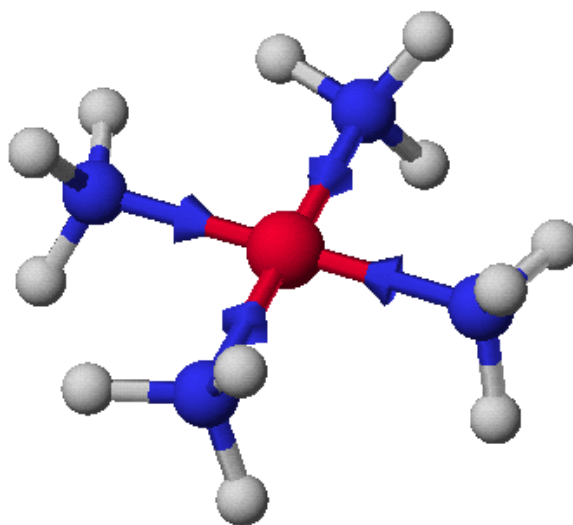
3. (2 points) Select the **incorrect** statement below. Two moles of C_3H_8 represent

- (a) six times Avogadro's number of C atoms
- (b) 88.0 g of material
- (c) 9.63×10^{24} hydrogen atoms
- (d) a material with 81.8% carbon
- (e) 6.62×10^{24} total atoms

4. (10 points) You recently carried out the following reaction in the laboratory.



- (a) The name of one of the reactants, CuSO_4 , is _____
- (b) You used 50.0 mL of 0.0123 M NH_3 . What quantity of NH_3 did you use?
- (i) 2.46×10^{-4} mol
 - (ii) 6.15×10^{-4} mol
 - (iii) 0.615 mol
 - (iv) 4.07 mol
- (c) What quantity of CuSO_4 (molar mass = 159.6 g/mol) is required to react completely with 0.014 mol of NH_3 ?
- (i) 0.559 g
 - (ii) 2.23 g
 - (iii) 2.39 g
 - (iv) 8.94 g
- (d) What mass of product, $\text{Cu}(\text{NH}_3)_4\text{SO}_4 \cdot \text{H}_2\text{O}$, is expected from 10.0 g of CuSO_4 (159.6 g/mol). That is, calculate the theoretical yield of $\text{Cu}(\text{NH}_3)_4\text{SO}_4 \cdot \text{H}_2\text{O}$ (molar mass = 245.6 g/mol).
- (i) 10.0 g
 - (ii) 15.4 g
 - (iii) 24.6 g
 - (iv) 30.8 g



Structure of the $\text{Cu}(\text{NH}_3)_4^{2+}$ ion (the complex you made in the laboratory). Notice that the Cu^{2+} ion and the 4 N atoms attached to it are at the corners of a square. Chemists call this a "square planar structure."

5. (11 points) A major use of carbon dioxide is in its reaction with ammonia to produce urea, $\text{CO}(\text{NH}_2)_2$, a common fertilizer.



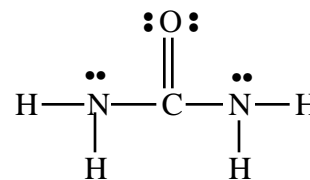
What quantity of urea (molar mass = 60.06 g/mol) can be obtained from 568 g of ammonia and 679 g of CO_2 ?

- (a) 2.00×10^3 g urea
 (b) 1.85×10^3 g urea
 (c) 1.00×10^3 g urea
 (d) 9.25×10^2 g urea
 (e) none of the above

The electron dot structure of urea is given here. What are the bond angles in the molecule?

H—N—H angle = _____

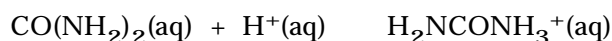
O—C—N angle = _____



The standard enthalpy change for the synthesis of urea from CO_2 and NH_3 (*the reaction above*) is $\Delta H_{\text{rxn}}^\circ = -133.6$ kJ. What is the standard molar enthalpy of formation of urea?

- (a) $\Delta H_f^\circ(\text{urea}) = +453.6$ kJ/mol
 (b) $\Delta H_f^\circ(\text{urea}) = -287.4$ kJ/mol
 (c) $\Delta H_f^\circ(\text{urea}) = -333.6$ kJ/mol
 (d) $\Delta H_f^\circ(\text{urea}) = -377.5$ kJ/mol
 (e) none of the above

Urea reacts with acids according to the net ionic equation



Suppose you have a 15.35 g sample of a white solid that you know contains some urea. Titrating that sample with HCl requires 36.54 mL of 0.163 M HCl. What is the weight percent of urea in the sample

- (a) 1.06 %
 (b) 2.33 %
 (c) 15.4 %
 (d) 42.0 %
 (e) none of the above

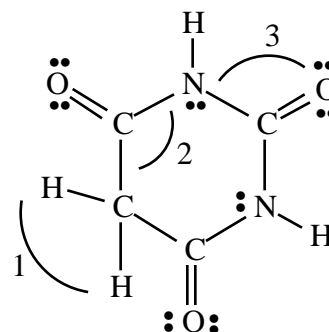
6. (3 points) More about urea. When urea is heated it decomposes to several products, among them a compound called cyanuric acid. Cyanuric acid has 27.91% C, 2.34% H, 32.56% N, and 37.19% O. The empirical formula of this compound is

- (a) CON_2H_4
 (b) CONH
 (c) $\text{C}_2\text{O}_2\text{N}_3\text{H}_5$
 (d) $\text{C}_3\text{O}_2\text{N}_4\text{H}_4$
 (e) None of the above

7. (6 points) Barbiturates are widely used sedative-hypnotic drugs. (Phenobarbital is widely prescribed as a sedative.) Urea reacts with malonic acid to produce a member of this class of compounds, barbituric acid.

Bond angles in barbituric acid:

- 1 H-C-H angle = _____
 2 C-C-N angle = _____
 3 N-C-O angle = _____



Barbituric acid

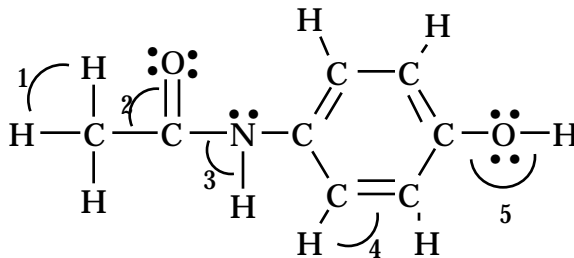
Barbituric acid (molar mass = 128.1 g/mol) reacts with common bases such as NaOH.



What quantity of 0.156 M NaOH is required to react completely with 1.53 g of barbituric acid?

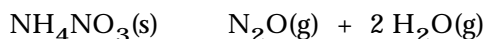
- (a) 11.9 mL NaOH
 (b) 13.1 mL NaOH
 (c) 15.3 mL NaOH
 (d) 23.9 mL NaOH
 (e) 76.6 mL NaOH
 (f) None of the above

8. (13 points) Acetaminophen, which is sold under the tradename Tylenol and Excedrin, among others, has the structure shown here. Notice that it has an N-H bond.



- (a) One Excedrin tablet contains 250 mg of acetaminophen, $C_8H_9NO_2$. What quantity of acetaminophen are you consuming in one tablet?
- 2.50×10^{-3} mol
 - 1.65×10^{-3} mol
 - 1.51×10^{-2} mol
 - 1.65 mol
 - none of the above
- (b) The weight percent is carbon in acetaminophen is
- 7.94 %
 - 48.0 %
 - 12.0 %
 - 63.6 %
 - none of the above
- (c) Give approximate values for the indicated bond angles in the molecule.
- 1 = _____
- 2 = _____
- 3 = _____
- 4 = _____
- 5 = _____

9. (6 points) A fertilizer plant blew up early in the morning of December 13, 1994 in Iowa. It was caused by ammonium nitrate, a compound widely used as a fertilizer and an explosive. Among the reactions that can occur is



Calculate the enthalpy change for this reaction using the data in your textbook.

- (a) -35.9 kJ
- (b) -200.1 kJ
- (c) 205.9 kJ
- (d) -767.1 kJ
- (e) none of the above

If one pound (454 g) of ammonium nitrate (molar mass = 80.04 g/mol) blows up, what is the total amount of heat liberated in the process?

- (a) 203.6 kJ
- (b) 1135 kJ
- (c) 1168 kJ
- (d) 4351 kJ
- (e) none of the above

10. (3 points) Liquid ammonia is widely used as a solvent for chemical reactions. You have a tank of gaseous ammonia at 24 °C. If you wish to liquefy 256 g of gaseous ammonia, what quantity of heat must the ammonia lose as it cools from 24.0 °C to the temperature at which it becomes a liquid (-33.3 °C) and then turns into a liquid?

Specific heat capacity of gaseous ammonia = 2.06 J/g•deg

Heat of vaporization of ammonia = 1372 J/g.

- (a) 3.02×10^4 joules
- (b) 3.31×10^5 joules
- (c) 3.51×10^5 joules
- (d) 3.56×10^5 joules
- (e) 3.81×10^5 joules
- (f) None of the above

11. (5 points) **Oxidation-Reduction Reactions.** Ammonia is converted to nitric acid in a redox process. The overall reaction is

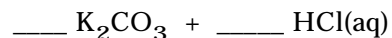


- (a) The oxidation number of N in NH_3 is _____ and the oxidation number of N in HNO_3 is _____.
- (b) The substance oxidized is _____ and the substance reduced is _____.
- (c) The reducing agent in this reaction is _____.
12. (3 points) Indicate whether each is soluble in water or not soluble.

Compound	Water Solubility
NH_4NO_3	_____
BaSO_4	_____
$\text{Ni}(\text{CH}_3\text{CO}_2)_2$	_____

13. (9 points) Complete and balance the equations a-c. Describe each of the four equations as an acid-base reaction, a precipitation, a gas-forming reaction, or a redox reaction:

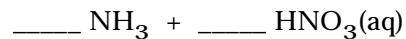
(a) Reaction type: _____



(b) Reaction type: _____



(c) Reaction type: _____



13. (6 points) Using the **spectroscopic notation**, [e.g., $1s^22s^2$], write electron configurations for the following atoms or ions. (You may use the noble gas notation for each case.)

(a) Si

(c) Mn^{2+}

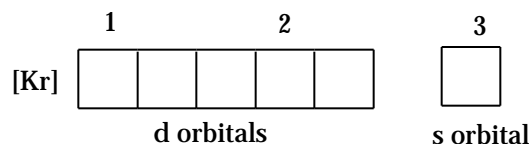
(d) Pt (platinum)

14. (4 points) Using the **orbital box notation**, write electron configurations for the following atoms or ions. Please use the noble gas notation for both answers!

(a) P

(b) Fe^{3+}

15. (5 points) The configuration for an element is given here.



(a) What is the identity of the element with this configuration? _____

(b) Are atoms of the element paramagnetic or diamagnetic? _____

(c) Write a complete set of quantum numbers for each of the indicated electrons.

Electron	n	l	m_l	m_s
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	_____	_____	_____	_____

16. (15 points) Atomic structure and quantum numbers

- (a) Each drawing below represents a type of atomic orbital. Give the letter designation for the orbital and its value of ℓ .



letter _____

ℓ value _____

- (b) What element has a $2+$ ion with the configuration $[\text{Ar}]3d^9$? _____

- (c) How many electrons can be associated with the following sets of quantum numbers?

Number of Electrons

$n = 4$, and $\ell = 2$ _____

$n = 3$, $\ell = 2$, and $m_\ell = +1$ _____

- (d) What noble gas atom has the largest atomic radius? _____

- (e) Of the elements O, S, and F, which has the smallest atomic radius? _____

- (f) Which anion is larger, S^{2-} or Cl^- ? _____

- (g) Which cation has the largest radius: K^+ or Ca^{2+} ? _____

- (h) Place the following elements in order of increasing ionization energy: O, S, and F

_____ *smallest IE*

_____ *largest IE*

17. (1 points) Who will win the national collegiate football championship this year?

- (a) Florida State
 (b) Virginia Tech
 (c) I could care less.
 (d) The New York Giants?

17. (14 points) Draw electron dot structures, and answer the accompanying questions, for the following molecules and ions.

(a) Carbon disulfide, CS_2 Total number of valence electrons = _____

The electron pair geometry around the C atom is _____ and the molecular geometry for CS_2 is _____. The S—C—S bond angle is predicted to be _____.

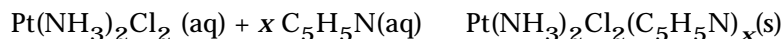
(b) Nitryl chloride, ClNO_2 (N is the central atom) Total number of valence electrons = _____

The electron pair geometry around the N atom is _____ The molecular structure is _____. The O—N—O bond angle is predicted to be _____.

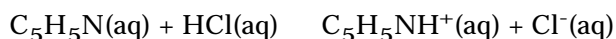
18. (4 points) The formate anion, HCO_2^- , is a common anion. Draw all the resonance structures for this ion.

GROUP QUESTION (10 points)

The cancer chemotherapy drug cisplatin, $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$, can be made to react with the organic compound pyridine, $\text{C}_5\text{H}_5\text{N}$, to form a new compound.



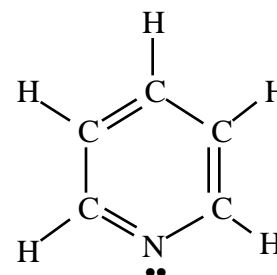
Suppose you treat 0.150 g of cisplatin with what you believe is an excess of liquid pyridine (1.50 mL; $d = 0.979 \text{ g/mL}$). When reaction is complete, you can find out how much pyridine was not used by titrating the solution with standardized HCl. If 37.0 mL of 0.475 M HCl is required to titrate the excess pyridine,



what is the formula of the unknown compound $\text{Pt}(\text{NH}_3)_2\text{Cl}_2(\text{C}_5\text{H}_5\text{N})_x$? **Show your work completely!**

The structure of pyridine, an organic base somewhat related to ammonia, is show here.

- (a) When an H^+ ion approaches a pyridine molecule to form $\text{C}_5\text{H}_5\text{NH}^+$, to what atom is the H^+ ion attached, C or N? _____
- (b) What is the average carbon-carbon bond order in pyridine? _____
- (c) What is the C-N-C bond angle? _____
- (d) Is the C_5N ring flat or bent out of planarity in some way?



Have a happy and healthy holiday and best wishes and good luck in the new century!

Name _____

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