

ANSWER KEY**Part 1. Multiple Choice (14 marks total)**

For each numbered statement below, write the letter that corresponds to the best answer. There is only one correct answer per question. Each question is worth 2 marks.

1. When sodium burns in air with excess oxygen, it gives a product that

- (a) dissolves in water to give an acidic solution
- (b) has a covalent Na-O bond
- (c) is stabilized by a triple bond
- (d) has oxygen in the -1 oxidation state
- (e) contains sodium in the $+2$ oxidation state

Answer:

D

2. Which one of the following series has four atoms or ions that are isoelectronic?

- (a) C, Si, Ge, Sn
- (b) C^{4+} , Si^{4+} , Ge^{4+} , Sn^{4+}
- (c) B, C, N, O
- (d) B^{2+} , C^+ , N, O^-
- (e) None of the above

Answer:

E

3. Which one of the following statements is false?

- (a) the first ionization energy of bromine is larger than that of calcium
- (b) the first ionization energy of barium is smaller than that of magnesium
- (c) in a given row in the periodic table, the alkali metal always has the largest first ionization energy
- (d) the melting points of the alkali metals decrease as their atomic weights increase
- (e) the second ionization energy of an element is always greater than the first ionization energy

Answer:

C

4. In which one of the following species does N have a $+1$ formal charge in the best Lewis structure? (The underlined atom is the central atom.)

- (a) HCN
- (b) ONCl
- (c) [NBCl] $^-$
- (d) NI $_3$
- (e) N $_2$ O

Answer:

E

5. Bromine, with an atomic weight of 79.90 g mol^{-1} , has only 2 stable isotopes. One isotope of bromine, present in 50.7% natural abundance, has 44 neutrons in its nucleus. The other stable isotope of bromine is:

- (a) ^{78}Br
- (b) ^{79}Br
- (c) ^{80}Br
- (d) ^{81}Br
- (e) ^{82}Br

Answer:

D

6. Which of the following compounds has an unpaired electron?

- (a) SF_5
- (b) SiF_4
- (c) IF_5
- (d) HNO_3
- (e) NaClO_4

Answer:

A

7. Which one of the following molecules could exist in both polar and non-polar forms, depending on the arrangement of the halogen atoms? (the underlined atom is the central atom)

- (a) Xe FCl
- (b) Xe Cl_2F_2
- (c) Si Cl_2F_2
- (d) S Cl_2F_2
- (e) P Cl_2F

Answer:

B

Part 2. Short Answer Questions

6 marks 1. For this question, consider only the following neutral elements as possible answers:

Li, Na, K, Rb, Cs
Be, Mg, Ca, Sr, Ba

For each part, give the symbol from the above list that makes the statement correct.

- (a) Be has smallest atomic radius.
- (b) Ca has valence electrons in the $n = 4$ shell with $Z_{\text{eff}} \sim 2$.
- (c) Cs is the alkali metal that reacts most explosively with water.

6 marks 2. (a) Write a balanced equation for the reaction of rubidium with water.



(b) Write a balanced equation for the reaction of cesium oxide with oxygen.



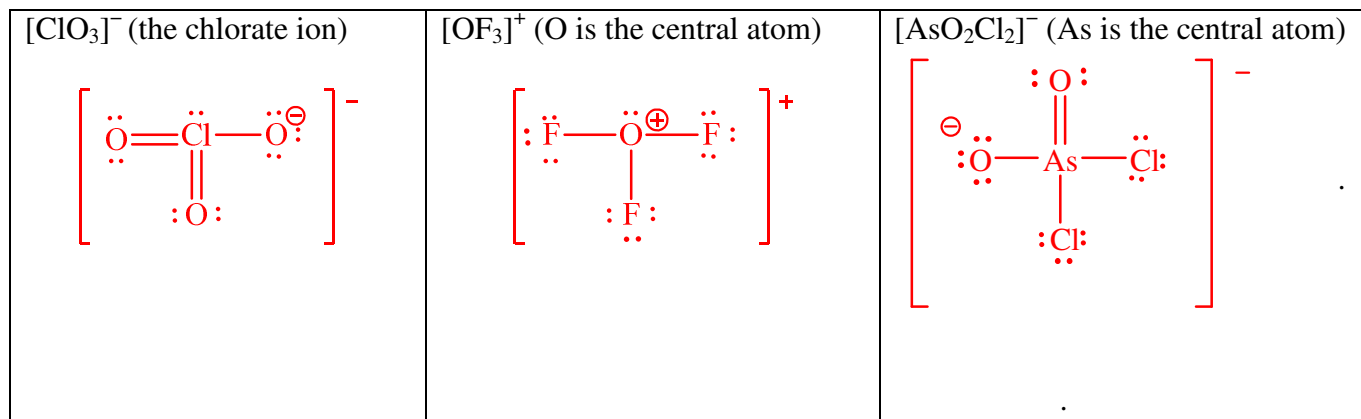
(c) When magnesium nitride (Mg_3N_2) reacts with water, two products are formed. One of the products is a neutral compound with a mass of 17 g mol^{-1} . Using this information, write a balanced equation for the reaction of Mg_3N_2 with water.



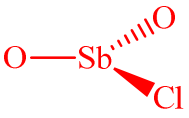
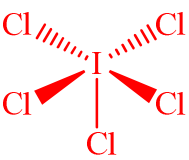
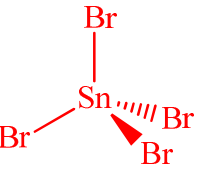
OR



12 marks 3. (a) Draw the best Lewis structure for each of the following ions. Draw only one structure when resonance is possible. Write any non-zero formal charges on the appropriate atoms, show all lone pairs of electrons as pairs of dots and all bond pairs as lines.

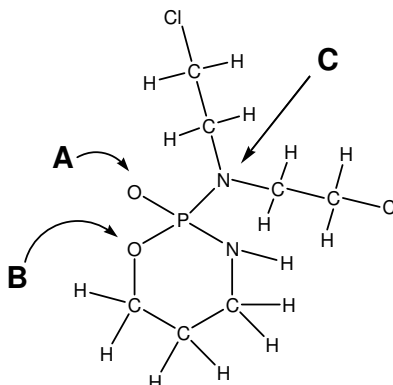


(b) Complete the following table by drawing the perspective diagram and specifying the molecular shape for each molecule. The central atom is underlined. In the last column, write “YES” if the molecule is polar, or “NO” if it is not polar.

Formula	Perspective Diagram	Molecular Shape	Is the molecule polar? (YES/NO)
<u>Sb</u> O ₂ Cl		Trigonal Planar	YES
<u>I</u> Cl ₅		Square-based pyramidal	YES
<u>Sn</u> Br ₄		Tetrahedral	NO

5 marks

4. Cyclophosphamide is a highly reactive molecule that binds to the guanine base of DNA, stopping cells from replicating. Cyclophosphamide is used to treat cancer. The following diagram shows the skeletal structure of cyclophosphamide. Answer parts (a) – (e) concerning the molecule below by circling the best answer.

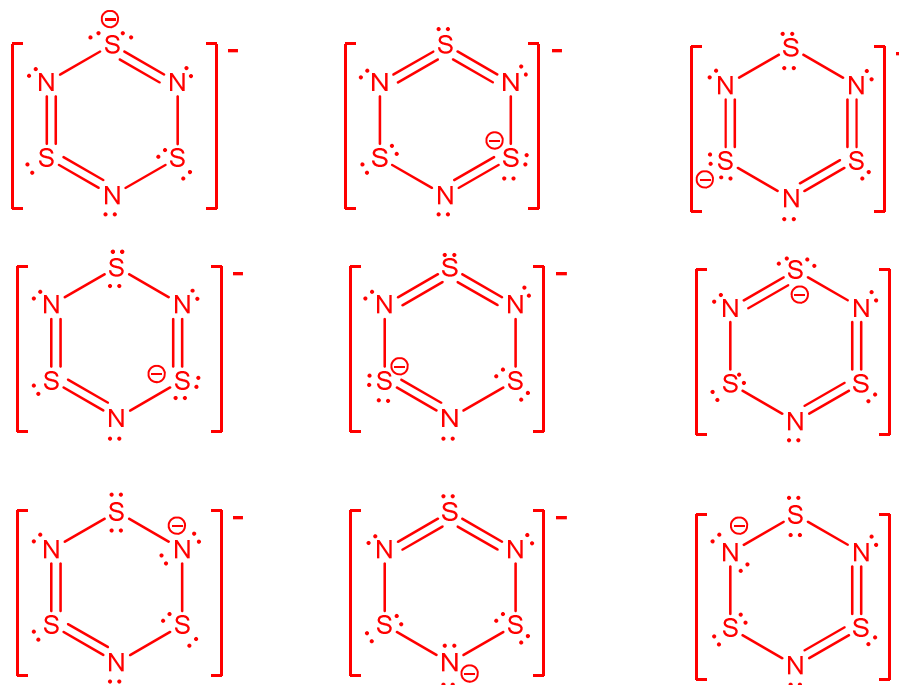


<p>a) The molecular shape at the atom labeled B is</p> <p>(i) Tetrahedral (ii) Linear (iii) Trigonal Planar (iv) Bent (v) Trigonal Pyramidal</p>	<p>d) The number of atoms with tetrahedral molecular shape in cyclophosphamide is</p> <p>(i) 7 (ii) 8 (iii) 9 (iv) 10 (v) 11</p>
<p>b) The estimated O-P-O bond angle is</p> <p>(i) 90° (ii) 120° (iii) 109° (iv) 145° (v) 60°</p>	<p>e) The formal charge on the atom labeled A in the best Lewis structure is</p> <p>(i) -2 (ii) -1 (iii) 0 (iv) +1 (v) +2</p>
<p>c) The estimated C-N-C bond angle at the atom labeled C is</p> <p>(i) 90° (ii) 109° (iii) 120° (iv) 145° (v) 60°</p>	

6 marks

5. The anion $[\text{S}_3\text{N}_3]^-$ is a ring with alternating sulfur and nitrogen atoms. Complete the templates below by adding lone pairs and bonds to show the three BEST resonance structures for $[\text{S}_3\text{N}_3]^-$. Show all lone pairs of electrons as pairs of dots and all additional bonds as lines. Write any non-zero formal charges on the appropriate atoms.

There are 9 solutions worth full credit:



Space for rough work:

- 6 marks** 6. Ytterbium (Yb) metal crystallizes in a face-centered cubic (fcc) structure with unit cell edge length of 5.48 Å and density of 6.90 g cm⁻³ at 25 °C and 1 atm pressure (room temperature and pressure).

(a) What is the metallic radius of ytterbium (in Å)?

Answer:

1.94 Å

Since this is a FCC structure, $a = 2\sqrt{2}r$

$$r = \frac{5.48}{2\sqrt{2}} = 1.937 \text{ Å}$$

(b) When ytterbium is compressed to 40,000 atm at 25 °C, it undergoes a phase change from a close-packed fcc to a body-centered cubic (bcc) lattice. In this high pressure form of Yb, what is the coordination number of Yb?

Answer:

8

(c) If the density of the high pressure (bcc) form of ytterbium is 8.71 g cm⁻³, calculate the unit cell edge length of this structure.

Answer:

4.04 Å

$$Volume = a^3 = \frac{mass}{density}$$

$$mass = MW \div 6.02 \times 10^{23} \text{ atoms mol}^{-1} \times 2 \text{ atoms}$$

$$mass = 5.78 \times 10^{-22} \text{ g}$$

$$density = 8.71 \text{ g cm}^{-3}$$

$$a = \sqrt[3]{mass/density}$$

$$a = 4.04 \times 10^{-8} \text{ cm}$$

(d) The result described in part (b) was published in the science magazine, *Science*. *Science* only publishes surprising and breakthrough ideas. Briefly state why this paper was published in *Science*. (What is truly surprising about this result?)

Upon compression, the solid changed from a closely packed structure (FCC) to a non-closed packed structure (BCC).

(Reference: Hall, H.T.; Barnett, J.D.; Merrill, L. *Science* **1963**, *139*, 111-112.)

5 marks

7. A chemist added 10.0 g of an unknown alkaline earth metal to 100 mL of 6 M sulfuric acid. After a vigorous reaction with evolution of a gas, only a clear, colourless solution remained. Next, she removed water and excess sulfuric acid from the solution by vacuum to leave a white solid. After recrystallization, she obtained 13.7 g of product, which represented a 65% yield. Chemical analysis of the white solid showed that it did not contain hydrogen. The white solid was found to be soluble in water and did not react with oxygen.

- (a) Identify the unknown metal with a chemical symbol. You must show your work for credit.



Theoretical Yield:

$$0.65 \times 13.7 \text{ g product} = 21.02 \text{ g metal sulfate}$$

moles of metal sulfate :

$$\frac{21.07 \text{ g metal sulfate}}{(MW_{\text{metal}} + MW_{SO_4})} = \frac{21.07 \text{ g metal sulfate}}{(MW_{\text{metal}} + 96 \text{ g mol}^{-1})}$$

moles of metal :

$$\frac{10 \text{ g metal}}{MW_{\text{metal}}}$$

moles metal sulfate = moles metal :

$$\frac{21.07 \text{ g}}{(MW_{\text{metal}} + 96 \text{ g mol}^{-1})} = \frac{10 \text{ g}}{MW_{\text{metal}}}$$

Solve for MW_{metal} :

$$MW_{\text{metal}} = 86.72 \text{ g mol}^{-1}$$

86.72 g mol⁻¹ corresponds to the alkaline metal Sr.

(Note: the question should have specified that the solid was insoluble in water, since SrSO₄ is barely soluble in water. Those who clearly used solubility to deduce the answer of Mg or Be were given credit.)

- (b) Write a balanced equation for the vigorous chemical reaction observed.

