1. Which of the following statements is incorrect about the chemical reaction of nitrogen and hydrogen forming ammonia (represented by the equation below), assuming that the reaction goes to completion?

$$N_2 + 3H_2 \rightarrow 2NH_3$$

A) 17 g of ammonia will be formed in the reaction of 14 g of nitrogen.
B) 17 g of ammonia will be formed in the reaction of 3 mol of hydrogen.
C) 2 mol of NH_3 will be formed from 1 mol of nitrogen.
D) 2/3 mol of NH_3 will be formed in the reaction of 1 mol of hydrogen.

2. Which of the following statements about halogen elements is not correct?
A) Their compounds with metals generally have a covalent nature.
B) The electronic configuration of their valence shell is ns^2np^5.
C) The simple substances exist as diatomic molecules.
D) In most compounds, they are univalent.

3. Which of the following statements about SO_2 are correct:
I) It can be formed in the reaction given by the following equation: $S(s) + O_2(g) \rightarrow SO_2(g)$
II) It can contribute to the formation of acid rain.
III) It is an ionic compound.
IV) The sulfur in SO_2 has a smaller atomic radius than oxygen.

A) I and II
B) I, II and III
C) III and IV
D) all of the above

4. Which of the following compounds are double salts?
I) $NaHSO_4$; II) $Cu(OH)Cl$; III) $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$; IV) KH_2PO_4

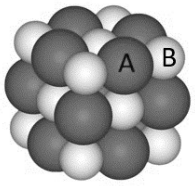
A) II and III
B) II
C) I and IV
D) all of the above

5. Which of the following oxides has the most pronounced basic properties?
A) BeO
B) MgO
C) Na_2O
D) P_2O_3

6. Which of the following statements about KF is correct?
A) It forms hydrogen bonds.
B) It dissolves easily in water.
C) It is in a gaseous state at room temperature.
D) It has a low melting point.

7. A chemist wants to make fireworks for the New Year's Day, that will produce a red color when burned. For this purpose, he should use:
A) $Ba(NO_3)_2$
B) $Sr(NO_3)_2$
C) KCl
D) $FeCl_3$

8. AB has the following structure at a given temperature:



AB reacts with water and its melting point is 2613 °C. AB is likely:
A) CO
B) NaF
C) CaO
D) HF

9. For conducting an experiment, the container should contain an equal number of Na and Cl atoms. What mass of chlorine should be added if there are 23 g of Na in the container? (A_r(Na) = 23, A_r(Cl) = 35.45).

A) 23 g
B) $6.022 \cdot 10^{23}$ g
C) 35.45 g
D) There is not enough information to determine the mass of chlorine.

10. A tablet of 640 mg contains 62.5% aspirin. If the recommended daily dose of aspirin is 300 mg, does the tablet provide the recommended dose to the body?

A) 100 mg more than the recommended daily dose is ingested.
B) Yes, exactly 300 mg are ingested, as recommended.
C) No, to ingest the recommended dose, two tablets should be taken.
D) A dose twice as large as the recommended dose is ingested.

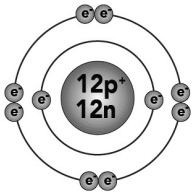
11. In the atom/s of which of the following elements are there 2 unpaired electrons: Mg, Si, S?

A) Mg.
B) Only Si.
C) Only S.
D) Si and S.

12. Cobalt-60 and iodine-131 are radioactive isotopes commonly used in nuclear medicine. How many protons, neutrons, and electrons do the atoms of these isotopes have?

A) ^{60}Co has 27 protons, 27 electrons and 33 neutrons, and ^{131}I has 53 protons, 53 electrons and 78 neutrons.
B) ^{60}Co has 27 protons, 27 electrons and 33 neutrons, and ^{131}I has 27 protons, 27 electrons and 104 neutrons.
C) Because they are isotopes, ^{60}Co and ^{131}I have the same number of protons, neutrons, and electrons.
D) ^{60}Co has 60 protons, 60 electrons and 33 neutrons, and ^{131}I has 131 protons, 131 electrons and 78 neutrons.

13. The picture shows (schematically):



A) Mg atom
B) Mg^{2+} ion
C) Cr^{2+} ion
D) $^{24}_{12}Cr$ isotope

14. For which of the following atoms would it be expected to form negative ions in binary ionic compounds: P, I, Cl, In, Cs, O, Co?

A) I, Cl and O
B) P, I, Cl and O
C) all of them
D) There is not enough information to determine.

15. Which of the following statements about $[Co(NH_3)_4Cl_2]Cl$ are correct?

I) Co is divalent.
II) Co is coordinated with 7 ligands.
III) The name of the compound is tetraammine dichlorocobaltate(II) chloride.
IV) Co is coordinated with anionic and neutral ligands.

A) I, II and III
B) I and III
C) IV
D) all of them

II. PROBLEMS

(In the tasks, write the solution method and the answer in the designated place.)

1. The following compounds are given: cesium chloride, ammonia, copper(II) sulfate, magnesium hydroxide, iron(III) chloride, perchloric acid.

   Fill in the blanks with the chemical formulas of the compounds:
   Colored solutions form: $CuSO_4$, $FeCl_3$
   Basic properties have: NH_3, $Mg(OH)_2$
   Polar covalent bonds contain: NH_3, $HClO_4$, $CuSO_4$, $Mg(OH)_2$
   Ionic bonds contain: $CsCl$, $CuSO_4$, $FeCl_3$, $Mg(OH)_2$

   6 points (0,5 point for each compound)

2. When heating 4.050 g of a simple substance E in the form of a cuboid with sides of 5 cm, 3 cm, and 1 mm, in the presence of oxygen, 7.652 g of the oxide of the element are obtained.

   (10 points total)

A. Calculate the empirical formula of the obtained oxide. (A_r(O) = 15.999)

(4 points)

Element	Colour	A_r	Electron configuration	Density (g/cm^3)
Lithium	Silver-white	6.941	$1s^2 2s^1$	0.533
Sodium	Silver-white	22.990	[Ne]$3s^1$	0.971
Cesium	Pale gold	132.905	[Xe]$6s^1$	1.886
Magnesium	Silver-white	24.305	[Ne]$3s^2$	1.738
Aluminium	Silver-white	26.982	[Ne]$3s^2 3p^1$	2.700
Silver	Silver	107.868	[Kr]$4d^{10} 5s^1$	10.503
Sulfur	Yellow	32.065	[Ne]$3s^2 3p^4$	2.070
Phosphorus	Red	30.974	[Ne]$3s^2 3p^3$	2.340
Carbon	Dark gray	12.011	[He]$2s^2 2p^2$	2.266

$V(\text{element}) = 5\ \text{cm} \cdot 3\ \text{cm} \cdot 0{,}1\ \text{cm} = 1.5\ \text{cm}^3$ (0.5 points)

$\rho(\text{element}) = m(\text{element})/V(\text{element}) = 4.050\ \text{g} / 1.5\ \text{cm}^3 = 2.7\ \text{g/cm}^3$ (0.5 points)

⇒ the element is Al (0.5 points)

$$\frac{n(\text{Al})}{n(\text{O})} = \frac{x}{y}$$

$n(\text{Al}) = m(\text{Al})/M(\text{Al}) = 4.05\ \text{g} / 26.982\ \text{g/mol} = 0.150\ \text{mol}$ (0.5 points)

$m(\text{O}) = m(\text{Al}_x\text{O}_y) - m(\text{Al}) = 7.652\ \text{g} - 4.050\ \text{g} = 3.602\ \text{g}$ (0.5 points)

$n(\text{O}) = m(\text{O})/M(\text{O}) = 3.602\ \text{g} / 15.999\ \text{g/mol} = 0.225\ \text{mol}$ (0.5 points)

$$\frac{n(\text{Al})}{n(\text{O})} = \frac{x}{y} = \frac{0.150\ \text{mol}}{0.225\ \text{mol}} = \frac{1}{1.5} = \frac{2}{3}$$ (0.5 points)

The empirical formula of the oxide is Al_2O_3 (0.5 points)

B. Then, the obtained oxide was subjected to a reaction with NaOH, resulting in the formation of a compound $Na_xE_yO_z$ with molar mass 81.97 g/mol, which is used as a coagulant for purifying drinking water and wastewater. (2 points)

The reaction in which this compound is obtained is as follows:

$$E_xO_y(s) + NaOH(aq) \rightarrow Na_xE_yO_z(aq) + H_2O(l)$$

Determine the formula of this compound if it is known that the mass percentage of Na is 28%, and the mass percentage of O is 39 %.

$w(\mathrm{Al}) = (100 - 28 - 39)\% = 33\ \%$ (0.5 points)

$$x : y : z = \frac{w(\mathrm{Na})}{A_r(\mathrm{Na})} : \frac{w(\mathrm{Al})}{A_r(\mathrm{Al})} : \frac{w(\mathrm{O})}{A_r(\mathrm{O})}$$ (0.5 points)

$$x : y : z = \frac{0{,}28}{22{,}990} : \frac{0{,}33}{26{,}982} : \frac{0{,}39}{15{,}999}$$ (0.5 points)

$$x : y : z = 0.0122 : 0.0122 : 0.0244$$

$$x : y : z = 1 : 1 : 2$$

The empirical formula of X is: $NaAlO_2$ (0.5 points)

C. What is the balanced equation of the reaction? (0.5 points)

$$Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(l)$$

D. What mass of $Na_xE_yO_z$ will be obtained from the reaction of the obtained E_xO_y and 8 g NaOH with 99.0% purity (M_r(NaOH) = 40.00)? (3.5 points)

$n(Al_2O_3) = m(Al_2O_3)/M(Al_2O_3) = 7.652\ \mathrm{g} / 101.96\ \mathrm{g/mol} = 0.075\ \mathrm{mol}$ (0.5 points)

$m(\mathrm{NaOH}) = w(\mathrm{NaOH}) \cdot m(\mathrm{NaOH}) = 0.99 \cdot 8\ \mathrm{g} = 7.92\ \mathrm{g}$ (0.5 points)

$n(\mathrm{NaOH}) = m(\mathrm{NaOH})/M(\mathrm{NaOH}) = 7.92\ \mathrm{g} / 40.00\ \mathrm{g/mol} = 0.198\ \mathrm{mol}$ (0.5 points)

$$\frac{n(Al_2O_3)}{n(\mathrm{NaOH})} = \frac{1}{2}$$

$n(\mathrm{NaOH}) = 2n(Al_2O_3) = 2 \cdot 0.075\ \mathrm{mol} = 0.150\ \mathrm{mol}$ (0.5 points)

⇒NaOH is in excess, Al_2O_3 is the limiting reagent (0.5 points)

$$\frac{n(NaAlO_2)}{n(Al_2O_3)} = \frac{2}{1}$$

$n(NaAlO_2) = 2 \cdot 0.075\ \mathrm{mol} = 0{,}150\ \mathrm{mol}$ (0.5 points)

$$m(NaAlO_2) = 0.150\ \mathrm{mol} \cdot 81.97 \frac{\mathrm{g}}{\mathrm{mol}} = 12.30\ \mathrm{g}$$ (0.5 points)

3. (4 points) In neutral atoms of *d*-elements *ns* orbitals are filled with electrons before the $(n\text{-}1)d$ orbitals. However, after the *ns* orbitals are filled, they have higher energy than the filled $(n\text{-}1)d$ orbitals.

The carbonate of some *d*- element decomposes according to the following equation:

$$MCO_3 \rightarrow MO + CO_2$$

After decomposition, the metal ion has the following electronic configuration: [Ar]$3d^8$ (Z(Ar) = 18).

A. (1 point) Determine which of the listed carbonates is being referred to: Na_2CO_3, K_2CO_3, $CaCO_3$, $NiCO_3$, $CuCO_3$, $ZnCO_3$ and write down the the electronic configuration of the metal (the neutral element).

Z(Na) = 11, Z(K) = 19, Z(Ca) = 20, Z(Ni) = 28, Z(Cu) = 29, Z(Zn) = 30.

The metal is: Z(Ni) = 28. The carbonate is $NiCO_3$. (0.5 points)

The electronic configuration of the neutral atom is: [Ar]$3d^8 4s^2$. (0.5 points)

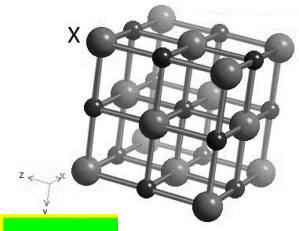
B. (1 point) What is the mass of the oxide MO that was formed if 44.8 dm^3 of CO_2 was released during the reaction under standard conditions?

(V_m = 22.4 dm^3/mol, R = 8.314 $Pa \cdot m^3 \cdot mol^{-1} \cdot K^{-1}$, p = 101325 Pa).

(A_r(Na) = 22.990, A_r(K) = 39.098, A_r(Ca) = 40.078, A_r(Ni) = 58.690, A_r(Cu) = 63.546, A_r(Zn) = 65.380)

$n(\mathrm{NiO}) = n(\mathrm{CO_2}) = V(\mathrm{CO_2}) / V_\mathrm{m} = 44.8\ \mathrm{dm^3} / 22.4\ \mathrm{dm^3/mol} = 2\ \mathrm{mol}$ (0.5 points)
$m(\mathrm{NiO}) = n(\mathrm{NiO}) \cdot M(\mathrm{NiO}) = 2\ \mathrm{mol} \cdot 58.690\ \mathrm{g/mol} = 117.38\ \mathrm{g}$ (0.5 points)

B. (2 points) The structure of the oxide is shown in the picture. Is the ion X the ion of the metal or oxygen? Calculate the mass of the X ions on one side of the cube.



X is oxygen (0.5 points)

$$N(\mathrm{O}) = 1 \cdot \frac{1}{2} + 4 \cdot \frac{1}{4} = \frac{3}{2}$$ (0.5 points)

$$m(\mathrm{O}) = \frac{N}{N_A} \cdot M(O) = \frac{3}{2 \cdot 6.022 \cdot 10^{23}\,\mathrm{mol^{-1}}} \cdot 15.999\,\frac{\mathrm{g}}{\mathrm{mol}} = 3.985 \cdot 10^{-23}\,\mathrm{g}$$ (1 point)