Stoichiometry and ideal gases exam

Name:

Unless otherwise stated, present your results with 3 sf.
Show your calculations and/or write your reasoning in all exercises.

1. Calculate:
a) How many moles of phosphoric acid are there in 102g? [2]

b) How many grams of ammonia are there in 0.24 mol? [2]

2. Gasoline, which is made mostly of different isomers of octane (C_8H_{18}) burns inside a car engine (technically, it doesn't burn, it explodes, but this difference doesn't affect the stoichiometry).

a) Write and balance said reaction [2]

b) If the engine injects 0.04g gasoline into the cylinder, what is the minimum amount (in g) of oxygen that must be injected alongside it in order for the gasoline to burn? [2]

c) How much volume would this be if the oxygen enters the cylinder at 44ºC and 1.08 atm of pressure? [2]

d) Given that only 17% of the air is oxygen and that the reaction goes well if there is 3 times more oxygen than needed, recalculate your answer to section c [2]

3. The biology department wants us to prepare a copper (II) sulfate ($CuSO_4$) solution for one of their experiments.
a) If the solution must be $6.4 \cdot 10^{-2}$ M, how much copper (II) sulfate must we weigh in order to prepare 3l of said solution? [2]

b) If each experiment requires $8 \cdot 10^{-6}$ mol of copper (II) sulfate, how many experiments can be done with the solution we prepared in a? [1]

4. We want to prepare a solution of sulfuric acid and we only have a bottle of concentrated sulfuric acid that contains 44ml of sulfuric acid 98% w/w and density=1.85g/ml . The solution we want to prepare must be 0.15 M.
How much solution can we prepare with the content of the bottle? [4]

5. Following the instructions for a given experiment, we add 5 ml of an ammonia solution 8% w/w and density 1.04 g/ml. Unfortunately we perform the experiment so many times that we run out of said solution, and all we have is a bottle of ammonia whose label says the concentration is 3M. How many ml of this new bottle must we add if we want the same amount of ammonia in the experiment? [3]

6. An anonymous celebrity has been found dead in his/her bed. A quick blood analysis shows high levels of a chemical compound that, according to forensic regulations, should be identified. Elemental analysis of said compound indicates that 56.44% of its weight is accounted for by carbon atoms, 8.306% is hydrogen, 16.46% is nitrogen and the rest is oxygen.
a) Find the empirical formula of this compound [4]

b) If the molecular weight is between 150 and 200, can you determine its molecular formula? [2]

7. Potassium nitrate can be obtained through the reaction of potassium hydroxide KOH with nitric acid. Potassium nitrate is a moderately common fertilizer that also has interesting uses in the removal of unwanted tree stumps.
a) Write and balance said reaction [1]

b) If we have twelve kilograms of potassium hydroxide and another twelve of nitric acid, which is the limiting reactant? [2]

c) In case b, how much of the other will be left? Give your answer with five sf. [2]

8. In a Haber-Bosch reactor, nitrogen is forced to react with hydrogen at moderately high temperature (300ºC) and unequivocally high pressure (300 atm).
The reaction is approximately this:

$$H_{2\,(g)} + N_{2\,(g)} \rightarrow NH_{3\,(g)}$$ note: not balanced

a) Balance the reaction [1]

Initially the reactor, which is only seven litres, is entirely full of hydrogen.
b) How much hydrogen is that?[2]

The reactor is not supposed to approach stoichiometric proportions between the reactants, and in fact the reaction goes best when there is much more hydrogen than needed, so only a small amount of nitrogen is injected into it.
100 litres of nitrogen, measured in SATP, are compressed and injected into the reactor.
c) How much nitrogen is this? [2]

d) How much hydrogen would be required for this nitrogen to react? [2]

e) If the yield is a mere 22%, how many grams of the product will we obtain? [2]

f) Discuss whether the nitrogen will need to be heated before being injected into the reactor. [2]

9. A chemical engineering student has prepared a 0.05M sodium hydroxide solution but, as it often happens with engineers, in an attempt to simplify lab procedures, left the bottle open, thus allowing the carbon dioxide from the atmosphere to partially neutralise the base.
In order to ascertain the actual concentration of the solution, we titrate it with a special acid that is used as a standard, which for the sake of simplicity we will call H_2Q. Its molecular weight is 231 amu.
a) Explain, including calculations, how you would prepare half a litre of H_2Q solution for the titration of the sodium hydroxide solution. [3]

Happily or sadly, after you have prepared your solution you find that there is already a bottle of H_2Q in the cupboard, prepared only one week ago by an experienced chemist, and whose label states that the concentration is 10^{-3} M.
Deciding to trust this bottle rather than the one you prepared, you titrate the sodium hydroxide in the bottle, finding that 30 ml of it required 20 ml of the H_2Q solution.
b) Determine the concentration of the sodium hydroxide solution. [2]

10. The Haber-Bosch reactor in exercise 8 works attached to two separate compression systems, one for nitrogen and one for hydrogen. The engineer in charge notices that, once the nitrogen is compressed, it doesn’t behave ideally, so the volume, pressure and temperature are no longer reliable if we want to know how much nitrogen we are injecting.
a) If the engineer trusts the ideal gas equation in order to calculate how much compressed nitrogen is being injected, will she be overestimating or underestimating the amount? Explain why [2]

b) This doesn’t seem to happen with hydrogen. Explain why [2]