

Stoichiometry and ideal gases

Questions set (v 6.0)

1. Sodium hydroxide NaOH reacts with phosphoric acid H_3PO_4 to give sodium phosphate Na_3PO_4 and water.

If we have 46g of sodium hydroxide and 40g of phosphoric acid:

- Which is the limiting reactant?
- How much of the other one (in g) is left?
- How much (in g) of sodium phosphate will be generated?

2. Sodium carbonate Na_2CO_3 reacts with nitric acid to give sodium nitrate NaNO_3 , carbon dioxide and water.

If we have 90g of sodium carbonate and 80g of nitric acid:

- Which is the limiting reactant?
- How much of the other (in g) is left?
- How much carbon dioxide (in g) is released?

3. Hexane is burnt.

If we have 300g hexane and 950g oxygen and the reaction occurs with 80% yield:

- Which is the limiting reactant?
- How much of the other is left?
- How much carbon dioxide (in g) is generated?

4. 10g ethanol ($\text{CH}_3\text{-CH}_2\text{-OH}$) react with 15g acetic acid ($\text{CH}_3\text{-COOH}$) to yield ethyl acetate ($\text{CH}_3\text{-COO-CH}_2\text{-CH}_3$) and water. This reaction takes place with a percentage yield of 70%.

- Which is the limiting reactant?
- How much of the other will be left?
- How much ethyl acetate (in g) will be generated?

5. Calcium oxide CaO reacts with water and the product is calcium hydroxide Ca(OH)_2 . Starting with 78g calcium oxide and 22 g water and assuming a yield of 75%:

- Which is the limiting reactant?
- How much (in g) of the other reactant will be left?
- How much product (in g) will be generated?

6. 115g of propane C_3H_8 are burnt with 308g of oxygen. Assuming that the yield is 95%:

- Which is the limiting reactant?
- How much (in g) of the other one will be left?
- How much carbon dioxide (in g) will be generated?

7. Inside a blast furnace, carbon monoxide reacts with iron (III) oxide to form carbon dioxide and iron. 60 kg of very fine and pure iron (III) oxide are fed to the blast furnace alongside 35 kg of carbon monoxide*. The yield of the reaction is a generous 85% thanks to centuries of experience and optimisation.

- Which is the limiting reactant?
- How much (in g) of the other one will be left?
- How much iron (in g) will be obtained?

*Not very realistic since the carbon monoxide in a blast furnace is generated inside it due to the incomplete combustion of coal, but let's accept it for the purposes of this exercise.

8. A marble plaque (calcium carbonate) is dissolved using sulphuric acid, forming calcium sulfate, carbon dioxide and water. The plaque weights 600g and we use the same mass of sulphuric acid. The yield of this reaction is very high, about 95%.

- Which is the limiting reactant?
- How much of the other will be left?
- How much calcium sulfate will be generated?

9. In order to prepare 0.6l of a Na_2CO_3 0.2M solution, how many ml of a 3M solution of the same compound are needed?

10. How much sodium hypochlorite NaClO must we use in order to prepare 100 ml of a 0.06M solution?

11. I have some concentrated H_2SO_4 left and I want to prepare a diluted solution of it. How much solution 0.05M can I prepare with 25 ml of solution 6M?

12. I want to prepare 3l of an HCl solution 0.25M and I have a solution of HCl 36% w/w and density 1.12 g/ml. How much of it must I pick in order to prepare the solution I want?

13. I have an opened bottle of HCl 30% w/w and density 1.1 kg/l. In said bottle there are 125 ml left. There is an unopened bottle of HCl 4M.

I want to prepare 2l of HCl solution 1M. Do I have enough with the opened bottle? If so, say how many ml I must pick. If not, say how many ml of the unopened bottle I must add.

14. A chemical compound has a molecular formula $\text{C}_6\text{H}_{12}\text{O}_6$. Calculate its molecular mass and what percentages of the weight are carbon, hydrogen and oxygen.

15. A given drug has been analysed and it has shown that 63.553% of its weight is carbon, 6.0127% is hydrogen, 21.167% is oxygen and 9.267% is nitrogen. Based on this information, deduce the molecular formula.

16. A very common drug has been analysed and it seems to consist of 75.677% carbon, 8.812% hydrogen and the rest is oxygen. Its molar mass is lower than 400 g/mol. Find the molecular formula.

17. An anaesthetic used in dentistry has undergone elemental analysis and it has shown to be 70.855% carbon, 9.1672% hydrogen, 12.716% nitrogen and the rest oxygen. The molar mass is below 300 g/mol. Find the molecular formula.

18. A hydrocarbon very commonly used in plastics consists of 92.243% carbon and the rest is hydrogen.

- Find the empirical formula.
- Given that the compound is styrene, suggest a hint regarding molecular mass that could be given in order to make said mass guessable.

19. An antimalarial drug has undergone elemental analysis and it has turned out to be 7.471% hydrogen, 9.8625% oxygen, 8.636% nitrogen and the rest carbon. Given that the molecular mass is above 100 and below 300 amu:

- Find the molecular formula.
- Discuss the hint about the molecular mass.

20. Another antimalarial drug (the person who owns the elemental analysis machine apparently was into those) shows to be constituted of 68.673% carbon, 6.9302% hydrogen and the rest oxygen. Given that the molar mass is somewhere around 250 amu, find the molecular formula.

21. Carbonic acid* is titrated using sodium hydroxide of a known concentration. 18ml of a carbonic acid solution were added to an erlenmeyer and required 6ml of a 0.0440M sodium hydroxide solution for its neutralisation.

Calculate the concentration of the carbonic acid solution.

*Not a realistic exercise, since carbonic acid tends to decompose by itself into carbon dioxide and water.

22. Potassium hydroxide KOH was titrated using nitric acid 0.06M. The erlenmeyer contained 4 ml of the KOH solution and it required 23 ml of the nitric acid solution. Calculate the concentration of the potassium hydroxide solution.

23. A magnesium hydroxide $\text{Mg}(\text{OH})_2$ solution was titrated using hydrochloric acid 0.122M. 21 ml of the magnesium hydroxide solution were put in the erlenmeyer, and they required 6.2 ml of hydrochloric acid to be neutralised. Calculate the concentration of the magnesium hydroxide solution.

24. Sulfuric acid is used to titrate a solution of calcium hydroxide. 15 ml of calcium hydroxide solution required 12.8 ml of sulfuric acid solution 0.072M. Calculate the concentration of the calcium hydroxide solution.

25. A solution of phosphoric acid is titrated with a solution of sodium hydroxide 0.079M. 15.6 ml of the solution of the base are needed to neutralise 7.4 ml of the acid solution. Calculate the concentration of the phosphoric acid.

26. 1.2g of magnesium are burnt, producing magnesium oxide MgO. This oxide is put in water, where it generates magnesium hydroxide. With this product, 500 ml of a solution are prepared. This solution of magnesium hydroxide is titrated with a solution of nitric acid 0.1M. 25 ml of the magnesium hydroxide solution required 30 ml of nitric acid solution to be neutralised. Calculate the percentage of the magnesium that eventually became magnesium hydroxide.

27. Pentane burns, giving the usual products. Starting with 200ml pentane and 280l of oxygen, calculate the volume (in l) of carbon dioxide generated.

Data: the density of pentane is 0.63 g/ml. The temperature is 11°C and the pressure is 1atm. The products of the combustion come out at a temperature of 50°C.

28. Inside a Haber-Bosch reactor, nitrogen reacts with hydrogen to form ammonia. This reaction takes place at about 400°C and 150atm. How much hydrogen is one litre of hydrogen at those conditions?

29. An old rule states that one mole of any gas at normal atmospheric pressure and 25°C has a volume of 22.4 l.

Given that we generally handle five significant figures and also we have two “standard conditions”, what would be the updated and accurate versions of this statement?

30. Lithium carbonate reacts with hydrogen chloride to form lithium chloride, water and carbon dioxide. Carbon dioxide is not directly poisonous, but humans can't survive in an atmosphere of pure carbon dioxide. If we are in an elevator with an air volume of 2 cubic metres, in order for the aforementioned reaction to produce enough carbon dioxide to fill the elevator (which is at a

temperature of 19°C), how much (in g) lithium carbonate and how much (in litres) hydrochloric acid 4M would we need?

31. Lithium perchlorate LiClO_4 decomposes more or less spontaneously into lithium chloride and oxygen. This is used in certain applications (such as submarines) as an emergency oxygen storage. Lithium perchlorate is a solid with a density of 2420 g/l.

Assuming a temperature of 21°C, at what pressure (in atm) would we have to store oxygen in order to have an amount of it equivalent to the oxygen released by the same volume of lithium perchlorate?

32. In a complete combustion the products are carbon dioxide and water, but in an incomplete combustion the products are carbon monoxide and water. This happens when there is not enough oxygen for complete combustion, but most often both types of combustion take place until there is nothing left of either reactant.

60g hexane burns with 200g oxygen.

- a) How much oxygen would be needed for a complete combustion of all the hexane?
- b) How much hexane will burn completely and how much will burn incompletely?
- c) How much carbon monoxide will be generated?

Answers: 1a) Sodium hydroxide. 1b) 2.41698g. 1c) 62.8748g

2a) Nitric acid. 2b) 23.7825g 2c) 27.4950g

3a) Oxygen. 3b) 84.5g 3c) 660.3g

4a) Ethanol. 4b) 5.8763g 4c) 13.3863g

5a) Water. 5b) 26.65038g 5c) 67.8497g

6a) Oxygen. 6b) 34.334g 6c) 241.45g

7a) Iron (III) oxide. 7b) 8165.05g 7c) 35671.22g

8a) Calcium carbonate. 8b) 41.7318g 8c) 775.365g

9) 40 ml

10) 0.44664g

11) 3l

12) 67.81994 ml

13) We must add 124.0 ml from the unopened bottle.

14) The molecular mass is 180.18 amu of which 39.993% is carbon, 6.7266% is hydrogen and 53.28% is oxygen.

15) It could be $\text{C}_8\text{H}_9\text{NO}_2$ but it could also be any multiplier.

16) $\text{C}_{13}\text{H}_{18}\text{O}_2$

17) $\text{C}_{13}\text{H}_{20}\text{N}_2\text{O}$

18) a) $(\text{CH})_n$ b) The molecular mass is above 94 and below 115, for example.

19) a) $\text{C}_{10}\text{H}_{12}\text{NO}$

20) $\text{C}_{15}\text{H}_{18}\text{O}_4$

21) 0.003333M

22) 0.345M

23) 0.01801M

24) 0.06144M

25) 0.0555M

26) 60.775%

27) 199.02 l

28) 2.71558mol or 5.48547g

29) 22.711 l for STP and 24.79 l for SATP

30) 5585.44g and 20.857 l

31) 1098.07 atm

32) a)211.601g b)0.57521mol and 0.12084mol c)20.3089g