

Chem 10 Chapter 8

Quantities in Chemical Reactions

Additional Practice Questions

Worked solutions at the end

Use your course periodic table and a calculator as needed. Show the setup, include units, and round at the end. Question numbers match the numbers in the solutions. Use heading navigation to move between sections.

Additional Practice Questions

Question 1

What does it mean to say that a reactant is present “in excess” in a process? Can the limiting reactant be present in excess? Does the presence of an excess reactant affect the mass of products expected?

Question 2

You heat 3.869 g of a mixture of Fe_3O_4 and FeO in oxygen to form 4.141 g Fe_2O_3 . What mass of oxygen reacted?

- A) 0.272 g
- B) 0.476 g
- C) 1.242 g
- D) 1.000 g
- E) none of these

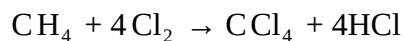
Question 3

When 233.1 g ethylene, C_2H_4 , burns completely in excess oxygen to give carbon dioxide and water, how many grams of CO_2 form?

- A) 731.4 g
- B) 365.7 g
- C) 182.9 g
- D) 8.31 g
- E) 299.4 g

Question 4

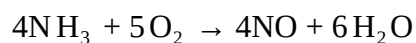
What mass of CCl_4 forms when 5.14 g methane reacts with excess chlorine?



- A) 12.3 g
- B) 0.54 g
- C) 791 g
- D) 49.3 g
- E) none of these

Question 5

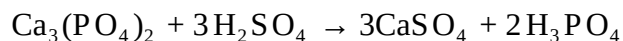
Nitric oxide, NO , is made by oxidation of NH_3 . What mass of O_2 is required to react completely with 6.85 g NH_3 ?



- A) 4.56 g O_2
- B) 10.3 g O_2
- C) 8.04 g O_2
- D) 16.1 g O_2
- E) 12.9 g O_2

Question 6

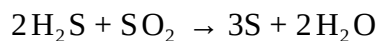
Phosphoric acid can be prepared by reaction of sulfuric acid with phosphate rock. Starting with 129 g $\text{Ca}_3(\text{PO}_4)_2$ and 97.4 g H_2SO_4 , which substance is the limiting reactant?



- A) $\text{Ca}_3(\text{PO}_4)_2$
- B) H_2SO_4
- C) CaSO_4
- D) H_3PO_4
- E) none of these

Question 7

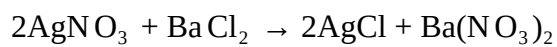
When 7.50 g H₂S reacts with 12.75 g SO₂, which statement applies?



- A) 6.38 g sulfur form.
- B) 10.6 g sulfur form.
- C) 0.0216 mol H₂S remain.
- D) 1.13 g H₂S remain.
- E) SO₂ is the limiting reactant.

Question 8

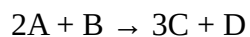
A 5.95 g sample of AgNO₃ reacts with excess BaCl₂ and produces 3.17 g AgCl. What is the percent yield?



- A) 45.0%
- B) 53.3%
- C) 31.6%
- D) 63.1%
- E) 100%

Question 9

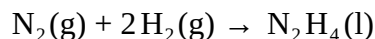
For the reaction below, 3.0 mol A and 2.0 mol B react to form 4.0 mol C. What is the percent yield?



- A) 50%
- B) 67%
- C) 75%
- D) 89%
- E) 100%

Question 10

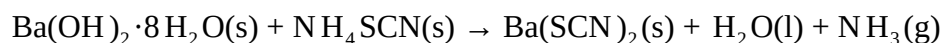
The percent yield of the reaction below is 82.0%. What actual mass of hydrazine, N_2H_4 , is produced when 25.57 g nitrogen reacts with 4.45 g hydrogen?



- A) 35.7 g N_2H_4
- B) 24.0 g N_2H_4
- C) 30.0 g N_2H_4
- D) 29.2 g N_2H_4
- E) 28.9 g N_2H_4

Question 11

One of the relatively few reactions that takes place directly between two solids at room temperature is shown below.

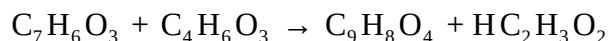


The $\cdot 8\text{H}_2\text{O}$ in $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$ means that eight water molecules are present per formula unit. This compound is barium hydroxide octahydrate.

- (a) Balance the equation.
- (b) What mass of ammonium thiocyanate, NH_4SCN , reacts completely with 6.5 g barium hydroxide octahydrate?

Question 12

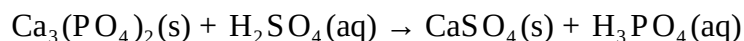
Aspirin, $\text{C}_9\text{H}_8\text{O}_4$, is synthesized by reacting salicylic acid, $\text{C}_7\text{H}_6\text{O}_3$, with acetic anhydride, $\text{C}_4\text{H}_6\text{O}_3$.



- (a) What mass of acetic anhydride is needed to consume 1.00×10^2 g salicylic acid completely?
- (b) What is the maximum mass of aspirin, the theoretical yield, that could be produced?

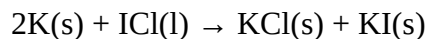
Question 13

Consider the unbalanced equation below. What masses of calcium sulfate and phosphoric acid can be produced from 1.0 kg calcium phosphate and 1.0 kg concentrated sulfuric acid that is 98% H_2SO_4 by mass?



Question 14

How much heat is liberated at constant pressure when 2.35 g potassium metal reacts with 5.68 mL liquid iodine monochloride? The density of iodine monochloride is 3.24 g/mL.



$$\Delta H = -740.71 \text{ kJ}$$

The enthalpy change is for the reaction as written, consuming 2 mol K and 1 mol ICl.

- A) $2.22 \times 10^3 \text{ kJ}$
- B) $8.40 \times 10^1 \text{ kJ}$
- C) $1.28 \times 10^2 \text{ kJ}$
- D) $2.23 \times 10^1 \text{ kJ}$
- E) $7.41 \times 10^2 \text{ kJ}$

Question 15

When 0.236 mol of a weak base, A^- , reacts with excess HCl, 6.91 kJ is released as heat. What is the enthalpy change per mole of A^- consumed?

- A) -34.2 kJ/mol A^-
- B) -59.4 kJ/mol A^-
- C) -29.3 kJ/mol A^-
- D) 34.2 kJ/mol A^-
- E) 29.3 kJ/mol A^-

Solutions

Find the solution with the same question number.

Question 1 Solution

A reactant being in excess means that there is more of it than is needed. An excess reactant by definition cannot be limiting. The expected amounts of products are determined by the limiting reactant. Therefore, adding more of a reactant that is already in excess cannot affect the expected mass of the products.

Question 2 Solution

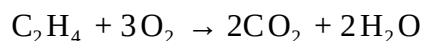
A. We do not know the composition of the Fe_3O_4 and FeO mixture, or the exact amounts involved in the reaction that gives Fe_2O_3 . It does not matter. From the law of conservation of mass:

Mass of the Fe_3O_4 and FeO mixture + mass of O_2 reacted = mass of Fe_2O_3 formed.

Mass of O_2 reacted = $4.141 \text{ g} - 3.869 \text{ g} = 0.272 \text{ g}$

Question 3 Solution

A. Oxygen is in excess, so C_2H_4 is limiting and can be used to find the answer.



Go from mass to moles, use the reaction stoichiometry, and then go from moles to mass.

$$233.1 \text{ g C}_2\text{H}_4 \times \frac{1 \text{ mol C}_2\text{H}_4}{28.06 \text{ g C}_2\text{H}_4} \times \frac{2 \text{ mol CO}_2}{1 \text{ mol C}_2\text{H}_4} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 731.2 \text{ g CO}_2$$

It is OK to have a slight difference from the correct choice in the last digit. The molar masses used here give 731.2 g, matching choice A, 731.4 g.

Question 4 Solution

D. Since Cl_2 is in excess, methane (the other reactant, CH_4) is limiting. The mass of CCl_4 formed is determined by the mass of CH_4 .

$M(\text{CH}_4) = 16.04 \text{ g/mol}$

$M(\text{CCl}_4) = 153.81 \text{ g/mol}$

$$5.14 \text{ g CH}_4 \times \frac{1 \text{ mol CH}_4}{16.04 \text{ g CH}_4} \times \frac{1 \text{ mol CCl}_4}{1 \text{ mol CH}_4} \times \frac{153.81 \text{ g CCl}_4}{1 \text{ mol CCl}_4} = 49.3 \text{ g CCl}_4$$

The middle conversion factor is the reaction stoichiometry.

Question 5 Solution

D. Convert grams of NH_3 to moles, use the 5-to-4 mole ratio, and then convert moles of O_2 to grams.

$$6.85 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.03 \text{ g NH}_3} \times \frac{5 \text{ mol O}_2}{4 \text{ mol NH}_3} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 16.1 \text{ g O}_2$$

Question 6 Solution

B. The molar masses are 310.18 g/mol for $\text{Ca}_3(\text{PO}_4)_2$ and 98.09 g/mol for H_2SO_4 . Find the moles of reactants present, then find the limiting reactant by dividing each by its respective coefficient in the reaction.

$$n(\text{Ca}_3(\text{PO}_4)_2) = \frac{129 \text{ g}}{310.18 \text{ g/mol}} = 0.416 \text{ mol}$$

$$n(\text{H}_2\text{SO}_4) = \frac{97.4 \text{ g}}{98.09 \text{ g/mol}} = 0.993 \text{ mol}$$

$$\text{Ca}_3(\text{PO}_4)_2: \frac{0.416}{1} = 0.416$$

$$\text{H}_2\text{SO}_4: \frac{0.993}{3} = 0.331$$

The value for H_2SO_4 is smaller, so it is the limiting reactant.

Question 7 Solution

B. First determine which reactant is limiting. Convert each mass to moles, then divide by its coefficient.

$$\text{H}_2\text{S}: 7.50 \text{ g} \times \frac{1 \text{ mol}}{34.08 \text{ g}} = 0.2201 \text{ mol}$$

$$\frac{0.2201}{2} = 0.1100$$

$$\text{SO}_2: 12.75 \text{ g} \times \frac{1 \text{ mol}}{64.066 \text{ g}} = 0.1990 \text{ mol}$$

$$\frac{0.1990}{1} = 0.1990$$

The value for H_2S is smaller, so H_2S is limiting. Since H_2S is limiting, none of it remains when the reaction is complete. This eliminates choices C, D, and E.

Determine the mass of sulfur formed from 7.50 g of the limiting reactant. We already calculated the moles of H_2S , so we can start there.

$$0.2201 \text{ mol H}_2\text{S} \times \frac{3 \text{ mol S}}{2 \text{ mol H}_2\text{S}} \times \frac{32.065 \text{ g S}}{1 \text{ mol S}} = 10.6 \text{ g S}$$

Question 8 Solution

D. Use molar masses of 169.9 g/mol for AgNO_3 and 143.4 g/mol for AgCl . First find the theoretical yield.

$$5.95 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.9 \text{ g AgNO}_3} \times \frac{2 \text{ mol AgCl}}{2 \text{ mol AgNO}_3} \times \frac{143.4 \text{ g AgCl}}{1 \text{ mol AgCl}} = 5.02 \text{ g AgCl}$$

$$\text{Percent yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

$$\text{Percent yield} = \frac{3.17 \text{ g}}{5.02 \text{ g}} \times 100 = 63.1\%$$

Question 9 Solution

D. We are already given the moles of reactants. Find the limiting reactant by dividing the mole quantities by their respective coefficients.

$$\text{A: } \frac{3.0}{2} = 1.5$$

$$\text{B: } \frac{2.0}{1} = 2.0$$

The value for A is smaller, so A is limiting. The theoretical yield is calculated using the limiting reactant's amount.

$$3.0 \text{ mol A} \times \frac{3 \text{ mol C}}{2 \text{ mol A}} = 4.5 \text{ mol C}$$

$$\text{Percent yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

$$\text{Percent yield} = \frac{4.0 \text{ mol C}}{4.5 \text{ mol C}} \times 100 = 89\%$$

Question 10 Solution

B. First determine the limiting reactant. Convert the reactant masses to moles and divide by their coefficients in the reaction equation.

$$\text{N}_2: 25.57 \text{ g} \times \frac{1 \text{ mol}}{28.02 \text{ g}} = 0.9126 \text{ mol}$$

$$\frac{0.9126}{1} = 0.9126$$

$$\text{H}_2: 4.45 \text{ g} \times \frac{1 \text{ mol}}{2.02 \text{ g}} = 2.20 \text{ mol}$$

$$\frac{2.20}{2} = 1.10$$

N₂ is limiting. Based on its amount and the reaction stoichiometry, calculate the ideal amount of N₂H₄ that would be produced.

$$0.9126 \text{ mol N}_2 \times \frac{1 \text{ mol N}_2\text{H}_4}{1 \text{ mol N}_2} \times \frac{32.05 \text{ g N}_2\text{H}_4}{1 \text{ mol N}_2\text{H}_4} = 29.25 \text{ g N}_2\text{H}_4$$

Use the definition of percent yield and solve for the actual yield.

$$\text{Percent yield} = \frac{\text{Actual yield}}{\text{Ideal yield}} \times 100$$

$$\text{Actual yield} = 29.25 \text{ g} \times \frac{82.0}{100} = 24.0 \text{ g N}_2\text{H}_4$$

Question 11 Solution

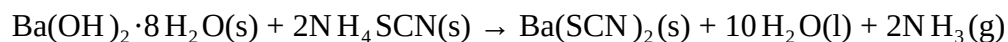
(a) It is useful to pay attention to what is going on in the reaction.

SCN⁻ (thiocyanate) is staying intact because we see it occur on both sides. There is a chance that some of the SCN⁻ might be doing more, but it is worth trying to see if the simple case is true.

H₂O also occurs on both sides of the reaction, as “crystal water” on the reactant side and ordinary water on the product side. While there is a chance that some crystal waters might have done more than simply get freed from Ba(OH)₂, it is worth trying the simple case.

It looks like the OH⁻ (hydroxide) groups grabbed an H⁺ from the NH₄⁺ (ammonium) groups and became H₂O, adding to the freed crystal waters.

We need two SCN⁻ groups on the reactant side to balance. That leads to two NH₄⁺ groups giving one H⁺ each to the two OH⁻ groups. These become two H₂O molecules in addition to the eight freed crystal waters.



(b) We need molar masses to go from grams to moles and back.

$$M(\text{NH}_4\text{SCN}) = 2(14.01) + 4(1.01) + 32.07 + 12.01 = 76.14 \text{ g/mol}$$

$$M(\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}) = 137.3 + 2(16.00 + 1.01) + 8[2(1.01) + 16.00]$$

$$M(\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}) = 315.48 \text{ g/mol}$$

$$6.5 \text{ g Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O} \times \frac{1 \text{ mol Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}}{315.48 \text{ g Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}} \\ \times \frac{2 \text{ mol NH}_4\text{SCN}}{1 \text{ mol Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}} \times \frac{76.14 \text{ g NH}_4\text{SCN}}{1 \text{ mol NH}_4\text{SCN}} = 3.1 \text{ g NH}_4\text{SCN}$$

Question 12 Solution

To use stoichiometry, we need to go from grams to moles first, then back to grams if needed. So we need molar masses.

$$M(\text{C}_7\text{H}_6\text{O}_3) = 7(12.01) + 6(1.01) + 3(16.00) = 138.13 \text{ g/mol}$$

$$M(\text{C}_4\text{H}_6\text{O}_3) = 4(12.01) + 6(1.01) + 3(16.00) = 102.10 \text{ g/mol}$$

$$M(\text{C}_9\text{H}_8\text{O}_4) = 9(12.01) + 8(1.01) + 4(16.00) = 180.17 \text{ g/mol}$$

(a) The mole ratio of acetic anhydride to salicylic acid is 1:1.

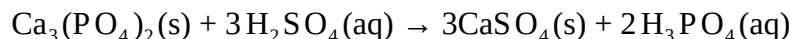
$$1.00 \times 10^2 \text{ g C}_7\text{H}_6\text{O}_3 \times \frac{1 \text{ mol C}_7\text{H}_6\text{O}_3}{138.13 \text{ g C}_7\text{H}_6\text{O}_3} \\ \times \frac{1 \text{ mol C}_4\text{H}_6\text{O}_3}{1 \text{ mol C}_7\text{H}_6\text{O}_3} \times \frac{102.10 \text{ g C}_4\text{H}_6\text{O}_3}{1 \text{ mol C}_4\text{H}_6\text{O}_3} = 73.9 \text{ g C}_4\text{H}_6\text{O}_3$$

(b) The mole ratio of aspirin to salicylic acid is also 1:1.

$$1.00 \times 10^2 \text{ g C}_7\text{H}_6\text{O}_3 \times \frac{1 \text{ mol C}_7\text{H}_6\text{O}_3}{138.13 \text{ g C}_7\text{H}_6\text{O}_3} \\ \times \frac{1 \text{ mol C}_9\text{H}_8\text{O}_4}{1 \text{ mol C}_7\text{H}_6\text{O}_3} \times \frac{180.17 \text{ g C}_9\text{H}_8\text{O}_4}{1 \text{ mol C}_9\text{H}_8\text{O}_4} = 1.30 \times 10^2 \text{ g C}_9\text{H}_8\text{O}_4$$

Question 13 Solution

First we need to balance the reaction equation. The PO_4^{3-} and SO_4^{2-} groups travel together, so we can keep track of them as entities. We can start by balancing Ca and propagate the consequences: 3 in front of CaSO_4 dictates 3 in front of H_2SO_4 to balance the sulfate groups, and so on.



We are given masses of both reactants, so we need to convert to moles and find which is limiting. We are not simply looking for the amount of one reactant just sufficient to react with a stated amount of the other. Arbitrary starting masses usually result in one reactant being limiting.

$$M(\text{Ca}_3(\text{PO}_4)_2) = 3(40.08) + 2[30.97 + 4(16.00)] = 310.18 \text{ g/mol}$$

$$M(\text{H}_2\text{SO}_4) = 2(1.01) + 32.07 + 4(16.00) = 98.09 \text{ g/mol}$$

$$M(\text{CaSO}_4) = 40.08 + 32.07 + 4(16.00) = 136.15 \text{ g/mol}$$

$$M(\text{H}_3\text{PO}_4) = 3(1.01) + 30.97 + 4(16.00) = 98.00 \text{ g/mol}$$

$$n(\text{Ca}_3(\text{PO}_4)_2) = 1.0 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol}}{310.18 \text{ g}} = 3.2 \text{ mol}$$

Moles of H_2SO_4 needed to react with this calcium phosphate:

$$3.2 \text{ mol Ca}_3(\text{PO}_4)_2 \times \frac{3 \text{ mol H}_2\text{SO}_4}{1 \text{ mol Ca}_3(\text{PO}_4)_2} = 9.6 \text{ mol H}_2\text{SO}_4$$

The concentrated acid contains 98% H_2SO_4 by mass. Its available amount is:

$$1.0 \text{ kg solution} \times \frac{1000 \text{ g solution}}{1 \text{ kg solution}} \times \frac{98 \text{ g H}_2\text{SO}_4}{100 \text{ g solution}} = 980 \text{ g H}_2\text{SO}_4$$

$$n(\text{H}_2\text{SO}_4) = \frac{980 \text{ g}}{98.09 \text{ g/mol}} = 9.99... \text{ mol}$$

H_2SO_4 is in excess because we have about 10 mol, more than the amount needed.

$\text{Ca}_3(\text{PO}_4)_2$ is the limiting reactant.

$$3.2 \text{ mol Ca}_3(\text{PO}_4)_2 \times \frac{3 \text{ mol CaSO}_4}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{136.15 \text{ g CaSO}_4}{1 \text{ mol CaSO}_4} = 1.3 \times 10^3 \text{ g CaSO}_4$$

$$3.2 \text{ mol Ca}_3(\text{PO}_4)_2 \times \frac{2 \text{ mol H}_3\text{PO}_4}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{98.00 \text{ g H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} = 6.3 \times 10^2 \text{ g H}_3\text{PO}_4$$

Keeping the unrounded intermediate amount, $1000/310.18 \text{ mol}$, gives the same final rounded answers.

Question 14 Solution

D. First determine the limiting reactant.

$$n(\text{K}) = 2.35 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.0601 \text{ mol K}$$

$$\frac{0.0601}{2} = 0.0300$$

For ICl, density times volume gives mass.

$$n(\text{ICl}) = 3.24 \text{ g/mL} \times 5.68 \text{ mL} \times \frac{1 \text{ mol ICl}}{162.36 \text{ g ICl}} = 0.113 \text{ mol ICl}$$

$$\frac{0.113}{1} = 0.113$$

The value for K is smaller, so K is limiting.

We treat the enthalpy change given with the reaction equation in the same way as the substances involved. We can use reaction stoichiometry to find heat evolved or absorbed when a given amount of limiting reactant reacts.

$$q = 2.35 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} \times \frac{-740.71 \text{ kJ}}{2 \text{ mol K}} = -2.23 \times 10^1 \text{ kJ}$$

Heat liberated is the negative of the reaction's enthalpy change: $2.23 \times 10^1 \text{ kJ}$, or 22.3 kJ , is released.

Question 15 Solution

C. We do not need to construct the reaction equation. All we need to know is how much heat is released per mole of A^- .

We also need to remember that "heat released" has the opposite sign of the enthalpy change. A positive enthalpy change means heat is added to the system. A positive amount of heat released means heat is removed, and the corresponding enthalpy change is negative.

$$\Delta H \text{ per mole } \text{A}^- = \frac{-6.91 \text{ kJ}}{0.236 \text{ mol } \text{A}^-} = -29.3 \text{ kJ/mol } \text{A}^-$$