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FACULTY OF EDUCATION

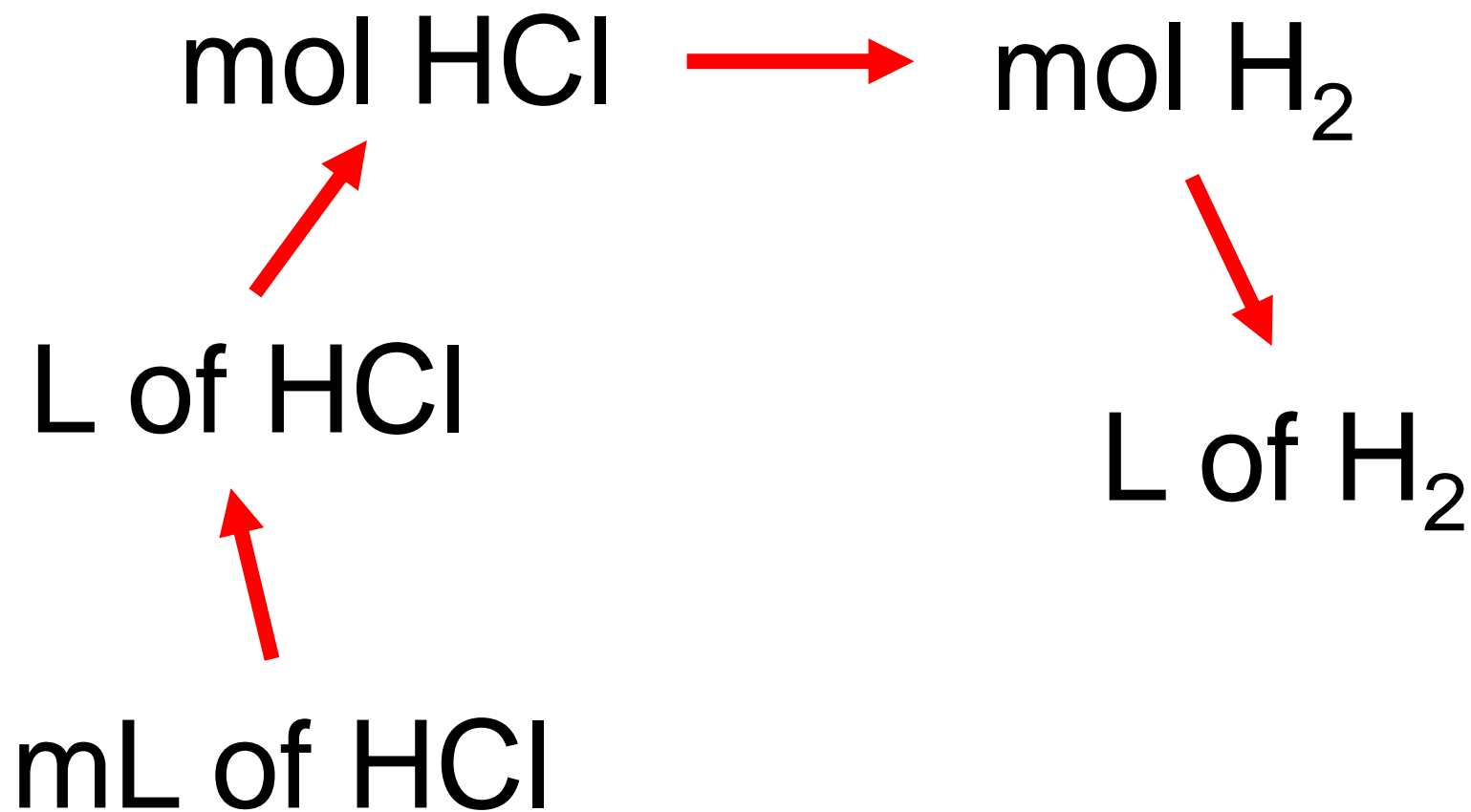
Department of  
Curriculum and Pedagogy

# Chemistry

# Stoichiometry

Science and Mathematics  
Education Research Group

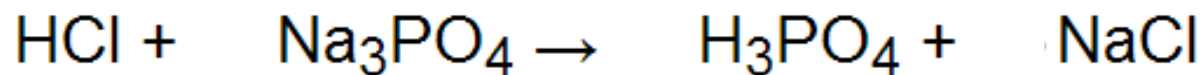
# Stoichiometry



# Stoichiometry I

Balance the following chemical equation.

What is the coefficient of  $\text{Na}_3\text{PO}_4$ ?

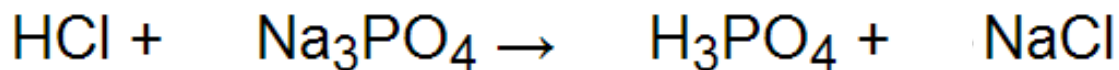


- A. 0
- B. 1
- C. 2
- D. 3
- E. 4

# Solution

**Answer:** B

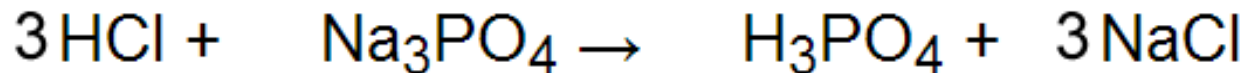
**Justification:** To balance the chemical equation, you need to determine how many of each part you have on either side of the equation and multiply by coefficients to make all parts equal on both sides.



H: 1    Cl: 1    Na: 3    PO<sub>4</sub>: 1  
x3

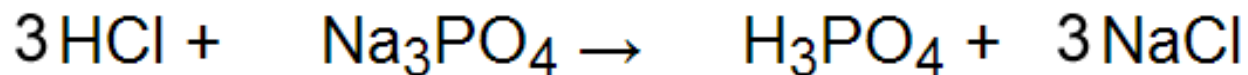
H: 3    Cl: 1    Na: 1    PO<sub>4</sub>: 1  
x3

The balanced chemical equation is thus:



Though nothing is written in front of Na<sub>3</sub>PO<sub>4</sub>, the coefficient of 1 is implied. The coefficient is not 0, as that would mean that no Na<sub>3</sub>PO<sub>4</sub> would be used.

# Stoichiometry II



If you have 4.5 g of HCl, how many moles of HCl would you have?

- A. 0.37 mol
- B.  $1.6 \times 10^2$  mol
- C. 0.12 mol
- D. 3.0 mol
- E. None of the above

# Solution

**Answer:** C

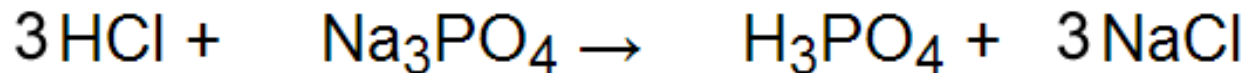
**Justification:** The molar mass of HCl is 36.5 g/mol. Thus, the calculation to convert grams to moles is:

$$4.5 \cancel{g} \text{ HCl} \times \frac{1 \text{ mol HCl}}{36.5 \cancel{g}} = 0.12 \text{ mol HCl}$$

A and D are incorrect because the coefficient (3) was used in the calculation. The coefficient is not needed to determine how many moles of a substance you have. Rather, it tells you the ratio of how much of each reactant will react with each other and how much of the product will be formed.

You would get B if you inversed the molar mass in the calculation.

# Stoichiometry III



Knowing that you have 0.12 mol of HCl, what conversion factor would you use to determine how many moles of  $\text{H}_3\text{PO}_4$  you would produce?

A.  $\frac{1 \text{ mol}}{98.0 \text{ g H}_3\text{PO}_4}$

B.  $\frac{3 \text{ mol H}_3\text{PO}_4}{1 \text{ mol HCl}}$

C.  $\frac{3 \text{ mol HCl}}{1 \text{ mol H}_3\text{PO}_4}$

D.  $\frac{98.0 \text{ g H}_3\text{PO}_4}{1 \text{ mol}}$

E.  $\frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$

# Solution

**Answer:** E

**Justification:** To determine the amount of product produced from a reactant, you need to use the mole ratio between the reactant and product as a conversion factor.

A and D are incorrect because they are the molar mass of  $\text{H}_3\text{PO}_4$ . To convert from moles of a reactant to moles of a product, you need the mole ratio not the molar mass.

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# Solution

**Answer:** E

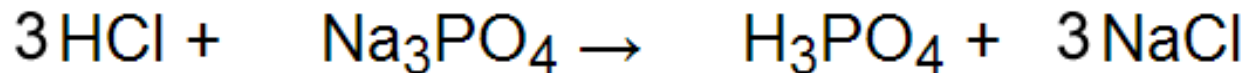
**Justification:** B is an incorrect mole ratio. Based on the balanced equation, we know that there would be 1 mol of  $\text{H}_3\text{PO}_4$  for every 3 moles of HCl; not the other way around.

C is incorrect because the mole ratio is inverted so that the units wouldn't cancel out.

The correct answer is shown below:

$$0.12 \text{ mol HCl} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$$

# Stoichiometry IV



Knowing that you have 0.12 mol of HCl, how many moles of NaCl would you produce?

- A. 3.0 mol
- B. 0.04 mol
- C. 1.0 mol
- D. 0.12 mol
- E. None of the above

# Solution

**Answer:** D

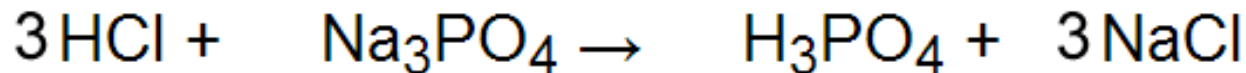
**Justification:** The mole ratio between HCl and NaCl is a 3:3 ratio (or 1:1). Thus the amount of moles of HCl that you start with would be the same as the amount of moles of NaCl that would be produced.

$$0.12 \text{ mol HCl} \times \frac{3 \text{ mol NaCl}}{3 \text{ mol HCl}} = 0.12 \text{ mol NaCl}$$

You would get B if you used the same 3:1 mole ratio from the last question.

A and C are incorrect because the values in the mole ratios do not tell you how many moles will be produced. Rather they tell you how much product relative to another substance will be produced.

# Stoichiometry V



What is the best way to write out a single calculation to determine how to go from 4.5 g of HCl to moles of  $\text{H}_3\text{PO}_4$  produced?

A.  $4.5 \text{ g HCl} \times \frac{\text{mol HCl}}{36.5 \text{ g/mol}} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$

B.  $\frac{4.5 \text{ g HCl}}{3 \text{ mol HCl}} \times \frac{\text{mol HCl}}{36.5 \text{ g}} \times 1 \text{ mol H}_3\text{PO}_4$

C.  $\frac{4.5 \text{ g HCl}}{36.5 \text{ g/mol HCl}} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$

D.  $4.5 \text{ g} \times \frac{1 \text{ mol}}{36.5 \text{ g}} \times \frac{1 \text{ mol}}{3 \text{ mol}}$

E. None of the above

# Solution

**Answer:** E

**Justification:** To do the calculation in one step you would multiply all of the individual conversion factors and mole ratios together one after the other.

All of these answers will get the correct answer, however the best way of writing out the steps was not an option. The best practice method is shown below:

$$4.5 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$$

Notice how each fraction is a different conversion factor.

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# Solution

**Answer:** E

**Justification:** It is important to use the proper method when writing out stoichiometry calculations so that it becomes easier to see what conversion factors were used, how the units cancel out and to identify which compound each conversion factor refers to (since the compounds are explicitly written in).

Notice that in the other answers, one or both of these objectives is not achieved.

$$\text{A. } 4.5 \text{ g HCl} \times \frac{\text{mol HCl}}{36.5 \text{ g/mol}} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$$

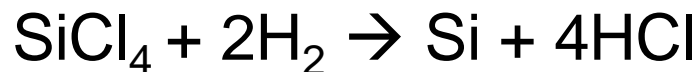
$$\text{B. } \frac{4.5 \text{ g HCl}}{3 \text{ mol HCl}} \times \frac{\text{mol HCl}}{36.5 \text{ g}} \times 1 \text{ mol H}_3\text{PO}_4$$

$$\text{C. } \frac{4.5 \text{ g HCl}}{36.5 \text{ g/mol HCl}} \times \frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol HCl}}$$

$$\text{D. } 4.5 \text{ g} \times \frac{1 \text{ mol}}{36.5 \text{ g}} \times \frac{1 \text{ mol}}{3 \text{ mol}}$$

E. None of the above

# Stoichiometry VI



To find out the mass (in grams) of HCl produced by reacting 5.0 moles of H<sub>2</sub>, you would first multiply 5.0 moles of H<sub>2</sub> by:

A.  $\frac{1 \text{ mol H}_2}{2 \text{ mol HCl}}$

B.  $\frac{4 \text{ mol HCl}}{2 \text{ mol H}_2}$

C.  $\frac{2 \text{ mol HCl}}{4 \text{ mol H}_2}$

D.  $\frac{36.5 \text{ g HCl}}{1 \text{ mol HCl}}$

E.  $\frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}}$

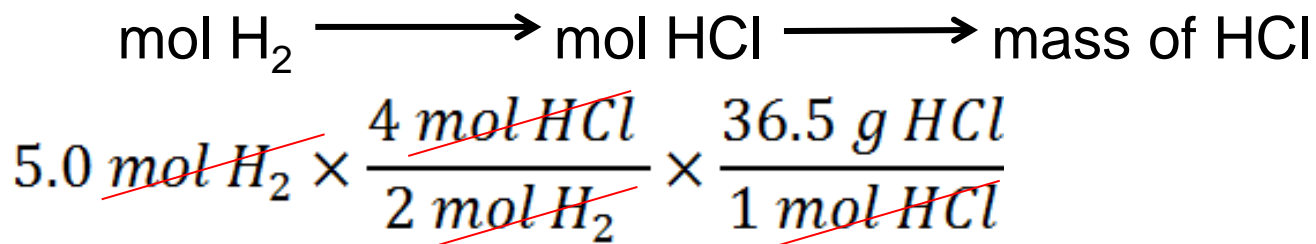
# Solution

**Answer:** B

**Justification:** D and E are incorrect because to determine the amount of product produced from the amount of a reactant. In questions like this, you always need to go through the mole ratio. After that you can use the molar mass of the product to determine the mass in grams produced.

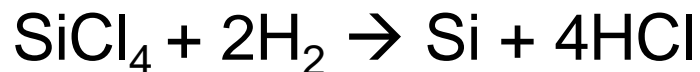
Instead of using a 4:2 ratio, you could also simplify it to a 2:1 ratio. A is incorrect however, because the ratio is inverted and the unit would not cancel.

To solve this question the sequence is:





# Stoichiometry VII



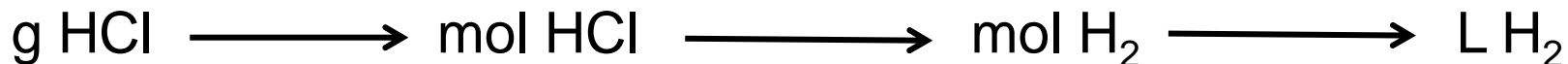
What conversion factors (in the correct order that you would multiply them) would you use in order to determine how many liters of  $\text{H}_2$  gas you would need to react to produce 25 g of  $\text{HCl}$  (at STP)?

- A. Mass of  $\text{HCl}$  / mole ratio between  $\text{HCl}$  and  $\text{H}_2$  / molar mass of  $\text{H}_2$
- B. Molar mass of  $\text{HCl}$  / molar mass of  $\text{H}_2$  / molar volume of  $\text{H}_2$
- C. Mass of  $\text{HCl}$  / mole ratio between  $\text{HCl}$  and  $\text{H}_2$  / molar volume of  $\text{H}_2$
- D. Molar mass of  $\text{HCl}$  / mole ratio between  $\text{HCl}$  and  $\text{H}_2$  / molar volume of  $\text{H}_2$
- E. None of the above

# Solution

**Answer:** D

**Justification:** The conversions that need to occur to convert the grams of the product into the volume of the reactant would be:



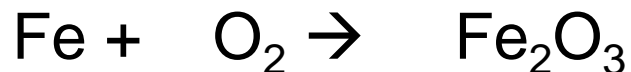
The conversion factors to achieve this are thus:

molar mass of HCl          mole ratio          molar volume of H<sub>2</sub>

A and C are not correct because the mass of HCl is not a conversion factor needed in this question.

B is incorrect because it does not include the mole ratio, which is needed to convert from one substance to another in a chemical reaction.

# Stoichiometry VIII



Rust ( $\text{Fe}_2\text{O}_3$ ) forms on iron according to the above unbalanced equation.

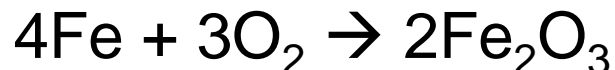
How much iron would have had to be reacted to form 10.0 g of rust?

- A. 3.50 g
- B. 14.3 g
- C. 10.0 g
- D. 7.0 g
- E. None of the above

# Solution

**Answer:** D

**Justification:** The balanced chemical equation is:



To determine the mass of Fe, the mass of rust had to be converted as shown below:

g of rust  $\rightarrow$  mol of rust  $\rightarrow$  mol of Fe  $\rightarrow$  g of Fe

$$10.0 \text{ g } \text{Fe}_2\text{O}_3 \times \frac{1 \text{ mol } \text{Fe}_2\text{O}_3}{159.7 \text{ g}} \times \frac{4 \text{ mol } \text{Fe}}{2 \text{ mol } \text{Fe}_2\text{O}_3} \times \frac{55.8 \text{ g } \text{Fe}}{1 \text{ mol } \text{Fe}} = 7.0 \text{ g } \text{Fe}$$

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# Solution

**Answer:** D

**Justification:** You would have gotten A if you did not balance the chemical equation or if you did not use the mole ratio in the calculation.

You would have gotten B if you had used the mass provided and tried to go “forwards” in the calculation as opposed to going “backwards”.

g of Fe  $\rightarrow$  mol of Fe  $\rightarrow$  mol of rust  $\rightarrow$  g of rust

as opposed to

g of Fe  $\leftarrow$  mol of Fe  $\leftarrow$  mol of rust  $\leftarrow$  g of rust

C is wrong since you can't make the assumption that you will end up with the same amount of product that you had of the reactant.

# Stoichiometry IX

Hydrochloric acid reacts with solid magnesium to form magnesium chloride and hydrogen gas.

If 25.0 mL of a 0.20 M solution of hydrochloric acid was used in this reaction, what volume of hydrogen gas would be produced (at STP)?

- A. 56.0 L
- B. 0.0560 L
- C. 0.28 L
- D. 0.005 L
- E. None of the above

# Solution

**Answer:** B

**Justification:** The balanced chemical equation is:



To determine the volume of  $\text{H}_2$ , the volume of  $\text{HCl}$  had to be converted as shown below:

mL of  $\text{HCl}$   $\rightarrow$  L of  $\text{HCl}$   $\rightarrow$  mol  $\text{HCl}$   $\rightarrow$  mol  $\text{H}_2$   $\rightarrow$  L of  $\text{H}_2$

$$25.0 \text{ mL HCl} \cdot \frac{1 \text{ L}}{1000 \text{ mL}} \cdot \frac{0.2 \text{ mol HCl}}{1 \text{ L}} \cdot \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}} \cdot \frac{22.4 \text{ L}}{1 \text{ mol H}_2}$$

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# Solution

**Answer:** B

**Justification:** You would have gotten A if you did not convert mL to L.

You would have gotten C if you did not use the concentration of HCl to convert the volume into moles. Remember, you must go through moles of a substance to determine the amount of moles of another substance.

You would have gotten D if you used the molar mass of  $H_2$  instead of the molar volume of the gas as the final conversion factor. Remember to read the questions carefully. Not, every stoichiometry calculation needs the molar mass.