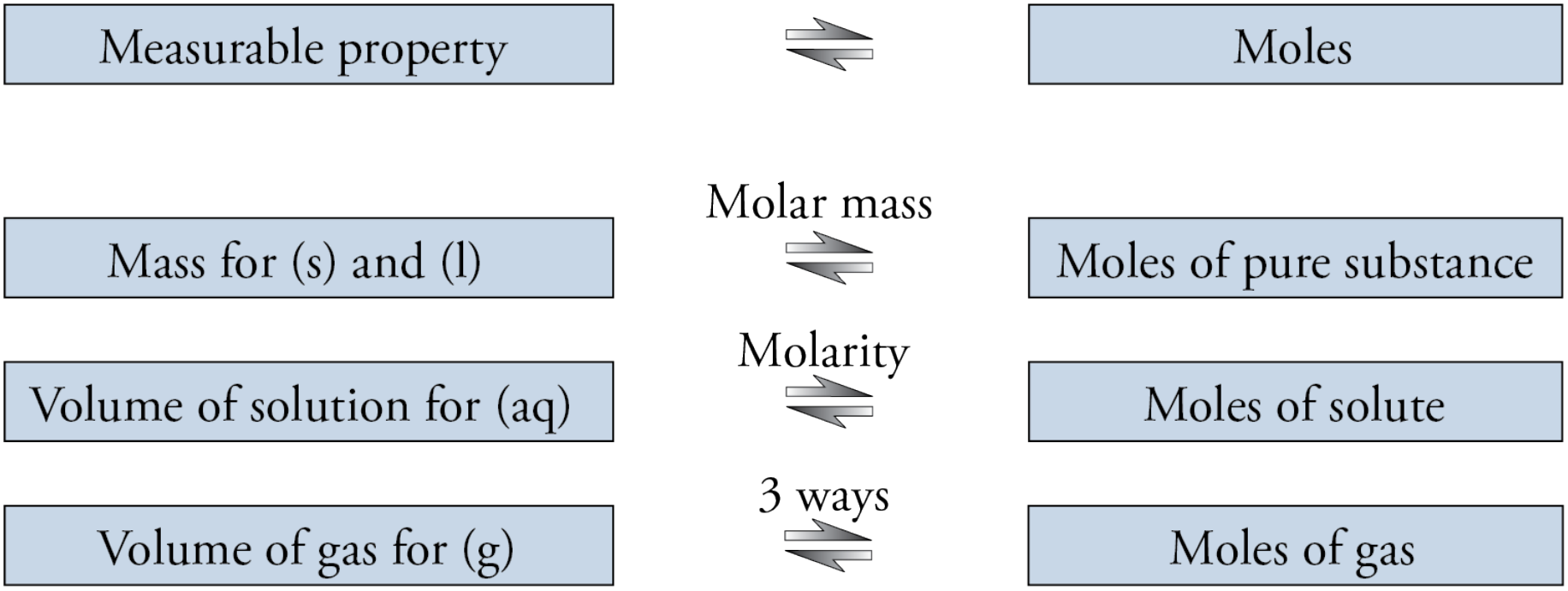
Measurable Property and Moles



Conversion between moles and volume of gas

- Using molar volume at STP (only for STP, which is rare)
- Using the Ideal Gas Equation

$$n = \frac{PV}{RT} \qquad V = \frac{nRT}{P}$$

- R as a conversion factor

$$\frac{\text{K•mol}}{8.3145\ \text{L•kPa}} \quad \text{or} \quad \frac{8.3145\ \text{L•kPa}}{\text{K•mol}}$$

$$\frac{\text{K•mol}}{0.082058\ \text{L•atm}} \quad \text{or} \quad \frac{0.082058\ \text{L•atm}}{\text{K•mol}}$$

Standard Temperature and Pressure (STP) and Molar Volume

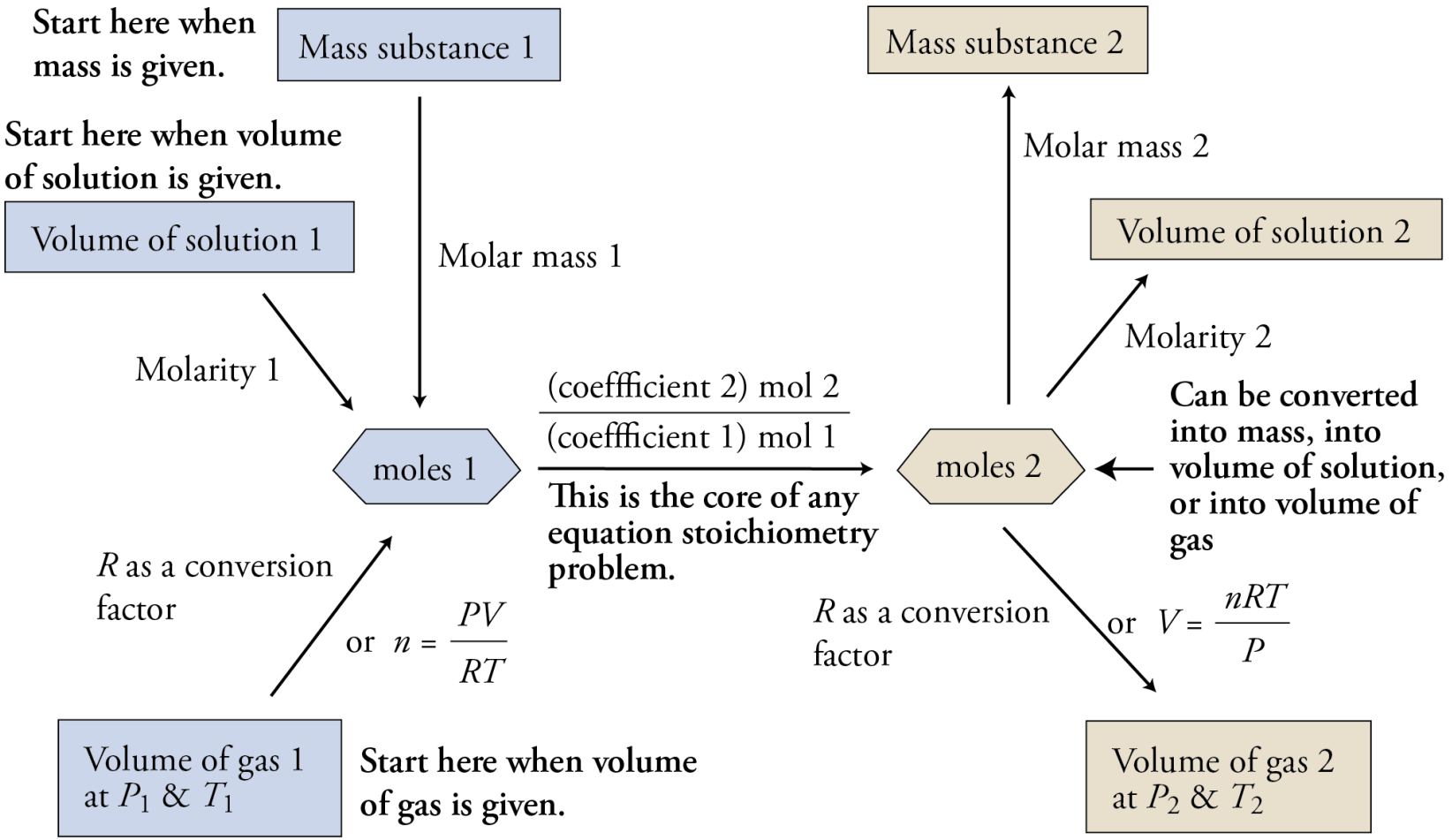
- **Common:** 0 ºC (273.15 K) and 1 atm

$$\frac{V}{n} = \frac{RT}{P} = \frac{\left(\frac{8.3145\ \text{L}\cdot\cancel{\text{kPa}}}{\cancel{\text{K}}\cdot\text{mol}}\right)(273.15\ \cancel{\text{K}})}{101.325\ \cancel{\text{kPa}}} = \left(\frac{22.414\ \text{L}}{1\ \text{mol}}\right)_{\text{STP}}$$

- **Correct:** 0 ºC (273.15 K) and 1 bar (100 kPa)

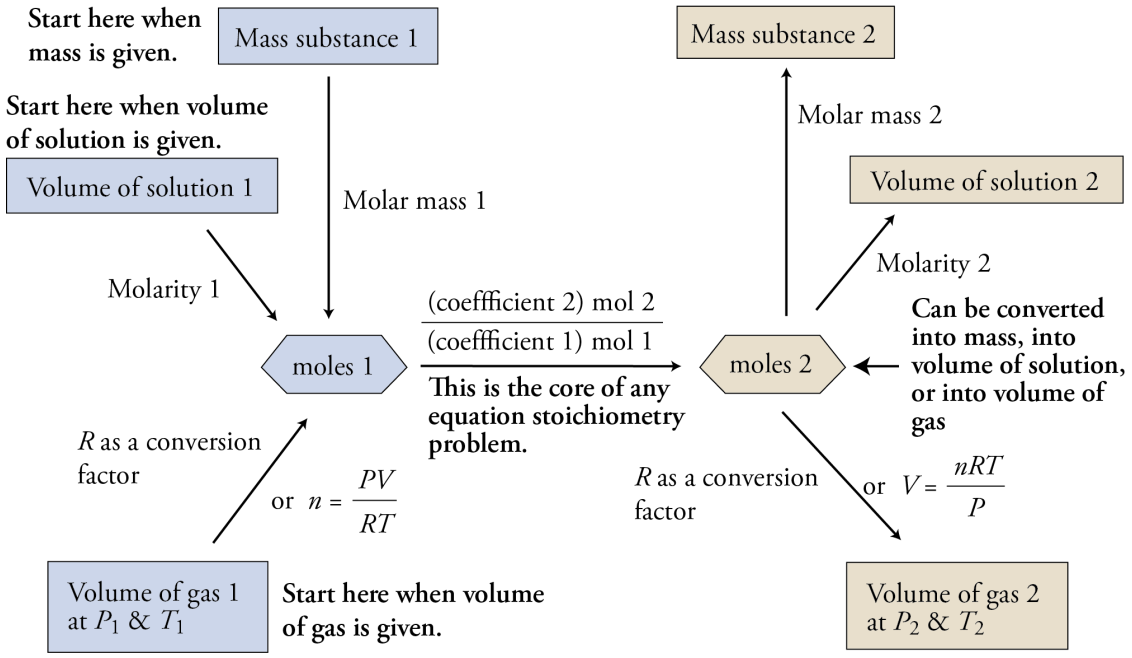
$$\frac{V}{n} = \frac{RT}{P} = \frac{\left(\frac{8.3145\ \text{L}\cdot\cancel{\text{kPa}}}{\cancel{\text{K}}\cdot\text{mol}}\right)(273.15\ \cancel{\text{K}})}{100\ \cancel{\text{kPa}}} = \left(\frac{22.711\ \text{L}}{1\ \text{mol}}\right)_{\text{STP}}$$

Equation Stoichiometry



Example 1

Iron is combined with carbon in a series of reactions to form pig iron, which is about 4.3% carbon. The first step in this process is the reaction of carbon with oxygen to form carbon monoxide. For this reaction, what is the maximum volume of carbon monoxide at 105 kPa and 35 ºC that could form from the conversion of 8.74×10^5 L of oxygen at 99.4 kPa and 27 ºC?



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- Conversion from units of one substance to units of another substance, both involved in a chemical equation, so it's equation stoichiometry.
- Write a balanced equation.

$$2C + O_2 \rightarrow 2CO$$

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$$2C + O_2 \rightarrow 2CO$$

- Convert from the units of substance 1 you have to moles substance 1.

$$n_{O_2} = \frac{PV}{RT} = \frac{99.4\ \cancel{kPa}\ (8.74 \times 10^5\ \cancel{L})}{\left(\frac{8.3145\ \cancel{L}\cdot\cancel{kPa}}{\cancel{K}\cdot mol}\right)(300\ \cancel{K})} = 3.48 \times 10^4\ mol\ O_2$$

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- Convert from moles of substance 1 to moles substance 2.

$$?\ mol\ CO = 3.48 \times 10^4\ \cancel{mol\ O_2}\left(\frac{2\ mol\ CO}{1\ \cancel{mol\ O_2}}\right) = 6.96 \times 10^4\ mol\ CO$$

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- Convert from the moles of substance 2 to units of substance 2 that you want.

$$V_{CO} = \frac{nRT}{P} = \frac{6.96 \times 10^4 \cancel{\text{mol}} \left(\frac{8.3145 \text{ L} \cdot \cancel{\text{kPa}}}{\cancel{\text{K}} \cdot \cancel{\text{mol}}} \right) 308 \cancel{\text{K}}}{105 \cancel{\text{kPa}}} = 1.70 \times 10^6 \text{ L CO}$$

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- Or unit analysis, using R as a conversion factor.

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$$= 1.70 \times 10^6 \text{ L CO}$$

Example 2

In the reaction of carbon with oxygen to form carbon monoxide, what minimum volume of oxygen at STP (273.15 K and 1 bar) is necessary to convert 125 Mg of carbon to carbon monoxide?

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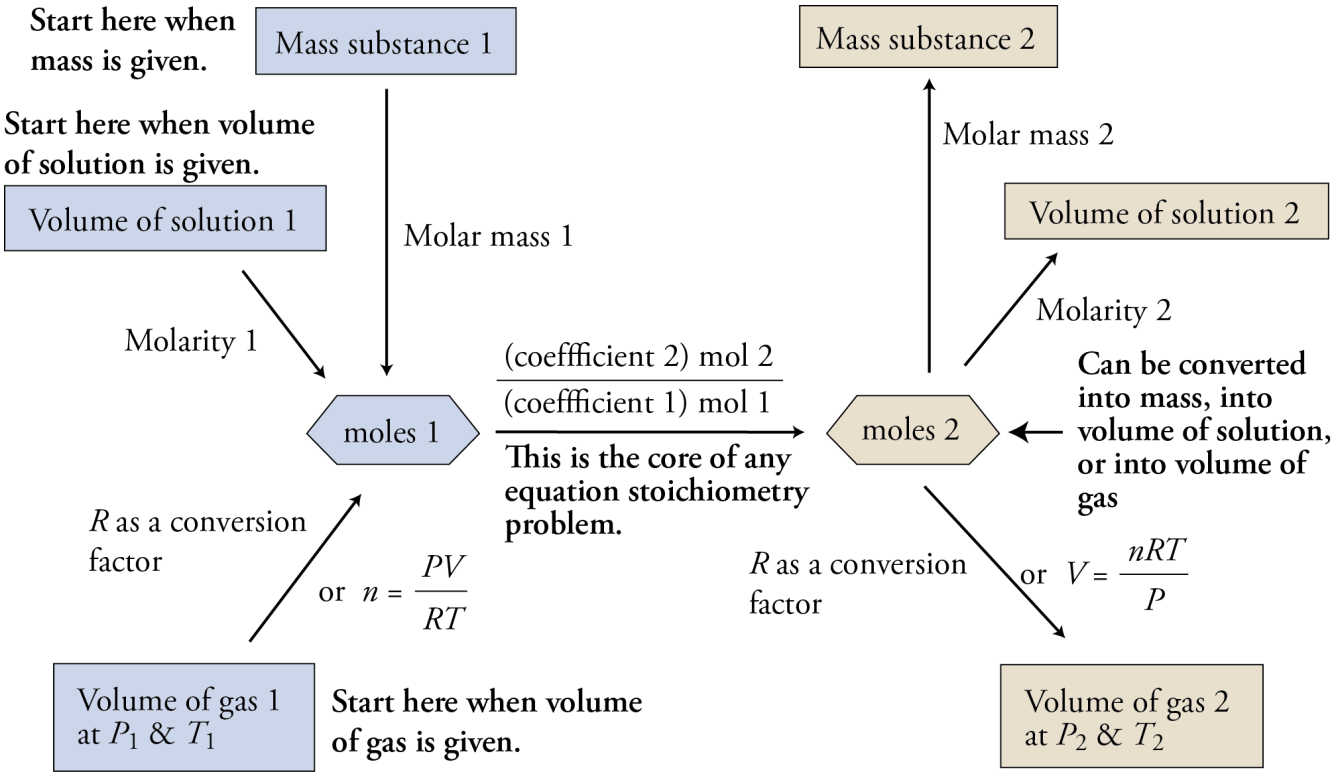

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$$? \text{ L } O_2 = 125 \text{ Mg } C \left(\frac{10^6 \text{ g}}{1 \text{ Mg}}\right)\left(\frac{1 \text{ mol } C}{12.011 \text{ g } C}\right)\left(\frac{1 \text{ mol } O_2}{2 \text{ mol } C}\right)\left(\frac{22.711 \text{ L } O_2}{1 \text{ mol } O_2}\right)_{STP}$$

$$= \mathbf{1.18 \times 10^5 \text{ L } O_2}$$

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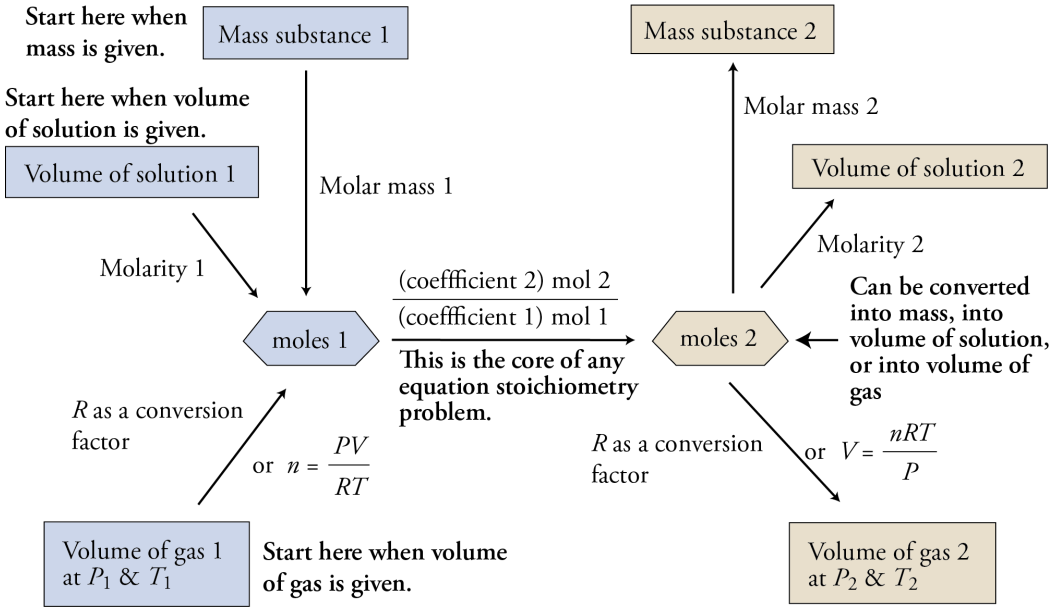
$$= \mathbf{1.18 \times 10^5 \text{ L } O_2}$$

Example 3

Sodium hypochlorite, NaOCl, found in household bleaches, can be made from a reaction using chlorine gas and aqueous sodium hydroxide:

$$Cl_2(g) + 2NaOH(aq) \rightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$$

What minimum volume of chlorine gas at 101.4 kPa and 18.0 ºC must be used to react with all the sodium hydroxide in 3525 L of 12.5 M NaOH?



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$$? \text{ L } Cl_2 = 3525 \text{ ~~L NaOH soln~~} \left(\frac{\quad}{1 \text{ ~~L NaOH soln~~}} \right)$$

$$? \text{ L } Cl_2 = 3525 \text{ ~~L NaOH soln~~} \left(\frac{12.5 \text{ mol NaOH}}{1 \text{ ~~L NaOH soln~~}} \right)$$

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$$= 5.26 \times 10^5 \text{ L } Cl_2$$