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Introduction to Reaction Powered Car

Baking Soda and Vinegar Lab WORKSHEET (50 lab Pts)

Kitchen Chemistry: The Baking Soda and Vinegar Reaction

1) Determine the molecular weight of each component and the stoichiometric coefficients to balance the reaction.

$$Vinegar(liquid) + BakingSoda(solid) \Rightarrow Water(liquid) + CarbonDioxide(gas) + SodiumAcetate(aq.)$$

AA, BS

$$[AceticAcid + Water] + SodiumBicarbonate \Rightarrow Water + CarbonDioxide + SodiumAcetate$$

$$[CH_3COOH(aq.) + H_2O(l)] + NaHCO_3(s) \Rightarrow H_2O(l) + CO_2(g) + NaCH_3COO(aq.)$$

Coefficients	1	1	1	2	1	1
MW	60 g/mole	18 g/mol	84 g/mole	18	44 g/mole	82 g/mole

C 2x12 = 24
H 4x1 = 4
O 2x16 = 32
60 g/mole.

Na 1x23 = 23
H 1x1 = 1
C 1x12 = 12
O 3x16 = 48

C 1x12 = 12
O 2x16 = 32

Na 1x23 = 23
C 2x12 = 24
O 2x16 = 32
H 3x1 = 3

2) Calculations to determine ~~the amount of~~ CO_2(g) produced in the BS-V reaction

Starting Material: 50 ml Vinegar (5vol% AA) S.G. (CH_3COOH) = 1.05

a) Calculate the **stoichiometric amount** (moles and grams) of **sodium bicarbonate** needed.

$$(50\,ml\ vinegar)\left(\frac{0.05\,ml\ AA}{ml\ vinegar}\right)\left(\frac{1.05\,g\ AA}{ml\ AA}\right)\left(\frac{1\,mole}{60\,g}\right) = 0.044\,mole\ AA$$

0.044 mole BS → ×84 g/mole → 3.67 g BS

0.044 mole CO_2 ← 0.044 mole BS

Stoichiometry
1 AA + 1 BS → 1 CO_2

b) Write the ***Ideal Gas Law.*** Identify the variables and their units.

$PV = nRT$
P = pressure (atm)
V = volume (L, m^3, ft^3)
n = gmoles
T = Temp. (K or °R)
R = Ideal Gas Constant (units vary)

c) Calculate the Ideal Gas Constant (R) in units of **liter-atm/mol-K**

NOTE: Remember R is calculated at Standard Temperature and Pressure (STP = 273 K, 1atm)

STP	T_s	P_s	V_s	n_s
SI	273K	1atm	0.0224 m^3	1 gmole
cgs	273K	1atm	22.4 L	1 gmole
ENG.	492R	1atm	359 ft^3	1 lbmole

$$R = \frac{P_S V_S}{T_S n_S} = \frac{(1\,atm)(22.4\,L/mole)}{273\,K}$$

$$R = 0.08205 \frac{L\text{-}atm}{mol\text{-}K}$$

d) Use the Ideal Gas Law to calculate the **volume of CO_2** produced at T = 20C.

$$V_{CO_2} = \frac{(n_{CO_2})(R)(T)}{P} = \frac{(0.044\ mols\ CO_2)(0.08205\ \frac{L\text{-}atm}{mol\ K})(293K)}{1\ Atm.}$$

$$\boxed{V_{CO_2} = 1.058\ L = 1058\ ml\ CO_2 \text{ @ } 20°C}$$

e) What is the pressure in a 700ml Gatorade Plastic Bottle? With 50ml. Vinegar. @ 20°C

$$P_{Bottle} = \frac{(n_{CO_2})(R)(T)}{V_{Bottle} - V_{Liquid}}$$

$$= \frac{(0.044\ mols\ CO_2)(0.08205\ \frac{L\text{-}Atm}{mol\ K})(293K)}{0.70\ L - 0.050\ L\ (\text{vinegar})}$$

$$\boxed{P_{BOTTLE} = 1.63\ atm}$$

Note: MAX pressure allowed in bottle = 5 Atm!

f.) Limiting reactant concept.

Limiting reactant = reactant in least amount present.

excess reactant = in excess relative to other reactants.

e.g. if we had $(1.8g\ BS)(\frac{1\ mol}{60g}) = 0.030$ moles BS. and 50ml vinegar.

∴ BS is limiting reactant.

$\boxed{0.030\ moles\ CO_2}$

Felder & Rousseau (Front Cover Table)

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5×10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482×10^5 dynes
Pressure	1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325×10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778×10^{-7} kW·h = 0.23901 cal = 0.7376 ft-lb_f = 9.486×10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486×10^{-4} Btu/s = 1.341×10^{-3} hp

Example: The factor to convert grams to lb_m is $\left(\frac{2.20462\ lb_m}{1000\ g}\right)$.

Standard Conditions for Gases (STP)

System	T_s	P_s	$\hat{V}_s$	n_s
SI	273K	1Atm	0.02241 m^3	1mole (gmole)
CGS	273K	1Atm	22.415 L	1mole (gmole)
Engineering	492°R	1Atm	359.05 ft^3	1bmole

Note: 1 lbmole = 454 gmole
1 kg mole = 1000 g mole

Ideal Gas Law: $PV = nRT$ ($\hat{V}$ = molar volume = V/n)

@ STP $P_s \frac{V_s}{n_s} = RT_s$ ∴ $\boxed{R = \frac{P_s V_s / n_s}{T_s}}$ * ideal gas constant

* Note: R always evaluated @ STP