Converting within the metric system

* metric units can be in standard form:

ex. length → metre (m)
mass → gram (g)
} table 4.4 pg 48

- if numbers are very small or large, prefixes are used.

ex. Kilo (K)
centi (c)
} table 4.5 pg 48

Kilo means $10^3 = 1000$: there are 1000L in a KL
there are 0.001 KL in a L

centi means $10^{-2} = 0.01$: there are 0.01g in a cg
there are 100cg in a g

mega means $10^6 = 1000\,000$: there are 1000 000g in a mg
there are 0.000001mg in a g

Conversion Factors:

5Km = ______ m

$5Km \times \frac{1000m}{1Km} = 5000m$

$\frac{1000m}{1Km}$ $\frac{1Km}{1000m}$

→ Choose this one b/c we want bottom Km units to cancel.

1583g = ______ cg

$1583g \times \frac{100cg}{1g} = 158300cg$

1583g = ______ Kg

$1583g \times \frac{1\ Kg}{1000\ g} = 1.583Kg$

PRACTICE QUESTIONS

Methods:
1) * convert to standard first.
2) * recognize the powers of 10 difference

1) 0.0012 Km = ________ cm

$0.0012Km \times \frac{1000\ m}{1\ Km} = 1.2m \times \frac{100cm}{1\ m} = 120cm$

2) $0.0012Km \times \frac{100000cm}{1Km} = 120cm$

2) $Km = 10^3$, $cm = 10^{-2}$ } 10^5 difference

$0.0024\ mm =$ ________ μm — 10^{-3}_{mm} $10^{-6}_{\mu m}$ → 10^3

$0.0024mm \times \frac{1000\ \mu m}{1\ mm} = 2.4\mu m$

4924 KL = ________ GL — $10^3 K$ $10^9 G$ → 10^6

$4924\ KL \times \frac{1\ GL}{1000\,000\ KL} = 0.004924\ GL$

2964cm = ________ Km — 10^{-2} 10^3 → 10^5

$2964cm \times \frac{1\ Km}{100\,000cm} = 0.02964Km$

26.4cm = ________ nm — 10^{-2} 10^{-9} → 10^7 = 264 000 000

564mL = ________ KL — 10^{-3} 10^3 → 10^6 = 0.000 564

0.21 Gg = ________ Kg — 10^9 10^3 → 10^6 = 210 000

* Going down table - move decimal right
* Going up table - move decimal left

PRACTICE QUESTIONS

1) $2.6 Kg = \_\_\_\_\_\_ g$ $10^3 \quad 10^0$ (10^3)

$$2.6 Kg \times \frac{1000 \ g}{1 \ Kg} = 2600 g$$

2) $292 m = \_\_\_\_\_\_ cm$ $10^0 \quad 10^{-2}$ (10^2)

$$292 m \times \frac{100 \ cm}{1 \ m} = 29200 cm$$

3) $2196 ms = \_\_\_\_\_\_ s$ $10^{-3} \quad 10^0$ (10^3)

$$2196 ms \times \frac{1 \ s}{1000 \ ms} = 2.196 s$$

4) $0.0012 mm = \_\_\_\_\_\_ \mu m$ $10^{-3} \quad 10^{-6}$ (10^3)

$$0.0012 mm \times \frac{1000 \ \mu m}{1 \ mm} = 1.2 \mu m$$

5) $3324 ML = \_\_\_\_\_\_ GL$ $10^6 \quad 10^9$ (10^3)

$$3324 ML \times \frac{1 \ GL}{1000 \ ML} = 3.324 GL$$

6) $0.0842 mol = \_\_\_\_\_\_ mmol$ $10^0 \quad 10^{-3}$ (10^3)

$$0.0842 mol \times \frac{1000 \ mmol}{1 \ mol} = 84.2 mmol$$

7) $1029 ms = \_\_\_\_\_\_ cs$ $10^{-3} \quad 10^{-2}$ (10^1)

$$1029 ms \times \frac{1 \ cs}{10 \ ms} = 102.9 cs$$

The Rule of 1000

0.1 ⟶ 1000 } numerical values are given within this range.

0.000000000124 Kg = 0.124 µg

K 10^3 10^6 = micro

1250g = 1.25 Kg

PRACTICE QUESTIONS

13 456mL = 13.456L

0.0345s = 34.5 ms

0.00652m = 6.52mm

5986 Kmol = 5.986 Mmol

Scientific Notation

→ an alternative to converting SI prefixes that allows the use of standard units (m, s, g) and still follows the rule of 1000.

2300 g = 2.3×10^3 g scientific notation

0.023 s = 2.3×10^{-2} s

0.0012 L = 1.2×10^{-3} L

moving decimal right = negative power of 10.

643290 s = 6.4329×10^5 s

0.0423 mol = 4.23×10^{-2}

4.9×10^4 g = 4.9×10000 g = 49000 g

2.9×10^{-3} L = 2.9×0.001 L = 0.0029 L

PRACTICE QUESTIONS

1263 g = 1.263×10^3 g

2.4×10^5 s = 240 000 s

6240 L = 6.24×10^3 L

1.32×10^{-4} mol = 0.000132 mol

Complete Q's # 24, 25 pg 151

Review

Rule of 1000

must be between 0.1 → 1000

$0.00256\,mg = 2.56\,\mu g$ - decimal to right goes down the table.

10^{-3} 10^{-6}

$256000\,L = 256\,KL$ - decimal to left goes up the table.

10^{0} 10^{3}

Scientific Notation

1) $2.15\,mL = 0.00215\,L$

$2.15\,mL \times \frac{1\,L}{1000\,mL} = \frac{2.15\,L}{1000} = 0.00215\,L$

$0.00215\,L = 2.15 \times 10^{-3}\,L$

2) $560\,Kg = 5.6 \times 10^{5}\,g$

560 000 g

3) $0.0000236\,mL = 2.36 \times 10^{-8}\,L$

$0.0000236\,mL \times \frac{1\,L}{1000\,mL} = 0.0000000236\,L$

PRACTICE QUESTIONS

#24
a) 2051 g = 2.051 Kg
b) 0.0067 Kg = 6.7 g
c) 54 891 mL = 54.891 L
d) 0.0985 L = 98.5 mL or 9.85 cL
e) 1996 ms = 1.996 s or 19.96 ds or 199.6 cs
f) 21 060 mol = 21.06 Kmol
g) 0.023 mol = 2.3 cmol or 23 mmol
h) 0.0040 Kmol = 4.0 mol

#25

a) 2988 mol = 2.988×10^{3} mol

b) 2.988 mmol = 0.002988 mol = 2.988×10^{-3} mol

c) 3765 Kg = 3.765×10^{6} g

d) 3765 g = $3.765 \times 10^{+3}$ g

e) 0.0067 L = 6.7×10^{-3} L

f) 0.0067 mL = 6.7×10^{-6} L

SI prefixes

giga	G	10^{9}
mega	M	10^{6}
Kilo	K	10^{3}
standards		10^{0}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

↑ decimal to left

↓ decimal to right

Mole = 6.02×10^{23}

1 mole of Ca has 6.02×10^{23} atoms in it.
→ the mole was chosen because it gives a usable amount of any substance.
1 mole of H_2O has 6.02×10^{23} molecules of H_2O.

* Atomic mass is measured in grams per mole (g/mol)

Molar Mass
→ the molar mass of calcium is 40.1 g/mol
What is the molar mass of H_2O?
2(1.01g/mol) + 16g/mol = 18.02g/mol

PRACTICE QUESTIONS

1) $Ca(OH)_2$ = 40.1 g/mol + 2(16g/mol) + 2(1.0g/mol) = 74.1g/mol

2) KCl = 39.1g/mol + 35.5g/mol = 74.6g/mol

3) Li_2SO_4 = 2(6.9g/mol) + 32.1g/mol + 4(16.0g/mol) = 109.9g/mol

4) $(NH_4)_3PO_4$ = 3(14.0g/mol) + 12(1.0g/mol) + 31.0g/mol + 4(16.0g/mol) = 149g/mol

pg 160 #42

a) H_2O = 2(1.0g/mol) + 16g/mol = 18 g/mol
b) CO_2 = 12.0g/mol + 2(16.0g/mol) = 44.0g/mol
c) NaCl = 23.0g/mol + 35.5g/mol = 58.5g/mol
d) $C_{12}H_{22}O_{11}$ = 12(12.0g/mol) + 22(1.0g/mol) + 11(16.0g/mol) = 342g/mol
e) $(NH_4)_2Cr_2O_7$ = 2(14.0g/mol) + 8(1.0g/mol) + 2(52.0g/mol) + 7(16.0g/mol) = 252g/mol

$NaCl = 58.5\ g/mol$

$= \frac{58.5g}{6.02 \times 10^{23}\ molecules}$

Calculate Moles given Mass

→ given the mass of a substance we can use molar mass as a conversion factor to convert to moles.

Convert 1.5 Kg of $CaCO_3$ into moles.

STEP 1: Calculate the molar mass.

$40.1 + 12.0 + 3(16) = 100.1\ g/mol$

STEP 2: Convert to standard units. (optional)

$1.5\ Kg \times \frac{1000g}{1\ Kg} = 1500g$

STEP 3: Convert to moles using molar mass.

$1500g \times \frac{1\ mole}{100.1g} = 14.99\ moles$

PRACTICE QUESTIONS

1) 325 mg sugar. Convert to moles.

$325mg \times \frac{1\ g}{1000\ mg} = 0.325g \times \frac{1\ mole}{342g} = 0.0009502924\ moles$

$= 9.5 \times 10^{-4}\ moles$

or 0.95 mmoles

2) 0.582 Kg Iron (III) Oxide. Convert to moles.

$0.582\ Kg \times \frac{1000g}{1\ Kg} = 582g \times \frac{1\ mole}{159.6g} = 3.65\ moles$

$Fe_2O_3 = 2(55.8) + 3(16) = 159.6\ g/mole$

PRACTICE QUESTIONS

pg160 #43

a) 10.00Kg bag of table sugar.

$10\,Kg \times \frac{1000g}{1\,Kg} = 10000g \times \frac{mole}{342g} = 29.24\ moles$

$C_{12}H_{22}O_{11} = 342g/mol$

b) 500g box of pickling salt

$500g \times \frac{mol}{58.5g} = 8.55\ moles$

$NaCl = 58.5g/mol$

c) 40.0g of propane, C_3H_8

$40.0g \times \frac{mole}{44g} = 0.909\ moles$

$C_3H_8 = 3(12) + 8(1) = 44g/mol$ $= 9.09 \times 10^{-1}\ moles$

d) 325mg of acetylsalicylic acid (Aspirin)

$C_6H_4CH_3COOCOOH = 9(12) + 8(1) + 4(16) = 180g/mol$

$325mg \times \frac{1g}{1000mg} = 0.325g \times \frac{mole}{180g} = 0.001806\ moles$

$= 1.806 \times 10^{-3}\ moles$

e) 150g of isopropanol (rubbing alcohol)

$CH_3CH_2OHCH_3 = 3(12) + 9(1) + 1(16) = 61g/mol$

$150g \times \frac{mol}{61g} = 2.459\ moles$

Converting from Moles to Mass

→ What mass does 3.46mmol of Na_2SO_4 have?

$2(23) + 32.1 + 4(16) = 142.1 g/mol$

$3.46 mmol \times \frac{1 mole}{1000 mmol} = 0.00346 mole \times \frac{142.1 g}{mole} = 0.491666 g$

→ Convert 45mol of $Mn(CO_3)_2$ to a mass measure?

$54.9 + 2(12) + 6(16) = 174.9 g/mol$

$45 mol \times \frac{174.9 g}{mole} = 7870.5 g$

Determining the number of entities

Entities: atoms or molecules

1 mole $= 6.02 \times 10^{23}$

ex. a copper wire has a mass of 325g. How many atoms of Copper are present? 63.5g/mol ⟶ $325 g \times \frac{mole}{63.5 g} = 5.118 moles$

STEPS:
1) Convert to standard units
2) Convert to moles
3) Convert to atoms, multiply the number of moles by Avagadro's number (6.02×10^{23})

$5.12 moles \times \frac{6.02 \times 10^{23}}{1 moles} = 3.08 \times 10^{24}$

ex. How many molecules are in a 1Kg bag of sugar?

342g/mol

$C_{12}H_{22}O_{11}$

$1 Kg \times \frac{1000 g}{1 Kg} = 1000 g \times \frac{mole}{342 g} = 2.92397 mole \times \frac{6.02 \times 10^{23}}{mole}$

$= 1.76 \times 10^{24}$ molecules

PRACTICE QUESTIONS

pg 162

#46 a) 15 mol of solid carbon dioxide - in dry ice

$CO_2 = 12 g/mol + 2(16 g/mol) = 44 g/mol$

$15 mol \times \frac{6.02 \times 10^{23}}{1 mole} = 9.03 \times 10^{24}$ entities

b) 15g of ammonia gas - in household cleaners

$NH_3 = 14 g/mol + 3(1.0 g/mol) = 17 g/mol$

$15g \times \frac{1 mol}{17g} = 0.88 mol \times \frac{6.02 \times 10^{23}}{1 mol} = 5.2976 \times 10^{23}$ entities

c) 15g of hydrogen chloride gas - in hydrochloric acid

$HCl = 1.0 g/mol + 35.5 g/mol = 36.5 g/mol$

$15g \times \frac{1 mol}{36.5g} = 0.41 mol \times \frac{6.02 \times 10^{23}}{1 mol} = 2.4682 \times 10^{23}$ entities

d) 15g of sodium chloride - in table salt

$NaCl = 23 g/mol + 35.5 g/mol = 58.5 g/mol$

$15g \times \frac{1 mol}{58.5g} = 0.256 mol \times \frac{6.02 \times 10^{23}}{1 mol} = 1.54 \times 10^{23}$ entities

#47 Predict mass of 1 entity of each.

a) water from respiration

$H_2O = 2(1.0 g/mol) + 16 g/mol = \frac{18 g/mol}{6.02 \times 10^{23}} = 2.99 \times 10^{-23} g$

b) carbon dioxide from respiration

$CO_2 = \frac{44 g/mol}{6.02 \times 10^{23}} = 7.308 \times 10^{-23} g$

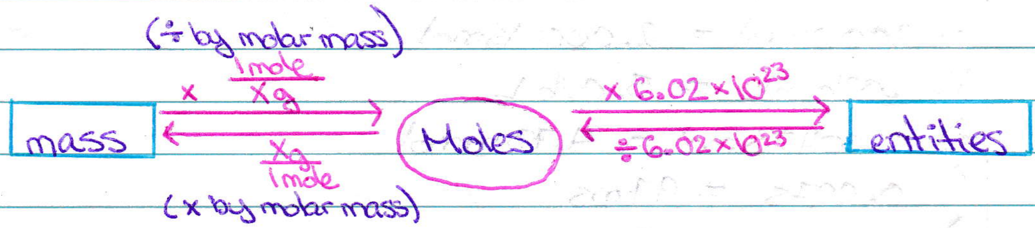
c) glucose from photosynthesis

$C_6H_{12}O_2 = 72 g/mol + 12 g/mol + 96 g/mol = \frac{180 g/mol}{6.02 \times 10^{23}} = 2.99 \times 10^{-22} g$

d) oxygen from photosynthesis

$O_2 = 2(16 g/mol) = \frac{32 g/mol}{6.02 \times 10^{23}} = 5.315 \times 10^{-23} g$

Conversion Summary



PRACTICE QUESTIONS

1) How many moles are present in 24g of $CaCl_2$?

$CaCl_2$ = 40.1g/mol + 2(35.5g/mol) = 111.1 g/mol $24g \times \frac{1mol}{111.1g} = 0.216$ moles

2) What mass would 0.0037 mol of CO_2 have?

CO_2 = 12g/mol + 2(16g/mol) = 44g/mol $0.0037mol \times \frac{44g}{1mole} = 0.1628g$

3) How many entities are present in 1.6mol of HCl?

~~HCl = 1g/mol + 35.5g/mol = 36.5g/mol~~ $1.6 mol \times 6.02 \times 10^{23} = 9.632 \times 10^{23}$ entities

4) What mass would 5.45×10^{24} molecules of NaCl have? NaCl = 58.5g/mol

$5.45 \times 10^{24} \times \frac{1mole}{6.02 \times 10^{23}} = 9.053 moles \times \frac{58.5g}{1mole} = 529.6g$

5) What would be the mass of one molecule of oxygen? O_2 = 32g/mol

$1 \times \frac{1mole}{6.02 \times 10^{23}} = 1.661 \times 10^{-24} moles \times \frac{32g}{1mole} = 5.316 \times 10^{-23}$

6) How many entities would be present in a Canadian nickel (assume pure Ni) that had a mass of 3.62g?

Ni = 58.7g/mol

$3.62g \times \frac{mol}{58.7g} = 0.0617 mol \times \frac{6.02 \times 10^{23}}{1mole} = 3.714 \times 10^{22}$

Complete pg181 # 11, 12, 13, 19, 26, 27, 28

11) a) 47 624 g = 47.624 Kg
b) 0.028 L = 28 mL
c) 2000 mol = 2.000 Kmol
d) 5026 mL = 5.026 L
e) 0.00473 mol = 4.73 mmol
f) 0.097 s = 97 ms
g) 0.002 Kg = 2 g
h) 13 429 mmol = 13.429 mol

12) a) mass = m
b) amount = n
c) molar mass = M

13) a) gram = g
b) millimole = mmol
c) gram per mol = g/mol
d) micromole = μmol
e) millilitre = mL
f) Kilogram = Kg

19) a) oxygen (respiration gas) O_2
2(16.0 g/mol) = 32 g/mol

b) calcium carbonate (limestone) $CaCO_3$
40.1 g/mol + 12.0 g/mol + 3(16.0 g/mol) = 100.1 g/mol

c) dinitrogen tetraoxide (pollutant) N_2O_4
2(14 g/mol) + 4(16 g/mol) = 92 g/mol

d) calcium phosphate (rock phosphorus) $Ca_3(PO_4)_2$
3(40.1 g/mol) + 2(31.0 g/mol) + 8(16.0 g/mol) = 310.3 g/mol

e) ethanol (grain alcohol) C_2H_5OH

2(12g/mol) + 6(1g/mol) + 16g/mol = 46g/mol

f) sodium carbonate decahydrate (washing soda) $Na_2CO_3 \cdot 10H_2O$

2(23.0g/mol) + 12.0g/mol + 13(16.0g/mol) + 20(1.0g/mol) = 286g/mol

26) a) 1.000 Kg of table salt $NaCl$ = 23g/mol + 35.5g/mol = 58.5g/mol

$1.000Kg \times \frac{1000g}{1Kg} \times \frac{1mol}{58.5g} = 17.09mol$

b) 1.000 Kg of table sugar $C_{12}H_{22}O_{11}$ = 12(12g/mol) + 22g/mol + 11(16g/mol) = 342g/mol

$1000g \times \frac{1mol}{342g} = 2.92mol$

c) 1.000 Kg of dry ice CO_2 = 12g/mol + 2(16g/mol) = 44g/mol

$1000g \times \frac{1mol}{44g} = 22.72mol$

d) 1.000 Kg of water H_2O = 2g/mol + 16g/mol = 18g/mol

$1000g \times \frac{1mol}{18g} = 55.55mol$

27) a) 1.50 mol of liquid oxygen O_2 = 2(16g/mol) = 32g/mol

$1.50mol \times \frac{32g}{1mol} = 48.0g$

b) 1.50 mol of liquid propane C_3H_8 = 3(12g/mol) + 8g/mol = 44g/mol

$1.50mol \times \frac{44g}{1mol} = 66g$

c) 1.50 mmol of liquid mercury Hg = 200.6g/mol

$1.50mmol \times \frac{1mol}{1000mmol} \times \frac{200.6g}{1mol} = 0.301g$

d) 1.50 Kmol of liquid bromine Br_2 = 2(79.9g/mol) = 159.8g/mol

$1.50Kmol \times \frac{1000 ~~Kmol~~ mol}{~~1000~~ ~~000~~ Kmol} \times \frac{159.8g}{mol} = 239700g = 239.7Kg$ or $0.2397Mg$

28) a) 0.42 mol of acetic acid (vinegar) CH_3COOH

$2(12 g/mol) + 4(1.0 g/mol) + 2(16.0 g/mol) = 60 g/mol \rightarrow$ not necessary

$0.42 \text{ mol} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}} = 2.5 \times 10^{23}$ molecules

b) 7.6×10^{-4} mol of carbon monoxide (poisonous gas) CO

$12 g/mol + 16 g/mol = 28 g/mol \rightarrow$ not necessary

$7.6 \times 10^{-4} \text{ mol} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}} = 4.6 \times 10^{20}$ molecules

c) 100g of carbon tetrachloride (poisonous fluid) CCl_4

$12.0 g/mol + 4(35.5 g/mol) = 154 g/mol$

$100g \times \frac{1 \text{ mol}}{154 g} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}} = 3.9 \times 10^{23}$ molecules

d) 100g of hydrogen sulfide (rotten egg gas) H_2S

$2(1.0 g/mol) + 32.1 g/mol = 34.1 g/mol$

$100g \times \frac{1 \text{ mol}}{34.1 g} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}} = 1.77 \times 10^{24}$ molecules

Molar Volume of Gases

Properties of Gases

Brainstorm: scubatanks (O_2), pressure systems (CO_2), propane

1. → gases have no fixed volume, they fill their container.
2. → gases are compressible & when pressure is applied, volume decreases.
3. → gases diffuse rapidly and mix with other gases.

* Temperature & Pressure both affect the volume of a gas.

↑ temperature = ↑ volume ex. hot air balloon
= ↑ pressure

↑ pressure = ↓ volume

Pressure is a measure of force per unit area.
- measured in (KPa)

$1 \text{ KPa} = \frac{1000 \text{ N}}{1 \text{ m}^2} = \frac{100 \text{ Kg}}{1 \text{ m}^2}$ (on earth) $= \frac{220 \text{ lbs}}{1 \text{ m}^2}$ (on earth)

Temperature = °C
Volume = L

→ the atmosphere places 101 KPa of pressure on our bodies.

* Gases can be considered at...
1) Standard Temperature and Pressure (STP)
   0°C, 101.325 KPa
2) Standard Ambient Temperature and Pressure (SATP)
   25°C, 101 KPa

BOYLE'S LAW

→ Boyle found that by increasing pressure on a gas, the volume decreases proportionally. Doubling the pressure decreases volume by 1/2.
- assume temperature is constant.

$$P_1V_1 = P_2V_2$$ Boyle's Law

ex. 3L of gas at 101 KPa has its pressure tripled. What is the new volume?

$$P_1V_1 = P_2V_2$$

$$\frac{(101\text{ KPa})(3L)}{303\text{ KPa}} = \frac{(303\text{ KPa})(V_2)}{303\text{ KPa}}$$

$$1\text{ L} = V_2$$

ex. A pump contains 1.5L of air at 101KPa. What pressure needs to be applied to change the volume to 0.5L?

$$P_1V_1 = P_2V_2$$

$$\frac{(101\text{KPa})(1.5L)}{0.5L} = \frac{(P_2)(0.5L)}{0.5L}$$

$$303\text{KPa} = P_2$$

ex. If a 1L helium balloon is purchased in Vancouver, BC, where atmospheric pressure is 101KPa, then transported to Banff, Alberta, where atmospheric pressure is 93KPa.

a) Why is atmospheric pressure lower in Banff than in Vancouver?
banff is at a higher elevation ∴ less atmospheric pessure.

b) What would be the new volume of the helium balloon? (assume temperatures are the same in both locations)

$$\frac{(101\text{KPa})(1L)}{93\text{KPa}} = \frac{(93\text{KPa})(V_2)}{93\text{KPa}}$$

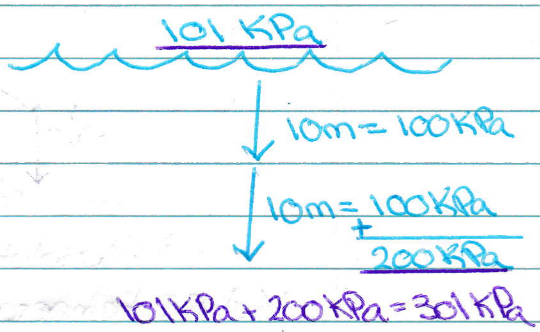
$$1.09\text{L} = V_2$$

ex. When diving underwater, pressures increase by 100KPa for every 10m of depth on top of atmospheric pressure (101KPa). If a diver at 20m of depth holds 4L of air in their lungs and is shot suddenly to the surface, what would be the new volume of air in the divers lungs? Why is it dangerous to surface quickly when diving?

$$P_1V_1 = P_2V_2$$

$$\frac{(301\,KPa)(4L)}{101\,KPa} = \frac{(101\,KPa)(V_2)}{101\,KPa}$$

$$11.9L = V_2$$



Complete pg227 Q'ns 5 & 6

5) $P_1V_1 = P_2V_2$

$$\frac{(101KPa)(0.65L)}{0.25L} = \frac{(P_2)(0.25L)}{0.25L}$$

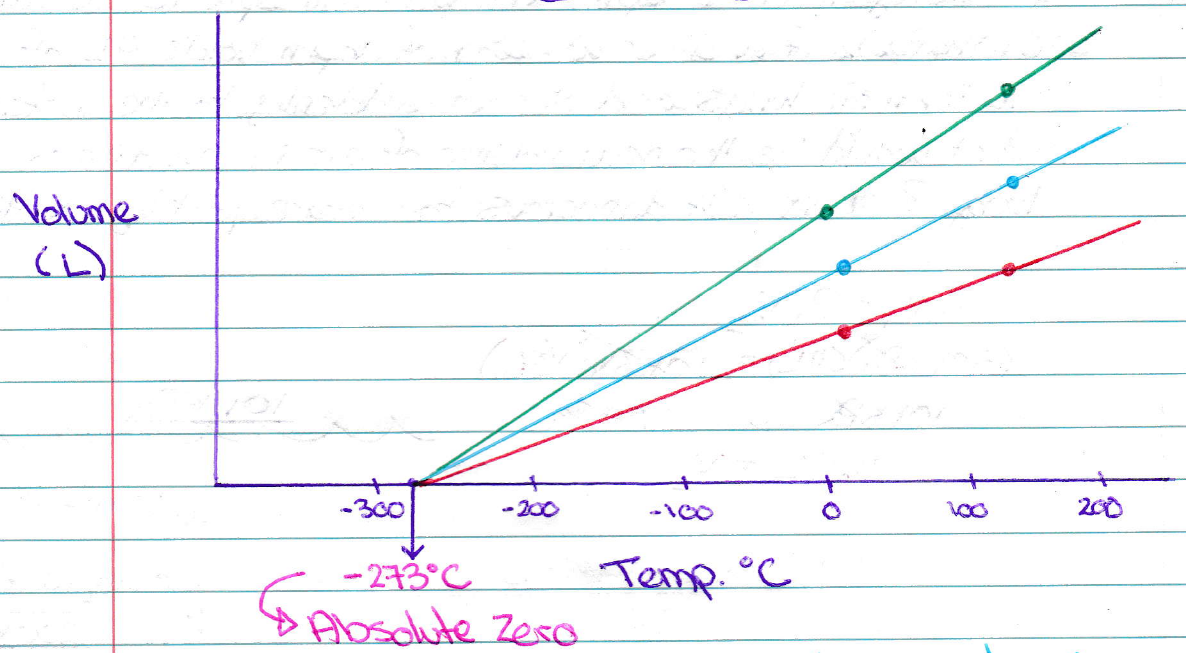
$$262.6\ KPa = P_2$$

6) $P_1V_1 = P_2V_2$

$$\frac{(98\,KPa)(35L)}{25\,KPa} = \frac{(25\,KPa)(V_2)}{25\,KPa}$$

$$137.2\ L = V_2$$

Temperature vs. Volume



Kelvin temperature scale starts at Absolute Ø.

0 K = −273°C

→ to convert between °C and K, add or subtract 273.

20°C $\overset{+273}{=}$ 293 K   0°C = 273 K

303 K $\overset{-273}{=}$ 30°C   0 K = −273°C

CHARLE'S LAW

→ Describes the relationship between Volume of a gas and its temperature in Kelvin.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ Charle's Law

ex. A hot air balloon has a volume of 20L at 20°C (→ 293K). The full balloon holds 400L of air. what temperature does the air need to be?

$$\frac{20L}{293K} = \frac{400L}{T_2}$$

T_2 = 5860 K or 5587°C

ex. A home contains 100,000 L of air at 20°C if temperature is raised by 5°C, how much air would escape the home?

$V_1 = 100,000 L$
$T_1 = 20°C$ or $293 K$
$V_2 = V_2$
$T_2 = 25°C$ or $298 K$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{100\,000 L}{293 K} = \frac{V_2}{298 K}$$

$V_2 = 101706.5 L$
$- 100000$
1706.5 L would leave.

Complete pg232 Qn #7

7) $V_1 = 0.1 L$
$T_1 = 25°C, 298K$
$V_2 = V_2$
$T_2 = 190°C, 463K$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{0.1 L}{298K} = \frac{V_2}{463K}$$

$V_2 = 0.155 L$

Combined Gas Law

→ Combines Boyle's Law and Charle's Law.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

ex. A hydrogen balloon at 20°C, 100 KPa and a volume of 7.5 L, rises in the atmosphere where pressure is 28 KPa and temperature is -37°C. What is the balloons new volume?

$P_1 = 100 KPa$
$V_1 = 7.5L$
$T_1 = 20°C, 293 K$

$P_2 = 28 KPa$
$V_2 = V_2$
$T_2 = -37°C, 236K$

$$\frac{(100 KPa)(7.5L)}{293 K} = \frac{(28 KPa)V_2}{236K}$$

÷ 28 KPa

$$V_2 = \frac{(236K)(100 KPa)(7.5L)}{(293 K)(28 KPa)}$$

$$V_2 = \frac{177\,000 L}{8204} = 21.57 L$$

ex. A 1L bottle of soda is stored at 4°C and has an internal pressure of 120 KPa. If the bottle is stored at a temperature of 20°C, what will the new internal pressure be?

$P_1 = 120\ KPa$
$V_1 = 1L$
$T_1 = 4°C, 277K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_2 = P_2$
$V_2 = 1L$
$T_2 = 20°C, 293K$

$$\frac{(120KPa)(1L)}{277K} = \frac{(P_2)(1L)}{293K}$$

$$P_2 = \frac{(120KPa)(1L)(293K)}{(277K)(1L)} = \frac{35160}{277} = 126.93KPa$$

Complete pg232 Q's #8-12

8) a) $V_2 = 62L$
b) 2.3 x volume increase
2.3 x pressure decrease

9) $V_2 = 5.8L$

10) $T_2 = 513K$ or 240°C

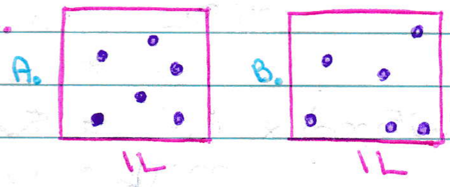
11) $T_2 = 5039K$ or 4766°C

12) $V_2 = 7.9L$

Molar Volume of Gases

→ 2 factors that affect the volume of a gas are:
Temperature & Pressure

- all gases at the same temperature & pressure will have the same volume.



*if T & P are equal, 6 molecules of each will have equal V.

Molar Volume at STP: 22.4 L/mole
Molar Volume at SATP: 24.8 L/mole
} conversion factors

Converting between amount (moles) and volume (litres):

ex. How many moles of O_2 gas are present in 5.6L at STP?

$$5.6L \times \frac{1\,mole}{22.4L} = 0.25\,mol$$

ex. How many moles are present in an average exhalation (4L) of CO_2 at SATP?

$$4L \times \frac{1\,mole}{24.8L} = 0.16\,mol$$

ex. What volume is occupied by 0.024 moles of helium at SATP?

$$0.024\,moles \times \frac{24.8L}{1\,mole} = 0.60L$$

ex. What volume of gas is occupied by 1.3 mmol of N_2 at STP?

$$1.3\,mmol \times \frac{1\,mole}{1000\,mmol} = 0.0013\,mol \times \frac{22.4L}{1\,mole} = 0.02912L$$

29.12mL

or, $$1.3\,mmol \times \frac{22.4L}{1000\,mmol} = 0.029L = 29mL$$

Complete pg239 Q's # 18-21

18) $7.50mol \times \frac{24.8L}{1mol} = 186L$

19) $50mL \times \frac{1mole}{24.8L} \times \frac{1L}{1000mL} = 0.002mole = 2mmol$

20) $2.25mol \times \frac{22.4L}{1mole} = 50.4L$

21) $20.0L \times 0.02 = 4L$

$4L \times \frac{1mol}{22.4L} = 0.179mol$

Molar Volume and Molar Mass

ex. What volume would 3.5g of He gas occupy at SATP?

Step 1 - convert to moles using the molar mass.

$3.5g \times \frac{1mole}{4g} = 0.875 moles$

Step 2 - convert to litres using molar volume.

$0.875 moles \times \frac{24.8L}{1mole} = 21.7L$

ex. Determine the volume of gas present in 54g of O_2 at STP?

$O_2 = 2(16.0) = 32g/mol$

$54g \times \frac{1mole}{32g} \times \frac{22.4L}{1mole} = 37.8L$

ex. We have a 32g block of Dry Ice (CO_2). What volume would this occupy after it sublimated @ SATP?

$12.0g/mol + 2(16.0g/mol) = 44g/mol$

$32g \times \frac{1mole}{44g} = 0.727mol \times \frac{24.8L}{1mol} = 18.03L$

ex. 108 L of CO_2 is present at STP. What mass is present?

$108L \times \frac{1mol}{22.4L} = 4.82mol \times \frac{44g}{1mol} = 212.08g$

Complete pg240 Q'ns # 22-26

22) a) 50.0g of C_8H_{18} (gasoline vapor)

$8(12g/mol) + 18(1.0g/mol) = 114g/mol$

$50.0g \times \frac{1mol}{114g} = 0.439 mol$

b) 70.0g of methanol (vapors from windshield washer antifreeze)

$CH_3OH = 12g/mol + 4(1.0g/mol) + 16g/mol = 32g/mol$

$70.0g \times \frac{1mole}{32g} = 2.1875 moles$

c) 575mg of chlorine (found in household bleach)

$Cl_2 = 2(35.5g/mol) = 71g/mol$

$575mg \times \frac{1g}{1000mg} = 0.575g \times \frac{1mol}{71g} = 0.0080985mol$

23) $CO_2 = 12.0g/mol + 2(16.0g/mol) = 44g/mol$

$0.13g \times \frac{mol}{44g} = 0.00295 moles \times \frac{24.8L}{1mol} = 0.07327L = 73.27mL$

24) $NO_2 = 14.0g/mol + 2(16.0g/mol) = 46g/mol$

$1.00Mg \times \frac{1000\,000g}{1Mg} = 1000\,000g \times \frac{1mol}{46g} = 21739.13mol \times \frac{24.8L}{1mol}$

$= 539130.43L = 539.13KL$

25) $CO_2 = 44g/mol$

$1000\,000g \times \frac{1mol}{44g} = 22727.27mol \times \frac{22.4L}{1mol} = 509090.91L = 509KL$

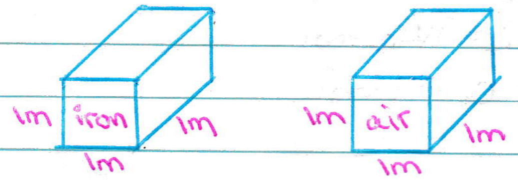
26) $1.9KL \times \frac{1000L}{1KL} = 1900L \times \frac{1mol}{24.8L} = 76.6mol \times \frac{32g}{1mol} = 2451.2g$

2.45Kg

$O_2 = 2(16.0g/mol) = 32g/mol$

Density

→ describes mass and volume (mol/L or g/L)



$1m^3$ — higher density, more mass.

$1m^3$ — lower density, less mass.

Density at SATP

$$1L \times \frac{1mol}{24.8L} = 0.0403 mol/L$$

Density at STP

$$1L \times \frac{1mole}{22.4L} = 0.0446 mol/L$$

ex. What is the density of O_2 at SATP?

$O_2 = 2(16.0g/mol) = 32g/mol$

$$\frac{32g}{1mol} \times \frac{0.0403 mol}{1L} = 1.29g/L$$

Complete pg240 Q'ns # 27-30

27) $H_2O = 2(1.0g/mol) + 16.0g/mol = 18g/mol$

$$1L \times \frac{1mol}{24.8L} = 0.04mol \times \frac{18g}{1mol} = 0.726g$$

28) $CO_2 = 44 g/mol$ x

$$\frac{44g}{\cancel{mol}} \times \frac{1\cancel{mol}}{24.8L} = 1.77 g/L$$

29) $N_2 = 2(14.0 g/mol) = 28 g/mol$

SATP

$$\frac{28g}{\cancel{mol}} \times \frac{1\cancel{mol}}{24.8L} = 1.129 g/L \times 0.80 = 0.9032 g/L$$

$O_2 = 2(16.0 g/mol) = 32 g/mol$

$$\frac{32g}{\cancel{mol}} \times \frac{1\cancel{mol}}{24.8L} = 1.29 g/L \times 0.20 = 0.258 g/L$$

$$0.9032 + 0.258 = 1.16 g/L$$

30) a)

b)

Ideal Gas Law

→ this law uses amount in moles (n).

$$pv = nRT$$

Universal Gas Constant (R)

p = pressure (kPa)
v = volume (L)
n = amount (mol)
T = temperature (K)

@ STP $R = \frac{pv}{nT} = \frac{(101.3\,kPa)(22.4\,L)}{(1\,mol)(273\,K)} = 8.3\,kPa\cdot L/mol\cdot K$

@ SATP $R = \frac{pv}{nT} = \frac{(100\,kPa)(24.8\,L)}{(1\,mol)(298\,K)} = 8.3\,kPa\cdot L/mol\cdot K$

$p = \frac{nRT}{v}$ | $v = \frac{nRT}{p}$ | $n = \frac{pv}{RT}$ | $T = \frac{pv}{nR}$

ex. 0.78g of H_2 gas is produced at 22°C and 125 kPa. What volume would this gas occupy?

T = 22°C = 295 K
p = 125 kPa
v = v
n = 0.39 mol

$v = \frac{nRT}{p} = \frac{(0.39\,mol)(8.3\,kPa\cdot L/mol\cdot K)(295\,K)}{125\,kPa}$

$= 7.64\,L$

$0.78\,g \times \frac{1\,mol}{2\,g} = 0.39\,mol$

ex. What mass of neon gas should be placed in a 0.88L tube to produce a pressure of 90 kPa at 30°C?

T = 30°C = 303 K
p = 90 kPa
v = 0.88 L

$n = \frac{pv}{RT} = \frac{(90\,kPa)(0.88\,L)}{(8.3\,kPa\cdot L/mol\cdot K)(303\,K)} = 0.03\,mol$

$0.03\,mol \times \frac{20.2\,g}{1\,mol} = 0.64\,g$

ex. At what temperature does 5.2g of Cl_2 gas exert a pressure of 212KPa in a 500mL cylinder?

T = T
p = 212KPa
v = 0.5L

$pv = nRT$

$T = \frac{pv}{nR} = \frac{(212KPa)(0.5L)}{(8.3KPa \cdot L/mol \cdot K)(0.073mol)} = 174.95K$

$5.2g \times \frac{1mol}{71g} = 0.073mol$

Complete pg245 Q'ns # 31-36

31) What amount of methane gas is present in a sample that has a volume of 500mL at 35°C and 210KPa?

v = 500mL = 0.5L
T = 35°C = 308K
p = 210KPa

$pv = nRT$

$n = \frac{pv}{RT} = \frac{(210KPa)(0.5L)}{(8.3KPa \cdot L/mol \cdot K)(308K)} = 0.04 moles = 4 \times 10^{-2} mol$

32) Determine the pressure in a 50L compressed air cylinder if 30mol of air is present in the container, which is heated to 40°C.

v = 50L
n = 30mol
p = p
T = 40°C = 313K

$pv = nRT$

$p = \frac{nRT}{v} = \frac{(30mol)(8.3KPa \cdot L/mol \cdot K)(313K)}{50L}$

= 1558.74 L

33) What volume does 50kg of oxygen gas occupy at a pressure of 150 KPa and a temperature of 125°C. O_2 = 32g/mol

n = 1562.5mol
p = 150KPa
T = 125°C = 398K
v = v

$50kg \times \frac{1000g}{1kg} = 50000g \times \frac{1mol}{32g} = 1562.5mol$

$pv = nRT$

$v = \frac{nRT}{p} = \frac{(1562.5mol)(8.3KPa \cdot L/mol \cdot K)(398K)}{150KPa}$

= 34410L = 344.1 KL

34) At what temperature does 10.5g of ammonia gas exert a pressure of 85 KPa in a 30L container?

T = T

p = 85KPa

v = 30L

n = 0.583mol

NH_4 = 18g/mol

$10.5g \times \frac{1mol}{18g} = 0.583mol$

pv = nRT

$T = \frac{pv}{nR} = \frac{(85KPa)(30L)}{(0.583mol)(8.3)} = 526.98K$

$= 253.98°C$

35) Starting with the ideal gas law, derive a formula to calculate the molar mass M of a gas, given the mass and volume of the gas at a specific pressure and temperature. Recall that n = m/M; that is, the amount in moles is equal to the mass divided by the molar mass.

pv = nRT

$n = \frac{pv}{RT}$

$\frac{m}{M} = \frac{pv}{RT}$ ∴ $m = \frac{pv}{RT} \cdot M$ ∴ $M = \frac{mRT}{pv}$

36) Using the formula derived in question 35, calculate the molar mass of 1.00L of gas that has a mass of 1.25g and that exerts a pressure of 100 KPa at 0°C

v = 1.00L

m = 1.25g

p = 100KPa

T = 0°C = 273K

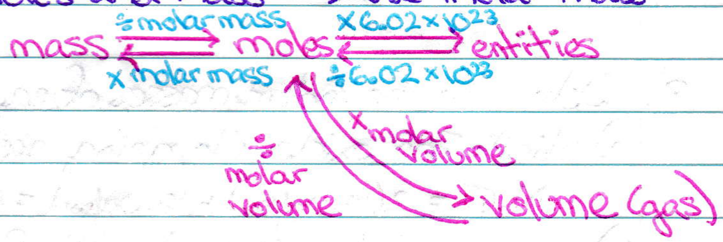
$M = \frac{mRT}{pv} = \frac{(1.25g)(8.3)(273K)}{(100KPa)(1.00L)}$

$= 28.3g/L$

Unit 2 Review

→ the rule of 1000 } metric conversions
→ scientific notation } STP, SATP values, gas laws

- convert between moles and mass → use molar mass



- when dealing with gas laws:
  1) convert °C to K
  2) watch out for conversions!
  3) do it the long way!
  4) Keep track of units
  5) only round at the end of a question

1 mole = 6.02×10^{23} entities (ie. atoms or molecules)

STP = 0°C, 101.325 KPa, 22.4 L/mole
SATP = 25°C, 100 KPa, 24.8 L/mole

* Complete pgs 247-249 Q's 7-14, 17-20, 23-26, 28

7) Convert each of the following temperatures into absolute values.

a) freezing point of water = 0°C = 273 K

b) 21°C room temperature = 21 + 273 = 294 K

c) 37°C body temperature = 37 + 273 = 310 K

d) absolute zero = -273°C = 0 K

8) Determine the molar masses of each of the following gases:

a) dinitrogen oxide (laughing gas)

N_2O = 2(14.0g/mol) + 16.0g/mol = 44g/mol

b) propane (alternative automobile fuel)

C_3H_8 = 3(12g/mol) + 8(1g/mol) = 44g/mol

9) Convert each of the following masses into an amount in moles.

a) 14g of neon (used in neon signs)

$14g \times \frac{mol}{20.2g}$ = 0.69 moles

b) 598mg uranium hexafluoride (separates uranium isotopes)

UF_6 = 238g/mol + 6(19g/mol) = 352g/mol

$598mg \times \frac{g}{1000mg} = 0.598g \times \frac{1mol}{352g}$ = 0.00169 mol = 1.69 mmol

c) 29.8Kg of sulfur dioxide (produces acid rain)

SO_2 = 32.1g/mol + 2(16g/mol) = 64.1g/mol

$29.8Kg \times \frac{1000g}{Kg} = 29800g \times \frac{1mol}{64.1g}$ = 464.9 moles

10) Calculate the mass of each of the following.

a) 26 mol of bromine Br_2 = 159.8g/mol

$26mol \times \frac{159.8g}{mol}$ = 4154.8g = 4.2Kg

b) 8.34 µmol of Krypton

$0.00000834 \text{ mol} \times \frac{83.8 g}{mol} = 0.0006989g = 698.9 \mu g$

c) 2.7 Kmol of sulfur trioxide $SO_3 = 32.1 g/mol + 3(16 g/mol) = 80.1 g/mol$

$2700 \text{ mol} \times \frac{80.1 g}{mol} = 216270 g = 216.3 Kg$

11) Convert each of the following gas volumes into an amount in moles.

a) 5.1L of carbon monoxide gas at SATP?

$5.1L \times \frac{1 mol}{24.8L} = 0.206 mol$

b) 20.7mL of fluorine gas at STP?

$20.7mL \times \frac{1L}{1000mL} = 0.0207L \times \frac{1 mol}{22.4L} = 9.2 \times 10^{-4} mol$

c) 90KL of nitrogen dioxide gas at SATP?

$90KL \times \frac{1L}{1000KL} = 0.09L \times \frac{1 mol}{24.8L} = 0.0036 mol = 3.6 mmol$

12) Calculate the volumes at SATP of the following amounts of gas.

a) 500 mol of hydrogen

$500 mol \times \frac{24.8L}{1 mol} = 12400L = 12.4KL$

b) 56 Kmol of hydrogen sulphide

$56 Kmol = 56000 mol \times \frac{24.8L}{mol} = 1388800L = 1.4ML$

13) Argon gas is an inert carrier gas that moves other gases through a research or industrial system. What is the volume occupied by 4.2Kg of argon gas at SATP?

$4.2Kg \times \frac{1000g}{1Kg} = 4200g \times \frac{1 mol}{39.9g} = 105.26 mol \times \frac{24.8L}{mol} = 2610.53L$

$= 2.6KL$

14) Freon gas is a chlorofluorocarbon (CFC) used as a coolant in air conditioners and refrigerators. If 500mL of freon at 1.50atm and 24°C is compressed to 250mL at 3.50 atm, what is the final temperature of the gas?

$V_1 = 500mL = 0.5L$

$P_1 = 1.5 atm$

$T_1 = 24°C = 297K$

$V_2 = 250mL = 0.25L$

$P_2 = 3.5atm$

$T_2 = T_2$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(1.5atm)(0.5L)}{297K} = \frac{(3.5atm)(0.25L)}{T_2}$$

$T_2 = 346.5K$ or $73.5°C$

17) Pressurized hydrogen gas is used to fuel some prototype automobiles. What is the new volume of a 28.8L sample of hydrogen in which the pressure is increased from 100KPa to 350KPa.

$P_1 = 100KPa$

$V_1 = 28.8L$

$P_2 = 350KPa$

$V_2 = V_2$

$$\frac{P_1V_1}{\cancel{T_1}} = \frac{P_2V_2}{\cancel{T_2}}$$

$(100KPa)(28.8L) = (350KPa)(V_2)$

$V_2 = 8.2L$

18) In Vancouver, a helium balloon containing 4.0L of helium at 101KPa was purchased. The balloon was taken on a trip to Banff where the atmospheric pressure was only 91KPa.

a) Why is the atmospheric pressure in Banff generally lower than in Vancouver?

Since Banff is at a higher altitude than Vancouver, there is less atmosphere above Banff than above Vancouver.

b) What will be the new volume of the balloon in Banff?

$P_1 = 101KPa$

$V_1 = 4.0L$

$P_2 = 91KPa$

$$\frac{P_1V_1}{\cancel{T_1}} = \frac{P_2V_2}{\cancel{T_2}}$$

$(101KPa)(4.0L) = (91KPa)(V_2)$

$V_2 = 4.4L$

c) What assumption is made in this calculation?

That temperature is the same when the volumes are measured.

19) A glass container can hold an internal pressure of only 195 KPa before breaking. The container is filled with a gas at 19.5°C and 96.7 KPa and then heated. At what temperature will the container break?

$P_1 = 96.7\,KPa$

$T_1 = 19.5°C = 292.5K$

$P_2 = 195\,KPa$

$T_2 = T_2$

$$\frac{P_1 \cancel{V_1}}{T_1} = \frac{P_2 \cancel{V_2}}{T_2} \qquad \frac{96.7\,KPa}{292.5K} = \frac{195\,KPa}{T_2}$$

$T_2 = 589.8\,K$ or $316.8°C$

20) Determine the final pressure of steam that is converted from 10.0 KL at 600 KPa and 150°C to 18.0 KL at 110°C.

$P_1 = 600\,KPa$

$V_1 = 10\,KL = 10000\,L$

$T_1 = 150°C = 423K$

$P_2 = P_2$

$V_2 = 18\,KL = 18000\,L$

$T_2 = 110°C = 383K$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(600\,KPa)(10000\,L)}{423K} = \frac{P_2(18000\,L)}{383K}$$

$P_2 = 301.8\,KPa$

23) What is the volume occupied by 1.0 g of carbon dioxide gas trapped in bread dough at SATP?

$CO_2 = 12\,g/mol + 2(16\,g/mol) = 44\,g/mol$

$$1.0\,g \times \frac{1\,mol}{44\,g} = 0.0227\,mol \times \frac{24.8\,L}{1\,mol} = 0.56\,L$$

24) Steam production during baking is a secondary reason why bread and cakes rise. What volume of water vapor is produced inside a cake when 1.0 g of water is vaporized at 190°C and 103 KPa?

$n = 0.05\,mol$

$T = 190°C = 463K$

$p = 103\,KPa$

$pV = nRT$

$$V = \frac{nRT}{p} = \frac{(0.05\,mol)(8.3)(463K)}{103\,KPa} = 2.1\,L$$

$$1.0\,g \times \frac{1\,mol}{18\,g} = 0.05\,mol$$

25) Large quantities of chlorine gas are produced from salt to make bleach and for water treatment. What is the volume of 26.5 Kmol of chlorine gas at 400 KPa and 35°C?

$pV = nRT$

$V = \frac{nRT}{P} = \frac{(26500mol)(8.3)(308K)}{400KPa}$

$V = 169361.5 L = 169.4 KL$

26) Bromine is produced by reacting chlorine with bromide ions in sea water. What amount of bromine is present in an 18.8L sample of gas at 60KPa and 140°C?

$V = 18.8L$

$p = 60KPa$

$T = 140°C = 413K$

$pV = nRT$

$n = \frac{pV}{RT} = \frac{(60KPa)(18.8L)}{(8.3)(413K)} = 0.329 mol$

28) "Standard ambient temperature and pressure" is a convention established by scientists to suit conditions on Earth. Suppose scientists were to establish standard conditions on the planet Venus as 800°C and 7500KPa. What is the molar volume of Venus's mainly carbon dioxide atmosphere under these standard conditions?

$n = m/M$ $CO_2 = 44g/mol$

$T = 800°C = 1073K$

$p = 7500KPa$

$n = 1mol$

$pV = nRT$

$V = \frac{nRT}{p} = \frac{(1mol)(8.3)(1073K)}{7500KPa} = 1.2L$